

Ian Burton
Michael F. Klaassen
Editors

Atlas of Extreme Facial Cancer

Challenges and Solutions



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Ian Burton
Private Practice
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This atlas is dedicated to all our patients who have endured facial cancer and trusted us to find them a solution.

Foreword

The challenge of healthcare delivery in the twenty-first century is rapidly increasing in a world of widening disparities between the haves and the have nots. Steadily rising costs of modern medicine across all communities in the face of the multipronged attacks of financial constraints, restricted access to treatment, against a background of the much larger issues of climate change and its global effects means we are likely to see across the board more advanced disease presenting later. The unprecedented complication of the Covid-19 pandemic and its impact of health service delivery only serves to exacerbate this risk.

Advanced head and neck skin tumours present a major burden to both the individual afflicted and their family as well as the medical professionals called on to manage these complex cases. By dint of these tumours frequently extending across anatomical subregions, their management often requires complex interactions between the conventional silos of modern medical and surgical practice.

This atlas superbly brings together all the elements of the multidisciplinary team necessary to assess and treat those presenting with extreme facial cancer. Recognizing that total management does not begin and end with medical and surgical specialists, this text broadens the discussion to include the role of the speech and swallowing therapists, dental and maxillofacial rehabilitation, as well as the epidemiology and biology of these most extreme cases.

Drawing together expertise across generations and from a number of continents the authors are to be congratulated for having successfully identified pathways available in most health systems to treat, reconstruct and where necessary palliate patients with extreme facial tumours.

Mark Moore,
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Preface

Some years ago I realized there were many excellent books published about the common-or-garden facial cancers that we encounter in everyday clinical practice. There seemed to be an absence of a book which focussed on the extreme cases, which, although rare, challenge the patient, their families and the various clinical teams trying to manage them. Over 30 years I had worked as a member of various head and neck cancer teams in the UK, Australia and New Zealand documenting a significant number of extreme facial cancer cases. By definition these are cases which require complex surgery to resect and reconstruct the problem, need adjuvant oncological therapies and ultimately may be life-threatening. The recorded cases, some of which had prolonged follow-up, provided an initial database on which to create an Atlas, illustrating the fundamental principles of plastic surgery developed by Gillies and others over a hundred years ago. Sir Harold Gillies (1882–1960) also emphasized the critical importance of the Team Concept in Cancer Surgery. Therefore I set about inviting various team members that I had either worked with or got to know through mutual interests in the field of head and neck cancer and encouraged them to contribute chapters to the Atlas.

This has been a challenge in itself—cajoling busy professionals to devote precious time to complete their chapters but we succeeded. A broad range of specialists from oncological to reconstructive surgeons, anaesthetists, radiologists, pathologists, speech and swallowing therapists, anatomists, scientists and epidemiologists, all familiar with the challenges of facial cancer, have come together in one multidisciplinary book. My appreciation of the different but key roles that my colleagues continue to make to this field of modern medicine has been an inspiration. We have been purposefully inclusive and also keen to consider innovation and future concepts such as the role of cancer stem cells, digital technology for prosthetic rehabilitation and modern morphing technologies.

With authors from around the world including Great Britain, China, South America, Australia and New Zealand this Atlas is truly an international effort, supported by the expert professionalism of the Springer Publishing Company. Facial cancer will continue to be a clinical challenge but the opportunities for either cure or palliation are many and it is important for all of us to highlight and share them. I am grateful to my co-editors, colleague and friend Dr. Ian Burton, FRACS, for his eagle eye and grasp of the English language.

Auckland, New Zealand
Gisborne, New Zealand

Michael F. Klaassen
Ian Burton

Acknowledgements

The editors Burton and Klaassen wish to thank the following surgeons who contributed to the early concepts, patient data and vision for this ATLAS. They include Dr Nicholas Otte [surgical trainee of Perth, Australia], Dr Nita Ling [plastic surgeon of Townsville, Australia] and Dr Steve Evans [maxillofacial surgeon of Hamilton, New Zealand]. We also acknowledge the efforts and professionalism of the Springer publishing team as well as the patience of our wives Sue Burton and Karen Klaassen.

Contents

Part I Epidemiology, Science, and Anatomical Concepts

The Skin Cancer Epidemic	3
Michael F. Klaassen, Ian Burton, Earle Brown, Patrick J. Beehan, and Swee T. Tan	
Cancer Stem Cells in the Head and Neck Cancers	17
Ethan J. Kilmister and Swee T. Tan	
Head and Neck Pathology: Practical Points to Ponder	31
Bridget Mitchell, Jing F. Kee, Lisa K. Peart, and Duncan Mitchell	
Applied Facial Anatomy	55
Michael F. Klaassen, Kate O'Connor, Patrick J. Beehan, Earle Brown, Lawrence C. Ho, and Kumar Mithraratne	
The Team Approach in Cancer Care	81
Michael F. Klaassen, Paul Levick, Jim Frame, Julia Maclean, Bridget Mitchell, Jing F. Kee, Lisa K. Peart, Su S. Thon, Alison Fleming, and Karolina Willoughby	

Part II Avoiding Complications

The Burden of Facial Deformity	93
Michael F. Klaassen, Ian Burton, Earle Brown, and Patrick J. Beehan	
Pedicle Versus Free Flaps	111
Damian D. Marucci	
The Novel Expanded Forehead Flap	119
Jincai Fan, Tiran Zhang, and Zhiguo Su	
Keystone Flap Concepts	141
Felix C. Behan, Michael F. Klaassen, and Andrew Sizeland	
Basal Cell Carcinoma: A Surgical Enigma	173
Earle Brown and Bridget Mitchell	

Part III Anatomical Focus

Scalp and Forehead Cancer	195
Michael F. Klaassen and Ian Burton	
Extreme Cancer of the Periorbital Region	215
Stephen G. J. Ng, Michael F. Klaassen, and Earle Brown	

Nose and Ear Cancer	275
Michael F. Klaassen	
Cheek and Perioral Cancer	313
Michael F. Klaassen and Ian Burton	
Palliative Surgery	347
Rafael Acosta-Rojas	
 Part IV Form and Function	
Metastatic Cancer to the Parotid Region	357
Robbie S. R. Woods and Nick McIvor	
Modern Maxillofacial Rehabilitation	381
Michael Williams, Peter Llewelyn Evans, and Muammar Abu-Serriah	
Perioperative and Anaesthetic Care in Head and Neck Cancer Surgery	421
Su S. Thon	
Assessment of Function Post-cancer	447
Julia Maclean	
Modern Morphing Technology in Facial Reconstruction	455
Horacio F. Mayer, Ignacio T. Piedra Buena, and Hernan A. Aguilar	
Index	465

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Part I

Epidemiology, Science, and Anatomical Concepts

The Skin Cancer Epidemic

Michael F. Klaassen, Ian Burton, Earle Brown,
Patrick J. Beehan, and Swee T. Tan

Core Messages

- High-risk cancers of the face are best managed by experienced plastic surgeons in a multidisciplinary setting.
- These cancers are relatively rare compared to the very common occurrence of skin cancer as a prevalent cancer in the general population, but require a unique surgical skill set.
- Accurate diagnosis and a precise surgical plan of management should be co-ordinated with adjuvant therapies including radiation, medical, and immunotherapy oncological protocols.

1 Introduction

Australia and New Zealand with a combined population of about 31 million citizens, many of Celtic heritage, who live in a region with very high solar ultraviolet index, are characterised by the highest incidence of skin cancer in the world. These cancers result in a significant health, economic, and social burden.

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Two in three people in Australia and New Zealand will develop skin cancer in their lifetime [1]. While the majority of these are the relatively indolent and slow-growing basal cell carcinomas (BCCs), there are a certain number of more aggressive skin cancers that present to plastic surgeons and other specialists. These include high-grade squamous cell carcinomas (SCCs), de-differentiated (basosquamous) carcinomas, malignant melanoma (MM), and rarer entities such as Merkel cell carcinoma, sebaceous carcinoma, adnexal carcinoma, and sarcoma. Cancer of the upper aerodigestive tract arising from the mucosal surface is also a significant entity affecting the head and neck. A distinctive feature of extreme facial cancers is perineural spread along the cranial nerves.

Australia and New Zealand have the highest incidence of skin cancer in the world. In 2014, Australia recorded 959,243 Medicare claims for the treatment of non-melanoma skin cancer (NMSC). This is an underestimate. The annual incidence of NMSC in the USA has been recorded as 3.5 million [2], with a population in 2020 of 331 million—one tenth the incidence of NMSC in Australia and New Zealand.

The risk of developing skin cancer in Australia and New Zealand is greater for men than for women (70% versus 58%). Deaths from skin cancer exceed those caused by road trauma with 2162 recorded for Australia in 2015, 1520 of which were attributed to MM. In 2017, 310 deaths were caused by MM in New Zealand.

Although mortality rates of skin cancer have been increasing in Australia and New Zealand since 2000, recent trends suggest stabilization of the numbers for those citizens <45 years of age. This is a result of reduced ultraviolet exposure resulting from successful and very prominent public education programs.

The ultraviolet levels in New Zealand are very high especially in summer months. The ozone “hole” over Antarctica, Celtic skin types, and a sun-seeking outdoor lifestyle of the population, all contribute to the high incidence of skin cancer. The National Institute of Water and Atmospheric

Research has shown that ultraviolet levels are 40% higher in New Zealand than at a corresponding latitude in the northern hemisphere [3]. The highest levels of annual ultraviolet exposure in New Zealand are in the Eastern Bay of Plenty region of the North Island, where the lead author (MFK) has provided a provincial plastic surgery service for the last decade. This in part triggered his interest in writing about the extreme forms of facial skin cancer. The second author (IB), a general surgeon practicing for over 30 years in a similar high-ultraviolet exposure regions (Gisborne, East Cape), has also managed patients with skin cancers affecting the face and other body sites, during his long surgical career.

The pathogenesis and molecular biology of extreme facial cancer are well detailed in later chapters by pathologists and research scientists. It involves genetic predisposition and solar ultraviolet radiation damage as well as complex mutations in tumor suppressor genes. There has been a paradigm shift in the theories of oncogenesis involving complex molecular pathways and the role of cancer stem cells.

From a day-to-day clinical management perspective, it is important to be aware of the risk stratification of skin cancers. BCCs with a morphoeic (sclerosing) histological pattern have a much higher risk of local recurrence and therefore require wider excision margins than the standard 4 mm. SCCs with poor histological differentiation and perineural and/or lymphovascular invasion have a predicted metastatic risk of 37% compared to the 0.3% risk for low-risk lesions in the head and neck [4]. Perineural spread caused by head and neck cancer is most often caused by skin SCC, and a high index of suspicion is needed. This also applies to radiological imaging studies of such patients [see Chap. 5 “The Team Approach in Cancer Care” on Applied

Anatomy]. MM, the third most common skin cancer in Australia and New Zealand, is responsible for almost 2000 deaths per annum.

2 Why Do Patients Present with Extreme Facial Cancer?

This is perhaps the most important question in this chapter, given the knowledge and expertise in the management of skin cancer generally and the public awareness of this common acquired disease. The reasons are multiple and include personal fear and social isolation, cultural practices such as chewing of carcinogens, lifestyle and workstyle practices, initial mis-diagnosis and or mis-management, specific tumour characteristics, immunosuppression, and/or previous radiation therapy.

All skin cancers of the human face start as small tumours.

Figure 1 shows a typical BCC of the face in a middle-aged woman, which was completely excised and repaired with a postauricular full-thickness skin graft.

Figure 2 shows a 71-year-old man with an infiltrating micronodular BCC of his left infraorbital region, widely excised and immediately repaired with a Mustardé cheek rotation flap. The final image shows the result at 4 years, when he was re-referred with an SCC on his right eyebrow.

Figure 3 shows the extreme disfiguring appearance of a locally advanced BCC in an elderly man who neglected this cancer because of his fear. He was eventually encouraged to seek specialist attention by his wife, who was concerned about food, drink, and saliva spilling out of his left cheek. Sadly, the BCC was very extensive with infiltration of the facial soft tissues and skeleton and was considered inoperable. Appropriate palliative care was provided.

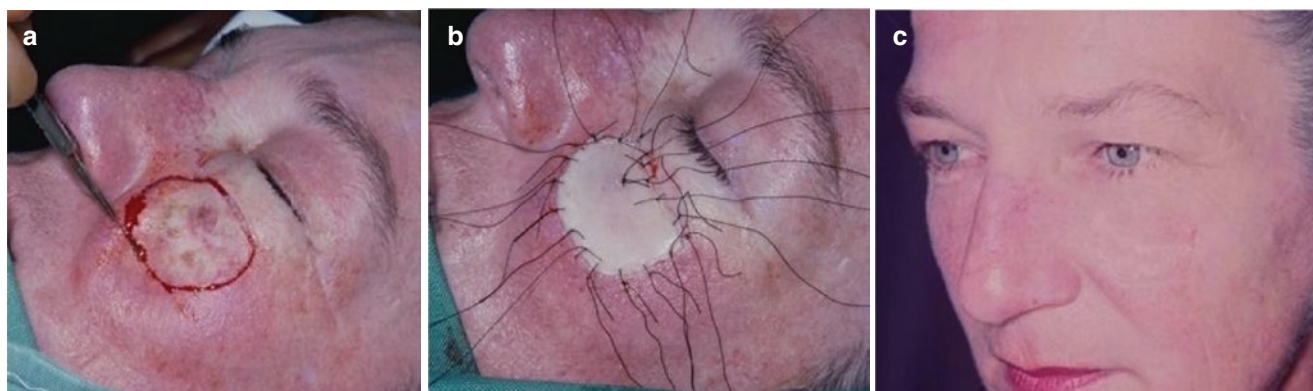


Fig. 1 (a–c) An infiltrating BCC of the left mid-cheek treated by the late Sir William Manchester (1913–2001) in the 1960s with wide excision and a post-auricular full-thickness graft

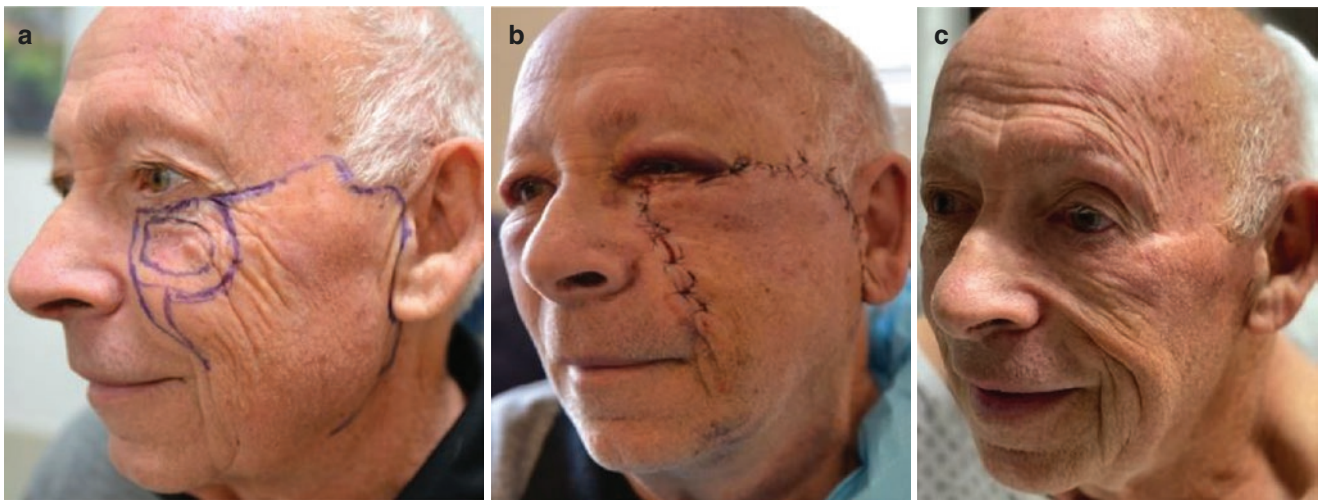


Fig. 2 (a–c) A case of the lead author – infiltrating BCC of the left infraorbital region widely excised and repaired with a Mustardé cheek rotation flap at 3 days and result at 4 years



Fig. 3 A neglected inoperable BCC with extensive involvement of the left hemi-face and invading the left maxilla and orbit in an elderly retired chemist seen by the lead author during his post-fellowship training in southern England circa 1990

3 Alternative Medical Misadventure: A Salutary Lesson

A 65-year-old woman sought advice from an alternative medicine practitioner regarding a 3 cm ulcerated lesion on her scalp who allegedly diagnosed the lesion as an “infected sebaceous cyst” and reassured the patient that it was benign. The patient was commenced on a skin treatment regimen involving the daily application of a herbal poultice and dressing changes. After 6 months of treatment, the lesion had grown to 8 cm and developed a purulent discharge. When the patient’s family became concerned that the treatment was ineffective, the alternative medicine practitioner allegedly dismissed these concerns and reiterated that the lesion was benign and advised against seeking conventional medical advice. After 16 months of treatment, the lesion had grown to 20 cm and eroded through the calvarium and involved the dura, confirmed by MRI and CT scans (Fig. 4). The tumour was treated by wide local excision including the underlying skull, the greater wing of sphenoid, and dura. Reconstruction included dural repair with a dura substitute, split rib grafts to span the bony defect, and an overlying latissimus dorsi muscle free flap covered with a split thickness skin graft (Fig. 4).

These four clinical cases contrast the relative simplicity of successfully managing early facial skin cancers, as opposed to only being able to offer palliation in the advanced cases. The third and fourth cases clearly illustrate the oncological and reconstructive challenges of the neglected skin cancer. A

case report of five patients from Hungary in 2011 shows that delays in the diagnosis and late presentation are usually because of the patient’s fears of the diagnosis and treatment. In some cases, the patient just becomes accustomed to the usually slow-growing tumour [6].

Dr. Milton Edgerton MD (1928–2018) of Johns Hopkins Hospital and Virginia University considered the problem of advanced BCC in his Hayes Martin Lecture to the American Society of Head and Neck Surgeons in 1982 [7]. Invasion of deep facial tissues by a BCC and especially the mucous membranes is not a trivial matter, and the patient may never again be tumour-free. His case presentation of a young woman treated with radiotherapy in the 1930s for facial acne chronicles the more than 30 years (1949–1980) of multiple complete reconstructions of her nose, cheeks, lips, and chin. One important principle remains: if the destructive effects of the tumour and the surgical treatment result in the removal of one or more major facial features, it is essential that reasonably prompt reconstruction be undertaken.

This is true for non-facial regions as well and was certainly the case in this retired gentleman, shown in Fig. 5, who presented with a large ulcerated BCC of his left posterior shoulder in 1990. The infiltration had extended into the left shoulder joint, and definitive surgical management necessitated a left forequarter amputation. A radial forearm free flap harvested from the amputated extremity and used to repair the extensive soft tissue defect.

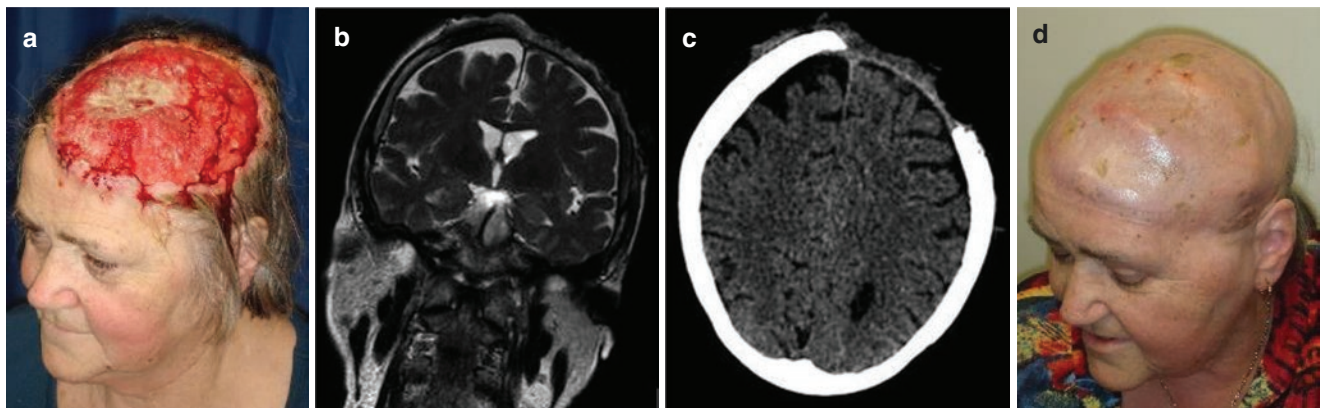


Fig. 4 An extensive scalp SCC with destruction of the soft tissues and underlying skull and invasion of the dura (a) also demonstrated on MRI (b) and CT (c) scans, treated with surgery and adjuvant radiotherapy (d). (Reprinted from Mistry et al. [5]; with permission)



Fig. 5 (a, b) A case of neglected BCC in a retired London accountant witnessed by the lead author in Southern England circa 1990. The extensive ulcerated tumour invaded the left shoulder joint and required

a forequarter amputation and reconstruction with a free radial forearm flap harvested from the amputated left upper extremity

4 Guiding Principles of Surgical Management

Whatever the cancer challenge, the guiding principles (Sir Harold Gillies 1882–1960) for the plastic surgeon remain the same, specifically:

1. Diagnose before you treat.
2. Make a plan and a pattern for this plan (incorporating the choice of reconstruction).
3. Treat the primary defect first.
4. Never let routine methods become your master.
5. Have a lifeboat.
6. Consult other specialists.
7. The aftercare is as important as the planning.

These principles are of course derived from some of the many fundamental truths that became intuitive for pioneers in plastic surgery like Sir Harold Gillies [8].

5 Management/Technique

This 68-year-old man with alcohol addiction (Fig. 6) presented with a neglected, locally advanced ulcerated SCC affecting his left posterior neck. He did not seek medical attention for several months. At one stage, he decided against the wishes of his family to drive to a remote location in North Queensland and attempted to drink himself to death under a eucalyptus tree. When this failed, he drove back to his home city thousands of kilometers away and sought medical attention.

On presentation, the extensive fungating tumor was inhabited by maggots. Physical examination and a CT scan indicated that surgical excision was feasible. A wide local excision along with a radical neck dissection resulted in a significant neck defect which was repaired with a pedicled trapezius myocutaneous flap. The large secondary defect was repaired with a meshed split skin graft. A keystone double advancement flap would also have been a reasonable option for closing

the secondary defect. A free flap could have been considered as an alternative reconstructive option, but Professor Michael Poole of Sydney, Australia, who led the surgery for this patient, and the lead author felt that his pre-surgical general condition and relative malnutrition resulting from alcoholism were a contraindication to lengthy microvascular surgery.

Figure 7 shows a 50-year-old woman who presented with an extensive ulcerated lesion of her right upper lip and nasolabial area, which had been treated as an inflammatory lesion for several months. A “delayed” biopsy showed an infiltrating BCC. After margin controlled wide excision and DRAPE (delayed reconstruction after pathology examination) protocol, a term coined by Professor Felix Behan FRACS of Melbourne, Australia, a staged reconstruction of her medial cheek, right alar base, and right upper lip was completed using a cheek rotation local flap, a paramedian forehead local flap, and a lower lip Abbé flap, with satisfactory results.

The 60-year-old man in Fig. 8 presented with extensive facial sun damage and a recurrent Merkel cell carcinoma of his right cheek and required a very extensive hemi-face resection and ipsilateral parotidectomy. A loco-regional flap was considered unreliable, so an ulnar forearm free flap was used for reconstruction. This proximal forearm flap initially described by Dr. Maxwell Lovie FRACS (1939–2000) et al. [9] provided sufficient soft tissue volume compared to the more frequently used radial forearm flap. The patient underwent post-operative adjuvant radiotherapy.

MM rarely presents with extensive facial lesions, but occasionally metastatic spread can pose a challenge, as in this a 70-year-old man (Fig. 9), who developed a nodal metastasis in his left neck, which involved the overlying skin and was adherent to the common carotid artery. In collaboration with the vascular surgeons, a wide local excision and neck dissection including resection of a segment of his carotid artery were performed, with a temporary carotid bypass shunt to preserve brain perfusion. A reversed saphenous vein bypass graft was utilized. The graft was then protected with a pedicled loco-regional pectoralis major myocutaneous flap.

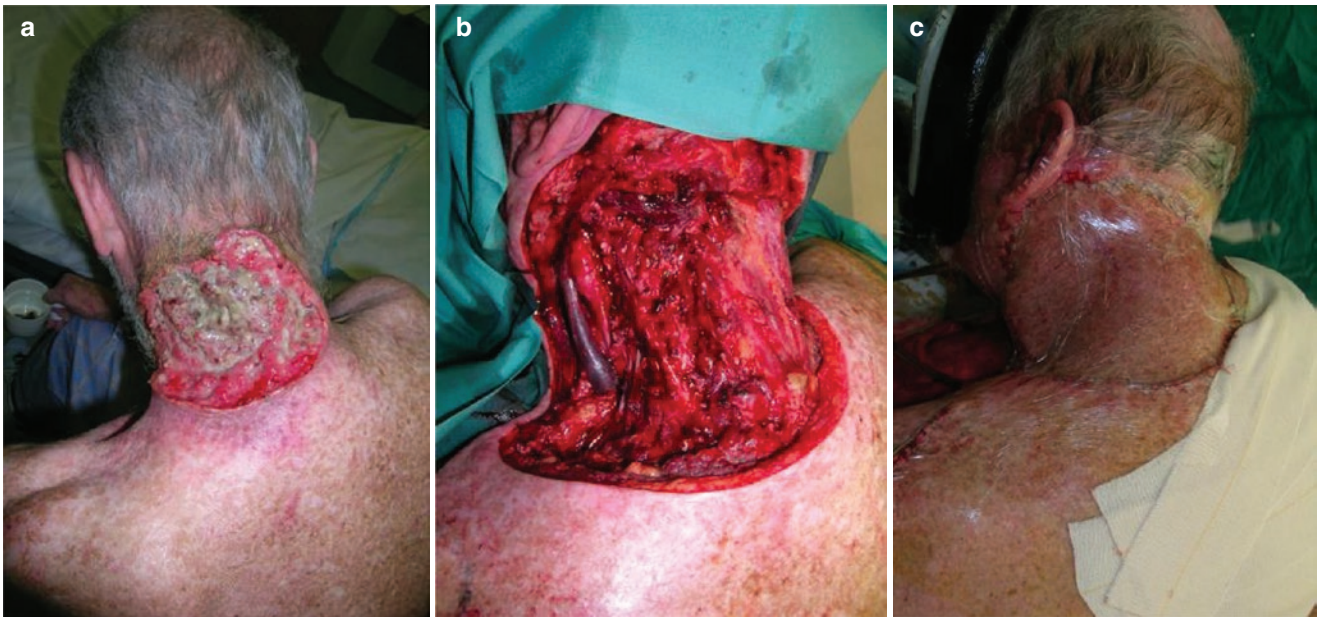


Fig. 6 (a–c) A neglected fungating SCC of the posterior neck in a 60-year-old gentleman with alcoholism, treated with wide local excision, radical left neck dissection and a pedicled trapezius myocutaneous flap reconstruction

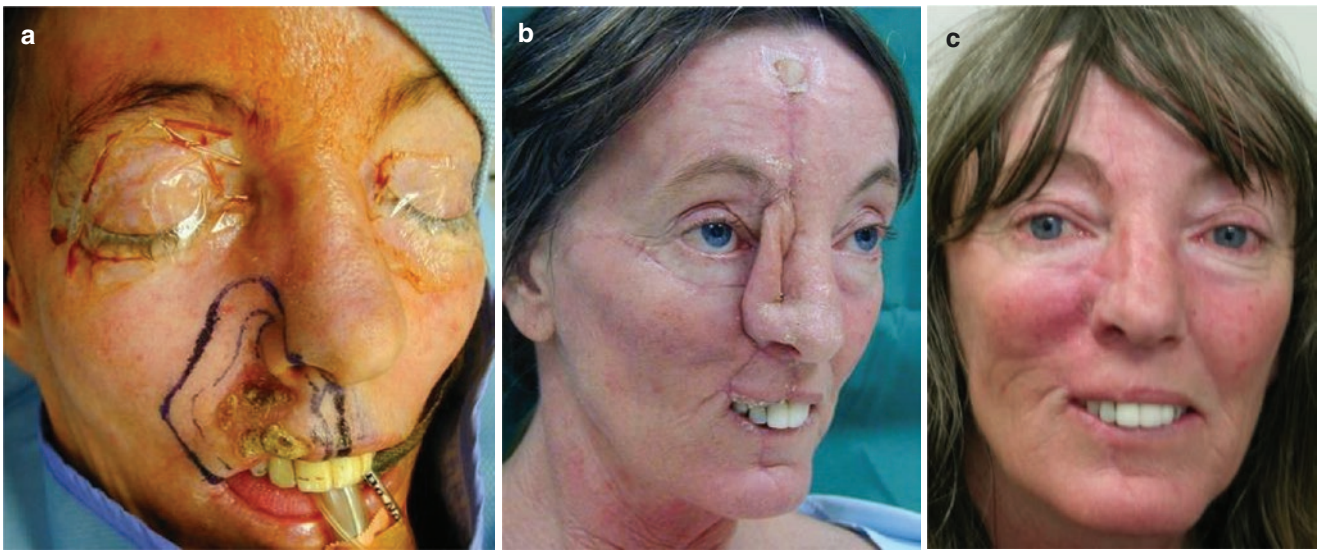


Fig. 7 (a–c) A misdiagnosed infiltrating BCC of the right upper lip and nasolabial area, widely excised and reconstructed with multiple local flaps (cheek rotation, paramedian forehead and Abbé lower lip-switch flap)

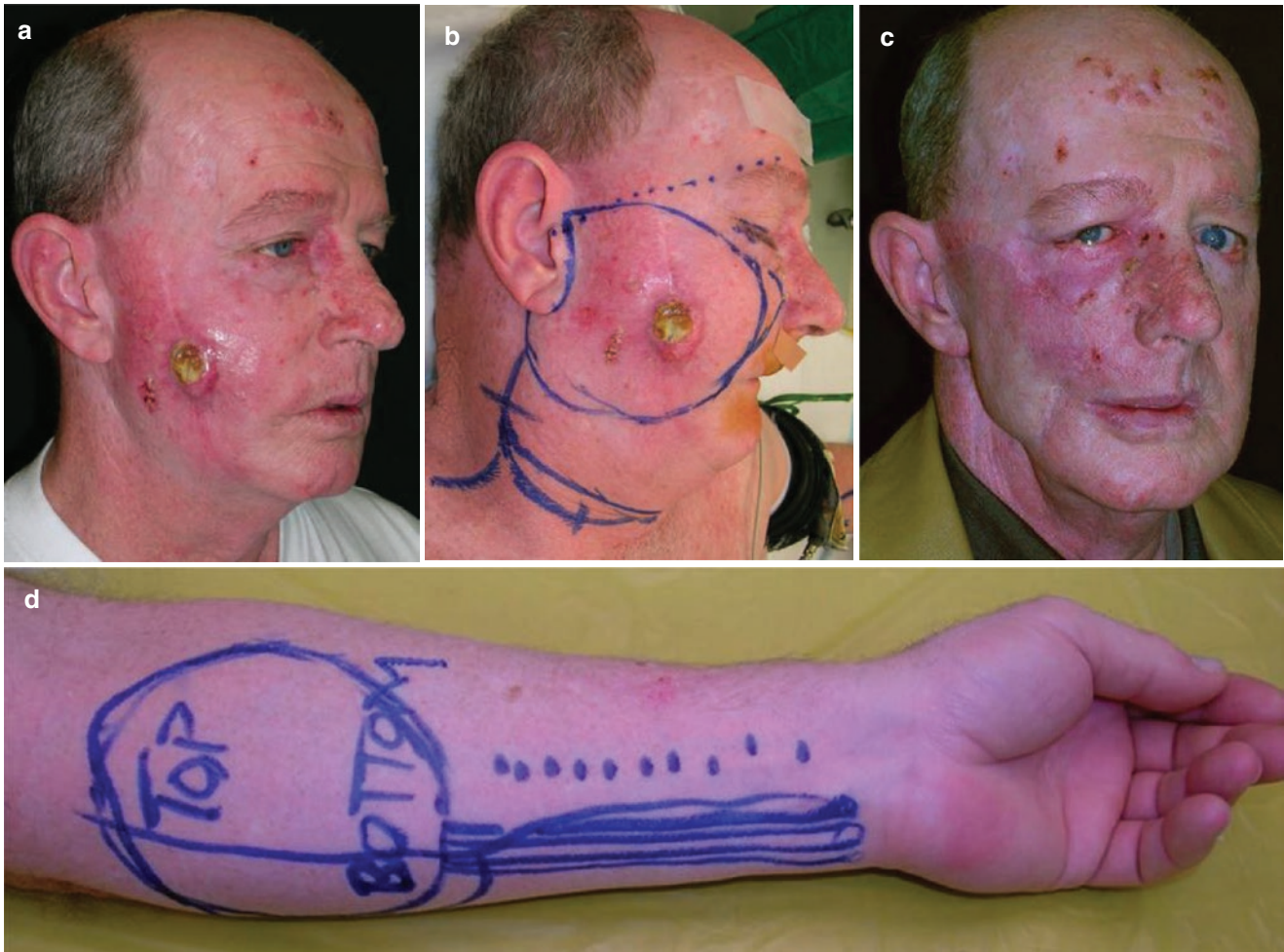


Fig. 8 (a–d) A recurrent Merkel cell carcinoma on the cheek in a 60-year-old man, was widely excised including a facial nerve-preserving superficial parotidectomy and immediate reconstruction with an ulnar forearm fasciocutaneous free flap, followed by adjuvant radiotherapy



Fig. 9 (a, b) Metastatic malignant melanoma in a 70-year-old man's left neck adherent to the left common carotid artery. Salvage surgery with local excision, neck dissection, bypass shunt, saphenous vein

bypass graft of the excised carotid artery and reconstruction with a pedicled left pectoralis major myocutaneous flap

6 Indications

Innovative reconstruction methods are required when the cancer burden is extensive, the resection defect considerable, and where traditional methods of repair are inadequate.

6.1 Loco-Regional Combined Flaps

This 45-year-old pastor from Papua New Guinea (Fig. 10), with extensive SCC affecting the lips and right cheek caused by longstanding betel nut chewing, was referred to our Interplast Humanitarian team. The betel nut was mixed with

an alkali lime powder from crushed seashells to reduce the acidity of the ingestion. Chewing betel nut is a traditional social practice in many Pacific Islands including the Solomon Islands, Papua New Guinea, and Vanuatu. Transfer to Australia or New Zealand for resection and free flap reconstruction was not an option, so the team planned a combination of loco-regional keystone flaps from his left cheek and anterior neck. An opinion was urgently requested by the Interplast Team leader (MFK), from Professor Felix Behan FRACS in Melbourne, Australia, via the Internet. The planned total forehead flap was not required for lining. The secondary defect of his submental region was repaired with a skin graft. The case was lost to follow-up.



Fig. 10 (a–e) An extensive perioral SCC of the lips in a 40-year-old Papua New Guinean pastor, referred to a New Zealand based Interplast surgical team. Wide excision in Port Moresby and immediate recon-

struction with keystone perforator island loco-regional flaps from the cervicomenal and left cheek regions

6.2 Free-Flap Option

This 43-year-old man (Fig. 11) presented to the oral and maxillofacial surgeons with a rapidly growing chondrosarcoma of his right maxilla. An initial right hemimaxillectomy was followed by rapid and aggressive recurrence, which therefore

required a wide orbital-heminasal midface resection, immediate reconstruction with a bi-paddled latissimus dorsi myocutaneous free flap, and post-operative adjuvant radiotherapy. Subsequent attempts were made to reconstruct his right heminose defect with a staged forehead flap and bone grafts. He is now 20 years post-treatment and free of disease.

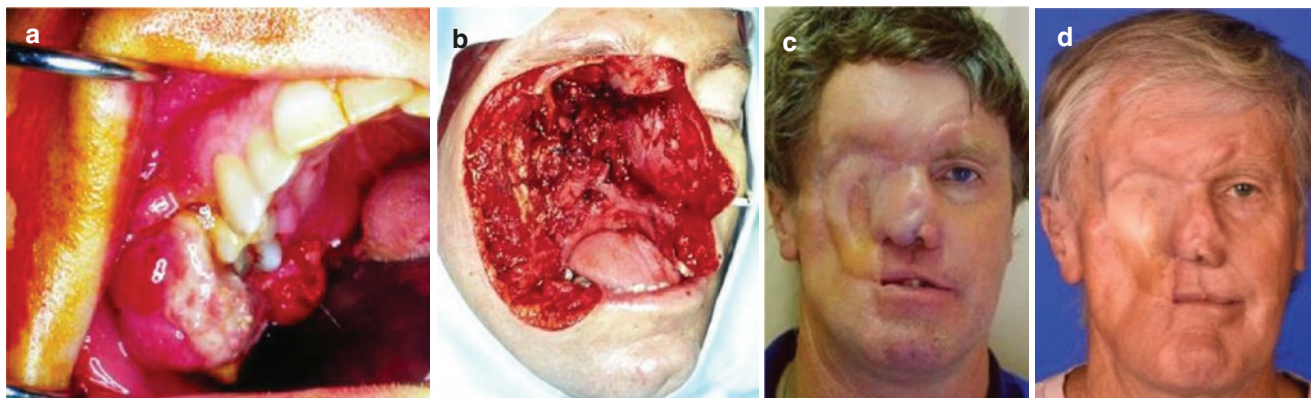


Fig. 11 (a–d) An aggressive chondrosarcoma of the right maxilla in a 43-year-old man, treated radically with right hemiface resection (right orbit, maxilla and heminose), staged reconstruction with a free bi-paddled latissimus dorsi flap and expanded forehead flap. Alive and well 20 years later

7 **Contraindications**

There are rare extensive facial cancers that are inoperable as shown in Fig. 3, in an elderly man with longstanding and neglected midface BCC. For some patients, their comorbidities and general medical status as defined by the American Society of Anesthesiology (ASA) Physical Status classification may preclude curative surgery [10]. Professor Michael Poole MD, FRCS (Fig. 12), plastic, craniofacial, and head and neck plastic surgeon in Sydney, Australia with whom the lead author collaborated for 3 years (2004–2006), was a firm and passionate advocate for palliative surgery in selected patients, to improve their quality of life (Fig. 13). The concept of palliative surgery is detailed by Dr. Rafael Acosta-Rojas FRACS, EBOPRAS, in Chap. 15 “Palliative Surgery”.



Fig. 12 Professor Michael Poole MD, FRCS – former director of the Oxford Craniofacial Unit, Radcliffe Infirmary, Oxford, UK and plastic surgeon/craniofacial surgeon Sydney, Australia. He mentored the lead author from 1999 to 2008

8 Palliative Surgery as an Option

Figure 13 shows a 78-year-old man with a metastatic skin SCC on the right side of his neck which failed to respond to primary radiotherapy. The fungating tumour resulted in a constant discharge and odour requiring daily dressings, affecting his quality of life significantly. Following a multi-disciplinary discussion, the patient was offered and pro-

ceeded with salvage surgery. This involved a right radical neck dissection and superficial parotidectomy with wide local excision of the involved overlying skin and amputation of the lower pole of the right ear. The extensive defect was repaired with a large pedicled pectoralis myocutaneous flap (with removal of the nipple). The donor site was closed with an anteriorly based transpositional subcostal fasciocutaneous flap.

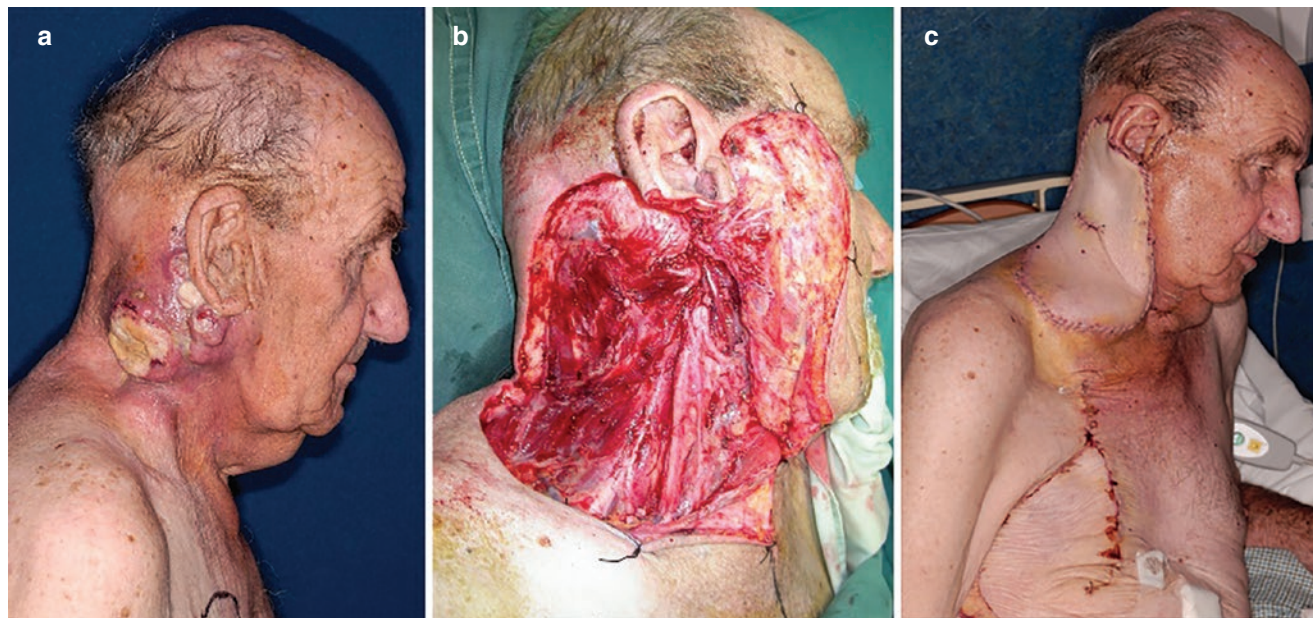


Fig. 13 (a–c) A 78-year-old man with a fungating metastatic skin SCC on the right side of his neck following primary radiotherapy (a), underwent right radical neck dissection and superficial parotidectomy with wide local excision of the involved skin including partial amputation of

the right ear (b). The resection defect was reconstructed with a large pedicled pectoralis myocutaneous flap and the donor site defect was repaired with a transpositional subcostal fasciocutaneous flap (c)

9 Innovations

The keystone perforator island loco-regional flaps of Professor Felix Behan continue to challenge our modern concepts of free flap surgery for major facial cancers. The keystone flap concept was based on clinical observation and the intuition that dermatomal planning of flaps guarantees a supportive vascular supply. Vessels follow nerves. The work-horse perforator flap concept has stood the test of time, for a quarter of a century. The lead author learned this flap from Dr. Simon Donahoe FRACS, a colleague of Behan in Melbourne at the Peter MacCallum Cancer Institute and has been a champion of its application for over a decade [11]. The keystone flap and its variants (Omega, double, Yin-Yang) provide a simple, quick, and reliable option with **pain-free** recovery, **aesthetic** reconstruction, low **complications**, and **economy** of effort and resources: Behan's **PACE acronym**. They are applicable anywhere on the face and neck including the scalp but in the latter experience is required [9]. Professor Behan et al. expand on the application of the keystone flaps in Chap. 9 "Keystone Flap Concepts".

10 Management of Complications

All surgery must balance the advantages of a given method with the risk of treatment. Complications can occur pre-operatively because of poor decision-making and planning (e.g., aspiration pneumonitis or sepsis). Problems may also arise peri-operatively because of imperfect technique, unheralded findings, and anaesthetic emergencies as well as post-operatively. The key post-operative complications include hematoma from bleeding which may compromise flap viability, partial or complete flap necrosis due to vascular insufficiency (most commonly venous outflow problems), injury to vital anatomical structures (e.g., facial nerve, thoracic duct), and sepsis. Incomplete cancer excision or cancer recurrence are also challenging complications. Knowledge of and situational awareness about complications are stressed to plastic surgeon trainees for their professional exam preparation. This becomes a mandatory skill set with consultant experience post final examinations! The philosophy with respect to complications may be a conservative approach, but sometimes a pro-active re-operative approach and salvage are required. The timing and judgment required for this are critical and follow the dictum of Sir Harold Gillies: *Don't do today what can be honorably be put off until tomorrow*. Professor Michael Poole MD, FRCS, from whom the lead author learned so much in the 2000s, would argue that *He who hesitates is lost*.

11 Controversies

Mohs micrographic surgery, a technique popularized by dermatologists in North America and pioneered by a Wisconsin medical student in the 1940s, has been described as a "precise" surgical technique for the treatment of skin cancer. During Mohs surgery, thin layers of cancer-containing skin are serially removed and examined until only cancer-free tissue remains. Although published studies comparing Mohs' surgery with conventional surgical excision claim superior results for BCC specifically, plastic surgeons worldwide question the oncological legitimacy and cost-effectiveness of this approach and its role in extreme facial cancers [12]. The technique is tedious, expensive, painful, and costly, although it may have a role in achieving clear resection margins for certain challenging BCCs, such as those with a morphoeic pattern and/or certain anatomic sites. Chap. 12 "Extreme Cancer of the Periorbital Region" in this Atlas describes cancers of the periorbital region, and Dr. Stephen Ng FRANZCO, an ophthalmic surgeon with a special interest in oculoplastic surgery, who collaborated with the lead author and third author (EB) for that chapter, has significant experience in reconstructing periorbital defects after Mohs micrographic surgery by dermatologists in his region.

12 Conclusion/Summary

Skin cancer is prevalent among the Caucasian population of Australia and New Zealand, with an incidence ten times that of other major developed countries such as the USA. During their careers, plastic surgeons can expect to be confronted with many challenges in the management of skin cancer and occasionally extreme, advanced, and even more challenging cases. Why these rarer cases ever present in the first place is an interesting and vexed question, for which the explanation is often complex and associated with multiple patient personality disorders. It is left for the experts in the field of cancer care to grapple with the challenge and conundrums of extreme facial cancer.

A surgical approach is suggested based on sound surgical principles including a definitive diagnosis, staging, and a multidisciplinary plan of management. Immediate reconstruction with the most appropriate method is ideal, but this may be delayed due to oncological concerns. A range of loco-regional and distant free flap options exist in the surgeon's toolkit, backed up by the adjuvant therapies of radiation and medical oncology. The team includes radiologists, pathologists, prosthetic specialists, specialized nurses, anaesthetists, psychologists, and palliative care specialists as well as surgeons.

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Cancer Stem Cells in the Head and Neck Cancers

Ethan J. Kilmister and Swee T. Tan

Core Messages

- Cancer stem cells (CSCs), the proposed origin of cancer, are present in many cancer types including primary and metastatic cutaneous squamous cell carcinoma and malignant melanoma.
- CSCs are highly tumorigenic, resist conventional therapies and are responsible for loco-regional recurrence and distant metastasis.
- CSCs are regulated by the microenvironment in which the renin-angiotensin system (RAS) plays a vital role.
- The RAS consists of multiple components, its bypass loops that provide redundancies, and convergent signalling pathways that provide crosstalk.
- A novel treatment approach for cancer is by targeting CSCs by regulating the RAS and its related pathways.

1 Models of Cancer

There are two concepts guiding cancer research: (1) the prevailing *clonal evolution model*, also known as the *stochastic model of cancer*, which proposes that normal cells acquire tumorigenicity to become cancer cells by accumulating genetic mutations (Fig. 1a), and (2) the emerging *cancer stem cell (CSC)* concept of cancer, also known as the *hierarchical model of cancer*. The latter proposes CSCs—a small subset of

highly tumorigenic cancer cells with embryonic stem cell-like (ESC) properties—as the origin of cancer (Fig. 1b) [1].

The clonal evolution model proposes that all tumour cells are clonally identical and have the same tumour forming ability and propensity for self-renewal (Fig. 1a) [2]. The CSC model proposes that a tumour consists of a heterogeneous population of cells with CSCs sitting atop the cellular hierarchy, sustaining tumour cell diversity, tumorigenicity, and metastatic potential [3]. These CSCs divide asymmetrically giving rise to non-tumorigenic cancer cells that form the bulk of the tumour and identical CSCs that are highly tumorigenic, resist conventional therapies and are responsible for metastasis and recurrence (Fig. 1b) [4].

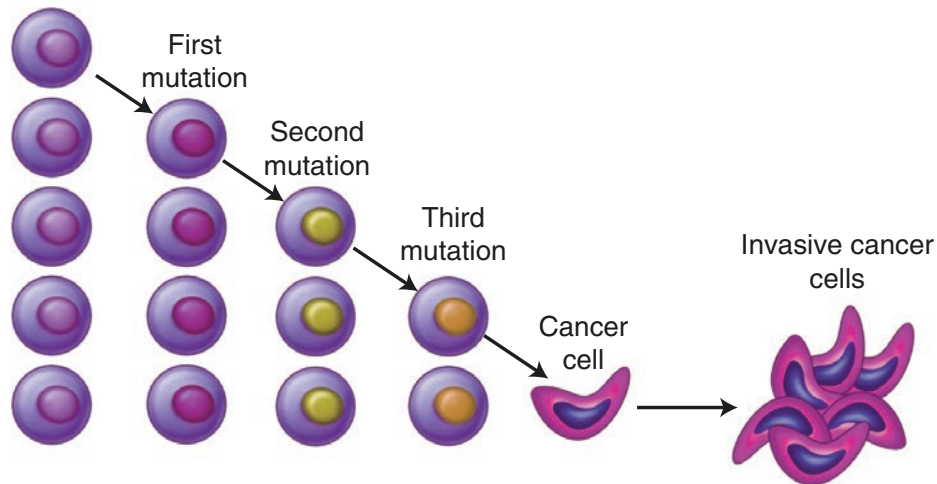
Processes involved in embryonic development are often reactivated under pathological conditions, such as carcinogenesis [5]. Cancer and embryogenesis share multiple common processes such as epithelial-to-mesenchymal transition (EMT) [5]. Another similarity between carcinogenesis and embryogenesis is the shared ability of ESCs and CSCs to undergo indefinite self-renewal and bypass the replicative barrier of 50–60 population doublings before senescence [6]. Both CSCs and ESCs can undergo differentiation giving rise to cells of all lineages and utilise signalling pathways such as the MAPK/ERK, PI3K/AKT, JAK/STAT and Notch pathways [7]. As somatic cells have a low rate of mutations and a relatively short lifespan, it raises the question of how cancer cells acquire so many essential genetic changes seen in ESCs. It is more plausible that cancer arises from CSCs that originate from resident adult stem cells or progenitor cells, which possess higher proliferative capacity and are more prone to mutations. ESCs undergo periods of high rates of clonal proliferation in a highly controlled manner, whereas the proliferation of cancer cells is not controlled. Furthermore, like ESCs, cancer cells can also establish themselves in various tissues in the body [7]. Using embryonic development as a framework for investigation of carcinogenesis could provide novel insights into the understanding and treatment of cancer.

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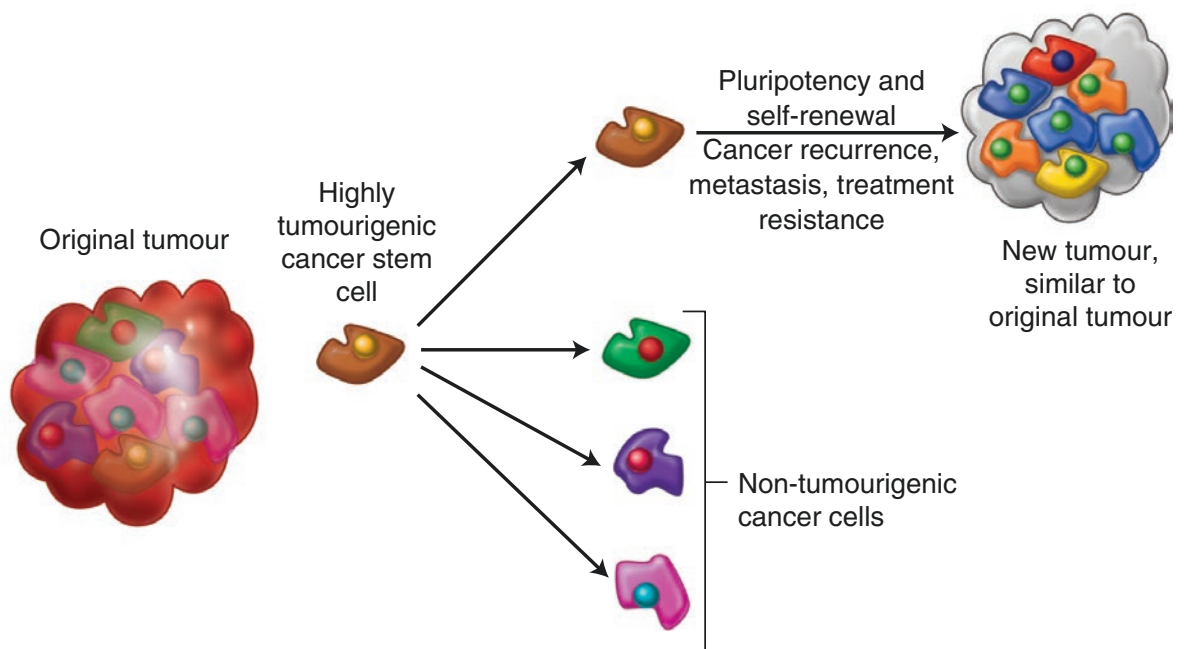
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aNormal
somatic cell

Clonal Evolution Model of Cancer

b

Hierarchal Model of Cancer

Fig. 1 (a) A diagram illustrating the clonal evolution model of cancer. A normal somatic cell acquires oncogenic mutations in a stepwise manner and becomes a cancer cell that clonally expands to form a tumour. (b) A diagram illustrating the cancer stem cell (CSC) model of cancer.

A highly tumourigenic CSC sitting atop the tumour cellular hierarchy which divides asymmetrically to form non-tumourigenic cancer cells that form the bulk of the tumour, and identical CSCs that form new tumours that are similar to the original tumour

2 Cancer Stem Cells

In 1937, Furth et al. [8] first showed that a single tumour cell from mouse leukaemia could establish a tumour following transplantation into another mouse. Identification of proliferating cells by radio-labelling and autography [9] in the ensuing decades enabled measurements of cell lifespan and the assessment of cellular hierarchy in normal tissues [10]. These methods led to a rapid advancement in stem cell research. In 1960, Pierce [11] demonstrated that teratocarcinomas contained tumourigenic cells that could individually differentiate into multiple differentiated non-tumourigenic cell types, resembling normal development. In 1963, haematopoietic stem cells were discovered, and stem-like cells were reported in multiple haematological malignancies in the ensuing decade [12]. Based on investigations using many other techniques over the subsequent decades, Pierce [13] advanced an early CSC concept—“A concept of neoplasms, based upon development and oncological principles, states that carcinomas are caricatures of tissue renewal, which have a marked capacity for proliferation and a limited capacity for differentiation under normal homeostatic conditions, and of the differentiated, possible benign, progeny of these malignant cells”. Evidence supporting the notion that cancer originates from CSCs has been accumulating rapidly over the past two decades. CSCs have now been identified in numerous types of solid cancers affecting all major organ systems [4, 14].

3 Identification of Cancer Stem Cells

CSCs express stemness-associated markers that are present on ESCs and display ESC characteristics such as self-renewal and pluripotency—the ability to differentiate into cells of all lineages [15]. CSCs have been identified in many cancer types [4] including cutaneous SCC (cSCC) and malignant melanoma (MM) by specific markers [16–20]. Their presence is confirmed by functional studies, such as tumour-sphere formation assays, organoid systems, and xenotransplantation of sorted tumour cells into immunodeficient mice [21]. Xenograft and teratoma experiments in animals are the gold standard for functional investigations that provide evidence of CSCs, and they remain valuable and perhaps essential for applications such as safety testing of therapies. However, teratoma assay protocols are often vague and inconsistent and are not highly standardised and reproducible [22]. To determine whether a cell population includes pluripotent cells, it is considered sufficient to employ directed or spontaneous differentiation and tumoursphere

formation which can be sustained over multiple passages and an analysis of pluripotency marker expression [22]. It has become more acceptable to use stemness-associated markers such as OCT4, SOX2, NANOG, SSEA4 and TRA-1-60, to identify pluripotent cells [23–26].

Many markers that are expressed on ESCs have been used to identify CSCs [27, 28]. CD44 is a cell surface marker with many functions, including the transduction of microenvironmental signals to membrane-associated cytoskeletal proteins and the nucleus, which influences the expression of genes that alter cell functions [29]. As an important regulator of CSC properties including stemness, self-renewal and metastasis, CD44 has been used as a CSC marker [29]. As it is not essential for tumour formation [30], CD44 is now considered a marker of progenitor cells, further down the stem cell hierarchy, rather than an ESC marker [27].

EpCAM, a cell adhesion molecule and a CSC marker, is expressed by nearly all carcinomas [31] including cSCC [31].

The surface marker CD133 has been used to identify CSCs in several solid cancers including glioblastoma [27] and pancreatic cancer and is associated with high tumourigenicity and metastasis [32]. Capan-1, a CD133⁺ pancreatic cancer cell line derived from human pancreatic cancer, recapitulates tumours in a xenograft model [32]. As CD133 is also expressed on more differentiated cancer cells, further down the stem cell hierarchy, and given tumours can also be grown from CD133[−] cells in xenograft models, it is now considered a progenitor cell marker rather than an ESC marker [27].

Phosphorylated signal transducer and activation of transcription 3 (pSTAT3) proteins have a broad range of functions, including cell cycle signalling, cell survival, pluripotency and self-renewal capability [33, 34]. STAT proteins are activated by cytokines, and they regulate growth factor and cytokine responses [35]. Aberrant STAT3 signalling has been demonstrated in multiple types of head and neck cancers [36]. The role of pSTAT3 in pluripotency is regulated by leukaemia inhibitory factor pathway, resulting in STAT3 translocating into the nucleus and triggering the expression of the ESC markers KLF4, SOX2, SALL4 and c-MYC [37–39]. pSTAT3 is also expressed by more differentiated cells [27].

Yamanaka et al. showed that human [24] and mouse [25] fibroblasts can be induced into an ESC state [24] by introducing the transcription factors OCT4, NANOG, SOX2, KLF4 and c-MYC. Thomson et al. [26] showed that generation of such induced pluripotent stem cells (iPSCs) was also possible with NANOG and LIN28 in place of c-MYC and KLF4. These studies underscore the sufficiency of these stemness-associated markers in generating iPSCs. Expression

of these stemness-associated markers provides preliminary evidence of the presence of CSCs. Some or all of these markers have been used to identify and characterise CSCs in many cancer types [40–44] including primary head and neck cSCC (HNcSCC) [18], metastatic HNcSCC (mHNcSCC) [45], head and neck metastatic MM to the regional lymph nodes (HNmMM) [17] and metastatic MM to the brain (mMMB) [46].

The observation that stemness-associated markers SOX2, pSTAT3, CD44 and CD133 are expressed by ESCs and cells downstream of ESCs highlights the challenges of using these available markers for the identification and characterisation of CSCs [27].

4 Origin of Cancer Stem Cells

The origin of CSCs remains unclear. CSCs have been proposed to originate from normal progenitor cells that have unlimited potential to replicate and/or from normal resident adult stem cells that have acquired oncogenic mutations [47]. Differentiated non-tumourigenic cancer cells have also been shown to de-differentiate into CSCs by acquiring stemness through cellular adaptation under the influence of the surrounding microenvironmental *niche* [48]. This can occur via EMT by which the genes expressed by epithelial cells change, and the cells develop mesenchymal traits [1]. CSCs share properties of mesenchymal stem cells (MSCs), such as the ability to migrate, resist programmed cell death and degrade extracellular matrix (ECM), to facilitate cancer invasion [1]. These characteristics make the tumour cell more CSC-like. The ability for CSCs to acquire mesenchymal traits endows CSCs the ability to disseminate and form metastases [1]. The tumourigenicity of cancer cells and CSCs changes in response to environmental cues and other influencing factors, such as cancer therapy, a change in the microenvironmental *niche*, gene mutations and epigenetic factors [4].

5 Cancer Metastasis

Metastasis, one of the hallmarks of cancer, causes over 90% of cancer-related deaths [49]. There is increasing evidence showing metastasis is driven and sustained by CSCs [50], via haematogenous and/or lymphatic spread [51]. Less than 0.02% of disseminated tumour cells are capable of developing distant metastases [50], and it is theoretically possible that just one disseminated tumour cell is sufficient to initiate a metastatic lesion [52].

Metastasis is a complicated process involving multiple steps: invasion, intravasation, transport, extravasation and colonisation [53] (Fig. 2). First, tumour cells spread into adjacent tissues, invade the basement membrane and enter the blood and/or lymphatic system (known as intravasation) and then travel as circulating tumour cells (CTCs). By this stage, tumour cells have acquired the traits that enable evasion of the immune system, shear stress and survival mechanisms to escape programmed cell death such as *anoikis*, which occurs following detachment from the ECM. Disseminated tumour cells carry similar driver mutations present in the primary tumour and undergo further selection pressures at the metastatic site in the new microenvironment, known as the metastatic *niche* [49, 54]. In this complicated process, two crucial phenotypic transitions occur: EMT and mesenchymal-epithelial transition (MET) (Fig. 2). During the initial phase of metastasis, tumour cells undergo EMT, whereby epithelial cells acquire a mesenchymal phenotype that conveys increased invasiveness and migratory capacity. EMT is influenced by transcription factors such as Twist, Snail and FoxC2, as well as the cytokine transforming growth factor- β (TGF- β) [55], acting as core regulators of EMT [53]. Upon arrival at the metastatic site(s), CTCs undergo MET, a crucial process that enables cells to re-differentiate into an epithelial phenotype and form metastatic tumours [56] (Fig. 2)—a process that occurs naturally during embryogenesis when the mesoderm becomes epithelial tissue during organogenesis [57].

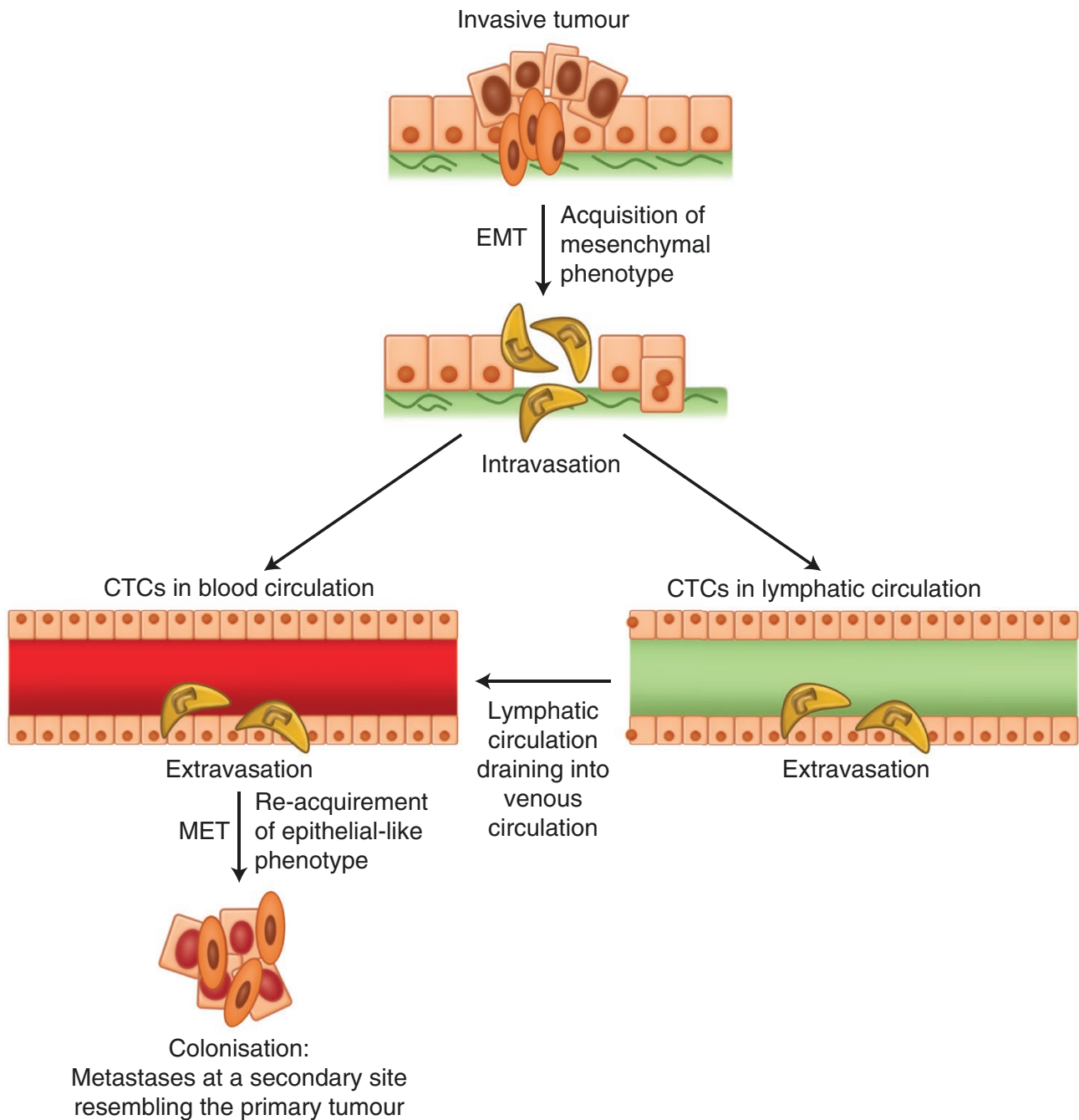


Fig. 2 A diagram showing the role of epithelial-mesenchymal transition (EMT) and mesenchymal-epithelial transition (MET) in cancer metastasis. Tumour cells within a cancer undergo EMT to form mesenchymal-like cells, which undergo intravasation to enter the blood and/or

lymphatic circulations as circulating tumour cells (CTCs). These CTCs then undergo MET and extravasate into distant tissue sites, where metastatic tumours may be established

6 Circulating Tumour Cells

The number of CTCs far exceeds the number of macrometastases that eventually develop [58]. Even a small tumour is capable of shedding millions of cancer cells [50]. However, many patients remain in remission or develop recurrence after a long latent period [50]. Metastases arise from complex processes involving CTCs, which bear CSC characteristics that enable them to colonise sites with a favourable microenvironmental *niche*. To be successful, CTCs need to be able to infiltrate tissue, evade immune mechanisms, adapt to a favourable microenvironmental *niche* and survive as slow cycle tumour initiating cells before eventually undergoing further genetic and epigenetic changes to form metastatic lesions [50].

As metastasis is a feature of CSCs, it is proposed that some CTCs are CSCs that form new metastatic lesions at distant sites [59]. The observation that most injected cancer cells do not form macrometastases, e.g., only 0.02% of injected melanoma cells into the portal circulation develop metastases at distant sites [60, 61], suggests a very small proportion of CTCs are circulating CSCs [62].

7 Cancer Stem Cells and Tumour Microenvironment

The observation that certain cancers preferentially metastasise to certain organs suggests the presence of an environmental *niche* within these organs that favours the formation of metastases for that particular cancer [50]. Both the CSCs—the “seed” and the surrounding microenvironmental *niche*, the “soil”—are critical ingredients for the development of metastasis [63]. The microenvironmental *niche* is a specialised set of environmental conditions that includes different elements such as cytokines, prostaglandins, growth factors, ECM components, immune cells, endothelial cells and cancer cells [49, 63]. Understanding CSCs and their environmental *niche* may lead to novel therapeutic targeting of CSCs directly, or their microenvironmental *niche*, in the treatment of cancer [47, 64].

Like adult stem cells, CSCs require input from their microenvironment to maintain a balance between self-renewal and differentiation [63]. Changes to factors influencing this *niche* affect CSC characteristics such as plasticity, tumour initiation ability, tumour progression and

patient outcome [63, 65, 66]. EMT is a crucial step that enables cancer cells to acquire a CSC-like state, underscoring tumour development and progression, local invasion and distant metastasis [63]. Interaction between cancer cells and the microenvironmental *niche* can induce EMT. For example, EMT can be induced by tumour-associated fibroblasts residing in the *niche* by releasing TGF- β , which has been shown to cause proliferation of CSCs in breast cancer [67] and oral cavity SCC [68].

CSCs use signalling pathways, such as STAT3, Wnt/ β -catenin, Notch, Sonic hedgehog, NF- κ B and epidermal growth factor signalling pathways [63], that regulate stem cell maintenance, self-renewal and pluripotency. STAT3 mediates signalling by the cytokines interleukin-6 (IL-6) and IL-10 released by immune cells and growth factors in the surrounding microenvironmental *niche*. When activated, STAT3 influences the expression of genes involved in tumour initiation, invasion and metastasis and angiogenesis [69]. STAT3 has also been shown to maintain CSCs and promote EMT [69]. NF- κ B is an inflammatory regulator that contributes to tumourigenesis and chemotherapy resistance [63, 70]. Activation of NF- κ B in ovarian CSCs has been correlated with drug resistance [71] and may play a role in other cancer types.

Tumour activating macrophages (TAMs), which are abundant in solid cancers [72], play an important role in the tumour microenvironmental *niche* that influences CSCs and the microenvironmental *niche* before and after tumour initiation [63]. Before tumour formation, TAMs cause DNA damage and contribute to oncogenic mutations and cancer-related inflammation by releasing inflammatory cytokines such as IL-6 and tumour necrosis factor (TNF) [63]. In advanced tumours, TAMs influence angiogenesis and immunosuppression and promote invasiveness, proliferation and survival of cancer cells [63]. Tissue macrophages have also been shown to regulate homeostasis in the haematopoietic stem cell *niche*, and it is interesting to speculate whether TAMs also influence CSCs [73]. Like CSCs, TAMs are plastic and vary in phenotype depending on their location and how they interact with the tumour microenvironment [74]. Furthermore, tumour cells release cytokines that attract cells which create an immunosuppressive microenvironment [75, 76].

MSCs residing in the microenvironmental *niche* promote tumour formation and metastasis by releasing various cytokines such as IL-6 and IL-8 [49]. Cancer cells can also release cytokines such as IL-1 to stimulate MSCs to produce

prostaglandin E2 [77], and other cytokines, to activate β -catenin signalling and facilitate CSC formation [78].

If CSCs play a crucial role in metastatic seeding, then measures that target them at diagnosis of the primary tumour, or factors that contribute to the pre-metastatic *niche* that support seeded CSCs, may improve treatment outcome [79].

The endocrine RAS (Fig. 3), classically known for regulating blood pressure and body fluid homeostasis, is an important constituent of the microenvironmental *niche* that influences stem cell maintenance and differentiation [80]. Different components of the RAS drive MSC differentiation into different cell types [81, 82]. For example, angiotensin-converting enzyme (ACE) enables expansion of haemangioblasts—multipotent haematopoietic precursor cells. Angiotensin II (ATII) receptor 1 (AT₁R) or ATII receptor 2 (AT₂R) signalling can determine the cell lin-

eage haemangioblasts differentiate into [83], underscoring the important role of the RAS in determining stem cell fate. The RAS also influences developmental processes such as vasculogenesis, erythropoiesis and haematopoiesis [80].

Cathepsin B and cathepsin D contribute to renin activation. Cathepsin D and chymase mediate conversion of angiotensinogen into angiotensin I (ATI). Cathepsin G promotes generation of ATII from ATI or directly from angiotensinogen [64] (Fig. 3).

The RAS interacts with stem cell signalling pathways [85]. Critically, pro-renin receptor (PRR) induces Wnt/ β -catenin [85], by activating multiple genes for the RAS [86]. Wnt/ β -catenin signalling is also important for normal stem cell development and cancer development [87]. For example, two of its downstream targets are the CSC markers CD44 and c-MYC [88], which regulate CSCs [89].

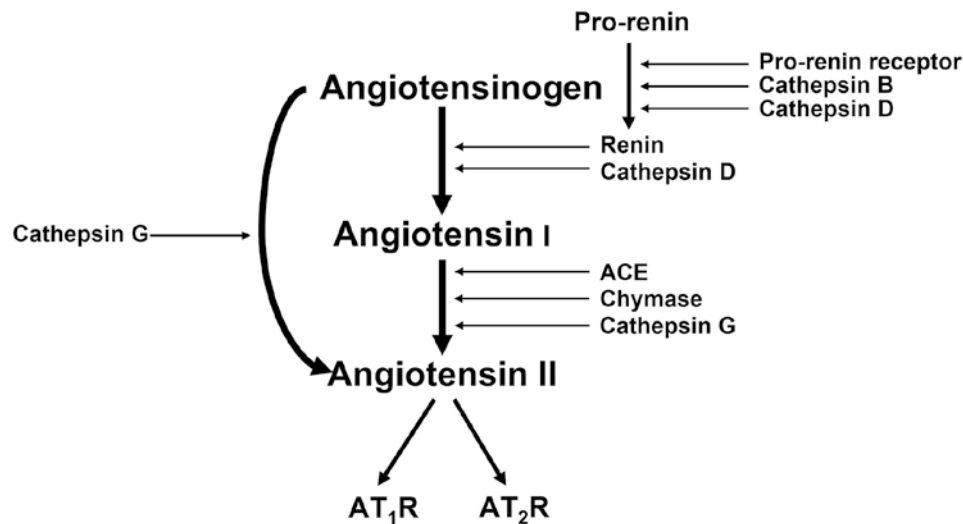


Fig. 3 A schema demonstrating the classical renin-angiotensin system, with cathepsins B, D and G and chymase, acting as bypass loops. Activation of pro-renin occurs upon binding with pro-renin receptor. Renin then converts angiotensinogen into angiotensin I (ATI), which is cleaved by angiotensin-converting enzyme (ACE) to produce the active peptide angiotensin II (ATII). The actions of ATII are mediated through

interactions with ATII receptor 1 (AT₁R) and ATII receptor 2 (AT₂R). Cathepsin B and cathepsin D contribute to renin activation. Cathepsin D and chymase mediate conversion of angiotensinogen into ATI. Cathepsin G promotes generation of ATII from ATI or directly from angiotensinogen [84]

8 Cancer Stem Cells and Treatment Resistance and Cancer Recurrence and Metastasis

There remain significant shortcomings in current cancer therapies, especially for patients with cancer recurrence and metastasis [1]. CSCs sustain and drive carcinogenesis and cause loco-regional recurrence and distant metastasis [47, 90, 91]. CSCs resist chemotherapy, radiotherapy [91] and immunotherapy [92] which target rapidly dividing cancer cells. The persistence of CSCs may explain why these treatments may decrease tumour size but do not affect survival [1].

Resistance of CSCs to chemotherapy, radiotherapy and immunotherapy is multifactorial, with one factor being the relatively slow cell cycle of CSCs compared to cancer cells [93]. CSCs also sustain less DNA damage during treatment, as they accumulate less reactive oxygen species (ROS) than cancer cells [94], due to increased expression of genes that protect CSCs against ROS [1]. Another factor is the tumour microenvironment, which contains various cytokines and growth factors, such as TGF- β , that promote survival of CSCs [55]. Conventional cancer treatments increase CSC properties in cancer cells and can even convert these cells into CSCs [95]. Conventional cancer treatments exert selection pressures that increase the relative proportion of CSCs to cancer cells [55]. The enrichment of CSCs, the increase in their stemness, and the conversion of cancer cells to CSCs cause the recurrent tumour to be more resistant to treatment with a poorer prognosis than the original tumour [55].

9 Cancer Stem Cells in Cutaneous Malignant Melanoma

Australia and New Zealand have the highest incidence of MM [96, 97]. MM affected >350,000 people globally in 2015 [98] and causes 60–80% of all deaths from skin cancers [99]. MM has been assumed to arise from a mature melanocyte. However, there is increasing evidence suggesting a melanocyte stem cell [100] or CSC [101] origin.

The mainstay treatment for primary MM is wide local excision, and surgery and radiotherapy for metastatic MM [102]. Over the past decade, targeted therapies including BRAF and MEK inhibitors [103] and immune checkpoint blockers [104] have improved outcomes of patients with advanced (stages III and IV) MM, compared to dacarbazine chemotherapy [105]. Adjuvant immunotherapy with pembrolizumab has also shown efficacy for stage III MM, with a recurrence-free survival at 1 year of 75.4%, compared to

Treatment with the BRAF inhibitor vemurafenib for stages IIIc and IV MM shows a complete or partial response rate of 50% and a median progression-free survival (PFS) of

5.3 months, compared to a 7% complete or partial response and 1.6 months of PFS for dacarbazine chemotherapy [107]. However, at 8 months, the PFS is similar between the two

MM patients, an adjuvant BRAF inhibitor regime of dabrafenib plus trametinib results in a recurrence-free survival of 54% at 4 years, versus 38% among patients receiving placebo [108]. Despite improved outcomes with immunotherapy, the 5-year overall survival for patients with stages III and IV MM are 41–71% and 9–28%, respectively [109]. Treatment failure has been attributed to the presence of CSCs which underscore cancer invasion and metastasis and treatment resistance [110, 111].

CSC subpopulations expressing some or all of the five stemness-associated markers involved in generation of iPSCs [17] have been identified in HNmmMM [17] and mMMB [46]. A Melan-A⁺ and a Melan-A⁻ subpopulation expressing one or more of the ESC markers OCT4, SALL4, SOX2 and NANOG, and a pSTAT3⁺ subpopulation localising to the endothelium of the tumour microvessels have been demonstrated in mMMB [46]. In HNmmMM an OCT4⁺/SOX2⁺/KLF4⁺/c-MYC⁺ CSC subpopulation has been demonstrated within the tumour nests (TNs) and the peritumoural stroma (PTS) with some of these CSCs also expressing NANOG [17]. Cells derived from HNmmMM express these stemness-associated markers and form tumourspheres in vitro [17]. Zimmerer et al. [112] demonstrated in vitro tumoursphere formation capacity, a core feature of CSCs, by the metastatic melanoma cell lines Na8, D10 and HBL. Other established cell lines from metastatic MM also demonstrated typical features of CSCs [112]. Cells derived from human MM can undergo melanogenic, adipogenic, chondrogenic and osteogenic differentiation [113]. Furthermore, the self-renewal capability of MM CSCs is preserved both in vitro and following xenotransplantation into mice [101].

10 Cancer Stem Cells in Cutaneous Squamous Cell Carcinoma

cSCC makes up 15–25% of all skin cancers [114], with its incidence rising rapidly globally [115]. It is the second most common skin cancer, affecting 118/100,000 people in New Zealand [116]. Risk factors for cSCC include European descent, pale complexion, immunosuppression and advancing age [114, 115]. 60% of cSCC occurs in the head and neck region with a 2% risk of metastasis, mostly to the parotid and/or neck nodes [117]. The 5-year survival for metastatic head and neck cSCC (mHNcSCC) is 34–48% despite intensive treatment with surgery and adjuvant radiotherapy [115, 118, 119]. This poor outcome has been attributed to the presence of CSCs [120].

Several CSC markers have been used to identify CSCs in cSCC including the five aforementioned transcription factors involved in the generation of iPSCs [18, 45], CD133 [19], CD49f [121] and CD44 [122].

CD133⁺, but not CD133⁻ cancer cells from primary cSCC recapitulate cSCC histology and the heterogeneous tissue hierarchy, and demonstrate self-renewal capacity, upon xenotransplantation into mice [18].

The transcription factor SOX2 is the most abundant stemness-associated marker expressed by cSCC in mice [123]. Tumour formation from chemical-induced tumour carcinogenesis significantly decreases following the deletion of *SOX2*, and ablation of SOX2⁺ cells leads to tumour regression [123].

CSCs have been identified in both primary HNCSCC [18] and mHNCSCC [16] and many other cancer types [124]. An OCT4⁺/NANOG⁺/SOX2⁺/KLF4⁺/c-MYC⁺ CSC population within the TNs and the PTS and an OCT4⁺/NANOG⁻/SOX2⁺/KLF4⁺/c-MYC⁺ in the PTS have been demonstrated in primary HNCSCC [18]. An OCT4⁺/NANOG⁺/SOX2⁺/KLF4⁺/c-MYC⁺ in the TNs and the PTS and an OCT4⁺/NANOG⁻/SOX2⁺/KLF4⁺/c-MYC⁺ CSC subpopulation in the TNs have been demonstrated in mHNCSCC [16]. Primary cell lines derived from mHNCSCC tissues that express these stemness-associated markers form tumourspheres in vitro [17].

CSC properties can be induced in cSCC by inhibition of PTEN—a protein encoded by the tumour suppressor gene *PTEN*, by the microRNA has-miR-142-5p [19]. Hsa-miR-142-5p can induce CSC characteristics, suggesting this microRNA may be a potential therapeutic target [19].

11 Cancer Stem Cells in Basal Cell Carcinoma

Basal cell carcinoma (BCC) is the most common skin cancer [125], comprising 65–75% of all skin cancers [126, 127]. BCC was thought to arise from the epidermal basal layer [125]; however, more recent studies suggest a follicular origin [125]. Stem cell markers including CD34, Bmi-1 and p63 have been demonstrated on BCC [125]. However, currently available stem cell markers are unable to confirm an adult somatic follicular stem cell or an intrafollicular CSC origin [125]. BCC may arise from resident follicular adult stem cells that acquire oncogenic mutations in a stepwise fashion or from a CSC residing in the follicle. However, the presence of CSCs within BCC remains to be proven.

Vismodegib, a targeted therapy for advanced BCC, targets the Sonic hedgehog pathway, which plays an important role in embryonic development, and is active in stem cells, follicular cells and skin cells [128]. The transmembrane receptor Patched (PTCH) normally inhibits Smoothened

(Smo) resulting in suppressor of fused (Sufu) inhibition of the transcription ability of Glioma-1/2 (Gli-1/2) [128]. PTCH suppression of Smo ceases, in the presence of a mutation affecting PTCH or Smo, or when hedgehog ligand is present, causing inhibition of Sufu and release of the transcriptional ability of Gli-1/2 [128]. Vismodegib blocks the Sonic hedgehog pathway by inhibiting Smo, which causes suppression of Gli-1/2 transcriptional activation [128]. Inhibition of this pathway utilised by stem cells results in an overall response rate (ORR) of 50% for patients with metastatic BCC. Of the 15 patients with locally advanced BCC treated with vismodegib, two had a complete response, seven had a partial response, four had stable disease, and two had progressive disease—an ORR of 60% [128]. Given the therapeutic benefit of vismodegib results from inhibition the Sonic hedgehog pathway that regulates stem cells, it is interesting to speculate the presence of CSCs in BCC. Further research into the presence of CSCs in BCC is warranted.

12 The Renin-Angiotensin System, Its Bypass Loops and Novel Cancer Treatment

The endocrine RAS (Fig. 3) regulates cardiovascular homeostasis. Pro-renin is converted to renin upon binding to PRR. Physiologically, renin, released by the kidneys in response to reduced blood volume or blood pressure, cleaves angiotensinogen to form angiotensin I (ATI), which is converted to ATII by ACE. ATII exerts its effects by binding to AT₁R and AT₂R. Binding of ATII to AT₁R causes vasoconstriction to increase blood pressure, whereas binding of ATII to AT₂R causes vasodilation [80]. A local RAS that acts in an auto-crine and paracrine fashion is also present in multiple tissue types [129], including the kidney [129], infantile haemangioma (IH) [130], vascular malformations [131, 132], microvessels in fibrotic conditions [133, 134], and cancer [47, 135, 136].

The RAS plays a critical role in carcinogenesis, and numerous studies have demonstrated its involvement in many cancer types [80]. For example, propranolol, which blocks renin, inhibits the growth of breast cancer in vivo [137], and ACE inhibitors (ACEIs) prevent tumour growth and invasion in different cancer types [80]. Similarly, angiotensin receptor blockers (ARBs) inhibit development of various cancer types [80]. The effect of different RAS modulators on tumour growth, invasion and metastasis in many cancer types warrants further investigation into repurposing these medications for cancer treatment [47, 80].

As RAS inhibitors (RASIs) are commonly used in the treatment of hypertension, their effects on cancer have been observed [80]. An early study demonstrated the association between administration of ACEIs and reduced risk of devel-

oping certain cancers, especially those affecting women [138]. There has been extensive epidemiological data on reduced cancer risk associated with RASIs depending on the cancer types, cohort characteristics and the type of RASI [80]. However, several large meta-analyses have shown mixed results, which may be attributed to the methodologies of the studies included in the analyses [80]. A recent meta-analysis of 55 studies demonstrates significant improvements in overall survival (HR = 0.82; 95% CI: 0.77–0.88; $P < 0.001$), PFS (HR = 0.74; 95% CI: 0.66–0.84; $P < 0.001$) and also disease-free survival (HR = 0.80; 95% CI: 0.067–0.95; $P = 0.01$) in patients taking ACEI and ARB compared

overall survival in patients with head and neck SCC (HR = 0.38; 95% CI: 0.12–1.20; $P < 0.10$) and MM (HR = 0.41; 95% CI: 0.10–1.68; $P = 0.22$) is associated with ACEI and ARB use, compared to non-users [139].

Components of the RAS are expressed by CSCs in many cancer types [140–143], including primary HNCSCC [144] and mHNCSCC [145], mHNMM [146] and mMMB [136]. Cathepsins B, D and G, which constitute bypass loops of the RAS, are expressed by CSCs in metastatic colon adenocarcinoma to the liver [135], oral tongue squamous cell carcinoma [147], glioblastoma [148] and HNCSCC [149]. It is interesting to speculate that the RAS acts in a paracrine fashion within the microenvironmental *niche* to influence CSCs, as with tumour stem cells in IH [130, 150].

Several clinical trials targeting the RAS, its bypass loops and other converging pathways are underway for multiple cancer types. A phase II clinical trial on patients with metastatic renal cell carcinoma treated with perindopril (an ACEI) or candesartan (an ARB), combined with other agents such as cyclooxygenase-2 (COX-2) inhibitor, demonstrates stabilisation of metastatic disease and reduced cancer recurrence [151]. A randomised clinical trial demonstrates reduced biomarkers of invasion and inflammation in patients with breast cancer treated with propranolol, combined with a COX2 inhibitor, which is well tolerated [152].

The RAS with its multiple components, the presence of bypass loops providing redundancy and the convergent signalling pathways onto the RAS with crosstalk require a system-wide approach using a combination of medications to provide optimal blockade of the RAS to target CSCs [47, 80]. This novel therapeutic approach has been shown to be safe and well tolerated with a trend towards improved survival in a phase I clinical trial on glioblastoma [153].

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Head and Neck Pathology: Practical Points to Ponder

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Core Messages

- Pathologists need information from clinicians and radiologists.
- Taking better specimens leads to better feedback to clinicians.
- Preparing the optimum specimen for your differential diagnosis.
- Being aware of all the testing modalities at the pathologists' disposal.
- Forming a symbiotic relationship with your pathologist.

1 Introduction

Anatomical pathology is the branch of medicine that deals with the examination of cells, tissues and organs, mainly for diagnostic purposes. It is a self-standing medical discipline, and its practitioners require specialist knowledge and skills. It best serves the needs of patients if it is conducted not in isolation but in harmony with the clinicians who are in direct patient contact [1]. The aim of our chapter is not to review the pathology of malignancies of the head and neck but rather to give the pathologists' perspectives of how best to achieve that harmony. We shall cover some practical information about what clinicians can do to enhance the subse-

quent contribution that pathologists can make to the team, and we shall cover how best to interpret the pathological report. Particularly in the field of head and neck pathology, providing appropriate clinical and radiological information, and the best possible specimens, massively assists what the pathologist can do to ensure the best outcome for the patient.

The specimens submitted by clinicians managing head and neck pathology most frequently are biopsy specimens. For the pathology laboratory to perform all the relevant testing and analysis required for the most accurate diagnosis, the most suitable specimen needs to be submitted, in the most appropriate transport medium. Pathologists have little leeway if the specimen is unavoidably small, and non-ideal handling of a small specimen before it reaches the laboratory can have irrecoverable consequences. So we will offer the pathologists' perspectives on specimen collection techniques and transport media.

Once a specimen has been received and processed through

clinicians and pathologists. The main tool of the anatomical pathologist remains the optical microscope, but today pathologists have access to a large range of special stains. Immunohistochemical stains and other molecular studies have vastly improved their diagnostic and prognostic capabilities, as well as their contribution to treatment planning. We shall offer a brief overview of some of these ancillary procedures.

If a cancer is identified in the specimen, the pathologist usually will submit a synoptic report that ensures that vital information about each cancer is recorded. Some of the important prognostic factors from these synoptic reports are tumour thickness and depth of invasion, pattern of invasion, perineural invasion and surgical margins, and we shall discuss how those factors are determined.

Not just at the report stage but throughout the process, we urge clinicians in direct contact with patients to interact with their pathologists. Discussions between pathologists and clinicians can help resolve a challenging diagnosis and encourage pathologists to review cases where initial pathological interpretations do not reconcile with the clinical picture.

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Also, when you really are in a bind and need something special, like rapid turnaround time, a pathologist, who you have established as an ally, can move mountains.

2 Obtaining a Specimen

We offer pathologists' views on the procedures that clinicians need to undertake to obtain and submit the best specimens. Practices in the hands of clinicians determine the capacity of pathologists to derive information from the specimen and consequently the value of the report submitted back to the clinicians. The procedures that we shall discuss are fine needle aspiration (FNA), biopsy for frozen section and biopsy for routine histology.

3 Fine Needle Aspiration

Fine needle aspiration, which can be freehand or ultrasound guided, trumps other procedures with regard to rapid diagnostic capability. When used in the appropriate setting, a fine needle aspirate may provide material for a quick, sometimes immediate diagnosis as well as material for ancillary testing. The procedure is technically simple, usually has few side effects, and is a great addition to the diagnostic armoury of the surgeon/pathologist team. Cellular tumours, lymph nodes, metastatic skin lesions, salivary tumours and thyroid lumps are examples of lesions that are good candidates for cytology. Certain other lesions, for example, fibrotic lesions, small ill-defined lesions, exclusively cystic lesions and stromal tumours, may not be amenable to, or easily diagnosed by, FNA.

Here is how to get the most from an FNA.

3.1

Whilst fine needle aspiration is a simple technique, there is an

1. Have all the necessary equipment, such as needles, clean syringes, labelled glass slides and transport medium, at hand before starting the procedure. This preparation reduces the time between aspiration of the material and its transfer to the slide. The longer the lag time, the greater the risk of creating a drying artefact (see Fig. 5) or allowing the material to clot in the needle, preventing expulsion.
2. Positioning the patient is equally important, especially if the fine needle aspirate is to be done freehand. Aim to achieve good access to the lesion and easy immobilisation of the lesion with your non-aspirating hand. Improving positioning can be as simple as tilting the chin or hyperextending the neck, the latter a useful technique for thyroid FNAs.
3. There is no universal agreement on the right needle gauge. As a general guideline, larger bore needles do not always yield better results. Avoid large needles such as 1.27 mm outer diameter (18 gauge) needles because they can promote bleeding, leading to blood clot obscuring target cells on the slide. Our preference is either 0.64 mm (23 gauge) or 0.52 mm (25 gauge) and a 10 mL syringe.
4. Tissue procurement can be done with or without suction. Both techniques have advantages and disadvantages. Suction may produce more tissue volume but at the risk of generating more bleeding. Our recommendation is to stop suction if there is bleeding at the site of sampling.
5. It is the fine backward and forward motion of the needle bevel that cuts loose target cells. The repeated forward

motion forces the loose cells to move up the needle shaft, even without suction. FNA expert Susan Rollins suggests that the ideal needle oscillation is three per second with an intralesional dwell time of between 3 and 5 seconds [2].

3.2 Smear Preparation

If you are making the smear yourself, using a reliable technique will ensure that the pathologist can use the material to your mutual best advantage. Whilst there are many possible techniques, we shall describe one [3].

1. Immediately after aspiration has been completed, remove the needle from the syringe, and pull back on the plunger to provide sufficient force to express the material onto the slide (Fig. 1).

Pitfall: Failure to disconnect the syringe barrel from the needle may pull all the aspirated material back into

the syringe, making transfer of the specimen onto the slide difficult or impossible.

2. Re-attach the needle, place the needle onto the upper third of the glass slide, and depress the plunger of the syringe to express the material (Fig. 2).

Pitfall: If your needle is held too far above the slide, the material will splatter. Worse than splatter is the dart-like needle projectile after excessive force is applied to express material clotted in the hub.

3. Invert a second slide over the first so that the material spreads from the weight of the slide only (Fig. 3).

Pitfall: Additional pressure creates the risk of introducing crush artefact (see Fig. 6).

4. Pull the slides apart with a gentle horizontal motion, creating two slides for every needle pass, facilitating Pap and Giemsa stains (Fig. 4).

5. Air-dry one of the slides with the assistance of a fan or hair dryer if necessary, and wet fix the other slide immediately using 95% alcohol or spray fixative.



Fig. 1 Remove the needle containing the aspirated material from the syringe and then pull the plunger back

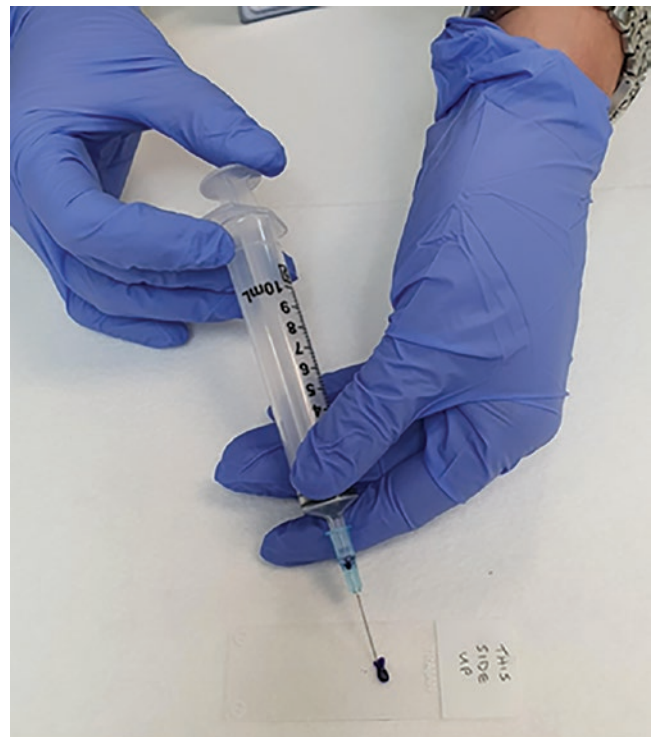


Fig. 2 Express the material onto the upper third of the slide

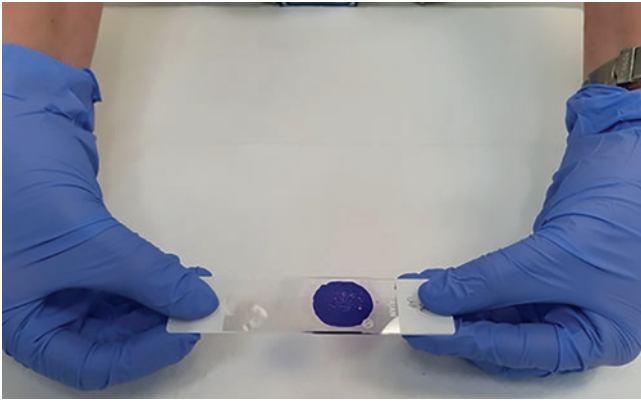
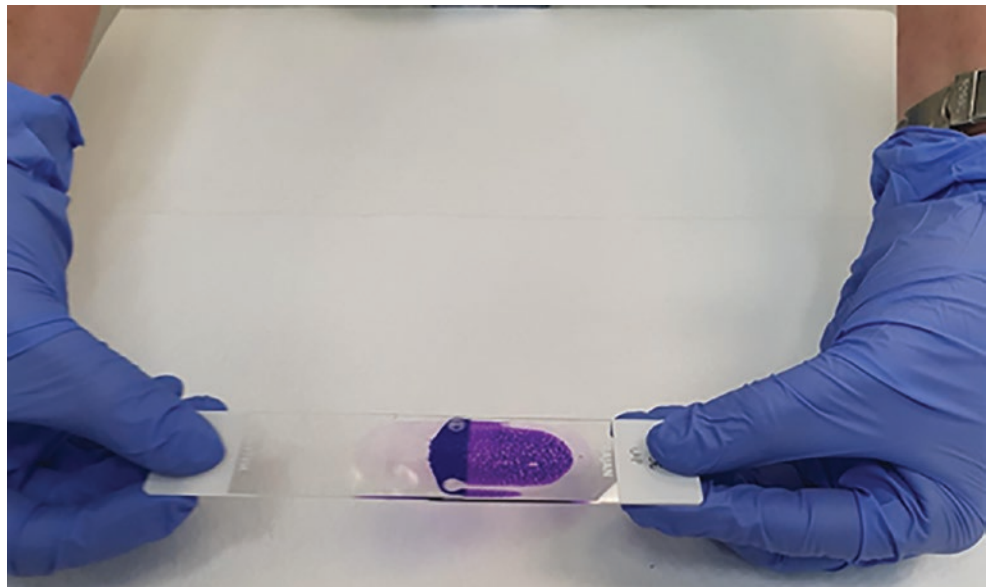


Fig. 3 Invert a second slide over the first, so that the material spreads from the weight of the slide only

Fig. 4 Gently pull the slides apart completely using a horizontal motion

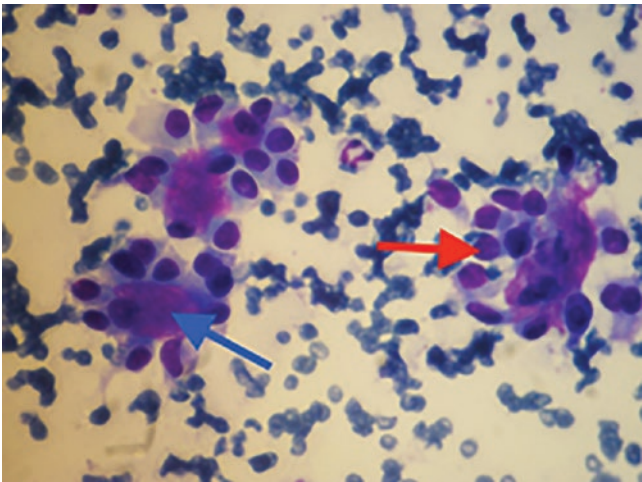
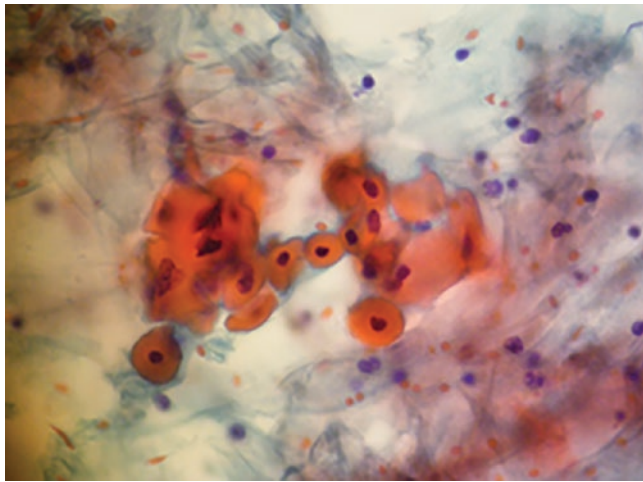
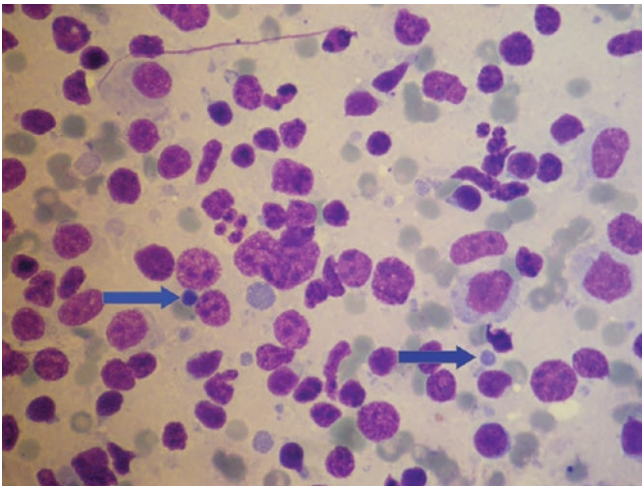
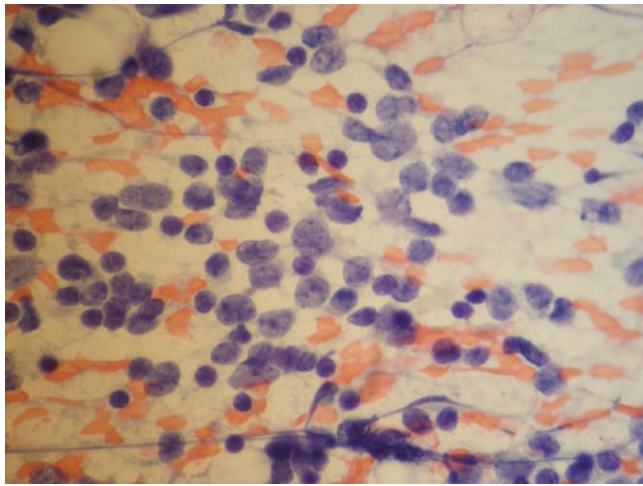


3.3 Papanicolaou Stain vs Giemsa/Diff-Quik Stain

The stains usually employed for histopathological examination of FNA smears are the **Papanicolaou stain**, for nuclear detail, and the Romanowsky-type stains (Giemsa/Diff-Quik), for **cytoplasmic detail** (Table 1). Some pathologists may have

a personal preference for one of these stains, but they highlight different cellular features [4]. The reason that we advised that one FNA smear be air-dried and the other wet-fixed is the Romanowsky-type stains require an air-dried smear and the **Papanicolaou stain** a wet-fixed smear. Providing both smears allows the pathologist to use both stains and the best opportunity to assess all aspects of the specimen.

Table 1 What pathologists can do with Romanowsky-type and Papanicolaou stains of FNA smears

Features emphasised by Giemsa/Diff-Quik stain	Features emphasised by Papanicolaou stain
Cytoplasmic detail and stromal components well demonstrated	Nuclear detail is excellent
Ideal for visualising: Colloid (thyroid) Mucin (salivary gland tumours) Basement membrane globules (adenoid cystic carcinoma) Lymphoglandular bodies (lymphomas)	Ideal for visualising: Squamous differentiation/keratinization (squamous carcinomas) Nuclear chromatin (e.g. salt and pepper chromatin of neuroendocrine tumours) Oncocytes (salivary gland tumours)
 Adenoid cystic carcinoma (Giemsa stain 400× magnification) The aspirate shows the presence of large globules of extracellular matrix material which stain purple (blue arrow). There are surrounding basaloid cells (red arrow)	 Squamous cell carcinoma (Papanicolaou stain 400× magnification) The cytoplasm of squamous cells stains bright orange. The nuclei appear almost black due to condensation of the nuclear chromatin
 Lymphoma (Giemsa stain 400× magnification) Small blue lymphoglandular bodies are visible in the background (blue arrows). These are small cytoplasmic fragments often seen in aspirates of lymphomas	 Merkel cell carcinoma (Papanicolaou stain 400× magnification) This stain highlights the typical salt and pepper chromatin seen in the nuclei of neuroendocrine tumours. Merkel cell carcinoma is a highly aggressive neuroendocrine carcinoma of the skin and is a prevalent cancer of the head and neck in elderly and immunosuppressed individuals

3.4 Artefacts: What Can Go Wrong in FNA Smears and How to Avoid It

3.4.1 Drying Artefact

The thyroid follicle cells show artefactual degenerative changes (Fig. 5). The nuclei are pale and have lost the nuclear detail, making assessment for lesions like papillary carcinoma challenging for the pathologist.

Problem: The material has dried or has been fixed too slowly.

Solution: Dry with a fan or hair dryer or fix material immediately after smearing.

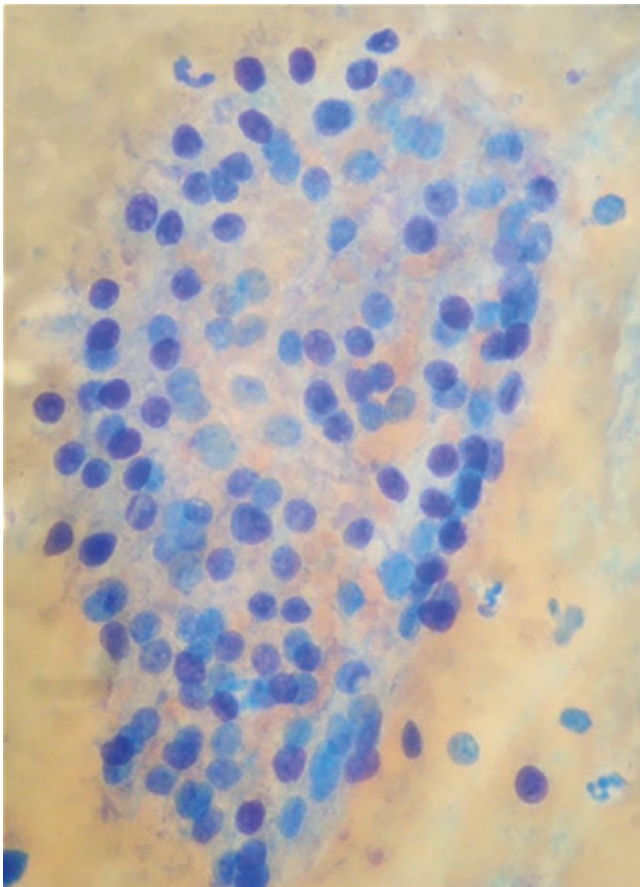


Fig. 5 Thyroid aspirate (Giemsa stain 200× magnification)

3.4.2 Crush Artefact

Problem: Too much force was used whilst smearing the slide (Fig. 6).

Solution: Use no more force than the weight of the top slide when preparing a smear.

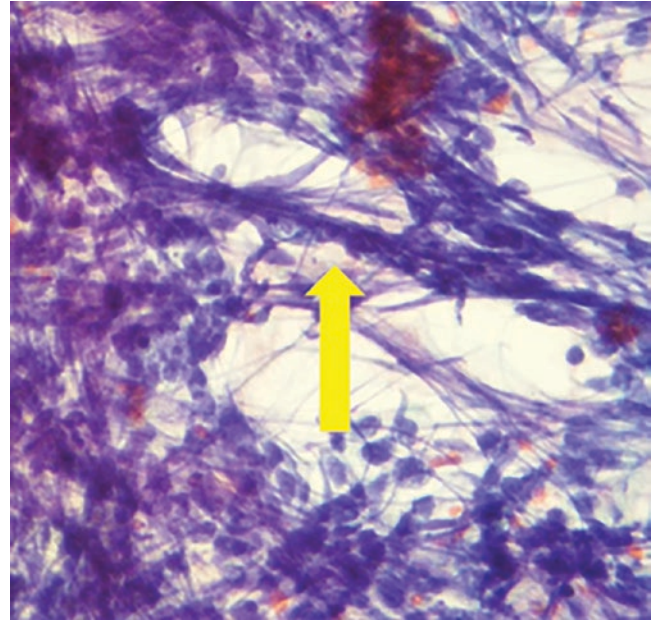


Fig. 6 Lymph node aspirate for metastatic Merkel cell carcinoma (Giemsa stain 200× magnification). In this slide the nuclei have been crushed leaving long blue strands of nuclear material (yellow arrow)

3.4.3 Too Thick

This aspirate from the lymph node is so thick that individual cell characteristics have been lost and it is difficult for the

Problem: Too much material in a localised area means individual cells cannot be seen.

Solution: Limit the amount of material and smear evenly. If you aspirate abundant material, it is better to prepare more slides than put a large drop on one slide.

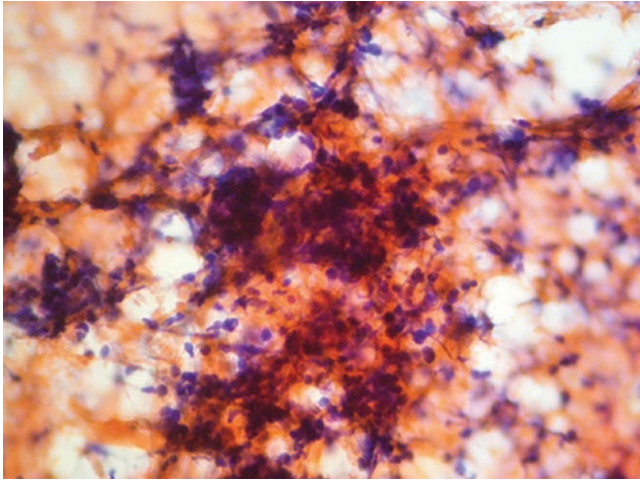


Fig. 7 Lymph node aspirate (Papanicolaou stain 200× magnification)

3.5 Preparing FNA Specimens for Ancillary Studies

smears to be supplemented with additional procedures (see “Ancillary histological studies”). The remaining material can be placed in liquid medium after smears have been prepared or primarily if a designated FNA pass is performed for this purpose. A small amount of the liquid should be drawn into the syringe and then expelled back into the medium container. This process may be repeated several times. In this

ology, a cell block, immunocytochemistry or molecular studies [5]. Whilst specific media are ideal, if they are not available, saline may be used, as long as the specimen is transported quickly to the laboratory. Because processing in the laboratory needs to be immediate if the specimen is in saline, let your pathologist know it is on its way. Try to avoid sending FNA specimens in saline late in the day, or before a weekend, because of the risk of deterioration of valuable cellular material.

4 Frozen Sections

Frozen sections are used when pathological analysis is required immediately, during surgery with the patient remaining anaesthetized. A specimen taken from the patient is frozen, and a thin section is cut on a cryostat machine (Fig. 8), which is a microtome with a freezing stage. The thin section is placed on a glass slide where it melts and is dried, stained and examined under the microscope. Pathologists can report on a histological examination by frozen section within 15–20 min of receiving the specimen.

Frozen section histological analyses usually are performed for one of three reasons [6]:

1. To guide intra-operative management, e.g. examination of margins of excisions.
2. For triaging of tissue for later special studies.
3. To confirm that lesional tissue is present in the specimen.

Specimens for frozen sections need to be provided fresh (not in formalin or other fixative) and should be accompanied by patient details including relevant clinical history and information about the tissue site and the reason for requesting frozen section. If the clinician is aware of, or suspects, an infection like tuberculosis, hepatitis B or HIV, this information also should be communicated to the pathologist so that the necessary protective and cleaning protocols can be instituted. Orientation of the specimen is vital, and a discussion with the pathologist about which

mation is being sought, will improve the information the pathologist will be able to provide.

Frozen section histological examination is not a rapid substitute for what the pathologist can do with a permanent section. Table 2 summarises the differences.

Requesting a frozen section in theatre because it would be “nice to know” the diagnosis but when knowing the diagnosis immediately actually does not impact on patient management is a waste of resources. Frozen sections are labour intensive and time-consuming. They require committed and concurrent time (often including travel time) from a pathologist and from a skilled technician. There are some frozen sections that would be deemed inappropriate, and even detrimental to the patient, including small melanocytic lesions where freezing the entire lesion may remove the possibility of better histological examination by permanent section.

Frozen section histology has a sensitivity of 89% and a specificity of 99% for the evaluation of margin status for head and neck squamous carcinomas [7]. The specificity and

sensitivity of frozen section histology for some other lesions, like follicular lesions of the thyroid, are much lower, and frozen section histology then is inappropriate. Even in ideal cir-

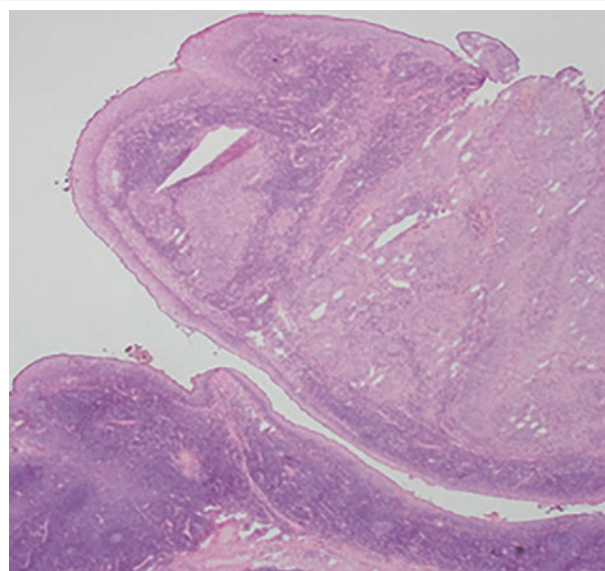
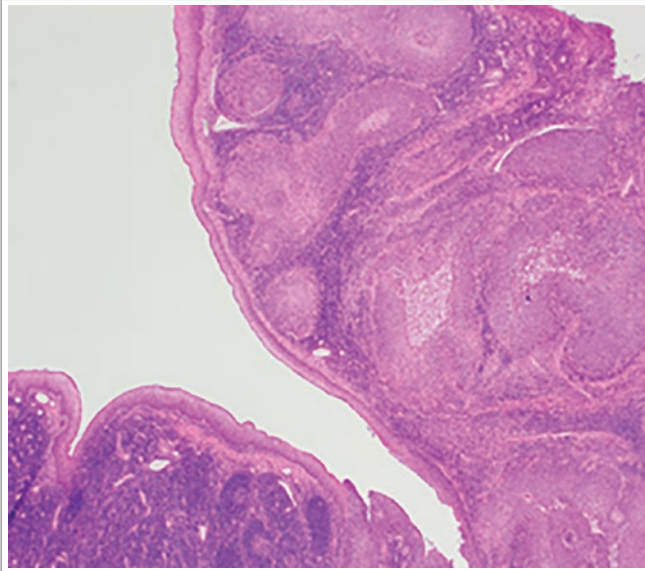
histology and permanent section histology of 3% has been reported [7].

Discrepancies between frozen section histology and permanent section histology may be due to sampling error or to interpretation error. A sampling error may occur, for example, if tumour tissue is not in the section that was stained at the time of the frozen section but is present on the deeper levels that can be examined in permanent sections. An interpretation error may occur, for example, if a pathologist, faced with the poorer resolution of a frozen section, interprets tissue on the slide as being tumour when it is not or interprets tumour tissue as benign. Interpretation errors can be reduced if pathologists specialise in an organ system and develop expertise, just as surgeons do.



Fig. 8 Leica™ CM1860UV cryostat machine, used for cutting frozen sections either in theatre or in the laboratory

Table 2 What pathologists can do with frozen section and permanent section histology

Frozen section	Permanent section
Done rapidly in theatre or laboratory	Usually processed over hours, in a laboratory
Creates freezing artefact which may impact diagnosis and later ancillary testing	No freezing artefact
Examines a targeted small proportion of the specimen	Multiple sections can examine the entire specimen
Ancillary testing is usually not performed	Ancillary testing, like special staining, immunohistochemistry and molecular markers, can be performed
Usually no opportunity for consultation with pathologist colleagues, for challenging cases	Consultation with pathologist colleagues is routine for challenging cases
 Frozen section p16-positive squamous carcinoma (200× magnification haematoxylin and eosin) Image resolution adequate but not ideal	 Permanent section p16-positive squamous carcinoma (200× magnification haematoxylin and eosin) Superior image resolution

5 Biopsy/Excision or Incision

The majority of the work undertaken by pathologists is excisional or incisional biopsies. Routine management of biopsy sometimes possible to accelerate the management, for exam-

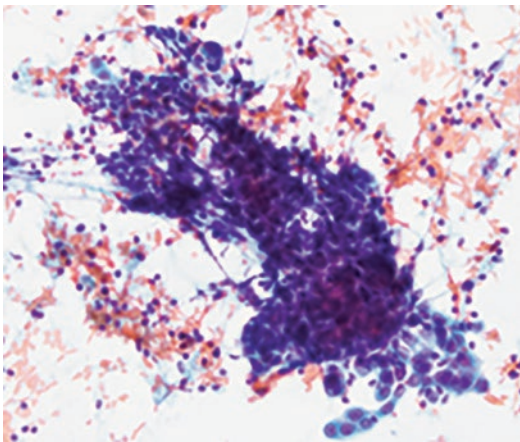
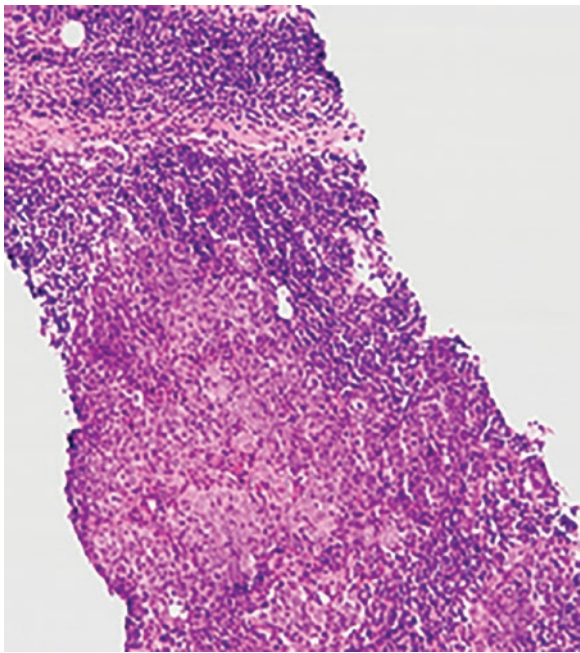
Accelerating the management is labour intensive and requires the technical staff to bypass usual processes, so is best reserved for the exceptional case where an urgent result is of the utmost importance to the patient. Accelerated management also requires communication with the pathologist so that every step of the process can be streamlined. Depending on the individual laboratory, it is possible to have slides prepared for the pathologist to examine within 3 1/2 h of a specimen arriving in the laboratory.

5.1 Core Needle Biopsy

Core needle biopsy usually is performed with a larger-gauge needle, ranging from outer diameter of 2.1 mm (14 gauge) to 0.91 mm (20 gauge), than is FNA [8]. The larger diameter of

get cells acquired and often with intact tumour architecture. We cannot over-emphasise the value of preserved tumour architecture in the slides used for cancer diagnosis. Indeed, tumour architecture preservation is the main advantage that core needle biopsy (or excisional biopsy for the same matter) has over fine needle aspiration. That said, core needle biopsy (and excisional biopsy) is not without flaws. The advantages and disadvantages of core needle biopsy and FNA are outlined in Table 3.

Table 3 Advantages and disadvantages, for the pathologist, of core needle biopsies and FNAs

	Advantages	Disadvantages
Fine needle aspiration	1. Rapid procedure 2. Can be done anywhere, including remote settings 3. No anaesthetic required, usually 4. Less traumatic and usually less bleeding due to smaller needle gauge 5. Specimen amenable to rapid on-site evaluation	1. FNA skills variable from operator to operator 2. Deeper lesions require needle guidance, e.g. by ultrasound 3. Less preservation of tissue architecture 4. Low yield for fibrotic lesions 5. Pathologist not always available for rapid on site evaluation
Core needle biopsy or excisional or incisional biopsy	1. Produces more tissue allowing more histological investigation 2. Better preserves tissue architecture for higher accuracy assessments 3. Processed as routine histology which is familiar to all pathologists (training in cytology not required)	1. May require a more elaborate set up with involvement of interventional radiologist and nurse. Cannot be done in a bedside setting 2. More costly 3. Relatively more traumatic; normally local anaesthetic will be given 4. Single trajectory of needle may limit the extent of sampling 5. Tissue requires fixing and longer processing. Rapid on-site assessment usually not possible
Left cervical lymph node with metastatic p16-positive squamous carcinoma FNA (Papanicolaou stain 200× magnification). Core biopsy (haematoxylin and eosin 100× magnification)		

5.2 The Complex Resection Specimen

There is no doubt that extreme facial surgery results in large complex histology specimens. Whilst we have general guide-

the laboratory, pathologists benefit, and the outcomes for clinicians and patients are better, from attention to multiple steps before that, some of which begin before surgery has been completed.

5.2.1 Submitting Pathology Specimens

The requirement for correct patient identification, identification of the requesting surgeon/ clinician and date of the procedure goes without saying, and these details invariably are provided. Adequate clinical history, sometimes provided less reliably, is of equal importance and has a direct impact on the ability of the pathologist to interpret the pathological features meaningfully. Whilst the vote of confidence is flattering, pathologists cannot accurately derive that clinical information from information on glass slides alone [9].

Clinical information beneficial to pathologists includes relevant prior diagnoses and, if histology has been carried out

tion as to which laboratory performed that earlier histology. Tell your pathologist the type of specimen and what you are trying to achieve by the procedure. For instance, does the specimen represent a debulking procedure or an incisional biopsy, or is it an attempt at a complete excision. The former requires little attention from the pathologist with respect to margin status, but establishing margin status is imperative in the latter. The locations and nature of some lesions that are clearly evident in vivo may become less obvious after excision and cessation of blood flow (e.g. vascular lesions and cystic lesions). Small lesions may be difficult for the pathologist to pinpoint, and specimens from lesions treated with neoadjuvant therapy may no longer be grossly identifiable [7].

If there is a specific request, or a specific question that needs to be answered, include that request/question on the form that accompanies the specimen. Pathologists will be able to respond better if they know about special needs before the specimen is processed as they may alter markedly the way in which a specimen is processed. For example, if the question is about clearance of a specific margin, the specimen needs to be sectioned to display that margin well. If the question is whether

submitted for culture and sensitivity. If it is whether a lymphoma is present, fresh tissue can be sent for flow cytometry.

5.2.2 Orientation of Pathology Specimens

Preserving the three-dimensional orientation of tissue after resection can be difficult. When complex anatomy and for-

malin fixation compound the issue, the orientation of the specimen that arrives in the laboratory may be even more obscure. To assist the pathologist, please consider the following:

1. Mark the designated borders/points of orientation with sutures, clips or ink during or immediately after resection [6]. Sutures of variable composition, length or number may be used. Sutures and clips also are useful to mark the resection margins of pertinent nerves or to identify a sentinel point, for example, 12 o'clock using a clock face template [10] for orientating the specimen (Fig. 9).
2. Pinning the specimen to a cork board (Fig. 10) has multiple benefits. The tissue is fixed in a non-rotated plane which is easier to section. Tissue shrinkage and tissue curling at the edges are reduced by pinning. Pins of different colours (e.g. indicating different anatomic locations) may be used to attach the tissue to the board and can be referenced in a specimen diagram (see Fig. 12).
3. Alternatively, the clinician may wish to define the orientation of the specimen by writing or drawing directly on the cork board. If so, the specific pen and ink need to withstand exposure to formalin. Some ink washes away almost entirely in formalin or smudges so badly that the writing/drawing becomes illegible. The images in Fig. 11 show the consequences for cork board drawings with different inks of being submerged in formalin overnight. This test is an easy one for clinicians to replicate when selecting a pen for this purpose.

Once the specimen is attached, the cork board should be inverted in the specimen container to ensure that the tissue is submerged in formalin.

4. Drawing a diagram (Fig. 12) is an excellent way of orientating a specimen. It gives the pathologist a clear

vides a platform for specific landmarks and margins to be identified. Diagrams also are convenient for identifying specific issues regarding the specimen for the pathologist's attention, for example, identifying a margin of concern.

5. Inking of the specimen to delineate margins or other landmarks usually takes place in the pathology laboratory. However, it also can be a valuable tool for the surgeon [11]. The surgeon may apply ink to orientate the specimen, to indicate a specific margin of concern or, conversely, to identify an area that does not represent a true surgical margin (Fig. 13). The ink can be applied with a cotton swab, patted dry and then dabbed with acetic acid (vinegar) as a mordant that combines with the ink to fix it to the material.



Fig. 9 Orientation of a specimen in situ using the clock face template. Orientation of a specimen is important especially if there is a positive margin on histology and the lesion requires re-excision



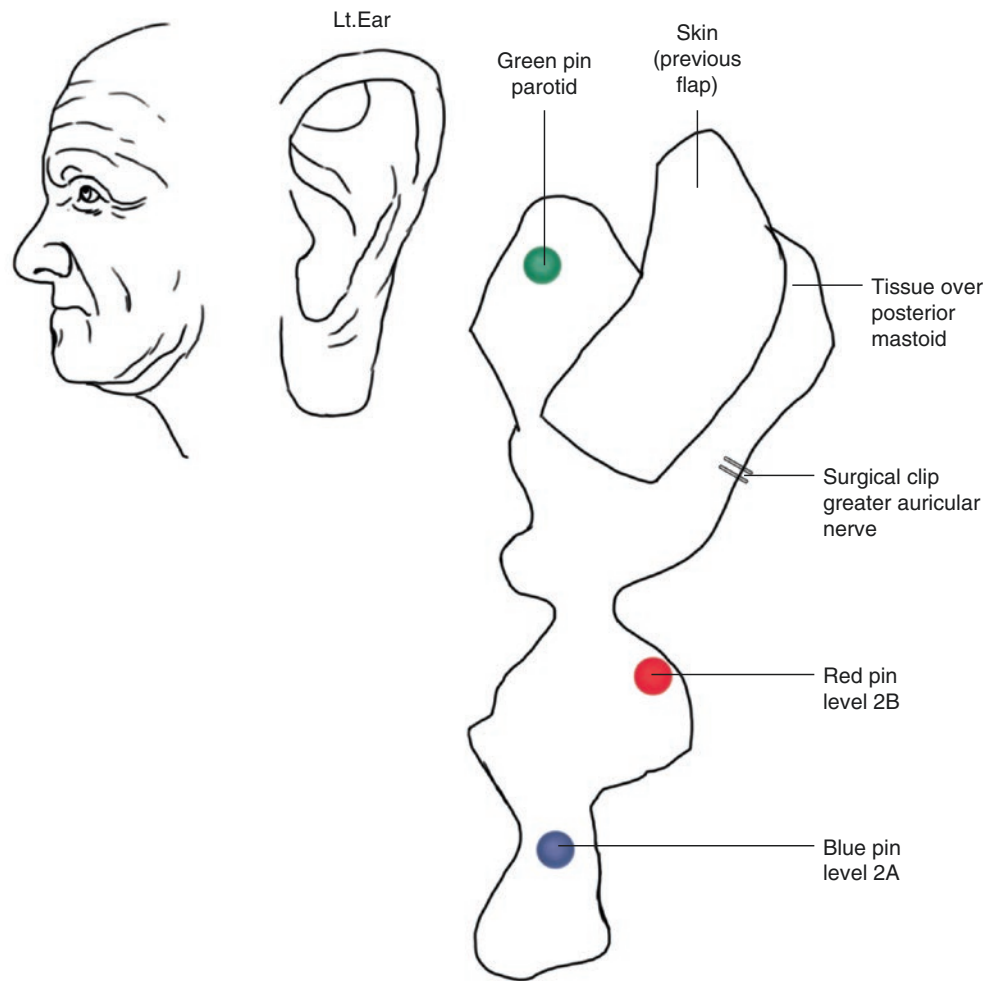
Fig. 10 A neck dissection specimen, including a level III cystic mass, pinned on a cork board and orientated with coloured pins



Fig. 11 (a) Drawings made with four different marking pens on cork boards (BIC vivid™, Premier™ ballpoint, Artline 210™ medium, Sharpie finepoint™ from left to right). The cork boards were then sub-

merged in 10% neutral buffered formalin for 24 h. (b) The same drawings after 24 h. Some pens resist formalin but are more difficult to use. Use a convenient pen in theatre but test its formalin resistance in advance

Fig. 12 Example of a drawing for which your pathologist would be very grateful



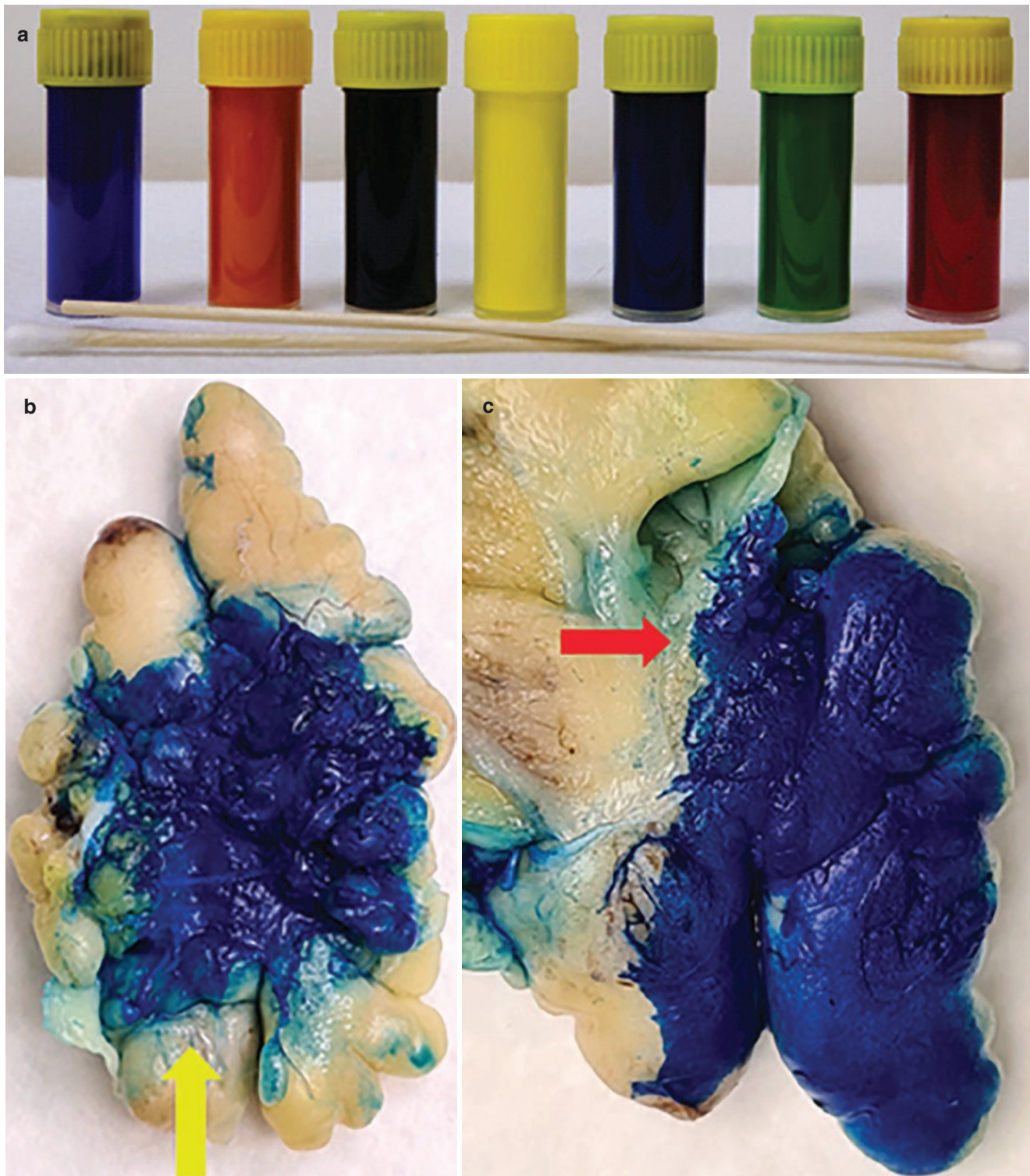


Fig. 13 (a) A range of ink colours (Aero Color Professional finest acrylic ink™) is available and can be used to orientate specimens. The ink can be applied with cotton swabs. Be sure to annotate which ink colour corresponds to which margin or other anatomical point of interest. (b and c) A lipoma inked with and without a mordant. (b) The lipoma has been inked with blue ink without a mordant. The inked mar-

gin denoted by the yellow arrow is fuzzy, and the ink has smudged and run into all the adjacent cracks. This problem may result in a pathology report with a false-positive margin. (c) The same lipoma has been inked with blue ink which has then been set with acetic acid (vinegar). The margin denoted by the red arrow is much sharper

6 Transporting a Specimen

Tissue undergoes cytolytic degeneration very quickly once extracted from the body. The smaller the volume of tissue, the more rapidly this degeneration occurs. Therefore it is crucial to prepare slides and to place any remaining material into an appropriate transport medium swiftly, for immediate preservation. The volume of transport medium should be at least ten times the volume of the specimen. Neutral buffered formalin is perhaps the best-known medium. There are situations, however, where alternative mediums are preferred. Table 4 below gives advice about which transport medium to use in different situations.

1. 10% neutral buffered formalin

Formalin is formaldehyde gas dissolved in water. Formaldehyde stabilises (“fixes”) tissue by creating crosslinks in macromolecules like proteins. Raw formalin is an acid solution, which reacts with haemoglobin to give a black precipitate, hampering subsequent histological assessment. To avoid this problem, a buffer such as sodium phosphate is added to the solution, to create “neutral buffered formalin”.

As long as formalin can penetrate all parts of the specimen, tissue preservation usually is consistent and reliable. For most core biopsies, punch or small open biopsies where the working diagnosis does not include lymphoma or require identification of microorganisms by culture, formalin remains the default option as the transport medium. Formalin-fixed paraffin-embedded tissue can be processed for routine haematoxylin and eosin staining and for immunohistochemistry and other molecular studies.

2. Alcohol-based transport medium

Alcohol stabilises tissue by coagulation. Alcohol-based preserving transport medium usually is supplied commercially in individual vials. Two products used commonly in Australasia are ThinPrep Cytolyt™ (by Hologic) and CytoRich™ (by BD). They are similar in the way that they render cells as monolayer films on the slides. Alcohol-based preservatives have become more popular over the years due to the consistency they produce, the ease of use and good level of cell preservation. Cells preserved in alcohol-based medium will be suitable for routine cytomorphology (either in addition to a direct smear or without), haematoxylin and eosin histology, immunohistochemistry and molecular studies [12].

3. Roswell Park Memorial Institute Medium (RPMI)

RPMI (also known as RPMI 1640) is a nutrient-rich medium containing 19 different amino acids, 11 vitamins, sodium bicarbonate and various salts. Iscove’s Modified Dulbecco’s Medium (IMDM) is a similar medium but with a higher calcium concentration. RPMI and IMDM are not fixatives. They do not preserve cells

but maintain viability of adherent cells. A nutrient-rich medium is the preferred medium for preserving and transporting cells destined for flow cytometry and mutational studies, including karyotyping. These nutrient-packed media need to be stored in a dark chilled environment (recommended storage temperature is 2–8 °C). They contain a pH-sensitive indicator to monitor possible degradation. Too long elapsed time and failure to store the medium in an appropriate manner will lead to degradation which is recognised by a change in colour from salmon orange to dark pink (Fig. 14).

4. Normal saline

Normal saline is the simplest transport medium. Without any cell fixing property or nutrient, normal saline

anything but urgent transit. However, if a specimen in saline can be sent to the laboratory sufficiently quickly, the specimen can be used for routine histology (cell block); flow cytometry; biochemical studies, e.g. thyroglobulin level for metastatic thyroid carcinoma; microorganism culture; and potentially molecular studies.

If a wide differential diagnosis has to be considered, more material than usual is required, which may require

complex exercise. If a pathologist or a trained lab technician can attend for rapid on-site evaluation, specimen triaging can be done immediately, and the differential diagnosis may be narrowed, reducing the number of specimens required.



Fig. 14 The bottle on the left shows the normal colour of IMDM. The bottle on the right shows a degraded IMDM which is unsuitable for specimen preservation

Table 4 Recommended transport mediums for different clinical scenarios and tests potentially to be done

Clinical scenario	Recommended medium		Tests to be done
	FNA	Biopsy	
Almost certainly carcinoma (including nodal metastasis) Non-nodal lesion, uncertain whether benign or malignant (lymphoma not being considered)	Alcohol-based medium or saline	Formalin	Histology with or without immunohistochemistry
Carcinoma and lymphoma both being considered	Preferably one pot with alcohol-based medium and a second pot with saline	One pot with formalin and a separate pot with either RPMI or saline	Histology with or without immunohistochemistry Flow cytometry
Carcinoma, lymphoma and infection all being considered	Same as above plus an extra pot with saline	Same as above plus an extra pot with saline	Histology with or without immunohistochemistry. Flow cytometry Bacterial and mycobacterial culture/sensitivity

7 Ancillary Studies

Only decades ago, a simple distinction between benign and malignant tumours was enough for cancer management. Up until the 1990s, classifying lung cancer as small cell carcinoma versus non-small cell carcinoma was all that was required for treatment. Tumour classification, including for head and neck tumours, has become much more complex

So-called ancillary studies have become essential components of diagnostic anatomical pathology. Special stains, immunohistochemistry, cell markers and molecular studies are amongst the techniques that a modern pathologist uses.

8 Special Stains

Use of special stains probably was the first step away from advent of more sophisticated ways of marking tissue has resulted in a decline in the use of special stains in diagnostic pathology. The few stains that still are used fairly commonly today include the mucin stains (e.g. mucicarmine) used to identify glandular differentiation, the Perl's stain (Perl's

Prussian blue) to aid in the distinction between haemosiderin and melanin, silver stains (e.g. Grocott-Gömöri [methenamine silver stain](#)) to identify fungal elements and Congo red stain for amyloid.

9 Immunohistochemistry

Immunohistochemistry has revolutionised diagnostic surgical pathology. There is a growing catalogue of immunohistochemical markers for histology. Whilst the interpretation of immunohistochemical markers can be challenging, the basic mechanism of action of immunohistochemical marking is quite simple. Immunohistochemical markers contain antibodies that bind to specific antigens and a coloured histochemical tag that makes the antigen-antibody binding visible. Most pathology laboratories tend to use a brown tag (chromogen) like 3,3'-diaminobenzidine tetrachloride [13].

Every tumour type has a unique antigen profile. Pathologists rely on those profiles to aid in a diagnosis. The catalogue of immunohistochemical markers already is extensive. In Table 5 we list some that one may encounter in pathologists' reports concerning the histological diagnosis of head and neck cancer.

Table 5 Immunohistochemical markers used commonly in histological diagnosis of head and neck cancers

Pan cytokeratin (Pan CK)	General epithelial marker. Positive in most if not all carcinomas regardless of origin/primary site
CK5, CK14	More specific cytokeratins. Positive in most squamous carcinomas. Highlight cell cytoplasm
CK20	Specific cytokeratin used typically to diagnose carcinoma of the intestinal tract, but in the context of head and neck skin cancer, positive in Merkel cell carcinoma
p40, p63	Squamous as well as myoepithelial markers. Highlight cell nuclei
BerEP4	An epithelial cell adhesion molecule. In skin cancer it is most useful in the distinction between poorly differentiated squamous carcinoma (negative) and basal cell carcinoma (positive)
Calponin	Myoepithelial cell marker
S100	Positive in most melanomas but also marks neural tissue
SOX10	Melanoma marker but also can mark myoepithelial cells
MelanA	Another melanoma marker
PRAME (preferentially expressed antigen in melanoma)	A relatively new marker. Positive in melanoma. Extremely useful in distinguishing between metastatic melanoma in lymph node (positive) and benign melanocytic nevus in lymph node (negative)
Synaptophysin, chromogranin	Neuroendocrine markers. Positive in Merkel cell carcinoma
DOG1	Positive in normal salivary serous acini and also in acinic cell carcinoma
Androgen receptor	Positive in salivary duct carcinoma
HER2	80% of salivary duct carcinomas show HER2 overexpression. HER2 overexpression is associated with a poorer prognosis, but these tumours may respond to a HER2 inhibitor [15]
Mammaglobin and GCDFP (gross cystic disease fluid protein)	Both are well known as breast markers. Positive in secretory carcinoma of salivary gland (previously known as mammary analogue secretory carcinoma)
p16	Surrogate marker for high-risk human papillomavirus. Positive in HPV-mediated non-keratinising squamous cell carcinoma of oropharynx
Ki67	Proliferation marker. The more nuclei this marker highlights, the more active or fast-growing the tumour is
BRAF V600e	This BRAF immunomarker for melanoma is a cheaper and more rapid substitute for the more comprehensive BRAF molecular test (Oncofocus™) and can be used in urgent cases to guide treatment options. The Oncofocus™ test is a next-generation DNA sequencing study which targets more than 250 different mutations affecting major oncogenes such as BRAF, EGFR, KIT, KRAS and NRAS

10 Flow Cytometry

Flow cytometry is a technique for detecting and measuring properties of cells from their diffraction patterns as they transit through a laser beam [14]. Flow cytometry is a highly efficient way of identifying a cell population of interest in a large volume of tissue. In head and neck cancer, it is particularly helpful in determining if there is clonality of lymphoid cells, indicating likely lymphoma. Flow cytometry is hardly ever used in the diagnosis of carcinoma. Flow cytometry requires fresh tissue so specimens should be submitted in RPMI/IMDM (preferred) or normal saline (see “transporting a specimen”). The specimen cannot be submitted in formalin or alcohol-based fixative.

11 Molecular Studies

Fluorescence in situ hybridization (FISH) has become an integral part of diagnostic pathology. In head and neck pathology, it plays an important role in the diagnosis of salivary gland tumours and sarcomas (Table 6). FISH is a cytogenetic technology based on the complementary nature of DNA and

Table 6 Some of the common nucleotide abnormalities that can be revealed by FISH in head and neck pathology [22]

PLAG1 fusion	Pleomorphic adenoma
MAML2 translocation	Mucoepidermoid carcinoma
MYB fusion	Adenoid cystic carcinoma
ETV6-NTRK3 translocation	Secretory carcinoma
SS18 translocation	Synovial sarcoma
FUS or EWSR1 translocation	Myxoid/round cell liposarcoma
FUS translocation	Low grade fibromyxoid sarcoma
USP6 translocation	Nodular fasciitis

RNA double strands. FISH probes are single-strand fragments of DNA or RNA that bind to complementary nucleotide sequences in target cells, including tumour cells [16]. The probes are tagged with fluorescent nucleotides.

Two common types of FISH probes used in diagnostic pathology are break-apart and fusion probes. The probes are used to detect translocations, the most frequent genetic defects in cancer cells. Break-apart probes reveal nucleotide sequence separations that occur typically in a cancer cell. Two tags of different fluorescent colours are placed at opposite ends of a probe with a nucleotide sequence complementary to a targeted gene breakpoint. In normal cells, there is no break in the gene,

(usually one red and one green) joined as a pair. When there is a translocation at that gene location, there is a break between the two tags, so they separate into individual colours. Fusion probes work in the opposite way and are used to reveal a specific rearrangement of nucleotides. Markers of different colours are placed on two different gene locations. In normal cells, the red and green signals remain separate, but when there is an abnormal fusion of those gene locations, the two colours emerge as a pair. FISH cytogenetics can be done on formalin-fixed paraffin-embedded tissue.

12 Making Sense of the Pathologist's Report

In the past pathology reports were entombed in long-winded text, but often important information was omitted. In recent times pathologists submitting reports on most malignancies rather use synoptic reports constructed on a prescribed format that ensures that all the relevant information is covered and succinctly. They frequently employ the TNM staging system of the American Joint Commission on Cancer (AJCC), which assigns T codes for the extent of the tumour, N codes for lymph node involvement and M codes reporting whether metastases are present or not. The benefits of synoptic reports include completeness of pathologists' reports for surgeons or other clinicians, easier readability and digestibility of information and providing a useful framework for research. Currently the synoptic reports tend to be paper-based, but in the future they undoubtedly will move to web-based systems, which, amongst other benefits, will allow for greater accuracy through the body of the report [17].

To help clinicians make sense of pathologists' reports, we comment on concepts that appear routinely in synoptic reports, in the context of squamous carcinomas, melanomas, basal cell carcinomas and salivary gland carcinomas, the most frequent tumours of extreme facial malignancies.

12.1 Tumour Thickness and Depth of Invasion

Tumour thickness and depth of invasion are not synonymous terms (Fig. 15). Tumour thickness refers to the largest verti-

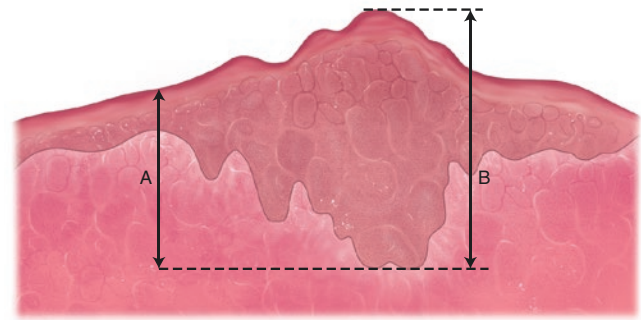


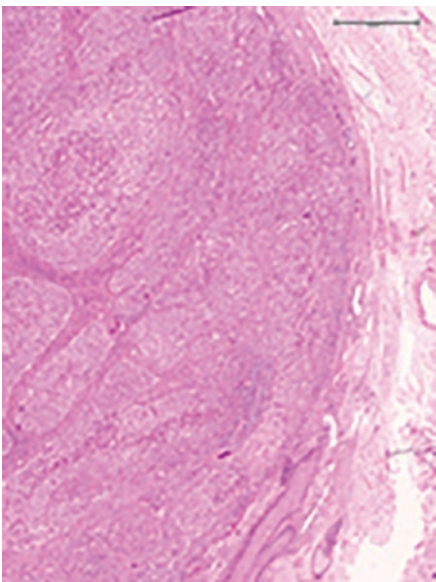
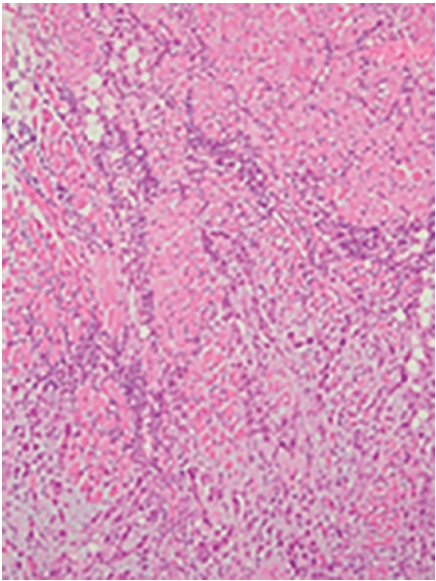
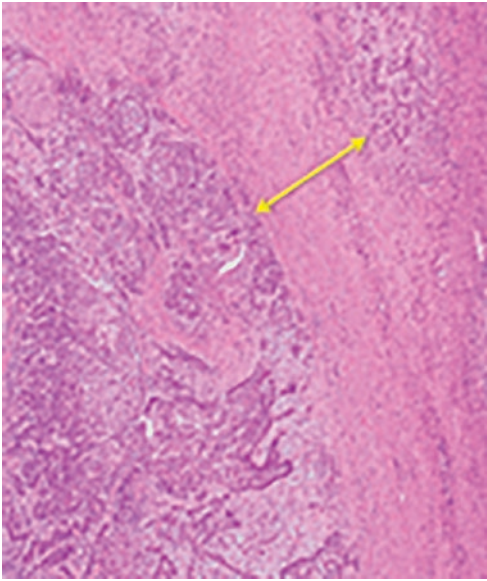
Fig. 15 Illustration of tumour thickness versus depth of invasion. (a) Depth of invasion is measured from the top of the granular layer of adjacent uninvolved skin to the base of the tumour (AJCC eighth edition). (b) Tumour thickness is measured from the granular at the apex of the tumour to its deepest base

cal dimension of the tumour, whilst depth of invasion gives an indication of how far a tumour has invaded into normal tissue. Tumour thickness/depth of a primary tumour is associated with adverse biological outcomes like risk of recurrence, metastasis or death [18]. The thicknesses of melanomas and depth of invasion of squamous cell carcinomas are measured differently. Melanomas are measured from the granular layer of the epidermis to the deepest level of invasion in the area of the tumour, whereas squamous carcinomas are measured from the granular layer of the nearest adjacent normal epidermis to the deepest part of the tumour. This method for squamous carcinomas adjusts for exophytic lesions. Ulcerated melanomas may have their thickness underestimated. Oral cavity carcinomas are measured differently.

12.2 Pattern of Invasion at the Tumour Front

Table 7 shows the three main patterns of tumour growth at the infiltrative front.

Table 7 The three main patterns of tumour growth at the infiltrative front

Cohesive	Non-cohesive	Dispersed
Large islands of cells	Small nests and single cell infiltration	Widely separated satellite foci
Pushing border	Infiltrative border	Cells more than 1 mm (yellow arrow) from the main tumour
Slow-growing tumour	Aggressive tumour	Most aggressive tumour
		

12.3 Perineural Invasion

Perineural invasion (Fig. 16) occurs when a tumour has invaded into the nerve sheath [19]. Squamous carcinomas of the head and neck often affect nerves and those that do tend to have poor outcomes, as the tumour may track the cranial nerves back to the brain. AJCC eighth Edition recognises the importance of perineural invasion in the staging for primary cutaneous carcinoma; involvement of a named nerve, an unnamed nerve of at least 0.1 mm diameter or an unnamed nerve deeper than dermis will upstage a tumour from a pT2 to pT3. For some of the salivary gland tumours, the presence of perineural invasion aids with the diagnosis of malignancy. This feature is particularly prominent in adenoid cystic carcinomas. Perineural invasion far away from the invasive front portends a poor prognosis.

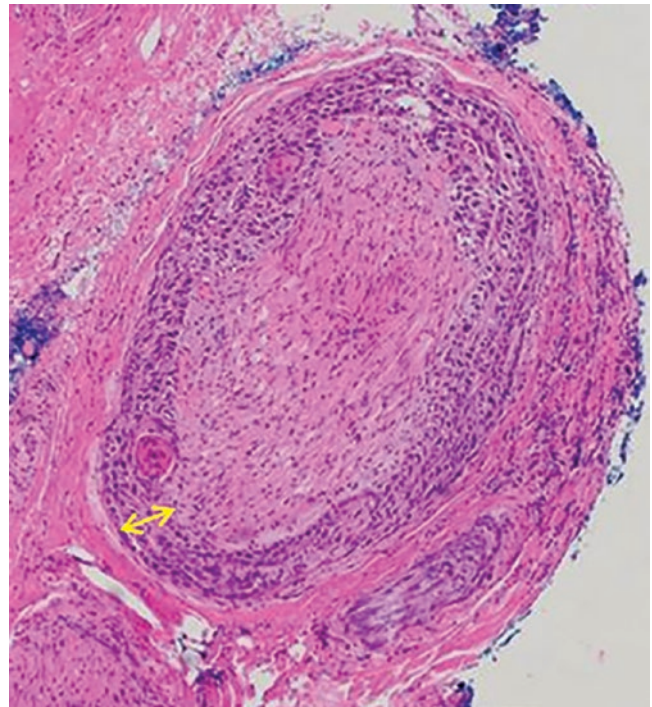


Fig. 16 Perineural invasion by moderately differentiated keratinising squamous carcinoma (haematoxylin and eosin 100× magnification). The nerve is surrounded by squamous carcinoma that is depicted by the yellow arrow

12.4 Margin Status

Pathologists pay a lot of attention to the margins of surgical specimens, especially resections for malignancy, because it is the condition of the margins that determines the completeness of the resection (Fig. 17). Sections can be taken either perpendicularly to the margin or *en face* at the margin. Perpendicular sections allow the pathologist to visualise the distance between the tumour and the surface of the specimen (the surgical margin) as both tumour and margin appear in the same section and so to advise the surgeon, if the margin is negative, how close to the resection surface the malignant tissue was. If the tumour is close to the margin, the pathologist can measure and report its separation from the margin using the graticule within the microscope's eyepiece or the scale on the microscope's stage. An *en face* section allows the pathologist to decide only whether the specimen is positive or negative for malignancy, so whether the margin from which it was taken was healthy or diseased.

What do pathologists report as a positive margin? If a specimen has been inked and tumour extends to the inked surgical margin, that margin is reported as positive. If tumour extends to a cautery artefact, that too is reported as positive. In some situations, for instance, in the case of a basal cell carcinoma, if the characteristic stroma of the tumour extends to the margin, even though the actual epithelial tumour islands are not at the margin, the margin also is reported as positive.

An adequate excision depends on the type of tumour but also on the anatomical site of the tumour. If a tumour has been excised inadequately, does the anatomy allow room for

additional surgery? If not, is the tumour type amenable to treatment with modalities other than surgery? Again communication between the surgeon and the pathologist is beneficial to arrive at the decision best for the patient, given the evaluation of the status of the margins, especially if the specimen is fragmented.

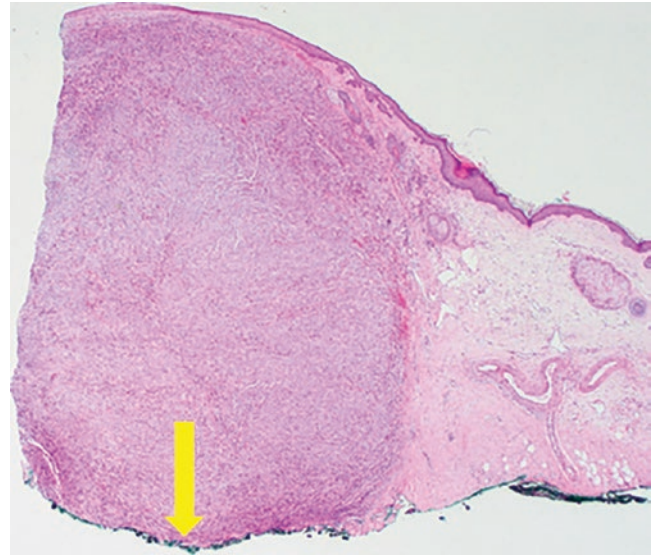


Fig. 17 Atypical fibroxanthoma extends to the deep margin (yellow arrow) (haematoxylin and eosin 100×). The differential diagnosis of an atypical fibroxanthoma includes a pleomorphic dermal sarcoma. One of the distinguishing features is extension into subcutaneous tissue. In this biopsy where the tumour is extending to the deep margin and the subcutaneous tissue is not visualised, a pleomorphic dermal sarcoma cannot be entirely excluded

12.5 Nodal Status and Pathological Staging

To deliver a good service, pathologists would like a selective neck dissection to yield at least 10 lymph nodes and a comprehensive neck dissection to yield 15 or more lymph nodes. We consider the proportion of nodes that are positive, the maximum dimension of the largest node and that of the largest metastatic deposit as important elements in the pathological assessment, though the UICC and AJCC staging systems base their pN categories on the size of the involved node, rather than the size of the tumour deposit. In some cases there may be a considerable difference in the dimensions of the largest metastatic deposit and the largest involved node, and, when both sizes are recorded, the oncologist will have extra information upon which to plan treatment.

Another element that we consider, and report, is extranodal extension, which is the spread of tumour outside the capsule of the lymph node into the perinodal soft tissue (Fig. 18). It is measured perpendicular to the external aspect of the node capsule and may be categorised as microscopic (≤ 2 mm in extent) or macroscopic (>2 mm in extent). Extranodal extension is a risk factor for a poor prognosis in cervical node positive carcinoma, except in HPV-mediated oropharyngeal cancer, where its significance has yet to be established. The presence of extranodal extension in head and neck cancers correlates with a risk of regional local recurrence and distant metastasis and may be an indication for adjuvant combined chemotherapy and radiotherapy. The risk of regional recurrence and distant metastasis is higher with macroscopic rather than microscopic extranodal extension. Tumours with extranodal extension should be excised with a clear margin. If a margin is positive, the risk of local recurrence is increased and is an indication for radiotherapy to that site [20].

We draw attention to changes relevant to interactions between clinicians and pathologists that have been introduced in the eighth edition of the AJCC [21] and also in the International Union for Cancer Control (UICC) cancer stag-

ing manuals. These changes have resulted in changes to the synoptic reports and staging of tumours. The changes include:

1. Separating p16-positive HPV-related carcinomas from p16-negative carcinomas.
2. Including extranodal extension in the pN categorisation for p16 negative oropharyngeal, hypopharyngeal, oral cavity, laryngeal, skin, major salivary gland, nasal cavity, paranasal sinus and unknown primary cancers.
3. Introducing a separate category for occult primary tumours of the head and neck with p16 and Epstein-Barr virus testing recommended.
4. Introducing a separate chapter for cutaneous squamous cell and other carcinomas (with the exception of Merkel cell carcinoma).

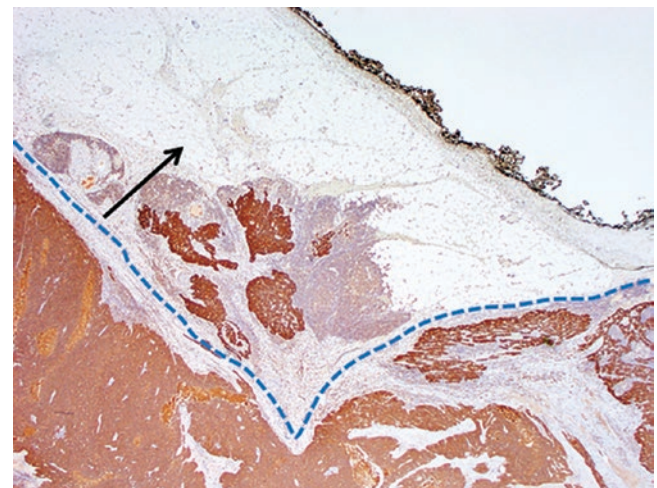


Fig. 18 Extranodal extension (Pan cytokeratin immunohistochemical stain 40× magnification). The black arrow perpendicular to the node capsule (indicated by dashed blue line) shows how extranodal extension is measured. The extranodal extension is clear of the surgical margin, inked black

13 A Take-Home Message from Pathologists

We have belaboured the theme of cultivating the clinician-pathologist relationship and amalgamating the diverse wealth of information to benefit patient care. A small consideration by clinicians about what they are going to biopsy and what they want to achieve with that biopsy, before taking the specimen, can make all the difference in the value to the clinician of what the pathologist can do subsequently. We cannot stress enough the importance of providing pathologists with all the relevant clinical and radiological details; our own experience is that important information is omitted regrettably often. Recognising, and making sense of, those features in a pathology report that may influence treatment will impact your patient's prognosis. We also submit that cultivating the clinician-pathologist relationship is personally stimulating, educational and fulfilling. Take time to ponder. We look forward to hearing from you soon.

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Applied Facial Anatomy

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Core Messages

- Cancer staging is important from an anatomical perspective.
- Modern radiological imaging techniques assist the multi-disciplinary team managing advanced facial cancer.
- The patterns of cancer spread are predictable and illustrated from a 3D anatomical perspective.

1 Introduction

The anatomy of the face can be considered in multiple dimensions (Figs. 1, 2, 3, 4, 5, 6, and 7). From a 2D perspective, the skin of the face and upper neck integument consists of composite layers of epidermis, dermis, a subdermal plexus of vessels, subcutaneous fat (panniculus adiposus) and superficial fascia (panniculus carnosus), now called the SMAS in the face and platysma in the neck. The subcutaneous plane is rather vascular, while the sub-

SMAS plane is relatively avascular. The muscles of mastication are in the periphery of the face (outside the true frontal plane of the face). They generally lie in a deeper plane, whilst the extensive mimetic muscles are superficial and lie centrally in the true front plane, with fine extensions into the overlying facial skin. Motor innervation of facial muscles is usually in the deep surface, but there are exceptions. Arterial supply and venous drainage are paired and run closely alongside the relevant nerves as neurovascular bundles. The sensory nerve supply of the face is from the three divisions of the trigeminal nerve, while the face/neck junction is supplied by the upper cervical nerves. The muscles of mastication are supplied by the trigeminal nerve and the mimetic muscles by the facial nerve branches. The face has a dual arterial supply from both the external

the external carotid artery. However, this dual supply has profound implications in clinical practice. The lymphatic drainage system with a network of loco-regional lymph node basins is also relevant to the 2D conceptualisation of the face and neck.

A 3D perspective has significance for the aesthetic reconstruction of the face after cancer resection. The 3D concept considers the various facial planes and contours that contribute to normal facial morphology, facial function and aesthetic beauty [1].

The cutaneous sensory nerve supply is from the three divisions of the trigeminal nerve (ophthalmic, maxillary and mandibular) for the face and cervical 2 and 3 for the face/neck junction. Most sensory nerve branches (V1 and V2) enter through the bony foramina and supply sensation to the overlying area of the skin and soft tissue.

The motor nerves of the trigeminal nerve supply the muscles of mastication (first pharyngeal arch) in the periphery of the face. They are located deeply and enter their target muscle on their deep surface.

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Fig. 1 Organisation of tissues in the human face

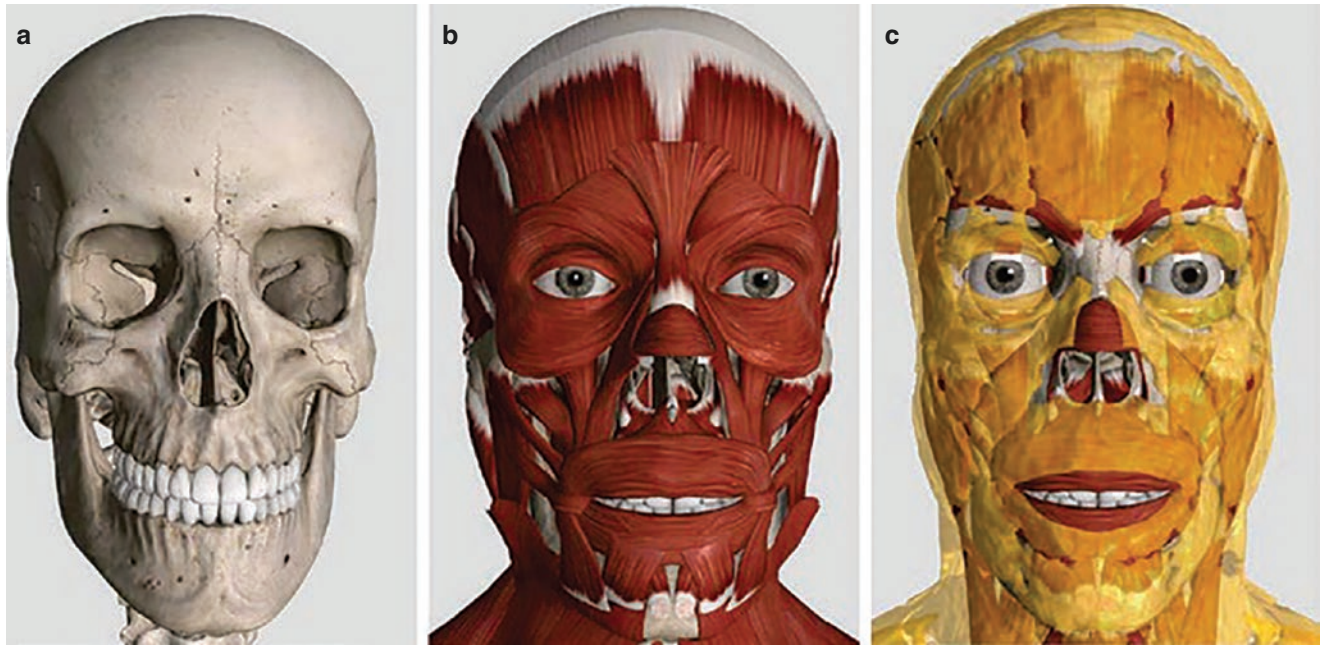
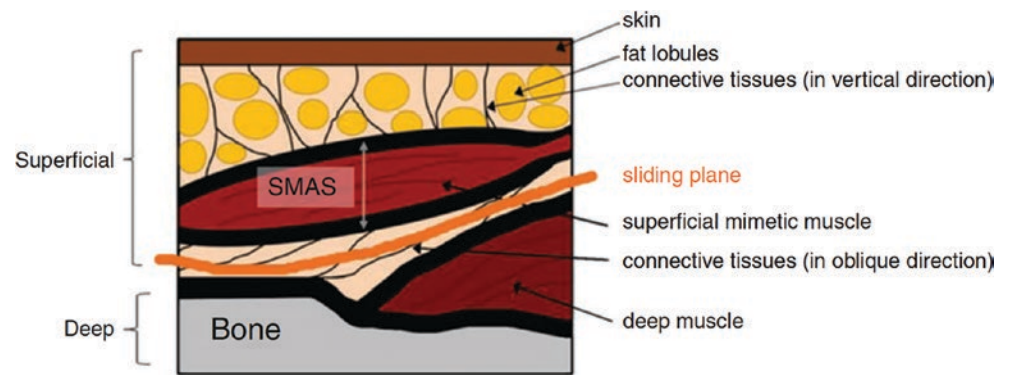


Fig. 2 (a–c) 2D concepts of applied facial anatomy. (From Ho et al. [1]; with permission)

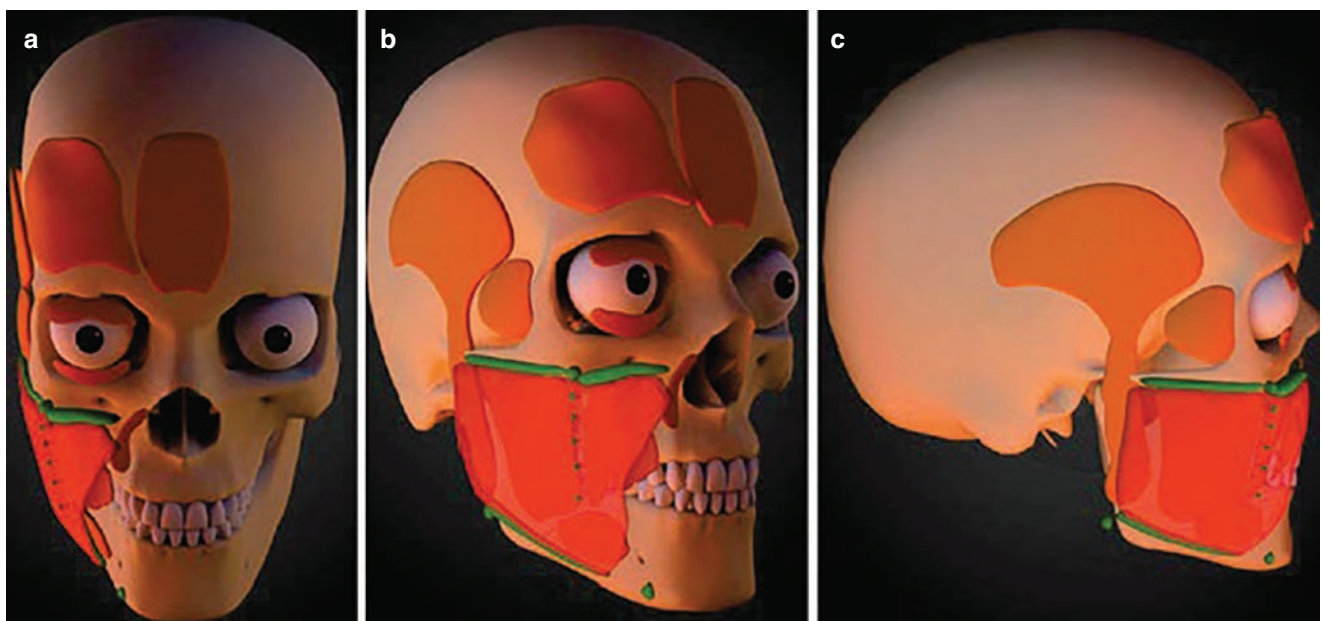


Fig. 3 (a–c) 3D concepts of applied anatomy

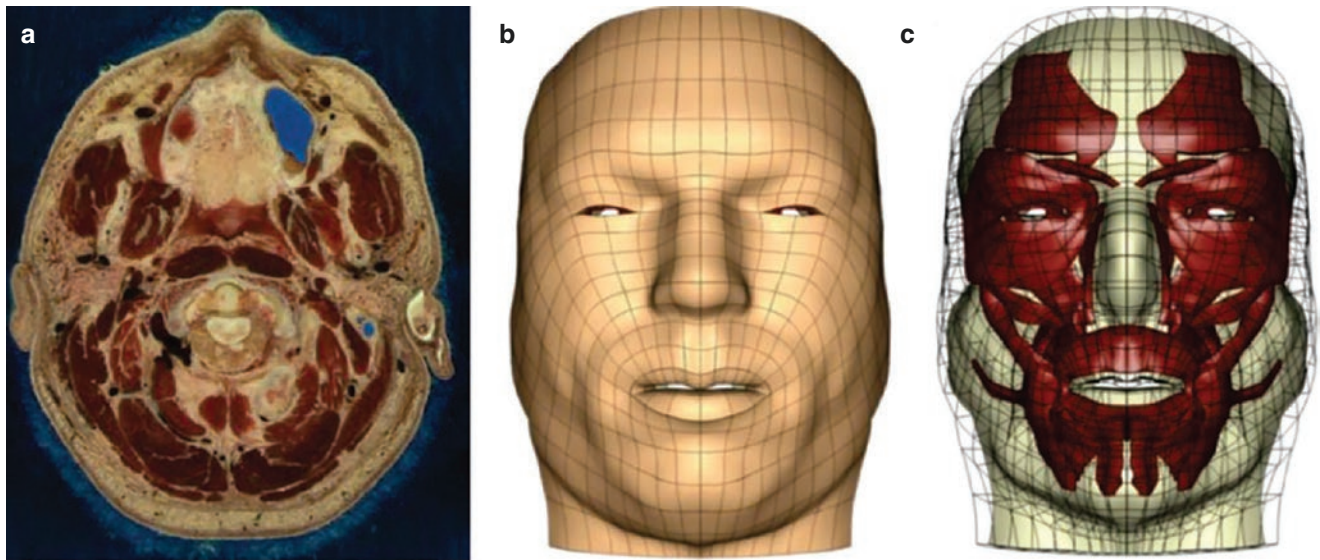


Fig. 4 (a–c) Mathematical formulation of structure and function for applied facial anatomy (from Ho et al. [1]; with permission)

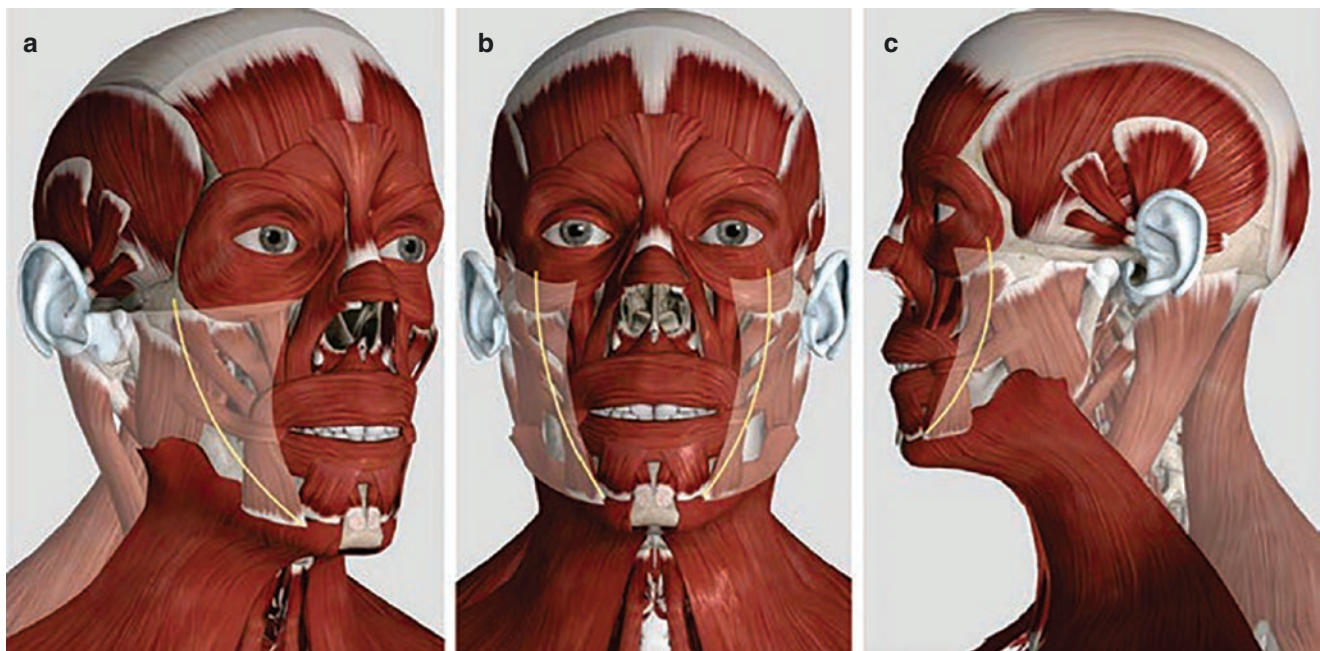


Fig. 5 (a–c) Lateral facial muscles of mastication and medial facial muscles of animation (from Ho et al. [1]; with permission)

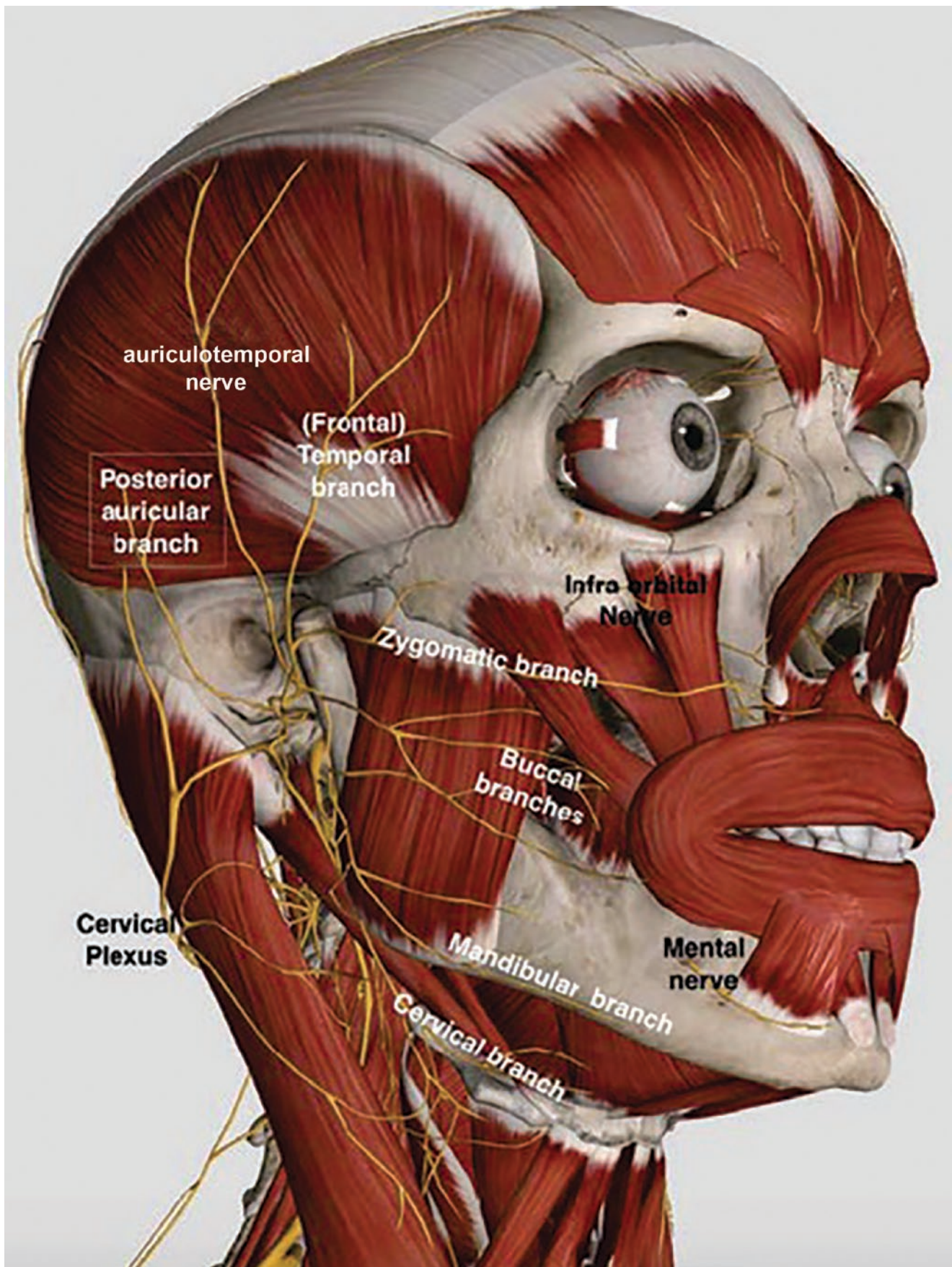


Fig. 6 Sensory and motor nerves of the human face

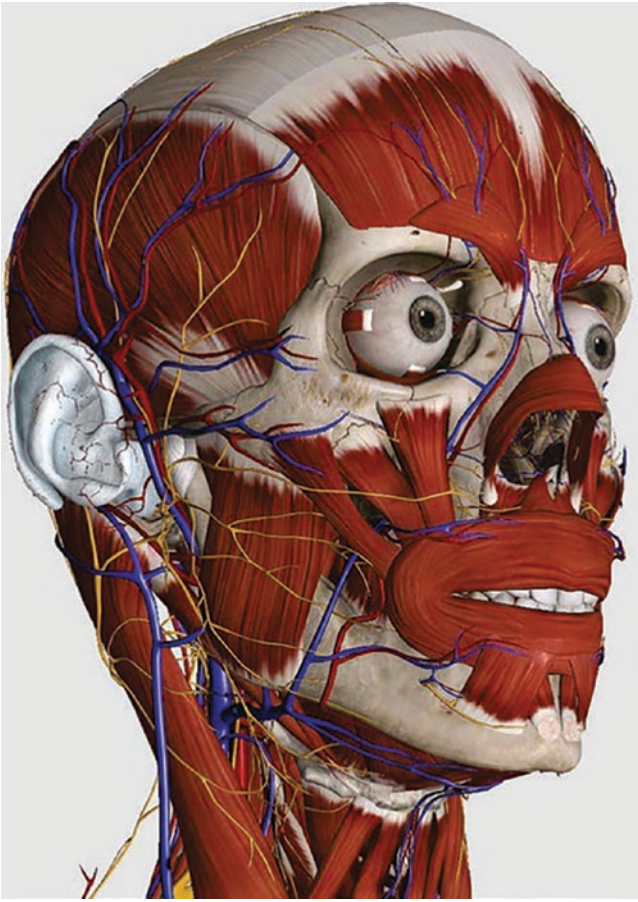


Fig. 7 Neurovascular bundles of the human face

2 Mechanisms of Cancer Spread

The next series of cases represent in radiological detail the mechanisms by which cancers of the face/head and neck spread by direct deep extension, via tissue planes and via lymphovascular or perineural routes.

2.1 Direct Extension

A 56-year-old woman presented with an aggressive SCC of the external auditory canal with deep subcutaneous extension into the infratemporal fossa and the skull base (Fig. 8). The sequential MRI scans are shown.

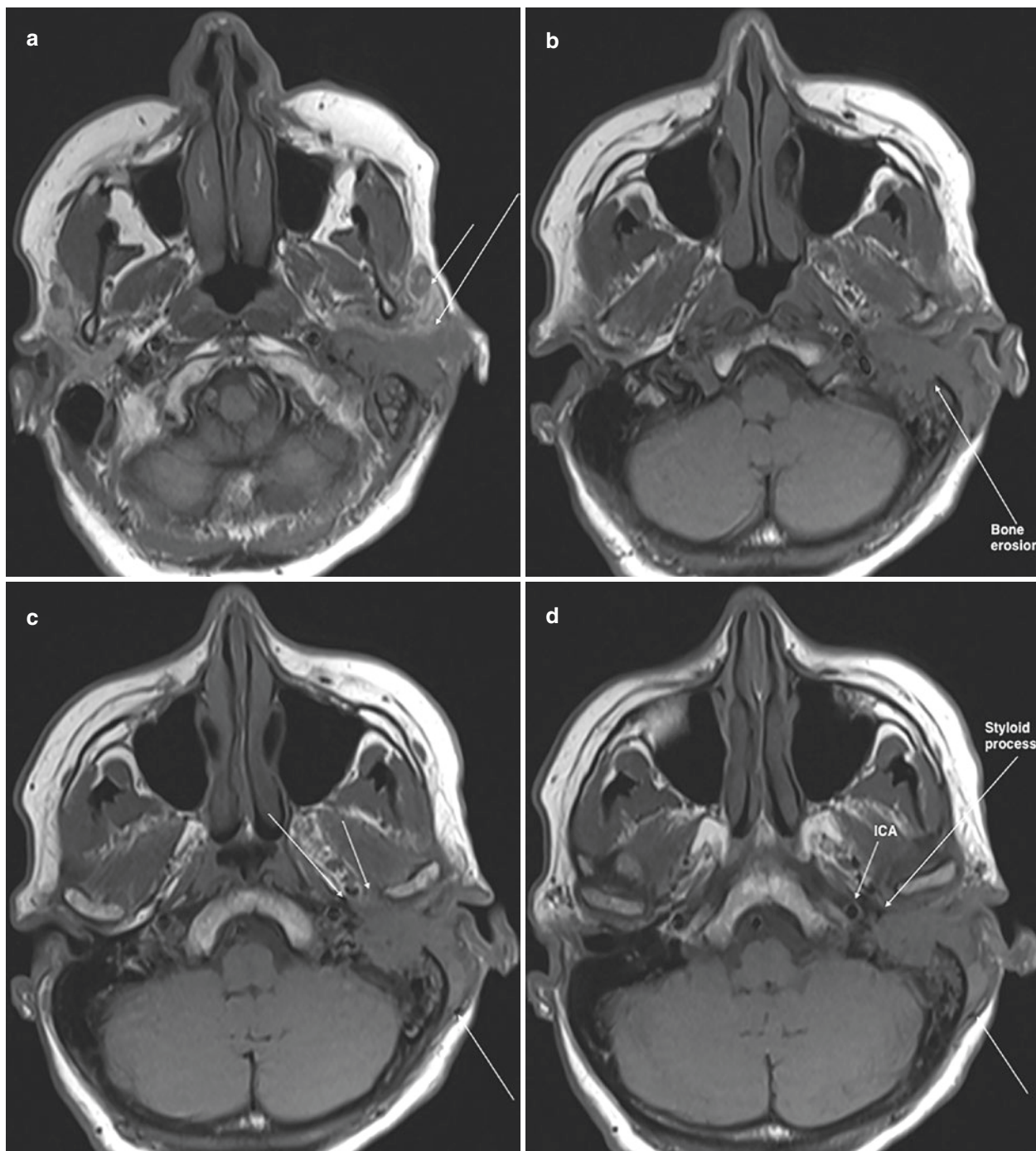


Fig. 8 (a) Arrow points to the left external auditory canal SCC in a 56-year-old woman. Note the fluid in the mastoid tip and the increased size of the lymph node in the anterior parotid gland. (b and c) Bone erosion is seen with loss of black cortex and infratemporal fossa exten-

and tumour abutting the mandibular condyle and probably involving the TMJ. (f and g) Extensive direct spread of aggressive SCC L ear canal into parotid gland, abutting skull base and under the L ear

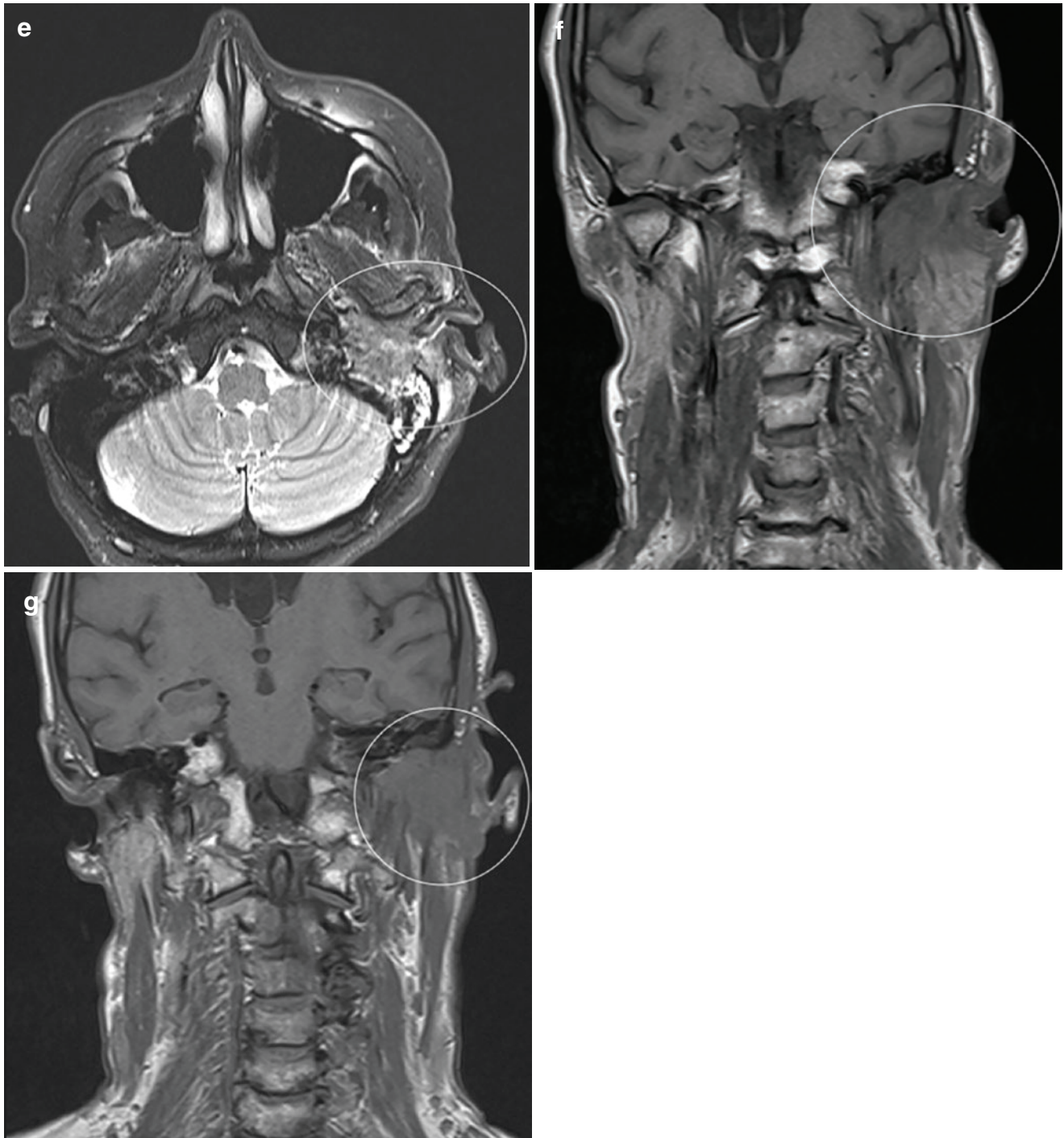


Fig. 8 (continued)

2.2 Spread from the Ear to the Parotid Gland

This is a 93-year-old man's CT images showing an aggressive SCC of his L ear with invasion of the parotid gland (Fig. 9).



Fig. 9 (a and b) Diffuse lesion invading the L parotid and ear. Note the L preauricular lymph node in b. (c and d) The L preauricular lymph node seen in axial CT and spread of the SCC down the external auditory canal to the L temporal bone. (e) The SCC abuts the L parotid gland



Fig. 9 (continued)

2.3 Perineural Invasion

Perineural invasion by cancers of the head and neck is always a bad prognostic indicator and its presence a factor that should be of concern for surgeons, radiologists and oncologists in the MDT. Squamous cell carcinoma is the most common culprit, and the most frequently affected nerves are the trigeminal and facial nerves of the face. Perineural invasion is most often a histological finding and many patients presenting with it are asymptomatic. Perineural tumour spread is defined as macroscopic tumour extension along a nerve from the primary tumour, which is apparent radiologically and sometimes clinically [2].

As experienced surgeons we have all been challenged by the patient with wide and complete excision of the facial squamous cell carcinoma on histological margins, but with later local recurrences and even late presentation with a facial palsy. We then ask ourselves the questions: how could we have recognized the problem of perineural invasion earlier, and what should/could we have done to prevent the neural spread? The significant morbidity and mortality of perineural invasion and tumour spread are reflected in the poor prognosis. There is new science that suggests a role of the nerve microenvironment and the immune system that act as mediators in the pathogenesis of perineural invasion and spread [3].

The following MRI images (Fig. 10) demonstrate the perineural invasion of the facial nerve deep in the parotid gland of a 72-year-old man with a moderately differentiated squamous cell carcinoma.

The 61-year-old man in Fig. 11 had progressive facial nerve symptoms and palsy over 6 months.

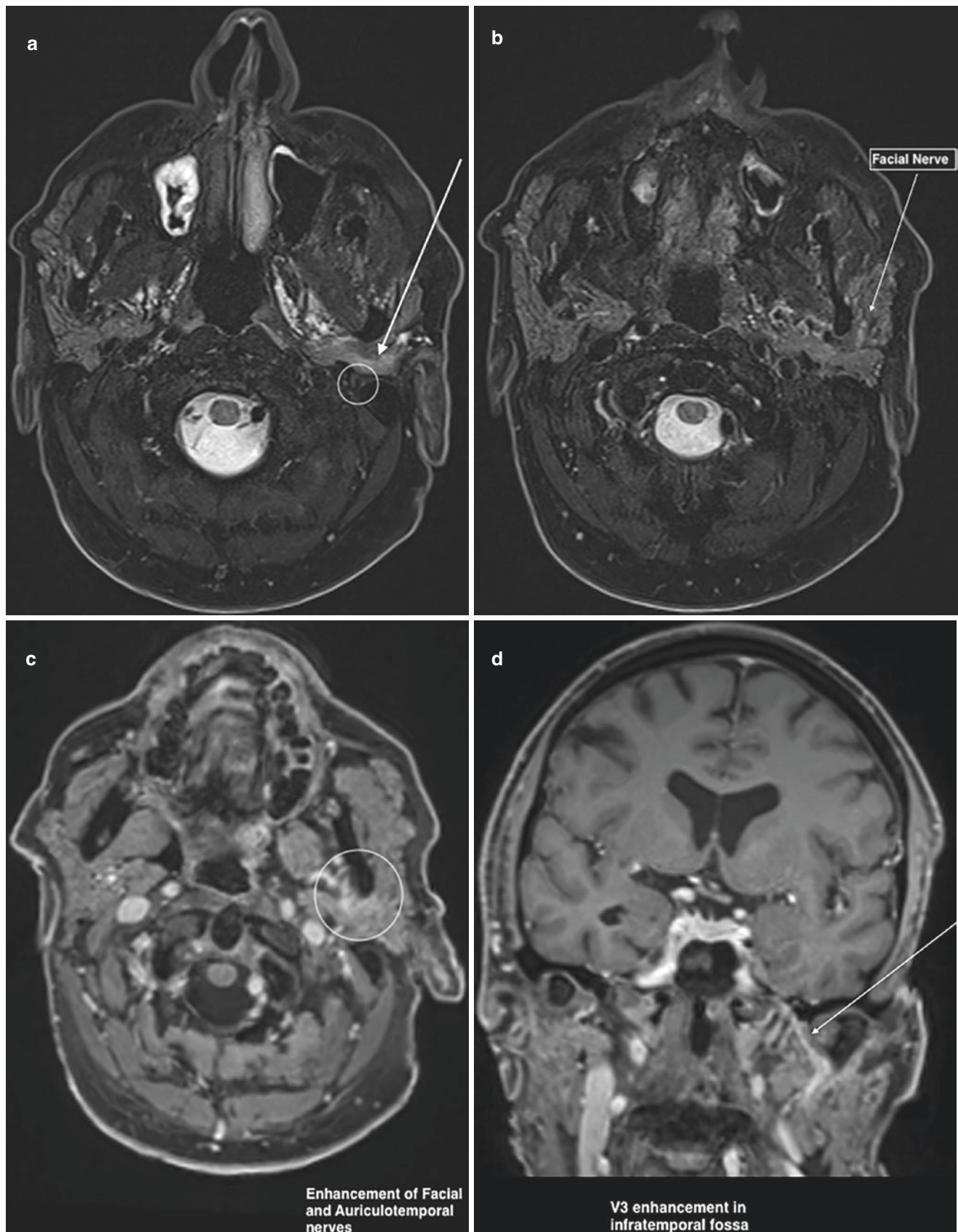


Fig. 10 (a and b) Moderately differentiated SCC in a 72-year-old man. In (a), the arrow shows increased signal in the parotid with the circle defining the stylomastoid foramen. (b) shows increased signal in the

facial nerve within the parotid gland. (c and d) (c) shows increased signal in the facial and auriculotemporal nerves behind the mandibular ramus. (d) shows enhancement of V3 in the infratemporal fossa

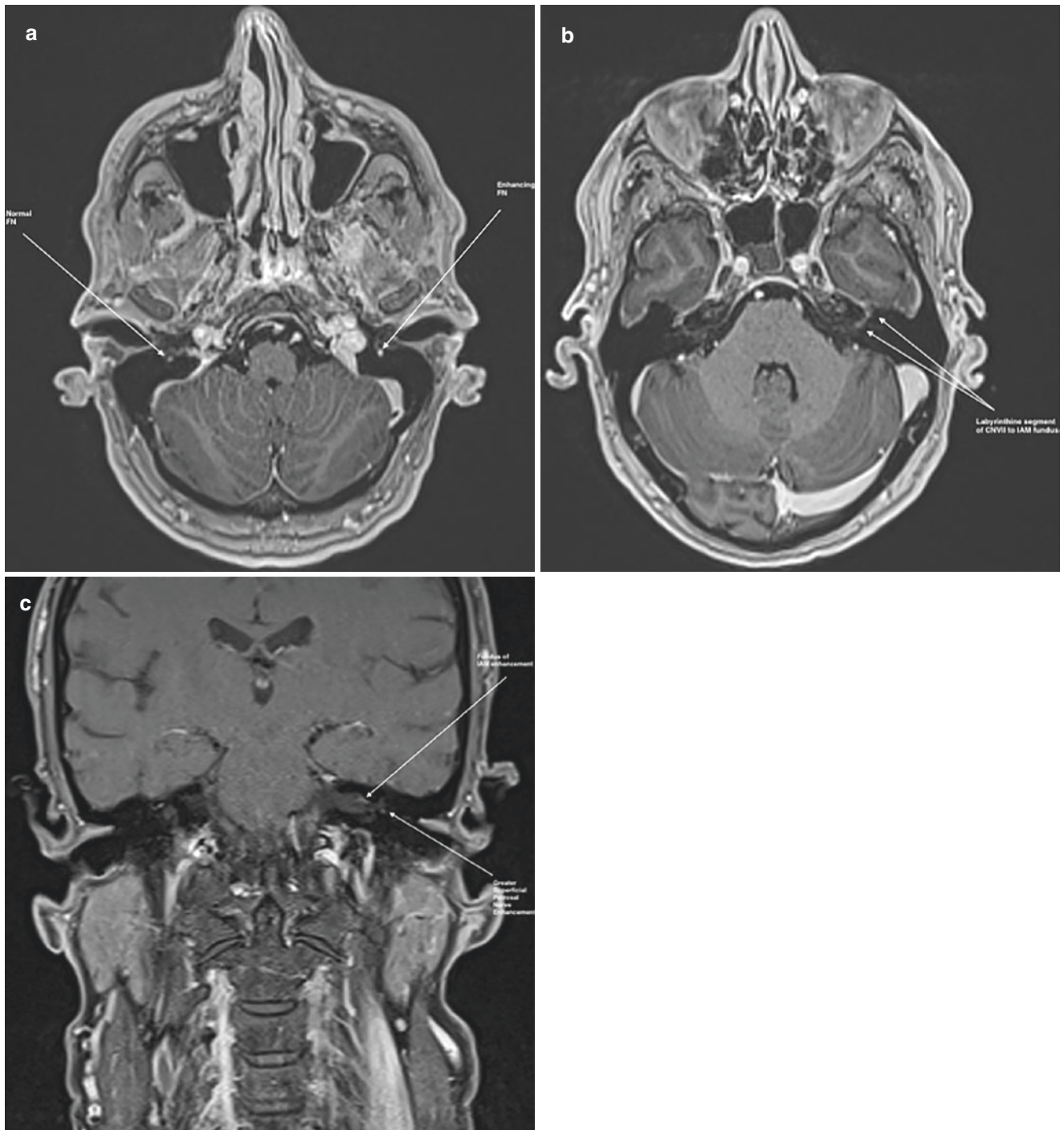


Fig. 11 (a–c) Shows the MRI scans in the 61-year-old man with progressive left facial nerve palsy over 6 months, with enhancement of the left

2.4 Lymphovascular and Perineural Invasion

The 78-year-old man in Fig. 12 has a pT3N3bM0 squamous cell carcinoma invading his left parotid gland with central necrosis of a parotid node and involvement of the greater auricular nerve all the way to the vertebral foramen and spinal canal.

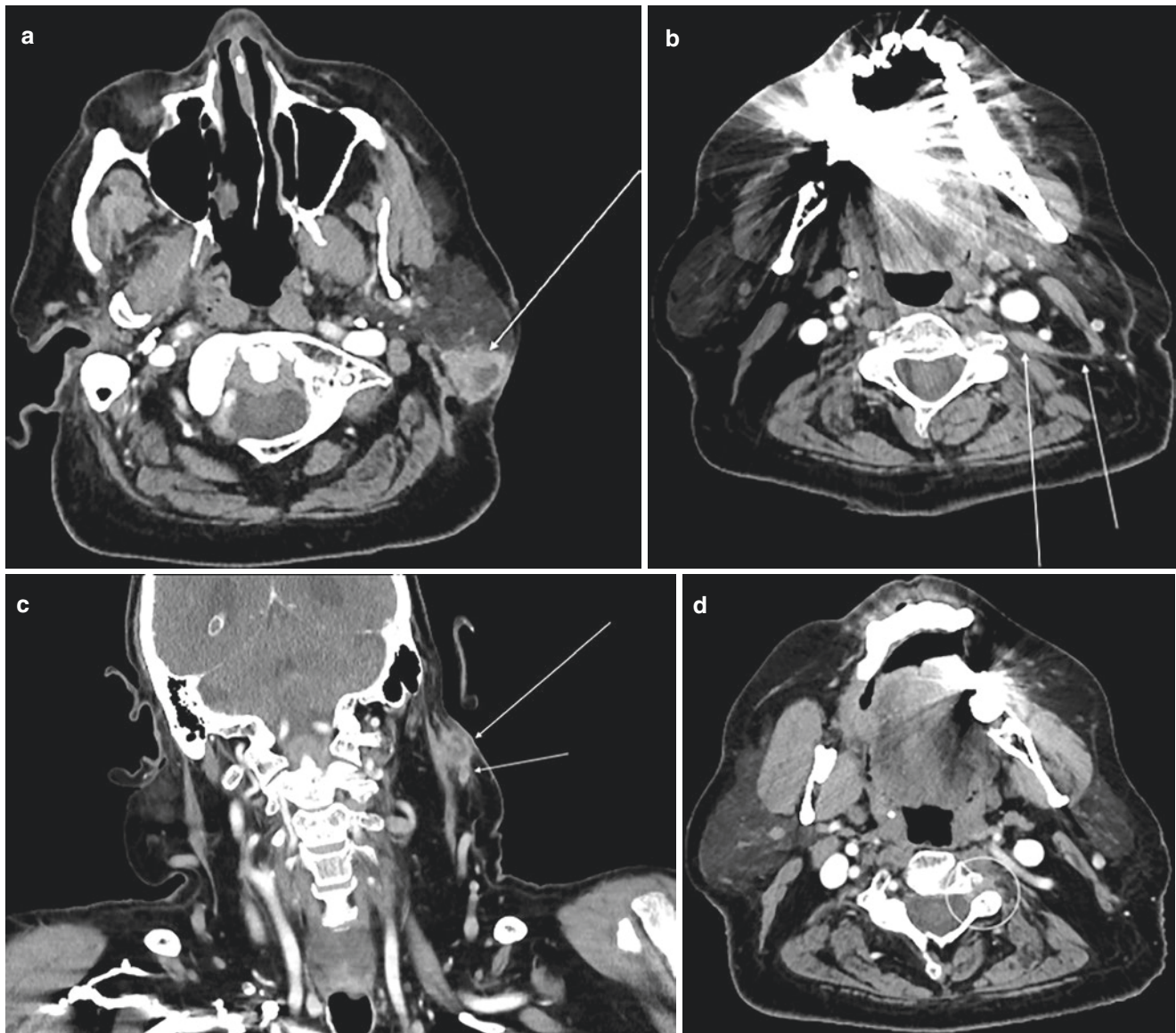


Fig. 12 (a–d) CT scans of a 78-year-old man with pT3N3bM0 SCC showing necrosis in a posterior left parotid lymph node, thickening and enhancement of the left greater auricular nerve all the way to the verte-

bral foramen and spinal canal (circle). (e and f) MRI scans complementing the CT scans of same case showing posterior left parotid SCC and the enhanced left greater auricular nerve traversing the neck

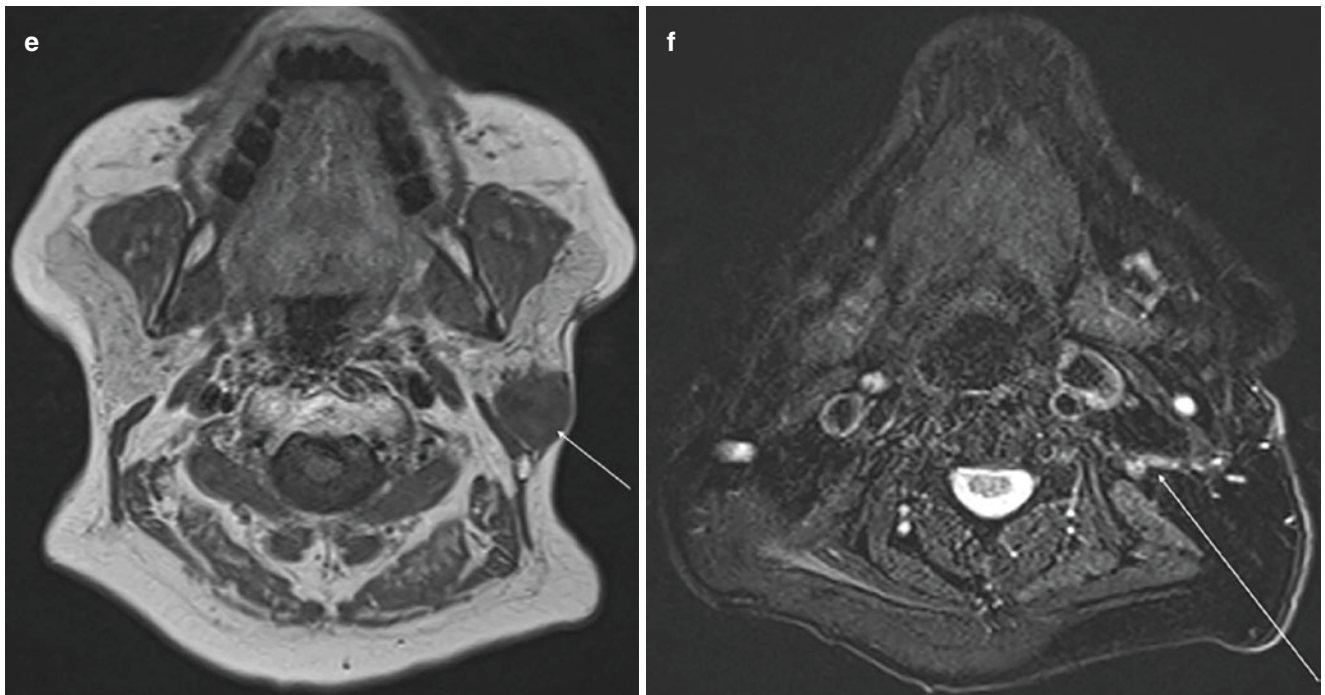


Fig. 12 (continued)

2.5 Metastases with Extranodal Spread

The 79-year-old man in Fig. 13 initially presented with a 7.5-mm-thick poorly differentiated squamous cell carcinoma

of his scalp. The series of CT scans show the lymphatic infiltration and spread to the neck, paravertebral muscles, the transverse process of C1, the suboccipital region and effacement of

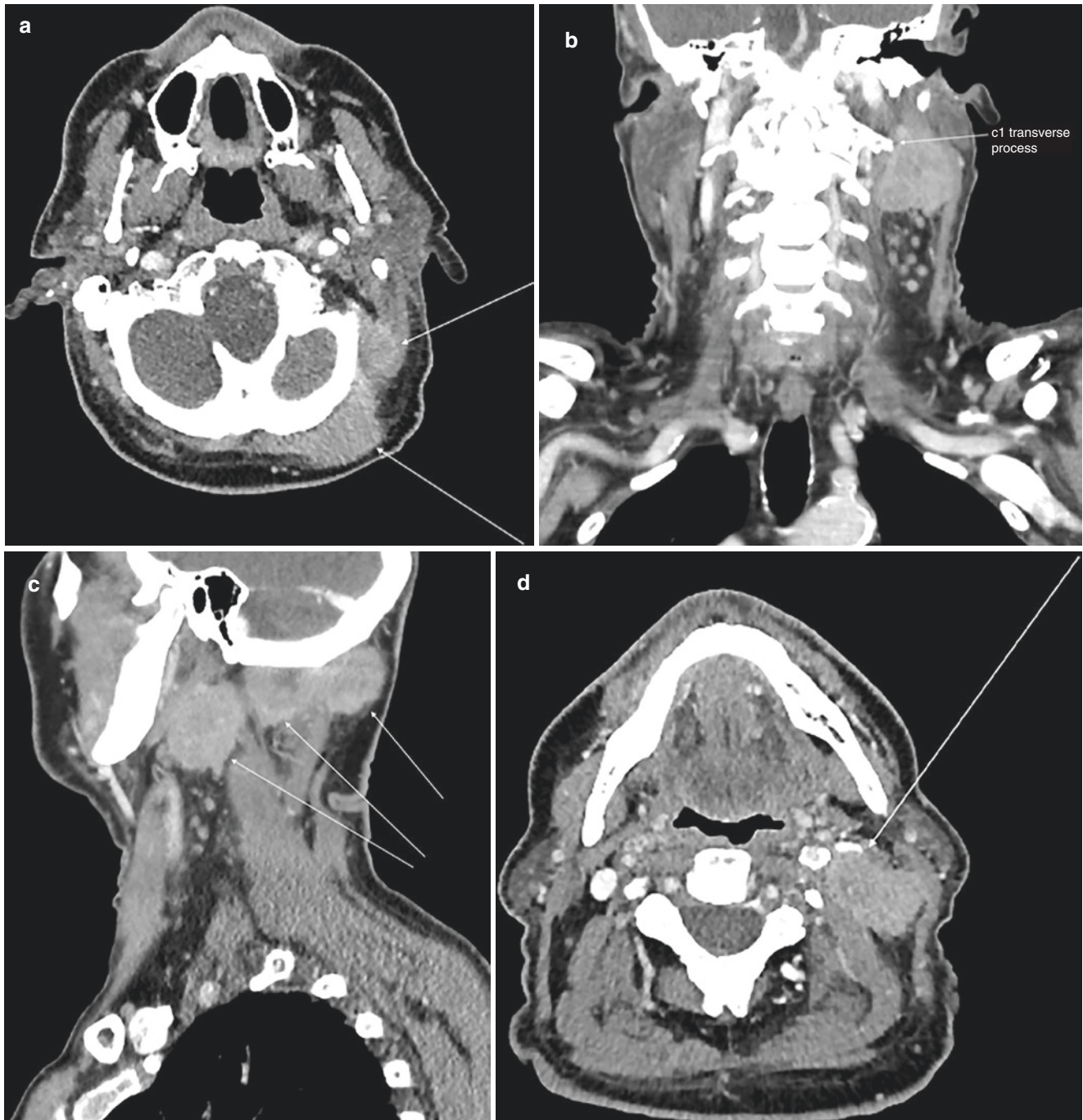


Fig. 13 (a–e) Poorly differentiated SCC of the scalp in a 79-year-old man, with axial and coronal CT views of lymphatic spread to the left neck, transverse process of C1, suboccipital region, effacement of the IJV and a level 5B node

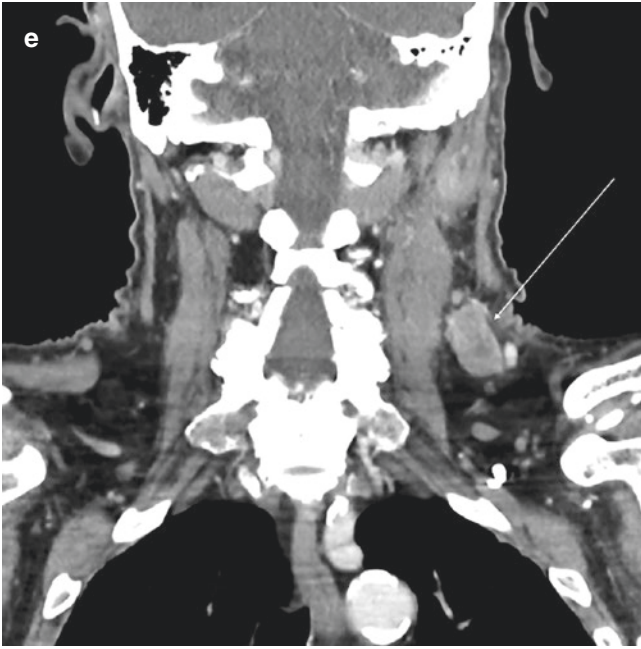


Fig. 13 (continued)

2.6 Periorbital Spread

The 87-year-old woman in Fig. 14 had a recurrent sarcomatous squamous cell carcinoma of her right scalp, which invaded her temporalis muscle and was characterized by perineural invasion. This resulted in orbital and intracranial spread.

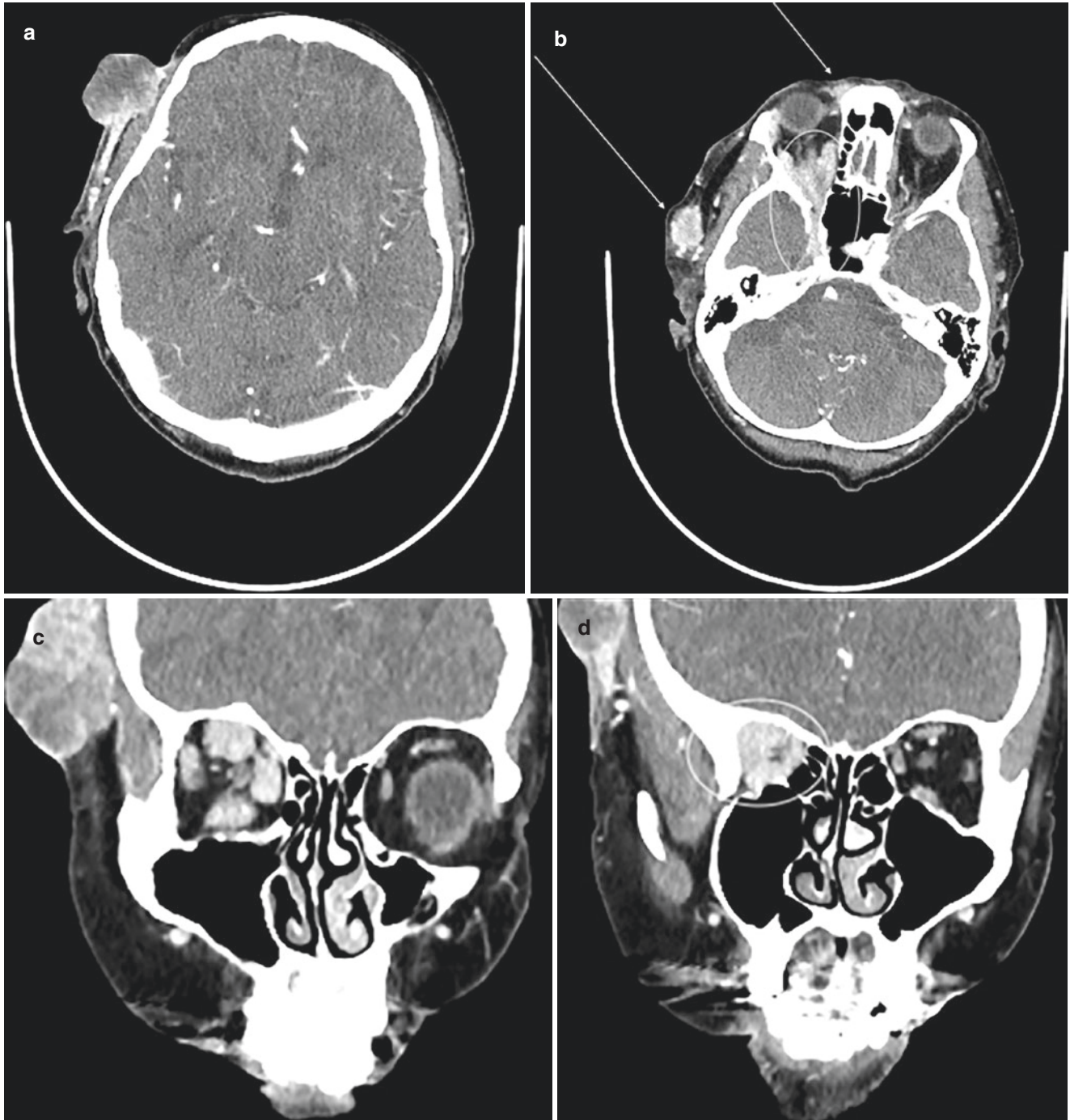


Fig. 14 (a and b) Recurrent sarcomatous SCC invading right temporalis muscle, right preauricular lymph node and by perineural spread to the apex of the right orbit (ringed), where it extends posteriorly to the right cavernous sinus. Note also the tumour at the medial canthal region. (c and d) Coronal CT views show involvement of all of the right extraocular muscles and the posterior right orbit where there is compression of the orbital nerve. (e and f) Axial MRI scans show the right optic

nerve surrounded by tumour and the right cavernous sinus invaded by tumour. The posterior arrow indicates enhancement of the right trigeminal nerve in the cistern. (g and h) Coronal MRI scans show tumour in the inferior orbital fissure and orbital apex (circled), V2 (Maxillary branch of the trigeminal nerve) at the foramen rotundum, the enhanced cavernous sinus (Meckel's cave) and the pre-ganglionic portion of the trigeminal nerve in the pre-pontine cistern

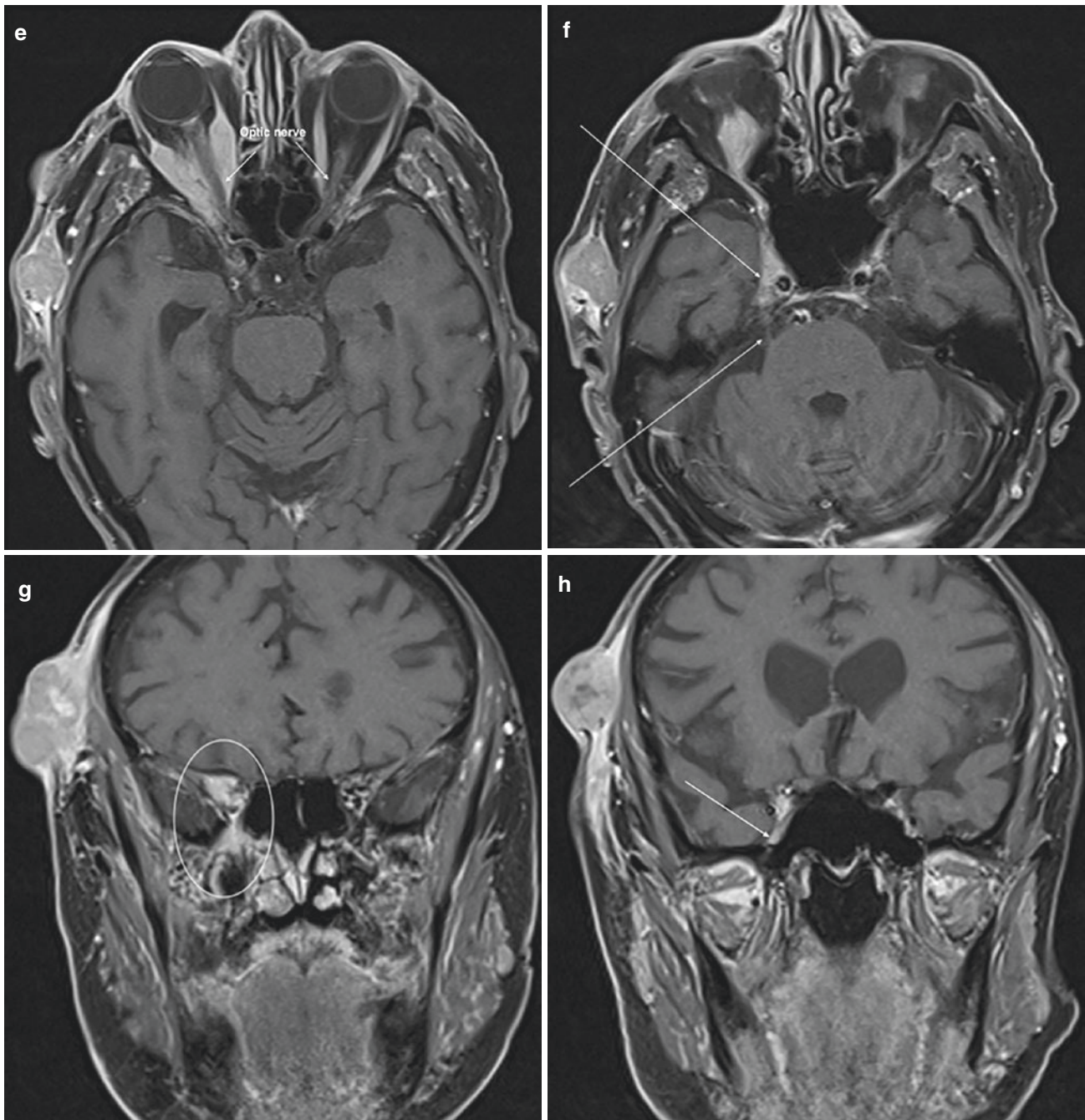


Fig. 14 (continued)

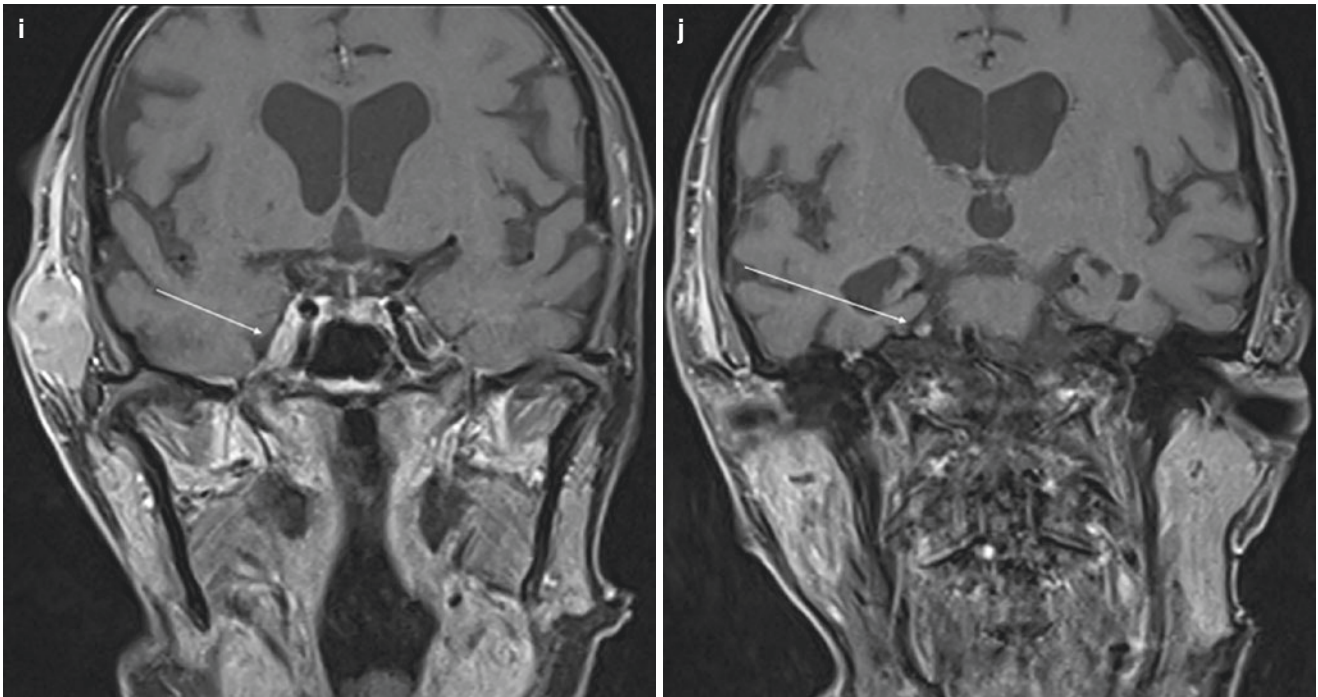


Fig. 14 (continued)

2.7 Peri-auricular Spread

This 93-year-old man (Fig. 15) has a diffuse SCC of his left ear invading the parotid gland with a preauricular lymph node and close to the left temporal bone.

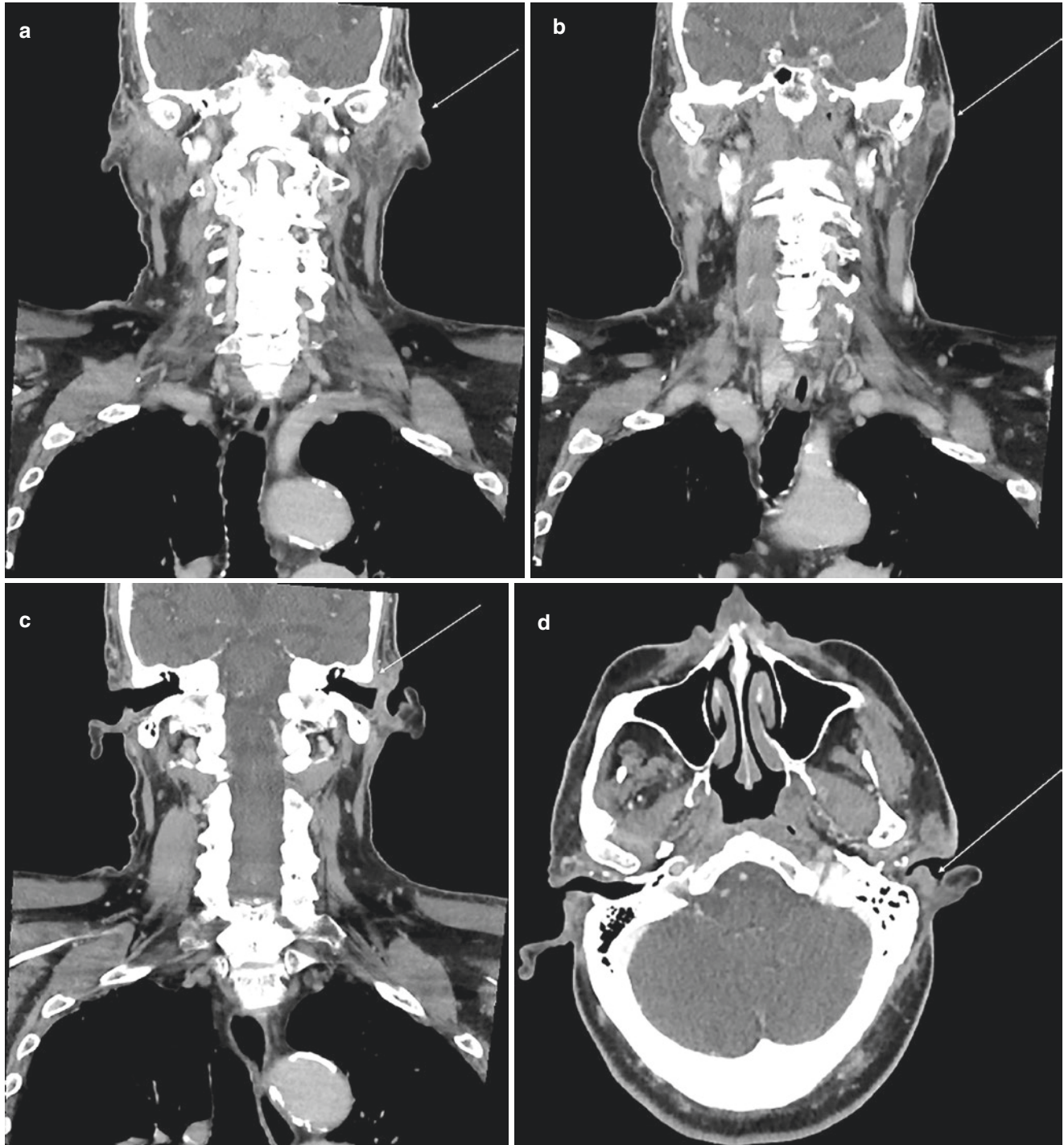


Fig. 15 (a–d) A 93-year-old man with aggressive SCC of his left ear invading the parotid, with a preauricular node and close to the left temporal bone. Note the fat plane preserved between the tumour thickening and the temporal bone in the last axial CT view

2.8 Bone Invasion

The 57-year-old man in Fig. 16 shows a squamous cell carcinoma involving the full thickness of the skin of the left occipital scalp and bone erosion of the outer table of the skull.

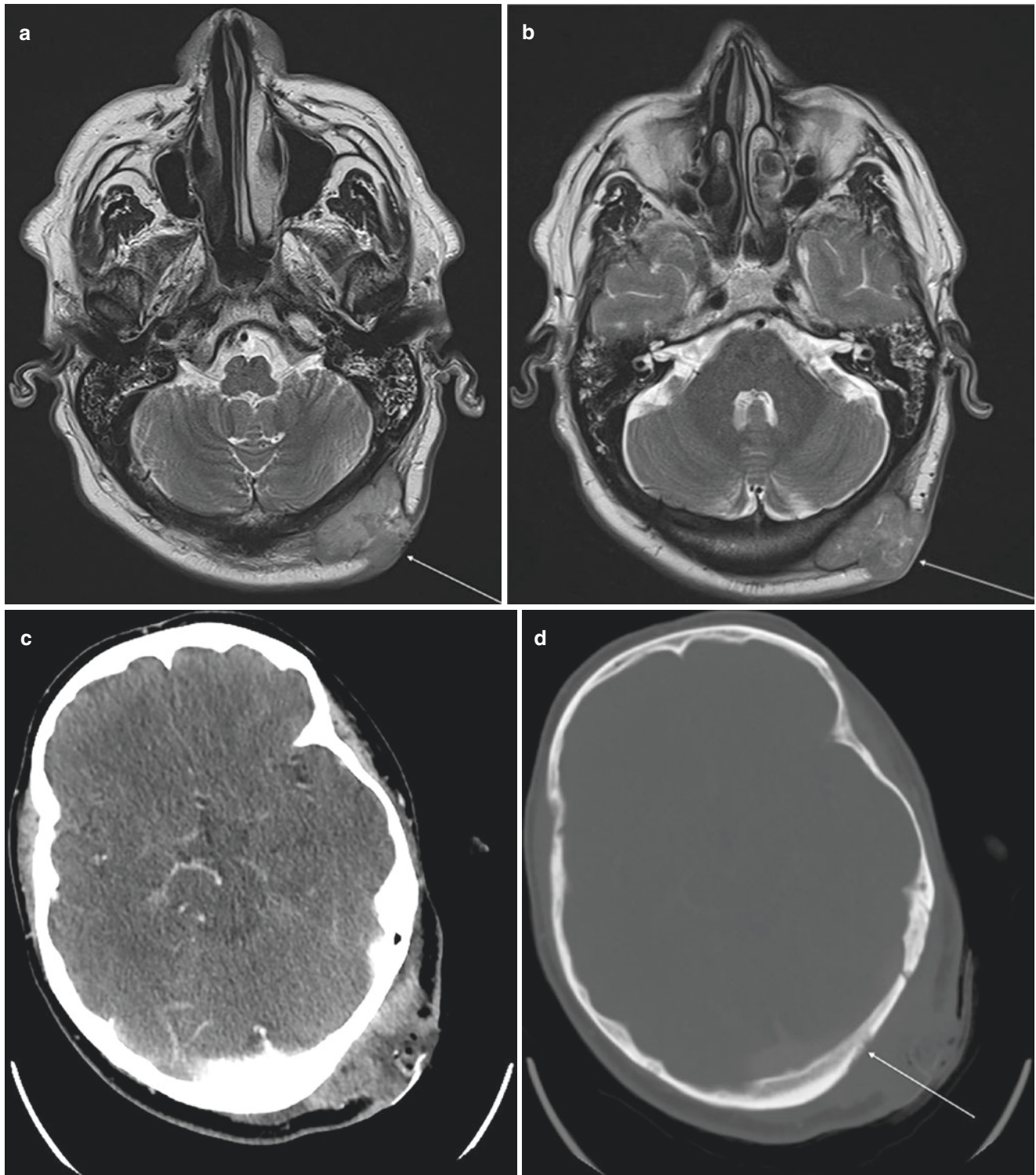


Fig. 16 (a–d) SCC of the left occipital scalp invading full thickness and eroding the outer table of skull. The first two images are MRI scans, and the second two images are CT scans, showing post-biopsy changes at the surface of the lesion and confirming calvarial invasion

2.9 CT Appearance of Lymph Node Spread

This 78-year-old man (Fig. 17) had a prior resection of a poorly differentiated squamous cell carcinoma 18 months earlier.

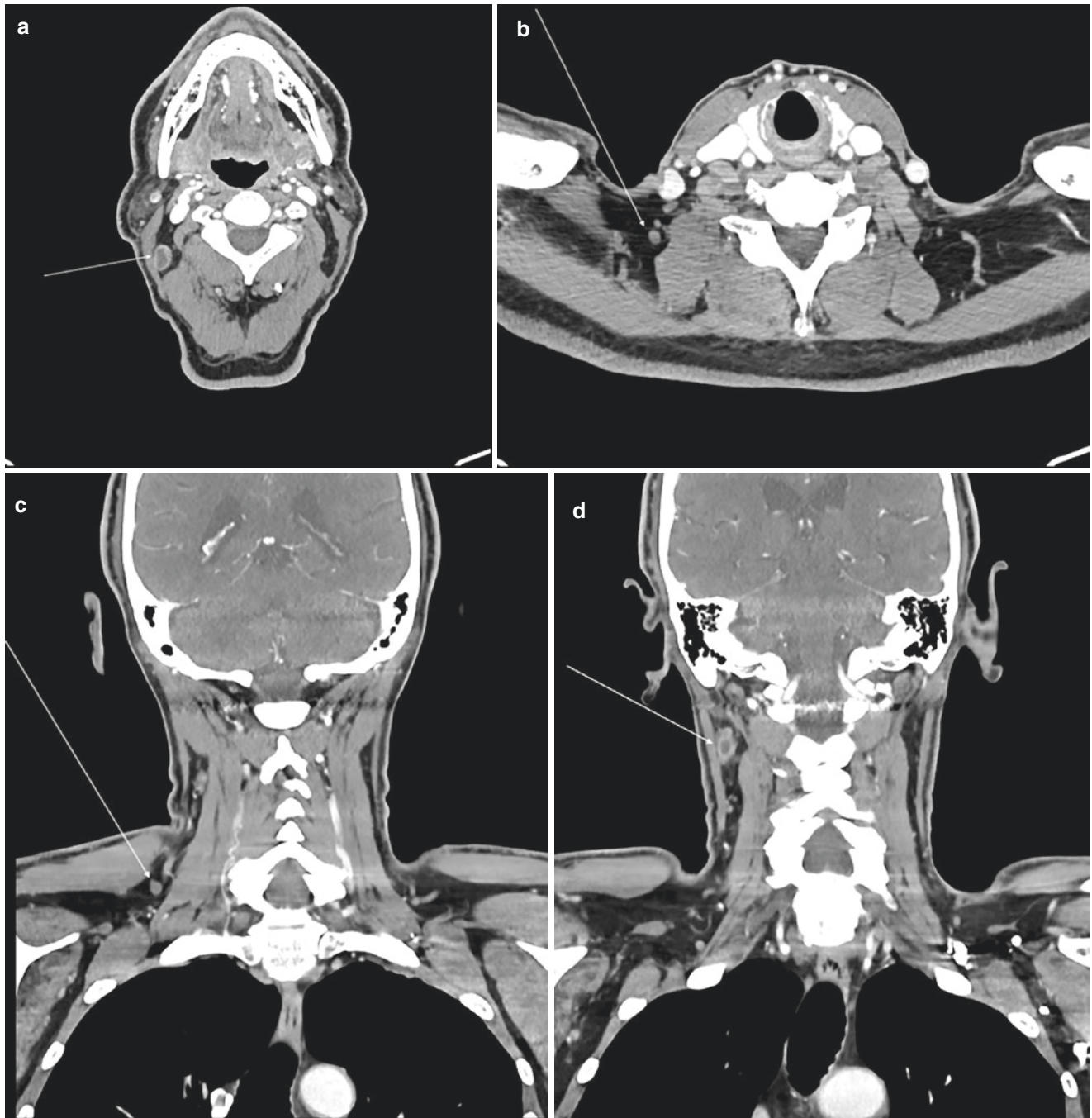


Fig. 17 (a and b) Axial CT scans show a right level 2B/5A cystic node and a small but suspicious node at level 5B. (c and d) Coronal CT scans show lymph node involvement at 5B and 5A/2B

2.10 Subdermal Spread

A 52-year-old man (Fig. 18) presented with subdermal and submucosal spread of a nasal tip squamous cell carcinoma into the septum, premaxillary tissues, columella and nasal spine.

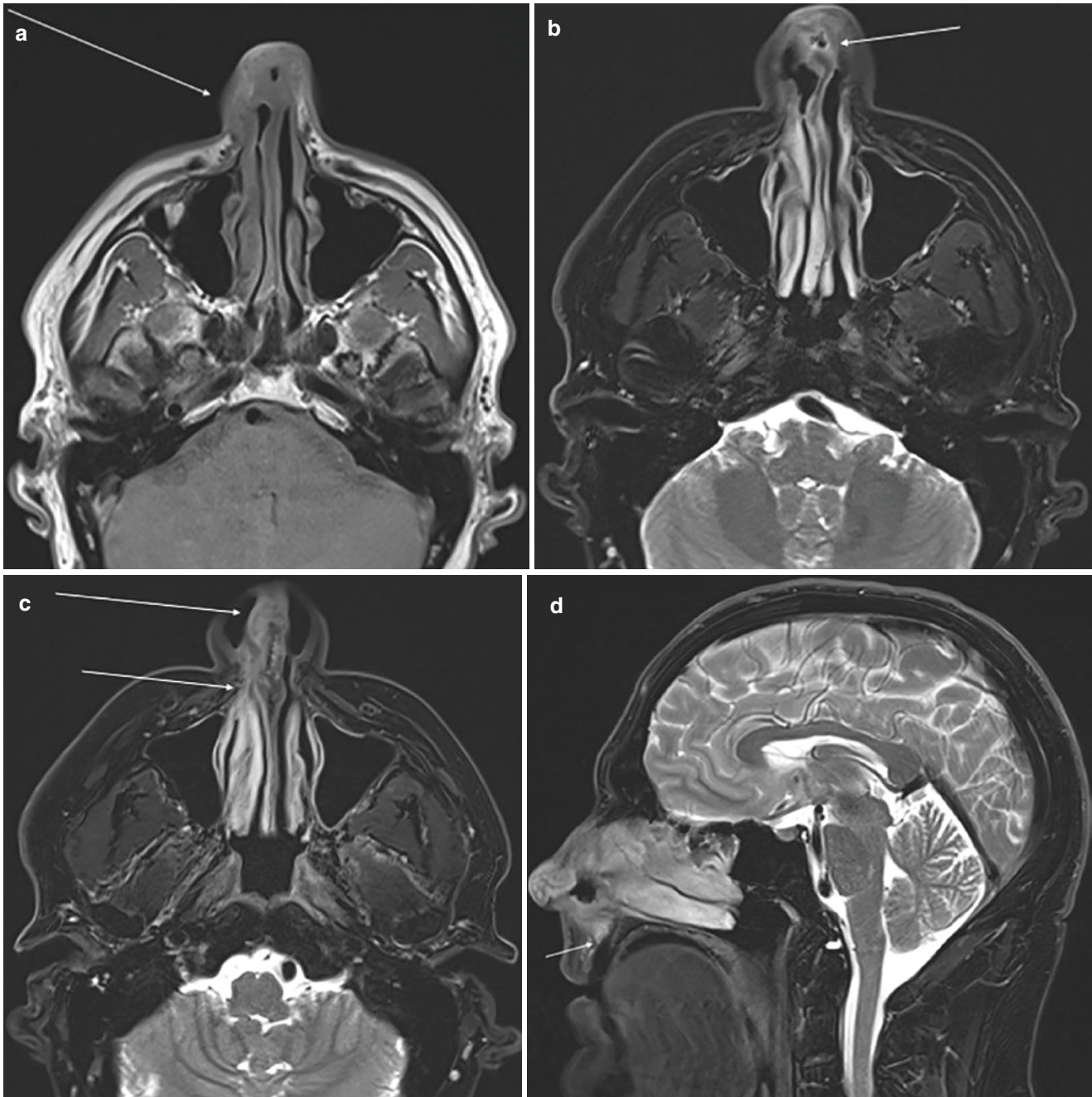


Fig. 18 (a–f) Subdermal spread of a nasal tip SCC in a 52-year-old man to involve the septum with ulceration, deep submucosal infiltration into the premaxilla and MRI enhancement images of the columella and nasal spine

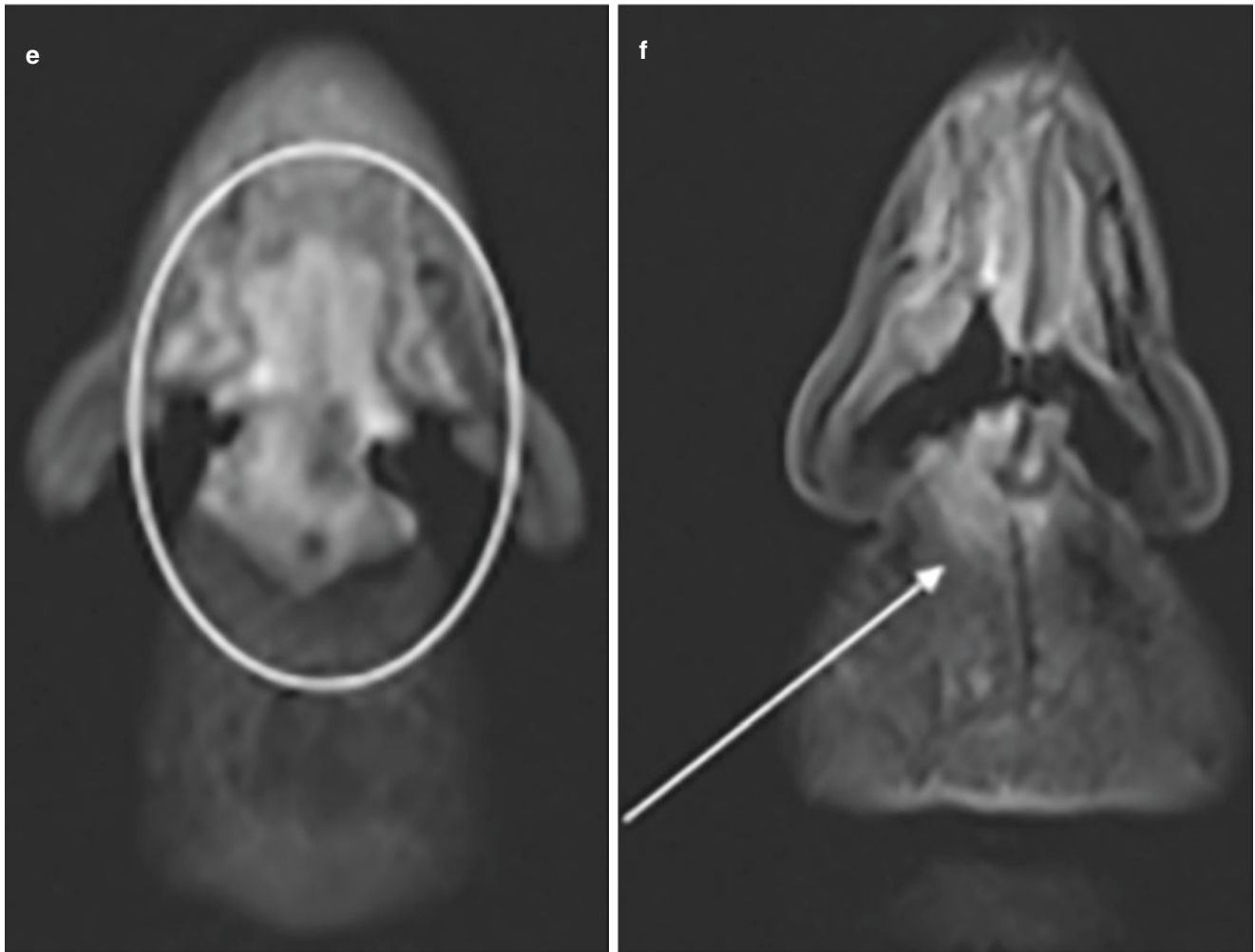


Fig. 18 (continued)

2.11 Skull Base Perineural Spread

The MRI scans in Fig. 19 are of a 63-year-old man with perineural spread into the mandibular branch of the trigeminal

nerve all the way to the foramen ovale and cavernous sinus. This degree of advanced facial cancer has life-threatening consequences with intracranial meningitis and cavernous sinus thrombosis.

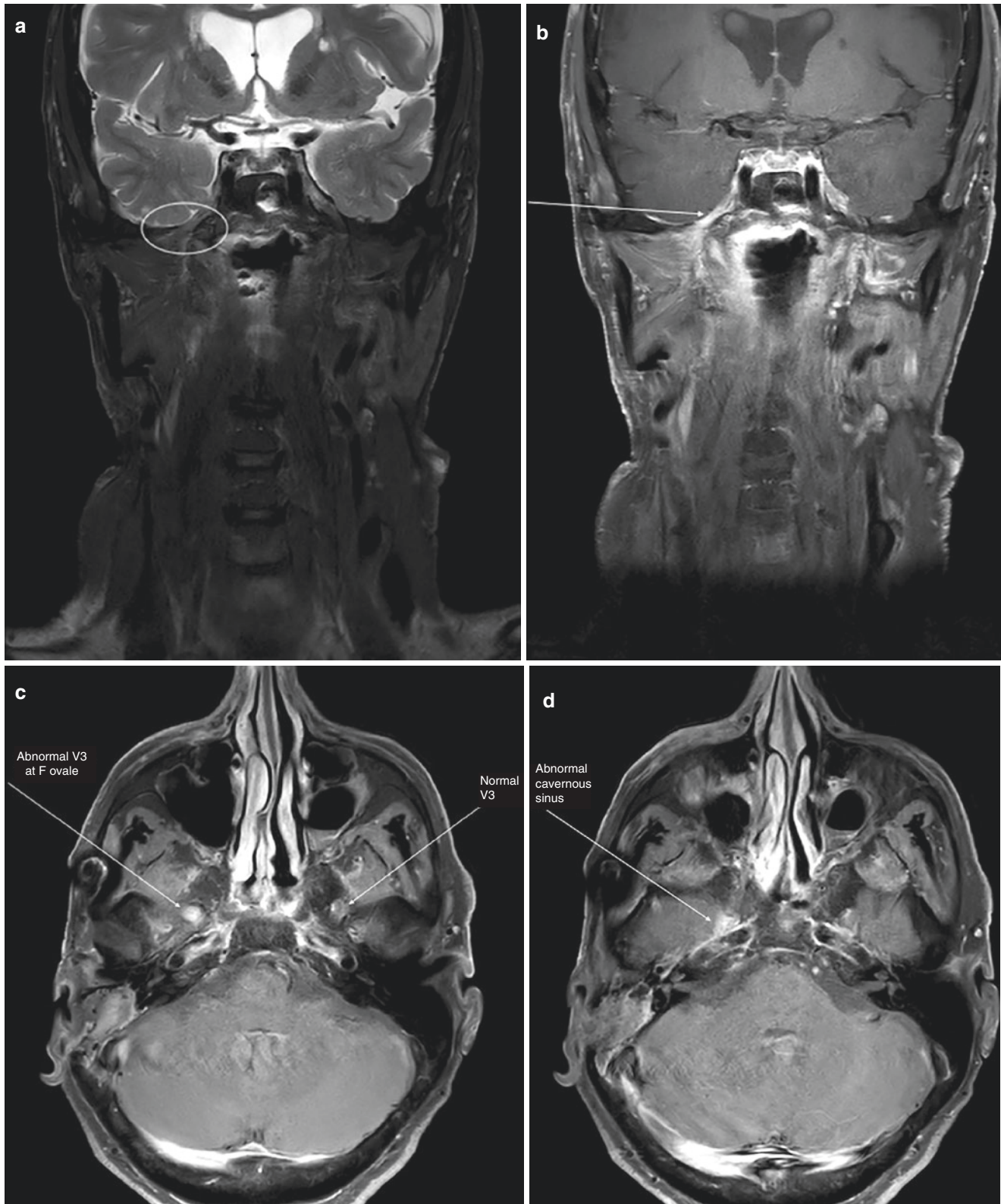


Fig. 19 (a–d) MRI scans of a 63-year-old man with increased signal in the right V3 (mandibular nerve) at the foramen ovale in the skull base and the nearby cavernous sinus. The abnormal right V3 is contrasted

with the normal left V3 at the foramen ovale. A slightly higher MRI slice shows enhancement along the cavernous sinus also

3 Complication Management

The late presentation, neglect or recurrence of extreme facial cancers like the right temple squamous cell carcinoma in the 71-year-old man (Fig. 20) is in reality a failure of CLEAR (Complete Local Excision + Aesthetic Reconstruction) and DRAPE (Delayed Reconstruction After Pathology Examination), the important principles of wide and clear cancer excision plus aesthetic and if appropriate immediate reconstruction [4]. Managing the complications of failure to

control the cancer locally and regionally is what follows in the remaining sections of this atlas.

The team approach with staging by a multi-disciplinary team, detailed pathological and radiological evidence, pre-anaesthetic workup, definitive or palliative resection, preservation of vital structures, function and immediate aesthetic reconstruction with the simplest flap method available is the oncological protocol. Post-operative care, follow-up and functional rehabilitation are then considered along with adjuvant therapies.

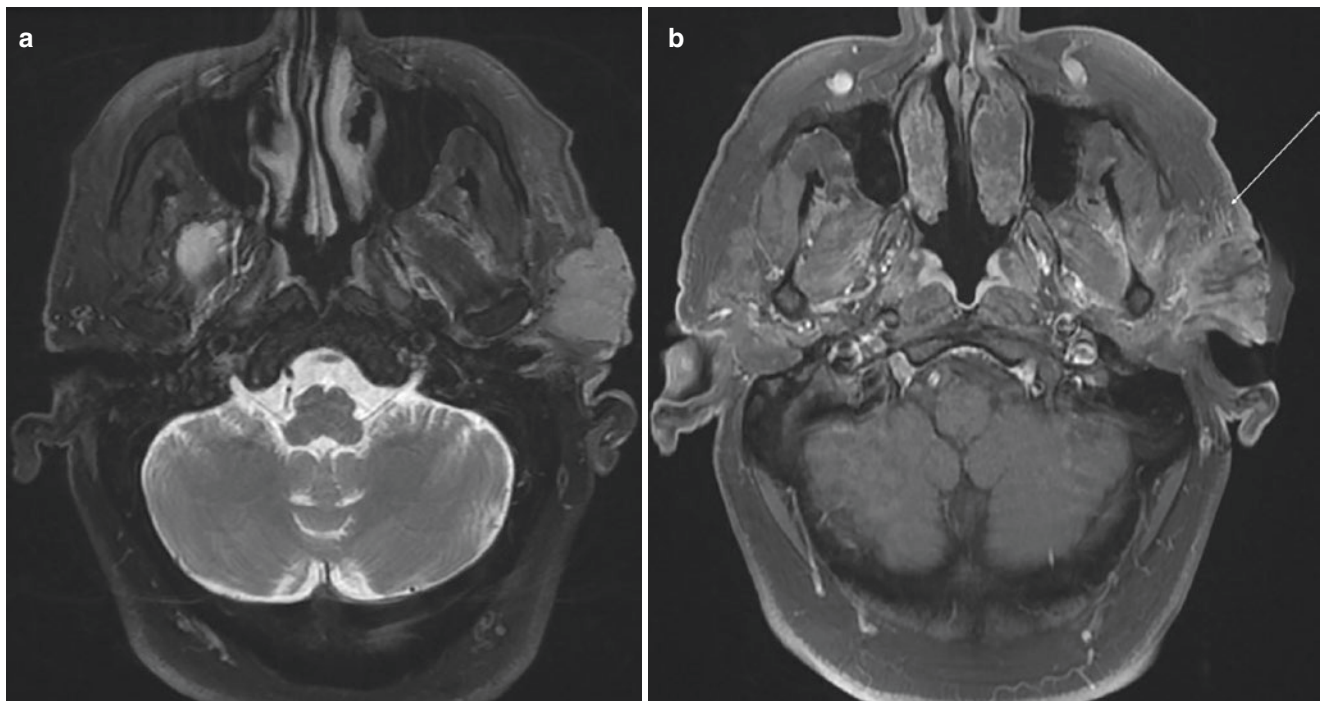


Fig. 20 (a and b) MRI scans of a 71-year-old man showing SCC invasion of left temple into parotid gland and SMAS layer. The arrow in the second image shows altered signal in the subcutaneous tissues anterior to the mass indicating possible dermal lymphatic involvement

4 Conclusion/Summary

This chapter is a collaboration between plastic surgeons, an experienced head and neck radiologist and a biomechanical research engineer. Applied anatomy is the bedrock on which all of us have practised our crafts and what drew us to the careers we have enjoyed. In extreme facial cancer (including the head and neck structures), an appreciation of 3D and applied anatomy is mandatory for best practice no matter which discipline or specialty you are based from. Failure to control an aggressive cancer locally will inevitably lead to loco-regional recurrence within soft tissue and bone tissue planes and may herald further metastatic spread to the facial skeleton, regional lymph node basins, the orbit, the cranium and intracranially. Poor differentiation of the primary tumour associated with lymphovascular or perineural invasion and spread is the common high-risk factor, which leads to greater challenges for successful clinical management. High-resolution radiological imaging with CT and MRI in a series

of head and neck cancer cases is presented to illustrate the common patterns of cancer spread in the face. Which modality is best, MRI or CT? This is often dependent on the individual case and the decisions of the team radiologist. Intracranial extension of common facial skin cancers has dire consequences for life-threatening terminal events including meningitis.

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The Team Approach in Cancer Care

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Su S. Thon, Alison Fleming, and Karolina Willoughby

Core Messages

- The team concept for surgery is a collaborative alliance of differently skilled professionals who come together under one roof to optimize the clinical outcome for the patient in the community.
- Sometimes cure is the outcome, but treatment is always the process even if palliation is the only realistic goal.
- Minimizing deformity and the stigma of disease is the collective goal with the focus on function, morphological rehabilitation and psychological support.
- Advances in techniques and outcomes are more likely to be achieved within a team setting, where each member of the team understands the problems for the patient.

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1 Introduction

The team concept in surgery has deep roots in history. Captain Harold Gillies was a newly qualified ENT surgeon at the outbreak of WWI in 1914 when he volunteered as a medical officer with the Red Cross on the Western Front in France. Born in Dunedin, New Zealand, he was an undergraduate in medicine at Cambridge University in the early 1900s, whilst in France the young Gillies was inspired and influenced by the European surgeons including Lindemann, Valadier, Nelaton, Ombredanne, Morestin, Esser and Joseph. He decided early on that a career of reconstructive surgery was his calling and that the team concept was key [1].

The authority on this plastic surgery evolution is a retired rheumatologist, Dr. Andrew Bamjii, who guarded and studied the thousands of records preserved at the modern Queen Mary's Hospital, Sidcup, in Kent between 1983 and 2011 [2]. Sir Harold Gillies was the mastermind at Sidcup, who understood the multidisciplinary concept for managing complex defects of the face. He acknowledged the strength of the team approach not only in military surgery but also later in civilian surgery. Anaesthesia and specialist nursing were equally important for successful reconstruction of the face [3].

Figure 1 shows Queen Mary and her escorts visiting the hospital named in her honour in 1918 and standing behind

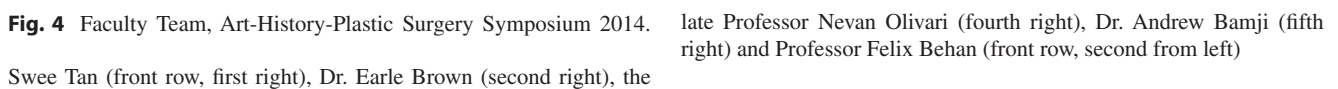
head of the British team and Pickerill (third from the left), head of the New Zealand team.

Between the world wars, Gillies trained key plastic surgeons of the next generation like Mowlem, McIndoe and Kilner, who in turn embraced the team concept in reconstructive surgery. An older Gillies is shown in Fig. 2 with his plastic surgery team at Rookdown House, a converted psychiatric hospital in Basingstoke, near Guildford, circa 1948.



Fig. 2 Rookdown House medical team 1948. Sir Harold Gillies in the front placing his jacket on the theatre sister's lap

Fig. 3 Head and Neck Cancer Multidisciplinary Team (Waikato Hospital 1990s). Montage includes senior author [MFK] using the operating microscope and Mr Michael Williams of the maxillofacial surgical team from chapter “Modern Maxillofacial Rehabilitation”



2 Management/Technique

The team approach for facial plastic surgery is perhaps best illustrated with the patient, who presents with previously failed attempts to reconstruct post cancer excision. The stigma of facial deformity is real, and a guiding principle of facial reconstruction is that it should follow aesthetic standards. The concept of aesthetica defined in the last few years refers to the application of cosmetic surgery techniques to improve the appearance of soft tissue defects [4]. When this standard is not reached, the outcome for many patients can be personally devastating and socially isolating.

3 Indications

This 62-year-old woman (Fig. 5), 2 years previously, had a superficial BCC widely excised from her left upper lip by a maxillofacial surgeon, and the defect repaired with a full-thickness preauricular skin graft. She also had a nodular BCC with squamous metaplasia on her left nasal tip biopsied, but was so concerned with the aesthetic result of her

graft repair, she did not return for further treatment. She overcame her anxiety neurosis and was encouraged by family to seek a second opinion from the lead author. With the concerted team support of family, surgeon and anaesthetist, she completed staged excision of her multiple nasal BCCs and revision reconstruction of her left upper lip. A staged left paramedian forehead flap with auricular cartilage grafts was used to repair the nose defect and a large cervico-facial rotation cheek local flap mobilized, to revise her left upper lip repair. Her result at 2 years and aged 64 years is shown.

The key to this patient's successful management after initial disappointment with an unaesthetic reconstruction was connecting with her on a personal level and winning her trust and confidence.

Harold Gillies famously stated: 'No man (or woman) can call themselves a plastic surgeon, unless they are adept at both reconstructive and cosmetic surgery'. Aesthetica is a concept that encapsulates this Gillies principle. It is vitally important to train plastic surgeons in all aspects of soft tissue reconstruction including cosmetic surgery to give the best possible outcomes, especially where there is facial disfigurement [4].

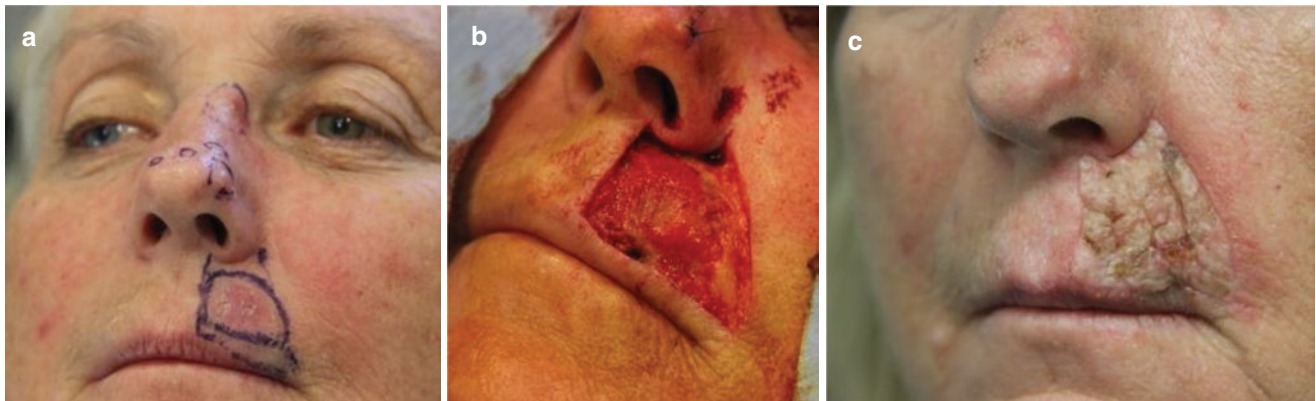


Fig. 5 (a–i) Initial BCC lip excision and graft aged 60 years (a–c). Aged 62 years with residual nasal BCCs and poor appearance of lip graft (d, e). Wide excision basosquamous cancer nose and staged fore-

head flap plus cervico-facial rotation flap for left upper lip revision (f–h). Final appearance aged 64 years (i)



Fig. 5 (continued)

4 Pathologist's Role

Pathologists are integral to the multidisciplinary cancer management team. Pathologists act as interpreters between tissue and clinicians. They correlate their cytological and histological findings with what surgeons and radiologists have found. Traditionally pathologists have been involved mainly in diagnosis, but today the pathologist's role includes, in the words of Skakeel and Mubarak (2018), 'participation in pre-clinical drug discovery and testing, determination of clinical trial eligibility of patients, assessment of novel prognostic markers, triage of tissue for molecular testing, companion

future clinical testing and research; and last but not the least, the evaluation of quality assessment of cancer programs' [5]. This is expanded further in Chap. 3 "Head and Neck Pathology: Practical Points to Ponder".

In the setting of extreme facial cancers, pathologists typically would be involved in carrying out fine needle aspirates of the primary lesions and of surrounding lymph nodes, visualizing frozen sections taken during the surgical procedure, handling of the biopsy and resection specimens, analysing the histological information and consulting with fellow pathologists. They are also responsible for interpreting the pathological findings and conveying the outcomes to surgeons and other members of the team, in terminology that all can share. An important forum for conveying the outcomes is the multidisciplinary team meeting, where pathologists not only present their data and share its interpretation but also contribute to the decision-making that decides on patient management. Two-way communication between the surgeon and the pathologist is fundamental to achieving the best shared outcome, with issues that ought to be communicated ranging from clinical history to orientation of the specimen. Whilst most pathology departments are stuck away in hospital basements or in remote rooms with no windows, some intrepid patients track us down to see their own tumours, and they are welcome, as are other members of the multidisciplinary team.

5 Psychological Issues/Body Image

The psychological, functional and social impact of facial dis-

within society quite differently. Congenital facial deformity is clearly evident at birth, and if unprepared antenatally, it is the parents and immediate family that need support. The surgeon, counsellors and rest of the team will have met as an MDT and will have planned and shared the roadmap for future invasive and non-invasive interventions required for

the child, with the parents before and almost immediately after delivery. Advances in outcome have followed centralization of services, and this has led to better outcomes, using evidence-based research.

The female shown (Fig. 6) was a delightful school teacher who is a devastating example of the danger of epilepsy and an open fire. The Odstock plastic surgery team in the UK led by Dr. John Barron (yet another Kiwi) did the self-explanatory surgeries, and she eventually returned to her classroom. Facial trauma in childhood may result in disfigurement, none more so than in severe burn injury. Children seem to cope better if less than 6 years of age, but beyond that there are severe psychological sequelae with risk of isolation, introversion, depressive illness and suicide. It seems

feel that they were a victim of the trauma and they find it

vors of the event and they are grateful for this and those around them. There is undoubted support from family and friends, but all except the most hardy would feel able to cope amongst complete strangers, if disfigured. Being accepted in society with facial disfigurement may be discriminatory at all levels, but early integration back to school and avoidance of secondary surgeries during school term mean that they are accepted readily amongst peers and confidence develops. Of course it is not fair, but society can be cruel unless educated. As adults, it is very difficult to accept new onset disfigurement or deformity even within a close family unit, but sometimes patient expectations from well-meaning but poorly performed surgery can cause undue harm as well. A surgeon must always work within the limitations of skill and capability. Depressive illness and suicide

lated and alone in many instances.

With deformity resulting from trauma or cancer resection, it is very unlikely there is any body dysmorphism, but those affected need lifelong connected multidisciplinary support and they always hold out hope that a miracle cure can be found. The male in Fig. 7 was a brilliant businessman who was persuaded to come and see the author (PL) by his fiancé, who wanted him tidied up for her big day.

Being discharged from follow-up can be devastating to many, and Professor Jim Frame in England feels compassion for those patients that he had managed over the many years, that he had to leave behind once he left the National Health Service. Continuity of care is vital, but not all physicians share each other's views and some want to clear waiting lists and discharge patients that they can no longer help. This is not what patients want to hear. They need support, and there

than that from the "Guinea Pigs" of East Grinstead.



Fig. 6 (a–e) A female school teacher who had an epileptic fit and fell into an open fire. Reconstructive surgeries by Dr. John Barron et al. at Odstock, Salisbury, UK. (Case provided by Dr. Paul Levick)



Fig. 7 (a–c) Businessman who was persuaded by his fiancé to get his lower lip vascular malformation tidied up for her big day. (Case provided by Dr. Paul Levick)

6 Anaesthetist's Role

Anaesthetists are involved in perioperative care from preoperative assessment to airway and pain management, ensuring adequate intraoperative conditions for surgery and maintaining patient physiology and postoperative care. Management of the shared airway is critical in head and neck cancer surgery (see Chap. 18 “Perioperative and Anaesthetic Care in Head and Neck Cancer Surgery”).

7 Nursing Care Issues

The modern role and dynamic of perioperative nursing has to increasingly balance technical and non-technical surgical skills. It is not enough to know the various instruments, steps of the operations, standards of operating room sterility and universal precautions. The modern operating room/theatre nurse has to understand the clinical indications of perioperative drugs including anaesthetic, analgesic, antibiotic and thrombolytic. This role overlaps and integrates with that of the anaesthetic technician or operating department practitioner. Perhaps even more challenging but as important is the modern theatre nurse's role as patient advocate, compassionate support person and reassuring kind face. Another equally challenging role is the reality of working within a highly functioning team and the potential disruptive behaviour of members of that team including other nurses, anaesthetists and historically the surgeons! For experienced theatre nurses, a specific situational awareness may be critical to anticipate the needs of the whole surgical/anaesthetic team.

Perceptual and anticipatory cognitive skills are critical for scrub nurses, as they enable them to gain information from various cues in the operating theatre. This helps the theatre nurse understand a patient's condition or anticipate a surgeon's requirements. Experienced theatre nurses are not only tuned into ‘overhearing’ conversations at the operating table and anticipating surgeon's needs, to ensure the operation progresses smoothly. They often also exhibit the ability to identify and cope with different surgeons' personalities and changing preferences. By predicting case needs ahead of time, this allows them to modify their own performance and therefore assist the surgeons more effectively [6].

8 Speech Pathologist/Nutrition Issues

Speech pathologists play an integral role in the successful multidisciplinary management of patients with head and neck malignancies. The crucial functions of breathing, speaking and swallowing are frequently impacted by head and neck surgical treatments. These functions are consistently rated by patients as priority quality of life concerns.

Nutritional optimization both pre-operatively, peri-operatively and post-operatively is a supporting rehabilitative principle for the cancer patient. These function-focused protocols and principles are documented in much more detail in Chap. 19 “Assessment of Function Post-cancer” by Associate Professor Julia Maclean of Sydney, Australia.

9 Innovations

The leadership and communication within a multidisciplinary cancer management team are vital to cope with the ever-increasing demands of more complex cases; the delays in presentation caused by global viral pandemics; and the challenges of face-to-face communication that these health crises present. ‘Too many cooks spoil the broth’ is an old proverb, which is relevant to the management of extreme facial cancer patients, where the potential for the patient to be overwhelmed by a crowd of specialists seeming to pull in different directions. It is this aspect of the compassionate care of the patient and their family where connectedness is such an important principle. The lead provider who brings the patient to the

communication about the diagnosis, management options and team recommendations is clear and transparent. Communication and expectations underpin the confidence the patient and their family have in the treatment process.

The MDT must have strong and experienced leadership with the chairman, who may be from any of the associated specialties, able to consider the opinions, distill the wide-

tice protocols. Personalities in medicine and surgery are complex, perfectionist and at times demanding. We have all witnessed the autocratic, domineering personality types who don't necessarily fulfill the role of a team leader, who leads by stewardship, calm reflection and with the spirit of fellowship.

The two editors over a number of years despite running surgical practices in different provinces have fostered a team concept of dual surgery, of collaboration and of shared care when difficult cases have necessitated it. This concept where a general surgeon and a plastic surgeon co-operate so closely for the surgical care of the patient raises the bar of successful surgical outcome and embraces the basic principle espoused by Gillies and Millard in number 13 of their 16 key principles:

9.1 Consult Other Specialists

Millard later expanded Gillies' principles into 33 including preparational, executional, innovational, contributinal and inspirational principles [7].

10 Conclusion/Summary

The team approach when dealing with extreme facial cancer is critical to the success of the treatment outcomes and the experience for the patient.

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Part II

Avoiding Complications

The Burden of Facial Deformity

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Core Messages

- Connectedness and good communication with your patient are key.
- In plastic surgery perfection is only just good enough.
- Replace what is normal in a normal position and retain it there.
- Losses must be replaced in kind.

1 Introduction

Plastic surgical techniques have advanced significantly since the 1950s but are still built on the bedrock of fundamental principles worked out by Gillies et al. during the Great War of 1914–1918.

An extensive facial skin cancer (Fig. 1) presenting to third-generation plastic surgeons like William Manchester of Middlemore Hospital, Auckland, New Zealand, in the early 1950s posed an extraordinary challenge, not least the anaesthetic challenge, lack of modern radiological imaging, only loco-regional flaps and skin grafts for repairing such extensive facial defects.

These old images from the Sir William Manchester archives illustrate an extensive basal cell carcinoma of the right hemisphere involving the right orbit, nose, cheek, mouth, ear and cra-

nium. This is a neglected facial BCC presenting in the late 1950s. The upper defect after radical cranio-orbital resection has been repaired with a large scalp transposition local flap. This reconstructive attempt preceded the arrival of microsurgical free flap transfers by at least two decades.

Another extreme facial cancer case is shown (Fig. 2), in which a middle-aged female has recurrent adenocarcinoma of her right orbit following previous radiotherapy.

The contour and colour match of an orbital reconstruction should be anatomically congruent to provide the potential for future prosthetic reconstruction, following orbital exenteration. A middle-aged man is shown (Fig. 3), several months after left orbital exenteration for recurrent basal cell carcinoma invading his orbit. The primary lesion had been a BCC of the left medial canthus, incompletely excised by a plastic surgeon and a decision to treat this with adjuvant radiotherapy. The recurrence, at least 5 years later, necessitated radical orbital resection, and the reconstruction performed by an ear, nose and throat or otorhinolaryngeal surgeon using a radial forearm free flap.

Another example of incongruent and unaesthetic reconstruction is illustrated for the elderly woman (Fig. 4), who had a malignant melanoma widely excised from her forehead and the defect repaired with a split skin graft by a dermatologist. Although skin grafts may often suffice as a temporary repair whilst the DRAPE principle of Behan is applied, secondary reconstruction with a local flap achieves the standard of Gillies, i.e. *Losses must be replaced in kind* [1].

The younger woman with a temporary skin graft to her nose after complete excision of a BCC (Fig. 5) later had a definitive aesthetic reconstruction with a staged paramedian forehead flap and conchal cartilage grafts.

The forehead flap is a very versatile donor site for local flap reconstruction as detailed in later chapters, but the elderly woman in Fig. 6 illustrates this best. After wide excision of her large infiltrating right supraorbital nodulocystic BCC, the defect was repaired with a subtotal forehead flap as a rotation advancement flap [2].

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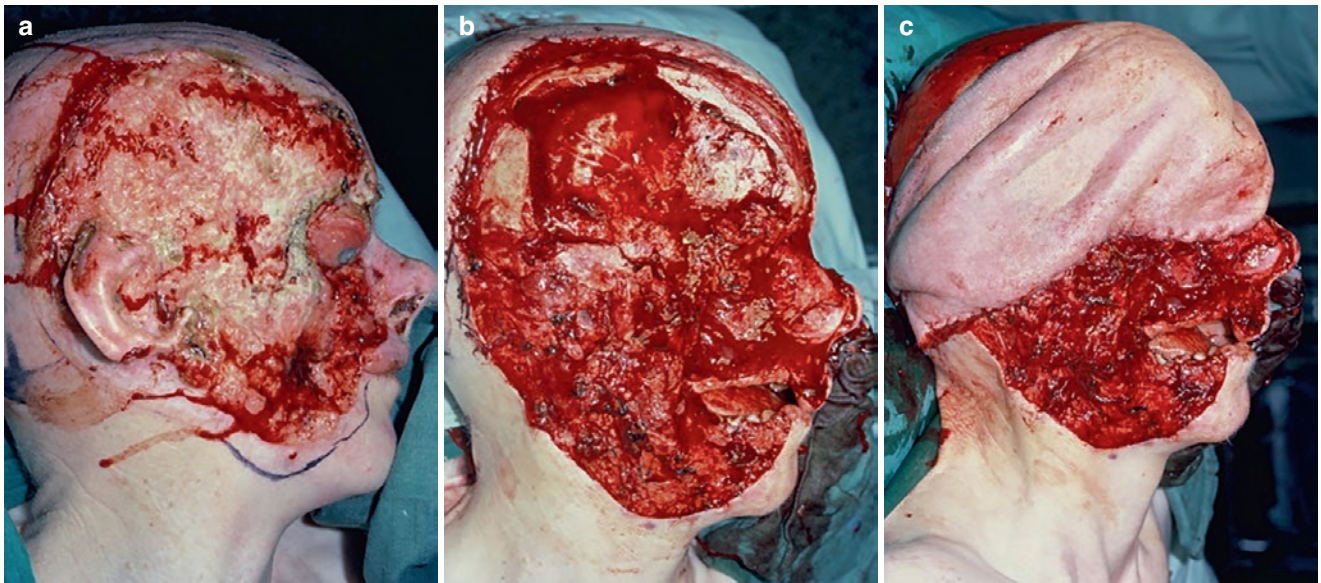


Fig. 1 (a–c) An extreme scalp and facial BCC managed by Mr. William Manchester at Middlemore Hospital, Auckland, NZ



Fig. 2 (a–f) A recurrent adenocarcinoma of the right orbit in the 1990s, managed with orbital exenteration and local flap repair over split free calvarial bone grafts. [Images provided by Mr. David Soutar FRCS of Glasgow, Scotland]

Figure 2 is a case from the early 1990s, when free tissue transfer was routine for head and neck reconstructive cases. However, her right orbito-cranial reconstruction has been achieved with split calvarial bone grafts, a temporalis trans-

position muscle and pericranial flaps deeply, plus a large cervico-facial flap for skin cover. Brachytherapy tubes are also placed deep to the skin flap for further adjuvant radiation.



Figs. 3 and 4 Clinical examples of incongruent and unaesthetic facial reconstructions by non-plastic surgeons in the orbital region and central forehead



Fig. 5 A young female with infiltrating BCC of her nasal tip, temporary skin graft as per the DRAPE principle of Behan. Later when BCC margins confirmed as clear, definitive reconstruction with paramedian forehead flap and conchal cartilage grafts



Fig. 6 (a–d) Application of the subtotal forehead flap as a rotation advancement local flap for repair of a large right supraorbital defect, following wide excision of a BCC. (From Klaassen et al. [2]; with permission)

2 Further Clinical Cases Illustrating the Principles of Aesthetic Reconstruction to Reduce the Deformity

A vast range of reconstructive techniques can be applied for significant facial defects following skin cancer resection. Selected clinical cases are illustrated with the surgical management and indications.

these rare cases in their long careers. The innovative technique of Glaswegian plastic surgeon (former ophthalmologist) Jack Mustardé remains the best technique for total upper eyelid reconstruction. It is a complex and staged method requiring an exacting technique and is precisely detailed in his textbook [3]. Mustardé was a consultant ophthalmologist prior to the Second World War when he was re-trained by Sir Harold Gillies, Archibald McIndoe and Pomfret Kilner, along with a whole new third generation of modern plastic surgeons [4].

3 Aesthetic and Functional Reconstruction

A middle-aged woman (Fig. 7) presented with a biopsy-proven sebaceous gland carcinoma of her right upper eyelid. Most plastic surgeons will be lucky enough to see one of



Fig. 7 (a–j) A sebaceous carcinoma of the right upper eyelid in this 54-year-old woman which was initially excised as a possible BCC. Later a subtotal upper eyelid excision and staged reconstruction using

the lower eyelid switch flap of Dr. Jack Mustardé. 20-year follow-up appearance. See details in Chapter 12, “Extreme Cancer of the Periorbital Region”

4 Planning in Reverse Principles

For complex and staged reconstruction, the plastic surgeon must have the vision of an artist and the eye of an eagle. With many years of experience this becomes automatic and intuitive, however, when getting started an important aide de memoire and reconstructive principle is the concept of planning in reverse. As with the subtotal upper eyelid reconstruction (Fig. 7), just illustrated, it was important for the surgeon to visualize the planned defect and to plan the reconstructive flaps in advance mentally and visually.

A one stage paramedian forehead flap based on the axial vascular supply of the right supratrochlear pedicle (Fig. 8) for a nose and right medial cheek defect after skin cancer excision is a good clinical case to demonstrate the art of planning in reverse.

The planned excision defect is mapped with a 3D mould using quarter-inch Steri-Strips applied and then glued with tincture of benzoin. The mould is carefully removed and flattened out, rotated 180° anti-clockwise and placed over the region of the donor site flap. It is important to include the de-epithelialised supratrochlear pedicle in the flap design (Fig. 8b). Like a seasoned tradesman, measure twice and cut once. Simulate the flap transfer with the moulded/flattened pattern, before making your first cut of the forehead flap. This reconstruction was planned as a one stage method, but two stages are the traditional technique. The final reconstruction is shown a year later.

A similar paramedian forehead flap has been the reconstructive flap of choice for this middle-aged woman (Fig. 9)

with a recurrent BCC in a previous full thickness graft to her right nasal alar region. The re-excision was performed by a dermatologist with Moh's micrographic surgery. A traditional two-stage paramedian forehead flap plus conchal cartilage graft was performed, with 3 weeks between the initial flap transfer, final division of the pedicle and flap inset. Note the site of the split skin graft on the raw undersurface of the forehead flap (Fig. 9c).

The final image (Fig. 9d) shows the result after another year when trimming and refinement of the flap reconstruction had been completed to an aesthetic reconstructive standard. For subtotal alar nasal aesthetic subunit reconstruction, staged local flap repairs with either nasolabial or forehead flaps yield the most aesthetic and contour congruent results. This is clearly demonstrated in the nasal reconstructions of the pioneers Gary Burget and Frederick Menick [5]. They were both mentored by Professor Ralph Millard Jnr, who was taught by Sir Harold Gillies in the 1950s.

The planning-in-reverse concept is illustrated again with the 69-year-old farmer with chronic photo-damage and multiple facial skin cancers, including these recent BCCs on his right alar region and right medial canthal region (Fig. 10). A paper template is used to estimate the skin required for the combined right lower nose and medial canthal defects and incorporated into the left paramedian forehead flap. A right crescent-shaped conchal cartilage free graft under the distal end of the flap was included to give structural integrity to the new right nostril margin. The immediate reconstruction post wide excision is shown in (d) and the 24 h result in (e).

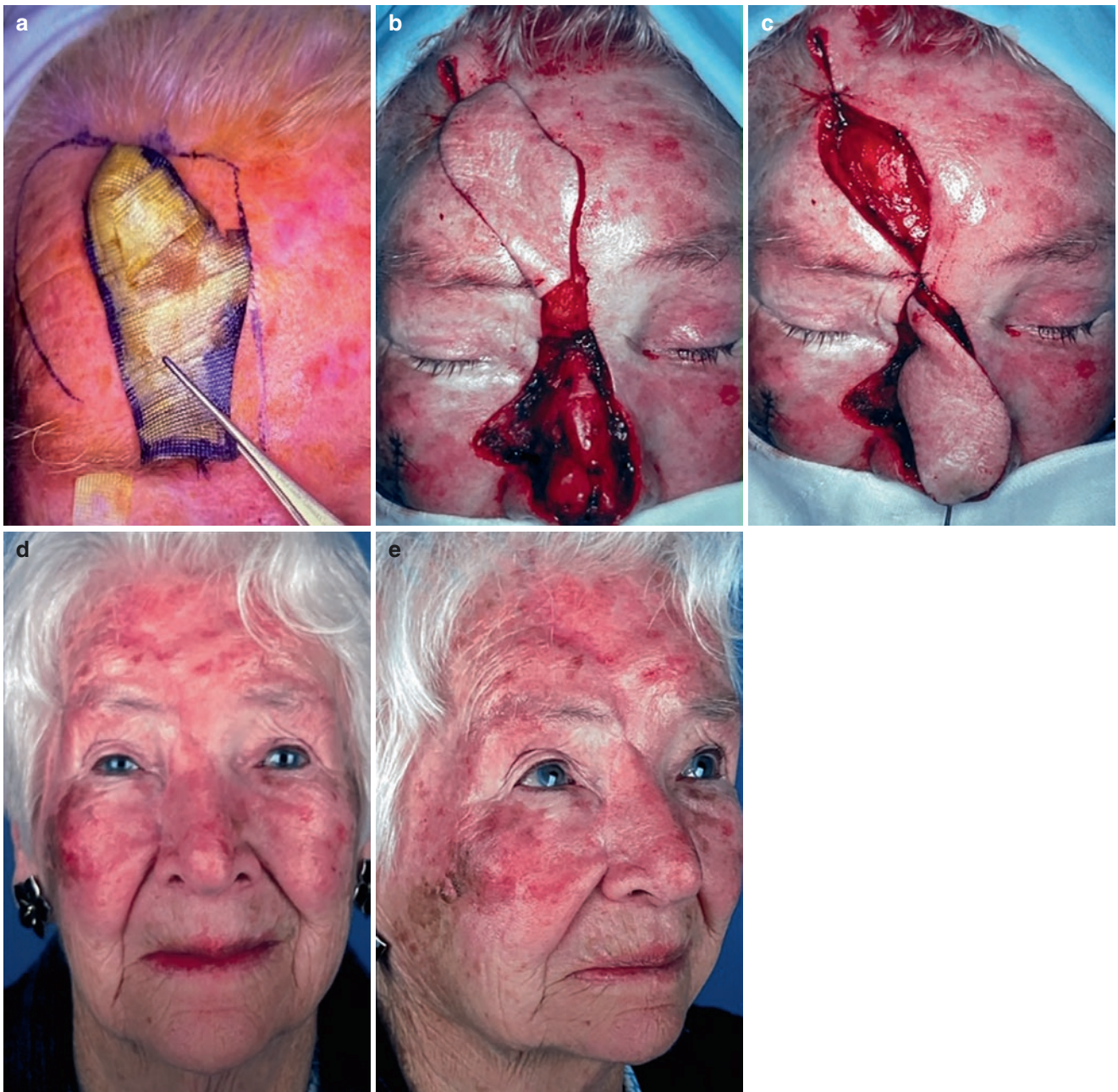


Fig. 8 (a–e) The principle of planning in reverse is illustrated for a woman with a subtotal nasal defect after extensive skin cancer resection. The planned right paramedian forehead flap is planned in reverse;

after first taking a 3D mould of the nasal defect with Steri-Strips which are glued together with tincture of benzoin. The result is shown 1 year following surgery



Fig. 9 (a–d) A nurse who worked with the senior author with a poor aesthetic result after excision and full thickness skin graft for an infiltrating BCC of her right alar nasal region. This was revised with a para-

median staged forehead flap, with later contour revision and the final result is shown at a year. Planning the flap in reverse helped achieve the result



Fig. 10 (a–f) A 69-year-old East Cape farmer with severe photo-damage of his face. Planning in reverse to design a paramedian forehead flap for the defect of his nose and right medial canthal regions following wide excision of BCCs. Immediate result and 18 months post-op shown

5 Planning for Multiple Local Flaps

In certain clinical cases, particularly those where the nasolabial mid-face region is the focus of the reconstruction, multiple flaps may need to be planned.

The middle-aged woman (Fig. 11) underwent margin-controlled excision of an infiltrating BCC of her left nasal alar. The surgical excision defect extending into the

medial cheek, left upper lip and left nasal sidewall aesthetic subunit illustrates the need for multiple local flaps. A V-Y islanded advancement nasolabial flap (1) recreates the platform for a new alar base, and the lateral nasal flap (2) is turned down as a hinge flap for the nasal lining, a conchal cartilage graft from the left ear for nostril support and a staged left paramedian forehead flap (3) for nasal skin cover.



Fig. 11 (a and b) Multiple local flaps and an auricular cartilage graft for staged reconstruction of a large left nasal alar, left nasal side wall, left cheek and left upper lip defect after wide excision of an infiltrating BCC left alar

6 Large Composite Facial Defects Requiring Free Flap Solutions

There are rare cases where local flap solutions are inadequate for the reconstructive task. A young man in his 30s (Fig. 12) presented to the Maxillofacial Surgical Service with a painful swelling of his left cheek, associated with a vague history of blunt trauma. Careful workup and biopsy confirmed an aggressive high-grade rhabdomyosarcoma of his left maxilla.

As a multidisciplinary case, he underwent radical surgery with an extended left hemi-maxillectomy including the full thickness of his left cheek and left oral commissure. Immediate reconstruction was achieved with a bi-paddled free rectus abdominis myocutaneous flap anastomosed to recipient vessels in his left neck. Subsequently flap revision was performed in stages, and he received brachytherapy to the tumour bed through the free flap. Despite further resections for a lateral cheek and zygomatic recurrence and another free flap repair with a latissimus dorsi flap, he lost his battle with this aggressive sarcoma 2 years later.



Fig. 12 (a–f) A male patient in his 30s with an aggressive rapidly growing rhabdomyosarcoma of his left maxilla. Left extended maxillectomy and immediate reconstruction with bi-paddled rectus abdomi-

nis myocutaneous free flap. Later adjuvant radiotherapy and recontouring of the left cheek soft tissues

7 Contraindications

In some cases the options for autologous reconstruction are contraindicated either because of the extensive nature of the proposed surgical defect or because of the patient's decision to decline autologous flap reconstruction. A man living in a third world environment (Fig. 13) with a very extensive and destructive mid-facial skin cancer involving the right lower eyelid and upper lip resulting from a longstanding infiltrative pigmented BCC, is an example of a contraindication for immediate local flap reconstruction. This is a case for keeping it simple and the DRAPE principles.

A 40-year-old woman (Fig. 14) is another example, who, following total rhinectomy for extensive nasal septal SCC, preferred a prosthetic nose reconstruction utilizing an adhesive retained acrylic base plate and magnetic keepers for attachment of the prosthetic nose (Fig. 14b).

Prosthetic maxillofacial reconstruction (Fig. 15) is considered and reviewed in much more detail in Chapter 17 "Modern Maxillofacial Prosthetic Rehabilitation" (Evans, Williams et al.).



Fig. 13 Mid-face and perinasal destructive skin cancer presenting to our interplast team in Indonesia, where the DRAPE principle was applied



Fig. 14 (a–c) A 40-year-old woman with penetrating SCC of her nasal septum, post total rhinectomy and an adhesive retained prosthetic reconstruction of her nose



Fig. 15 Modern maxillofacial prosthetic rehabilitation

8 Innovations

As well as the refinements in multiple local and distant flaps, supported by advances in applied functional human anatomy and microsurgical technology, the ability for the reconstructive surgeon to have the visual and spatial skills of an artist has also become an important concept. This has been championed by Professor Michael Esson (Fig. 16), formerly of the School of Fine Arts, University of New South Wales, Sydney, Australia, with his international

series of courses, called The Art of Reconstruction. These workshops have been specifically designed to assist plastic surgeons and other reconstructive surgeons (e.g. breast) to improve their aesthetic skills, through drawing and modelling. The goal is to develop strategies for better understanding and appreciating the interpretation of structure and space. Many surgeons including the lead author have benefitted from the Art of Reconstruction Workshops, and this has contributed directly to the achievement of better aesthetic reconstructions.



Fig. 16 (a–c) Professor Michael Esson and plastic surgeon/sculptors participating in Art classes

9 Conclusion/Summary

The goals in reconstructive surgery of the face include complete excision of the cancer with adequate margins and then to remove the stigma of the disease and the deformity. Plastic surgeons have a bedrock of historical experience for this task starting with the earliest attempts to manage facial war wounds from the Great War (1914–1918) with pioneers like Gillies, supported by his nursing, maxillofacial and anaesthetic colleagues. The TEAM approach at the Queen's Hospital in Sidcup, Kent, southern England, where this began with some momentum in 1916, remains an important principle. This means that multidisciplinary and protocol-driven management in the modern world allows the treatment of complex cases to become routine. Individual variation, diversification and innovative novel approaches are also important. Finally, and of no lesser importance, are the unique skills of

an artistic approach to form, anatomy and structural space. In plastic surgery, perfection is only just good enough [6].

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Pedicled Versus Free Flaps

Damian D. Marucci

Core Messages

- Although facial skin cancer defects can be adequately reconstructed with simple closure or local flaps, larger or more complex defects will require pedicle or free flaps.
- Pedicled flap options are generally faster, easier to raise and more appropriate for patients with low aesthetic demand and multiple pre-existing comorbidities.
- Free flap reconstruction allows for the transfer of large amounts of skin and soft tissue with high reliability in experienced hands. Specific combinations of tissue types can be transferred.
- Pedicle and free flap options may be equivalent for many types of defect. Patient, defect and surgeon factors should guide flap selection.

1 Introduction

The reconstruction of extensive facial defects following cancer excision requires a careful appraisal of the patient, the defect and the reconstructive options. Facial reconstruction is not one size fits all, and what may be appropriate for one patient may be inappropriate for another. The goal of this chapter is to discuss the decision-making process for larger and more extensive facial defects, where the surgeon needs to choose between pedicled flaps, whether local or regional, and free flaps, which may be taken from distant sites on the body.

2 Defect Analysis

A thorough evaluation of the defect is an essential component of facial reconstruction. The size, depth, planes of tissue involvement (skin, fat, fascia or bone), quality of surrounding soft tissues, anatomical location and proximity to surrounding structures are important to assess and document. Smaller defects may be amenable to primary closure or reconstruction with local flap techniques. Larger defects will require locoregional or free flaps. Defects involving deeper tissue planes, especially those involving the bone, will almost certainly require pedicle if not free flap reconstruction. The reconstruction of defects near the eye or mouth may result in the functional deficits of ectropion or loss of oral competence, respectively [1]. Functional deficits may result from the defect itself due to the sacrifice of motor nerves as part of the cancer extirpation. Loss of specialised anatomical features, such as the nasal alae or eyebrow, should also be appreciated, and decisions made as to how best restore facial balance and symmetry. Assessment of the surrounding skin for colour, texture, presence of scars or evidence of damage by previous radiotherapy will also affect surgical decision-making. A history of radiotherapy increases the risk of wound healing problems and free flap failure [2, 3].

Previous or concurrent surgery in the head and neck region may also impact surgical decision-making. Previous or concurrent neck dissection, for example, may preclude the use of flaps based on the facial vessels. Patients with previous sur-

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Table 1 Defect analysis

Size	Larger defects need larger flaps
Depth	Deeper defects need thicker flaps to prevent contour distortion
Planes of tissue involvement	Replace like with like. Flap composition should ideally reflect defect characteristics
Surrounding skin quality	Presence of adjacent scars, irradiated tissue, etc. will affect reconstructive choices
Anatomical location	Reconstructing defects near to the eye and mouth may cause secondary ectropion or loss of oral competence
Subunit analysis	Most areas of the face can be divided into anatomical subunits which may guide the reconstructive techniques employed
Specialised anatomical locations	Reconstruction of the nose, vermillion, eyelids and eyebrows will involve specialised techniques even if the defects are small
Facial nerve involvement	Static or dynamic facial nerve reconstruction should be planned as part of facial reconstruction
Previous/concurrent head and neck surgery	Location of incisions in the head and neck region, the presence of a vessel depleted neck, division or facial vessels as part of neck dissection are important to appreciate
Need to adjuvant radiotherapy	Robust coverage is required

gery may have a vessel-depleted neck, compromising the ability to perform further free flap reconstruction. The presence or absence of appropriate local or regional vessels may sway flap selection between pedicled and free flap options.

Knowledge of the likelihood of postoperative adjuvant radiotherapy at the time of reconstruction is important. Robust soft tissue coverage is required for patients planned to undergo postoperative radiotherapy to better protect vital deeper tissues and ensure uncomplicated wound healing. Whether pedicled or free, flap coverage is important in these situations (Table 1).

3 Patient Analysis

Reconstruction of facial defects mandates an appreciation of the patient and patient specific factors that will impact surgical decision-making and surgical outcomes (Table 2). Patient age, gender and ethnicity are all important. Patient expectations in terms of scar burden, extent of surgery and cosmetic outcomes must be ascertained. The aesthetic demand of the patient will influence reconstructive technique selection. Patients with a high aesthetic demand are generally more willing to tolerate extensive surgery that may be multistage with a high likelihood of revision to further improve the outcome. Patients more interested in functional rather than cosmetic outcomes may be satisfied with a faster simpler reconstruction which may be less radical. Pedicled flaps generally take less time, resulting in decreased perioperative morbidity especially in elderly patients and those with significant comorbidities [4]. As a general rule, pedicle flaps tend to have poorer aesthetic

Table 2 Patient analysis

Age
Gender
Ethnicity
Comorbidities
Fitness for surgery/nutritional status
Cosmetic demand
Willingness to undergo prolonged/multistage reconstruction

outcomes, although good functional results can be achieved.

Patients with advanced facial cancers are often elderly with multiple comorbidities. Age is a risk factor for poor surgical outcomes [4]. Patients must be deemed fit enough to tolerate the proposed anaesthetic and surgical insult. Diabetes, smoking, corticosteroids and immunosuppression may impair wound healing and lead to reconstructive failure [3]. Frail patients who represent a significant anaesthetic risk may most appropriately be reconstructed with single-stage techniques which do not involve lengthy surgery, even at the expense of functional or aesthetic outcomes.

Nutritional status may be impaired in patients with head and neck malignancy for many reasons. Age, comorbidities or secondary effects of the cancer on swallow function all may contribute. Preoperative nutritional status is a known predictor of postoperative outcome. Albumin and pre-albumin levels should be assessed, and nutritional optimisation performed preoperatively whenever possible [5]. More detail on functional rehabilitation is found in Chap. 19 “Assessment of Function Post-cancer”.

4 Reconstructive Options

Although this chapter is focused on the reconstruction of larger facial defects with locoregional or free flaps, knowledge of the appropriateness of less complex techniques is essential.

4.1 Primary Closure

Primary closure can be an acceptable option for defects of the cheek, lips and forehead. The cheek is a vast area of skin which often becomes lax in the elderly, facilitating primary closure following excision of lesions [1, 6]. Similarly, defects of the lower lip, even up to 50%, can be primarily closed as a linear wedge without causing oral incompetence or lip eversion [6]. The key tenets of primary closure are to perform undermining only as needed, dog ear excision at time of surgery and careful observation of the effects of wound closure on adjacent anatomical structures to confirm that no distortion is occurring. Primary closure minimises the risk of haematoma and tissue loss.

4.2 Skin Grafts

Skin grafts are a simple reconstructive option for many facial defects. They have the advantage of not increasing the scar burden in the area of surgery. Skin grafts may also be used as a temporising measure whilst awaiting formal histopathology results to confirm tumour clearance.

Skin grafts may result in cosmetically acceptable results on the nose and inner canthi. Skin grafts are also viable repair options for patients with significant comorbid disease which would preclude extensive surgical procedures, such as pedicled or free flaps [1].

The difficulties with skin graft closure include the potential cicatricial distortion of surrounding structures, especially the eyelid and mouth, resulting in the potential functional problems of ectropion and loss of oral competence, respectively. Further, there is the challenge of finding an appropriate skin graft donor site match for facial skin colour and texture [1]. Skin taken from above the clavicle will have the best colour match with facial skin.

4.3 Biological Wound Agents

A significant advance in cutaneous wound reconstruction has been the development of biological scaffolds. These scaffolds consist of biodegradable material into which the host cells can migrate. There currently exist a number of these biological

wound agents which are routinely used in the reconstruction of partial- and full-thickness skin defects. The most commonly used products in the head and neck area are dermal regeneration templates. Integra (Integra LifeSciences Corp., Plainsboro, N.J.), for example, is a bilaminar product consisting of a dermal replacement layer composed of cross-linked collagen and glycosaminoglycan hydrogel covered by a silicone layer [7].

Dermal regeneration templates have revolutionised facial reconstruction, especially scalp reconstruction. Full-thickness scalp defects, where the pericranium is absent, cannot be resurfaced with skin grafts alone. By burring down the exposed calvarium to deep punctate bleeding, an adequate recipient bed is formed for a dermal regeneration template. These templates are “taken” as grafts and are later resurfaced with thin split skin grafts. Microfollicular hair transplantation of these dermal regeneration templates has been described [6]. Although acceptable in the balding scalp, dermal regeneration templates are not ideal in hair-bearing areas and may not be resilient to postoperative radiotherapy. Defects of the vermilion of the lip may be adequately reconstructed with biological wound agents, instead of the more traditional but morbid vermilion or tongue flaps [6]. Similarly, small nasal defects may also achieve adequate reconstruction with dermal regeneration templates alone [8].

4.4 Flap Reconstruction

Flap reconstruction of a facial defect may be local, pedicle/regional or free. In using flaps to reconstruct facial defects, surgeons should be guided by the principles of Gillies and Millard [9]:

1. Replace like with like—replacing tissue lost with the same or similar tissue [10].
2. Think of reconstruction in terms of aesthetic units and subunits.
3. Always have a pattern and a back-up plan, so the surgeon is prepared for all eventualities.
4. Steal from Peter to pay Paul—utilise tissue from one region to reconstruct another.
5. Never forget the donor site—minimise donor site morbidity.

With these principles in mind, for defects not amenable to primary closure, the superiority of flap reconstruction to skin graft or skin substitute techniques becomes obvious.

In sufficiently small defects, local flaps are a good option. Local flaps offer excellent colour and texture match, and most can be performed on an outpatient basis under local anaesthesia or with sedation [11]. The V-Y flap and the lateral cervico-facial rotation flap for cheek reconstruction can be re-elevated in many cases, making them ideal for moder-

ate sized defects in this region [1, 12]. Recent studies have demonstrated that the patient's anticoagulation status does not need to be modified for local flaps and skin grafts in the head and neck region. However, local flaps are limited in size. Local flaps may result in "alphabet-type" scarring of the face which may cause pin-cushioning and interfere with future flap readvancement.

4.5 Regional and Free Flap Reconstruction

Extensive or complex facial defects may not be adequately reconstructed with skin graft or local flaps. Large composite flaps of tissue may be transplanted to the head and neck region as either pedicle flaps or free flaps. Pedicled flaps are transferred without interruption of their intrinsic blood supply. Free flaps involve isolation of the flap of tissue on its vascular pedicle, which is then divided and anastomosed to recipient vessels in the head and neck area.

4.6 Pedicle Flaps

There are many options for pedicle flaps for use in head and neck reconstruction. Pedicled flaps tend to take less operative time and require decreased hospital stays with overall decreased hospital costs compared with free flaps [4]. Many of the pedicled flaps commonly used for head and neck reconstruction have low donor site morbidity with secondary defects that can be closed primarily [4]. A pedicled flap could be considered in situations where palliative debulking of an extensive malignancy could offer a short operation giving acceptable functional, cosmetic and cost-effective outcomes [13].

4.6.1 The Submental Island Pedicled Flap

The submental island pedicled flap is based on the submental branch of the facial artery and can be used to reconstruct defects of the cheek and floor of mouth. The flap has excellent colour and texture match to facial skin, and the donor site is well-concealed beneath the mandible [10]. Many variants of the original fasciocutaneous flap have now been described, including harvesting skin, muscle, submandibular gland and even bone to enable this flap to reconstruct even complex facial defects [10]. By dissecting the facial artery to its origin and utilising the communicating branch between the facial and external jugular veins, the flap can be advanced to reach up to the mid-forehead [10]. The flap may not be possible in patients who have undergone a neck dissection where the vessel is likely to have been disrupted [14].

4.6.2 The Supraclavicular Artery Island Flap

The supraclavicular artery island flap is a cutaneous flap which is based on a branch of the thyrocervical trunk. The supraclavicular artery is a branch of the transverse cervical artery and can be located in the triangle formed by the posterior border of the sternocleidomastoid, the external jugular vein and the clavicle [15]. The flap venous drainage is via the venae comitantes running with the artery, reaching the transverse cervical vein or the external jugular vein. The flap donor site is located in the supraclavicular and deltoid region. This flap can be rapidly and reliably raised requiring only Doppler confirmation of vessel location. The SCAIF is thin, pliable and hairless. The arc of rotation of the flap ranges up to 180 degrees. It is capable of reconstructing defects on the face and neck, with good colour and texture match [14, 15]. The flap can be tunnelled under cervical skin to reconstruct a defect or rotated as a distant flap, with division of the pedicle at 3 weeks.

4.6.3 The Pectoralis Major Flap

The pectoralis major flap is supplied by the thoracoacromial axis [16]. The pectoralis major myocutaneous flap (PMMC) is straightforward to raise, versatile and in close proximity to the head and neck region and provides large quantities of well-vascularised tissue for use in reconstruction [16] and can be used to reconstruct extensive defects of the neck, lower face, floor of mouth and lateral skull (including lateral temporal bone defects) [14]. The PMMC may be used in combination with free flaps in order to reconstruct larger defects, protect vital structures especially neck vessels or treat complications of wound healing problems [16]. The PMMC can also be used as a salvage flap in cases of free flap failure or as an alternative to free flaps in patients who have significant comorbidities precluding the prolonged surgery associated with microsurgical head and neck reconstruction [16]. The limitations of the pectoralis major myocutaneous flap include its limited reach, neck contracture caused by fibrosis of the proximal muscle and the frequent unsightly bulge in the base of the neck [14]. This neck bulge can be partially avoided by tunnelling the PMMC underneath the clavicle. The subclavian route also increases the rotational arc and axial extension of the flap, facilitating coverage of more superior defects. This subclavian route is not possible in all cases [16]. The blood supply to the most distal portions of the skin paddle can be unreliable, leading to wound healing problems in cases of tip necrosis. Complete flap failure is rare but has been reported [16].

Reconstructing the anatomical complexities of the nose is one of the greatest challenges for the plastic surgeon. Defect analysis traditionally classifies defects as involving

mucosal lining, cartilaginous support and skin coverage. Although local flap and skin grafts suffice for small skin defects, the multistage pedicled paramedian forehead flap has long been the workhorse flap used in nasal reconstruction. Its use in nasal reconstruction dates back almost 2500 years where it was first described in India [17]. The forehead flap brings a large amount of well-vascularised tissue to the defect with ideal colour match and minimal donor site morbidity [6]. It can be used to reconstruct individual aesthetic subunits or for total nasal coverage. For composite defects with intact nasal lining, forehead flaps can be used to cover cartilage grafts used to provide structural support. Even full-thickness defects of the alar region can be reconstructed using a multistage folded forehead flap with cartilage grafting for support [17]. The pedicled nasolabial flap can be used in a staged manner to reconstruct the nasal tip, alar or columellar subunits in appropriately selected patients [18].

Posterior scalp defects can be reconstructed with pedicled trapezius myocutaneous flaps [13]. Lateral scalp/periauricular defects can be reconstructed with pedicled pectoralis major myocutaneous flaps [19] or latissimus dorsi myocutaneous flaps [13].

A unique style of pedicled flap is the keystone perforator island flap (KPIF). First described by Behan in 2003 [20], this versatile flap concept has been applied to almost every region of the body to reconstruct lesions both large and small. The KPIF is a curvilinear-shaped trapezoidal skin design consisting of two end to side V-Y flaps, the overall appearance resembling the keystone of a Roman arch [21]. KPIF can be designed and used as small local flaps for various defects of the head and neck region. The KPIF utilising the skin and soft tissue of the cervicomenal area can be planned and raised as a locoregional flap for reconstruction of extensive defects of the cheek, temple and lower lateral scalp [22]. The flap transfers submental skin of the C2/C3 dermatome, with the base of the flap based on the middle third of the posterior border of the sternocleidomastoid muscle. Defects on the face and lower scalp can be reached through a 90-degree rotation of the flap. The KPIF does not routinely require preoperative imaging, has a short learning curve and a short operative time and does not require perforator dissection.

4.7 Pedicle Flap Limitations

Pedicle flaps have a maximum arc of rotation. This limits the extent to which the pedicle flap can be translocated. Furthermore, the tip of the pedicle flap is usually the most critical in defect reconstruction whilst simultaneously having the most precarious blood supply, due to it being the

most distant part of the flap angiosome. Tip necrosis can lead to delayed wound healing, inadequate coverage of the defect as well as potentially delaying the commencement of planned adjuvant therapies. Pedicled flaps may not be appropriate for defects involving segmental bone loss, or defects require very large amounts of vascularised tissue [4].

5 Free Flaps

The ability to transfer free vascularised individual or composite tissue types from a distant donor site to a recipient bed in the head and neck has been an enormous advance in facial reconstruction. Free flap reconstruction has allowed the maxim of “replace like with like” to be taken to its zenith, as specific bone and soft tissue composites can be transplanted from a donor site to the facial area in a single procedure. Bony stability can be provided at the same time as soft tissue coverage. Free flap reconstruction has a success rate of around 95% in high volume institutions [14]. Free flaps can be performed in patients with a history of previous chemoradiation or surgery, even previous free flap surgery, although the complication rate may be slightly increased in these cases [10].

Free flaps are especially indicated for large complex defects where extensive skin, soft tissue and bony loss have occurred [1]. Defect analysis is important to identify the key structures that require reconstruction. For example, a full-thickness defect involving the skin, mandible and oral mucosa will require a flap which is capable of reconstructing both the cutaneous and mucosal surfaces, as well as re-establishing bony stability and, perhaps, offering the potential for future dental rehabilitation. Such defects would be difficult to reconstruct with local flaps; however a single free flap, such as a fibular osteocutaneous flap with two skin paddles, would provide a solution.

For extreme facial cancer defects, the patient has commonly undergone a neck dissection, facilitating recipient vessel harvest for microsurgical transfer. These patients frequently undergo adjuvant radiotherapy. Robust flap coverage with timely wound healing that will not delay the commencement of adjuvant chemotherapy or radiotherapy is important. Options for composite defects involving bone and facial skin include the deep circumflex iliac artery flap, fibular osteoseptocutaneous flap, radial forearm free flap with bone and scapula osteocutaneous flaps [14].

Microsurgical free flap reconstruction does require specific resources—appropriately trained specialised surgical staff, costly instrumentation and rigorous postoperative monitoring—which may not be available at all centres [15, 16]. Flap elevation and training in microsurgical techniques are now routine for all plastic surgery trainees.

Careful examination of potential free flap donor sites prior to surgical resection is important. Angiographic evaluation of potential flap donor sites is commonly undertaken to facilitate flap harvest and identify anatomical variations which may cause devastating donor site complications if not appreciated preoperatively. Similarly, CT angiography may be used to identify atherosclerotic disease in potential flap recipient vessels and thereby guide surgical decision-making [5]. Free flaps require close monitoring in the early postoperative period for signs of vascular thrombosis, which usually occurs within 3 days of surgery. Flap monitoring is usually clinical—colour, temperature, capillary return and Doppler monitoring being the most common measures [3].

Many different free flap donor sites have been used for facial reconstruction, the most common being the radial forearm, anterolateral thigh, lateral arm and scapula [3]. These flaps provide relatively large areas of skin and soft tissue, good calibre flap vessels for microsurgical anastomosis and straightforward flap harvest with acceptable donor site morbidity. These flaps from the limbs can be raised concurrently with tumour extirpation, decreasing total operative time. The groin flap has fallen out of favour as a free flap donor site for head and neck reconstruction due its bulk, donor site wound healing problems, lymphorrhoea and the risk of transferring pubic hair to the face [5]. These problems are largely eliminated with the increased use of perforator flaps, such as the superficial circumflex iliac artery flap (SCIA), which is harvested from the same region of the body.

The development of perforator flaps has revolutionised free flap reconstruction. Thin pliable flaps can be planned and raised with minimal donor site morbidity. Using advanced microsurgical techniques, the flap vessels can be harvested at a more peripheral level than the main vessel, preserving blood flow to tissues distal to the donor area. Further, not using the main vessel may be advantageous in avoiding atherosclerotic disease which affects perforators less [5]. Although some perforator flaps have short vascular pedicles, advanced microsurgical techniques can be employed so that the perforator free flap is itself anastomosed to a perforator at the head and neck donor site. This perforator to perforator technique minimises dissection and disruption at both the donor and recipient sites.

Thinning of free flaps can be performed primarily with some flap types, by raising the flap with minimal subcutaneous tissue at either a fascial or suprafascial level [2, 5]. These thin flaps are usually perforator flaps, such as the anterolateral thigh flap (ALT) or superficial circumflex iliac artery flap (SCIA). Thin flaps have the advantages of decreased bulk and increased pliability, whilst still offering robust soft tissue which is more resistant to the trophic effects of any future radiotherapy than a skin graft [5]. Defatting of flaps can be performed at the time of flap elevation, but there is a risk of damaging flap vascularity [5, 23]. Secondary debulk-

ing is most commonly performed with either liposuction or direct surgical excision of subcutaneous fat [5].

The fibula osteocutaneous flap is the one most commonly used for composite mandibular defects. In addition to providing good bone stock for future dental rehabilitation, the highly reliable skin paddle can be used for cutaneous reconstruction, whilst the flexor hallucis longus muscle which accompanies the flap can be used to fill soft tissue defects following neck dissection [14]. For skin paddles less than 6 cm in width, the donor site can be closed primarily, whereas larger skin paddles require split skin graft resurfacing. It is recommended that 6 cm of fibular be preserved at the lateral malleolus to prevent ankle instability.

The salvage of free flap failure is controversial. Some surgeons are of the opinion that if a free flap was the ideal reconstruction for a defect, a second free flap should be undertaken if the first one fails. Others see pedicled flaps as an ideal “salvage” in a situation where a free flap has failed, precluding the need for a second major microsurgical undertaking with oedematous and friable recipient vessels [13].

5.1 Free Flap Limitations

As previously discussed, microsurgical free flap reconstruction does require specialised surgical training, expensive equipment and materials in addition to intensive postoperative monitoring. Although routine in the developed world, these requirements may be lacking in developing countries.

Free flap reconstruction of facial defects may be challenging in patients who have undergone previous neck dissection surgery, resulting in a “vessel depleted neck”. A free flap cannot be performed in the absence of suitable recipient vessels. Vein grafts to more distant recipient vessels located in the proximal neck or thorax are possible, but at the increased risk of thrombotic microsurgical complications. Previous studies have also documented an increased risk of free flap failure after previous radiotherapy [2, 4].

Delayed wound healing at free flap donor sites may be a cause of patient deformity and morbidity. The radial forearm free flap often requires an unsightly donor site skin graft resurfacing [3]. Raising flaps at a suprafascial level minimises donor site morbidity, may preserve sensory nerve to supply to distal areas and improves skin graft take when required [5]. Suprafascial flap elevation may increase operating time, however.

There are disadvantages of facial reconstruction with free flaps from remote sites. Free flap skin often has a different colour and texture to delicate facial skin [11]. This is because the most common donor sites for fasciocutaneous flaps are on the limbs. Only skin tissue from sites superior to the clavicle has similar colour and texture properties to facial skin [11]. Revisional procedures to reduce this mismatch have been described, including de-epithelialisation of the free flap

and resurfacing of the flap with skin grafts or cultured endothelial autograft from donor sites on the head or neck [11]. Hair-bearing flaps from the limbs will not match a beard or vellus hair of the face.

6 Comparison of Pedicle and Free Flap Reconstruction in Facial Reconstructive Surgery

Reconstructing large facial defects can be challenging, and the reconstructive surgeon should be familiar and proficient at both pedicle and free flap options. Flap selection and design should be tailored to the defect and the patient. For a given defect, pedicle and free flaps may be alternatives, or one may be preferable with the other kept as a salvage backup should the initial selection fail. Although there are many situations where a free flap only could be used, or where either a free or pedicled flap would be equally useful, there are relatively few cases where a pedicled flap would be the only option. Such cases would include the vessel depleted neck, where no recipient vessels existed for free tissue transfer or in a patient not fit for a prolonged anaesthetic that usually accompanies free flap reconstruction.

There are a number of circumstances where pedicled and microvascular flaps compete for the same indications. Lateral temporal bone defects, for example, may be effectively and equivalently reconstructed with either a free fasciocutaneous free flap, such as an ALT, or else a pedicled pectoralis major myocutaneous flap [13]. Reliability of both free flap and PMMC flaps for head and neck reconstruction is over 95% in many series [24, 25]. Donor site morbidity for many workhorse pedicled and free flaps is comparable [13], although the newer freestyle perforator flaps offer distinct advantages by generally leaving the deep fascia intact [3]. The radial forearm free flap donor site, in particular, has been associated with long-term sensory and functional deficits [26].

Even though we are in an era of increasing free flap innovation and utilisation, pedicled flaps still afford valid and safe options for facial reconstruction, with good functional and aesthetic outcomes [13]. Some studies have suggested improved wound healing with pedicled flaps over free flaps in patients with comorbidities, but this remains controversial [4]. Pedicled flaps are often as effective as free flaps in reconstructing complex defects of the head and neck [13]. Previous studies comparing free flaps with pedicled flaps for head and neck reconstruction have reported comparable outcomes in terms of function, flap necrosis, complications, complications or overall survival. Pedicled flaps may be preferable in patients who are elderly, have multiple comorbidities where prolonged surgery would be contraindicated and have had previous surgery or recurrent disease [4, 15].

Free flap reconstructions generally involve longer operating times than pedicled flaps, require more expensive specialised equipment and may involve preoperative imaging and postoperative monitoring resulting in a cost differential between the two. For this reason, pedicled flap reconstruction is more common in developing countries [13].

Free flaps are more useful than pedicled flaps in the reconstruction of major bony defects. Bone free flap donor sites include the fibula, the scapula and iliac crest. All these osseous flaps can optionally contain muscle, skin and subcutaneous fat. Pedicled local or regional flaps (e.g. pedicled calvarial flaps) cannot offer the same amount and quality of bone. Also, free flaps are the only options for head and neck defects which are too distant for a pedicled flap to reach, for example, large defects on the vertex of the scalp [13]. Free flaps are also especially useful for defects requiring thin pliable soft tissue. Finally, the pedicles of free flaps tend to be smaller than those of pedicled flaps, resulting in easier passage of the pedicle from the site of microanastomosis to the defect and limiting distortion of anatomical structures surrounding the defect [13].

Pedicled flaps have no place in lip reconstruction, where wedge closure or local flap options, such as the Abbe, V-Y and modified Webster-Bernard flaps, are frequently sufficient. Free flap reconstruction may be required for total upper or lower lip reconstruction. Free flap reconstruction of the lip results in an atonic, static, insensate lip with a high incidence of oral incompetence [27].

Total nasal reconstruction represents a significant challenge to the reconstructive surgeon, usually requiring both pedicle and free flaps. Excellent results can be obtained with multistage procedures. Initially, a fasciocutaneous free flap, most commonly a radial forearm free flap, can be used for lining and soft tissue. This is later shaped, with costal cartilage used to provide structural support and a pedicled forehead flap used for cover [28]. The pedicled forehead flap is much better at matching facial skin colour and texture than free flaps from distant sites. Total pre-laminated microvascular forearm flaps (the “nose of the forearm” technique of Pribaz et al.) using cartilage and skin grafts, which are later transferred to the nose, have been described [29]. However, problems exist with skin colour and texture match, in addition to issues with soft tissue contracture [28].

Both pedicle and free composite flaps, which may contain skin, fat, muscle and bone, tend to have more bulk than the surrounding facial tissues, causing contour mismatch and distortion of surrounding structures [11]. Bulky flaps in head and neck reconstruction may also have functional effects on airway patency, speech and swallowing [5]. Bulky flaps used in facial reconstruction, whether pedicle or free, may cause secondary ectropion due to the weight of the flap on the thin skin of the lower eyelid or may compromise oral competence in a similar fashion due to the weight of the flap distorting

the lips. Adequate suspension of large flaps is essential to prevent secondary distortion due to flap ptosis.

7 Conclusion

The various options available to the reconstructive plastic surgeon when faced with the challenge of restoring form and function to the face (head and neck) after curative or palliative

pedicled or free flaps. Surgical experience, patient factors, hospital resources and anatomical variants must all be considered in the clinical mix before reaching a final decision about which flap for which patient. This is where the concept of the team approach and open discussion between different specialists making up a multidisciplinary clinical team can help define the best solution for the particular patient and cancer problem. A lifeboat salvage plan should also be kept in mind for unexpected events and complications. Clear communication and connectedness with the patient and their loved ones will facilitate the difficult discussions which inevitably must be had. “Never let routine method become your master” is the significant principle enunciated by Sir Harold Gillies so many generations of plastic surgeons ago.

What could I do, what do I want to do, what should I do?... are questions that help guide the surgeon through the various choices and options.

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The Novel Expanded Forehead Flap

Jincai Fan, Tiran Zhang, and Zhiguo Su

Core Messages

- A forehead flap is designed according to the size, shape and location of the lesion.
- Diminishing the donor site morbidity.
- An axial flap is highly reliable.
- The concept of the facial aesthetic unit is highlighted.
- The relaxed skin tension lines are respected.

1 Introduction

Facial tumours whether benign or malignant usually leave a wide and deep defect after excision which may require local flap repair. The flap should maintain function and have optimal aesthetic quality. Historically, this began with the Indian flap (forehead flap) in approximately 600 BC, as an early application of plastic surgery [1, 2]. In the fifteenth century, the Branca family and Gaspare Tagliacozzi developed the upper arm flap, well known as the Italian flap, to form a nose [1, 2]. Over time, the many techniques of facial reconstruction evolved from the above two techniques, leading to many modifications. These methods of facial reconstruction required multiple stages. In the 1960s–1970s, with the progression of the microvascular technique, a free flap could be transferred to a distant defect in a one-stage operation by anastomosing the flap vessels to recipient vessels. Microsurgical techniques thus provided a one-stage reconstructive option for complex facial reconstruction. However, each technique has certain drawbacks. Many free flap options available do not achieve the aesthetic quality of the planned reconstruction because of colour mismatch and contour imperfections. Local facial flaps or the forehead flap (with or without a tissue expander) provides an excel-

lent option with reduced morbidity. As usual, the forehead flap becomes an optimal candidate. However, the traditional design of the forehead flap is based mainly on the supra-trochlear vessels from the midline or paramedian region of the forehead [1, 2]. The remaining donor scar is still obvious, even with the aid of a tissue expander [3–6]. Instead, a new technique of the forehead flap has been developed in our unit, especially with the aid of tissue expansion. The flap is designed from the frontal hairline, based on the lateral pedicle including the frontal branch of the superficial temporal artery [7–13]. With this technique, the donor site scar can be kept to a minimum.

A variety of forehead flaps have been designed and applied in this way for reconstruction post cancer excision.

2 Basic Surgical Anatomy

When designing a forehead flap, it is important to be familiar with the anatomy of the region. The blood supply of the forehead is excellent and allows the development of a variety of axial pattern flaps. There are three pairs of arteries for the main blood supply: the superficial temporal arteries with their frontal branches, which are the important vessels for the forehead surgery; the supratrochlear arteries; and the supraorbital arteries. The medial forehead is mainly supplied by the supratrochlear and supraorbital branches from

mainly nourished by the frontal branch of the superficial temporal artery from the external carotid artery. The frontal branch of the superficial temporal artery usually divides from the main stem at a point between 2 and 4 cm above the zygomatic arch. It runs tortuously upwards and forwards supplying all the layers of the forehead region. Between these three pairs of arteries, there is an extensive network of vascular anastomoses. This is the reason why forehead flaps survive so well and can be designed as axial pattern flaps without delayed procedures.

The veins of the forehead usually follow the arteries. However, there are many anatomical variations for venous

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return in this region, especially from the frontal branch of the superficial temporal veins. These changes in venous return or outflow are the reason venous outflow obstruction is the most commonly seen complication of the superficial temporal vascular pedicle flap. In fact, there is a triangular gap in which the frontal branch of the superficial temporal artery misses the concomitant veins. Moreover, the main drainage vein is usually located in the superficial temporal fascia, but there is only a small concomitant vein attached to it in this region, which is not sufficient for venous drainage alone (Fig. 1).

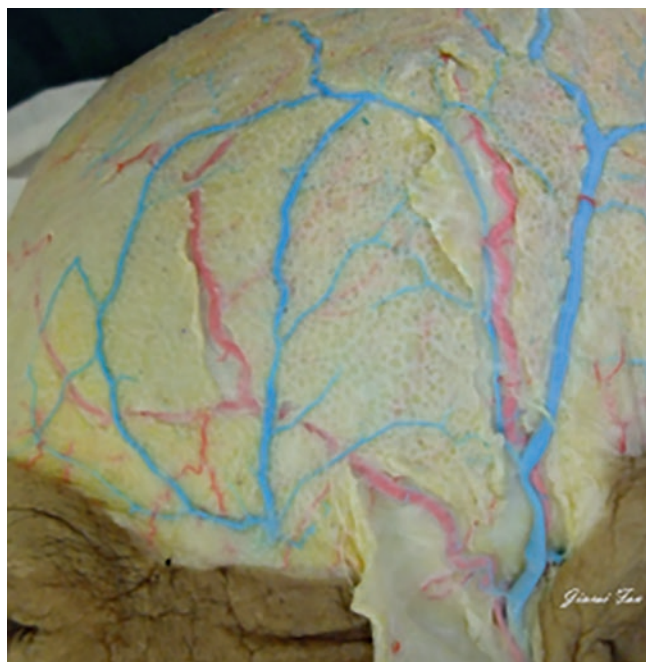


Fig. 1 The venous drainage pattern of the forehead region

The sensory innervation of the forehead is provided by the paired supraorbital and supratrochlear nerves which are part of the ophthalmic division (V1) of the trigeminal nerve. The frontal muscle is innervated by the paired temporal branches of the facial nerves which are usually situated over 1–2 cm lower than the accompanying vessels. This is very important when transferring an axial flap from the forehead.

3 Indications and Technique Selection

Basically, the technique selected is usually influenced by the characteristics of the lesion (benign or malignant), the defect size, the potential donor morbidity, the complexity of the surgery and the expectations for the aesthetic reconstruction. Generally, a local small lesion can be repaired by direct closure or by using a local flap with the donor site closed directly [1]. For a large lesion of the face, a large forehead flap, or even a total-forehead flap, can be used to repair the defect, with the donor site repaired using a skin graft. Alternatively, a tissue-expanded forehead flap is generally a better option, since the donor site can be closed directly [14–17].

4 Techniques and Management

The techniques of the forehead flap are able to be performed either as a local flap, a loco-regional flap, an axial flap or even a free flap. It is very important that the associated vascular supply should be evaluated pre-operatively.

4.1 Advancement Forehead Flap

4.1.1 Serial Excision of a Congenital Forehead Naevus (Fig. 2)

This young boy presented with a congenital naevus of the forehead close to his right eyebrow (Fig. 2). A horizontal serial excision was designed, parallel to the eyebrow. Subcutaneous undermining was performed cephalad to and double the size of the lesion after the excision of the naevus. Several anchor sutures were placed to fix the overlying flap down to the periosteum, while the flap was advanced caudally. The wound was then closed directly after the naevus

was partially excised. More than 6 months later, the remaining naevus was totally excised without changing the position of the eyebrow and repeating the serial excision surgery.

4.1.2 Bilateral Advancement Flap for a Case of Carcinoma (Fig. 3)

This high school female had a carcinoma of her mid-forehead (Fig. 3). To achieve an aesthetic reconstruction, a sliding advancement random flap with bilateral pedicles was designed along the lesion cephalad into the hair-bearing scalp after the tumour was excised down to the periosteum by the surgeon. The upper incision of the flap, the same width as the defect, was incised down to the periosteum, parallel to the direction of the hair follicles. The flap was elevated by undermining deep to the frontalis muscular plane and advancing caudally, to close the wound in layers. The donor site in the scalp was closed with a skin graft. The results are quite satisfactory with the unsightly donor site hidden by her long hair.



Fig. 2 (a–c) Serial excision of a congenital forehead naevus



Fig. 3 (a–c) Carcinoma of the mid-forehead, excised and the defect repaired with a bilateral sliding advancement local flap

4.2 Transposition Forehead Flap

4.2.1 Midline Forehead Flap with an Inter-eyebrow Pedicle (Fig. 4)

An elderly man presented with a carcinoma near his right inner canthus. The wide excision defect involved loss of the medial 2/3 of the upper eyelid after the tumour was widely excised. A midline forehead flap was elevated with an inter-eyebrow pedicle, including the paired bundles of supratrochlear vessels. The flap was elevated under the frontalis muscular layer and transposed into the defect of the upper eyelid (after the conjunctiva was repaired with a cross-conjunctival flap from the lower eyelid) in a sliding advancement fashion. The donor site in the forehead was closed directly by advancing the skin from both sides of the wound into the midline. Eight months later, the patient returned for the second stage operation, to divide his

closed eyelids. It can be seen that the flap donor site has healed well.

4.2.2 Staged Interpolated Transverse Forehead Flap (Fig. 5)

This elderly man had a carcinoma in the area of the nasal root (Fig. 5). The excised area included the base of nose the right inner canthus and the medial parts of the right upper and lower eyelids. A transverse forehead flap was designed along the right eyebrow and based on the contralateral supra-trochlear vessels. The flap was then elevated under the frontalis muscular layer and transposed into the defect after the involved palpebral fissure was temporarily closed with a tarsorrhaphy. The donor site in the forehead was closed with a skin graft. Three weeks later, the inner palpebral fissure was re-opened, and the extra tissue of the pedicle trimmed and partially returned to the donor site.

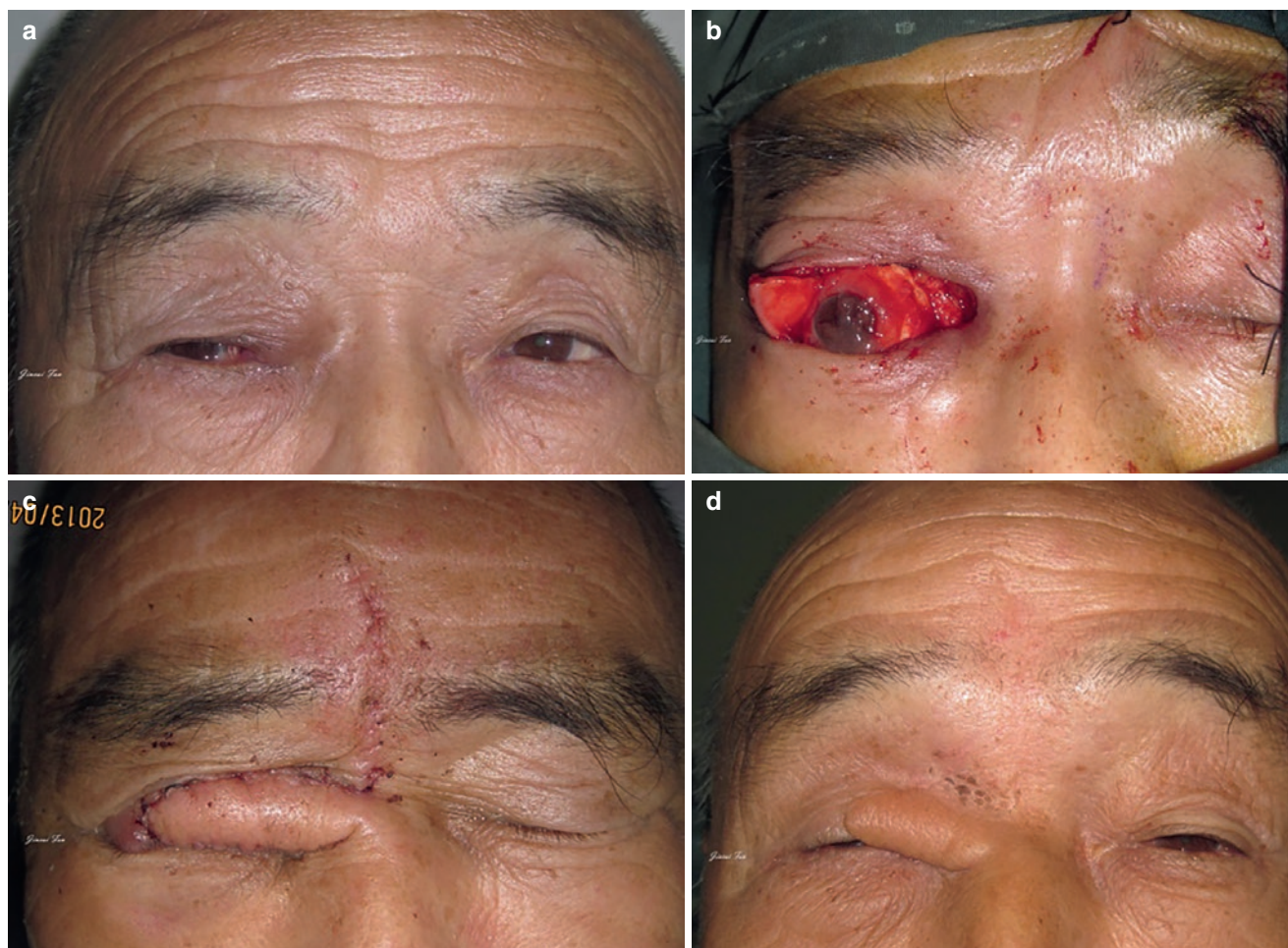


Fig. 4 (a–d) Carcinoma near the inner canthus, widely excised to leave a defect 2/3 of the right upper eyelid



Fig. 5 (a–e) Carcinoma of the nasal root, widely excised and the defect repaired with a staged transverse interpolated local forehead flap

4.3 Axial Forehead Flap

4.3.1 Island Forehead Flap to Repair an Upper Eyelid Defect (Fig. 6)

This elderly man presented with a carcinoma of the left upper eyelid. An island forehead flap was designed along the left frontal hairline (Fig. 6), based on the ipsilateral pedicle including the frontal branch of the superficial temporal vessels. The flap was elevated along the feeding vascular pedicle, attached only to the superficial temporal fascia and then transferred into the defect by passing it through a subcutaneous tunnel. The donor site in the forehead was closed with a skin graft. The patient will have secondary revision surgery to improve the appearance of the flap.

4.3.2 Over-extended Forehead Flap for Nasal and Hemi-mid-facial Reconstruction (Fig. 7)

This woman suffered from recurrence of a basal carcinoma in her nose and left cheek extending to the lower eyelid after the cancer had been surgically treated in another local hospital. When the recurrent basal cell carcinoma was completely excised, an island forehead flap was designed using the whole of the forehead, based on the ipsilateral pedicle including the frontal branch of the superficial temporal vessels. Thereafter, the flap was elevated and transferred into the defect. The donor site was completely covered with a skin graft. Over 4 weeks later, the pedicle was divided, and the base of the flap returned to the temporal region.

Meanwhile the lower eyelid was suspended between the inner canthus and the outer canthus with a fascial strip harvested from the deep temporal fascia, by passing it through a subcutaneous tunnel. At long-term follow-up around 4 years later, no recurrence of the carcinoma had occurred.



Fig. 6 (a–f) Carcinoma of the left upper eyelid widely excised and the defect repaired with an island forehead flap based on the superficial temporal fascia and tunneled into the defect. Early result before final revision



Fig. 7 (a–h) A recurrent BCC in the nose and left cheek of a woman, widely excised and the defect repaired with an island forehead local flap, based laterally on the superficial temporal vessels. Later, a fascial strip graft was used to re-suspend the left lower eyelid



Fig. 7 (continued)

4.4 Expanded Forehead Flap

An expanded forehead flap for hemi-forehead reconstruction (Fig. 8). This young man complained of the unsightly skin graft on his left hemi-forehead following surgical excision of a large congenital naevus in childhood (Fig. 8). A round tissue expander, 200 mL in volume, was implanted in the subfrontalis area of the right forehead and serially inflated, 1–2 times per week, with normal saline to reach 250 mL in volume. A rotation-advancement forehead flap was designed along the hairline. It was then raised and transferred to replace the defect remaining after excision of the unsightly skin graft. Later further surgery was needed to revise the dog-ear flap and to improve the hairline symmetry. The aesthetic reconstruction achieved at follow-up, 3 years post-procedure, is shown.

An expanded forehead flap for peri-orbital reconstruction (Fig. 9). This schoolboy had an unsightly skin graft in the left peri-orbital region after his congenital naevus was surgically treated in his childhood. A 200 mL rectangular tissue expander was implanted into a subfrontalis pocket of the forehead and serially inflated, 1–2 times per week, with normal saline to reach 300 mL in volume. A rotation-advancement forehead

flap was designed along the hairline. The old skin graft was excised and the palpebral fissure was temporarily closed with a tarsorrhaphy. After the expander was removed the expanded flap was raised and the pre-auricular defect was repaired with the assistance of another tissue expander. Four weeks later, the palpebral fissure was re-opened to restore the normal left eyelid anatomy.

An expanded midline forehead flap for reconstruction of right cheek (Fig. 10). This school boy had been treated unsuccessfully with irradiation for a congenital hemangioma of his right face and orbital region. A 200 mL rectangular tissue expander was implanted into the subfrontalis pocket of the medial forehead and serially inflated, 1–2 times per week, with normal saline to 250 mL in volume. A traditional forehead flap (Indian paramedian) was vertically designed in the middle of the forehead, based on the pedicle using the supratrochlear vessels. After the expander was removed the flap was then elevated, transferred and the facial lesion excised. The residual defect was repaired with assistance of another tissue expander in the pre-auricular area. Three weeks later, the pedicle was divided during the second stage. The procedure produced an excellent long-term aesthetic reconstruction.

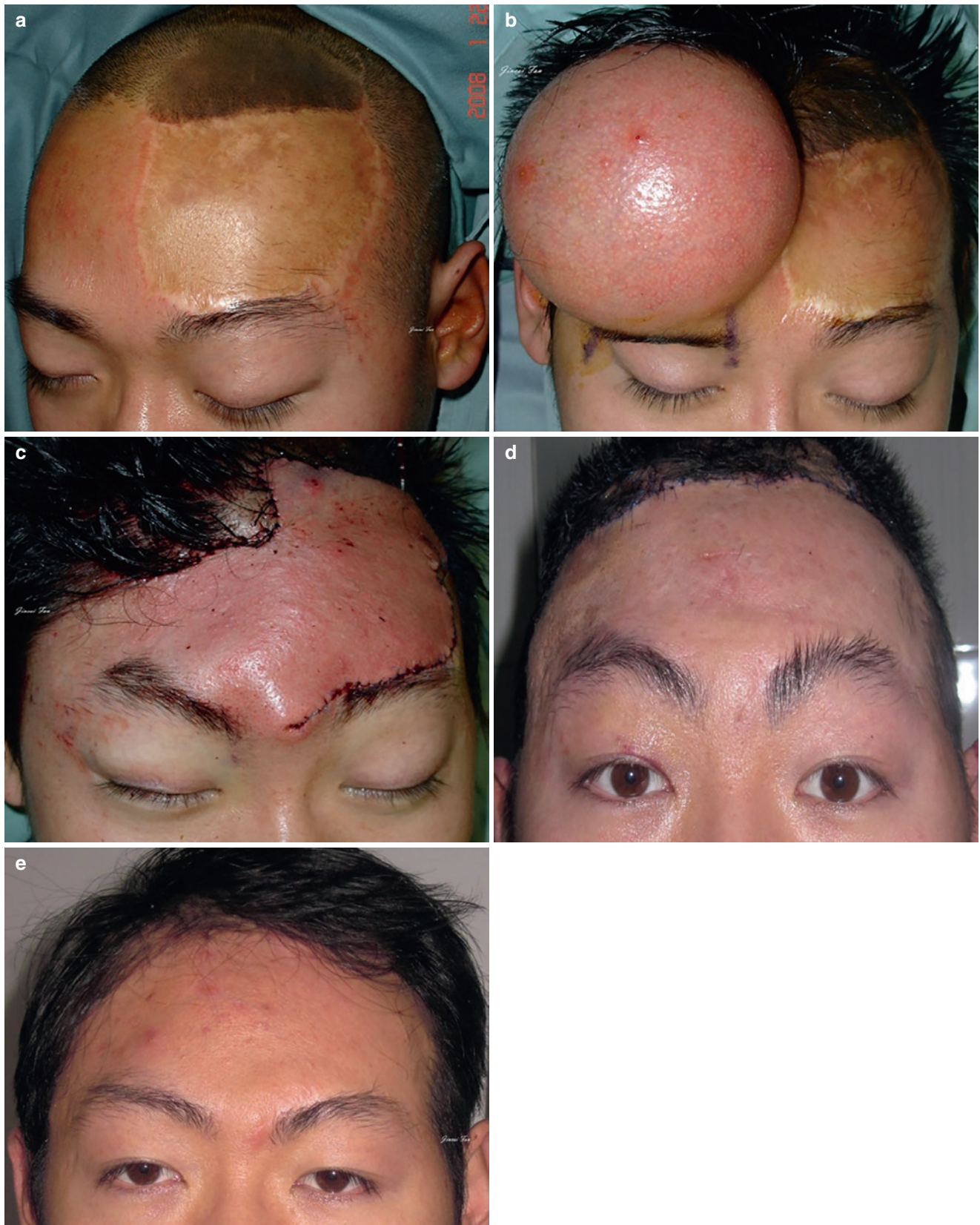


Fig. 8 (a–e) Revision of an unsightly skin graft in the left forehead of a young man, post congenital naevus excision, with an expanded forehead flap



Fig. 9 (a–f) An unsightly left periorbital graft in a schoolboy, revised with an expanded forehead flap and left lateral temporal flap



Fig. 10 (a–e) Radiation attempted for congenital naevus right cheek and periorbital region unsuccessfully and now the old scars have been revised with an expanded forehead flap



Fig. 11 (a–e) Adolescent patient with radiation damage following haemangioma left nose and cheek. Reconstruction with expanded islanded forehead flap

5 Contraindications

The expanded forehead flap illustrated in the cases above is an excellent technique for benign lesions or established deformities where urgent reconstruction is not the goal. For the patients with a malignant lesion, the time limitations for tissue expansion may contraindicate this management approach.

6 Innovations

6.1 New Concept of Expanded Forehead Flap

The traditional design of the forehead flap, pioneered by the ancient Indians in 600 BC, is mainly used in nasal reconstruction and based on the supratrochlear vessels from the midline or paramedian region of the forehead. Donor morbidity is a potential stigma, even when tissue expansion of the forehead flap is used. Instead, a new technique of the forehead flap has been developed in our unit, with the aid of tissue expansion. The flap is designed from the region of the frontal hairline, based on the lateral pedicle including the frontal branch of the superficial temporal artery. The donor morbidity of the forehead scar can be significantly reduced in the frontal hairline, avoiding an unsightly scar in the forehead. However, there are many variations in venous drainage for the temporal region. The main drainage vein is usually located in the superficial temporal fascia, but there is only a small concomitant vein attached to it in this region. The flap venous drainage after the surgery often challenges plastic surgeons, resulting in venous stasis. Based on the understanding of the local anat-

an island flap [8], a unilateral-pedicled flap, a bilateral-pedicled flap [7, 10, 13], a super-charged flap [11, 12] and a free flap [9], depending on the context of the pedicle blood supply.

An island flap for nasal reconstruction (Fig. 11). This adolescent girl presented with scarring of her left lower nasal and nasolabial regions after radiotherapy for a haemangioma. A 200 mL tissue expander was placed into a subfrontalis pocket of the forehead and serially inflated with normal saline for 7 weeks. A 4.5 cm × 9 cm expanded forehead flap was designed from the hairline region in a transverse fashion, based on the lateral pedicle. After the

irradiated scar was excised, the island flap was elevated and transferred to the nasal defect by passing it through a subcutaneous tunnel between the base of the flap and the defect. The forehead donor site was closed directly in the frontal hairline by using the remaining forehead tissue. The early final result is shown.

A unilateral pedicled flap for facial cheek reconstruction (Fig. 12). This young girl presented with a giant hairy naevus of her left cheek which extended into the hair-bearing scalp. A 200 mL rectangular tissue expander was placed into the subfrontalis pocket of her forehead and serially inflated, 1–2 times a week, with normal saline to reach 300 mL in volume. A unilateral forehead flap was designed transversally along the hairline to the opposite forehead, based on the unilateral pedicle including the frontal branch of the superficial temporal vascular bundle. The flap was elevated and transferred to the defect following excision of the naevus with the pedicle being rolled to a tube shape by suturing both sides of the wounds together. The forehead donor site was closed directly into the frontal hairline by using the remaining forehead tissue. Four weeks later, the pedicle was divided and inset for the non-hair-bearing area of the temporal region. The remaining defect was repaired with a scalp flap augmented with another tissue expander. A good result was achieved with long-term follow-up over 1 year.

A bilateral pedicled flap for reconstruction of the lower face and neck (Fig. 13). This young man presented with a congenital spongy haemangioma in the lower face extending from the lower lip to his neck/presternal region. This was treated initially with radiotherapy and phototherapy. A 300 mL tissue expander was placed into a subfrontalis pocket of his forehead and serially inflated with normal saline, for about 3 months. To help control bleeding during haemangioma excision, the external carotid arteries were ligated bilaterally before the resection. A bilateral expanded forehead flap was designed transversely along the hairline region. This was based on the bilateral pedicles including branches of the superficial temporal vascular pedicles, with a certain amount of hair-bearing scalp for his beard reconstruction. After the lesion was excised, the flap was elevated and transferred to the defect as a visor flap. The donor site of the frontal forehead was closed directly in the frontal hairline by using the remaining forehead tissue. The temporal wound was temporarily closed with a skin graft. Two weeks later, the pedicles were divided and returned to the temporal region to replace the temporary skin grafts. The follow-up image at 3 months shows the good result achieved.



Fig. 12 (a–d) Giant hairy naevus in a young girl excised and the defect reconstructed with an expanded total forehead and temporal scalp flaps on a unilateral pedicle



Fig. 13 (a–h) Reconstruction of the lower face of a young man with a spongy haemangioma, treated initially with radiation/phototherapy, using a bilateral pedicled expanded total forehead flap. Final result shown at 3 months



Fig. 13 (continued)

7 Complication Management

The complications resulting from the surgical application of the forehead flap include problems with flap viability, healing and the donor scars.

Pre-surgical evaluation of the flap's vascular supply is key to the success of the flap and this can be achieved with a portable laser Doppler flowmeter. The concomitant veins usually follow the arteries, however, veins draining the flap frequently have variable anatomy in the temporal region. Further examination, with CTA or MRI (venous phase), is quite helpful to facilitate the flap design. During the operation, the flap dissection should be performed with precision and accuracy to avoid vascular pedicle damage. It is important that the design of the forehead flap is slightly larger than the defect, to allow for elasticity in the tissues. Avoid excessive tension and pressure on the flap at the time of transfer and initial inset. Good haemostasis is another important factor. A suction drain should be used routinely under the flap. Close post-operative flap monitoring and early intervention if flap vascular insuffi-

ciency becomes a problem are important. The flap in crisis can be managed with the adjustment of body posture, local massage, medical leeches, vasodilators or emergency surgical exploration if pedicle thrombosis is suspected (Fig. 14).

Further, the incision of the forehead flap should be designed in the relaxed skin tension lines as much as possible, in areas with loose tissue or as far away from the central position as possible. A skin graft may be needed if the wound closure of the donor site is under high tension. Dr. Gary Burget MD taught us that small donor site forehead defects can be left to heal by secondary intention. Concerning the tissue expansion of the forehead, the frontal bone may be affected by the mechanical tissue expansion in children and cause some flattening of the contour (Fig. 15). The process of the tissue expansion should be slowed down in such paediatric patients, and an osteotomy procedure may be required later.

Pain during the serial inflation of the tissue expander may occasionally happen if the filling is too rapid [18, 19]. This is resolved by slowing down the expansion process or aspirating some volume from the expander.



Fig. 14 (a and b) Vascular insufficiency in a facial flap salvaged with early intervention



Fig. 15 Flattening of the frontal cranial contour with rapid tissue expansion in a paediatric patient

8 Controversies

The techniques for facial reconstruction, after carcinoma excision, are selected according to the size, depth and location of the defect after cancer resection. Reconstruction following resection of a malignancy has time limitations in terms of utilizing the benefits of tissue-expanded local flaps. Tissue expansion is therefore better indicated for delayed reconstruction of defects resulting from the resection of benign or malignant lesions.

If the defect is quite superficial, a full-thickness skin graft may be a suitable choice. However, the results may be unsatisfactory, mainly due to the problem of altered pigmentation in the grafts. For a small skin defect, a local flap is usually satisfactory. For moderate to large defects, the expanded forehead flap offers many design options, to achieve both aesthetic and functional reconstructions. The technique of tissue expansion of the forehead flap produces a large volume of soft tissue and helps minimize the donor site defect. Of course, when the forehead donor is unavailable, other loco-regional flaps and microsurgical free flaps could be alternatives.

9 Conclusion/Summary

The expanded forehead flap is an optimal method for facial reconstruction. Versatile design can expand its clinical application in many challenging reconstructive cases.

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Keystone Flap Concepts

Felix C. Behan, Michael F. Klaassen, and Andrew Sizeland

Core Messages

Clinical observation translates into good research.

In the reconstruction of facial defects after cancer resection, careful design of the keystone perforator island loco-regional flaps will avoid the need for microsurgical free flap transfers and deliver a superior aesthetic outcome.

The PACE acronym defines the observational clinical advantages of the keystone flap option: **p**ainless, **a**esthetic reconstruction, **c**omplication-free and **e**conomic in time and cost.

1 Introduction

The concept of the keystone flap first arose in 1973 when the senior author was a post-fellowship research fellow in London, studying the blood supply of the skin. He and co-researcher Wilson introduced the concept of the angiotome, a system of linked axial pattern flaps, and presented this to the sixth International Congress of Plastic and Reconstructive Surgery in Paris, 1975. Professor William Manchester of Middlemore, Auckland, came up to Dr. Felix Behan and

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urged him to keep going with his research but admitted he didn't have a clue what it all meant [1]. The basic concept of the keystone flap is that vessels in the skin integument follow the nerves. The flap is therefore based on random axial perforating vessels and as a neurovascular island flap is designed within the local dermatomal pattern, close to the defect. The pioneering German surgeon Dieffenbach (1792–1847) described a V-Y advancement local flap concept in 1845, which has been refined over the last 150 years of modern surgery [2]. The senior author's keystone flap mirrored

Dieffenbach's original concept with a double V-Y advancement and introduced a curvilinear design in 1995. He originally called it the Bézier flap after the French engineer and his Bézier curves, but a colleague and fellow plastic surgeon, Alan Briedal FRACS of Adelaide, convinced him to re-name it the keystone flap. This recognizes the keystone in a masonry arch or bridge, which is curved and wedge-shaped (Fig. 1).

Over the last nearly 50 years, the senior author has refined the design and applications of the keystone perforator island flap [3–18].

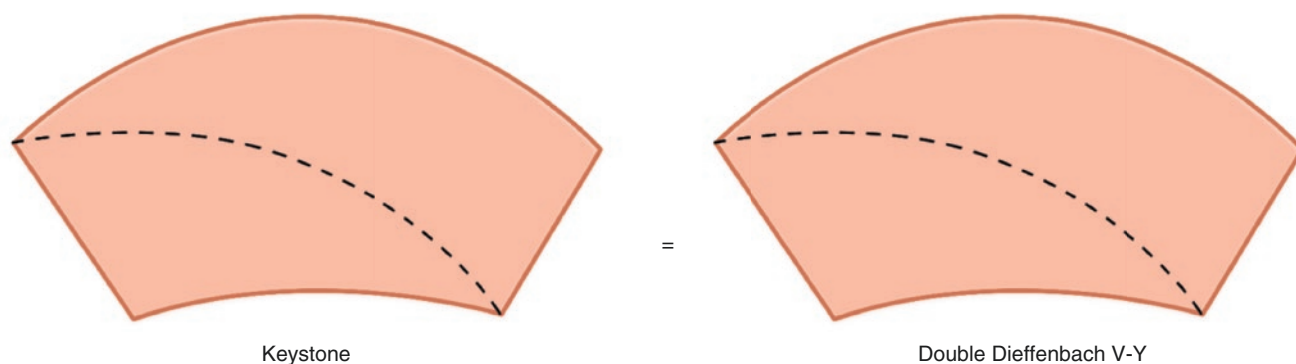


Fig. 1 The keystone flap is a double V-Y Dieffenbach flap

2 The Science Behind the Keystone Flap

William Osler (1849–1919) the influential Canadian physician said that ‘observation is the basis of scientific advancement’. The senior author’s observations of the behaviour of various islanded local flaps led him on to search for the physiological basis for how they work. This was inspired by other research published in the surgical literature on angiogenesis, the increased blood supply in tissue-expanded flaps and concepts in endothelial stress and facial nerve repair.

The challenge was how to come up with a good research question from the clinical observations. The senior author believes that the hypothesis for the question can be framed by considering the following:

1. A questioning attitude is the first step in the research process.
2. Research begins with a question which leads to the hypothesis.
3. Most quality research consists of comparisons.

the quality of the research can be improved.

5. The best questions come from the investigator’s subject of interest.
6. The key is to start small and choose an experienced mentor.

3 Clinical Signs and Observational Facts for the Keystone Flap

These can be categorised as arterial, venous and neural features.

1. The flap is a total island flap and, for the lateral face region, is composed of the skin, subcutaneous tissue, SMAS and platysma muscle. This confirms it as a myocutaneous local flap.
2. In type IV versions of the flap, undermining of 40–50% in the upper regions of the keystone flap including the skin, fat and fascia by blunt dissection is important.

3. The flap is planned with random localization, without the need for the use of a Doppler probe.
4. The red dot sign (point rouge) is a sign of hyperaemia in the island flap as the perforators vasodilate.
5. It is technically important to retain all draining venous tributaries including the external jugular vein, using blunt dissection.
6. This blunt dissection facilitates undermining and stretching with movement around the limits of the flap.
7. For undue tension in certain cases, a full-thickness graft is used to repair the secondary defect.
8. Postoperatively the pain is minimal, because the flap has temporary cutaneous denervation. This recovers in a few months.

4 Dermal Precincts

The dermatomes are the aide memoire to define random perforators. This avoids the costly investigation of angiography, which has not been applied to any of these KPIF cases. Intact nerve supply indicates intact blood supply. The common dermatomes for the lateral face reconstruction are illustrated in Fig. 2.

The clinical features of the keystone island perforator flap can be summarized in the acronym PACE.

Pain: the keystone flap reconstructions are relatively pain free, reducing the need for strong analgesia such as narcotics. There may be a feeling of tightness and loss of sensation in the flap, which recovers in 3 months.

Aesthetics: the outcomes produce aesthetically acceptable reconstructions and reflect Gillies’s principle of using ‘like for like’. This avoids the colour mismatch of many microsurgical free flap transfers such as the radial forearm free flap, which doesn’t look good for facial repair.

Complications: these are uncommon and only sometimes occur when the tension skin sutures at the key points are removed prematurely and lead to wound rupture.

Economics: Time is money and these flaps are quick to raise and advance, without complex technology, compared to microsurgical free flaps.

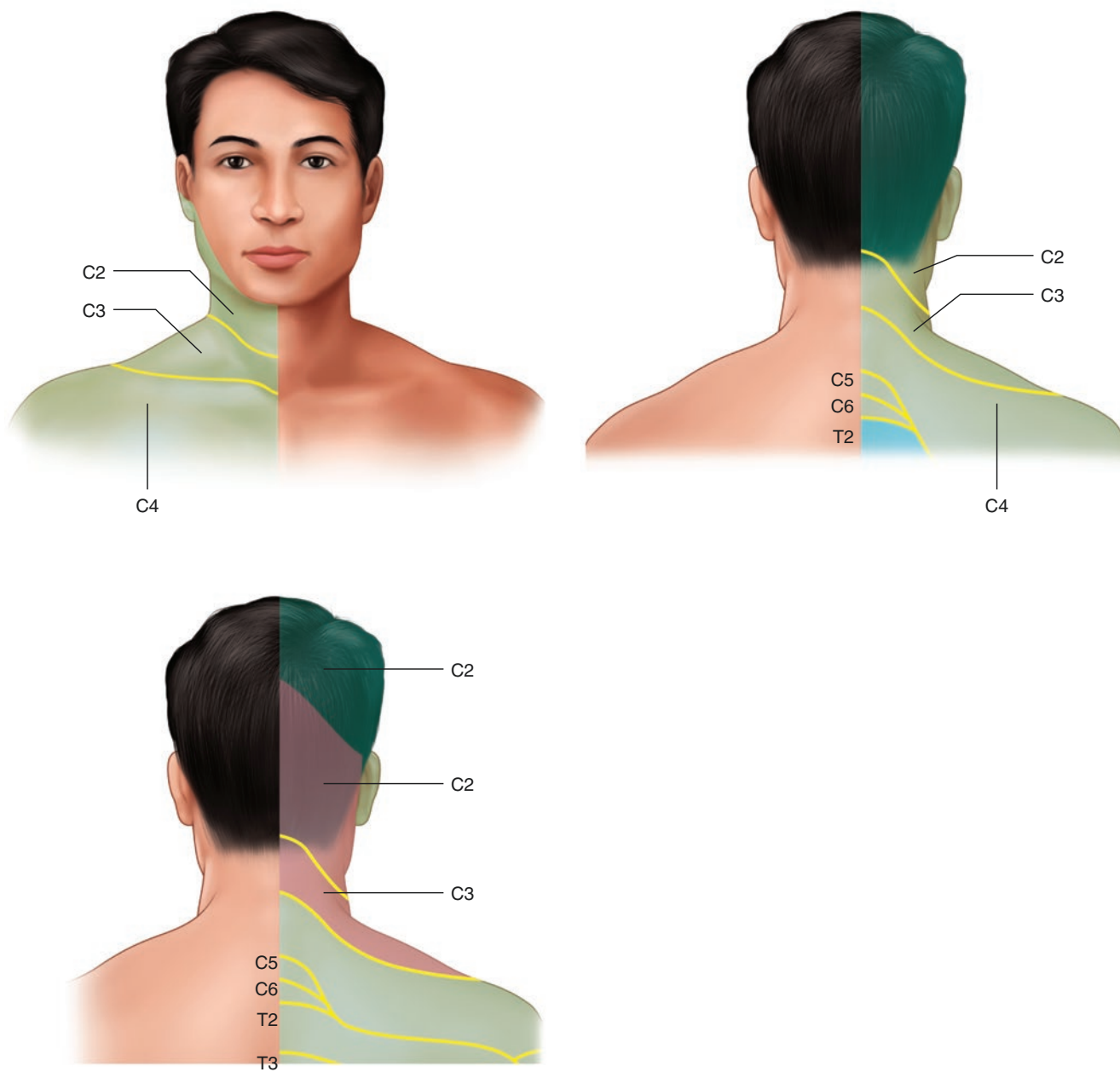


Fig. 2 The dermal precincts on which keystone flaps for the parotid/preauricular region defects are planned

5 Surgical Principles for Raising a Keystone Island Flap

1. Dermatomal alignment is the basis for location of the flap design.
2. The keystone shape surrounds one side of the defect.
3. Blunt dissection after incising the deep fascia at the limits of the flap is the key to separating the tissue planes.
4. The flap consists of skin/fat/fascia and all possible neurovascular connections, particularly superficial veins to eliminate venous stasis.
5. To facilitate rotation/advancement/transposition, the keystone flap can be undermined at the subcutaneous plane for up to 2/3 of its dimension, with the remaining 1/3 attached for random perforator perfusion.

6 Case Presentations

A series of 14 cases is illustrated to demonstrate the clinical and surgical application of the keystone island perforator loco-regional flap for patients with advanced cancers of the parotid and peri-auricular regions.

6.1 Case 1

The diagnosis in this 84-year-old male is squamous cell carcinoma of the left preauricular groove. After resection, preserving the left facial nerve, the defect was repaired with an anterior KPIF with 2/3 of the flap undermined to facilitate movement (Fig. 3). The width is a 1:1 ratio KPIF to defect size and 2/3 undermined above the facial nerve plane.

Islanding the flap creates hyper-vascularity to ensure good healing.

A pain-free postoperative phase was ensured and an aesthetic reconstruction. There were no wound complications and an economic timeframe (operating time 1 hour). Additionally, there was no flap necrosis, no recurrence at 18/12 and full facial nerve function.

Fig. 3 (a–d) An 84-year old gentleman with SCC of his left preauricular groove, widely excised preserving seventh nerve and leaving a defect measuring 4×7 cm. Repair with keystone flap of dimensions 17×4 cm and undermining $2/3$ of the flap. Initial markup and 1 year result shown



6.2 Case 2

This is a 48-year-old male with recurrent basal cell carcinoma of his right preauricular groove after radiation treatment and associated basosquamous regional node metastases (Fig. 4). After wide resection incontinuity with a right neck

dissection, the defect was repaired with an anterior cheek KIPF and an islanded neck flap to improve the blood flow.

The intra-operative appearance shows the anterior KIPF cheek flap which is 2/3 undermined but islanded throughout. The neck flap caudally is also created into an island leaving a 1/3 deep attachment.



Fig. 4 (a–d) A 48-year-old male with recurrent BCC in right preauricular groove, radiation damage, previous skin graft to right temple and neck metastases. The defect after resection and neck clearance was 6×4 cm. The anterior KIPF dimension was 15×5 cm. Immediate

result shown with additional islanded neck flap to stimulate physiological hyperaemia in the irradiated field. Note some alopecia postauricular regions due to radiation. Result at 5 months

6.3 Case 3

A 76-year-old man presented with recurrent squamous cell carcinoma in a radiation-damaged field of the right mastoid region (Fig. 5). The irradiation had been to the C2 and C3 dermatomes.

Keystone perforator island flaps are characterised by hyperaemia. This is hypothesised as a sympathectomy effect with increased blood flow to expedite healing in radiation-damaged tissue.

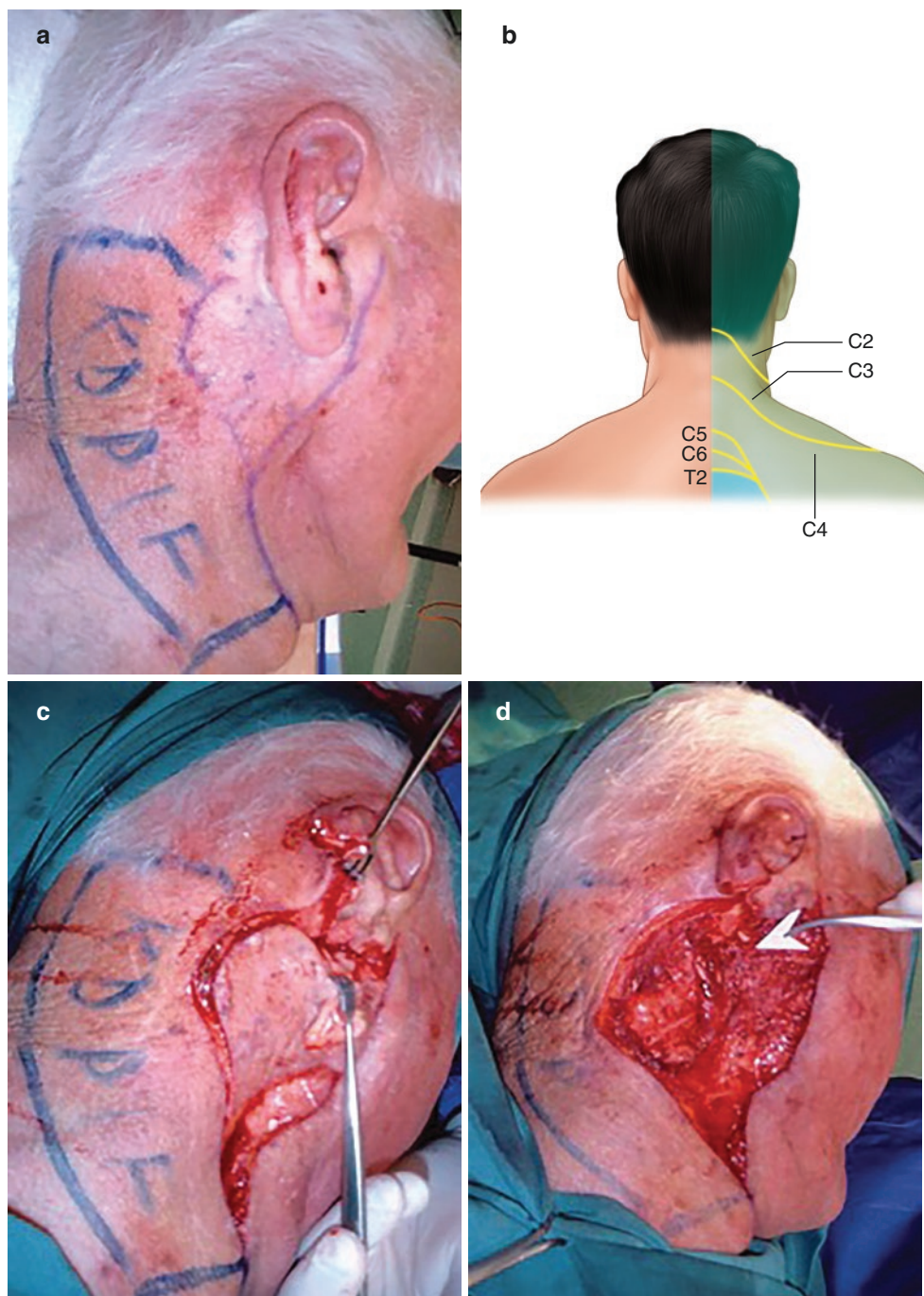
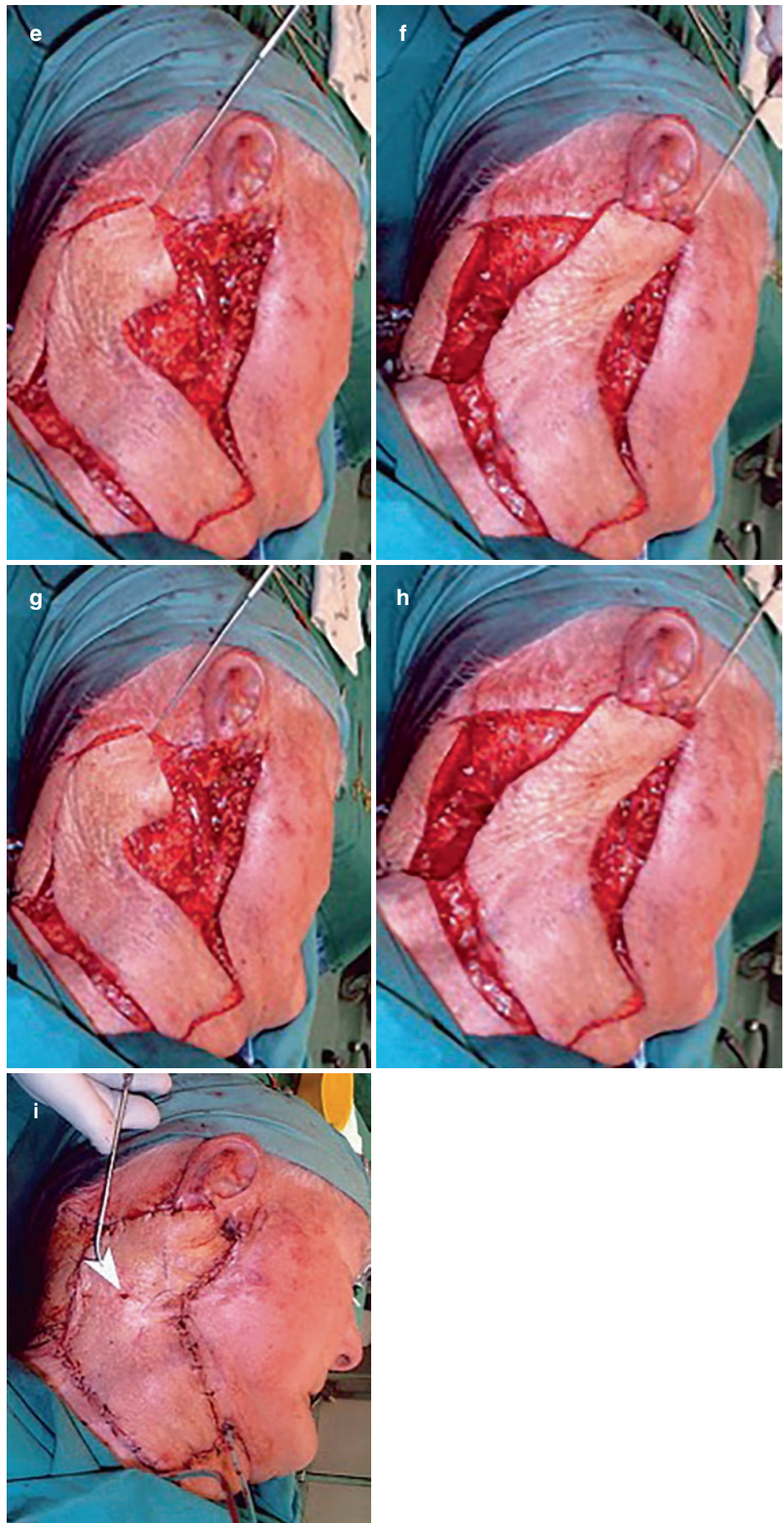


Fig. 5 (a–i) This 76-year-old male had wide excision of the recurrent SCC right mastoid region in an irradiated field, including an upper neck clearance preserving the spinal accessory nerve. The resection defect was 6×4 cm and the KPIF based on the C2 dermatome was 15×5 cm. The C2 dermatome follows the line of the right sternomastoid muscle.

The upper 2/3 of the flap are undermined. Random sternomastoid perforators in the inferior 1/3 of the flap provide the vascularity. The red dot sign is shown by the white arrow in Fig. 5i. The flap is attached to the right ear, and the external auditory canal reconstructed with the flap insertion

Fig. 5 (continued)

6.4 Case 4

This 35-year-old man presented with a morphoeic basal cell carcinoma of his right cheek, which was widely excised and the defect repaired with a keystone flap based on the C2 and C3 dermatomes (Fig. 6).

The red dot sign of hyperaemia in the keystone flap is shown (white arrow) and the white lines of tension, which

disappear eventually. At the points of maximum tension, the authors recommend interrupted locking mattress sutures followed by a continuous horizontal mattress suture for flap wound edge closure. No deep sutures are placed as this risks compression of the random perforating vessels. A Redivac drain is mandatory in such a large flap and is placed for safety.

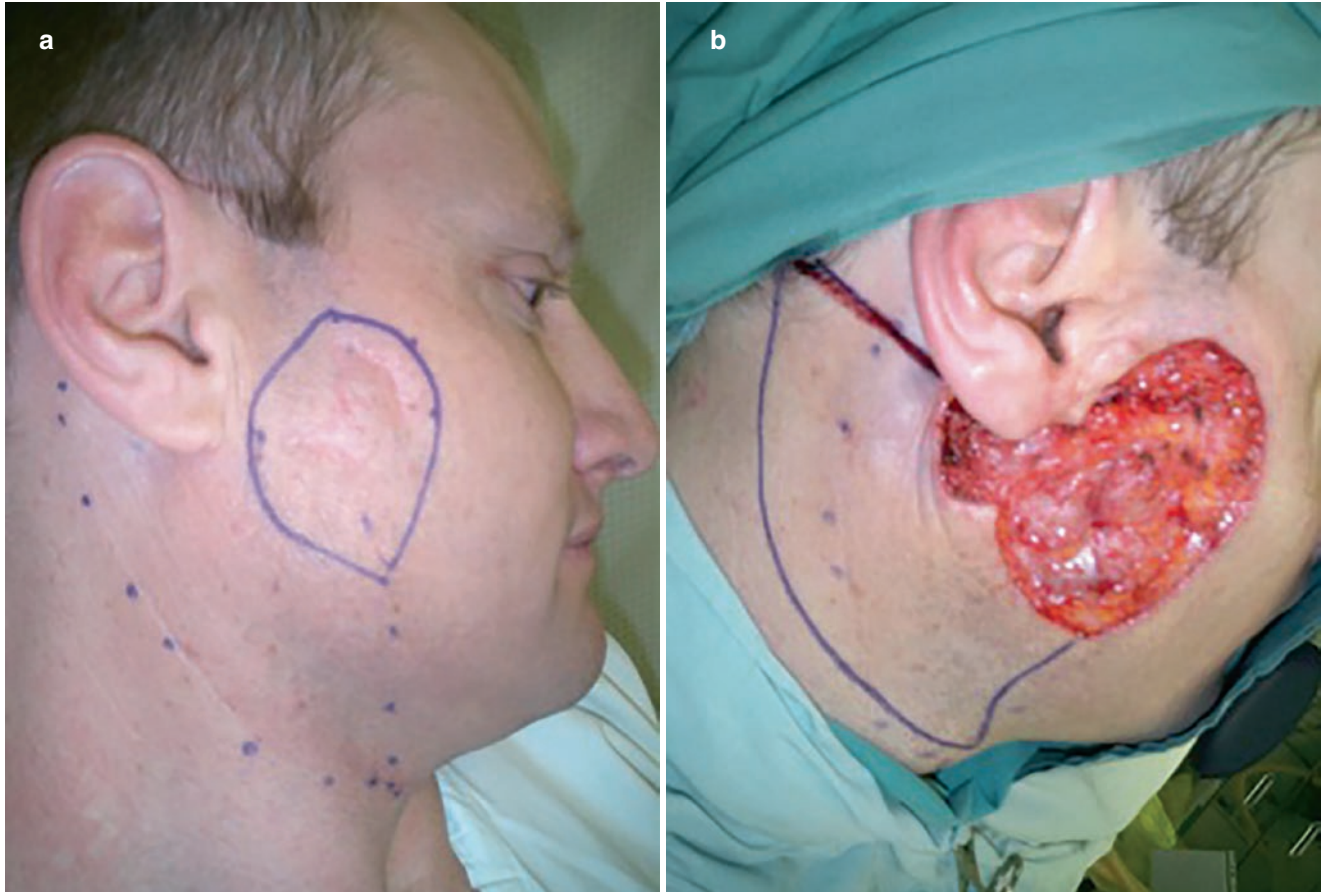


Fig. 6 (a–f) A 35-year-old male with morphoeic BCC right cheek, widely excised to leave a defect of $4.9 \times 4.5 \times 1.2$ cm. A postauricular KPIF was designed on the C2 and C3 dermatomes and measured

15×5 cm in dimension along the line of the right sternomastoid. Early post-operative result shown



Fig. 6 (continued)

6.5 Case 5

This 84-year-old man presented with a squamous cell carcinoma of his left conchal fossa. After wide excision there was

a 4 × 3 cm defect, which was reconstructed with a 15 × 5 cm KPIF based on the C2 and C3 dermatomes and sternomas-toid myocutaneous perforators (Fig. 7).



Fig. 7 (a–h) An 84-year-old man with SCC left conchal fossa widely excised and reconstructed with KPIF based on C2 and C3 dermatomes with a de-epithelialised segment (white arrow) at the posterior edge of

conchal defect. Immediate, 2 week, 4 week and 3 year results shown. No sign of recurrence. All the white arrows point to the de-epithelialised part of the keystone flap



Fig. 7 (continued)

6.6 Case 6

This 78-year-old man had an invasive squamous cell carcinoma of his left external auditory canal and into the left temporomandibular joint (Fig. 8). Radical excision included the left facial nerve, TMJ, zygomatic arch and the lateral temporal bone. A postauricular mastoid region

type IV (upper 1/3 attached, lower 2/3 undermined) KPIF was raised to reconstruct the large defect. The tight closure has a static lifting effect, which helps correct some cheek laxity due to the facial nerve sacrifice. A fat graft fills the deep part of the external auditory canal. Immediate excision of the dog-ear produced by the folding of the KPIF.



Fig. 8 (a–f) A 78-year-old man with invasive SCC left external auditory canal and parotid, requiring total parotidectomy, resection TMJ and zygomatic arch as well as lateral temporal bone resection. This resulted in a defect of 10 × 8 cm. Reconstruction with 16 × 8 cm type

IV KPIF based on the C2 and C3 dermatomes and postauricular mastoid region. Tight closure has a benefit for his left facial palsy. Result shown at 2 years after adjuvant radiation and lateral tarsorrhaphy at 1 year post original resection



Fig. 8 (continued)

6.7 Case 7

This 77-year-old man presented with a recurrent malignant melanoma in his right parotid region (Fig. 9). The wide exci-

sion was repaired with a posterior KPIF based on the C2 and C3 dermatomes and preserving the draining external jugular vein. The omega (Ω) variant was used based on the perforators of sternomastoid muscle, and the 1 week result is shown.



Fig. 9 (a–e) A 77-year-old man with recurrent malignant melanoma right parotid region, widely excised and the 5 × 5 cm defect repaired with a posteriorly oriented KPIF with Ω variant. One week result shown with good flap viability



Fig. 9 (continued)

6.8 Case 8

This 77-year-old man had recurrent squamous cell carcinoma of his left external auditory canal after failed radiotherapy (Fig. 10). Wide excision including left auriculectomy and a left neck dissection was repaired with a posterior KPIF,

type IV based on C2 and C3 and a full-thickness skin graft to the superior secondary defect.

Again, in this case, the Ω variant allows defect closure with simple skin grafting of the superior scalp secondary defect. The skin graft has been fenestrated to prevent haematoma, and there is also a Redivac under the flap repair.

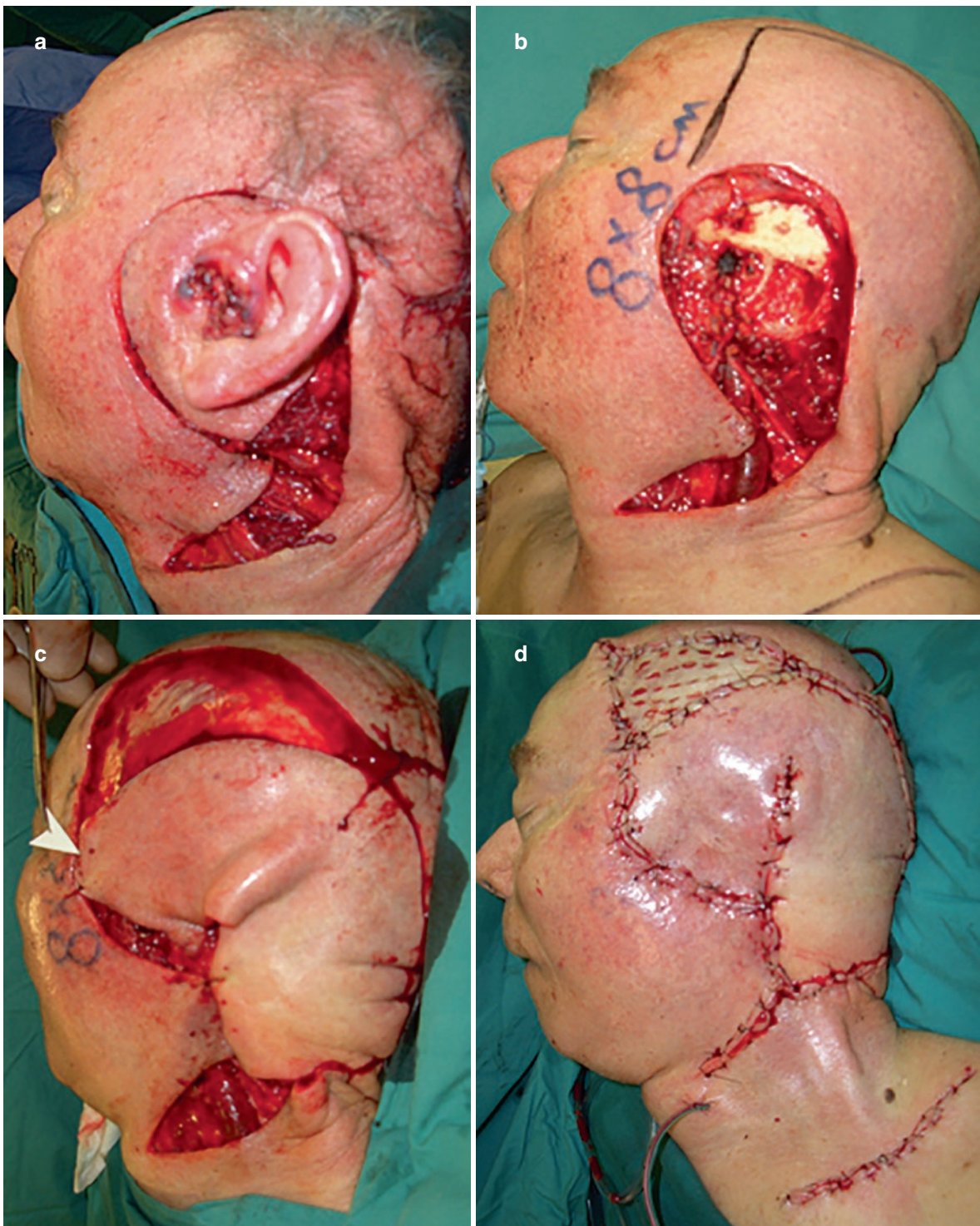


Fig. 10 (a–g) A 77-year-old man with recurrent SCC left external auditory canal in an irradiated field, widely excised including left ear leaving a defect of 8 × 8 cm which was repaired with a posterior KPIF

based on C2 and C3 from the scalp to the neck. A full-thickness skin graft was required for the superior secondary defect. The early result at 10 days and late result at 10 months are shown



Fig. 10 (continued)

6.9 Case 9

This 86-year-old woman had a malignant melanoma of her left parotid region with neck node metastases (Fig. 11). After wide excision and neck dissection, the defect was reconstructed in

55 min with a submental KPIF based on the C2 dermatome. The omega (Ω) is a useful design for this region, and the external jugular vein is preserved in the neck dissection.



Fig. 11 (a–d) An 86-year-old with malignant melanoma of the left parotid region with metastatic neck nodes. Wide excision and neck dissection left a defect of 7×5 cm which was repaired with KPIF Ω vari-

ant based on perforators from sternomastoid muscle in C2 submental region. Result at 1 week. The patient was so comfortable she self-discharged

6.10 Case 10

This elderly man presented with a squamous cell carcinoma of his left parotid and preauricular region and illustrates the application of the submental keystone flap for facial defect

reconstruction (Fig. 12). The resection defect was repaired with a submental KPIF based on the C2 dermatome with undermining of the anterior 2/3 of the flap at the level of the cervical fascia. The anterior segment is transposed 90 degrees into the defect, and the secondary defect is closed directly after flexing the neck.

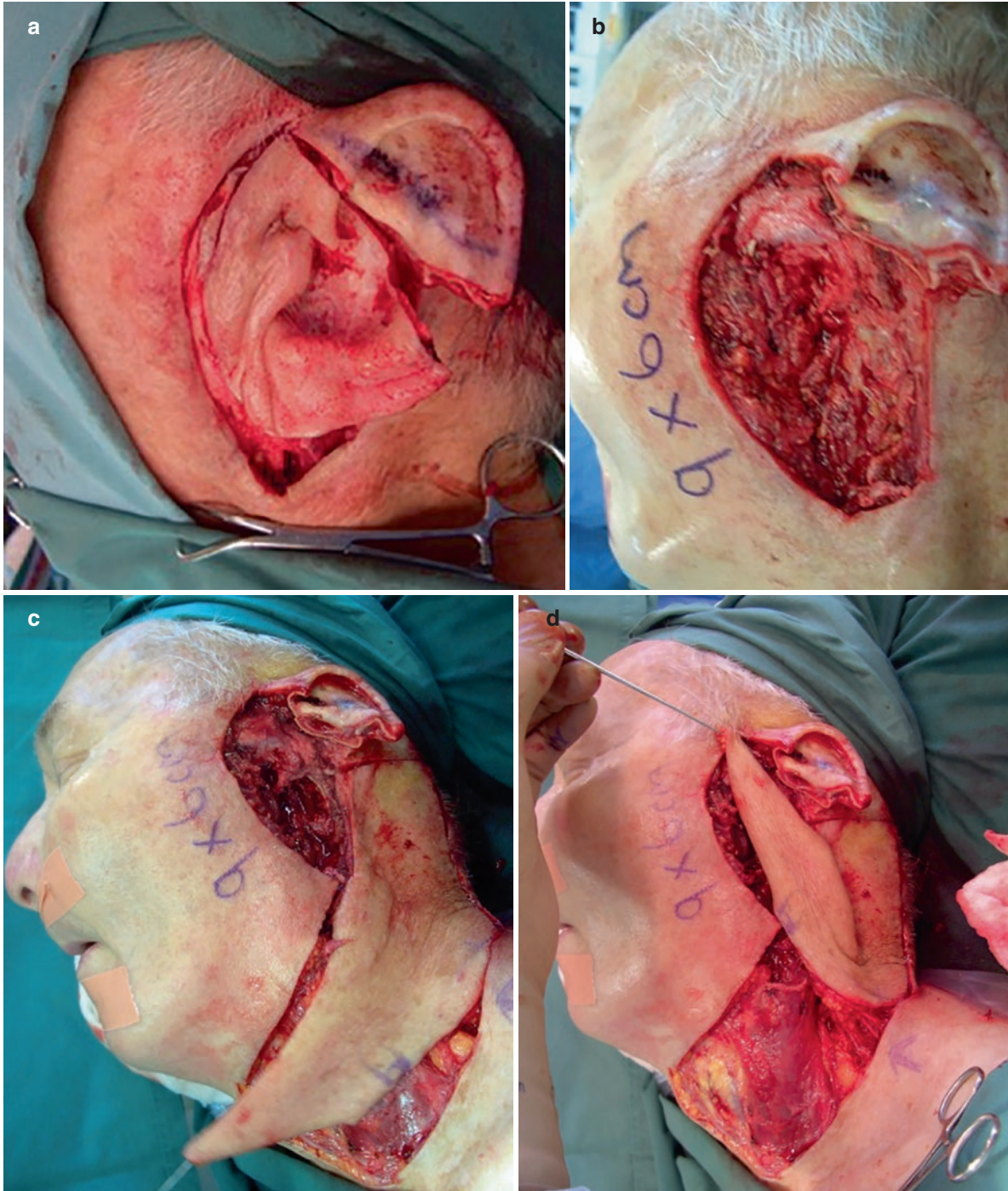


Fig. 12 (a–e) Elderly gentleman with SCC of the left parotid and preauricular region. Wide excision and repair of the 9 × 6 cm defect with a KPIF designed on C2 dermatome in the submental region with under-

mining of the anterior 2/3 and transposition into the defect. Direct closure of the secondary defect by flexing the neck. One year result shown. Patient declined further revision of his left ear remnant



Fig. 12 (continued)

6.11 Case 11

This 68-year-old man presented with squamous cell carcinoma of the left parotid region associated with 5/13 metastatic neck nodes (Fig. 13). The wide excision and neck

clearance were repaired with a type IV KPIF based on the C2 dermatome. The longitudinal neurovascular structures were retained in the flap dissection and the distal 1/3 of the flap left attached to the sternomastoid muscle perforators.

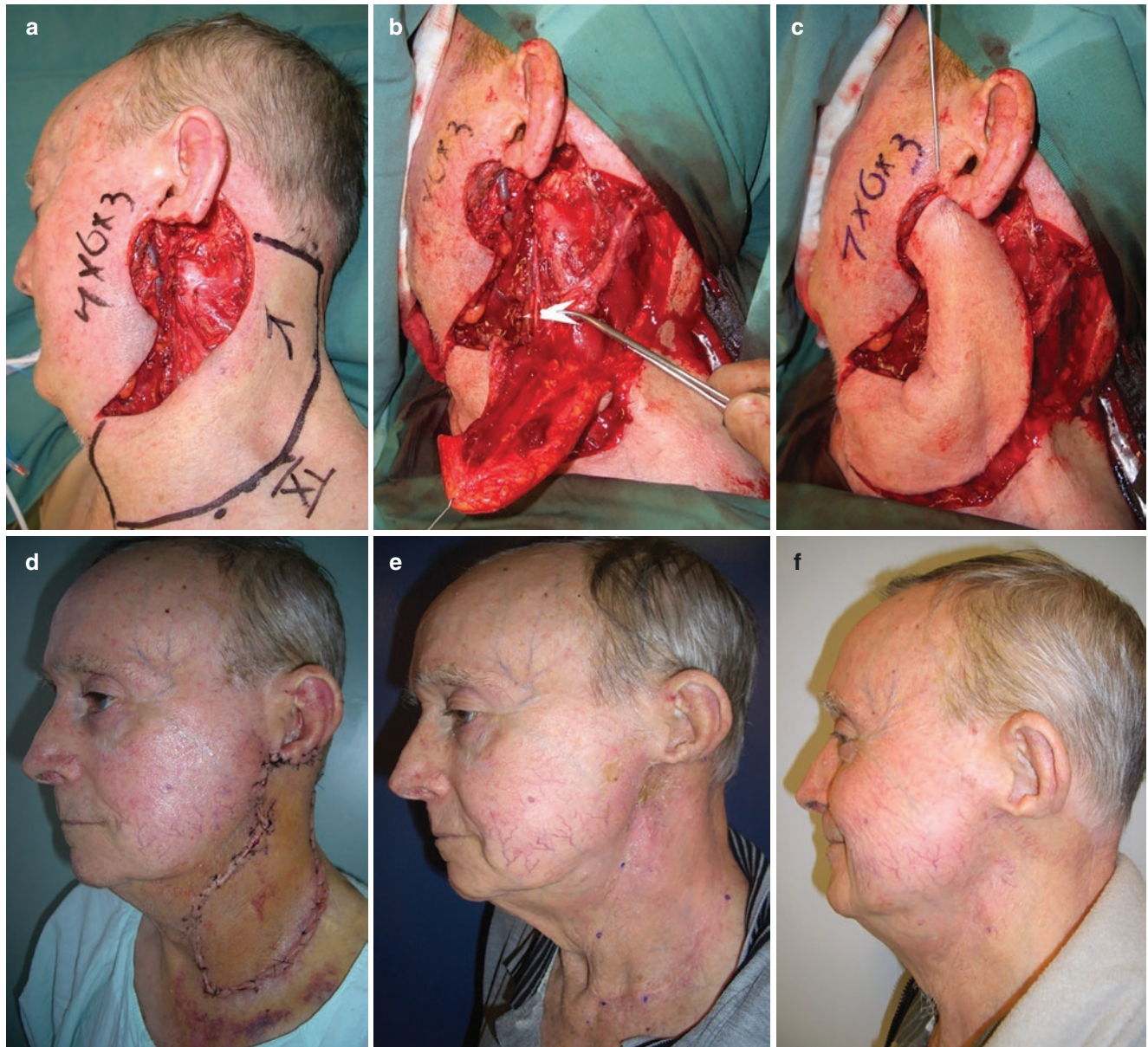


Fig. 13 (a–f) A 68-year-old man with left parotid SCC associated with metastatic neck nodes 5/13, wide excision leaving a defect of 7 × 6 cm, and repair with KPIF type IV method. Result shown at 1 week, after adjuvant radiotherapy and at 5 months where he remains disease-free.

This case highlights the merits of the PACE acronym: pain free, aesthetic reconstruction, complication free and economic (reconstruction time 55 min)

6.12 Case 12

In certain clinical scenarios, a second loco-regional keystone flap can be designed for salvage reconstruction (Figs. 14 and 15). This 90-year-old man with a squamous cell carcinoma of his left supra-auricular region had wide excision down to the bone, and the 7 × 7 cm defect was repaired with a 15 × 8 cm KPIF based on the superficial temporal artery branch perforators of the scalp. The omega variant (Ω) form

of the KPIF was employed, whereby the inferior limb of the KPIF was undermined and turned 180° with excision of the posterior dog-ear. Because the flap is vascularized from the deep fascial perforators, it is safe to excise the dog-ear superficially at the primary flap repair.

Later, a radio-necrotic ulcer developed and required a secondary procedure (Fig. 15). An island flap based on the superficial temporal artery was raised to repair the ulcer defect, and the secondary defect was repaired with a skin graft.

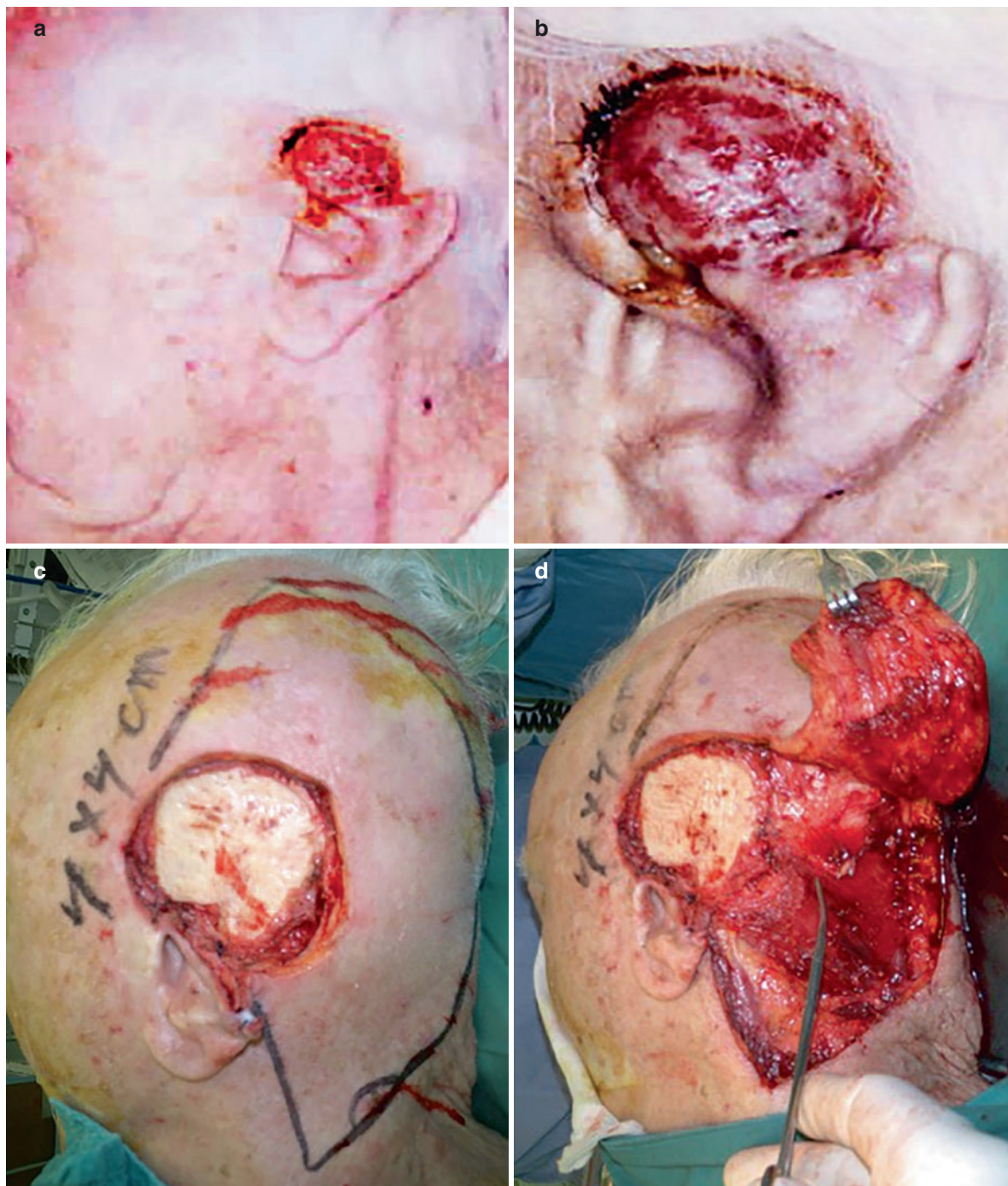


Fig. 14 (a–g) Wide excision of a left supra-auricular SCC in a 90-year-old man repaired with a KPIF of the omega (Ω) variant, with the dog-ear excised immediately and healed 3-month result shown



Fig. 14 (continued)



Fig. 15 (a, b) Same patient with complication of radio-necrotic ulcer, excised and salvaged with an islanded flap based on the superficial temporal artery. Skin graft to secondary defect. Salvaged result shown 6 weeks later

6.13 Case 13

The keystone islanding principle can be utilised in clinical situations where skin undermining has reduced the perfusion in the wound edges. This 65-year-old man presented with a supraclavicular melanoma metastasis, unknown primary

(Fig. 16). This was widely excised as a neck dissection including an island of overlying skin. The upper cervical flap was islanded leaving 2–3 cm of deep attachment to improve the perfusion and achieve sound wound healing. The posterior cervical flap was also islanded to improved perfusion (see red dot sign).

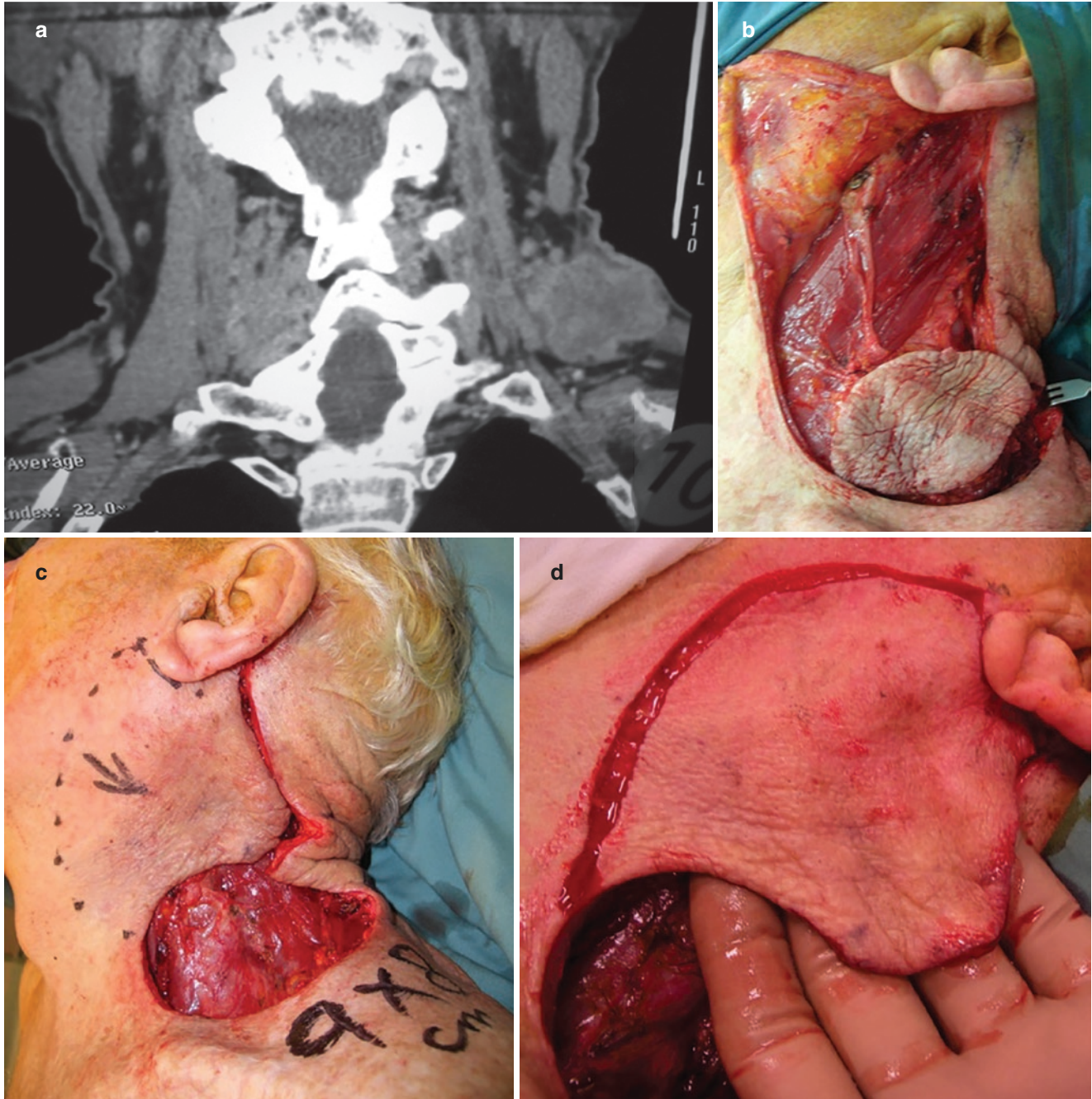


Fig. 16 (a–g) A 65-year-old man presents with metastatic melanoma left supraclavicular region, unknown primary. After wide excision with a neck dissection and overlying skin island, the neck wound flaps are

undermined and islanded as keystone perforator island flaps superiorly and posteriorly to aid with neck closure. The result is shown at 2 weeks



Fig. 16 (continued)

6.14 Case 14

The final case demonstrates the value of the keystone perforator island flap concept for patients with comorbidities and high ASA scores. This elderly gentleman with alcohol-induced dementia presented with a squamous cell carcinoma of his left parotid region (Fig. 17). Wide excision left a 10 × 6 cm defect which was reconstructed with a KPIF based

on the SMAS anteriorly and as an omega (Ω) variant. The KPIF is undermined cephalad and caudally to leave 1/3 of the flap attached to the deep perforators along the left nasolabial fold.

In all the above 14 cases, the PACE acronym was evident: **p**ain free, **a**esthetic repair, **c**omplications minimal and **e**conomic timeframes for rapid surgery.



Fig. 17 (a–f) Elderly gentleman with comorbidities including alcohol-induced dementia with SCC left parotid region. Wide excision and reconstruction with anteriorly-based KPIF Ω variant and perfused by

deep attachments along the left nasolabial fold. The tight closure has a beneficial static lifting effect for the left facial palsy



Fig. 17 (continued)

7 Contraindications

In some head and neck cancer reconstructions, the composite defects will be such that loco-regional flaps such as the key-

stone perforator island flap will be inadequate. Free flaps with microsurgical technique then become an option, but increasingly we witness that they are often the first option considered as in the cases shown in Fig. 18.



Fig. 18 (a, b) Two cases of parotid/peri-auricular cancer reconstruction with a free radial forearm flap in an elderly man associated with right facial palsy and right cheek laxity plus lower lid ectropion. The second case is a younger man whose free flap reconstruction has left

him with a significant facial deformity, with the consequences that he has become a recluse. Both cases referred to the senior author from other surgical units

7.1 Cases 15 and 16

The widespread use of free flaps in head and neck reconstruction by plastic surgeons and non-plastic surgeons has its place but often at an economic and aesthetic reconstructive cost. This is emphasized in chapter “The Burden of Facial Deformity”, where the burden of deformity for patients with poor facial reconstructions is considered.

8 Conclusion/Summary

The concept of the angiotome, from which the keystone flap evolved, began in 1973 when the senior author was researching the blood supply of the skin whilst doing his post-fellowship training in London. The junior author was still a schoolboy then but later became a champion of the keystone perforator island flap method for skin defect repair after 2014. Simon Donahoe FRACS also from Melbourne finally opened his reconstructive mind to the possibilities of the keystone at an Interplast Teaching Workshop in Suva, Fiji Islands. The keystone concept emphasizes the role of the dermatome precincts and the intrinsic neuro-cutaneous vascular supply of the human skin. These flaps are robust all over the body and complications in-frequent even in older debilitated patients, diabetics, the immunosuppressed or the patients burdened with aggressive skin cancers. Almost as an antithesis of our thinking as plastic surgeons, deep sutures are not required, and closure of the flaps under tension is the norm. Blood vessels and lymphatic vessels follow the nerves, so the KPIFs are based on random multiple arterial perforators, their venae comitantes and the fine vascular networks that accompany the nerves. The release of the deep fascia to allow movement of the keystone flap was the sentinel surgical technique that took the junior author some time to fully appreciate. It is a very straightforward flap to raise, quickly, safely and will often avoid the need for more complex, time-consuming, risky and more expensive methods of head and neck repair. In this chapter, 14 of the senior author’s classic cases where the keystone perforator island flap has achieved a sound and reliable repair are presented in detail and colour.

Dr. Frederick J. Menick wrote in 1998 about the interface of aesthetic and reconstructive surgery in facial reconstruction [19]. Distant tissue does not match facial skin in colour, texture or thickness. Nor does it have facial shape. The subunit approach employing loco-regional tissue in contrast improves the aesthetic reconstructive result. Herein lies the useful option of the KPIF for facial reconstruction.

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Basal Cell Carcinoma: A Surgical Enigma

Earle Brown and Bridget Mitchell

Core Messages

- Not all facial basal cell carcinomas are the same.
- It is important for the surgeon to understand and recognise the high-risk growth patterns of more aggressive BCC variants.
- Collaboration and close teamwork with the consulting pathologist are the key to this oncological challenge.

1 Introduction

The most common skin cancer on the face and scalp is a basal cell carcinoma. This is a very chronic, steadily progressive skin tumour typically affecting middle-aged persons of European or Celtic descent who have been exposed to a lifetime of sun exposure (ultra violet radiation) or to previous therapeutic radiotherapy (Fig. 1).

In these persons, it is not uncommon to see a mixture of actinic keratoses, basal and squamous cell carcinomas within areas of severely solar damaged skin. Other persons at risk of multiple tumours are the geno-dermatoses such as Gorlin's syndrome, xeroderma pigmentosa and those having treatment with immunosuppressive drugs (Fig. 2).

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Fig. 1 (a and b) A typical fair-skinned 82-year-old gentleman, with Fitzpatrick type 1 skin, severe photo-damage and at least two decades of multiple facial skin cancers including BCC, SCC, malignant melanoma and Merkel cell carcinoma



Fig. 2 A 45-year-old woman from North Queensland with possible xeroderma pigmentosa and at least a decade of multiple facial BCCs requiring multiple excisions and reconstruction with skin grafts and local flaps. The stigma of facial deformity is comparable to a severe facial burn

2 Fitzpatrick Skin Types [1]

This is a classification of skin types according to the skin’s reaction to sunlight exposure and depends on the quantity of melanin pigment in the skin (Table 1).

In the past, some have questioned if basal cell carcinoma is a malignant tumour as some biopsy-proven tumours have remained unchanged over many years and metastases are extremely rare.

This tumour can be regarded as less severe than the potentially metastatic squamous cell carcinoma and malignant melanoma, with curative rates of 95% obtainable, in the vast majority of cases. There are certain tumours that can be regarded as having a high risk of recurrence, which can lead to a lifetime of problems and even death. Destructive and sometimes rapid growth can occur in a previously quiescent tumour. Slow, deep and silent penetration can invade deeper parts of the face and scalp without being clinically apparent. This is considered radiographically in Chap. 4 “Applied Facial Anatomy”, where the applied anatomy of the face in relation to extreme cancers is described.

Table 1 Classification of skin types according to Fitzpatrick [1]

Type	Features of unexposed skin	Tanning and burning
1	Very pale white skin, often with green or blue eyes and fair or red hair	Burns without tanning
2	White skin, often with blue eyes	Burns and does not tan easily
3	Fair skin with brown eyes and brown hair	Burns first, then tans
4	Light brown skin, dark eyes and dark hair	Burns a little and tans easily
5	Brown skin, dark eyes and dark hair	Easily tans to a darker colour and rarely burns
6	Dark brown or black skin, dark eyes and dark hair	Never burns but tans darker

3 Classification of Basal Cell Carcinoma

The lesion should be examined carefully with the naked eye and then with magnification, using Binocular Loupes or a Dermatoscope. There are a number of classifications of this tumour, describing the localised nodular lesion and the variants of the more diffuse, infiltrating and multifocal variants. The latter have poorly defined edges, often extending further in the skin than can be detected by the naked eye, and consequently tend to be associated with greater degrees of morbidity.

We follow the classification of Emmett and O'Rourke [2] but recognise four different types of tumour, based on their clinical description and confirmed on histological correlation.

4 Papulo-Nodular BCC

This is the commonest type of BCC. Its nodular shape and clearly defined edge, both macroscopically and microscopically, mean that a surgical excision with margins of

several mms should result in complete excision in all cases (Fig. 3).

Nodular BCC typically presents as a shiny, translucent (pearly), telangiectatic papule or nodule. The translucent or pearly appearance is more obvious if the clinician stretches the skin during examination. As the lesion enlarges, the dilated capillaries may be seen coursing across the surface of the lesion.

Ulceration may occur with time and may lead to central umbilication of the lesion with a more raised rolled border. Islands of pigmentation may become clinically visible, and the lesion may become darkly pigmented.

Typical histological appearances are illustrated with photomicrographs (Figs. 4 and 5).



Fig. 3 (a and b) Examples of papulo-nodular BCC

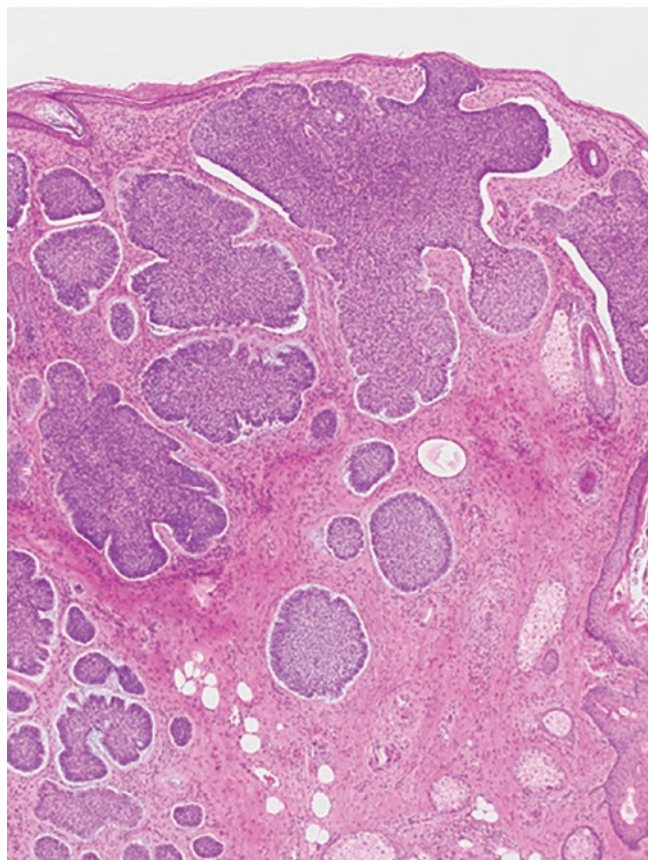


Fig. 4 Nodular BCC (haematoxylin and eosin 40× magnification). The basal cell carcinoma is invading into the underlying dermis in small islands of nodules of tumour. The nodular subtype is the most common form of basal cell carcinoma

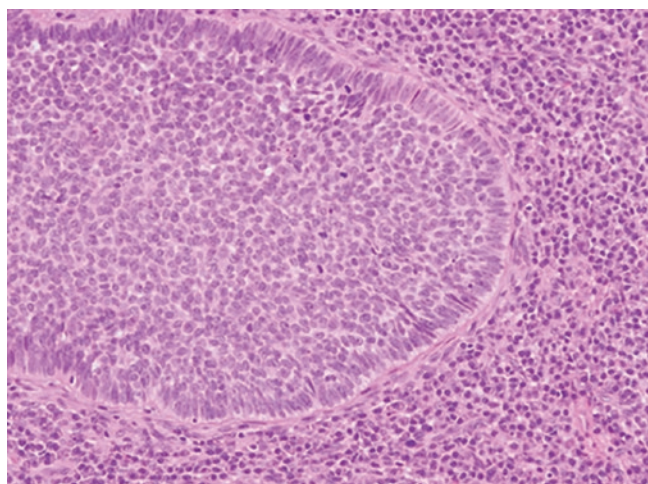


Fig. 5 Nodular basal cell carcinoma (haematoxylin and eosin 200× magnification). A higher-power image of a nodular basal cell carcinoma showing the typical peripheral palisading of the tumour cells

5 Superficial BCC

Superficial BCC usually presents as a reasonably well-defined, erythematous, scaling or slightly shiny macular lesion. Stretching the lesion will highlight the shiny surface and may reveal, to the naked eye, a peripheral thread-like pearly rim or islands of pearlyness distributed through the lesion (Fig. 6).

A minority of superficial BCCs are symptomatic, with itching being the most common symptom.

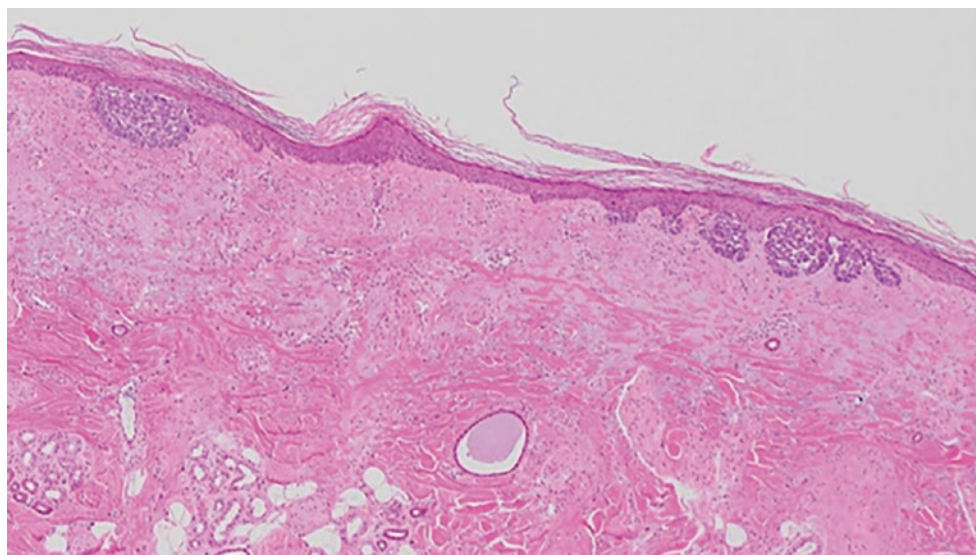
Many superficial BCCs will progressively enlarge over months to years and, if left, may reach 5–10 cm in diameter. Some may be relatively stable and a few will regress. With time, areas of nodular and even sclerosing growth pattern may supervene within the original superficial BCC.

Lesions of the superficial variety are frequently multifocal (the so-called ‘field fire’ basal cell cancer) (Fig. 7).



Fig. 6 Superficial BCC right scapular region

Fig. 7 Superficial multifocal BCC (haematoxylin and eosin 40× magnification). Small lobules of basal cell carcinoma are seen extending down from the lower aspect of the epidermis. These lobules often coalesce and become invasive lesions



6 Infiltrating BCC

This is a less common type often arising as a red scaly area, sometimes with ulceration and slightly raised edges or deeper induration, not unlike a rash in sun-exposed skin.

While one can have a high degree of clinical suspicion, the diagnosis is confirmed on microscopic examination. This shows infiltrating irregular thin long strands and cords of basal cells lacking the usual palisading appearance and at times having a spindle cell appearance.

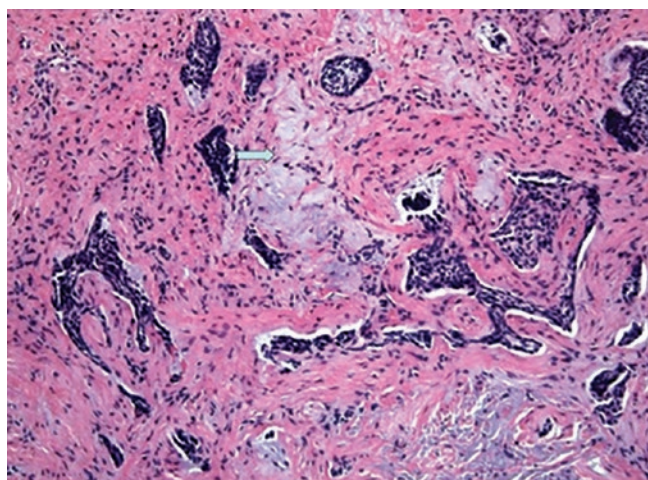


Fig. 8 Photomicrograph of infiltrating BCC histology. These lesions almost invariably arise in sun-damaged skin, the morphologic evidence of which is solar elastosis (arrow). (Crowson [4])

Spiky thin cords or tongues of cells project out with loose stroma and may penetrate far and wide along tissue planes and nerves, producing recurrence and spread, despite apparently adequate excision (Fig. 8).

The clinical appearance is illustrated in this infiltrating multifocal BCC of the left supraorbital region (Fig. 9).



Fig. 9 Infiltrating multifocal BCC supraorbital forehead region

7 Multifocal BCC

This is similar in appearance to the infiltrating type with an ill-defined margin and variable induration.

Like the infiltrating BCC, the diagnosis is confirmed on

8 Morphoeic or Sclerosing BCC

These are usually noted to be a flat whitish plaque that may go unnoticed for several years. A fine pearly edge may be seen on the periphery of the plaque, especially on stretching the skin and viewing it with magnification. Central

regression may occur, giving the appearance of scar tissue (Fig. 10).

The typical histological appearance is illustrated in Fig. 11. Sclerosing BCCs may remain undetected by doctor and patient for many years and may slowly enlarge and deepen to reach a large size before being treated.

Recurrence in sclerosing BCCs can be common and therefore requires regular monitoring. Some recurrence may be due to incomplete local excision with satellite islands of BCC either having not been visible at the time of surgery or being distant from the primary lesion, particularly in those patients, with certain genetic syndromes such as Gorlin's syndrome (naevoid BCC syndrome) or those with immunosuppression.

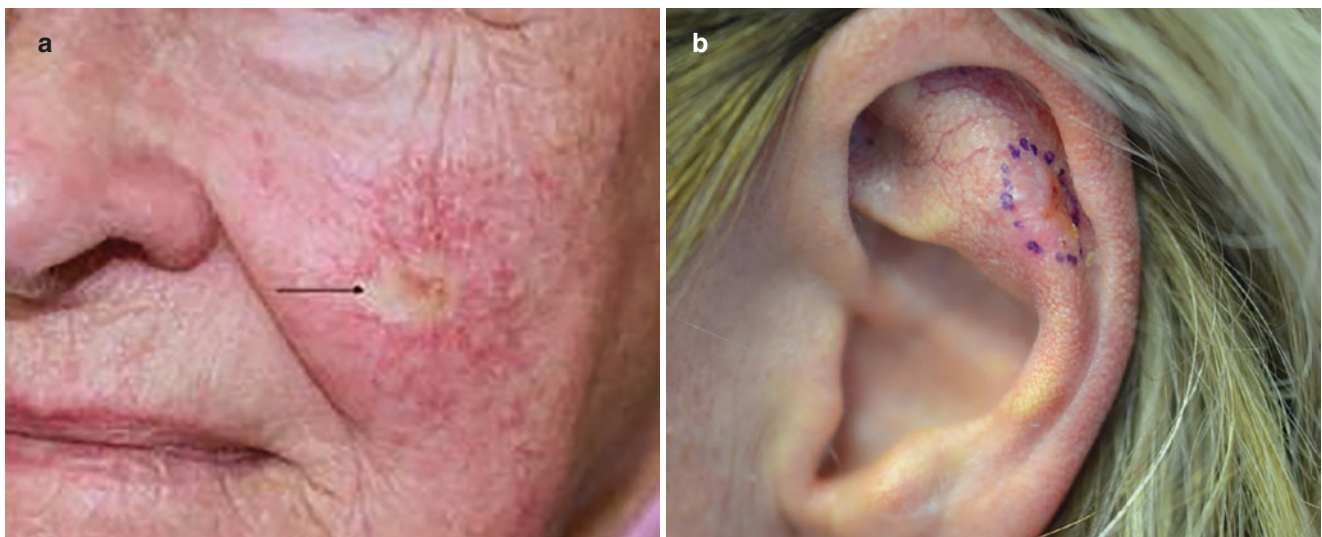


Fig. 10 (a and b) Clinical examples of morphoeic/sclerosing BCCs

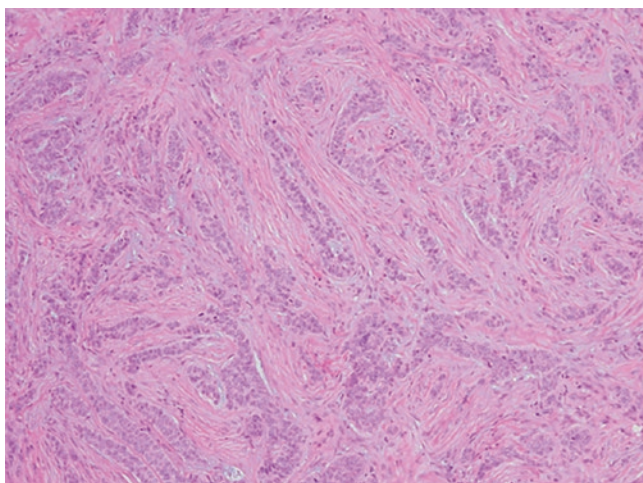


Fig. 11 Photomicrograph of a sclerosing or morphoeic BCC variant (haematoxylin and eosin 200× magnification). In a sclerosing basal cell carcinoma, there are cords and small nests of malignant cells separated by dense fibrous connective tissue stroma. Retraction artefact is present but seen less commonly than in nodular and superficial BCCs. These tumours are often poorly demarcated and often extend into the reticular dermis or subcutaneous tissue

9 Incompletely Excised BCC

This may present as a clinical and pathological quandary (Fig. 12).

One of the enigmas of this tumour reported in the literature is that despite a histological report of incomplete excision, a considerable number of patients do not develop a recurrence at the surgical site.

One's usual response to a histological incomplete excision is to arrange a wider and deeper excision of this area. However, if the surgical site is re-excised with a wider margin, residual tumour cells are found only in between 25 and

It has been confirmed that the incomplete excision rate decreases with the size of the surgical margin.

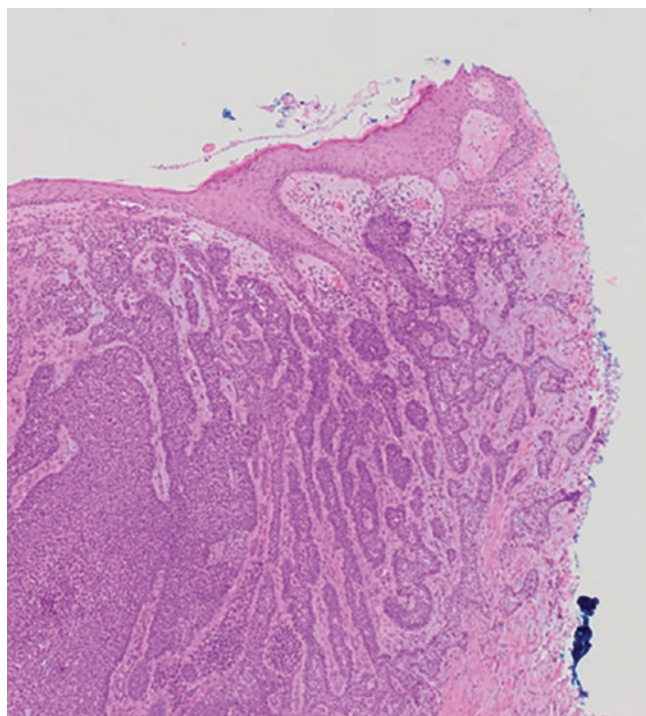


Fig. 12 Incomplete margins for infiltrating BCC (haematoxylin and eosin 100× magnification). This is a nodular and infiltrative basal cell carcinoma extending to the inked margin

10 Recurrent BCC

Recurrences can occur any time after the primary excision, but usually within 3 years [3].

A smaller number have been reported as recurring many years later (Fig. 13). The histological appearance is diagnostic (Fig. 14).



Fig. 13 Ulcerated multifocal recurrent BCC left orbital region

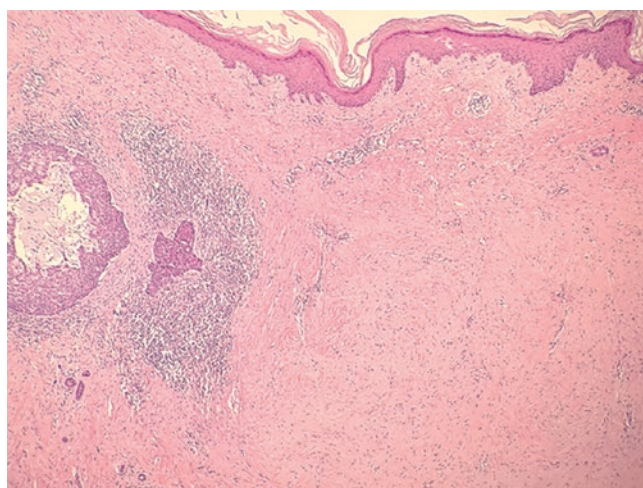


Fig. 14 Recurrent basal cell carcinoma (haematoxylin and eosin 40× magnification). The nodule of basal cell carcinoma can be seen on the left side within scar tissue on the right side of the picture

11 High- and Low-Risk BCCs

In 2006, Crowson divided BCC into indolent and aggressive types depending on the histology [4]. Indolent BCC includes superficial and nodular subtypes. Aggressive BCC includes infiltrative, metatypical, micronodular and sclerosing subtypes. It has been shown in various studies that aggressive tumours are associated with increased subclinical extension, indicating that aggressive tumours require wider surgical margins. Based on the size and histology type, the BCC is

2 cm in size may demonstrate wider subclinical invasion; therefore, lesions larger than or equal to 2 cm in either width

lesions and aggressive subtypes like morphoeic are also

size, nodular, and superficial spreading subtypes are included

We believe that this differentiation between indolent and aggressive tumour should be widely recognised, as it has a direct bearing on treatment and in particular the width of the margins chosen for surgical excision.

Sites such as the so-called H zone (central face, eyelids, eyebrows, periorbital, nose, lips, chin, mandible, preauricular, postauricular skin and sulci, temple and ear) have a higher risk of recurrence, and recurrence can be much more difficult to treat than the primary lesion.

12 Case Records of Complex Advanced Cases

In this section, we describe several patients who had many years of suffering due to regular recurrences of their BCCs.

In his Hayes Martin lecture in 1982, Milton Edgerton mentioned that he had treated 15 patients with invasive multifocal basal cell carcinoma involving multiple facial features, during his long and distinguished career at Johns Hopkins Hospital [5]. He proceeded to highlight the problems that can be associated with such a tumour with a case presentation. In his presentation at an International Conference, Edgerton commented that within all her surgical procedures, he had reconstructed this patient's face three times. This patient, aged 38 years, had a history of radiation treatments to the face for teenage acne and further radiation treatment for basal cell carcinomas of the cheeks and nose. She consulted Dr. Edgerton 2 years following a wide surgical excision of a recurrent BCC involving the right cheek and upper lip. She was left with a large unreconstructed wound, covered with a bandage. Edgerton

proceeded to widely excise the unhealed wound and residual BCC and in a series of procedures reconstructed her cheek, upper lip and nose. In spite of this radical surgery, she continued to get recurrences requiring further surgery and facial reconstruction. Over the next 30 years, she had over 100 major operations to remove recurrent tumours and reconstruct her face.

13 The Neglected BCC

13.1 Case A

This is a very sad situation where patients have actively avoided medical care until they can be persuaded to have a medical examination. Complications such as arterial haemorrhage or meningitis arising from the tumour growth may force the reluctant patient to seek help (Fig. 15).

This 67-year-old man presented with an 18-year history of a lesion on his right ear. It is possible that he had early treatment by a dermatologist. In 2018, he attended a hospital emergency department with arterial bleeding from the tumour. He was examined by lead author, MK, and noted to have an extensive tumour, 10 × 12 cm in area, with erosion of all the right ear, deep soft tissue, skull base invasion and a right facial palsy. Despite all attempts to arrange a full surgical workup and imaging, he refused all offers of medical assistance.



Fig. 15 Neglected advanced destructive BCC of right ear with mastoid invasion and facial nerve palsy. All treatment declined

13.2 Case B

This man presenting in the 1960s (Fig. 16) had a very long history of a BCC on his face involving the lips, nose, orbit

and ear. The tumour was widely excised, and the wound repaired with a huge scalp flap above and a neck flap below. Once the wounds were healed, he did not return for follow-up assessment.

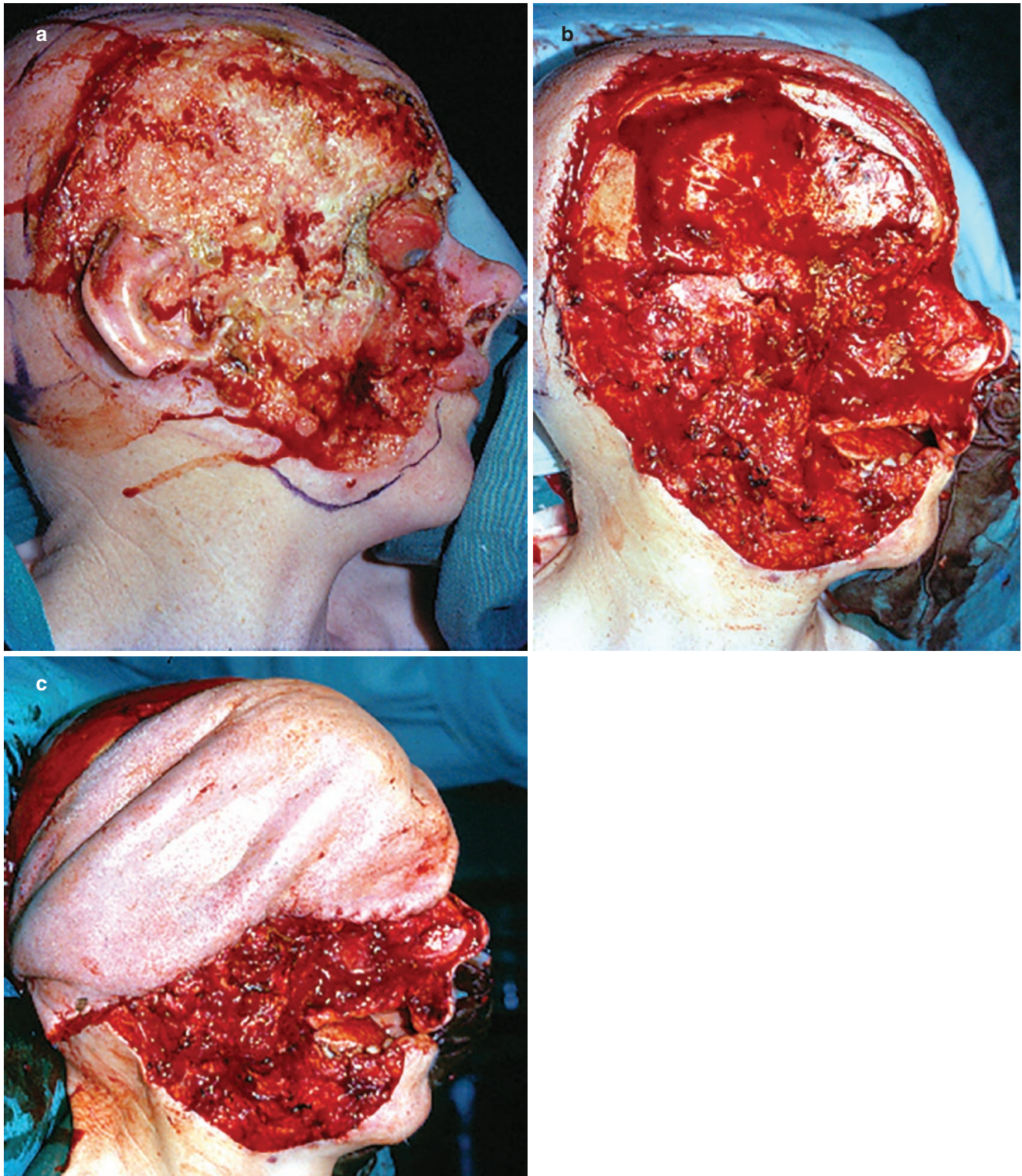


Fig. 16 (a–c) 1960s case from Middlemore Hospital, Auckland

13.3 Case C

A 64-year-old woman presented with a BCC of the right forehead and scalp, measuring 12 cm in diameter. She stated that the lesion occurred after a visit to the hairdresser, and she attributed it to a burn after having fluid and heat applied to her hair for a 'perm'.

Eighteen years later she was persuaded to seek treatment for this large tumour, involving the right upper forehead, frontal scalp and it was densely adherent to the underlying frontal skull. Because of the bony involvement, and proximity to the sagittal sinus, a neurosurgeon assisted with the operation. The tumour was excised with a 2 cm margin down to the underlying skull. The neurosurgeon excised the bone under the soft tissue incision, to expose the underlying dura mater. The sagittal sinus was retained intact in the depths of the wound. The large surgical defect was then repaired with a large scalp transposition flap, and the flap donor site repaired with a split skin graft.

Histological examination revealed a large infiltrating basal cell carcinoma, invading down to the inner table of the skull. Wound margins were clear of tumour. Following regular follow-up, 3 years later she was noted to have a possible recurrence at the posterior margin of the original incision. A biopsy recorded this as a basosquamous carcinoma. This was widely excised to include underlying temporal bone and dura mater. Repair was with a fascia lata graft to reconstruct the gap in the dura and another large scalp flap. She was reviewed regularly in the follow-up clinic, for 7 years before being discharged from care, tumour-free. The patient died aged 77 years apparently tumour-free.

14 Post Radiotherapy Tumours

14.1 Case D

A 32-year-old man was referred to the plastic surgical unit for a BCC on the nose, recurrent after radiotherapy. The lesion was excised and the surgical defect repaired with a full-thickness skin graft. Histology confirmed the lesion to be a BCC, with tumour close to the deep margin.

He presented again, aged 37 years, with a tumour recurrence on his nose and new lesions on his nose and upper lip. These were excised and proved to be BCCs incompletely excised. In further surgery that year, he had excision of lesions from the right cheek and left inner canthus. These lesions were also BCCs, incompletely excised.

Two years later he had recurrent lesions on the right cheek, left upper lip and left cheek. He declined treatment but returned a year later and had further surgery. Over the next 25 years, he had 20 surgical procedures on his face. Despite wider excision margins, and in some cases histologi-

cal completeness of excision, the progress of the BCC was relentless, and he required enucleation of the right eye and a right mastoidectomy. He was given a course of radiotherapy when imaging showed a recurrence at the posterior aspect of the right orbit, extending into the brain.

Following the initial operations, the surgical wounds on the right cheek were repaired with split skin grafts. The surgical wound following exenteration of the right orbit was repaired with a temporalis muscle flap, which was covered with a split skin graft. After his radical surgery to the right ear and mastoid, the repair was with a large scalp flap.

He died aged 64 years secondary to cerebral invasion of the BCC, having spent more than 30 years of his life affected by this tumour.

15 Sclerosing BCC

15.1 Case E

A 50-year-old woman presented with a two year history of a BCC on her left forehead. This was excised and the wound repaired with a full-thickness skin graft. Histology showed a sclerosing BCC with narrow excision margins. Five years later she presented with a recurrent tumour, which was excised. Histology showed an incompletely excised sclerosing BCC with perineural invasion. A further wide excision was done, with clear margins.

Over the next 20 years, she developed recurrences, mostly on the posterior excision margin, which were excised with ever increasing margins. At each procedure, all the previously used skin graft was excised in continuity with the recurrence. This resulted in a large skin graft involving the left side of her forehead and the fronto-parietal scalp, the latter being masked with a wig.

16 Infiltrating BCC

16.1 Case F

This 58-year-old woman presented with a BCC on the lower lip that had been present for at least 9 years. Her surgical treatment included a wide excision and flap repair. The histology confirmed the diagnosis and the margins were clear but close.

Two years later she was noted to have a recurrence in a junctional scar of the previous repair. A wide excision of the recurrence included scars from the previous surgery plus a shaving of the underlying mandible. Pathology was similar to the initial excision with one close histological margin. The following year she had surgery including more of the outer cortex of the mandible for a further recurrence. Excision

margins were clear on histology. Following a further recurrence 2 years later and 5 years since her initial presentation, she was treated with radiotherapy.

An extensive recurrence was noted 2 years later. Tube pedicle flaps were prepared, and she then underwent a radical excision of the lower face, neck, mandible and floor of mouth. Histology confirmed the recurrent BCC, with clear margins. Over the next 3 years, she had further surgery to remove tumours in her neck which were considered metastatic BCC. Further radiotherapy was given for a tumour in the region of the right trapezius. She died a year later, aged

70 years, following 12 years of treatment with a recurrent and inoperable BCC.

17 Tumours Following Immunosuppression

Patients like those in Fig. 17 are renal transplant recipients who require long-term immunosuppressant drugs and consequently are more susceptible to facial skin cancers.



Fig. 17 (a and b) Renal transplant patients with challenging nasal skin cancers secondary to immunosuppression. Patient A was treated with wide excision and a nasoaxial V-Y advancement local flap. Patient B had a rhinectomy but died within 2 years of his surgery

18 Local Recurrence of BCC

This can be defined as ‘a lesion arising in the same or contiguous site of previous treatment following its incomplete removal’ [6, 7]. The gentleman in Fig. 18 shows a recurrent BCC of his left lower nose following previous wide excision and skin graft repair.



Fig. 18 A 67-year-old man with recurrent BCC left supratip after previous excision and skin graft

19 Histopathology

19.1 Orientation of Excised Lesion

A surgeon submitting an excised lesion to the histopathologist should orient the specimen. This is commonly done by inserting a suture in the specimen margin at the 12 o'clock position. It is also helpful to add additional sutures for more complex excisions and to add a diagram and clinical information on the request form. The processing of the specimen in the laboratory is different depending on the type of specimen submitted. The procedures used for punch biopsies, elliptical excisions, wedge excisions and specimens from Mohs procedures are discussed below.

19.2 Punch Biopsy

Punch biopsies can be used as a diagnostic technique prior to a definitive excision. In this scenario, a 2 or 3 mm punch usually is sufficient, and the entire punch is submitted in its entirety. In some instances, where a lesion is small, a larger punch biopsy (5 mm and larger) may be used as an excisional technique. Here the punch biopsy is bisected off-centre, and the entire specimen is processed (Fig. 19).

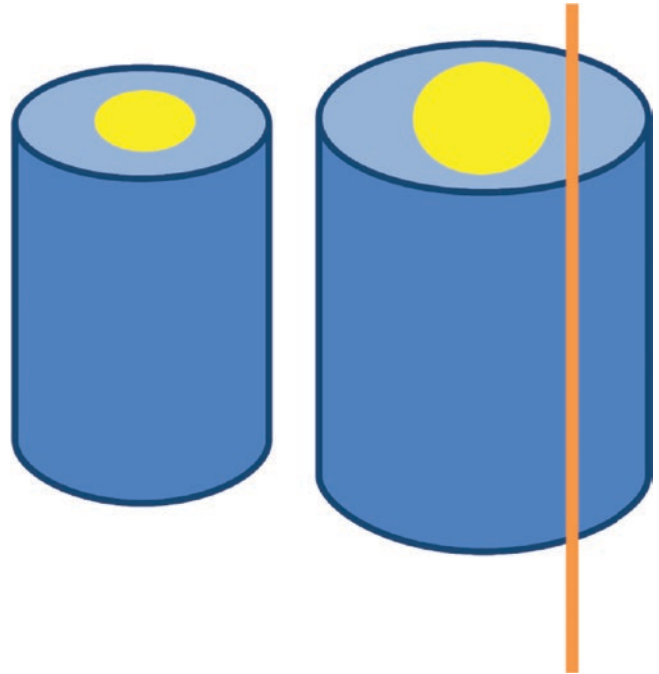


Fig. 19 The blue cylinders represent the punch biopsies. The punch biopsy on the left side is small and processed as is. The larger punch biopsy on the right is bisected (orange line). The yellow dot represents the lesion of interest

19.3 Elliptical Excisions

Ellipses usually have the margins inked blue if not orientated or blue (12–3–6 o'clock) and black (6–9–12 o'clock), if the specimen has been orientated and are then transversely sectioned. All of the specimen is processed if it fits in one block or just the lesion if the skin is bigger than one block. Oval or circular skin lesions are handled in a similar fashion (Fig. 20).

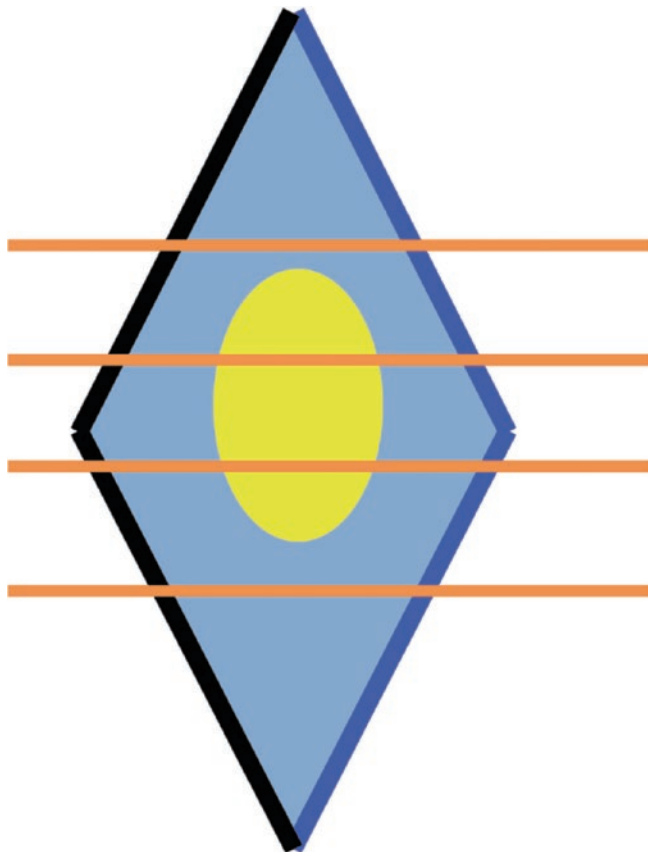


Fig. 20 The 12–3–6 o'clock margin is inked blue; the 6–9–12 o'clock margin is inked black. The lesion of interest is represented by the yellow dot. Transverse sections are shown by the orange lines

19.4 Wedge Excision

If a wedge excision is taken from the lip, eyelid, ear or nose, the margins are inked blue and black and are submitted *en face*, and a central transverse section is taken through the lesion (Fig. 21).



Fig. 21 One margin is inked blue, and the other margin is inked black. The lesion of interest is represented by the yellow dot. Sections are shown by the orange lines

19.5 Slow Mohs Procedure

In the laboratory, we also occasionally perform a slow Mohs procedure for basal cell carcinomas. This is where a piece of skin is removed, fixed in formalin and processed urgently through the laboratory. The wound in the patient is left open until the results are received the next day. This procedure is useful to ensure negative margins in areas like the eyelid where the smallest possible margin is needed for either function or cosmesis. The slow Mohs is usually performed for melanoma in situ; however, occasionally it is also used for squamous carcinomas or basal cell carcinomas. The margins are processed en face and the rest of the tissue is then serially sectioned. The central tissue is inked blue and black as per usual ellipses (Fig. 22).

The usual Mohs procedure is more commonly performed by dermatologists in their own rooms.

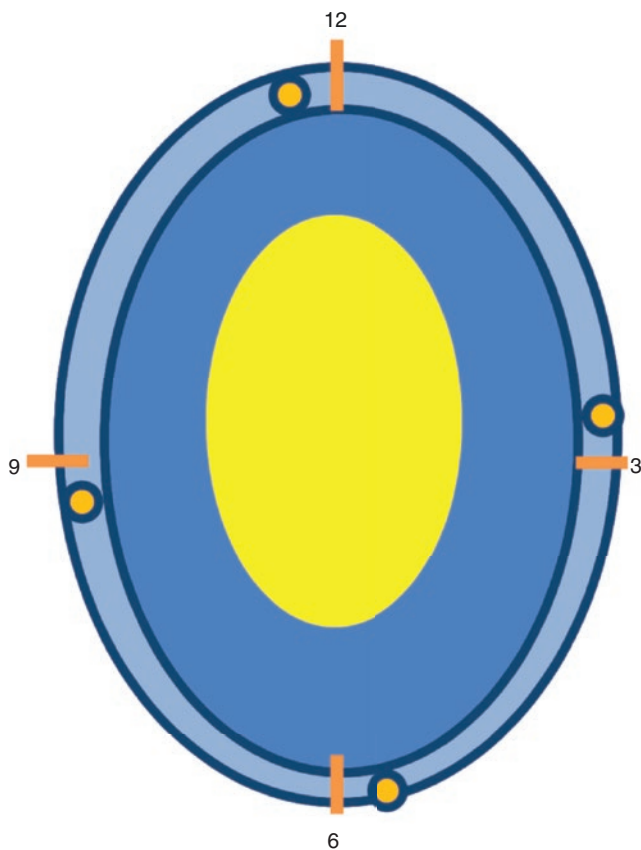


Fig. 22 The resection margins for the Mohs procedure are taken around the clock face with an orange ink dot placed at the edge with the highest number around the clock for orientation. The pieces of tissue are embedded *en face*

19.6 Frozen Sections

In exceptional circumstances, frozen sections can be performed with the pathologist attending while the patient is under anaesthetic. The specimen is frozen, sectioned in a cryostat, stained and then examined by the histopathologist (see Chap. 3 “Head and Neck Pathology: Practical Points to Ponder”).

19.7 Tissue Stains

Most basal cell carcinomas can be diagnosed with haematoxylin and eosin alone. In some cases, it can be difficult to distinguish between a basal cell carcinoma and a squamous cell carcinoma. In this scenario, the use of a few immunohistochemical stains like EMA and BerEP4 can aid in the distinction.

20 Management/Technique

20.1 Primary Treatment Goals

To completely remove the tumour, both clinically and histologically, to avoid a later recurrence.

To avoid any functional impairment caused by the treatment.

To produce the best possible aesthetic reconstructive result.

In the past, a multitude of treatments have been advocated.

As surgeons, we believe that for the majority of patients, the primary treatment of any of these lesions is by early and complete surgical excision.

The surgical principles of Sir Harold Gillies are as important today as when they were first enunciated nearly 100 years ago and outlined in *Principles and Art of Plastic Surgery* (1957) [8, 9].

20.2 Observation Is the Basis of Surgical Diagnosis

Diagnose before you treat. If there is any doubt about the clinical diagnosis, consider a diagnostic biopsy.

Make a plan and a pattern for this plan. Use paper, bandage or Jaconet cloth shaped to the defect, and carry out a simulation operation in reverse.

Make a record. Start with a diagram in the notes. Photograph the lesion, proposed surgical margins, and repair plan.

The lifeboat. It is well to have a reserve or plan B. Consider the possibility of the patient developing further lesions in the future, and do not squander good flap donor sites for small lesions that can be repaired with simple advancement flaps.

21 Guidelines

Many organisations around the world have developed clinical guidelines for the overall management of skin tumours [10].

The New Zealand authors tend to follow the Australian guidelines, as the conditions of climate, population ethnicity and incidence of tumour occurrence closely mimic our conditions. Each chapter is written by authorities who are eminent in that particular aspect of treating keratinocyte cancer.

The Cancer Council Australia and Australian Cancer Network (CCA/ACN) guidelines categorise BCC lesions as simple and complex when determining appropriate surgical excision margins. Simple BCCs are defined as small, nodular or superficial, and not located on the central face. Complex BCCs are defined as complex secondary to anatomic location, histologic subtype or ill-defined nature [12–14].

22 Excision Margins

The CCA/ACN advise the use of 2–3 mm peripheral margins for simple BCCs and 3–5 mm for complex BCCs. The deep margin is recommended to include subcutaneous fat.

Nahas et al. [11] have summarised a number of global guidelines on surgical margins for non-melanoma skin cancers. Some international studies show that in low-risk tumours, a margin of 3 mm will achieve complete excision in 85% of cases and a 4 mm margin should achieve a complete excision rate of 95% or more. For high-risk tumours, margins between 5 and 10 mm have been recommended. It is generally agreed that the wider the excision margin, the less likely there is to be an incomplete excision or a tumour recurrence.

While it is possible to produce an algorithm to define surgical margins in various situations, it is only a guide and does not allow for the flexibility needed to treat each tumour by its site, size, histology and risk rating.

23 Management of the Incompletely Excised BCC

One of the enigmas of this tumour, reported in the literature, is that despite a histological report of incomplete excision, a considerable number of patients do not develop a recurrence at the surgical site.

One's usual response to a histological incomplete excision is to arrange a wider and deeper excision of this area. However, if the surgical site is re-excised with a wider margin, residual tumour cells are found only in between 25 and

It has been confirmed that the incomplete excision rate decreases with the size of the surgical margin.

Of major concern is how to treat patients with neglected tumours or those that have resisted all attempts to completely excise the tumour as reviewed in the previous case reports.

Consideration should be given to removing as much tumour as possible and repairing the wound as a palliative procedure. This recognises that the primary aim of a cancer cure has failed and we are now in a situation of cancer control.

24 Surgical Repairs: Graft Vs Flap

There are a number of surgical repair techniques that should be considered following excision of a BCC. The main concern is to obtain complete excision of the tumour. When treating small lesions on the face, we recommend surgical excision and a *local flap* repair. This has the advantage of repairing the surgical wound with tissues similar to those at the excision site and leaving a cosmetically acceptable result [12].

Where there is insufficient local tissue available for repair, a full-thickness skin graft is the most cosmetically acceptable repair (Fig. 23).

An alternative option for the bridge and tip of the nose when a deeper excision exposes the bony cartilaginous framework is a paramedian loco-regional flap such as has been used in Fig. 24.

If there is any doubt concerning the completeness of excision, and the surgical defect is too large to be repaired with a direct closure, a split thickness skin graft repair should be considered. This is the best option in patients with severe

solar damage to the skin, who will need further treatment in the future, or those who have had several procedures and have regular recurrences.

The repair of large surgical defects following major surgical excision require a more sophisticated repair. Large local flaps from the scalp and the neck can be considered.

Large micro-vascular flaps of tissue harvested from other parts of the body can often provide the best solution.

Surgical reconstructions of facial features can be complex and require a number of procedures to restore function and appearance.

In the past, facial prostheses were advocated for areas that were difficult to repair. Almost all patients find facial prostheses disappointing in replacing the nose, cheek, lips or orbit. No matter how artfully they are constructed, these masks do not relieve the patient's sense of deformity as they are not incorporated into the body image.



Fig. 23 (a and b) Full-thickness supraclavicular graft for reconstruction of the dorsal aesthetic subunit of the nose in a 50-year-old female, after wide excision of multifocal BCC supratip region. 2-year result shown (case from Klaassen et al.)



Fig. 24 (a and b) A 51-year-old fair-skinned mining worker from North Queensland, where he has been exposed to chronic severe UV irradiation. Multiple BCCs forehead, nasal tip and both cheeks. Repair with a combination of direct closure, local flaps and a full-thickness skin graft

25 Conclusions and Summary

As medical professionals let us never forget that we are treating a fellow human being who happens to have a tumour. This is where we can make a big impact on the patient's treatment. Full discussion and informed consent should be mixed with empathy for the patient and a willingness to listen to their fears and concerns. This becomes of paramount importance in those who are now in the cancer control stage.

The previously described cases provide a salutary lesson on the dangers of treating facial and scalp BCCs as little more than troublesome lesions that are more a nuisance than a life-threatening tumour. Our challenge is to recognise the potential of each particular basal cell cancer and to make treatment appropriate.

The best chance of curing (totally excising) a basal cell carcinoma is the first operation.

If there is any doubt about the diagnosis, a diagnostic biopsy should be considered.

Managing the tumour margins in high-risk cases can be monitored by the pathologist with frozen sections.

Should the histology report show incomplete excision or narrow excision margins, we believe that a wider and deeper excision of the previously excised tumour site is indicated.

Adopting a 'wait and see' policy can lead to a later recurrence and even a lifetime of problems.

Once a person has developed a basal cell carcinoma on the face or skull, it is highly likely that more tumours will develop with the passage of time. This makes patient education about sun protection, awareness of new tumours and regular skin checks a mandatory exercise.

As surgeons, we are highly reliant on the histology reports of excised lesions. A good working relationship with a dermatopathologist is essential.

Australian plastic surgeon, Tony Emmett, personally looked at all the histology slides of his patients [13].

We believe that regular clinical pathology meetings to review patients and discuss tumour histology are essential.

The management of the patient who has passed from the cancer cure stage to the cancer control stage should be a multi-disciplinary exercise. The oncologist can play a major part in alleviating tumour recurrences with radiation

therapy and the possible use of Hedgehog pathway inhibitors [12, 14, 15].

To quote Edgerton in his Hayes Martin Lecture [5].

‘It is not enough to learn about the diagnosis, pathology, prognosis, and treatment possibilities for cancer. Each of us must make judgements about when to try for cure, what to tell the patient, how long to continue palliation. These are never easy questions’.

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Clinical Images: Michael F. Klaassen.

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Part III

Anatomical Focus

Scalp and Forehead Cancer

Michael F. Klaassen and Ian Burton

Core Messages

- The scalp layer is relatively inelastic but has a robust blood supply to all layers (skin, dense connective tissue, galea/occipitofrontalis muscle and pericranium).
- Local flaps based on the superficial temporal and occipital vascular pedicles should be designed large to cover the convex contour of the cranium.
- Skin grafts to the secondary defects are sometimes necessary but can be revised with tissue-expanded scalp flaps as elective final stages in the scalp reconstruction.

1 Introduction

The scalp is regularly exposed to the sunlight, and invasive cancer is common particularly in balding elderly men with chronic actinic-damage. Scalp skin cancer may include squamous cell, basal cell and malignant melanoma in decreasing frequency. Other rare cancers of the adnexal structures in the dermis may also be seen [1]. Squamous cell cancer is the most common malignancy seen in the lead author's surgical practice here in New Zealand over the past 30 years. Mostly this is due to the damaging cumulative effects of ultraviolet ionizing radiation in fair-skinned, outdoor-working individuals like farmers, fishermen and forestry workers. Squamous cell cancer may also arise in previously scarred or damaged scalp skin, such as at the sites of burns and chronic ulcers. Local extension is the usual mode of growth of most scalp SCCs which may involve surrounding scalp areas as well as the deeper scalp layers and eventually the calvarium itself. Intracranial extension is rare but may present in recurrent cases, particularly after adjuvant radiotherapy. SCCs may metastasize to loco-regional nodal basins in the parotid,

occipital and cervical regions, and this is also the mode of spread for the rarer malignant melanomas.

Clinical diagnosis, staging and histopathological confirmation are all important aspects of the initial workup. For the most challenging scalp malignancies, the multidisciplinary team approach is favoured. *Diagnose before you treat* is the most important initial principle defined by Gillies. The standard reconstructive ladder or pyramid is the toolbox that all plastic surgeons are raised on. The goal is to achieve Complete Local Excision and Aesthetic Reconstruction (CLEAR) in as few stages as possible to save the patient unnecessary suffering. The options for repair include secondary intention, skin grafts (split and full thickness), local or loco-regional flaps (with or without pre-surgical expansion) and distant flaps including free tissue transfer.

When the clinical scenario is unusual or atypical, the guidance of an experienced histopathologist is mandatory. The lead author has always relied on questioning the pathology when the clinical situation seems unusual. The very rare case of a relatively innocuous scalp basal cell carcinoma de-differentiating into a poorly differentiated squamous cell carcinoma with local and regional nodal metastases is a case in point (see later).

2 Management/Technique

A number of clinical cases managed by the lead author are described with principles of reconstruction and challenges encountered along the way.

3 Squamous Cell Cancer

This 65-year-old man (Fig. 1) was referred with a pT2 well-differentiated SCC arising at the site on his frontal scalp where a chronic sinus had formed from the use of a hairpiece fixed with a metal clip. He had worn the hairpiece for >20 years to disguise his significant alopecia. The 5 cm

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Fig. 1 (a–c) A 65-year-old man with frontal scalp SCC caused by toupee hair piece clip (a: pre-surgical plan, b: immediate large scalp rotation flap, c: day 1, d and e: 5 months post-surgery)

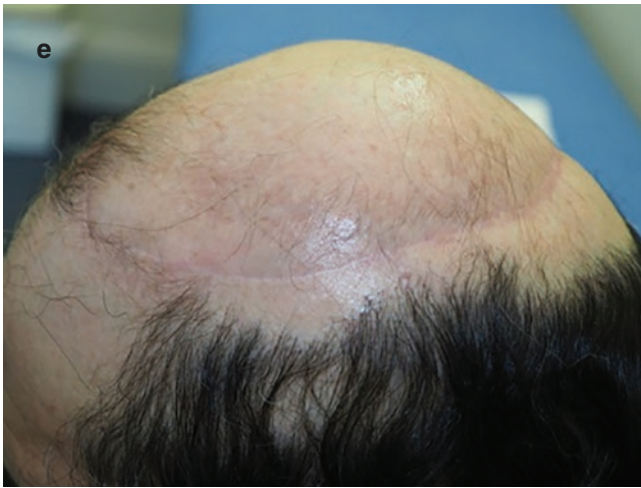


Fig. 1 (continued)

diameter scalp tumour was widely excised down to and including the frontal periosteum. Immediate repair was achieved with a large scalp rotation flap raised on the right superficial temporal vascular pedicle and the donor site closed directly over a suction drain. He is shown immediately, day 1 and 5 months post-surgery with the scalp flap well healed.

Another case is the 59-year-old man (Fig. 2) referred with a rapidly growing T4 lesion of his left frontal scalp, which had been biopsied and reported as a keratoacanthoma. Although the tumour was mobile on the pericranium, there were associated subdermal nodules in the draining lymphatic distribution of the left temple and parotid regions. A wide excision incontinuity with a left superficial parotidectomy and selective neck dissection was performed preserving the facial nerve branches. A rotation scalp flap repaired the defect, but a split skin graft was required for the posterior scalp secondary defect. Final histology revealed a well-

differentiated SCC with reactive hyperplasia in the pre-parotid lymph nodes. His result at 7 years post-surgery is shown, with no sign of recurrence.

This 73-year-old man (Fig. 3) presented with a large (40 mm) ulcerated poorly differentiated SCC of the vertex. The duration of growth was 2 years, and associated palpable right occipital lymph nodes were also widely excised. Histologically these showed reactive hyperplasia only. Large rotation scalp flaps were planned anteriorly and posteriorly. However, after wide excision down to calvarium, it was decided that a large posterior rotation flap based on the left occipital vascular pedicle, raised at the suboccipitalis-galea plane and scored to increase elasticity would close the defect. A drain was placed under the flap, and the secondary posterior defect repaired with a split skin graft. Post-surgery the patient underwent adjuvant radiotherapy. Figure 3f shows the almost healed secondary defect, skin grafted and prior to commencement of adjuvant radiation therapy.

Sometimes the local scalp skin has such extensive actinic damage that local flap repair is contraindicated. This is where skin grafts can be a good reconstructive choice. The 86-year-old man (Fig. 4) with extensive scalp sun damage and previously treated scalp melanoma was referred with multiple actinic lesions including a moderately differentiated SCC of his left frontal region and other neighbouring lesions which proved to be SCC in situ. He had multiple wide excisions and repair with full-thickness skin grafts from a supraclavicular donor site. Aged 90 years he returned with another SCC on his right frontal region, which was widely excised and repaired with a full-thickness skin graft, this time from his submental donor site. Note the colour match of the grafts from the supraclavicular and submental donors, compared to the pale graft to the dorsum of his nose, which came from his medial arm donor site.



Fig. 2 (a–e) A 59-year-old man with SCC left frontal scalp and associated left parotid lymphadenopathy. Wide excision incontinuity with a superficial parotidectomy, selective neck dissection and repair with

large rotation local scalp flap. Skin graft to secondary defect required and late result at 7 years



Fig. 2 (continued)



Fig. 3 (a–f) A 73-year-old man with longstanding SCC vertex scalp widely excised down to calvarium and repaired with a large rotation local flap, with split skin graft to the secondary defect. Image f shows delayed healing of graft margins, prior to adjuvant radiation therapy



Fig. 4 (a–f) A 90-year-old gentleman with multiple scalp SCCs treated by wide excision and repair with full-thickness skin grafts

4 Recurrent SCC Post-surgery and Radiation

This is a particularly challenging oncological and reconstructive problem as seen in the 70-year-old man (Fig. 5) who was born with congenital ectodermal dysplasia and had multiple previous operations for BCCs and SCCs of his scalp. Several years before an incomplete margin had been treated with high-dose radiotherapy. He was referred with two large areas of exposed calvarium with obvious osteoradionecrosis. CT and MRI scan showed full-thickness skull bone necrosis and thickening of the underlying dura mater. A

combined neurosurgical/plastic surgical craniectomy of the necrotic skull was performed preserving the sagittal sinus but resecting the underlying dura and finding local recurrence on the brain surface. Immediate reconstruction was performed with a free fascia lata graft for dural repair and a large free latissimus dorsi myocutaneous flap for scalp cover. Further radiotherapy was given and also protective head gear with future plans to replace the resected calvarium later when there was no risk of infection. This major surgery was in reality palliative because 2 years later an intracranial recurrence led to his untimely death.

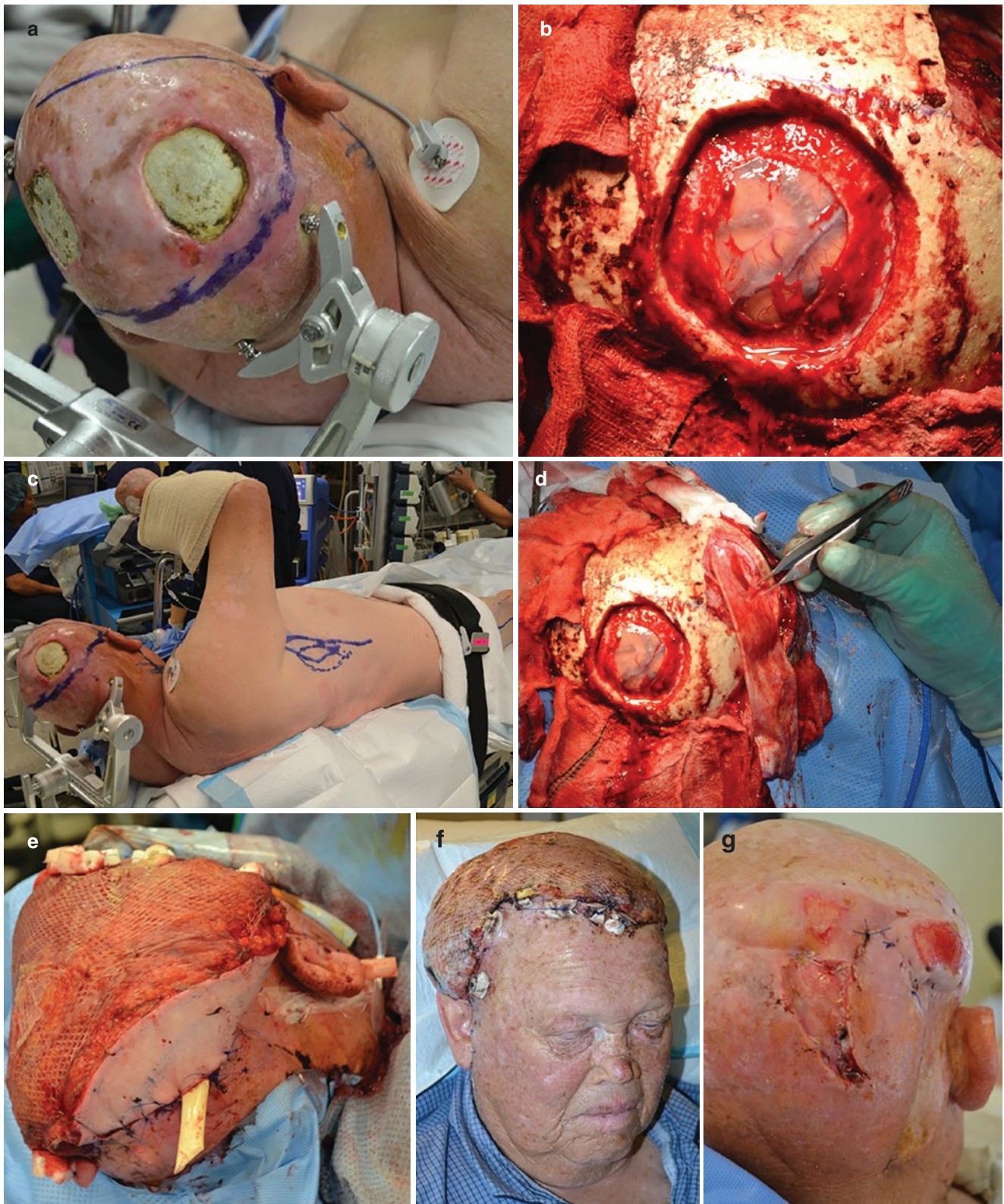


Fig. 5 (a–g) A 70-year-old farmer with congenital ectodermal dysplasia and recurrent SCC in irradiated scalp and calvarium, requiring a cranial resection and free flap reconstruction

5 Melanoma

This 50-year-old man (Fig. 6) was referred with a Breslow thickness 2 mm nodular melanoma of his hair-bearing frontal scalp, despite a benign biopsy 1 year earlier. With a 2 cm wide margin, a full-thickness scalp excision was performed. A large scalp rotation flap based on the left superficial temporal vascular pedicle easily repaired the defect once galeal scoring had been performed to increase the flap elasticity.

Unfortunately as part of his radiological workup for the pT2aN0M1 nodular melanoma, a CT scan confirmed

metastases in his brain, lungs, chest wall and liver. Despite radiotherapy and immunotherapy with a BRAF inhibitor + pembrolizumab (Keytruda), he did not survive his melanoma and succumbed to his disease within 12 months.

Another patient in his 80s (Fig. 7) presented with local multiple cutaneous scalp metastases. These were confirmed as recurrent melanoma despite wide excision of the primary some years before. The lesions were widely excised from his left forehead and frontal scalp, down to the pericranium, and repaired with a split skin graft.



Fig. 6 (a–d) A 50-year-old man with frontal scalp 2 mm thick nodular melanoma, widely excised and the defect repaired with a large rotation scalp flap



Fig. 7 (a and b) An 80-year-old gentleman with cutaneous scalp malignant melanoma metastases, widely excised and defect repaired with split skin graft

6 Basal Cell Cancer

Although BCCs may arise on the scalp, the lead author's long experience has been that they are more common on the forehead and the rest of the face. These BCCs range from nodulocystic well-demarcated local cancers to the widely infiltrating morphoeic/sclerosing subtypes and also multifocal BCCs.

For the larger BCCs, local flap repair is a good option for the CLEAR principle, and the double advancement local flap H-plasty is ideal.

This 39-year-old woman (Fig. 8) presented with a large infiltrating BCC of her right upper forehead near the anterior hairline. It had desmoplastic features on diagnostic punch biopsy. A wide excision was performed, and immediate reconstruction achieved with a large H-plasty local flap design.

The bilateral advancement is designed to be at the subfrontalis plane and Burow's triangles at either lateral end of each advancement flap improve the closure, by reducing tension.

A similar but more caudally located large infiltrating BCC of the lower central forehead/forehead region is shown in this 74-year-old woman (Fig. 9). This had been biopsied 18 months previously and revealed only an actinic keratosis. Clearly de-differentiation into a malignant cancer had occurred. Wide excision and repair with a large H-plasty flap making up half the width of the forehead was designed to be camouflaged in the relaxed skin tension lines of the mid-forehead and supra-orbital margins. Like the previous case, surgery was performed under local anaesthetic with intravenous sedation as a day case. The four lateral Burow's triangles are more clearly marked in the flap design.

The potentially most difficult BCCs of the scalp are the very rare de-differentiating subtypes which recur despite initial complete excision and transform into more aggressive malignancies with metastases. This subtype also known as basosquamous is reported as occurring in the ratio of 1:10,000 standard BCCs [2].

This 63-year-old gentleman (Fig. 10) was referred with a 40 × 35 cm nodular infiltrating BCC of his right fronto-parietal scalp, partially hidden in his hair. Initial wide excision and repair with an inferiorly based temporal scalp rotation flap were performed under general anaesthetic as a day case. Within 6 months a local recurrence again reported as an ulcerated nodular BCC was narrowly excised just caudal to the original primary in the right temporal scalp. A year following the original scalp BCC, he returned with an infiltrating poorly differentiated SCC on his right sideburn region, caudal to the previous nodular BCC recurrence. It was infiltrating downwards into the preauricular tissues.

Wide excision and a further local flap + split skin graft proved unsatisfactory as the SCC had invaded subcutaneous tissue and superficial temporal fascia with perineural invasion. CT scans revealed right parotid and cervical lymph node metastases, so he was referred for wide excision of all previous tumour sites, superficial parotidectomy, neck dissection and a free radial forearm flap repair. There was confirmed nodal and extranodal disease. A large 'beaver tail' of forearm fat was designed to reconstitute the parotid contour over the ramus and angle of the mandible. The radical surgery and reconstruction were followed by chemo-radiation therapy, and he remains well and disease-free at 24 months after completing 18 cycles of immunotherapy pembrolizumab (Keytruda).



Fig. 8 (a–d) A 39-year-old female with infiltrating BCC showing desmoplastic growth pattern before, immediate, 3 weeks and 1 year post reconstruction with H-plasty advancement local flaps

Fig. 9 (a–d) A 74-year-old female with infiltrating BCC glabellar forehead region, widely excised and reconstructed with H-plasty local flap. Micropore taping at 1 month and result at 4 months





Fig. 10 (a–f) Frontal scalp nodular BCC which de-differentiated into a poorly differentiated SCC with perineural invasion and regional nodal metastases to parotid and cervical nodes, when it recurred at 12 months

7 Complication Management

The plastic surgeon must always have a lifeboat when plan A fails [3]. These lifeboats are required for unplanned failures as well as those that make their way eventually for reconstructive salvage. One of MK's surgical mentors once said 'Plastic surgery is the common pathway for lost causes' and was a timely reminder of what reality and time will serve up.

The elderly man (Fig. 11) in his late 70s presented with an infected wound and exposed right parietal calvarium after attempted resection of a recurrent SCC of his scalp by his general practitioner. The failed rotation flap attempt was widely debrided under general anaesthetic and a pericranial flap based on the supraorbital pedicles transposed to cover the exposed skull. After a period of negative pressure wound

dressings as an inpatient, the granulating pericranial flap was covered with a split skin graft, and satisfactory healing achieved.

This 78-year-old man (Fig. 12) was referred by a district nurse with exposed right frontal calvarium and a chronic wound. Three years previously a dermatologist had incompletely excised an SCC from his scalp and repaired the defect with a skin graft. Subsequently radiation therapy for the incomplete SCC excision led to graft failure over the frontal bone. A second dermatologist then attempted reconstruction with an 'S-flap'. My recommendation was for wide excision, removal of osteo-necrotic outer table of skull and repair with a large scalp rotation flap based on the right superficial temporal pedicle, with a skin graft to the posterior secondary defect. He was lost to follow-up.

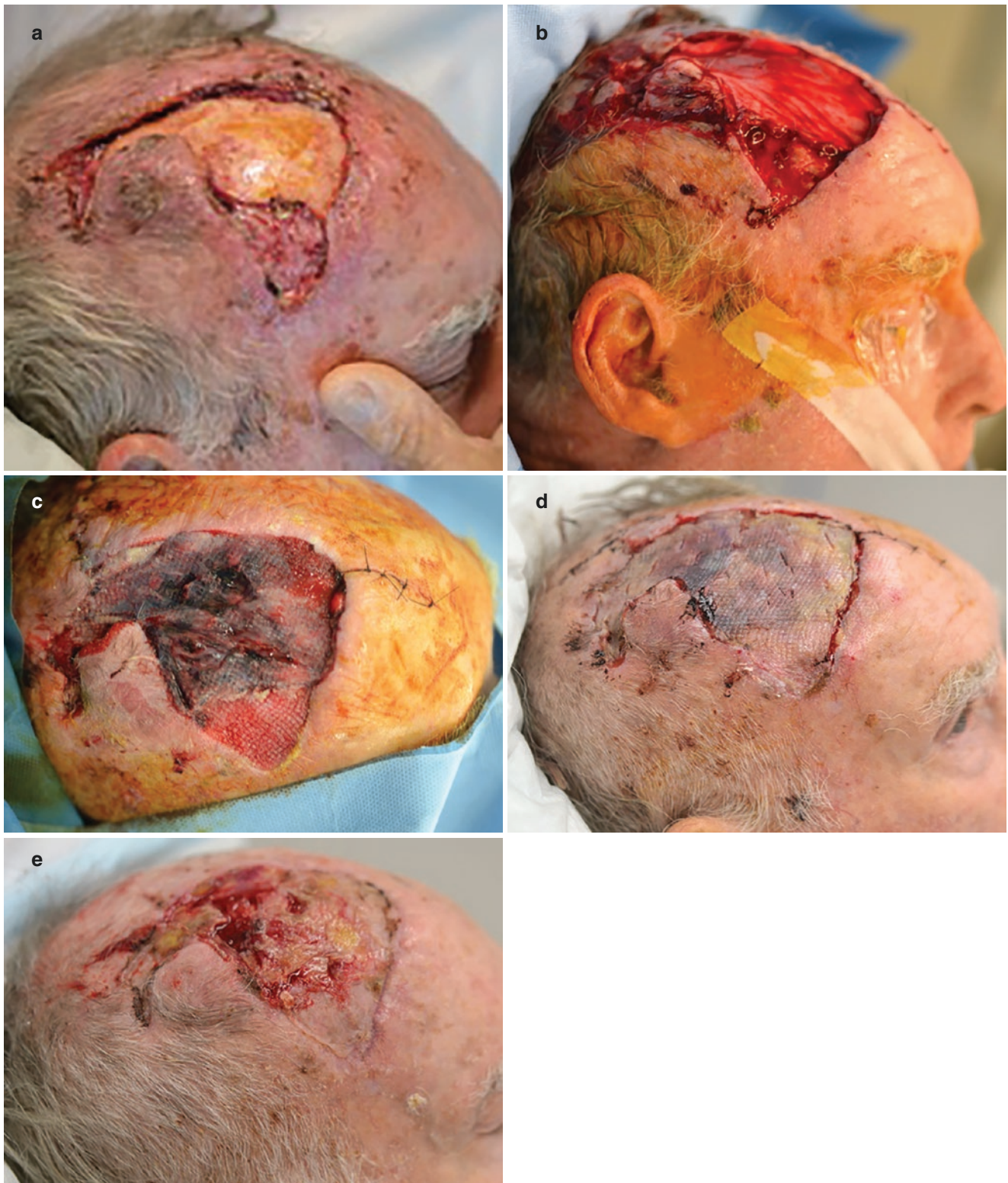


Fig. 11 (a) Post-debridement of original attempted repair, (b) pericranial local flap, (c) after VAC dressing removed from pericranial flap, (d and e) early appearance of split skin graft (partial take)



Fig. 12 (a and b) Complications of incomplete excision, adjuvant radiotherapy, devascularisation and local flap failure, leading to exposed calvarium

8 Controversies

The most significant controversy in recent years is the trend for non-surgeons (GPs and dermatologists) to attempt scalp cancer excision and repair beyond their surgical skill set. This has been documented in Australia/New Zealand and continues to challenge the reconstructive services.

9 Conclusion and Summary

Skin cancer of the scalp and forehead is considered as a combined anatomical and reconstructive challenge. The many and varied options for repairing a cutaneous defect can be a challenging decision pathway for the novice surgeon, dermatologist or GP. For the experienced plastic surgeon with decades of reconstructive practice, the choices are often simply automatic. This is based on many cases, of trial and error, of success and failure, of restoring ana-

tomical repair initially and then refining this into aesthetic reconstruction. The plastic surgical tool kit offers a vast array of options, and ‘to flap or to graft?’ is often the rhetorical question.

Extreme scalp and forehead cancers require a team effort and a multidisciplinary setting. The consequences of mismanagement are considerable both in terms of morbidity and potential mortality. The highest standards of oncological and reconstructive management are only just good enough.

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Extreme Cancer of the Periorbital Region

Stephen G. J. Ng, Michael F. Klaassen, and Earle Brown

Core Messages

- Invasive cancers in the periorbital region have the potential to invade the orbit and cause loss of vision, distant disease and life-threatening complications.
- Resection of cancers in the periorbital region needs to be complete, and reconstruction aimed to preserve normal eyelid and visual function.
- Optimal management is achieved by a multidisciplinary team (MDT).
- Depending on the clinical situation, retaining an eye's vision can take priority over optimal disease control or vice versa.

1 Introduction

Extreme cancers of the periorbital region are rare but an even greater challenge that often requires the expertise of an MDT. Dr. Jack Mustardé (1916–2010) initially an ophthalmologist before retraining as a plastic surgeon in Britain during the Second World War emphasised the complex structures of the small but vital eyelids.

Eyelids are multilaminar but for surgical purposes are considered as bi-laminar structures composed of an anterior lamella of skin and orbicularis oculi muscle and a posterior lamella of tarsus lined by conjunctiva. Unique structures in the eyelids include the elevators of the upper eyelid. The upper eyelid contains Muller's muscle and the levator aponeurosis arising from the levator palpebrae superioris.

Analogous to the levator aponeurosis in the lower eyelid is the capsulopalpebral fascia, which lowers the eyelid on contraction of the inferior rectus muscle. The orbital septum is a fibrous, inelastic membrane that arises from orbital periosteum at the orbital rim (the arcus marginalis) and extends to the tarsal plates. Posterior to it are the orbital tissues. Highly organised connective tissue septa are found within the orbit. The periorbital area also contains the lacrimal apparatus consisting of the lacrimal glands and the tear outflow system [1–3].

The periorbital region is a common site for facial cancers due to the high prevalence of ultraviolet light exposure. This varies with ethnicity, latitude and other environmental factors.

Extreme periorbital facial cancers can occur due to patient-related factors including immunosuppression and hereditary conditions such as the basal cell naevus (Gorlin-Goltz) syndrome. Anatomical factors include periorbital tumours invading the adjacent orbit and the lack of intra-orbital barriers to tumour spread after the orbital septum is breached. There is potential for distant tumour spread by pagetoid, lymphovascular and perineural invasion. Another surgical challenge is the difficulty obtaining clear surgical margins in the orbit and around an eye if it is essential in a case to preserve the vision.

Multidisciplinary care is required in extreme periorbital facial cancers due to the eye's location in the orbit, its proximity to the nose, sinuses and intracranial cavity. This includes various surgical specialities: oculoplastic, plastic surgeons, head and neck and maxillofacial surgeons. The input of Mohs surgeons and neurosurgeons can also be required. Medical specialities in the multidisciplinary team include histopathologists, radiologists, radiation and medical oncologists, geriatricians, palliative care physicians, anaesthetists and maxillofacial prosthetic technicians.

Multimodality therapy, e.g. surgical excision coupled with adjunctive radiotherapy, is often required due to the limitations of surgery to obtain clear margins around the orbit. Preservation of vision is always a consideration but often needs to be balanced against treatment to achieve the best oncological result.

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2 Management/Technique

2.1 Multidisciplinary Care

Complex and extreme facial cancer cases may be managed by an experienced surgeon, but ideally the forces of a multidisciplinary team (MDT) should be employed to offer the patient a wide range of experienced opinions and treatment options. With the aid of modern internet audiovisual systems, this can be organised virtually, but it is still mandatory that the patient has a specialist who is their nominated lead provider and with whom all communications and offers of management are coordinated.

Sir Archibald McIndoe (1900–1960) always maintained the principle that connectedness with your patient equals a confident and trusting patient. This holds true for not only the severely traumatised patient but also the patient with an extreme and perhaps even a life-threatening facial cancer.

Each member of the MDT arguably brings a prejudice to the table, based on their specialty of origin and varying years of surgical, oncological and anaesthetic experience. Egos and prejudices are inevitable and should be acknowledged and left out of the final decision-making process.

Young surgeons will gain much from being involved in clinical cases managed over their long careers will also find inspiration and education from this collective environment. The key is finding the balance, the best practice and at all times being patient-focussed with a bedrock of sound surgical and scientific principles.

Plastic surgeons and oculoplastic surgeons will inevitably bring different approaches to the management planning table. For example, the supratarsal skin bipedicle or unipedicle Tripier flap is a common choice for anterior lamella lower eyelid reconstruction (*see* Figs. 10 and 11) used by plastic surgeons since the 1950s. This flap is not commonly used by oculoplastic surgeons. Plastic surgeons are wary about using posterior lamellar tissue from the upper eyelid for lower eyelid reconstruction. On the other hand, oculoplastic surgeons are comfortable using the upper lid tarsal plate as donor material (*see* in Fig. 13 the Hughes tarsoconjunctival flap). Plastic surgeons would also probably rely less on Mohs micrographic excision techniques (predominantly the choice of dermatologists) or the laissez-faire philosophy of allowing an eyelid defect to heal by cicatrization and secondary intention. Oculoplastic surgeons utilise these techniques routinely. Plastic surgeons are driven perhaps obsessively by the mantra of the late Sir William Manchester (1913–2001) who often stated ‘that in plastic surgery, perfection is only just good enough’ [4]. The key is for all multidisciplinary

team members to work collaboratively, utilising its philosophy of inclusiveness and diversity, to achieve the best result for the patient.

The important steps for either the individual surgeon or MDT of which he or she is a member are tumour staging and determining a treatment plan for each patient considered.

2.2 Staging

According to Sir Harold Gillies’ second fundamental principle ‘diagnose before you treat’, the first step is to obtain a diagnosis with an incisional biopsy. Special cases encountered in the periorbital region are sebaceous gland carcinomas and cutaneous melanomas. In the former, it is mandatory to do a full-thickness (wedge resection) eyelid biopsy to detect pagetoid intraepithelial invasion. Conjunctival biopsies are also used by many surgeons to detect pagetoid conjunctival epithelial invasion in otherwise normal-appearing conjunctival tissue [5, 6]. Suspected nodular melanomas require an excision biopsy to determine the Breslow thickness. Further treatment will then include wide local excision and staging.

Once the diagnosis is established and to detect loco-regional and distant metastases, the management may include a sentinel lymph node biopsy and radiological assessment including computed tomography scanning of the head, neck and beyond. Magnetic resonance imaging (MRI) is used to image soft tissue disease and detect perineural invasion. Positron emission computed tomography (PET CT) also has a role in staging of periorbital tumours. The expertise and anatomical insights of an experienced head and neck radiologist are pivotal in the diagnosis and surgical planning, which are illustrated in Chap. 4 ‘Applied Facial staging system’ [7].

Based on a discussion with an MDT, management options including surgery, reconstruction, radiotherapy, immunotherapy, chemotherapy and palliation can then be presented to the patient and their family. A clear goal must be established—whether treatment is for cure or palliation.

3 Treatment

3.1 Margin Control in Tumour Excision

In facial basal cell carcinomas, excision with a 4 mm margin has been shown to have up to a 95% cure rate [8]. However other authors reported that in 54% of primary tumours removed with a 3–4 mm margin of normal-appearing eyelid

tissue, frozen sections demonstrated tumour in at least 1 margin [9]. In a study using frozen section margin control in eyelid basal cell carcinoma, after 5 years a 1.8% recurrence rate was reported [10].

Mohs micrographic surgery (MMS) can be employed to excise non-melanoma tumours in the periocular region. Mohs reported 5-year cure rates of 99% in 1773 cases of basal cell carcinoma and of 98.1% in 213 cases of squamous cell carcinoma of the eyelids [11]. In a large prospective, multicentre Australian case series, the 5-year basal cell carcinoma recurrence rates were 1.4% for primary tumours and 4% for recurrent tumours [12]. For squamous cell carcinomas, the corresponding 5-year recurrence rates were 2.6% and 5.9% [13].

In the periocular region, to minimise disruption to the eye and the vision, a key consideration in tumour management is to conserve as much as possible of the conjunctiva, eyelid tissue, palpebral ligaments and the lacrimal outflow system. Narrow margins are possible with MMS and therefore it maximises tissue conservation. Plastic surgeons would take an alternative view, based on the wide range of reconstructive options they can offer. Therefore, for plastic surgeons, the size of the periorbital defect is not a concern.

At the medial canthus, the anatomical barrier to orbital invasion, the orbital septum, is deficient. If tumours are not completely excised, orbital invasion can result. The high cure rate from MMS means it is strongly indicated for excising medial canthal tumours. Plastic surgeons would favour wider surgical margins and immediate reconstruction with like tissue, instead of MMS.

The cost of MMS, compared with other techniques of margin control, has been cited as a significant limitation for its use. When recurrences are taken into account, the cost is comparable to multiple surgical procedures over many years [14]. The cost can potentially be reduced when Mohs surgeons are co-located with other members of the multidisciplinary team. In common with other methods of margin control, MMS cannot provide margin control for tumours that have invaded orbital fat.

In response to the historical limited availability of MMS services, several authors have proposed alternative margin control techniques [15, 16].

A key advantage of MMS is the separation of tumour excision and eyelid reconstruction. The Mohs surgeon will remove periocular tissues containing tumour without needing to be concerned about how the eyelid will be reconstructed. Similarly, the reconstructive surgeon can proceed without concerns about tumour clearance. When a single surgeon performs tumour excision and then reconstruction, the oncological result can be compromised. The periocular region is the ideal location for Mohs surgeons and reconstructive surgeons to collaborate and provide optimal oncological and reconstructive outcomes.

3.2 Surgical Treatment

Surgical treatment is multidisciplinary with the principles of CLEAR and DRAPE (Complete Local Excision + Aesthetic Reconstruction/Delayed Reconstruction After Pathology Examination). The concept of DRAPE was coined by Professor Felix Behan FRACS, in his pioneering work describing the anatomy, physiology and clinical application of the keystone perforator island loco-regional flap [17]. The concept of CLEAR was an original idea by Klaassen when compiling a book with Dr. Earle Brown, to aid plastic surgical trainees preparing for their final professional exams. It was a conceptual framework around which to organise thought processes in considering any common skin cancer case, in response to the Mohs concept advocated by dermatologists, and it dovetails conveniently with the DRAPE concept. No matter where the surgeon is practising, these and other fundamental principles will give a clear and reliable guideline to make the best decisions for the patient [18].

Special considerations in the management of periocular facial tumours are below.

3.2.1 Vision

In the management of periocular tumours, the eye and vision are crucial considerations. An ophthalmic assessment is required to assess the vision in both eyes. If due to treatment of a periocular tumour, the vision in an eye is likely to be compromised, it is important to assess the vision in the contralateral eye. To maximise visual function, the contralateral eye's vision may need to be maximised with spectacles or surgery (e.g. cataract surgery) prior to treatment of the periocular tumour. If one eye must be sacrificed to optimise the oncological result, an ophthalmologist can advise on the loss of binocularity. This is to enable safe mobility, returning to driving and other activities such as operating machinery.

3.2.2 Structural Considerations

To maintain vision, it is important to note the role of the periocular tissues in maintaining a healthy ocular surface, the eyelids' role in preventing mechanical damage and the lacrimal apparatus' role in tear drainage.

3.2.3 Tears

The ocular surface must be bathed in tears. The tear film is a multilaminar liquid comprised of mucin, aqueous and an overlying oily film that retards evaporation. Aqueous tears are secreted by the lacrimal gland and accessory lacrimal glands scattered through the conjunctiva. Mucin-secreting glands are located in the conjunctival epithelium. The eyelid meibomian glands in the tarsal plates secrete the tear's oily component. Tears deliver dissolved oxygen to the corneal epithelium.

Tears have a protective function to dilute noxious fluids and wash away foreign bodies. If the tear film is compromised, adverse effects range from chronic ocular irritation, drying of the ocular surface with secondary reflex tear hypersecretion and epiphora, reduced vision due to glare, loss of contrast and exposure keratitis. In severe cases corneal ulceration, scarring and permanent vision loss can occur.

In some cases of facial palsy (e.g. due to cerebellopontine angle syndrome), there is concomitant reduced corneal sensation. Such cases of neuropathic, dry corneas have a high risk of decompensation leading to corneal perforation, infection and irretrievable loss of vision.

3.2.4 Blinking

Passive blinking from frequent reflex contraction of the orbicularis oculi spreads the tear film across the ocular surface. Blinking is the key component of the 'lacrimal pump' that forces tears medially to the lacrimal puncta and lacrimal outflow system. Altered passive blinking frequency or amplitude can be caused by eyelid scarring or ill-suited reconstructive techniques. The resultant lagophthalmos (incomplete eye closure) and ocular surface drying cause chronic irritation, corneal scarring and possible loss of vision. The blink reflex is crucial for protective rapid eye closure and the 'sweeping' of foreign bodies from the corneal surface.

3.2.5 Eyelid Posture

Upper eyelid ptosis, causing visual obstruction, can occur in upper eyelid reconstruction if a bulky graft or flap is used or the medial or lateral ends of the eyelid are pulled inferiorly. A ptotic eyelid also affects vision by distorting the cornea and inducing astigmatism.

After lower lid reconstruction, a common complication is ectropion. It results from cicatrisation of the eyelid's anterior lamella. If the posterior lamella is also involved, lower eyelid retraction results. Mechanical ectropion can also occur due to a bulky lower lid reconstruction that distracts the eyelid away from the ocular surface. Ectropion and lower eyelid retraction result in varying degrees of corneal exposure and lagophthalmos. The resulting evaporative dry eye causes chronic ocular irritation, mucus over-secretion, exposure keratitis and secondary hypersecretion of tears. Compromised blinking disrupts the lacrimal pump. Stasis of tears occurs in the trough formed between the ocular surface and an ectropic eyelid. This causes chronic conjunctivitis and epiphora.

The medial palpebral ligament consists of an anterior and a posterior limb. It is the latter which inserts into the posterior lacrimal crest to pull the lid posteriorly so that the lower lid sits against the anterior surface of the eye. (See in Complication Management—Ectropion.)

If the lid margin is distorted, the eyelashes can become misdirected (trichiasis) and abrade the ocular surface, causing chronic irritation, corneal scarring and loss of vision.

In cases of posterior lamellar cicatrisation and loss of the lid margin mucocutaneous junction, keratinised skin and vellus hairs can also abrade the eye. In addition, loss of the protective function of the lashes can occur, further compromising the blink reflex.

3.2.6 The Periorbital Tissues' Mechanical Protective Function

The periocular tissues have a protective mechanical function for the eye. An intact orbital rim protects the eye from direct mechanical trauma. The eyelids are the eyes' most important protective barrier. Bell's phenomenon consists of reflex upwards eye rotation with reflex blinking. It protects the cornea from mechanical trauma. If it is absent (10% of otherwise healthy persons) or inverted, an eye with compromised blinking is at greater risk of corneal damage and visual loss.

3.2.7 Tear Drainage

If tears are not able to drain from the eye via the tear outflow system, epiphora results. Depending on the site of the obstruction, chronic conjunctivitis can also occur due to stasis of tears in the conjunctival and/or lacrimal sac. Significant visual disability can result and have a significant adverse effect on a patient's quality of life. If the nasolacrimal duct is obstructed, stasis of tears in the lacrimal sac occurs. Epiphora occurs and in some cases bacterial colonisation, causes chronic or acute dacryocystitis. In severe cases, abscess formation and facial cellulitis can occur. In extreme cases, or if there is delayed treatment, orbital cellulitis and even cavernous sinus thrombosis can occur. Nasolacrimal duct obstruction can be corrected by a dacryocystorhinostomy.

3.2.8 Orbital Invasion by Facial Tumours

Facial skin tumours invade the orbit by direct spread through the orbital septum or perineural invasion. In the post-septal orbit, there are no anatomical barriers to tumour spread. Due to the ultrastructure of the orbital fat, it is not possible to obtain histologically clear margins.

Furthermore, it is not generally possible to remove a significant amount of orbital soft tissue without damaging the extraocular muscles, the intermuscular septa and intraorbital nerves and blood vessels. Invariably the result is altered vision and/or disabling diplopia. Therefore, the standard approach for addressing intraorbital spread of facial skin cancers is orbital exenteration.

Sacrificing a seeing eye is never an easy decision but must sometimes be considered in extreme periorbital cancer cases.

Exenteration removes, within the periorbital envelope, the anterior two thirds of the orbital tissues and the eye. Piecemeal removal of the posterior orbital soft tissues is then performed. Adjunctive radiotherapy is used postoperatively to treat microscopic disease.

3.2.9 Perineural Invasion

Perineural invasion centripetally along the infraorbital and supraorbital nerves is not uncommonly encountered in periorbital squamous cell carcinomas. It can also occur rarely with basal cell carcinomas. Perineural invasion is often heralded by abnormal skin sensations along the distribution of the ophthalmic and maxillary branches of the trigeminal nerve.

3.2.10 Lymphovascular Invasion and Tumour Staging

Anatomically the medial half of the upper and lower eyelids drain to the submandibular nodes. The lateral half of the lids drain to the preauricular nodes. Sentinel lymph node biopsy has been advocated as a staging method in eyelid melanoma, SCC, SGC and Merkel cell carcinomas. The exact correlation between sentinel lymph node biopsy, tumour recurrence rates and patient survival is not yet known [19].

4 Indications

4.1 Medial Canthal Lesions

4.1.1 Basal Cell Carcinoma of the Medial Canthus

The medial canthal region is one of the commonest sites for BCC in the oculoplastic surgeon's/plastic surgeon's clinical practice. It is most important to treat these early and get good clearance. Incomplete excision can lead to recurrence and invasion down the medial side of the bony orbit. This anatomical region with its concave contour acts like a sun trap, and BCCs vary from small to moderate to extensive cancers (Fig. 1). Local flaps from the glabellar region or full-thickness skin grafts are a simple solution for reconstruction.

The glabellar local flap is a variant of the rhomboid flap. It brings thicker forehead and upper lateral nasal skin into the surgical defect. It is an easy flap to raise and transpose into the medial canthal defect after wide excision of the tumour. This surgery is commonly performed under local anaesthetic with or without intravenous sedation (Figs. 2 and 3). Sometimes secondary thinning of the local flap contour is required.



Fig. 1 (a–c) BCCs of the medial canthal region are a common clinical presentation and can be widely excised and the defect repaired with a local glabellar flap, where there is spare skin



Fig. 2 (a–d) A 58-year-old man with 2 cm diameter morphoeic BCC of the left medial canthal region associated with perineural invasion, widely excised with 5 mm margins and reconstructed with glabellar transposition flap. Immediately after conclusion of surgery, 1 month and 16 month views

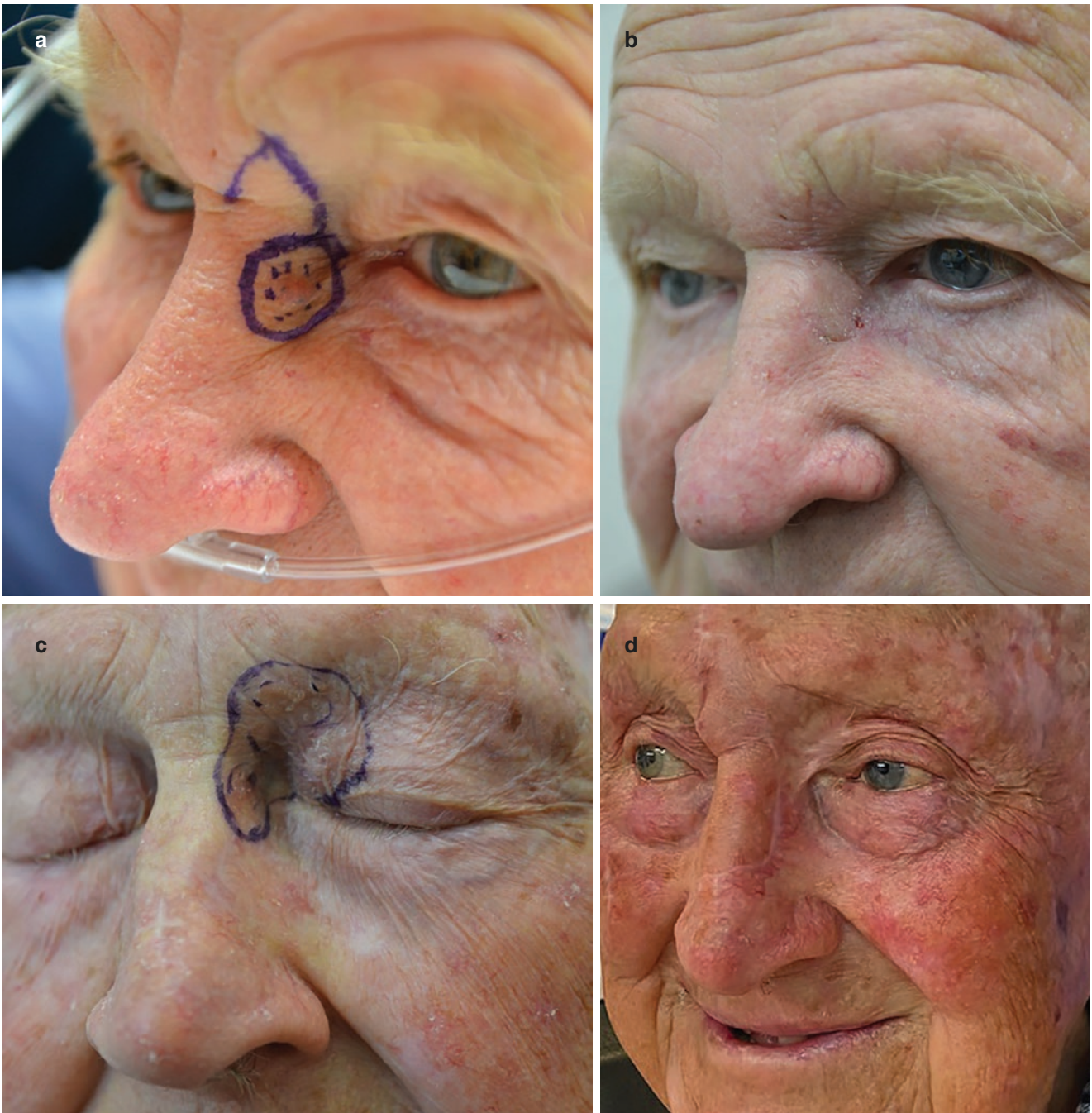


Fig. 3 (a and b) 1-year appearance of glabellar local flap for nodular BCC left medial canthal region in an 85-year-old man. (c and d) 5-year appearance of a full-thickness graft (supraclavicular donor site) in a

85-year-old man, with what was reported as an SCC in situ. He has also had a forehead flap reconstruction of his nasal dorsum for an SCC, 3 years previously

4.1.2 The Rhomboid Flap in Medial Canthal Reconstruction

The rhomboid flap, usually performed under local anaesthetic, is a rapid and effective flap for reconstructing medial canthal defects. Suturing the cut medial lower lid

edge to the lateral edge of the rhomboid flap exerts an upwards traction on the eyelid's anterior lamella. This assists in preventing ectropion (Fig. 4) [20].



Fig. 4 (a–c) An 82-year-old man underwent Mohs micrographic surgery to excise a recurrent medial canthal BCC. The cut medial end of the tarsal plate was reattached to the medial palpebral ligament rem-

nants. The anterior lamellar defect was repaired with a rhomboid flap from the bridge of the nose (outline of flap in blue). Figure 4c shows the result after 3 weeks

4.1.3 Full-Thickness Skin Grafts for Medial Canthal Reconstruction (Fig. 5)



Fig. 5 (a–d) In this 74-year-old man, Mohs micrographic surgery was used to excise a recurrent BCC involving the medial canthus, upper tear outflow system and the medial ends of the upper and lower eyelids. A medial periosteal flap was used to reattach the cut medial ends of the eyelids. A full-thickness skin graft from the upper inner arm was used

to cover the skin defect. Tethering of the medial end of the repaired upper eyelid caused a visually significant ptosis. This was corrected with a medial canthoplasty to release the medial upper lid followed by a Muller's muscle resection to correct the residual ptosis

4.1.4 The Pericranial Flap in Medial Canthal Reconstruction (Fig. 6)



Fig. 6 (a–d) A 76-year-old woman with a defect of the medial canthus, side wall of the nose (with periosteum excised) and medial lower eyelid, after excision of an SCC using Mohs micrographic surgery. The defect of the periosteum at the medial canthus was covered by a forehead pericranial flap. This provides vascularised tissue onto which a skin graft can be placed. A transverse scalp incision just below the hair-

line provided access to form a 3-cm-wide pericranial flap. This was hinged above the supraorbital neurovascular bundle. It was sutured inferiorly to the cut edge of the nasal periosteum. If required, the cut medial ends of the eyelids can be secured to the pericranial flap. A full-thickness skin graft was placed on to the pericranial flap. This is a less bulky alternative to a median forehead flap

4.1.5 Squamous Cell Carcinoma of the Medial Canthus with Orbital Invasion

This 70-year-old man (Fig. 7) with chronic lymphocytic leukaemia was referred as an urgent case from a district hospital, with a neglected and significantly ulcerated SCC of his nasal bridge and left medial canthal regions. The latter appeared to be invading his left medial orbit and was highly vascular. During resection, the tumour was close to the left nasoethmoid bones, and a retrobulbar haematoma occurred in the left orbit, intra-operatively. This was decompressed immediately and his left eye vision was saved. A month later the large right paramedian forehead flap was divided and inset. Further extensive skin cancers of his temples and cheeks bilaterally were also excised (Fig. 7a–d).

His progress after this was predictably downhill. Within a year, he developed metastatic SCC in his left parotid gland as well as recurrent SCC of his right cheek, which invaded his right maxilla and right orbital floor. Despite further radical resection of his right hemiface and free flap reconstruction followed by adjuvant radiation therapy, a year later he became demoralised, withdrew from treatment and died in a palliative care facility just over 2 years after initial presentation. (We acknowledge the contribution of Dr. Nita Ling FRACS from Townsville Hospital, North Queensland, for his follow-up care.)



Fig. 7 (a–d) Invasive SCC left medial canthal/nasal bridge region in a high-risk patient (who had chronic lymphocytic leukaemia) with multiple facial cancers

4.1.6 Lower Eyelid Reconstruction

Sir William Manchester (1913–2001), who founded the Middlemore Plastic Surgical Unit in Auckland in late 1950 after training with Gillies, McIndoe and Mowlem during the 1941–1942 WWII period, was a skilled surgeon in periorbital reconstruction. His influence on the two plastic surgeon authors (MFK and EB) was considerable, and we still follow

his fundamental principles [21]. Figure 8, showing an infiltrating extensive BCC of the left medial canthal region and medial lower eyelid, illustrates the use of a chondro-mucosal septal graft for the posterior lamella and a staged right paramedian forehead flap for the anterior lamella. These images were from his teaching slide collection which cover the 1950s–1970s.

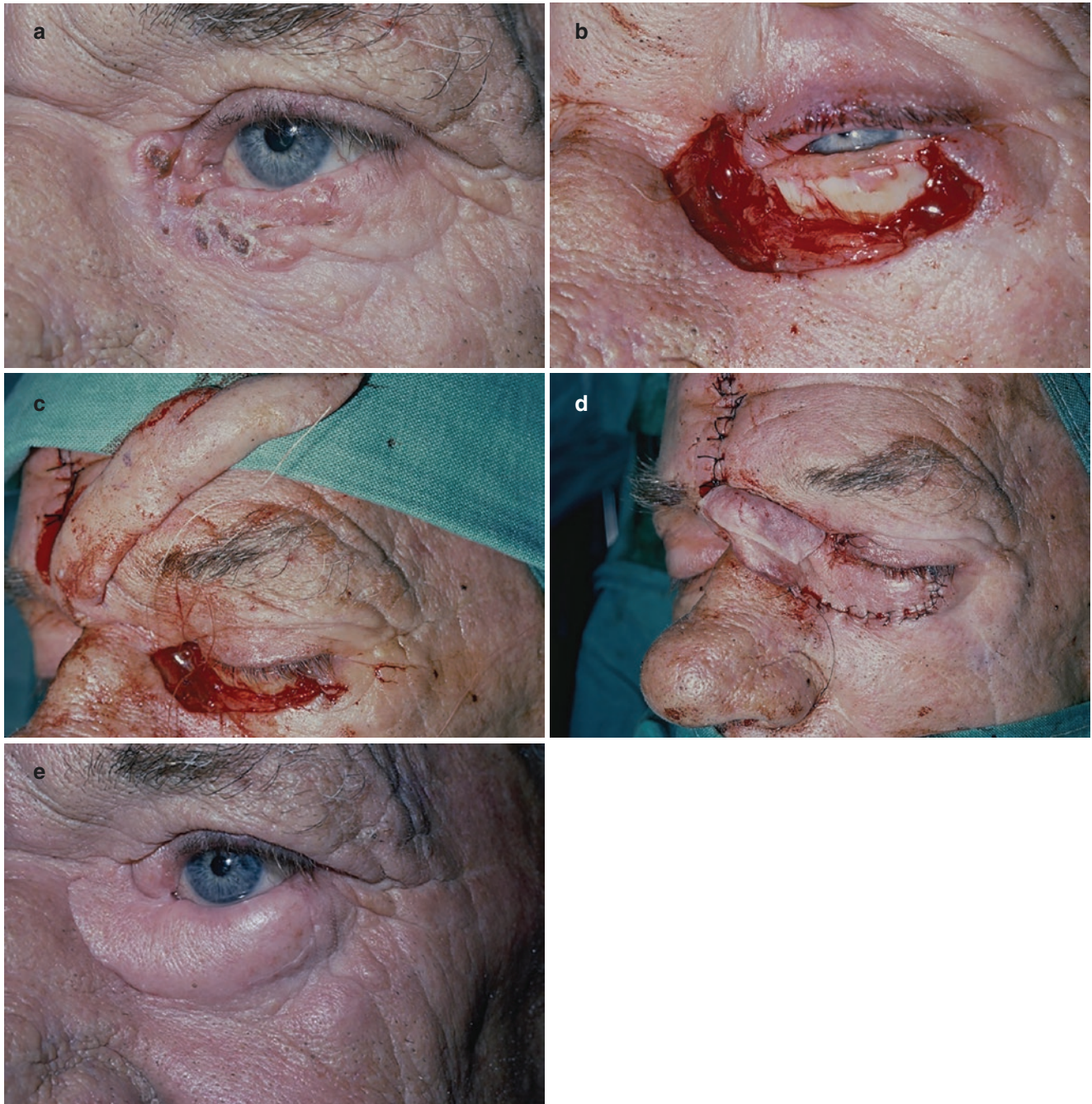


Fig. 8 (a–e) Infiltrating BCC of the left medial canthus and lower eyelid managed in the 1960s by Manchester with wide excision, chondro-mucosal septal graft and staged right paramedian forehead flap (with acknowledgment of the Manchester Archives)

4.1.7 The Lacrimal Outflow System

To prevent epiphora, lacrimal procedures performed at the time of primary surgery are more effective than later secondary procedures. Excision of the punctum or partial excision of a canaliculus can be treated by marsupialisation of the remaining vertical or horizontal part of the canaliculus. Various lacrimal stents can be used to prevent canalicular obstruction if the canalicular wall is breached or a segment of canaliculus is excised. If the canaliculi are unable to be repaired, or the lacrimal sac is partially excised, a glass (Lester Jones) tube can be inserted as a secondary procedure by an oculoplastic surgeon. However, this may not be required if the lid posture approximates the normal lid posture and ocular exposure is minimised, thus reducing drying of the ocular surface and secondary hypersecretion of tears (Figs. 9, 10, 11, 12, and 13).

One of the authors (EB) has had personal experience of a BCC infiltrating his lower eyelid: Dr. Earle Brown's right lower lid BCC, wide excision and repair by Glenn Bartlett FRACS (Fig. 14).

The Tripier bipediced upper eyelid local flap is a staged reconstruction which was championed by Sir William

Manchester. The case illustrated in Fig. 15 is one of his cases from over 60 years ago and emphasises the precision and perfection required for reconstruction of the lower eyelid region [23]. Interestingly, Manchester did not favour the supraorbital Fricke local flap because of its bulkiness.

The patient in Fig. 16 is a 72-year-old woman from a high UV light region and a long history of multiple skin cancers including malignant melanoma and BCC. She presented with a rapidly growing nodular BCC close to her left lower eyelid margin. A full-thickness excision with 4 mm margins was performed under IV sedation and local anaesthetic. The eyelid defect was immediately reconstructed with a lateral cantholysis and a McGregor lateral temporal local flap incorporating a Z-plasty. The healed result is shown at 3 months post-surgery.

For defects of the lower eyelid after excision of lower eyelid lesions, alternative techniques commonly used by oculoplastic surgeons are direct closure (which can be facilitated by lateral canthotomy/cantholysis), the Hughes tarsconjunctival flap (*see* Fig. 17), composite grafts and laissez-faire (*see* Fig. 23).



Fig. 9 Probing of the canaliculi should be performed at the time of medial canthal and eyelid reconstruction to determine if repair is required

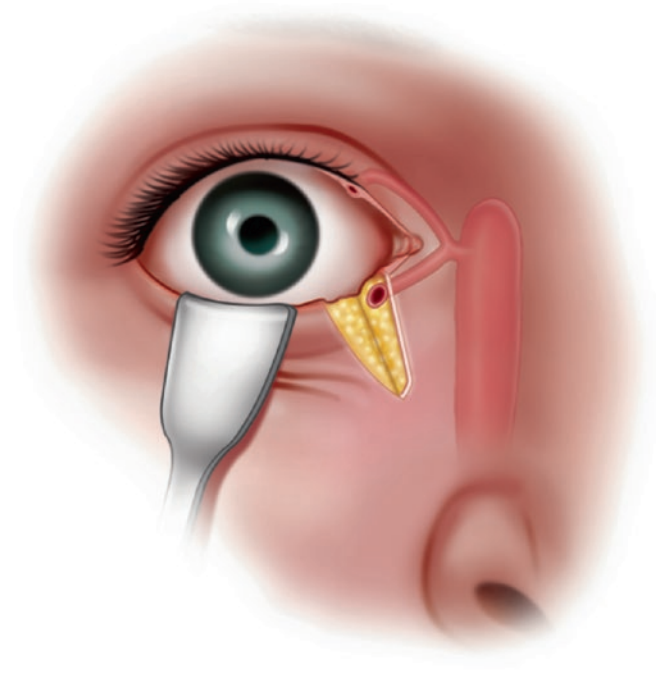


Fig. 10 If the punctum has been excised (and therefore a self-retaining stent cannot be secured), the remaining canaliculus can be marsupialised to maintain tear drainage into the lacrimal sac

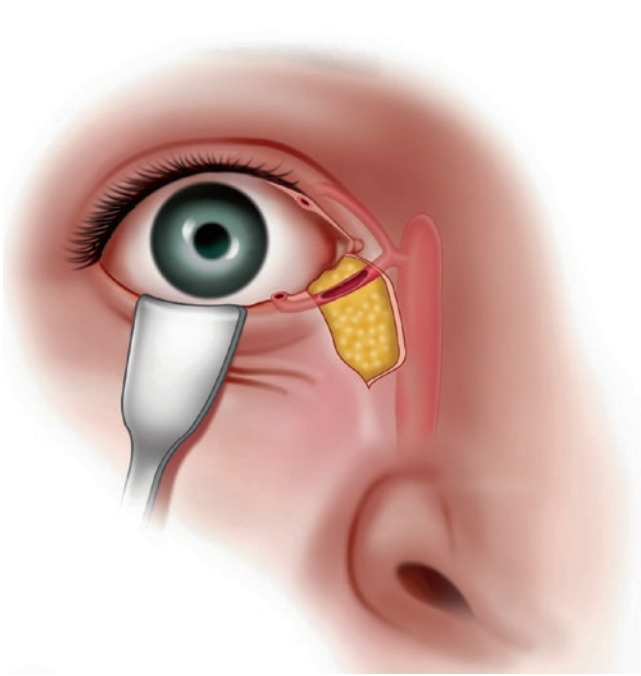


Fig. 11 Treatment of breaches of the canalicular wall or excisions of a segment of the horizontal part of the canaliculus. These are treated by inserting a self-retaining stent and the pericanalicular tissues are apposed (the 'one-stitch' canalicular repair [22])

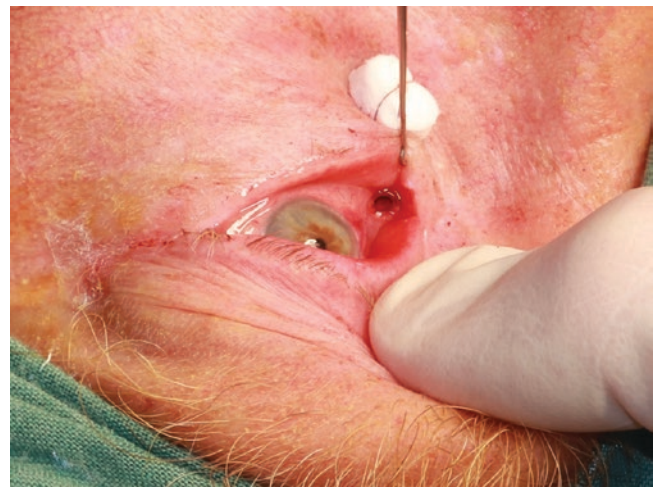


Fig. 13 Lester Jones tube in situ. The superior opening of the tube is visible in the medial fornix

Fig. 12 (a) Mini-Monoka® self-retaining monocanicular stent (FCI S.A.S. Paris, France). (b) A mini-Monoka stent being inserted into an upper canaliculus. (c) A Lester Jones tube (Gunter Weiss Scientific Glassblowing, Hillsboro, USA)

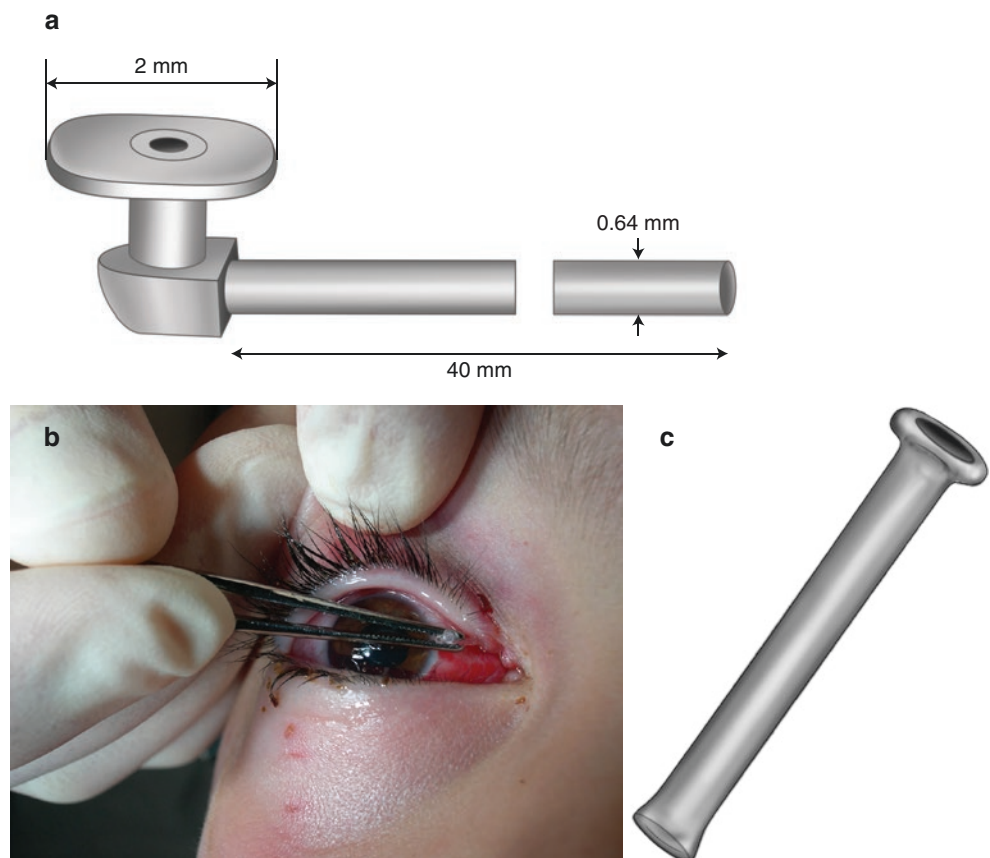




Fig. 14 (a–f) An infiltrating BCC of the right lower eyelid and involving the lower lacrimal punctum, widely excised and repaired with a bipediced upper eyelid Tripier local flap for anterior lamella and a sep-

tal chondro-mucosal graft for posterior lamella. Images show the eyelid margin tumour, early and later postoperative results. There was no epiphora at long-term follow-up

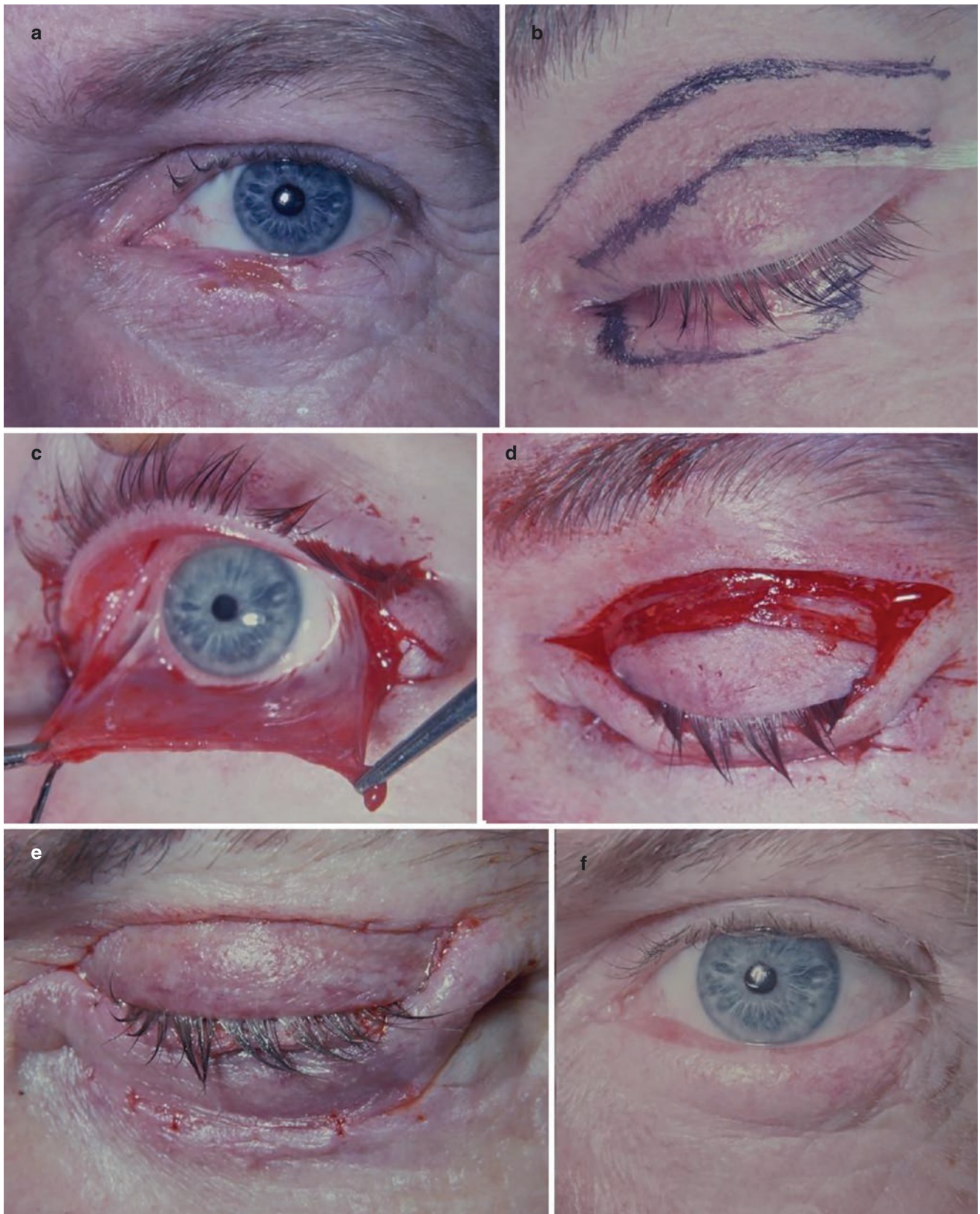


Fig. 15 (a–f) Manchester's case from the 1960s, BCC left lower eyelid widely excised leaving a horizontal full-thickness defect and reconstructed in stages with conjunctival flaps and a bipedicle upper lid Trippier flap (with acknowledgement of the Manchester Archives)

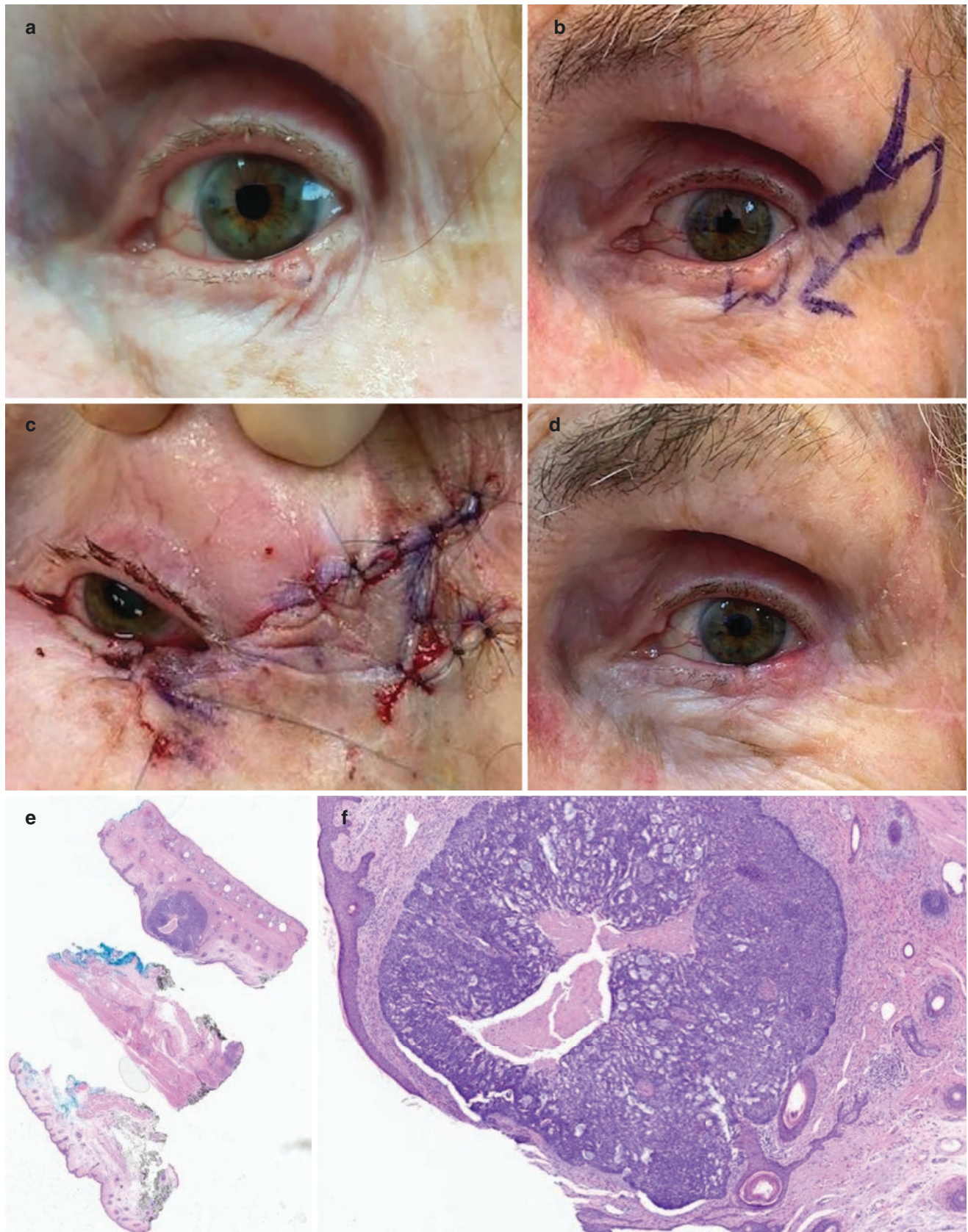


Fig. 16 (a–f) Nodular BCC close to the left lower eyelid margin, widely excised and repaired with a McGregor local flap. Haematoxylin and eosin-stained photo-micrographs (low and high power). Thickness 2.3 mm. Cutaneous margins were 3 mm. Result shown at 3 months

4.1.8 The Hughes Tarsconjunctival Flap in Lower Eyelid Reconstruction

A variety of tissues can be used to replace an eyelid's posterior lamella. Oculoplastic surgeons commonly use the Hughes tarsconjunctival flap [25]. This flap can be performed under local anaesthetic alone or with sedation. It uses the ipsilateral upper eyelid, and a graft does not need to be harvested from a remote site. Alternative remote site free grafts are hard palate, conchal cartilage or nasal septal cartilage. The former's epithelial surface will not abrade the cornea. The latter two grafts must be lined posteriorly by residual conjunctiva. The main disadvantage of the Hughes flap is that the eye is sutured

closed. Another procedure is needed to divide the flap and reopen the eye. However, the second stage can be performed from as little as 7 days after the initial surgery [26]. This flap cannot be used if the operative eye is the patient's only seeing eye.

If the posterior lamellar graft has an inherent vascular supply, as in the Hughes flap, the anterior lamella can be replaced by a full-thickness skin graft. Skin/muscle advancement flaps from residual lower eyelid tissue are also commonly used. If the posterior lamellar graft is a free graft, a pedicle flap must be used, e.g. a skin/muscle advancement flap from the lower eyelid, a Fricke flap, forehead flap or a cheek rotation flap (Fig. 17).

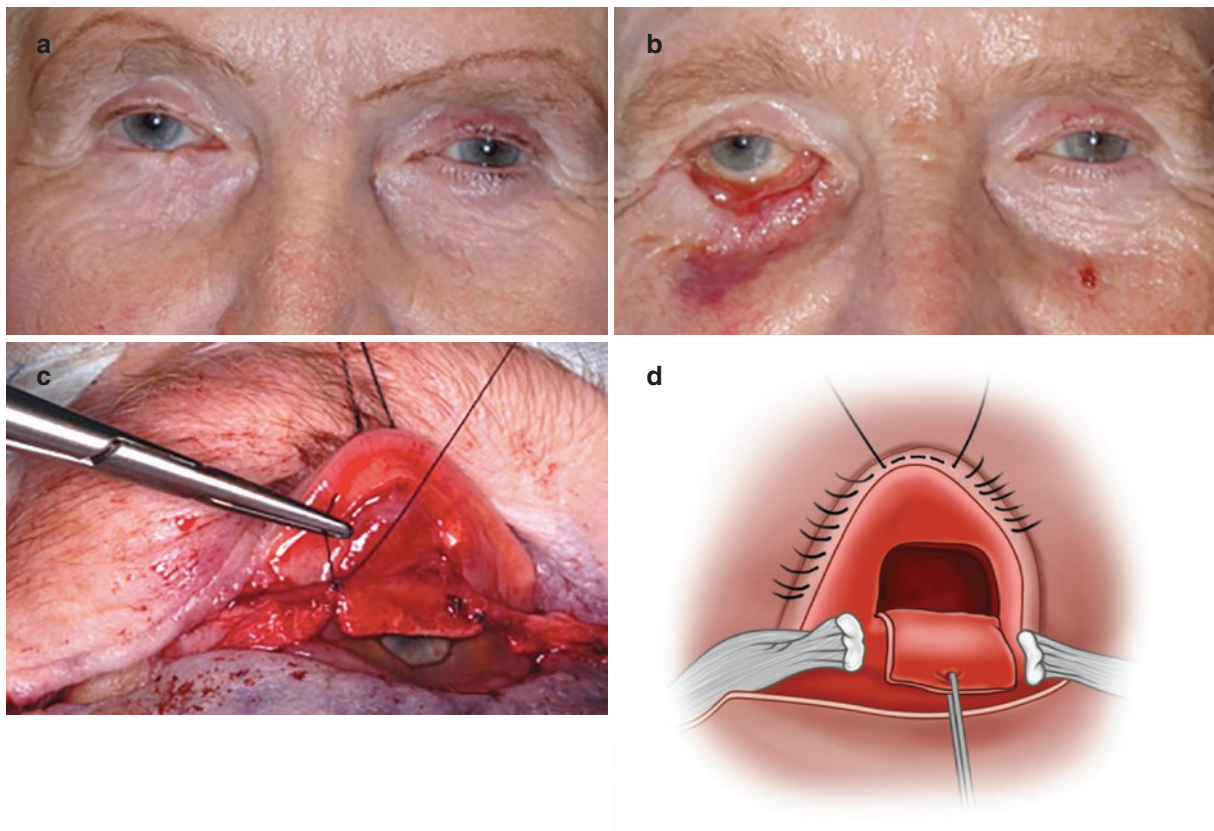


Fig. 17 (a–i) Mohs micrographic surgery was used to excise a recurrent BCC in this 76-year-old woman. The defect involved the whole lower eyelid. The posterior lamella of the lid was reconstructed using medial and lateral periosteal flaps, and a central tarsconjunctival flap 15 mm in horizontal extent (the Maximal Hughes procedure [24]). The

tarsconjunctival flap is harvested from the superior part of the upper lid tarsal plate. The inferior 4 mm of the tarsal plate is left intact. The anterior lamella was reconstructed with a skin/muscle advancement flap. The division of the tarsconjunctival flap was performed after 2 weeks. The new lower eyelid margin is left to granulate

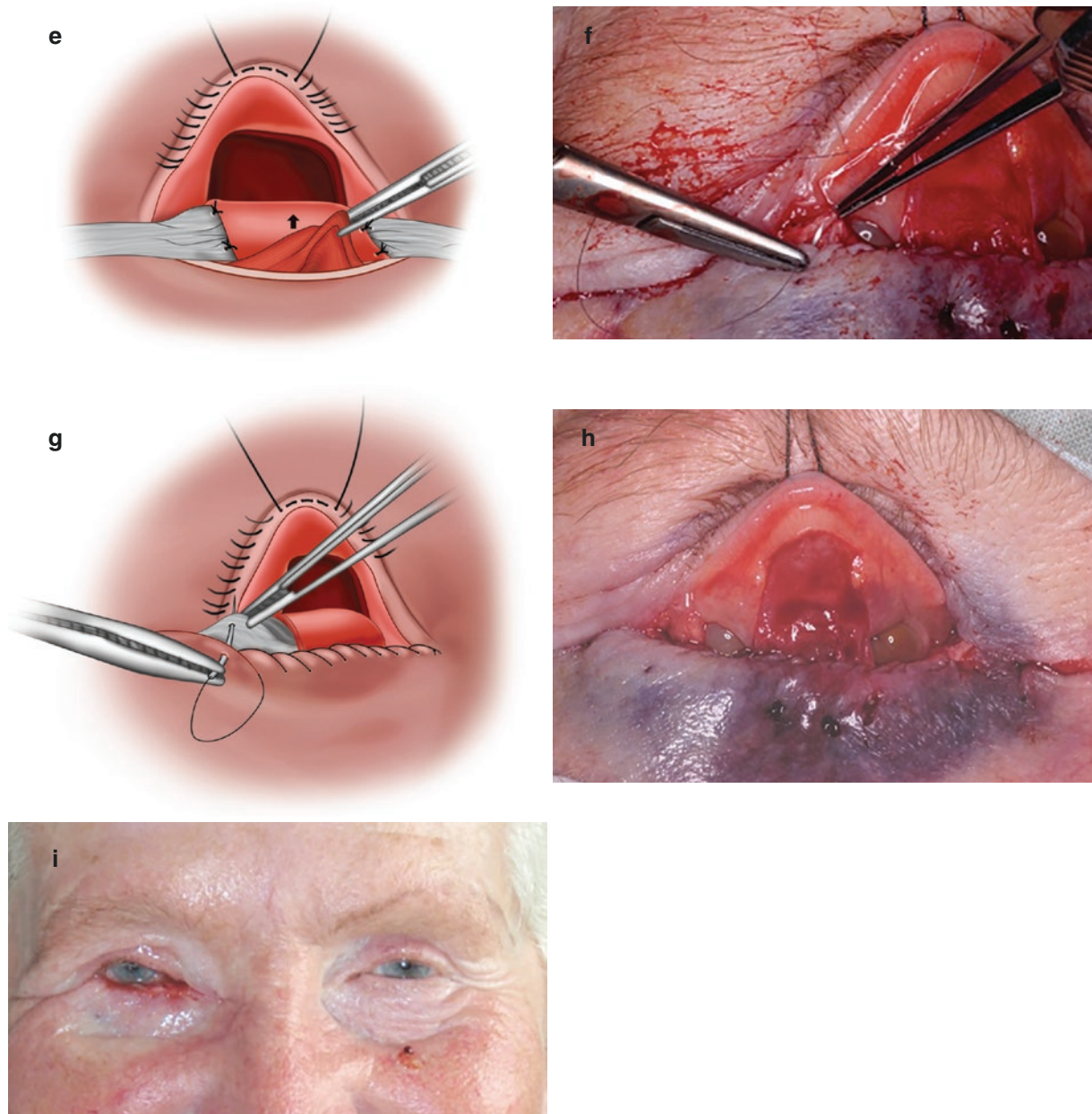


Fig. 17 (continued)

4.1.9 Periosteal Flaps in Eyelid Reconstruction

Periosteal flaps are used to anchor the medial or lateral ends of the lower eyelid if the medial or lateral palpebral ligaments have been excised. They are constructed from the medial and lateral orbital rim periosteum. Access to the periosteum is through a defect or horizontal incisions at the medial and lateral canthi. To minimise ocular exposure, the medial and lateral contour of the eyelids is approximated by hinging the flaps as posterior as possible at the orbital rim.

The medial periosteal flap is hinged at the anterior lacrimal crest, and the lateral periosteal flap is hinged posterior to the arcus marginalis.

A periosteal flap can be horizontally divided to provide anchor points for both the upper and lower eyelids. An upper eyelid periosteal flap must be long enough to allow for upper eyelid excursion and to avoid inducing ptosis.

4.1.10 The Lateral Periosteal Flap (Fig. 18)

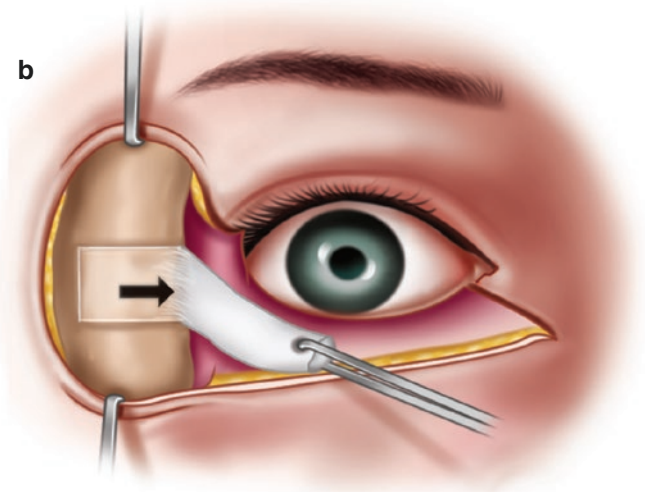
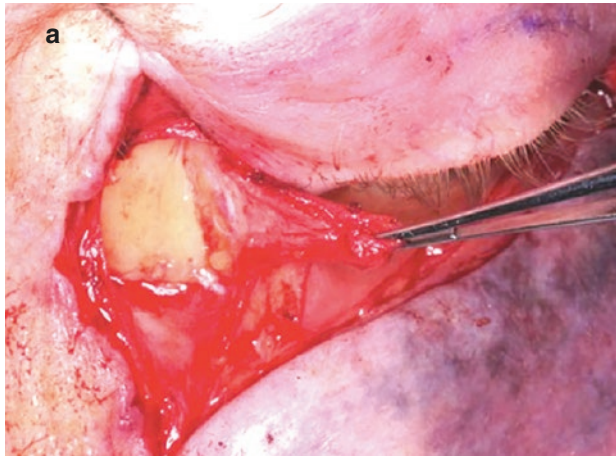


Fig. 18 (a and b) Formation of a lateral periosteal flap. (Author's own diagram)

4.1.11 The Medial Periosteal Flap (Fig. 19)

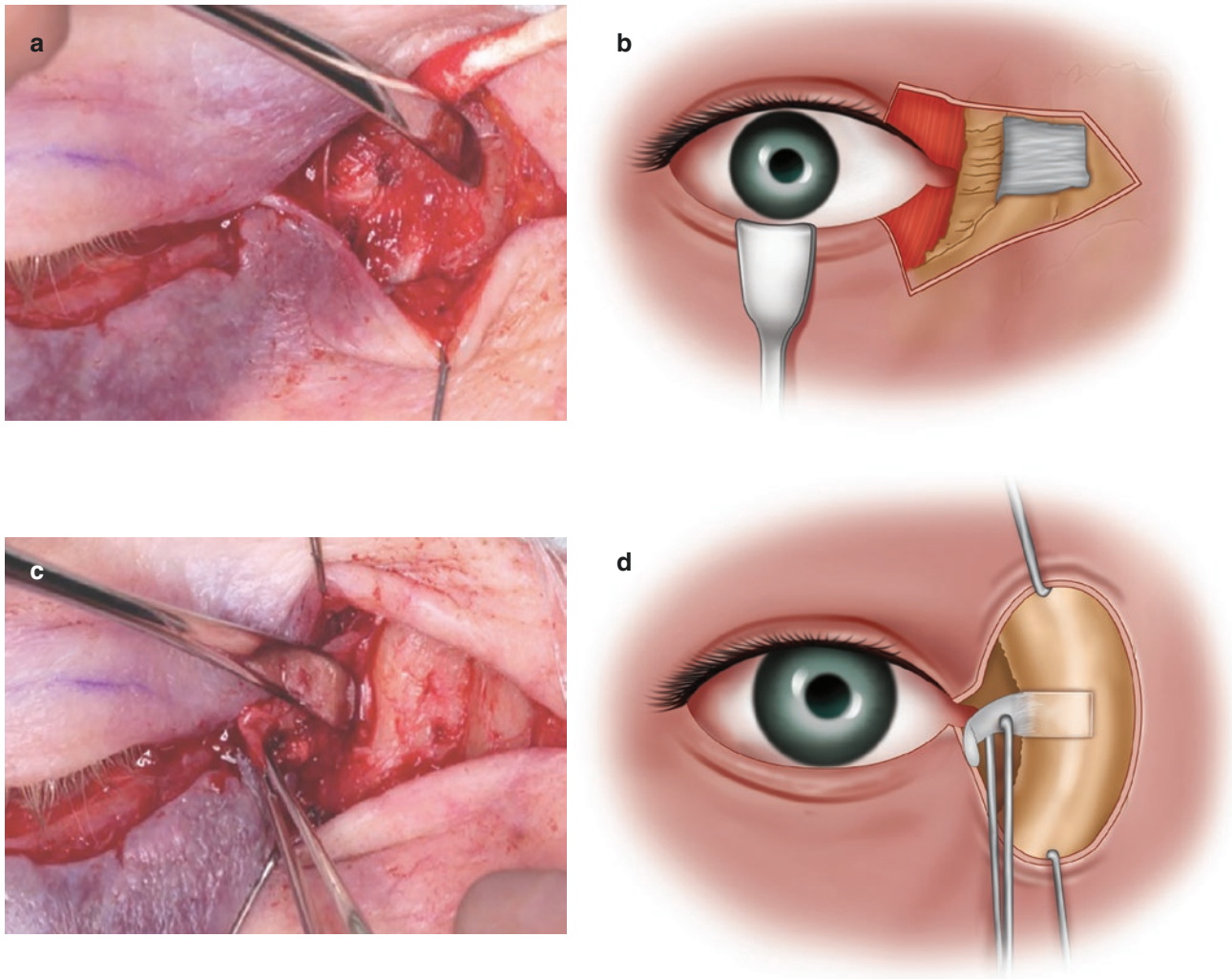


Fig. 19 (a–d) Formation of a medial periosteal flap. (Author's own diagram)

4.1.12 The Mustardé Cheek Rotation Flap in Lower Eyelid Reconstruction (Fig. 20)



Fig. 20 (a–c) A 72-year-old man with severe actinic skin damage and an extensive SCC involving the side of the nose. This was excised using Mohs micrographic surgery. A forehead pericranial flap was used to cover the exposed bone on the sidewall of the nose. The medial cut end of the lower eyelid tarsal plate was then attached to the periosteal flap.

The eyelid was pulled superiorly and medially to prevent postoperative lower lid ectropion. A glabellar flap and a cheek rotation flap were used to cover the medial canthus, side of the nose and lower lid anterior lamella

The cheek rotation flap [1] as described by Mustardé transposes close-matching, adjacent lower lid and periocular skin into lower eyelid defects. It can fill a large anterior lamellar eyelid defect usually in the lateral two-third of the lower eyelid. Disadvantages, due to the extensive cheek dissection, are a risk of damage to the branches of the facial nerve to the

orbicularis oculi muscle, haematomas and induced lower eyelid ectropion. To reduce the risk of postoperative lower eyelid ectropion, the superior edge of the flap is sutured to the periosteum at the lateral orbital rim. This results in an upwards vector of tension on the medial end of the flap (Figs. 21 and 22).



Fig. 21 (a–d) A 78-year-old woman with a Merkel cell carcinoma of the left lower eyelid. This was excised with 6 mm margins. Complete excision was confirmed with conventional tissue processing & histo-

logical examination. A Hughes tarsoconjunctival flap was used to reconstruct the posterior lamella. A Mustardé cheek rotation flap was used to reconstruct the anterior lamella



Fig. 22 (a–d) An infiltrating SCC in an 82-year-old man was excised using Mohs micrographic surgery. A lateral periosteal flap was used to re-attach the detached upper and lower eyelids. The anterior lamella

was reconstructed with a Mustardé cheek rotation flap. Due to the severely sun-damaged, taut skin, part of the secondary defect from the flap was covered with a split-thickness skin graft

4.1.13 Laissez-Faire in Eyelid Reconstruction

A “Less is More” approach for periocular defects can be utilised, and it is often welcomed by patients. The lower eyelid and medial canthus are particularly suitable sites. It can be used when surgery would be hazardous or contraindicated, e.g. patients unsuitable for anaesthesia and extensive surgery due to significant cognitive impairment or systemic health conditions. It can be used in monocular patients if the operative eye is their only seeing eye and reconstructive surgery

can temporarily or permanently disrupt the vision. Disadvantages of laissez-faire, depending on the amount of eyelid involved, include worsening of pre-existing ectropion, eye exposure, irritation, redness, inflammation, discharge and watering. Secondary surgery can be required, e.g. to address hypertrophic scars or lid margin notching. It should be noted that these complications can also occur after eyelid reconstructive surgery.

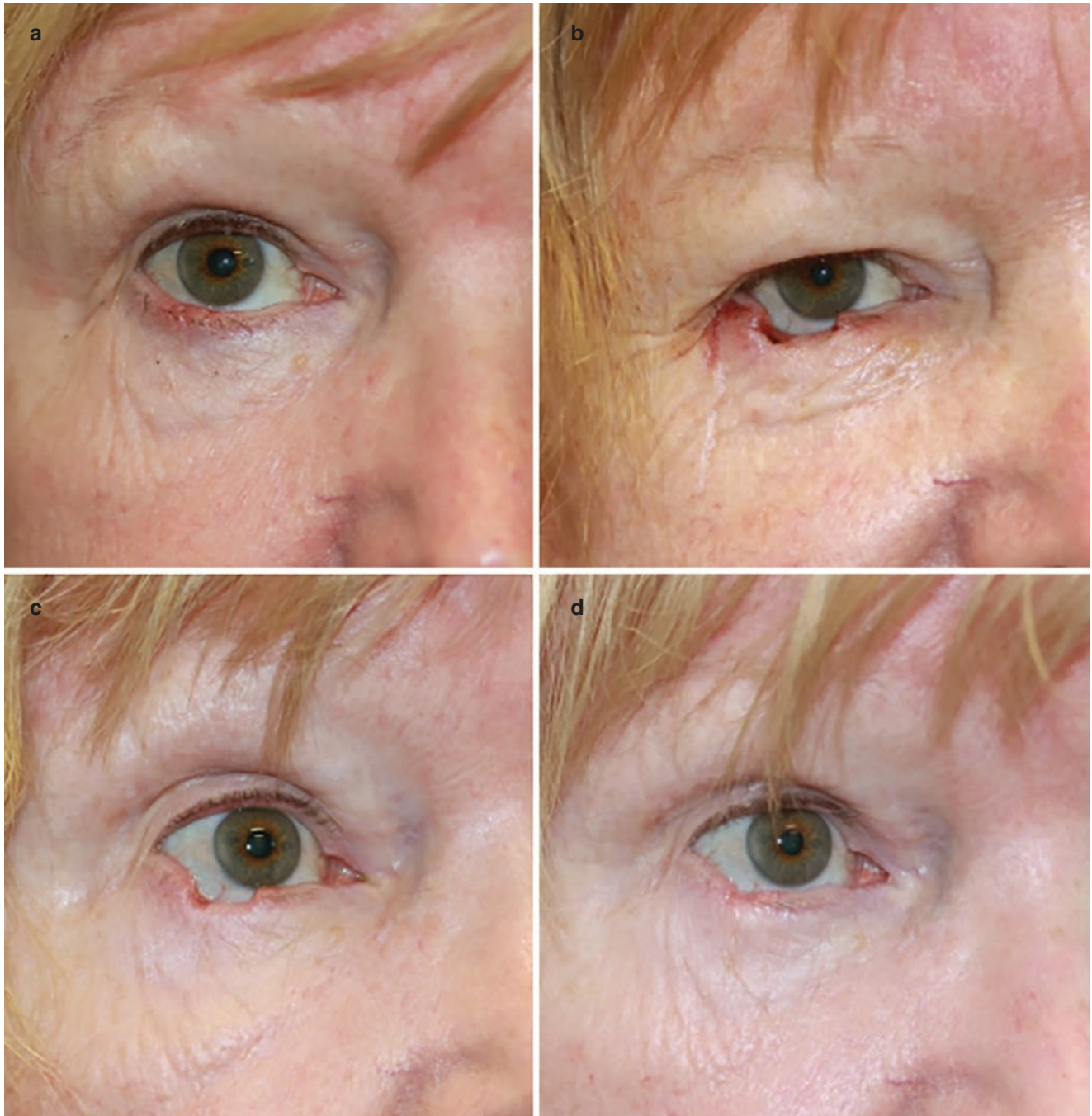
Laissez-Faire for Full-Thickness Eyelid Margin Defects (Fig. 23)

Fig. 23 (a–d) A right lower eyelid margin BCC in a 66-year-old woman was removed using Mohs micrographic surgery. The resulting defect was left to granulate. The lower two photos show the wound after 1 week and 3 weeks

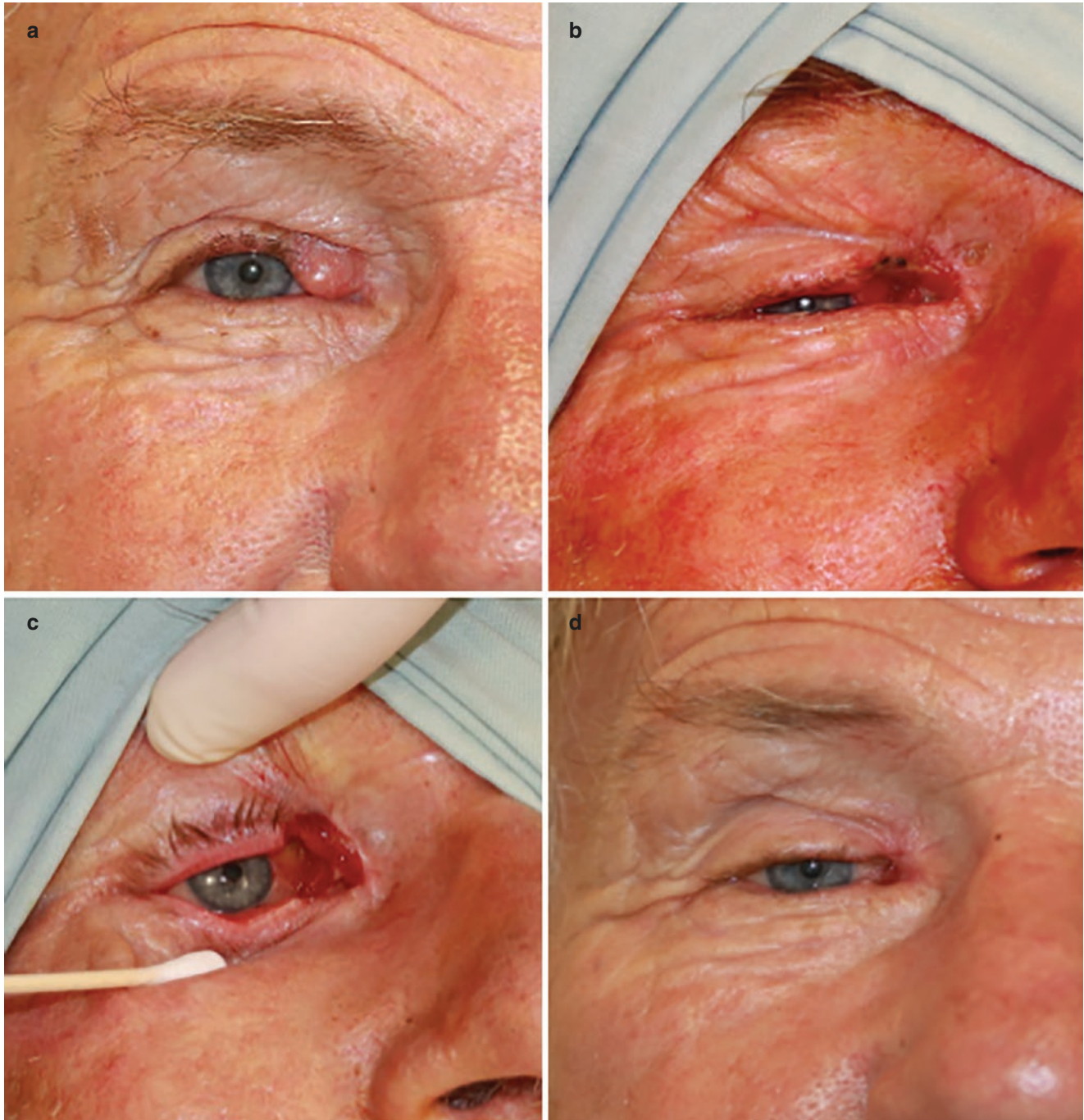
Laissez-Faire for Medial Canthal Defects (Fig. 24)

Fig. 24 (a–d) A 65-year-old man with right upper eyelid sebaceous gland carcinoma (SGC). This was excised with 6 mm margins. Conventional tissue processing and histological examination of the specimen demonstrated the lesion had been completely excised. Reconstruction was undertaken 7 days after excision. In the upper eye-

lid, posterior slips of the medial palpebral ligament were intact. Eyelid closure was not affected. In the lower lid, the canaliculus and medial palpebral ligament were intact and did not require repair. The skin and canthal conjunctival defects healed satisfactorily by granulation

Laissez-Faire for Large Lower Eyelid Defects (Fig. 25)

Loss of an upper eyelid inevitably leads to loss of vision since the upper eyelid has an essential role in maintaining

corneal hydration. However, an eye can retain satisfactory visual function after loss of an entire lower eyelid.

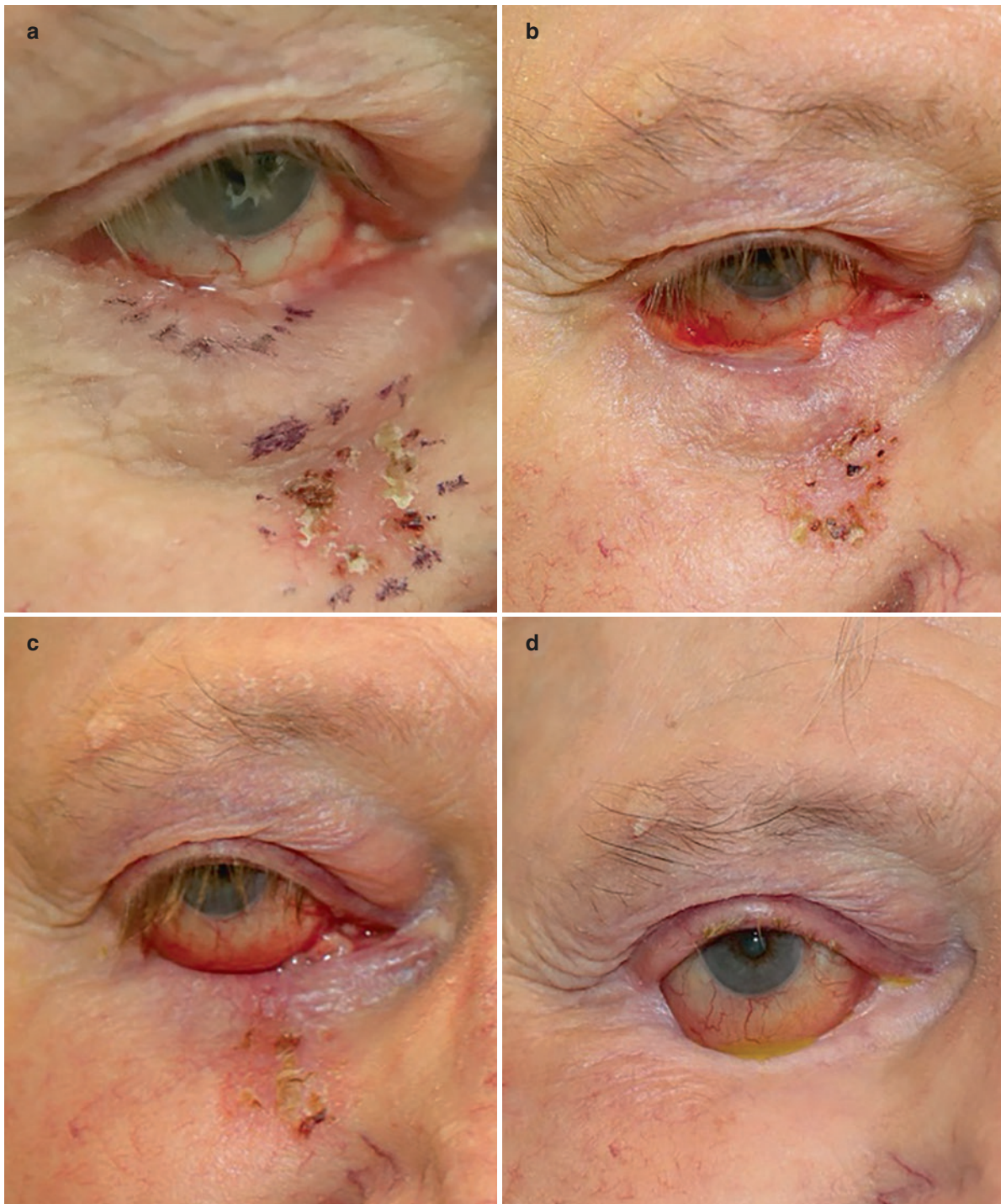


Fig. 25 (a–d) A multiply recurrent lower lid BCC affecting the whole lower eyelid in an 82-year-old man. At the time of Mohs micrographic surgery, tumour was found to be invading the anterior orbital fat. Due to the risk of worsening his pre-existing cognitive impairment, an anaesthetic was considered to be too hazardous so further tumour excision

was not undertaken and the eyelid was left to heal by laissez-faire. Adjunctive radiotherapy was performed after 6 weeks. The vision remained at 6/9 unaided. Exposure and inferior corneal drying were managed conservatively with ocular lubricants

5 Large Upper Eyelid Defects

5.1 Upper Eyelid Reconstruction with the Mustardé Lower Lid Flap

This eyelid-sharing technique described by Mustardé [1] transposes a full-thickness lower eyelid pedicle flap into a moderate-sized upper eyelid defect. After several weeks, the

pedicle is divided in a second stage. Advantages are that it is a single flap of identical eyelid tissue (lined by conjunctiva). It transplants into the defect a normal upper eyelid margin complete with eyelashes. A disadvantage is the temporary closure of the eye and the requirement for a second surgical stage. If the upper eyelid defect involves the medial or lateral commissures, eyelid distortion can occur, and corrective secondary surgery may be required (Figs. 26 and 27).

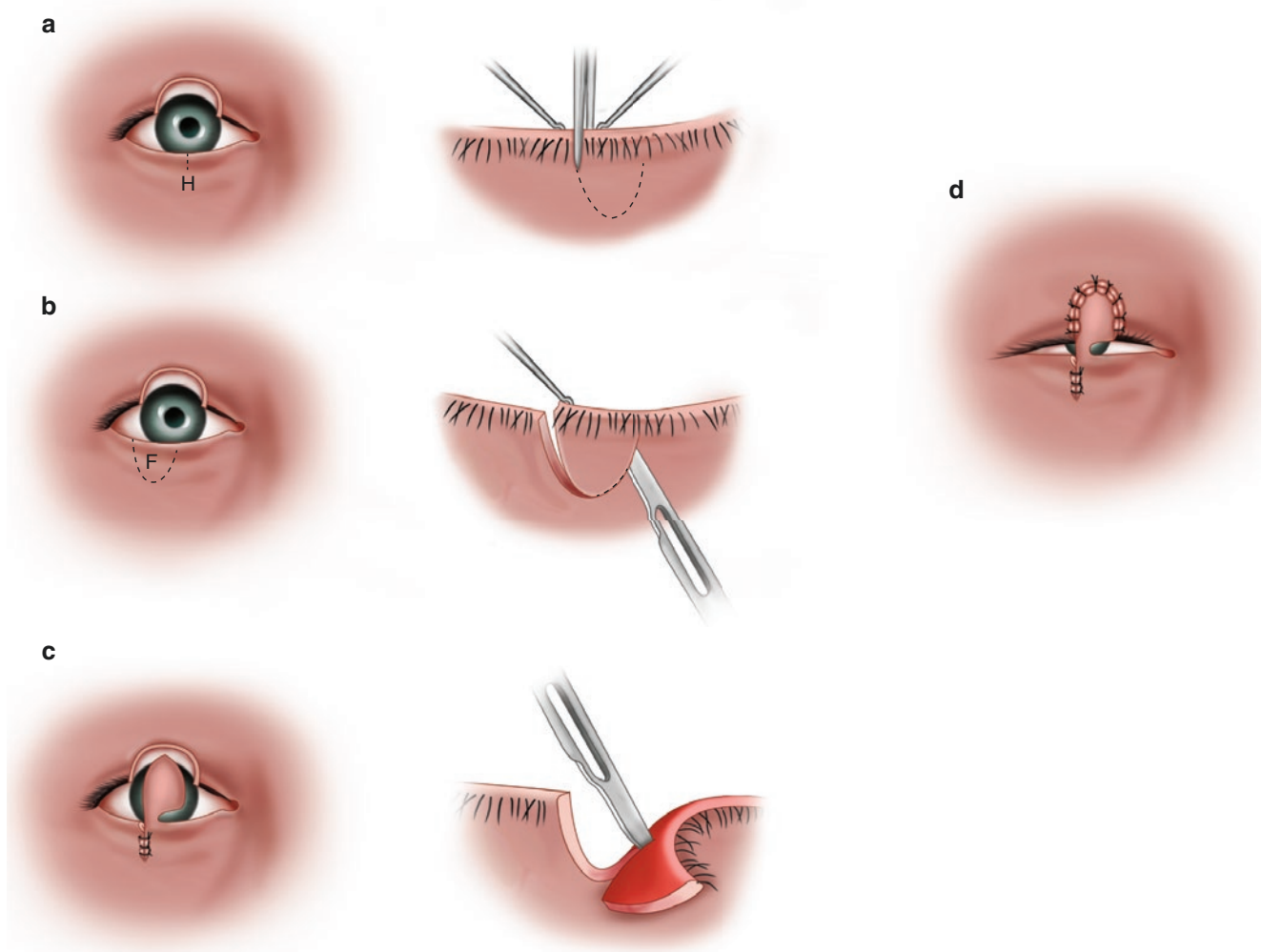


Fig. 26 (a–d) The lower eyelid flap of Mustardé

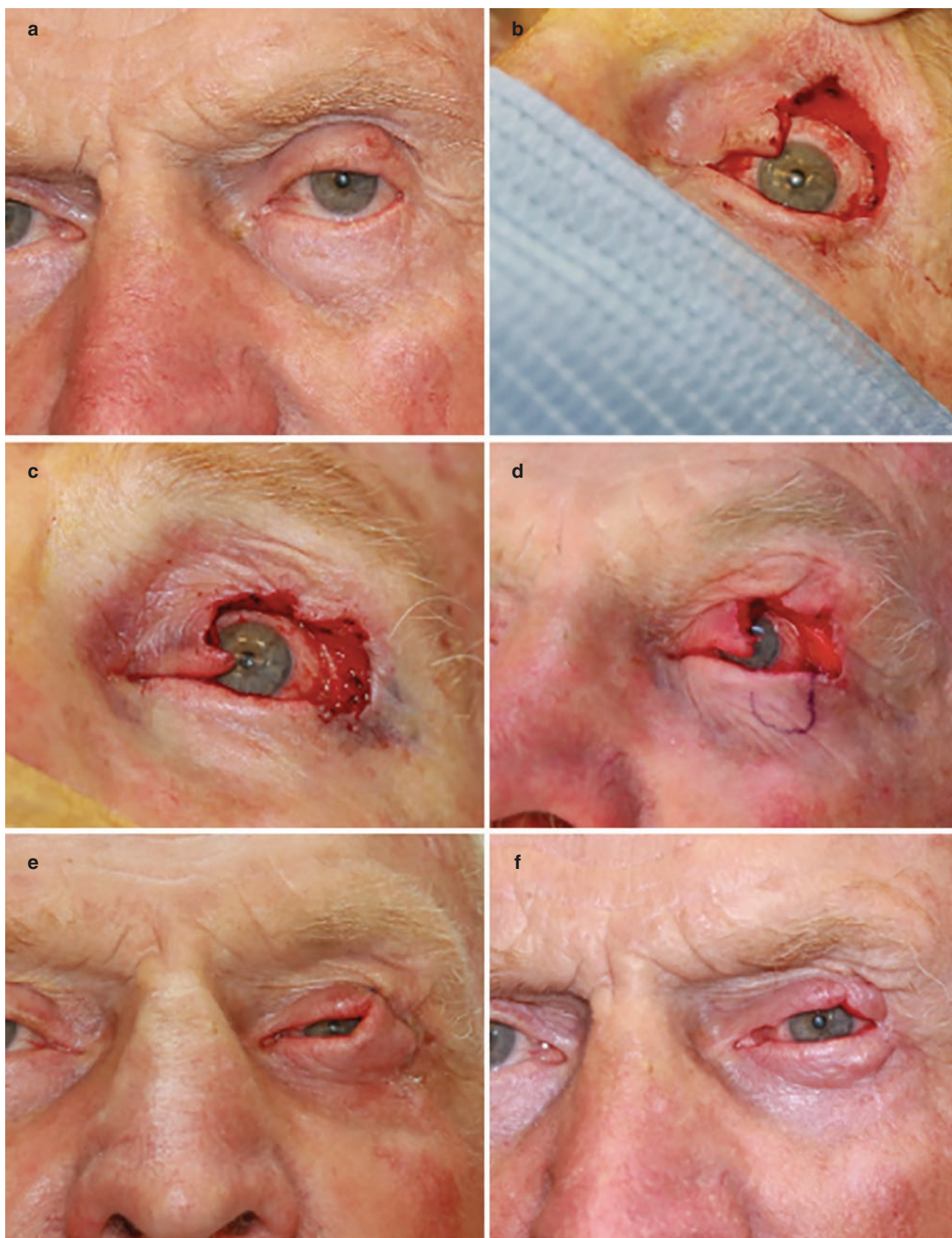


Fig. 27 (a–f) A 77-year-old man with left upper eyelid SGC. The tumour was excised with a 6 mm margin. Conjunctival map biopsies were also performed. Conventional tissue processing and histological examination were performed. Pagetoid intraepithelial invasion was present at the lateral eyelid wound margin, a further excision biopsy

was performed and further histological examination was undertaken. No further disease was identified. The conjunctival map biopsies did not demonstrate any disease. The wound was repaired using a Mustardé lower eyelid flap. Three weeks later the eyelids were opened and the lid margins reformed

5.2 Subtotal Upper Eyelid Reconstruction with a Mustardé Staged Lower Eyelid Flap

This 54-year-old woman (Fig. 28) presented with a biopsy-proven SGC of her right upper eyelid. This had arisen as a crusty lesion on her right upper eyelid over the previous 18 months and had not responded to cryotherapy from her family doctor. The initial wedge excision assumed that the tumour was a BCC. Under general anaesthetic the previous scar was widely excised (10 mm) full thickness, and the margins checked with frozen section biopsies. This confirmed no tumour present, so stage 1 subtotal upper eyelid reconstruction proceeded according to the technique of Mustardé [1]. A laterally based full-thickness lower eyelid flap was turned 180° and cephalad in a caterpillar fashion. This was inset into the lateral upper eyelid defect. The levator palpebrae muscle

and aponeurosis were identified and attached laterally to the tarso-muscular layer of the lower eyelid flap. The conjunctival lining was mobilised and sutured to protect the right cornea. Protective eye dressings were applied (Fig. 28a–c).

Two weeks later, the second stage was completed again under general anaesthetic with division and inset of the lower eyelid flap and formal reconstruction of the right lower eyelid donor site. This was achieved with a Mustardé rotation cheek flap. Under the Mustardé flap, a nasal septal chondro-mucosal free graft provided the posterior lamella. The levator muscle was sutured to the orbicularis oculi muscle layer of the lower eyelid flap (Fig. 28d–f). The 2-year result is shown with a close-up of her right upper lid reconstruction at 2 years post-surgery and a long-term photograph kindly supplied by her daughter at 20 years post-surgery (Fig. 28g–j).

This patient survived with no recurrence until she was 75 years old, when she died of natural causes.



Fig. 28 (a–j) This 54-year-old woman presented with an SGC of her right upper eyelid. Wide excision and a staged reconstruction were performed with a Mustardé lower eyelid flap and a total lower eyelid reconstruction. 2-year and 20-year results shown



Fig. 28 (continued)

5.3 The Cutler Beard Procedure for Upper Eyelid Reconstruction

This is a full-thickness cutaneo-conjunctival lower eyelid advancement flap suitable for elderly patients with lax lower eyelid tissues (Fig. 29).

The advantage of this procedure is that it can fill large defects of the upper eyelid. It can be combined with periosteal flaps if the medial and lateral palpebral ligament upper eyelid

attachments have been excised. Disadvantages include a period of eye closure until the second stage is performed, having to use a graft from a remote site (a free conchal or other cartilaginous graft) and secondary lower eyelid laxity. Lower eyelid laxity is corrected with a lower lid wedge resection at the time of the second stage of surgery. Conjunctival sutures can cause corneal damage if not adequately buried. Postoperative lagophthalmos can occur, resulting in chronic ocular surface dryness, irritation and altered vision.

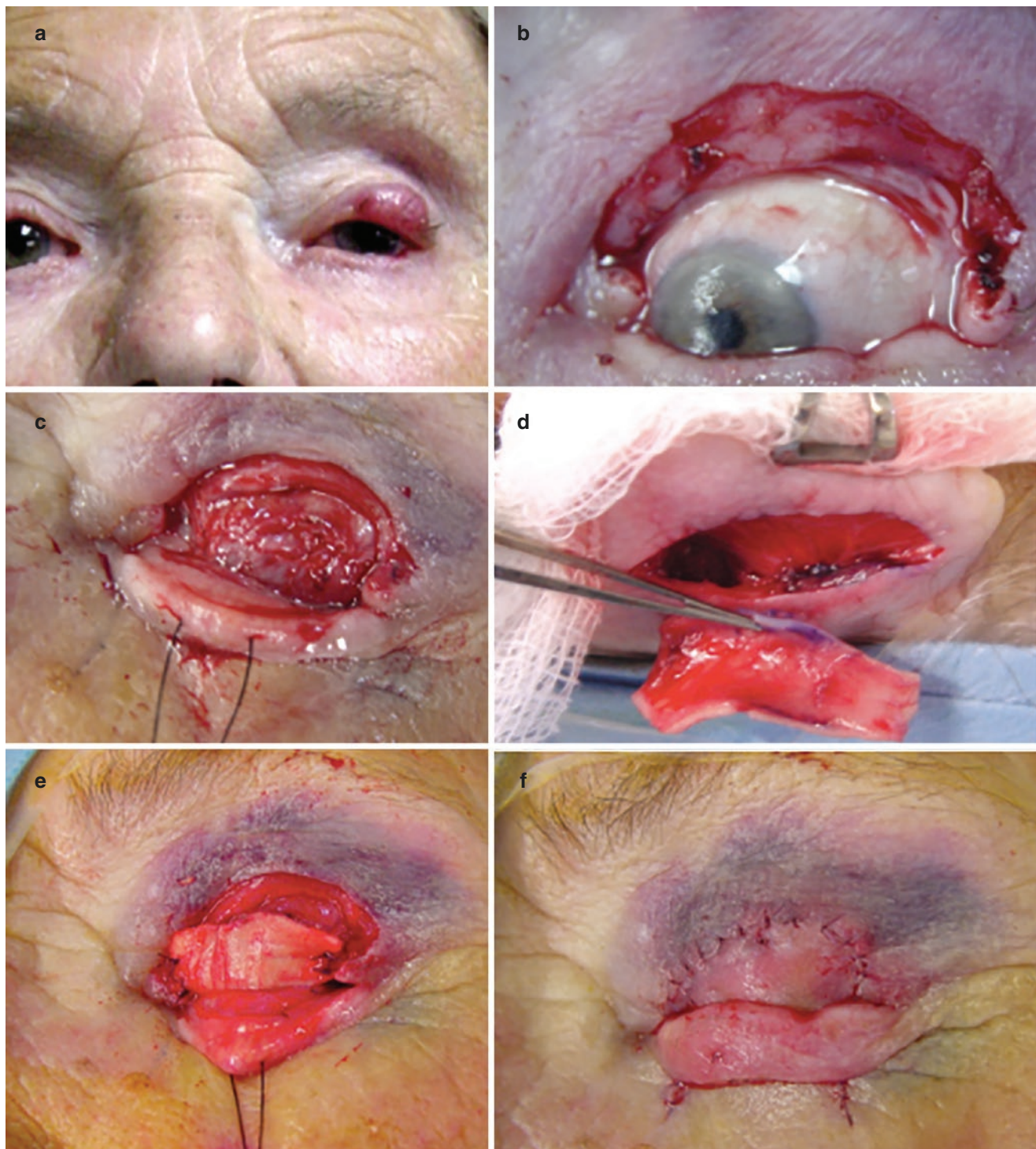


Fig. 29 (a–h) An 85-year-old woman with a left upper eyelid Merkel cell carcinoma. The tumour was removed with a 6 mm margin. Complete tumour excision was confirmed with conventional tissue processing & histological examination. A Cutler-Beard procedure was performed. A lower eyelid conjunctival pedicle and a pedicle of lower

eyelid anterior lamella were pulled superiorly and sutured to the cut ends of the corresponding layers in the upper eyelid defect. A shaped conchal cartilage graft was placed between these two layers. A second stage opening of the eyelids was performed after 1 month. A wedge resection was performed to correct the resulting lower eyelid laxity

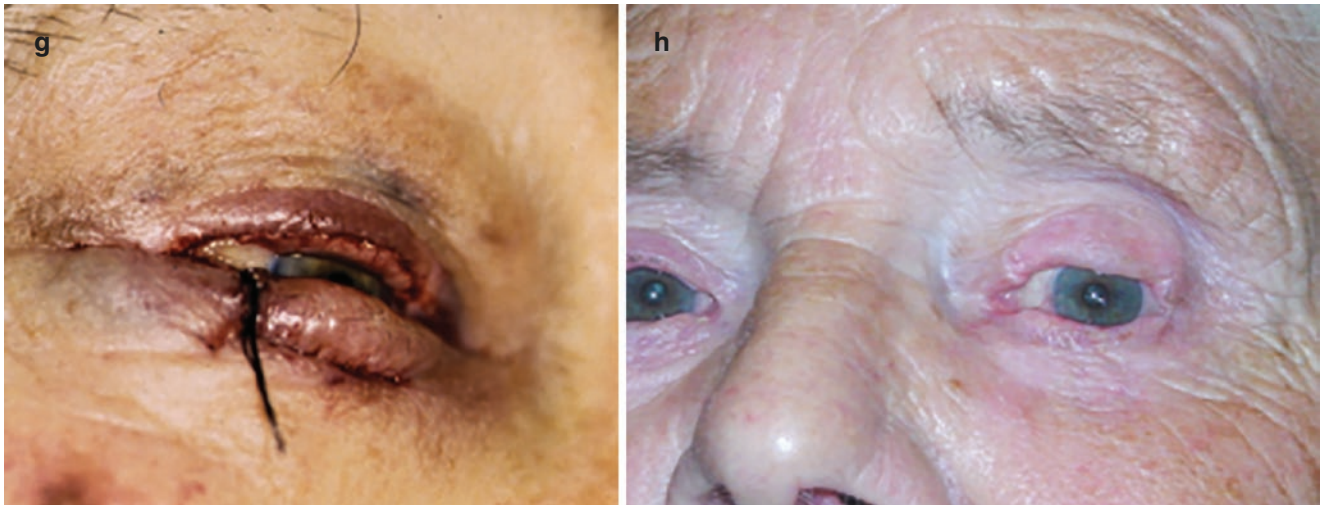


Fig. 29 (continued)

5.4 The Upper Eyelid Composite Graft in Upper Eyelid Reconstruction

This utilises a free composite graft from the contralateral upper lid (Fig. 30).

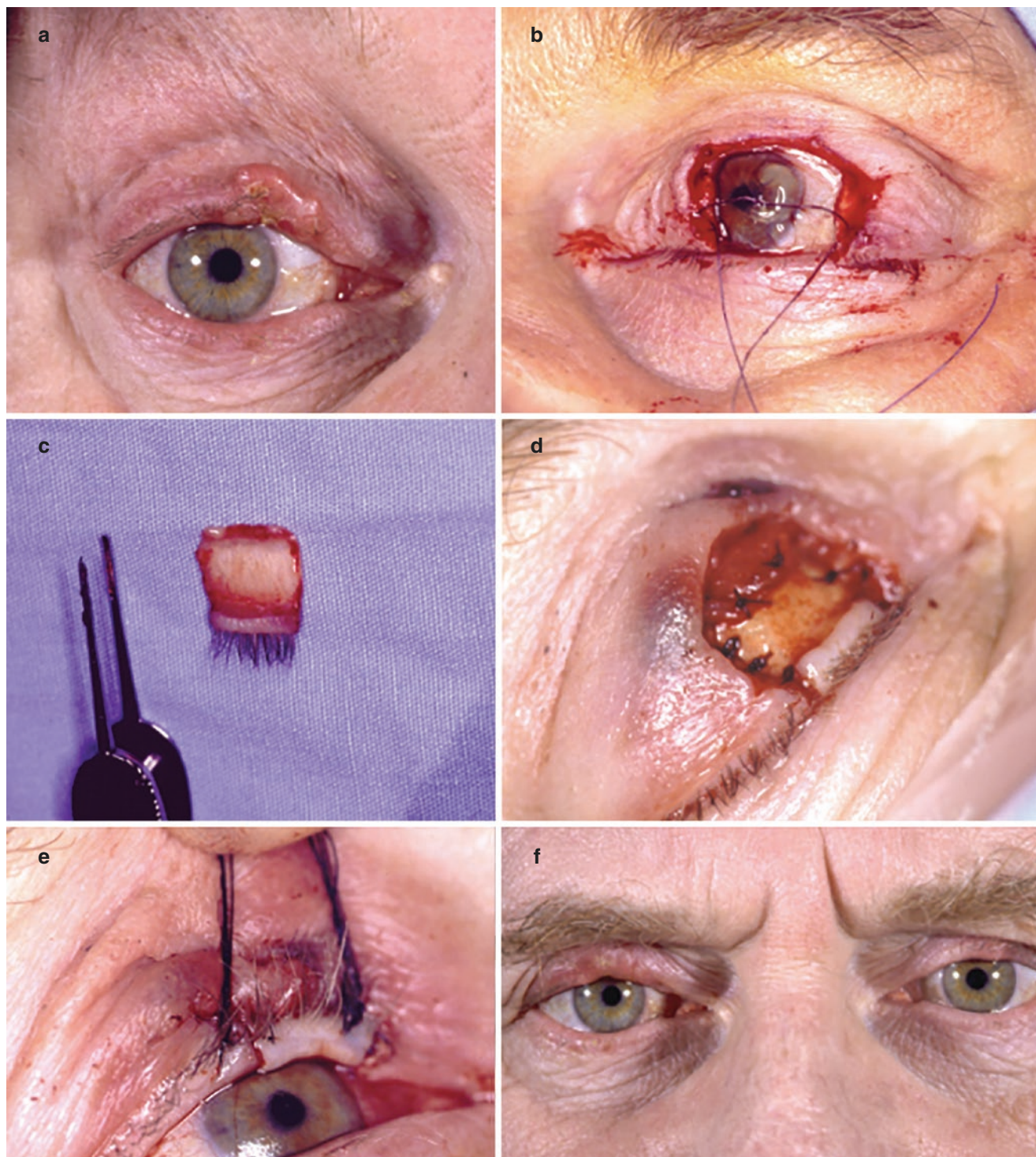


Fig. 30 (a–f) A 73-year-old man with a central right upper eyelid defect after excision of a BCC. This was reconstructed with a full-thickness eyelid wedge graft harvested from the contralateral upper

eyelid. This technique can be used for central upper lid defects involving up to approximately 1/3–1/2 of the eyelid

6 Lateral Canthal Lesions (Fig. 31)



Fig. 31 (a–e) An 80-year-old woman with a recurrent BCC of the lower eyelid and lateral canthus. The defect after Mohs micrographic surgery involved the whole lower eyelid margin, the lateral canthus and the lateral one-third of the upper eyelid. To prevent a postoperative ectropion, the lower eyelid was drawn upwards and laterally by suturing

the lower eyelid septal remnants to a periosteal flap. The cut end of the upper eyelid tarsal plate was sutured to the upper limb of the periosteal flap. The eyelid margins were left to granulate. The lateral skin wound was then closed directly. Photo e) shows the result after 3 months

6.1 Basal Cell Carcinoma of the Lateral Canthus

This 91-year-old man presented with a 2×3 cm infiltrating nodular BCC of his right lateral canthus, of at least 12 months duration. Under local anaesthetic with intravenous sedation,

a wide excision was performed including the lateral 25% of the lower lid. A lateral canthoplasty was performed with mobilisation of a conjunctival local flap, and the large lateral canthal defect reconstructed with a Mustardé rotation local flap from the right lateral cheek region (Fig. 32). The result is shown at 3 months post-surgery.



Fig. 32 (a–d) Infiltrating BCC right lateral canthal region in a 91-year-old man, widely excised and repaired with a Mustardé local cheek rotation flap and lateral canthoplasty. Figure 32d shows the result after 3 months

6.2 Squamous Cell Carcinoma of the Lateral Canthus

This 70-year-old man (Fig. 33) presented with a 2.5-mm-thick (Clark's level III), moderately well-differentiated SCC of his right lateral canthus/lower eyelid region, which had an expansile and exophytic growth pattern. There was a nearby 4.1-mm-thick nodular BCC of his right lateral eyebrow region. Clinical and histological images are below. He was taking warfarin for a previous mesenteric vein thrombosis which increased the peri-operative risk of bleeding and haematoma. A wide excision of the SCC was performed under local anaesthetic with intravenous sedation. The defect was triangulated caudally, and the deep margin included a cuff of lateral orbicularis oculi muscle. The repair was achieved with a Mustardé lateral cheek rotation flap, which incorporated the excision defect for the cephalad BCC. Auersvald haemostatic net sutures were placed through the centre of the

rotation local flap to close the dead space and prevent haematoma formation. These were removed at day 3 (Fig. 33b) and the final result is shown at 3 months.

This 59-year-old man (Fig. 34) presented with a large fungating SCC of his left lateral canthal/lower eyelid region. There was an additional infiltrating BCC on the dorsum of his nose. This case was being considered by a junior colleague, and the lead author offered his assistance. The original plan had been for a wide excision and Mustardé upper temporal rotation flap with a skin graft for the dorsal nasal defect. Reconstruction with a temporary Fricke supra-orbital transposition flap was undertaken initially while awaiting a CT scan to assess the left lateral orbit. The CT scan showed no obvious sign of left intraorbital tumour spread. A glabellar local flap was used to repair the dorsal nasal defect. The early result is shown at 1 week post-surgery (Fig. 34a–f).

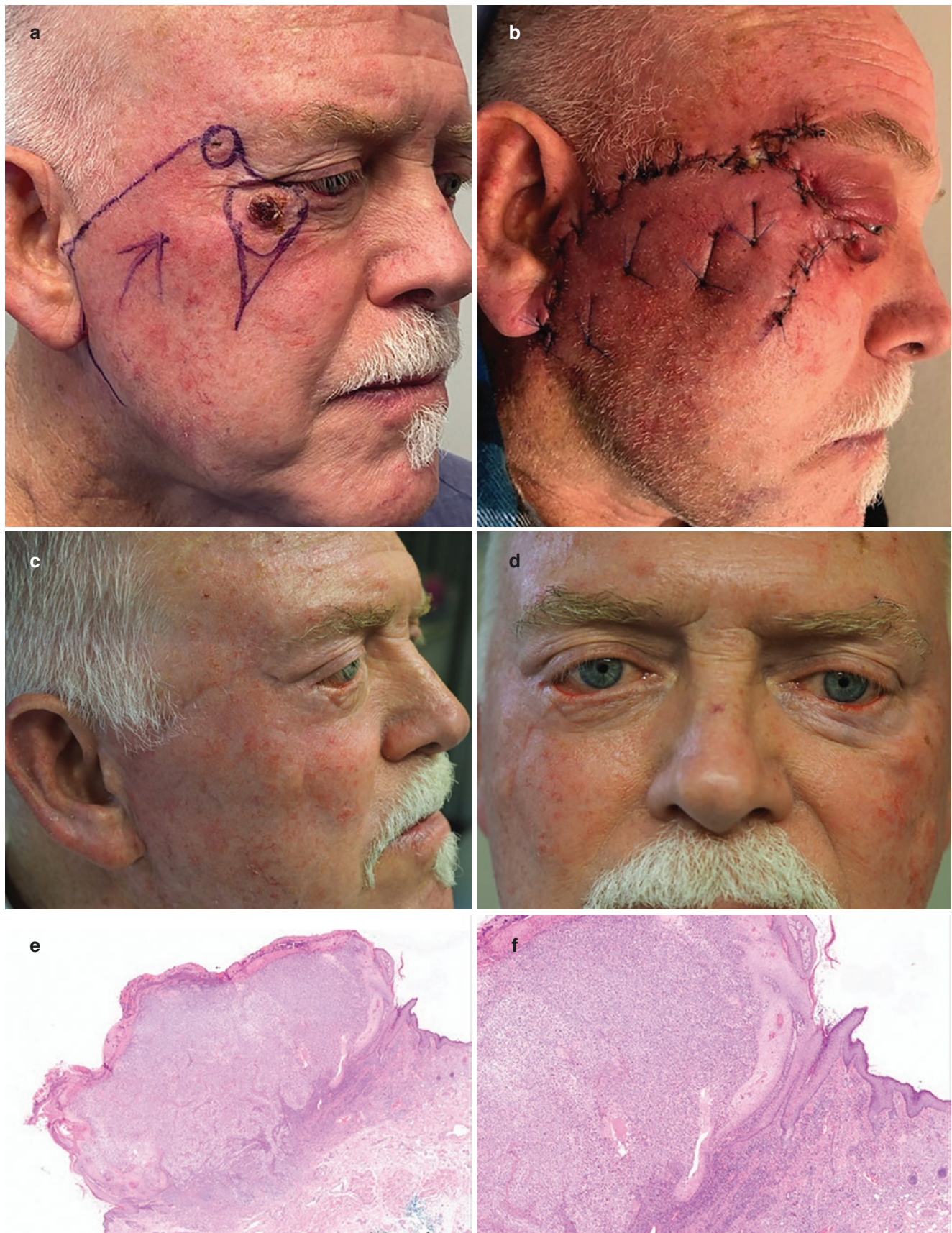


Fig. 33 (a–d) Invasive SCC of the right lateral canthus in a 70-year-old man, with nearby BCC. Mustardé principle of immediate reconstruction again. Result shown after 3 months. (e and f) Moderately well-

differentiated SCC low-power and medium-power photo-micrographs. (g and h) Nodular BCC low-power and medium-power photo-micrographs (with thanks to Dr. Ben Tallon FRACP)

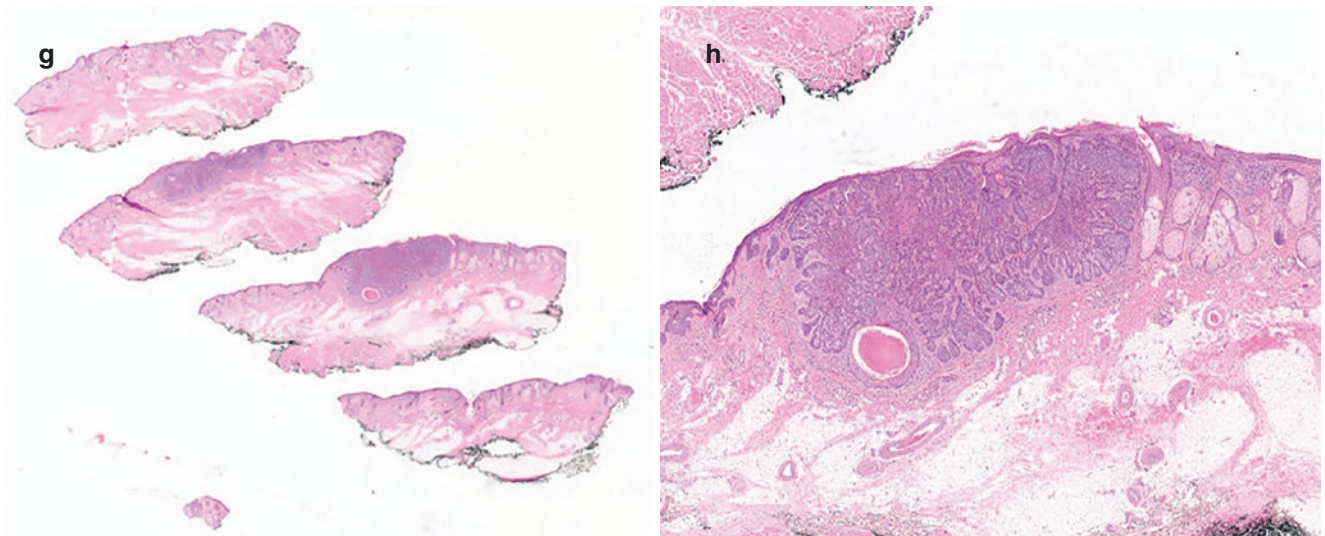


Fig. 33 (continued)



Fig. 34 (a–f) Invasive SCC of the left lateral canthus repaired with a Fricke supraorbital local flap and a BCC of the dorsum nose repaired with a glabellar local flap

6.3 Uncommon Orbital Invasion at the Lateral Canthus by a Desmoplastic SCC

Orbital invasion at the lateral canthus is uncommon yet may occur with aggressive variants of squamous cell carcinoma. Figure 35 shows an 84-year-old retired farmer with an aggressive desmoplastic SCC of the right temple. Two years prior to presentation, the SCC had been excised and treated with adjuvant radiotherapy. Mohs micrographic surgery was used to excise the cutaneous and subcutaneous tumour. Orbital fat infiltration was identified but the patient declined orbital

exenteration. The defect was covered with a large scalp rotation flap. Since he had previously had radiotherapy, further adjunctive radiotherapy could not be used. An extensive recurrence occurred 11 months later. Salvage surgery was undertaken: orbital exenteration, periorbital resection, parotidectomy and neck dissection. One year later a further orbital rim recurrence occurred and was treated with palliative radiotherapy. This highly aggressive subtype of squamous cell carcinoma produces dense collagenous stroma around the tumour. When it occurs in the periorbital region, there is a high risk of orbital invasion and vision and life-threatening complications [27].

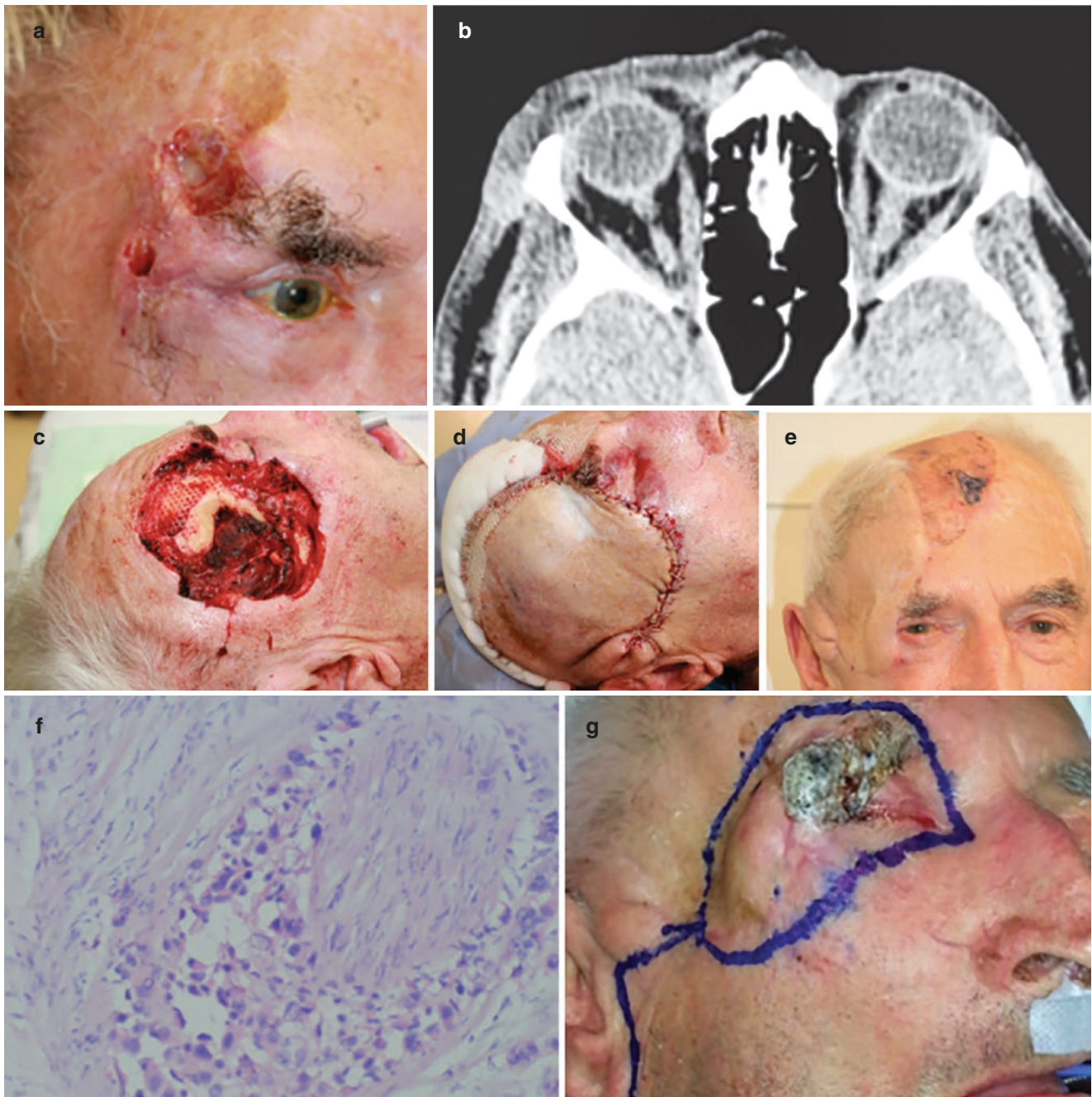


Fig. 35 (a–g) Orbital invasion at the lateral canthus

7 Loss of the Entire Upper and Lower Lids (Figs. 36 and 37)

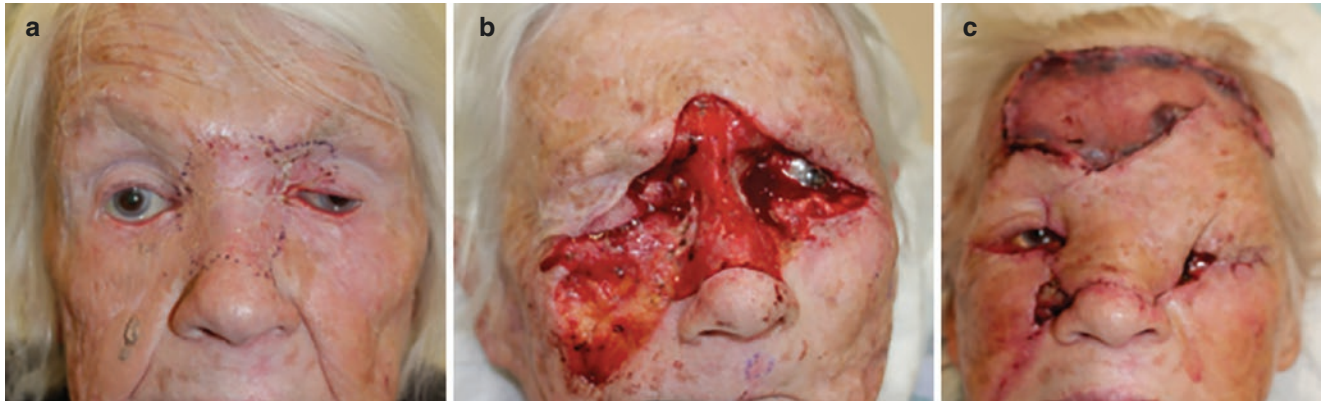


Fig. 36 (a–c) A multiply recurrent, locally advanced BCC in an 81-year-old woman. There was an extensive facial defect after Mohs micrographic surgery involving complete excision of the left upper and lower eyelids and the right lower lid. No suitable eyelid donor tissue

remained to reconstruct the left upper eyelid. Therefore the left eye's conjunctival remnants were closed to cover the cornea, and a forehead flap was used to cover the skin defect

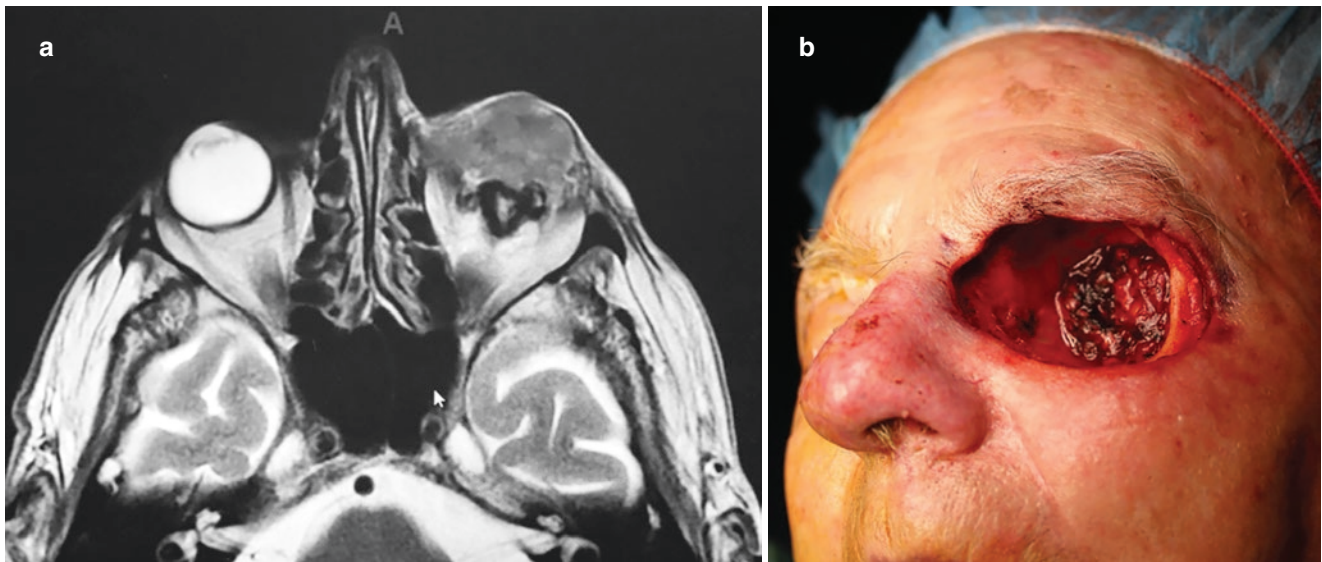


Fig. 37 (a and b) A 92-year-old man with a recurrent left conjunctival SCC, initially diagnosed as a conjunctival SCC. Four years earlier the cornea had perforated and the eye had been eviscerated. The patient

presented with rapid growth of a painful anterior orbital mass. He underwent orbital exenteration and adjunctive radiotherapy

7.1 Orbital Invasion by Facial Cancer

The 87-year-old retired farmer in Fig. 38 presented with a longstanding ulcerated BCC of his left supraorbital region and a large melanoma in situ of his medial cheek/nasojugal region. The duration of tumour growth was 2 years. The pre-surgery images show left brow ptosis and loss of left forehead wrinkles suggesting frontalis muscle invasion. Wide excision down to the periosteum of his left supraorbital ridge revealed transection of the deep margin and both focal perineural and lymphovascular invasion. Local flap repair was performed for wound closure, but a further wide excision did not occur. Within a year he re-presented with left orbital invasion and recurrence. This was managed by an MDT, and he was offered palliative radiotherapy, which failed to cure him. He also lost

the sight in his left eye. This subtype of BCC has an incidence of 1–3% and is associated with recurrence rates of up to 45%. It is most common in elderly males, with white skin and extensive actinic damage as in this patient.

The female patient in Fig. 39 is a case of recurrent adenocarcinoma of the right orbit shown also in Chap. 6 “The Burden of Facial Deformity”. Invasion of the orbit by cancer is an indication for exenteration of the orbit. Her vision had already been lost due to the tumour and radiotherapy, but she is an example of the principle that sometimes the eye has to be sacrificed to save life. Her right orbito-cranial reconstruction was achieved with split calvarial bone grafts, a temporalis transposition muscle and pericranial flaps deeply, plus a large cervico-facial flap for skin cover. Brachytherapy tubes were placed deep to the skin flap for further adjuvant radiation.

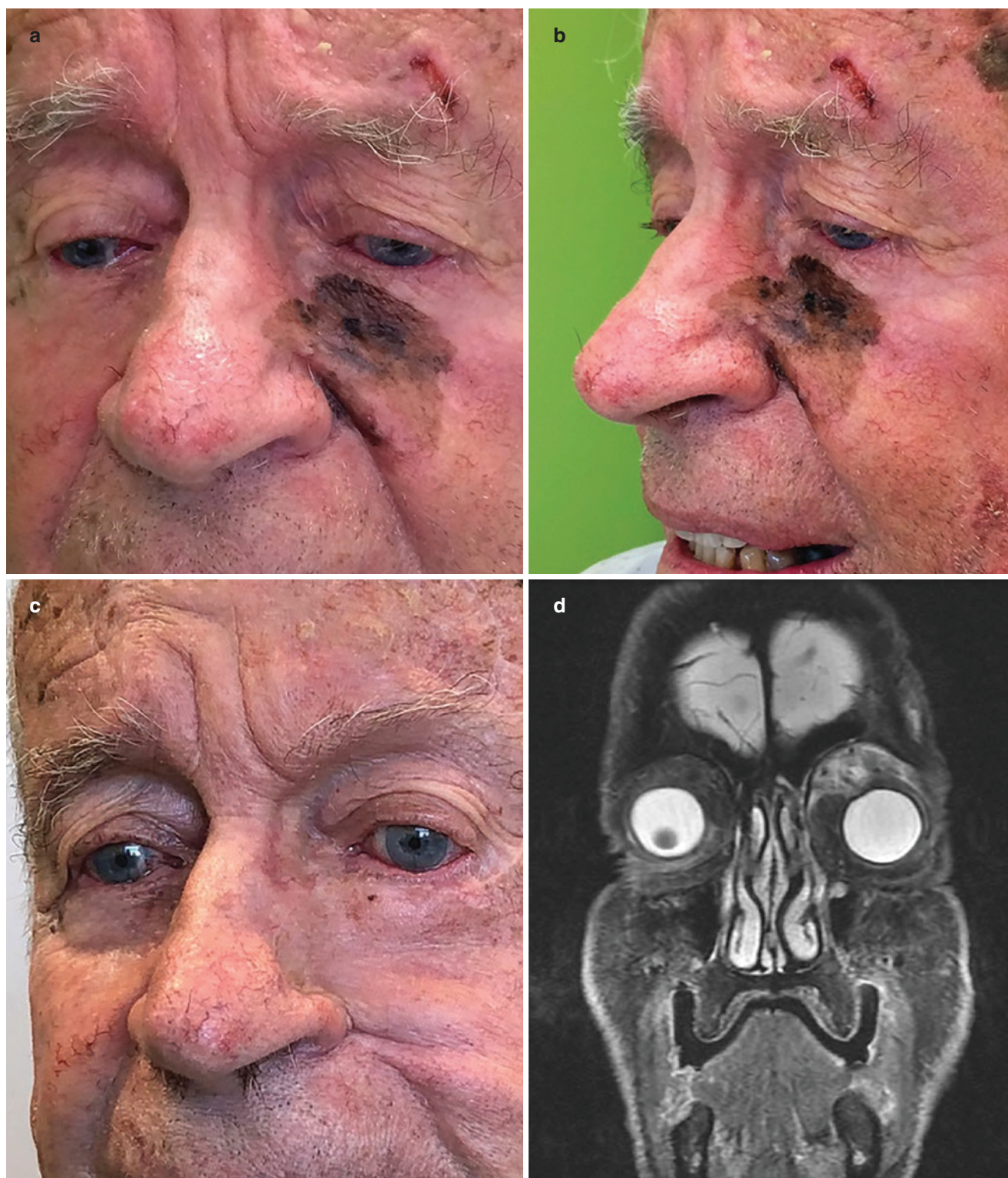


Fig. 38 (a–e) Recurrence of a high-risk left supraorbital ulcerated BCC in the left orbit despite initial surgical excision in a retired 87-year-old farmer. The MRI scan demonstrated frontal bone and superior orbital invasion. The scan also demonstrated perineural invasion into

the cavernous sinus and the mandibular division of the trigeminal nerve. The final image shows a centrolateral tarsorrhaphy used to treat chronic painful corneal ulceration and prevent corneal perforation after radiotherapy



Fig. 38 (continued)



Fig. 39 (a–f) A young woman with recurrent adenocarcinoma of the right orbit after radiotherapy treatment. She underwent orbital exenteration, orbito-cranial resection and a complex combined regional flap and

calvarial bone graft reconstruction. She had brachytherapy for further post-surgical radiotherapy



Fig. 39 (continued)

8 Prosthetic Rehabilitation/ Reconstruction

The use of prosthetic options began in the Great War (1914–1918) with painted tin masks and has evolved to a modern science/craft with 3D computerised planning, life-like silicone prosthetic implants and osseo-integrated abutment technology for fixation. This is covered comprehensively in Chap. 17 “Modern Maxillofacial Rehabilitation”, by the authors Williams et al.

The male patient in Fig. 40 has a large right orbito-cranial defect after exenteration, which has been reconstructed with an elegant life-like prosthetic by Dr. Keith Pine PhD,

an experienced ocular prosthesis, who previously worked in Sir William Manchester’s Middlemore Plastic Surgery/Dental Unit, from the 1970s for 16 years. He has published a textbook on Ocular Prosthetics in 2015, the first textbook to offer a comprehensive account of ocular prosthetics and the evidence used to underpin and support this field of healthcare [28].

A case (used with permission from Michael Williams) of ocular prosthesis is shown in Fig. 41. The aesthetic standard of the right orbital reconstruction with osseo-integrated prosthetic is exceptional, with added spectacle frames.



Fig. 40 (a and b) Orbito-cranial defect reconstructed with an elegant modern maxillofacial prosthetic. (acknowledgements to Dr. Keith Pine BSc (Psych), MBA, PhD (Optom), MIMPT, Ocular Prosthetist, Honorary Research Fellow, University of Auckland, who supplied the images)

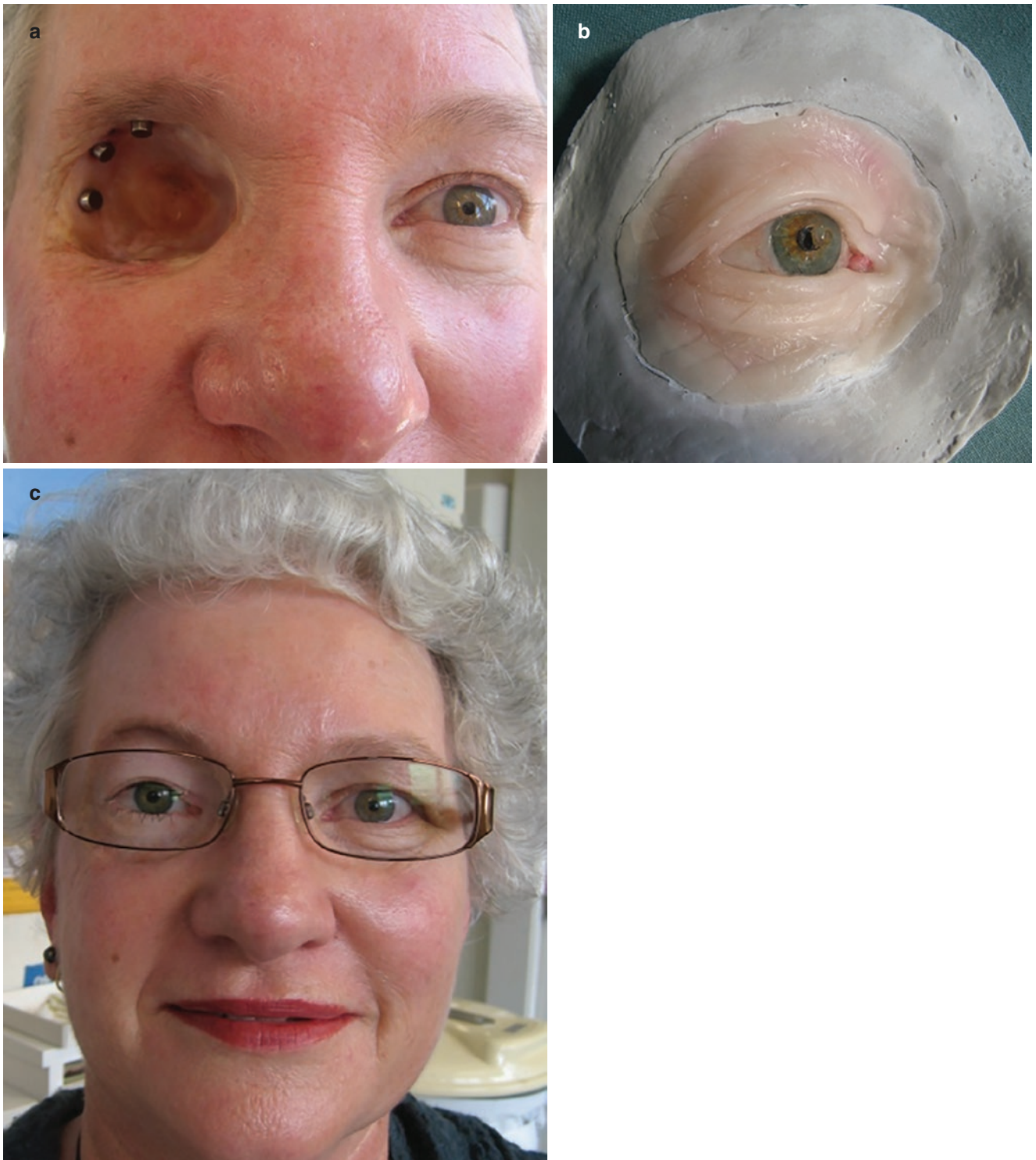


Fig. 41 (a–c) A patient with an exenterated and skin-grafted right orbit with osseointegration studs in place to retain a prosthesis. An orbital prosthesis during construction. Orbital prosthesis in position, further disguised by spectacles

9 Complication Management

9.1 Lower Eyelid Ectropion (Figs. 42, 43, and 44)

All lower eyelid reconstruction needs to pre-empt postoperative lower lid ectropion. Lower lid skin grafts must be accompanied by procedures to horizontally shorten the palpebral ligaments. Generally, the lateral palpebral ligament is shortened, for example, by a lateral tarsal strip or other lateral palpebral tightening procedure [29]. If the lateral end of the lower lid has been disinserted, fixation of the cut end of the tarsal plate and/or other orbital septal remnants to the lateral orbital rim or periosteal flap is required.

Shortening the posterior limb of the medial palpebral ligament is more difficult to achieve. The posterior limb of the

medial palpebral ligament, which is the key structure holding the lower lid in apposition to the eye, is more diffuse than the lateral retinacular tissues and difficult to suture to the posterior lacrimal crest which has a very fragile, thin periosteal covering.

If there is a defect of the medial lower eyelid and palpebral ligament, the best approximation is to suture the cut medial eyelid tarsal plate to the medial remnants of the medial palpebral ligament's anterior limb or to a medial periosteal flap. To recreate the normal lower lid contour, the medial eyelid should be pulled slightly superiorly.

Secondary correction of a cicatricial ectropion is achieved by addressing laxity of the inferior retractors of the lower eyelid, horizontally shortening the lower lid and replacing the shortened anterior lamella by a full-thickness skin graft [30] or transposition flap.

Fig. 42 (a–c) Lower eyelid wounds must be closed vertically to prevent ectropion. Figure 42c shows fixation of the cut end of the tarsal plate and other lateral retinacular tissues to the orbital rim periosteum (dotted lines indicate the location of the lateral orbital rim) to prevent postoperative ectropion



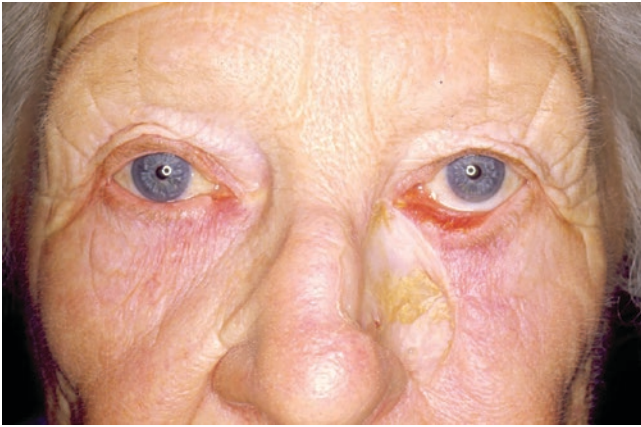


Fig. 43 Medial ectropion after medial canthal tumour excision repaired with a full-thickness skin graft. Correction would involve horizontally tightening the posterior limb of the medial palpebral ligament, taking care not to damage the lower canaliculus. Alternatively a medial canthoplasty could be used to support the medial lower eyelid. The anterior lamella of the medial lower eyelid requires vertical lengthening with a full-thickness skin graft or a transposition flap from the nasal bridge or glabella



Fig. 44 (a–e) In this case of a lower eyelid and lateral canthal recurrent BCC in a 78-year-old woman, the defect after Mohs micrographic surgery was initially reconstructed with a partial direct closure, horizontal

eyelid shortening and full-thickness skin graft from the upper eyelid. Due to vertical scar contracture, the ectropion recurred. This was successfully corrected with a cheek rotation flap

9.2 Recurrent Tumour at the Site of Previous Tumour Causing Lower Eyelid Cicatricial Ectropion (Fig. 45)



Fig. 45 (a–g) A 79-year-old man with a medial cicatricial ectropion after previous excision of a lower eyelid BCC. An incisional biopsy at the site of the previous surgery revealed a recurrent infiltrating morphoeic BCC. After several stages of Mohs micrographic surgery, the procedure was abandoned as the patient was not able to tolerate further excision. In Fig. 45b, the circled areas had residual disease that was not able to be excised by the Mohs surgeon. The resulting defect was repaired with glabellar and island cheek flaps. Necrosis of the tip of the

cheek flap resulted in a medial ectropion. The upper eyelid was tethered medially and laterally. Further cicatrization occurred after adjuvant radiotherapy. The resulting ptosis interfered with the left eye's vision. The medial end of the lid was released, and the medial conjunctival fornix reformed with a buccal mucous membrane flap. Further surgery including a Hughes tarsconjunctival flap & a full thickness skin graft was planned to correct the lower eyelid cicatricial ectropion

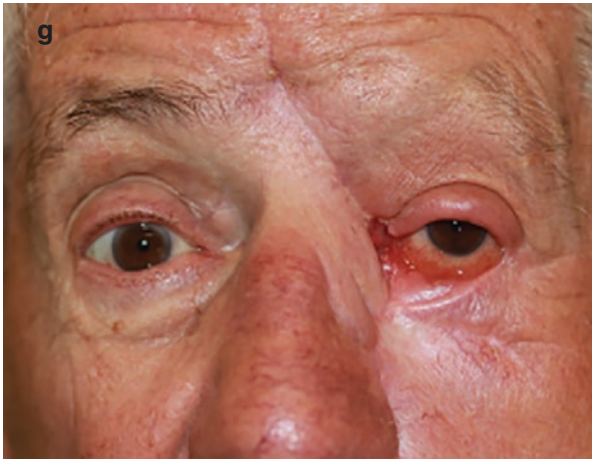


Fig. 45 (continued)

9.3 Lagophthalmos (Fig. 46)

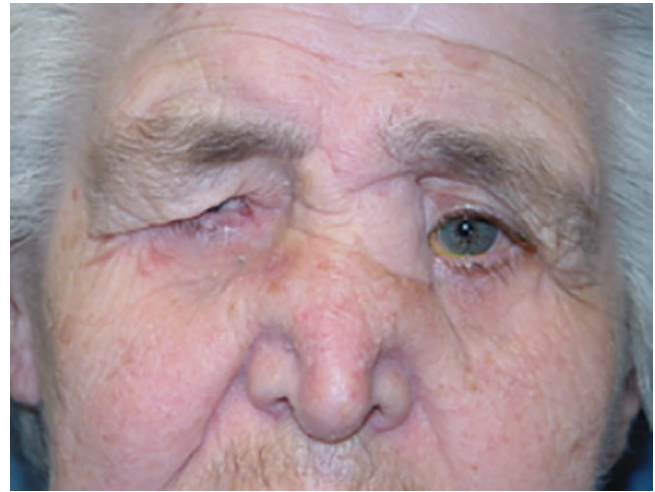


Fig. 46 An 81-year-old woman who had a paramedian forehead flap to repair a left medial canthal defect. The patient's upper eyelid was sutured to the skin of the flap, immobilising it. This resulted in lagophthalmos, chronic ocular irritation and reduced vision. Care must be taken when attaching the thin flexible eyelid tissues to flaps with thicker skin and subcutaneous tissue. To maintain satisfactory eyelid excursion, periosteal flaps are a more suitable option for reattaching disinserted upper eyelids

9.4 Severe Postoperative Lagophthalmos and Blindness (Fig. 47)

This is the most feared complication of eyelid surgery. At the conclusion of eyelid reconstruction, the surgeon must ensure that the eye can passively close. In addition, to prevent corneal abrasions, scarring and vision loss, any graft overlying the cornea must be lined with non-keratinising epithelium,

e.g. conjunctiva, buccal mucosa, hard palate mucosa or homologous amniotic membrane. A temporary or permanent tarsorrhaphy may be required to protect the cornea from abrasions and dehydration. A temporary suture tarsorrhaphy will usually last up to 3 weeks. Permanent tarsorrhaphies are usually constructed so they can be reversed, when appropriate (Fig. 48).

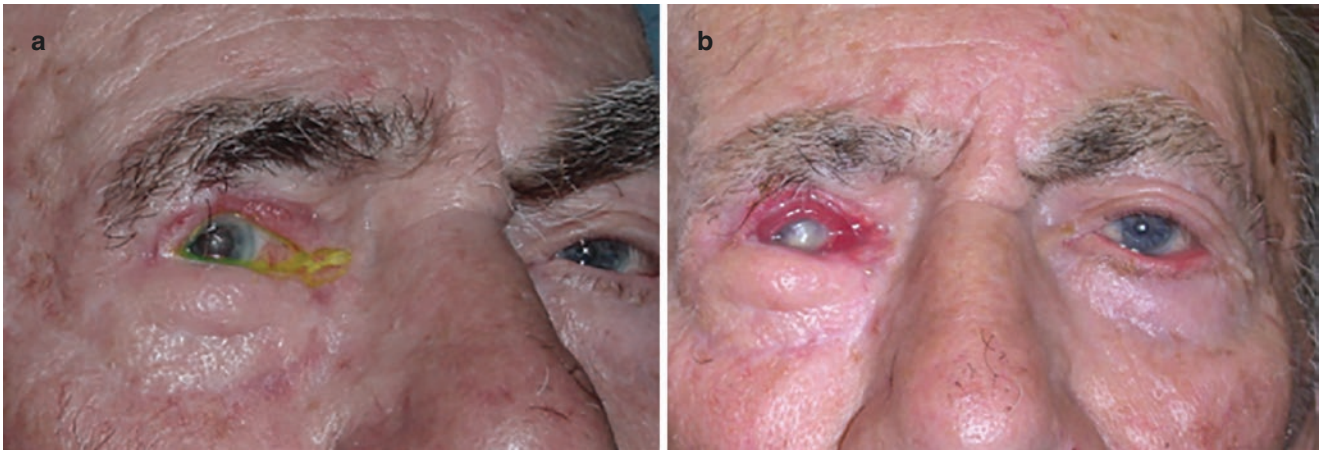


Fig. 47 (a and b) An 83-year-old man who underwent upper eyelid reconstruction after excision of an extensive upper eyelid BCC. The upper eyelid was tethered, resulting in postoperative lagophthalmos, severe corneal ulceration, corneal scarring and vision loss

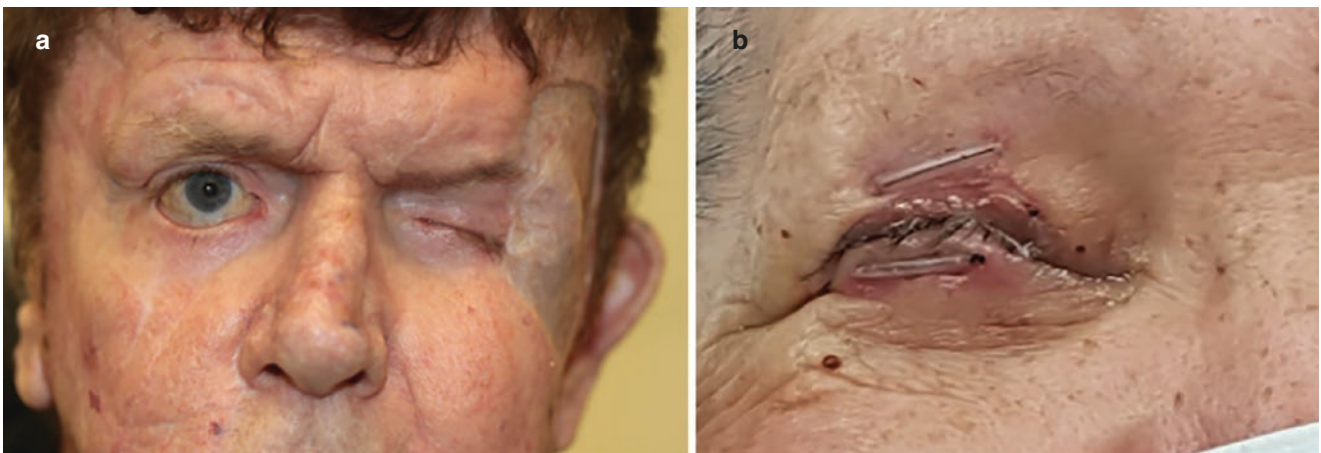


Fig. 48 (a and b) Permanent and temporary tarsorrhaphies performed at the end of reconstructive eyelid surgery

9.5 Postoperative Diplopia (Fig. 49)



Fig. 49 (a–d) Conjunctival symblepharon causing diplopia. In this 63-year-old man, Mohs micrographic surgery was used to excise an infiltrating right medial canthal BCC. Bulbar conjunctiva was infiltrated with tumour and excised. The eyelids were reconstructed with a medial periosteal flap, glabellar flap and full-thickness supraclavicular skin

graft. Generally the conjunctiva will granulate satisfactorily. In this case, a conjunctival adhesion caused restriction of right eye abduction and diplopia. The scarred bulbar conjunctiva was excised and replaced with an amniotic membrane graft

10 Innovations

Immunotherapy drugs are indicated in extreme facial cancer cases if other therapeutic options have been exhausted or are contraindicated. These include vismodegib, pembrolizumab and cemiplimab.

Vismodegib is a selective inhibitor of abnormal signalling in the molecular driver of BCC – the ‘hedgehog’ pathway. It can be considered in adults with locally advanced disease who are not able to undergo surgery or radiation [31]. It can also be used in metastatic BCC and in basal cell naevus (Gorlin-Goltz) syndrome. Vismodegib has also been used as neoadjuvant treatment to shrink large locally advanced BCCs prior to surgery. While it can be very effective, resistant BCCs have been reported to grow despite vismodegib treatment [32]. Rebound BCC growth after cessation of treatment has also been reported [33].

Cemiplimab and pembrolizumab are drugs that target programmed cell death (PD-1) receptors. They can be used for patients with advanced local or metastatic cutaneous SCC that is not treatable by surgery or radiation [34, 35].

11 Conclusion/Summary

The management of periorbital cancers is a challenge, and preservation of visual function is a priority. In the most extreme cases, vision may have to be sacrificed to preserve the patient’s life. The periorbital region has a direct connection to the ocular system, key cranial nerves and the central nervous system. Gillies’ enduring principles 12 and 13 are important to remember in this anatomical region:

12. Never let routine methods become your master.
13. Consult other specialists.

As in many other fields of oncology, the periorbital region may require solutions only possible with the collaboration of a co-ordinated and efficient multidisciplinary team. For the future, plastic surgeons and ophthalmologists specialising in oculoplastic surgery can learn much from each team member’s approach.

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Nose and Ear Cancer

Michael F. Klaassen

Core Messages

- The unique shape and 3D contours of the nose and ears should be appreciated in what Ralph Millard Jnr termed *The Beautiful Normal*.
- Curative resection and/or adjuvant chemoradiation should be in unison with aesthetic reconstruction.
- The principles of reconstruction are defined essentially by Harold Gillies from early World War One (WW1) surgical experience and post-war by his student Millard. Others like Burget and Menick have refined these.

1 Introduction

The modern-day plastic surgeon needs to have experience and flair for the very challenging field of nose and ear reconstruction. Following curative cancer ablation, the restoration of form and function is a priority for normal appearance, removal of the stigma associated with deformity and positive body image. Not all BCCs, the commonest facial skin cancers, are equal. As discussed in an earlier chapter (Chap. 10 “Basal Cell Carcinoma: A Surgical Enigma”), BCCs have variable characteristics of infiltration histologically and it is important to identify high-risk lesions. The high-risk BCCs commonly present in the facial zones of the nose and the ears.

The nose, which is central face, is the gateway to the at rest breathing pathway and has a complex physiological mechanism plus external aesthetic nasal subunits, with contours of ridges and valleys. Nasal breathing, olfactory function and aesthetic beauty are the main functions of the human nose.

The ears are lateral as uniquely human appendages, also with defined contours, aesthetic subunits and aesthetic vari-

ability. The external ear is not mandatory for hearing but total or partial absence of this human appendage is a significant deformity.

Burget and Menick in the 1990s who were prodigies of Millard, who himself was trained by Gillies in the 1950s, have defined the modern principles of aesthetic nose reconstruction in adults and children [1]. Gillies always understood the importance of the lining layer in nose reconstruction, which is also emphasised in the publications of his descendants. The trilaminar reconstructive approach of lining, supportive framework and finally cover are the basis for complex and often staged nose reconstruction. The beautiful normal is the concept that underpins this surgical approach and is illustrated in the clinical cases presented.

Ear reconstruction is like nose reconstruction in terms of the reconstructive challenges to restore the beautiful normal. The human ear is a complex form to restore in total and requires multiple stages and considerable cartilage sculpting skills. Partial defects are usually suitable for immediate or staged reconstruction with a variety of periauricular local flaps including postauricular, preauricular and temporal fascial flaps [2].

2 Management/Technique

For either the nose or ears, it is imperative to have a diagnosis and a surgical plan including the best option for immediate reconstruction. We recommend the CLEAR principle. **C**omplete **L**ocal **E**xcision + **A**esthetic **R**econstruction. If there is any doubt that CLEAR can be achieved in one stage, then we rely on the alternative principle of **D**RAPE (**D**elayed **R**econstruction **A**fter **P**athological **E**xamination) [3]. For the surgical record, clear photographs of the lesion and surgical plan are helpful, especially when reviewing clinical results and pathology reports.

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The management of skin cancer resection and reconstruction for the nose and the ears is illustrated below, with common clinical scenarios compared with rarer and more difficult cancer challenges. For all cases, the same set of time-honoured principles are followed:

1. Diagnose before you treat.
2. Make a plan and a pattern.
3. Make a record.
4. Consider lifeboats for unexpected complications.
5. Never let routine method become your master.
6. The aftercare is as important as the planning.
7. Perfection is only just good enough.

3 Indications

Skin cancers predominantly of the basal cell carcinoma type are very common in fair-skinned individuals with Celtic heritage living in the south-west Pacific region of the globe.

These BCCs are often infiltrating, multiple and synchronous with other related malignancies such as squamous cell carcinoma and malignant melanoma.

4 Forehead Flap Options

The classic double-staged paramedian forehead flap is useful for the distal nose where a significant part of the nasal tip aesthetic subunit is missing after cancer resection (Figs. 1 and 2).

The rarer basosquamous carcinoma is occasionally encountered as in this 70-year-old woman with a biopsy-proven cancer of her nasal tip/columellar junction (Fig. 3). After margin controlled initial excision by her GP, a wider excision of the columella nasal tip subunit was performed. Then a staged reconstruction using a long paramedian forehead flap reached the columellar upper lip junction.



Fig. 1 (a–f) Diffusely infiltrating BCC nasal tip in a 65-year-old woman. Wide excision and staged reconstruction with a left paramedian forehead flap. Division and inset of the flap pedicle at 2 weeks. 1-year result



Fig. 2 Close-up views before (a) and 13 months after (b) forehead flap rhinoplasty

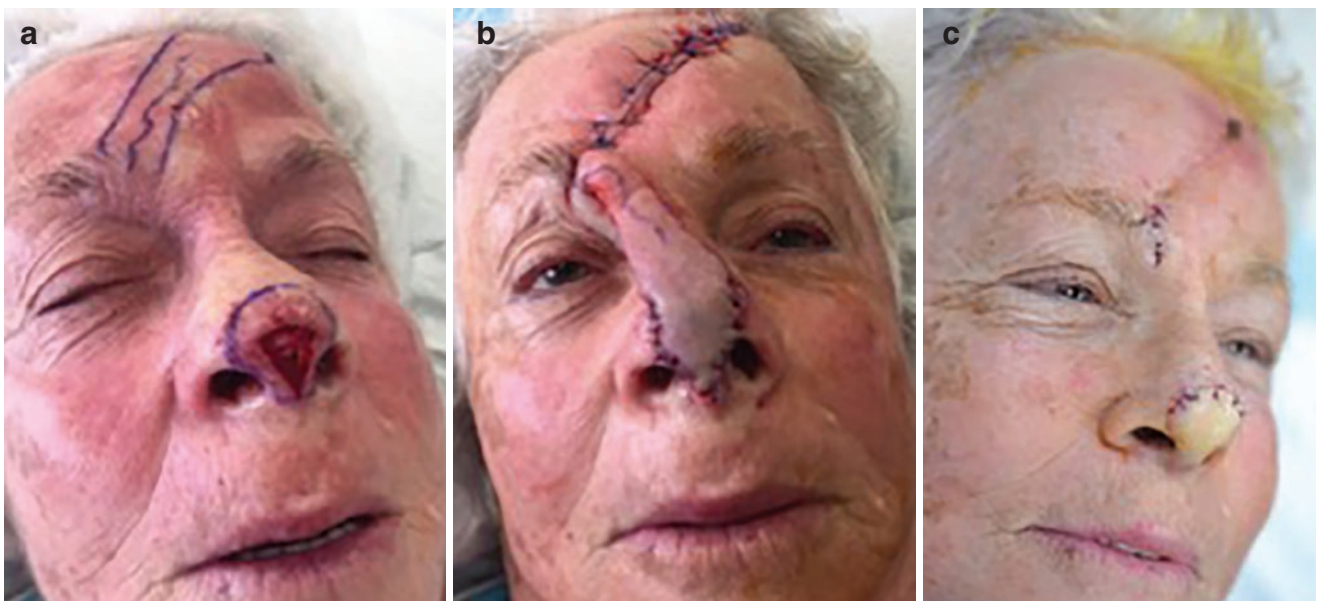


Fig. 3 (a–c) Basosquamous carcinoma columellar—tip junction, widely excised and reconstructed with a staged paramedian forehead loco-regional flap

5 Forehead Flap and Skin Graft

Occasionally, it is necessary to combine reconstructive techniques to deal with non-synchronous skin cancers in the same anatomical region (Fig. 4). This 86-year-old gentleman presented initially with a diffuse SCC in situ of his left

medial canthal/medial upper lid region, which was completely excised and repaired with a full-thickness supraclavicular skin graft. A couple of years later, he developed a diffuse invasive SCC of his upper nasal dorsum. This was widely excised and repaired with a left paramedian one-stage forehead flap. The result is shown at 3-year follow-up.



Fig. 4 (a–d) SCC in situ left medial canthal region excised and repaired with FTSG. Later invasive SCC upper nasal dorsum widely excised and repaired with paramedian forehead flap (one stage). Result shown at 3 years

6 Recurrent Multifocal Nasal BCCs Despite Mohs Surgery

The 74-year-old woman in Fig. 5 had endured years of serial Mohs surgery for multiple BCCs of her nasal region. She had lived in a beach suburb in a region with New Zealand's highest ultraviolet light exposure. Frustrated with the recurrent nature of her nasal skin cancers over the past decade (2008–2016) and the resulting scars, she sought a second opinion and elected to have total nasal skin resection. Punch biopsies confirmed recurrent BCC in her nasal tip, bilateral lower lateral nose and left upper lateral nose.

Wide excision and immediate staged reconstruction with her forehead as the donor site were planned. The first stage encountered scarring and deformity of the right lower lateral nasal cartilages, so these were replaced with conchal cartilage grafts from her right ear. An extended paramedian forehead flap provided total nasal cover, and the extensive forehead donor site was reconstructed with bilateral forehead rotation flaps and an advancement frontal flap. The forehead flap based on the left supratrochlear pedicle was divided and inset at day 18. The final result is shown 4 years later (Fig. 5f) after some minor scar revisions at 6 months post-stage 2.



Fig. 5 (a–f) Multiple recurrent BCCs of nose in a 74-year-old woman, despite Mohs surgery, total nose cover resection and staged reconstruction with left paramedian forehead flap, local flaps for donor site repair.

Secondary forehead flap and donor scar revision at 6 months. Final result at 4-year follow-up, no sign of BCC recurrence

7 Double Forehead Flaps—When a Second Nasal Reconstruction Is Required

Very rarely, a patient returns with a new nasal skin cancer and the best reconstructive option is again the trustworthy paramedian forehead flap. Can the surgeon use another paramedian forehead flap based on the contralateral supratrochlear pedicle? The answer is YES. The 81-year-old gentleman in Fig. 6 had been referred to me 20 years before with a difficult and challenging recurrent malignant fibrous histiocytoma of his nasal tip/columellar junction. When he was a youthful 61 years, I had widely excised his nasal tip/columella aesthetic subunit and reconstructed the defect with a

staged right paramedian forehead flap. There was no sign of further recurrence for the next 20 years, but then he was referred back with an infiltrating BCC on the dorsum of his nose. He wanted another forehead flap if possible. The BCC was widely excised, and a one-stage left paramedian forehead flap, with a tunnelled and de-epithelialised pedicle, was used to repair the dorsal defect. I also took the opportunity to revise the donor scar on his forehead from the original right paramedian forehead flap.

This 45-year-old woman from North Queensland with probable xeroderma pigmentosa (Fig. 7) remains for the author one of his most challenging reconstructive projects. Her courage and determination to have her face reconstructed after years of skin cancer are nothing short of inspirational.

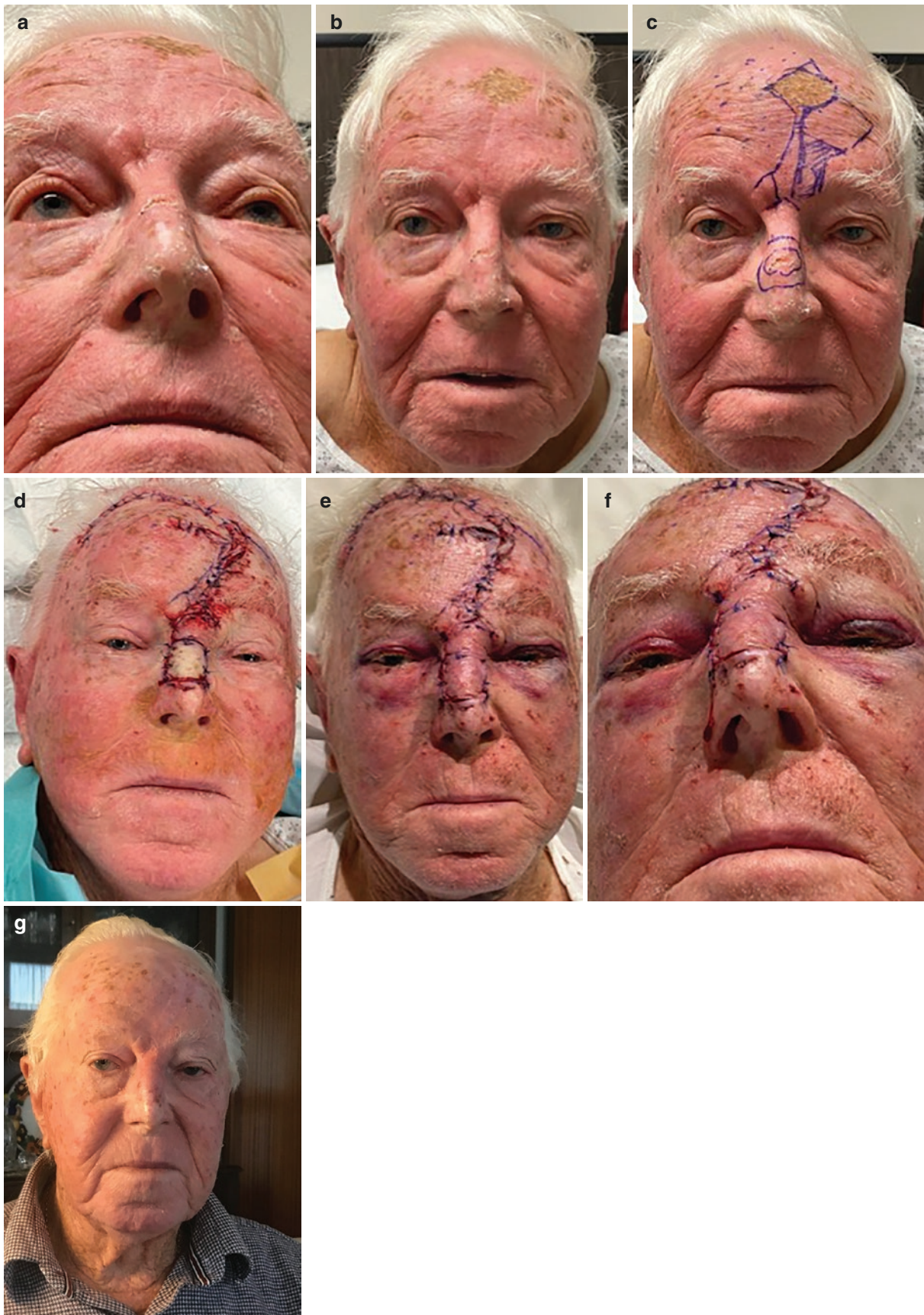


Fig. 6 (a–f) Double paramedian forehead flaps for nose reconstruction 20 years apart. (g) ten months after second forehead flap



Fig. 7 (a–g) 45-year-old woman failed previous left paramedian forehead flap, so years later a right paramedian forehead flap with auricular cartilage grafts was used to restore her nasal form. 18-month follow-up image supplied by the patient



Fig. 7 (continued)

8 Penetrating Nasal Skin Cancers Involving the Lining

Rarely, some basal cell carcinomas may infiltrate through the full thickness of the nasal skin to involve the nasal lining. This must then be replaced in kind with either a nasal lining flap or a skin graft (composite). Aggressive squamous cell carcinomas may penetrate the full thickness of the nasal skin as in this 65-year-old man (Fig. 8). He presented with a 3-month history of a granulomatous tumour of his right lateral nose. Initial wide excision and repair with a staged right nasolabial interpolated local flap were altered by the histological report of a 2 cm dimension pT2 infiltrative, moderately differentiated SCC with extensive incomplete deep margins. Within a week of receiving this pathology diagnosis, a right hemi-nose resection including all the previous nasolabial local flap was performed. A left septal lining flap hinged superiorly and interpolated through a septal window, provided the important lining layer whilst conchal cartilage grafts and the paramedian forehead flap in stages provided the remainder of his right hemi-nose reconstruction. Adjuvant radiation therapy was considered by the radiation oncologists but on balance was discounted. He remained free of recurrence at 4 years post-surgery.



Fig. 8 (a–d) Penetrating SCC right lower lateral nose requiring right hemi-nose resection and staged reconstruction with septal lining flap, conchal cartilage grafts and large paramedian forehead flap. 4-year follow-up

9 Cancers of the Nasal Vestibule

These tend to be aggressive SCCs in chronic smokers as illustrated in the two patients in Figs. 9 and 10. The 48-year-old woman was referred by her ENT surgeon with a rapidly growing SCC of her right nasal vestibule and columella region. Wide excision, reconstruction with costal cartilage grafts, septal mucosal lining flaps and an extended right paramedian forehead flap in three stages plus adjuvant radiotherapy led to a curative outcome (Fig. 9).

This 74-year-old woman with a chronic smoking history also presented with a biopsy-proven poorly differentiated SCC of her left nasal vestibule and columella. Wide excision left a complex full-thickness defect, which required staged reconstruction with septal and conchal cartilage grafts for framework, contralateral septal mucosal flap for lining and contoured right paramedian forehead flap for lining and contoured right paramedian forehead flap and nasolabial local flaps (Fig. 10). The final result is shown at 6 years, and her reconstruction required 7 separate stages.



Fig. 9 (a–f) 48-year-old woman, chronic smoker with penetrating SCC of her right nasal vestibule and caudal septum. Wide excision and staged composite reconstruction with lining, framework grafts and cover. Result at 1 year



Fig. 10 (a–c) Composite nasal tip and columella radical excision for aggressive SCC, which was reconstructed in several stages with contra-lateral septal mucosal lining flap, septal and conchal cartilage grafts and

a contoured paramedian forehead flap. Latest appearance at 6 years with no sign of SCC recurrence

10 The Art of Planning in Reverse

This principle is applied universally in designing the precise form and match of all local flaps, but particularly for aesthetic nose reconstruction using the paramedian forehead flap. We covered this previously in Chap. 6 “The Burden of Facial Deformity”, which focused on reducing the burden of deformity.

The planning in reverse principle again helped to achieve an aesthetic forehead flap reconstruction, for this 67-year-old woman, a heavy smoker with an infiltrating BCC of her left nasal tip/columella aesthetic subunits (Fig. 11). Auricular cartilage grafts were used to reconstruct her left tip nasal framework and a full-thickness postauricular graft for nasal lining. Stage 2 to divide and inset the flap performed 4 weeks after stage 1.

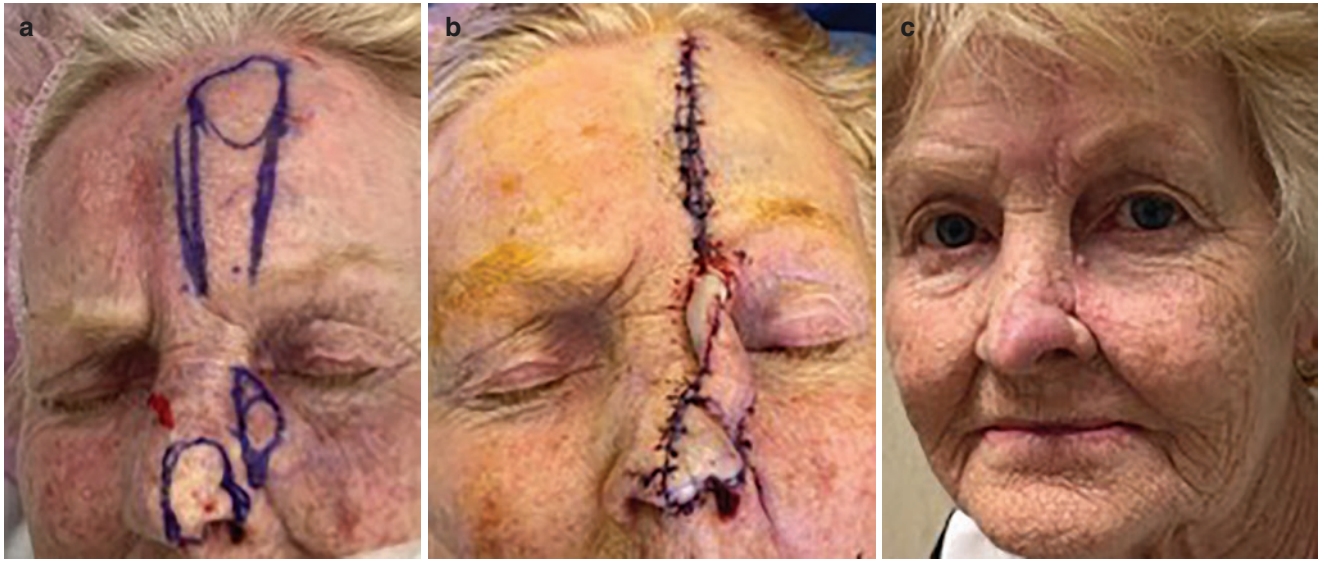


Fig. 11 (a–c) Left staged paramedian forehead flap with auricular cartilage grafts for tip support in a 67-year-old heavy smoker with a large infiltrating BCC of her left nasal tip/columella unit. Result shown 6 weeks after stage 2

11 The Nasolabial Flap Option

11.1 Multiple Staged Nasolabial Flap

The nasolabial local flap has been used since at least 1881, when Nelaton designed a two-stage nasolabial flap for columella reconstruction [2]. The late Professor Neven Olivari preferred double (bilateral) nasolabial flaps for extensive nose reconstruction, as a strategy to keep the workhorse paramedian forehead flap in reserve, for potential future cancer recurrences [4]. The author prefers the nasolabial flap as a staged interpolated flap for complex alar reconstruction,

often with a conchal cartilage graft to stabilise the contour of the nostril rim.

This 59-year-old woman is a classic example of an infiltrating high-risk BCC of her right alar nose (Fig. 12). The BCC was widely excised as an aesthetic nasal unit and immediate reconstruction with a staged nasolabial interpolated local flap. An ipsilateral conchal cartilage graft was used to support the nostril rim. The infiltrating high-risk BCC was focally close to the deep margin histologically, so at stage 2, planned for 5 weeks post-stage 1, further deep and inferior excision margins were taken, as the flap was divided and inset.



Fig. 12 (a–e) 59-year-old woman with high-risk infiltrating BCC right alar region. Wide excision and reconstruction with a 2-stage right nasolabial flap + conchal cartilage graft. Result shown at 3 weeks post-stage 2



11.2 Single-Stage Nasolabial Flap

This 59-year-old woman had a nodular BCC at the junction of her right lateral nose and right alar subunits widely excised and the defect reconstructed with a single-stage nasolabial transposition flap. She is shown a month post-surgery and 7 months later when the flap contour was revised by judicious de-fatting (Fig. 13).

Fig. 12 (continued)



Fig. 13 (a–c) A single-stage nasolabial flap for repair of a lower lateral nose defect following wide excision of a nodular BCC. Appearance at 1 month and 12 months, after revision of flap contour and excision glabellar neurofibroma

11.3 Longer Nasolabial Flaps in Women for Nasal Tip Repair

This 93-year-old woman was on a waiting list with multiple facial BCCs including the large ulcerated nodular BCC of

her nasal tip (Fig. 14). Given the multiple repairs required in one session, I elected to repair her nasal tip defect with an extended left nasolabial flap from her lax left medial cheek. The result is shown at only 6 weeks, when further revision and refinement of the flap base were planned.



Fig. 14 (a–c) Long nasolabial local flap for nasal tip repair after wide excision ulcerating BCC nasal tip. Early result after one stage at 6 weeks

12 Other Traditional Local Flaps for the Elderly

This 91-year-old lady with an ulcerated BCC of her right supratip and relative nasal droopiness had it widely excised

and the defect repaired with a traditional dorso-nasal advancement with proximal Burow's triangles. The large left forehead SCC was simultaneously widely excised and repair achieved with an H-plasty double advancement local flap. The result is shown at 6 weeks (Fig. 15).



Fig. 15 (a–d) Traditional advancement flap to repair defect of right supratip following ulcerated BCC wide excision in 91-year-old lady. Result at 6 weeks

13 Ear Cancers

13.1 Clinical Presentation

Cancer of the ear region in this section includes those where significant anatomical restoration is required to avoid ear deformity post-cancer. The cancers are usually BCCs and SCCs involving the helical rim, conchal fossa or general ear surface anteriorly and posteriorly. Rarely auricular cancers present after neglect and long duration of growth where any human form of the anatomy is lost (Fig. 16). These cases

often require radical loco-regional cancer resection and free flap reconstruction.

More manageable ear cancers include those of the helical rims and conchal fossae. The 87-year-old gentleman in Fig. 17 was referred with an ulcerated, moderately differentiated SCC of the upper pole of his left ear. This was widely excised including the underlying rim of cartilage and reconstructed with a superiorly based postauricular transposition local flap. The cartilage defect was replaced with a free graft from the ipsilateral conchal fossa. His result at 2 years is shown.



Fig. 16 (a and b) Two clinical cases of extreme advanced T4 SCCs of the ear which had been neglected and presented late



Fig. 17 (a–e) Ulcerated SCC upper helical rim, widely excised and reconstructed with conchal cartilage graft and postauricular flap in one stage. 2-year result shown

13.2 Other Variations of the Postauricular Local Flap

A broad-based postauricular local flap can be designed for helical rim reconstruction as in this 82-year-old gentleman, who was referred with a biopsy-proven SCC + BCC of his right ear (Fig. 18). Wide excision of the double ulcerated cancer including a rim of helical cartilage was reconstructed immediately with a broad posteriorly based postauricular local flap ($7 \times 5 \times 6$ cm dimensions). Seven weeks later, because of COVID-19 lockdown delays, this was divided at its base, the right ear released from a setback position and the secondary defect repaired with a postauricular full-thickness graft from the contralateral ear.

The other common site for BCCs and SCCs of the ear is the conchal fossa. These present in various forms and are

best widely excised in continuity with the underlying conchal cartilage and immediately reconstructed with the traditional mastoid island flap. Also called “the revolving door” flap, this provides an efficient and aesthetic reconstruction, preserving the ear shape (Fig. 19). This case shows a 69-year-old man, who presented with a well-differentiated SCC of his right conchal fossa abutting the mid-antihelical fold. Complete excision under local anaesthetic and immediate repair with a mastoid island flap were achieved as a day case. His result 1 month later is shown.

Postauricular local flaps can be designed as mastoid island flaps or alternatively as interpolated transposition flaps for the anterior surface of the ear and or the lower helical rim (Fig. 20).

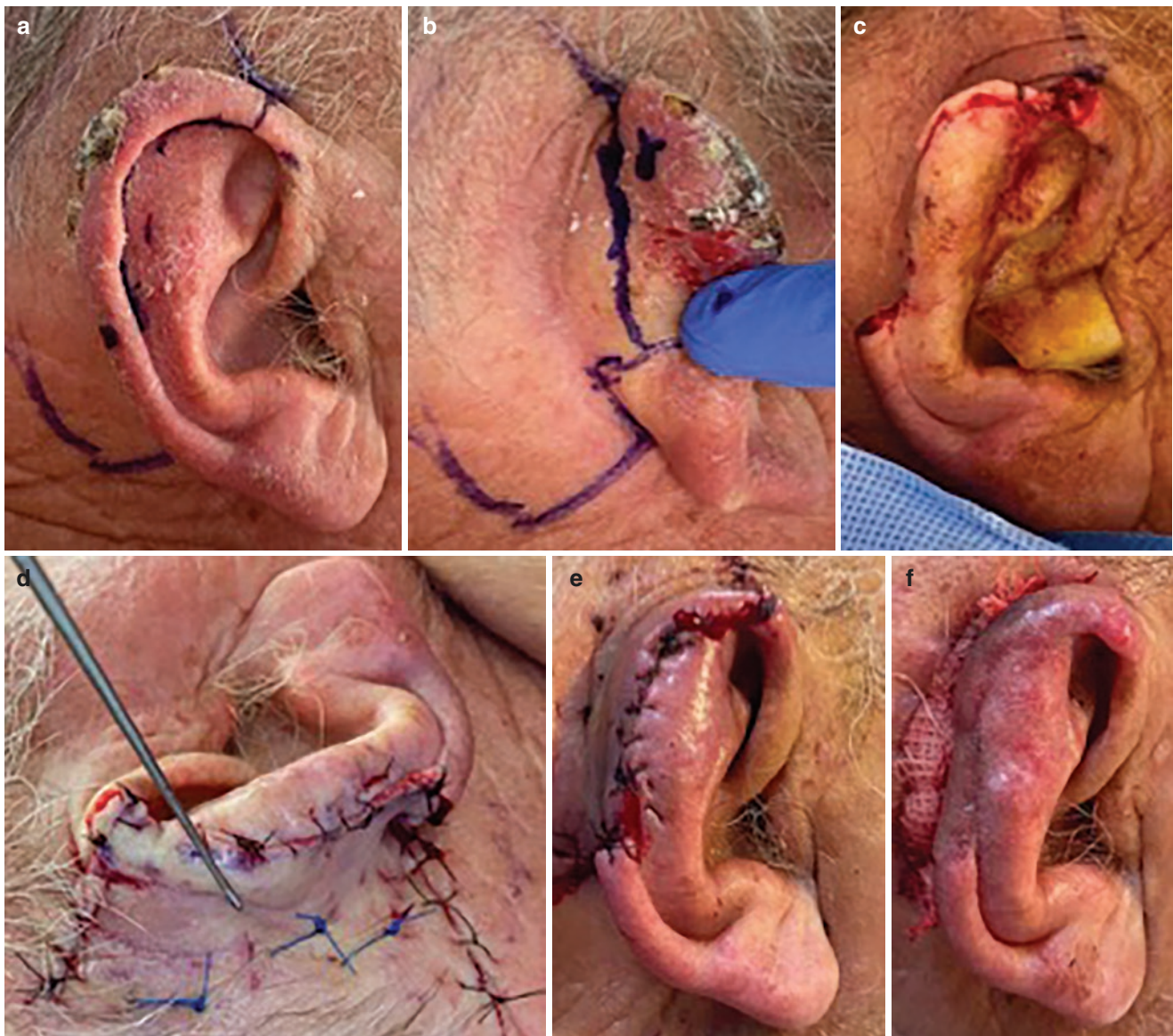


Fig. 18 (a–h) 82-year-old male with SCC/BCC ulcerated complex tumour upper right helical rim, widely excised and repaired with a staged broad-based postauricular flap and full-thickness skin graft. Result at 3 months



Fig. 18 (continued)



Fig. 19 (a–e) SCC of the right conchal fossa, completely excised and reconstructed with a mastoid island local flap (revolving door flap). Early result at 1 month shown



Fig. 20 (a–i) Variations of the postauricular flap (superiorly or inferiorly based) for auricular reconstruction post-BCC excision

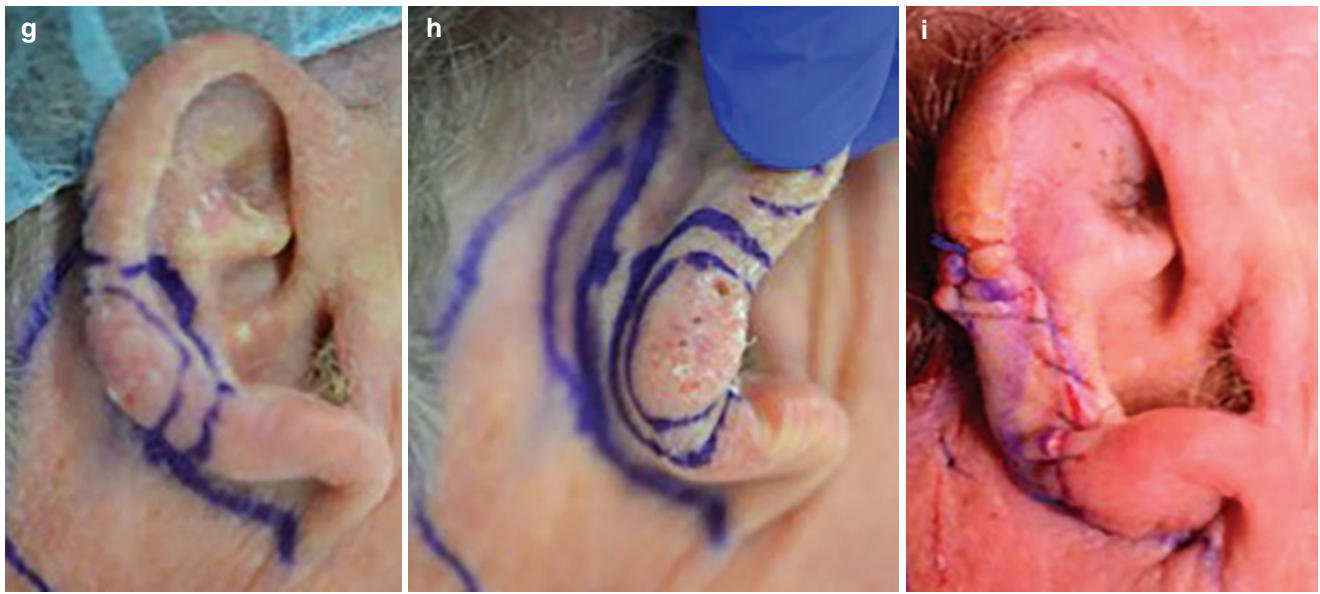


Fig. 20 (continued)

13.3 The Preauricular Flap for Ear Reconstruction

I have previously published the case of the 57-year-old woman (Fig. 21), with an infiltrating BCC of her right conchal fossa, which I widely excised and repaired with a large preauricular interpolated local flap [2]. This was partially de-

epithelialised and tunnelled deep to her right earlobe. Simultaneously, a left mini-facelift was performed to avoid asymmetry and to achieve an overall conservative facial rejuvenation. The same patient is illustrated 2 years later (Fig. 22). The preauricular flap design was used also for this case of a recurrent BCC of the intertragal right ear region in a 53-year-old woman (Fig. 23).



Fig. 21 (a–f) The same patient is illustrated 2 years later (Fig. 22)



Fig. 22 Same patient aged 59 years



Fig. 23 (a–e) Recurrent BCC right ear intertragal notch region in a 53-year-old woman, widely excised and immediately repaired with a preauricular transposition flap as one stage. Aesthetic reconstruction shown at 3 weeks, BCC completely excised

14 Contraindications

There should be no contraindications to effective and aesthetic ear reconstruction when partial excision is required. This challenging case, in a 61-year-old man, who had been operated on previously by ENT surgeons for recurrent con-

chal BCC, was presented to the plastic surgeon (Fig. 24). A significant ulcerated recurrence of the BCC in the left postauricular sulcus associated with multiple sinuses and perineural invasion was widely excised, including the residual concha and repaired with a split skin graft to the postauricular defect and a postauricular local flap for the concha.

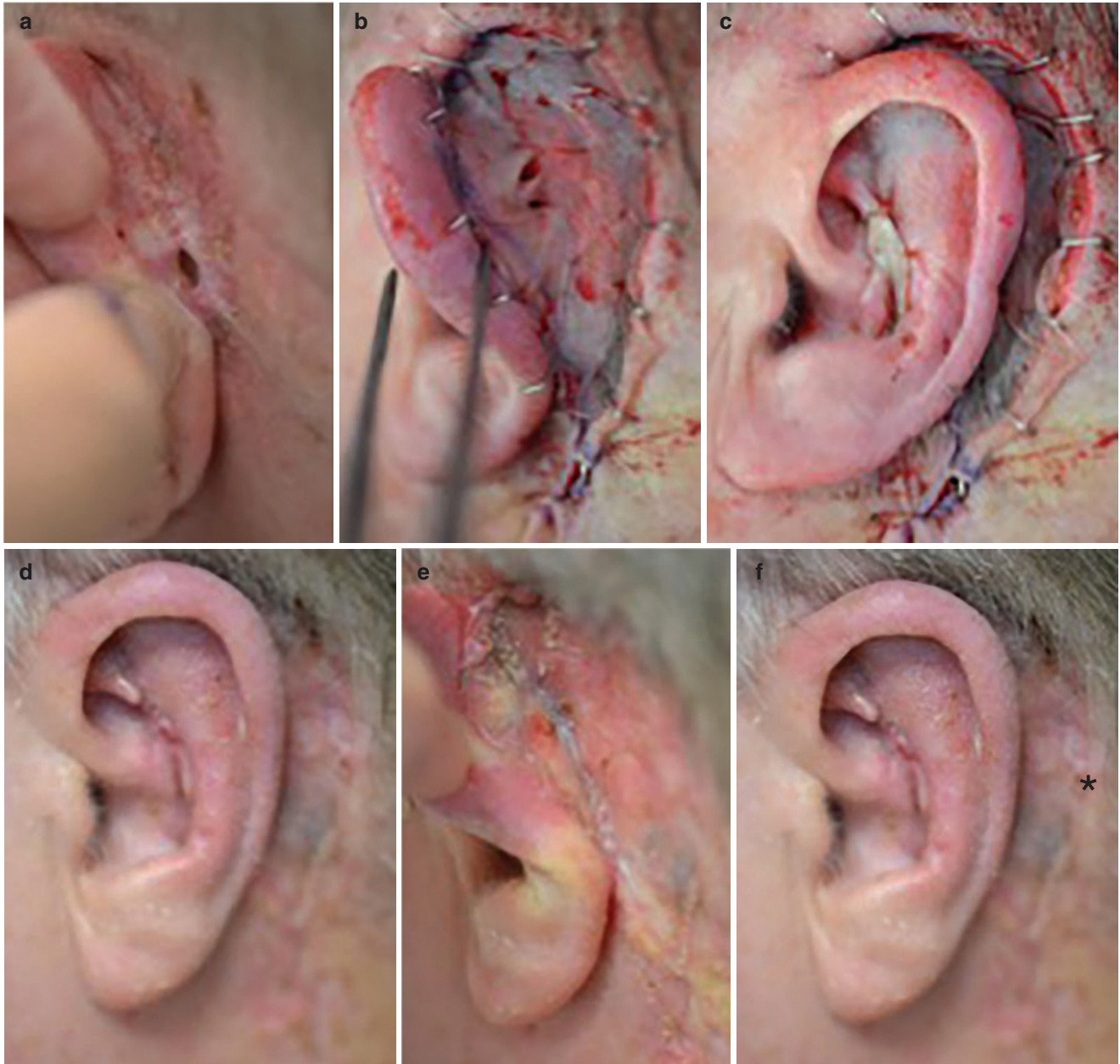


Fig. 24 (a–f) 61-year-old man with recurrent BCC left postauricular sulcus associated with perineural invasion. Wide excision and repair with combination of postauricular flap for conchal fossa and split graft

for large postauricular defect. Positive margin at 9 o'clock *. Watch and see policy

15 Innovations

Probably, the greatest innovation for reconstructive rhinoplasty using the historic forehead flap is Dr. Gary Burget's philosophy of both applying the nasal aesthetic subunit prin-

ciple and leaving the forehead donor site defect to heal by secondary intention, where it cannot be repaired directly. The former principle is illustrated below (Fig. 25), and the latter principle in many of the other nose reconstructions presented.



Fig. 25 (a and b) Demonstrating the one-stage nasal aesthetic subunit reconstruction in a nasal human bite trauma case

16 Complication Management

16.1 How Robust Is a Forehead Flap?

This patient with a nasal tip and right alar BCC complex and staged forehead flap rhinoplasty was seen by a junior surgical doctor the first night after her surgery, with bleeding from the raw underside of the forehead flap pedicle. She needed to remain on her low-dose aspirin for cardiac reasons. Inexperienced and dangerously bold, he decided to inject the pedicle of the flap with 1:1000 adrenaline. No phone calls to

senior staff were made! The next morning, the flap looked like a classic case of vascular insufficiency (Fig. 26). An anxious time was had by the plastic surgical team and the patient as we waited. The second image shows the state of the flap circulation by day 5, when recovery was confirmed. At 4 weeks, she went on to have stage 2, to divide and inset the forehead flap and is shown 3 months later with a satisfactory nose reconstruction. The unidentified junior doctor was never seen again. Conclusion: beware of junior staff; forehead flaps are quite robust.



Fig. 26 (a–e) Attempted assassination of a paramedian forehead flap by a junior doctor armed with a 1.0 mL of 1:1000 adrenaline. (a)—day 01, (b)—day 05, (c)—day 14, (d)—stage 2, (e)—3-month result

16.2 The Notched Alar Rim Deformity

The stigma of a notched or retracted alar/nostril rim after failed repair is a particular challenge. This 73-year-old woman had a BCC near her right alar rim completely excised by her general practitioner in a provincial centre. The nasolabial flap used for the wound repair suffered necrosis of the distal end, and a notched alar deformity was the result (Fig. 27).

The ear usually heals well because of its reliable blood supply. If the cartilage suffers necrosis and becomes chronically infected, it is analogous to chronic osteomyeli-

tis in pathogenesis. This 70-year-old man had a SCC wedge excised from the upper pole of his right ear a year previously by a general surgeon. For reasons still not clear, he developed a chronic infection with *Serratia marcescens* cultured and a discharging sinus from the site of the direct closure (Fig. 28). With antibiotic cover pre-operatively, the sinus was probed and widely excised including the necrotic cartilage of the upper antihelical fold. This was then reconstructed using a pedicled temporalis fascial flap to plug the dead space and augment the blood supply to the problematic site.



Fig. 27 73-year-old woman with right alar notch and retraction post-BCC excision and failed local flap. Attempt to reconstruct 1 year later with an auricular composite graft failed due to poor blood supply. Final

salvage reconstruction was achieved with a staged paramedian forehead flap, conchal cartilage batten graft for nostril rim and final contouring at 2 and 3 years later

Fig. 28 (a–d)
Chondrocutaneous
discharging fistula associated
with chronic chondritis
following wedge excision of a
right ear SCC. After a year of
recurrent sepsis, it is widely
excised, debrided and
salvaged with a pedicled
temporalis fascial flap. Result
at 3 months



17 Conclusion/Summary

Skin cancers of the nose and ears make up a significant workload for the plastic surgeon interested in facial cancer. Many of these are found in middle-aged to elderly individuals prone to chronic sun exposure, such as farmers, fishermen, golfers, orchardists, forestry workers and those just obsessed with a lifestyle of sun worshipping. A definitive diagnosis before excision helps guide the width of excision, and if this is not available, the eyes and hands of surgical experience can be relied upon. Complete local excision with histological margins appropriate for the type of cancer is a mandatory first step before embarking on aesthetic reconstruction. Immediate and single-stage reconstruction is ideal for the patient who is motivated to move on with better things to do, but sometimes a delayed and staged approach is required. It is the intuitive thinking and skill of a seasoned plastic surgeon, which makes this process

almost automatic. It should never be taken for granted though, because there lurk atypical and unusually aggressive cancers, which will challenge your surgical management in more ways than one. Sound surgical principles underpin this work and a sharp appreciation of the beautiful normal, when it comes to distinctive and landmark human facial features.

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Cheek and Perioral Cancer

Michael F. Klaassen and Ian Burton

Core Messages

- As surgeons, we ignore history and the patient's history at our peril.
- Facial disfigurement is catastrophic. In reconstruction, perfection is only just good enough.
- First, mentally create a plan deciding whatever sized defect is required to excise the cancer and then think what is missing and what is displaced?
- Replace like with like.
- Always strive to perform better surgery and be open to new and innovative methods.

1 Introduction

History teaches us. Although plastic and reconstructive surgery developed as a specific discipline of surgery relatively

the umbrella of plastic surgery were developed hundreds of years ago. An example being the forehead flap for nasal reconstruction described in the Sushruta Samhita, a Sanskrit medical treatise from the fifth-century BC.

It is to the pioneers of yesteryear that we owe respect and admiration as theirs are the footsteps in which we follow. The former professor of philosophy at Harvard, George Santayana, stated “Those who cannot remember the past are condemned to repeat it”. In both medicine and surgery, therapeutic options that lost favour are sometimes revitalized and come back into favour as the problems that occur with the latest and greatest are realized.

Michael Tempest FRCS (former editor of the British Journal of Plastic Surgery) recorded that a full-page editorial in the Lancet on 24 July 1920 reviewed the new book by Major Harold Gillies CBE, FRCS of the Royal Army Medical

Corps and titled *Plastic Surgery Of The Face* [1]. Sir Harold Gillies (1882–1960), a New Zealander and a surgeon of remarkable inventiveness and vision, had documented his unrivalled experience of treating the casualties of World War 1. It included burns of the face as well as gunshot and blast injuries, with a chapter on the application of prosthetics by Captain W. Kelsey Fry M.C., RAMC and remarks on anaesthesia by Captain R. Wade, RAMC. The editorial noted the rapid development of plastic surgery as a remarkable vindication of the value of teamwork. The value of the graphic record, sparing of words but lavish of pictures and diagrams was another laudation. In many respects, this monumental book by Gillies was the inspiration for *An Atlas of Extreme Facial Cancer*.

Sir Benjamin Rank (1911–2002) of Australia, who was a pupil of Gillies pre-World War 2, experienced the “indelible imprint” of the master surgeon and wrote the foreword to the facsimile of *Plastic Surgery Of The Face* published in 1983. In it, he praises the opening chapter on principles and the fundamental Gillies principle “To restore to their normal relationships, those parts damaged by disease or injury and to reconstruct or substitute for parts lost, tissues like in kind and amount”.

Rank also reminds us that Gillies himself acknowledged the use of all methods described in his text before, some of which had been described more than six centuries before. The Indian forehead and Italian arm flaps for nasal reconstruction of course, along with the lesser known local cheek flap of Middelburg which was illustrated in an 1857 Surgical Atlas by Bruns (Fig. 1).

The thousands of hideous facial injuries from war, treated in the temporary hutted hospital set in the grounds of the country estate of the first Viscount Sydney, are documented for eternity. An example of Gillies' reconstructive skills for the face is illustrated below in Fig. 2. Private Bell sustained a gunshot wound to his mid- and lower face on the Western Front circa 1916–1917. He was managed initially by Charles Valadier a French American dentist with whom the young Gillies had originally been mentored in the treatment of war facial injuries at the beginning of WW1. Valadier referred

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the young man to Gillies who had established the Face and Jaw Injuries Unit at the Queen Mary's Hospital, Sidcup, Kent, England in 1917. In his 1920 monumental textbook, *Surgery of the Face* [1], Private Bell is case 525 with total loss of his upper lip, a contracted mouth and pouting lower lip. Gillies recorded that the whole of Private Bell's nose was also lengthened and depressed (due to maxillary bone loss). In his first of several operations dated 23 July 1918 at Sidcup, Gillies recorded in his detailed operative note, drawings and photographs the surgical plan. The scar tissue was excised, and the stumps of the upper lip that had been crudely approximated by Valadier were separated and returned to their normal position. This principle determines what tissue is missing and what tissue is displaced. The nose was freed from its scars and repositioned cephalad on a small but vital upper skin bridge, which maintained its vascularity. Later, a total of six cheek–chin local flaps were mobilized and inset to provide lining and skin cover. A vulcanite upper prosthesis maintained the structural support for the new upper lip and nose.

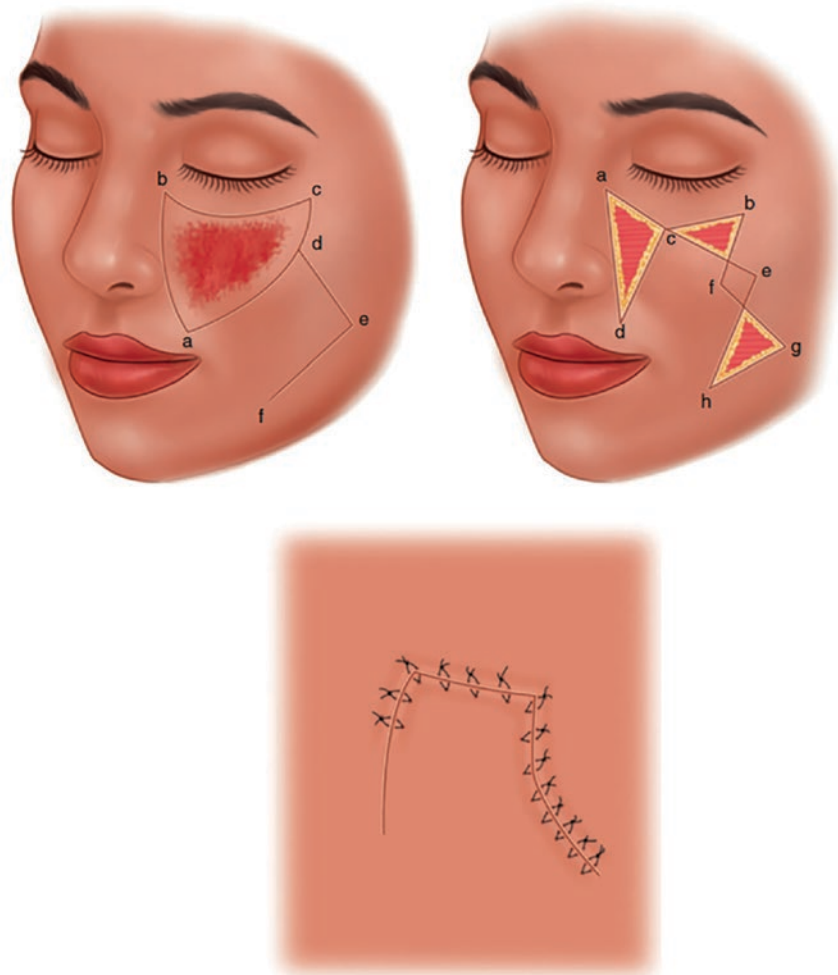
Sir Benjamin Rank reflects that injuries like Private Bell presented as surgical, social and humane problems of the highest order. Gillies himself hoped that the book would be distributed as a deterrent to the politicians of every country, to promote peace and not war. Dr. Andrew Bamji the Gillies Archivist has written about this and the historical evolution of plastic surgery in his excellent *Faces From The Front* [3].

Gillies divided the face into regions and each region into

overlapped so that cheek injuries often involved the lower eyelids, nose and mouth. Gillies wrote that the cheek is an area of plastic surgery, which lends itself to good results by restoring the lining membrane, the supporting bone structure and the skin cover.

Almost 70 years later, Professor Ian McGregor FRCS (1921–1998) of the Canniesburn Plastic Surgery Unit in Glasgow, Scotland reminded us of the generous quantity and quality of donor skin that was available in the cheek and neighbouring cervical region for modern methods of loco-regional facial reconstruction (Fig. 3).

Fig. 1 The flap of Middelcorp for a cheek defect, perhaps the precursor of the modern rhomboid local flap and illustrated in a 1857 Bruns Chirurgischer Atlas (courtesy of the late Professor Neven Olivari; re-used with permission from Klaassen et al. [2])



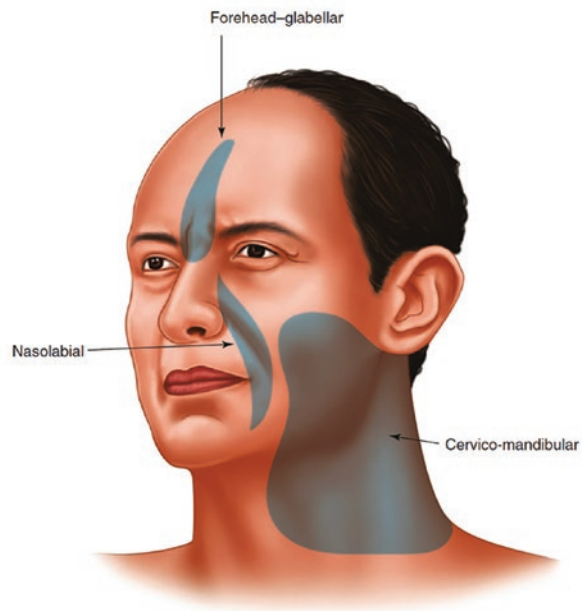


Fig. 3 Areas of spare cheek skin on the face (*from* Klaassen et al. [2]; *with permission*)

2 Modern Concepts

Dr. John J. Coleman III wrote an excellent chapter in 1994 describing the modern principles for osseous reconstruction of the midface and orbits [4]. He stressed the importance of understanding both the functional and aesthetic relationships of the midface unit. For large composite defects of the midface, the reconstructive solutions varied between prosthesis versus replacement of the tissue defect with vascularized free flaps of bone and soft tissue. Refinements in both the design of perforator free flaps and the osseointegrated maxillofacial prostheses have added many options to these most challenging cases. The addition of vascularized bone and soft tissue is particularly valuable in the setting of radiation damage or high bacterial colonization of the facial wound. For complex composite defects of the orbitomaxillary region the subscapular pedicle with its thoracodorsal and circumflex scapular vascular branches provide free flaps with soft tissue and more than one segment of bone. The details of these refinements are described further in Chap. 7 “Pedicled Versus Free Flaps” and Chap. 17 “Modern Maxillofacial Rehabilitation”.

Dr. Frederick J. Menick of Arizona, USA wrote a very helpful article in the August 2011 issue of *Plastic and Reconstructive Surgery*, which the author recommends [5]. Menick also refers to the topographic units of the face by anatomy, contour and colour. The central units are more demanding for the reconstructive surgeon than the peripheral units and restoration of normal appearance should always be the goal, if possible. The design of anteriorly based and posteriorly based cervicofacial flaps using an extensile approach, which may include chest skin, is clearly described. Skin

grafts are best for temporary cover, and distant flaps have a poor colour match and are best used for providing hidden lining or vascularized bulk for large and deep defects of the cheek.

Accompanying nasal defects, which may be overlapping with the cheek defect, are best reconstructed secondarily, once a stable cheek platform is achieved and this is brilliantly illustrated in the textbook co-written with the late Dr. Gary Burget (1941–2017) of Chicago, USA [6].

The choice of reconstructive options includes the pyramid concept of direct closure (when skin laxity allows), local flaps, loco-regional flaps, distant flaps (pedicled and free) and finally facial transplantation. The detailed choices of pedicled versus free flaps have been carefully considered by Professor Damian Marucci FRACS in Chap. 7 “Pedicled Versus Free Flaps”. In the illustrated cases below, the author describes the challenges he has faced when dealing with patients with cheek cancers.

3 Management/Technique

3.1 Direct Closure After Undermining

In the elderly patient and those with skin laxity in the lower face and neck, direct closure of moderate-sized defects of the lateral cheek can be achieved after undermining. The author uses the techniques of face and neck lift surgery with plication sutures of the platysma muscle at the first neck crease and the preauricular superficial musculoaponeurotic system (SMAS) with vertical vectors. These aid skin closure by shifting the tension to the deep plane (Fig. 4).



Fig. 4 (a–d) A 94-year-old woman with a biopsy-proven 5 × 2 cm well-differentiated SCC of her left jawline. Wide excision and direct closure after undermining and platysma—SMAS plication to reduce tension on skin closure

3.2 Local Cheek Flap

The author's local flap closure technique of choice is the sigmoid oblique island advancement local flap described by Dr. Ono of Japan [7]. This shifts skin and subcutaneous tissue from an area of laxity to the area of tension and respects the relaxed skin tension lines (Fig. 5). This Ono flap was for a small defect, but the right infraorbital location made the risk of postoperative lower lid retraction a reality.

The next case in an older gentleman, with a larger SCC tumour of his left malar region, demonstrates the

application of a larger Ono flap based on the relaxed skin tension lines (Fig. 6). Despite wide and complete excision, the SCC recurred 6 months later whilst the author was abroad. Another colleague managed the recurrence with further wide excision, repair with a posteriorly based cervicofacial local flap and adjuvant radiotherapy. The patient returned some years later with further BCCs of his nose, right preauricular and right temple regions. The latter were widely excised, and the defects were repaired with a type II facelift local flap [2].



Fig. 5 (a–d) A 58-year-old gentleman with a nodulocystic basal cell carcinoma of his right infraorbital region, widely excised and the defect repaired with a sigmoid oblique island advancement flap of Ono, immediate, 6-month and 5-year results



Fig. 6 (a–f) An 88-year-old gentleman with a moderate–poorly differentiated squamous cell carcinoma of his left malar cheek region widely excised and the defect repaired with a sigmoid oblique island advancement local flap. The tumour recurred at 6 months at the lower end of the flap and was again widely excised, salvage repair with a

cervicofacial flap and 17/20 fractions of adjuvant radiotherapy given. A year later, he returned with nodular basal cell carcinomata of his supratip nose, right temple and right preauricular regions. The latter were excised, and the defects were repaired with a facelift advancement flap. Final result is shown at 3-year follow-up



Fig. 6 (continued)

3.3 The Facelift Flap

The concept of aesthetica, previously referenced in Chap. 5 “The Team Approach in Cancer Care”, was reported by James Frame FRCS, Paul Levick FRCS and the author in 2017 [8]. It was an idea the author had after hearing Professor Frame present the Flick lift for minimalist facial rejuvenation early in 2017 at the Face Symposium in Queenstown, New Zealand. Aesthetica is a new and modern terminology that describes the application of cosmetic surgical techniques to improve the appearance of congenital or acquired soft tissue defects.

A classic example is the facelift incision and preauricular flap raised to access the sebaceous cyst in this young woman’s left masseteric region. The aesthetica approach avoids a large scar over her lateral cheek (Fig. 7). There is a small scar representing the excised punctum.

The 89-year-old patient in Fig. 8 is one of the clinical cases reported in the 2017 Aesthetica paper [8].

The next clinical example is a more traditional direct advancement facelift flap for an infiltrating ulcerated SCC of an elderly patient’s lower left preauricular and earlobe region (Fig. 9). The excision margins for the SCC lesion are the inner marking and the outer anterior markings are the planned undermining in the facelift plane, between subcutaneous tissue and SMAS.

The author defined a classification for facelift flaps for cheek repair in his 2018 publication with Dr. Earle Brown and Professor Felix Behan, *Simply Local Flaps* [2]. Type I is a mini-preauricular facelift flap, type II is a moderate-sized flap and type III is an extended facelift flap. Figures 10 and 11 show clinical examples of these.



Fig. 7 (a–d) Facelift flap approach to remove a left preauricular sebaceous cyst (20 × 13 mm) in a 28-year-old woman, result at 6 weeks



Fig. 8 (a–h) An active 89-year-old tennis player with severe facial photo-damage and large areas of SCC in situ both cheeks. In two stages, these areas were completely excised and the defects were repaired with the Flick lift flap

Fig. 9 (a and b) An elderly female patient with an ulcerated, infiltrating SCC of her lower left preauricular region. Widely excised including partial left earlobe and repair with a direct advancement type II facelift flap, after moderate undermining



Fig. 10 (a and b) Two male patients with zygomatic cheek region malignant tumours suitable for wide excision and immediate repair with the extended type III facelift flap



Fig. 11 (a and b) A 93-year-old woman with rapidly growing well-differentiated SCC right zygomatic arch region of upper lateral cheek. Wide excision and repair with type III facelift advancement flap. Result shown at 3 weeks

3.4 Anteriorly Based Cervicofacial Rotation Advancement Local Flaps of the Cheek

These are in design similar to the Mustardé cheek rotation flap described in Chap. 12 “Extreme Cancer of the Periorbital Region” on cancers of the periorbital region but are an evolu-

tion of the facelift flap concept (Figs. 12 and 13). Increasingly, the author is using the haemostatic net sutures of Auerswald from Brazil, which were taught to him by Dr. Daniel Labbé of Caen, France, in 2019. These reduce the risk of haematoma and avoid the need for a drain under the flap. They are removed usually at day 3 [9].



Fig. 12 (a–d) An 83-year-old woman with biopsy-proven melanoma in situ of the right cheek widely excised with >5 mm margins radially and repaired with an inferiorly based cheek rotation flap. NB Auerswald’s haemostatic net sutures. Result at 2 months



Fig. 13 (a–c) A 77-year-old gentleman with a squamous cell carcinoma in situ of his left malar region, completely excised and the defect repaired with a Mustardé inferiorly based lateral cheek rotation flap

after triangulating the defect. Note the haemostatic net sutures of Auerswald, which were removed on day 3 postsurgery and the result at 8 weeks

3.5 Posteriorly Based Cervicofacial Rotation Advancement Local Flaps of the Cheek

These flaps are a variant of the anteriorly based cervicofacial flaps. Usually, the medial flap edge follows the nasola-

bial fold. They can be combined with a Z-plasty in the neck as illustrated in Fig. 14. This is a patient of Dr. Swee Tan [2].

Occasionally, this flap may be combined with other local flaps such as the paramedian forehead flap if the cheek defect also involves the nasal region (Fig. 15).

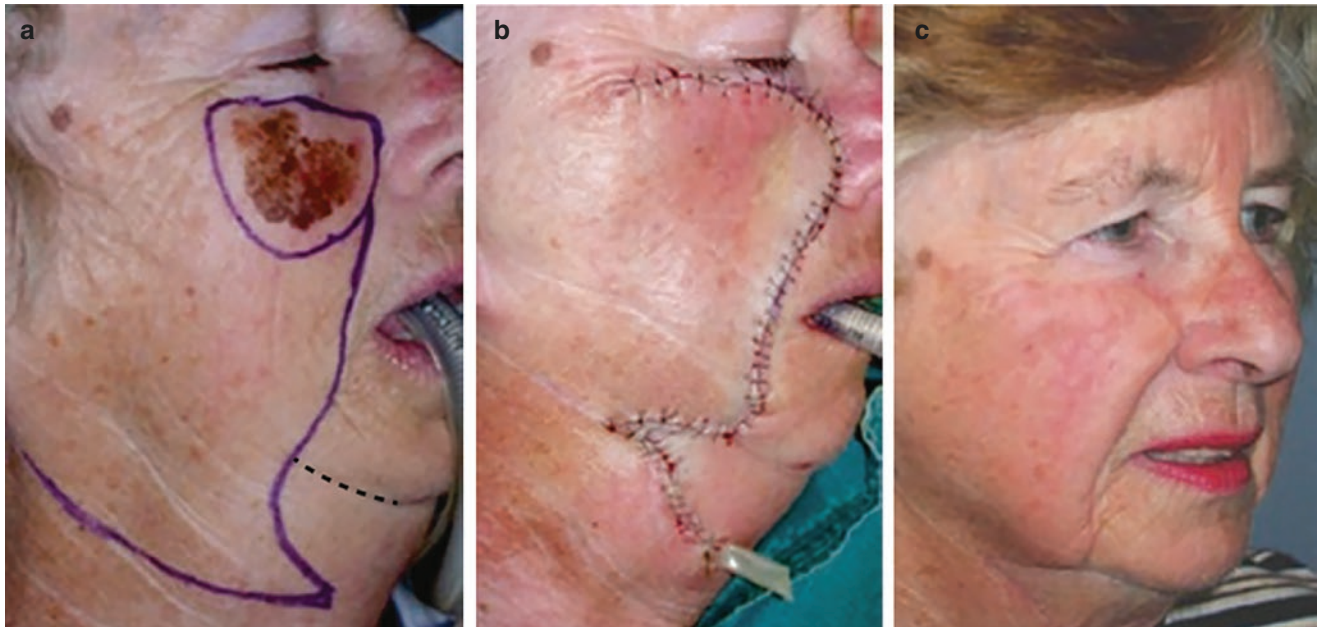


Fig. 14 (a–c) A 76-year-old patient of Dr. Swee Tan MD, FRACS with wide excision of a medial upper cheek melanoma in situ and reconstruction with a posteriorly based cervicofacial rotation local flap incor-

porating a Z-plasty in the submental region. Final appearance at 14 months (from Klaassen et al. [2]; with permission)

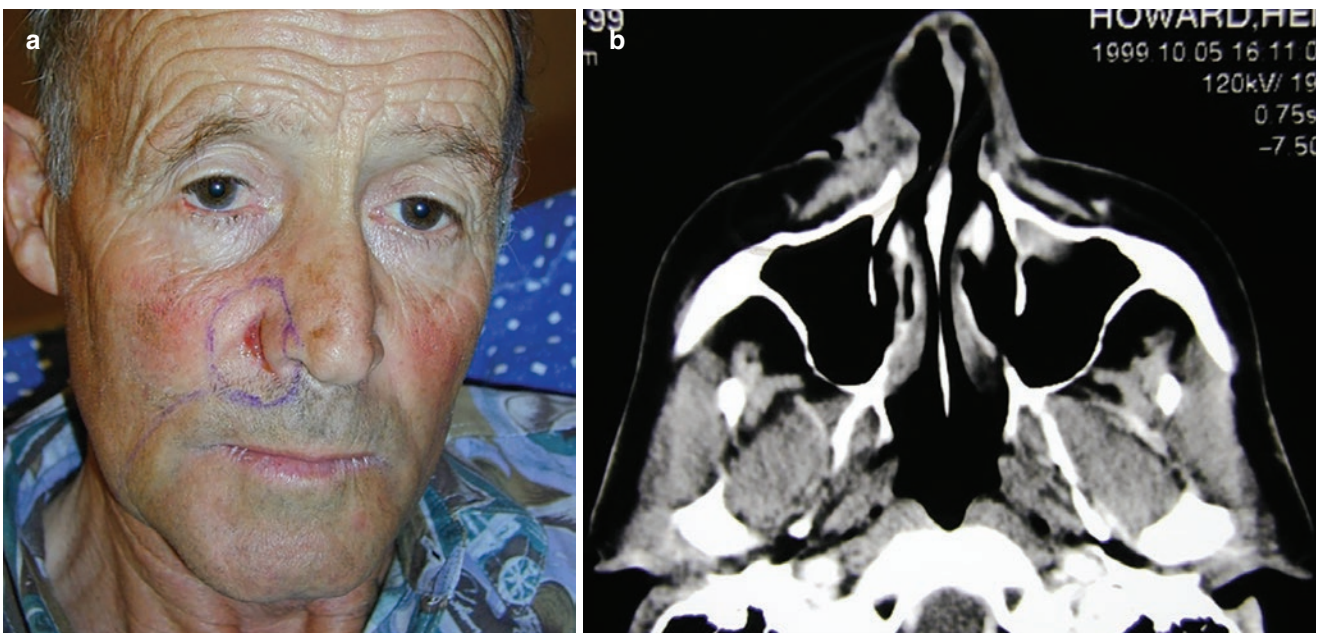


Fig. 15 (a–e) An ulcerated amelanotic malignant melanoma of the right nasolabial groove/alar nasal junction. CT scan shows proximity to right maxilla. Wide excision and staged reconstruction with large pos-

teriorly based cervicofacial flap, paramedian forehead and auricular cartilage grafts. 1-year appearance



Fig. 15 (continued)

4 Lip Reconstruction

The lips and perioral region are the central unit of the mid-face facial region. The late Dr. Gary Burget et al. wrote an elegant paper in the February 1998 issue of *Operative Techniques in Plastic and Reconstructive Surgery*, about the aesthetic reconstruction of the confluence of the nose, lip and cheek, which illustrates the relationship of the various central face aesthetic units very well [10].

Cancers of the lip and perioral region are common in every plastic surgeon's practice and most defects will be small–moderate, being less than one third of either the upper or lower lip. The late Dr. Stephen S. Kroll of Texas USA defined reconstruction of large lip defects in another issue of *Operative Techniques in Plastic and Reconstructive Surgery* (November 1999) [11]. Large defects are always difficult because of the special form and function of the lips. This challenge is addressed in more detail by Dr Rafael Acosta Rojas FRACS in Chap. 15 “Palliative Surgery”.

A typical lower lip cancer is shown in Fig. 16. This was a 62-year-old man who presented to the author with a 4-month history of lip dysplasia and an associated central lower lip well-differentiated squamous cell carcinoma. A combined wide wedge resection and lip shave were repaired with partial bilateral Karapandzic neurovascular island local flaps designed along the relaxed skin tension lines of the lower lip–chin junction.

The full bilateral Karapandzic flaps are more suitable for a subtotal lower defect as seen in the young woman in Fig. 17 who was referred by a dermatologist with a biopsy-proven desmoplastic malignant melanoma of her central lower lip. Radical excision including the right mental nerve was followed by immediate flap reconstruction and adjuvant radiotherapy.

Large defects present a real challenge as in this 45-year-old patient from Papua New Guinea, referred to the author's Interplast Team in 2000. The images in Fig. 18 show the extensive fungating SCC of his upper lip, right cheek, lower lip and chin from chronic betel nut chewing. This practice of chewing is widespread in parts of the Pacific.



Fig. 16 (a–d) A 62-year-old man with 4-month history of biopsy-proven well-differentiated pT2 SCC of the central lower lip with associated lower lip dysplasia. Wide excision + lip shave and reconstruction

with bilateral subtotal neurovascular island Karapandzic local flaps and mucosal advancement flap. Last image shows the result at 12 months



Fig. 17 (a–e) A young woman with desmoplastic malignant melanoma of her lower lip vermillion. Wide full-thickness lower lip resection in continuity with right mental nerve to the foramen in her mandible (see oriented specimen), immediate reconstruction with bilat-

eral Karapandzic neurovascular island local flaps. No Abbe flap is required from upper lip. Postoperative radiotherapy. Appearance at 1 year



Fig. 17 (continued)



Fig. 18 (a–e) An extensive fungating SCC in a 45-year-old clergyman from Port Moresby, Papua New Guinea (*from* Klaassen et al. [2]; *with permission*)

5 Chin Reconstruction

The chin subunit is closely related to the lower lip and neck units. Serendipitously for the reader, the modern master of facial reconstruction, Dr. Frederick Menick from Arizona, USA published a paper on Subunit Reconstruction of the Chin in the

same issue of Operative Techniques in Plastic and Reconstructive Surgery (November 1999) as Dr. Stephen Kroll's large lip defect paper [12]. The author has not had cause to use Menick's staged submental local flap for total chin soft tissue reconstruction but has used the reliable keystone perforator island local flap of Behan, to achieve aesthetic reconstructions (Figs. 19 and 20).



Fig. 19 (a–d) A 73-year-old woman with a biopsy-proven infiltrating BCC of her left chin, widely excised and repaired with a keystone perforator island local flap. Immediate, 2-month and 8-month results shown



Fig. 20 (a–c) A 74-year-old woman with nodulocystic BCC of her central chin, widely excised and the defect repaired with a keystone perforator island local flap. Immediate result and early result at 1 month postsurgery

6 Very Extreme Cases

These are fortunately rare but require a comprehensive workup and surgical plan within the context of a Multidisciplinary

Team. Curative intent may often be unrealistic, and palliative resection plus reconstruction is more the norm. This cohort of patients is detailed in Chap. 15 “Palliative Surgery”, and some cases treated by the author are illustrated below (Fig. 21).



Fig. 21 (a–d) Extreme cheek cancers including an ulcerated long-standing BCC of the left hemi-face, an ulcerated SCC of the right pre-auricular cheek with associated right facial palsy, a recurrent Merkel

cell cancer right midcheek and the defect following radical resection of a rhabdomyosarcoma of the left cheek and maxilla

7 Fundamental Surgical Techniques/ Surgical Anatomy

These are best seen and experienced in the anatomy dissecting room, where the novice surgeon will learn from experienced mentors and then have greater confidence in the

Melbourne-based plastic surgeon anatomists organized the Inaugural Head & Neck Reconstruction & Aesthetic Facial Surgery Applied Anatomy Workshop. This was inspired by the Canniesburn Flap Course from Glasgow, Scotland and the subsequent Waikato Liverpool Hospitals Flaps Courses in the 1990s. Led by the author and hosted by the Surgical Training Centre, University of New South Wales, Sydney, Australia, the enthusiastic organizing committee included Dr. Antonio Fernandes, Dr. Lawrence Ho, Dr. Paul Stephens and Sven Kunkel (Manager STC). The passionate teaching faculty included Professor Michael Poole, Dr. Bryan Mendelson, Dr. Swee Tan, Dr. Lawrence Ho, anatomists Assoc. Professor Brian Freeman and Dr. Dzung Vu. Professor Michael Esson from the UNSW School of Fine Arts also contributed. Fourteen participants included Drs Ahmed Alkadhi, Lee Brown, Eddy Dona, Peter Callan, Ian Carlisle, John de Waal, Megan Hassall, Ian Holten, Gary Kode, Nita Ling, Stephen Mills, Zak Moaveni, Sandrine Roman and Andy Williams. It was a 3-day course, and we hoped to make it an annual Sydney event, but circumstances prevented this. In 2009, the late Dr. Simon Bernard (1967–2011) and Dr. Bryan Mendelson started, what would evolve into the Melbourne Advanced Facial Anatomy (MAFAC) course, which is still an annual event and also international.

From little things, big things grow (song by Paul Kelly, 1991).

8 Parotidectomy

The key is identification and preservation of the facial nerve trunk and its branches coursing between the superficial and deep lobes of the parotid gland. A facelift incision behind the tragus and taking a little bit of the tragal cartilage to make the skin more viable is our technique. The incision is deepened into the parotid fascia, where the facial nerve is still at least 4 cm deeper. Find the cartilaginous meatus and dissect anteriorly along it, which is an easy plane. The lip on the anterior edge of the bony meatus points to the trunk of the facial nerve exiting the stylomastoid foramen and a good 5 cm deep to the earlobe. The mastoid process and attachments of the sternocleidomastoid and posterior belly of digastric muscle are posterior landmarks.

9 Neck Dissection

A functional neck dissection aims to remove the fascial compartments of the neck that contain the draining lymph nodes. These are levels 1, 2 and 3. A submental flap is raised in the relaxed skin tension lines and a supra-platysma plane dissected up to the lower border of the mandible. The marginal mandibular branch of the facial nerve is identified and dissected free of its attachments if necessary. A safe approach is to identify the anterior facial vein as it runs over the submandibular gland. By ligating and retracting it cephalad, the marginal mandibular branch of VII is protected. The greater auricular nerve is usually sacrificed as the investing cervical fascia is divided. Begin the dissection posteriorly over the sternocleidomastoid muscle, lifting the node-containing soft tissues anteriorly. The spinal accessory nerve (XI) is seen entering the deep layer of sternocleidomastoid in its upper third and exits the muscle in the midneck. The surgeon should be aware of palpable nodes in the upper cervical chain. This means that the spinal accessory nerve cannot be spared from an oncological perspective. The XI nerve crosses

the atlas vertebral bone. It is best to ligate the IJV superiorly first to get rid of the “sausage”. The cervical plexus branch of XI is divided anteriorly and the dissection continues caudally over omohyoid muscle and the floor of the posterior triangle of the neck where the levator scapulae will be seen. The carotid sheath and the hypoglossal nerve (XII) will also be seen. In the patient with a previously irradiated neck, the levator scapulae muscle can be turned over to protect the carotid vessels. The omohyoid muscle is in the lower posterior triangle of the neck and deep to its fascia lies the brachial plexus, IJV, phrenic and vagus nerves. In this deeper plane on the left side lies the thoracic duct.

10 Tracheostomy

The airway is a shared anatomical region in all head and neck surgery for trauma, cancer and congenital anomalies. It is the authors' personal view that all clinicians should be competent in the emergency management of the airway.

In the neck dissection scenario, it is important to keep the tracheostomy wound separate from the neck dissection wound, if possible. This can be achieved with both a horizontal and short vertical skin incision. The midline strap muscles are separated, and the thyroid isthmus may need to be retracted cephalad or surgically divided. The tracheal rings are exposed, and a hole is cut for the tracheostomy tube placement. This is best done in the author's experience with

a Bjork inferiorly based tracheal ring flap, but alternatives include a horizontal or vertical cut, wide enough to take the tube. Ideally, the tracheostomy and neck dissection wound should not communicate. Revision of tracheostomy scars is an easy elective procedure down the track.

11 Gaining Access to the Oral Cavity

This is predominantly for the treatment of oropharyngeal cancer. Any compromise of treatment will adversely affect the patient's survival and quality of life. Functional aspects of chewing, swallowing and speech are a priority and covered comprehensively in Chap. 19 "Assessment of Function Post-Cancer" by Professor Julia Maclean of Sydney, Australia. Radical surgical excision with or without adjuvant chemoradiation is therefore the goal, and surgical exposure should be designed to maximize adequate exposure of the cancer and adjacent structures. The surgeon should also think about the potential dimensions of the resection defect, the loco-regional lymph node zones and the potential recipient vessels for microvascular free tissue transfer. The management of oral cancer is covered in more detail in Chap. 17 "Modern Maxillofacial Rehabilitation". Dr. David Soutar FRCS always emphasized the value of a proper examination under anaesthetic (EUA) for initial surgical assessment and planning [13]. Endoscopic examination combined with CT/MRI imaging is also worth considering in the workup. There are various approaches to the oral cavity exposure including transoral (with or without robotic technology), transhyoid pharyngotomy and the traditional lower lip splitting mandibulotomy. The latter is the preferred method of the author. After splitting the lower lip, the mandibular periosteum is exposed, mobilized and a step osteotomy is performed with a powered mini-saw anterior to the mental foramen. Whilst the genioglossus and geniohyoid muscles are left attached to the central mandibular segment, a cut is made through mylohyoid muscle and its attachment to the lateral mandibular segment. The mandibulotomy is swung laterally and this gives great access to the posterior tongue and posterior oropharynx. Composite resections will require mandibular reconstruction ideally with vascularized bone flaps and rigid fixation with reconstructive plates and screws. For hemi-maxillectomy access, a Weber–Fergusson incision paranasally and through the upper lip is combined with an upper buccal sulcus incision. See Chap. 17 "Modern Maxillofacial Rehabilitation" for more details.

12 FAMM Flap

The author champions the mirror image of the external skin nasolabial flap, the facial artery myomucosal flap (FAMM flap) for reconstruction of small–moderate defects intraorally. This flap was first described in 1992 by Professor Julian Pribaz FRCS, FRACS an Australian of Italian birth who moved to the Harvard Medical School, Boston, USA [14]. This flap was taught to the author by Professor Michael Poole FRCS and is an exceptional flap for intraoral application. The markings for the facial artery are drawn from the angle of the mandible towards the nasolabial groove. It runs a tortuous path cephalad giving off superior and inferior labial branches. The deep course of the facial artery is drawn inside the buccal sulcus anterior to Stenson's parotid duct. The facial artery runs on the outer surface of the buccinator muscle but deep to the risorius muscle and the lip elevators. The FAMM flap can be based superiorly or inferiorly, and the surgeon should try and include the facial vein in the pedicle and leave a cuff of soft tissue around the artery. The superiorly based FAMM flap can be used to reconstruct defects in the hard palate, alveolus, maxillary antrum, nose, upper lip and orbit. The inferiorly based FAMM flap, after dividing the facial artery superiorly at the top end of the flap, can be used to reconstruct defects of the hard and soft palate, the tonsillar fossa, alveolus, and floor of mouth and lower lip [14].

13 Deep Facial Spaces

These were described by Drs Bryan Mendelson also of Melbourne, Australia and Steven Jacobson of the Mayo Clinic USA in 2008 [15]. The fourth layer of the face is akin to the fourth layer of the scalp schematically and is the gliding loose areolar layer, which contains the retaining ligaments of the face attached to the facial skeleton. Between the ligaments are the deep facial spaces: pre-masseteric space, pre-zygomatic space and cephalad, the pre-septal space. The facial nerves and vessels traverse through the walls, but do not enter the spaces. The orbicularis fascia forms the roof of the deep facial spaces, whilst the deep fascia or periosteum forms the floor of these spaces. The retaining ligaments branch out through the SMAS layer (third layer), to form the perpendicular part of the reticular dermis, which fixes to the dermis [15]. The spaces and their distension with ageing of the face have relevance for rejuvenation surgery but also for dissection planes in reconstructive facial surgery after cancer resection. This is particularly important for preserving the multiple facial nerve branches exiting the anterior part of the parotid gland.

14 Innovations

14.1 Changes to the Classification and Staging of Lip SCC

A recent paper by Yung et al. from Sydney has analysed the new classification of SCC of the vermillion lip (vlSCC) as

This is a feature of the eighth edition of the American Joint Committee on Cancer compared to the former seventh edi-

tion and causes important aberrations leading to unwarranted upstaging of pT1 lesions [16].

14.2 Tissue-Expanded Local Flaps

This is covered extensively in Chap. 8 “The Novel Expanded Forehead Flap” showing many examples of the novel forehead flap for forehead and cheek reconstruction as a delayed procedure (Fig. 22).



Fig. 22 (a and b) A radiation-induced lesion of the right midcheek, excised and reconstructed with tissue-expanded local flaps

14.3 Keystone Interposition Flap

The author has used the keystone perforator island flap frequently for facial defects where the sigmoid oblique island advancement flap of Ono is inadequate and a common clinical

scenario is when two cancerous lesions are in close proximity as in Fig. 23. The wide application of the keystone perforator island flap concept is discussed comprehensively by Professor Felix Behan FRACS, in Chap. 9 “Keystone Flap Concepts”.



Fig. 23 (a and b) This 61-year-old cardiac transplant patient (15 years previously) on long-term immunosuppressants was referred with multiple scalp and facial SCCs. The left midcheek well-differentiated SCC and left preauricular region poorly differentiated SCC were in close

proximity, which precluded direct closure after wide excision. The novel use of an interposition keystone flap, described by the author conveniently, closes both defects without undue tension

15 Complication Management

Skin grafts are generally contraindicated for midface and cheek reconstruction except for temporary cover, whilst the Delayed Reconstruction After Pathological Examination (DRAPE) principle is being observed. The

colour match and contour are poor and shrinkage of the graft may lead to malposition and deformity of the lower eyelids. This is illustrated in Figs. 24 and 25 below.

And finally, an unusual case of a pedicled pectoralis major myocutaneous flap to the right face, which was never divided! (Fig. 26).



Fig. 24 (a and b) Lower lid malposition secondary to contracture of skin grafts, released and repaired with a full thickness skin graft (FTSG), result at 30 days



Fig. 25 Contour, colour and contraction complications of a split skin graft used for a midface cheek reconstruction. The left lower eyelid cicatricial ectropion needs to be released, the lower eyelid malposition restored with a lateral canthoplasty and new skin cover provided for the infraorbital, cheek and mandibular regions. A tissue-expanded posteriorly based cervicofacial flap would be one solution



Fig. 26 (a–d) Eleven years previously, this 82-year-old gentleman had radical surgery and radiotherapy for recurrent SCC of his neck resulting from a primary on the right ear. This was complicated by radionecrosis and an ulcer in his right submandibular region, which was reconstructed

with a pectoralis major myocutaneous pedicled flap. He got lost to follow-up and the flap was not divided and inset until the author came across him during a locum in North Queensland. Early postoperative result shown

16 Conclusion/Summary

The cheek and perioral regions are common anatomical locations for cancer. The related anatomical zones of the ear, orbit, nose and mouth may have overlapping reconstructive needs after cancer ablation. The modern master facial reconstructive surgeon Dr. Frederick Menick from Tucson, Arizona, USA is experienced and knowledgeable about the historical evolution of modern plastic surgery, and his refinements of the reconstructive principles are to be recommended. In his own words from the *Introduction* to the February 1998 issue of *Operative Techniques in Plastic and Reconstructive Surgery* “*Thoughtful analysis is the secret of facial reconstruction*”.

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Palliative Surgery

Rafael Acosta-Rojas

Core Messages

- Palliation is an integral part of the whole spectrum in the treatment of head and neck cancer.
- The aim of surgery in these instances is to excise and reconstruct to offer the patient palliation, with the aim of minimising morbidity and to offer a greater quality of life to the patient.
- Microsurgical free flap transplantation offers this possibility.
- Multidisciplinary approach.

Several consequences may result from exophytic tumours in the palliative patient: necrosis, bacterial contamination, malodour and even the ability to feed and drink normally. Social isolation and family disruption may also occur.

It would be difficult to provide the reader with a flow chart to guide the choice of appropriate procedures. All the reconstructions we have encountered in these cases are complex, and if reconstructions are to be done, we believe reliable methods are essential, so as not to increase the morbidity.

The purpose of this chapter is to share our experience in treating some of these cases.

1 Introduction

Although the head and neck team has the aim of providing curative treatment, occasionally this is not possible due to the aggressiveness of the disease or the patient's general condition.

This creates not only a medical situation for the patient but also a social problem as we have noted that the patients tend to isolate themselves or in few cases they lose contact with the family. A very important issue is the isolation that these patients may be subjected to sometimes by their own family.

In this situation, palliation is aimed at improving the quality of life and providing dignity to the patient.

A multidisciplinary approach is of the utmost importance.

Occasionally, the reconstructive surgeon is confronted with cases that require out of the box solutions. The reconstruction ladder in these cases might not be useful, and the surgical team should be prepared to offer alternative palliative solutions.

2 Reconstruction

In the field of plastic and reconstructive surgery, we have an abundance of flaps we can choose with different types of donor sites, skin quality, pedicle length and diameter of vessels as well as possibilities to make them sensate or with different types of tissue (skin, fat, muscle, bone, mucosa, etc.).

The team should ideally be familiar with them.

Preoperative studies such as CT angiography or MRI angiography have proved to be of great help in the field of reconstruction using free flaps. We have used these techniques in assessing the receptor vessels and found them useful.

A two-team approach is used with the excision team working and the reconstructive team raising the free flap. It is not always possible to do this simultaneously as sometimes the surgical excision strategy may change. In our experience final receptor vessel preparation is done by the reconstructive team.

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3 Clinical Examples

3.1 Advanced Squamous Cell Cancer of the Midface

A 60-year-old man with advanced squamous cell carcinoma involving the upper lip, nose, cheeks and anterior maxillae as well as metastasis to the neck is shown in Fig. 1. He had problems eating and with hygiene as there was a considerable amount of necrosis and anaerobic contamination. A multidisciplinary approach was followed. Palliative resection of the midface cancer was combined with neck dissection. The excision included a premaxillae resection.

The midface defect was covered with a single osteofasciocutaneous-free scapular flap. This flap was chosen as we could use the scapular bone for reconstruction of the premaxillae and provide oral competence. Osteosynthesis was achieved with plates and screws. Suspension sutures from the corner of the mouth to the temporal fascia were placed with non-absorbable sutures. The nasal opening was secured with a temporary nasal mould. The donor defect was closed primarily but was complicated by dehiscence which healed by secondary intention. There were no complications with the reconstruction. The patient survived for another 2 years (Fig. 2).

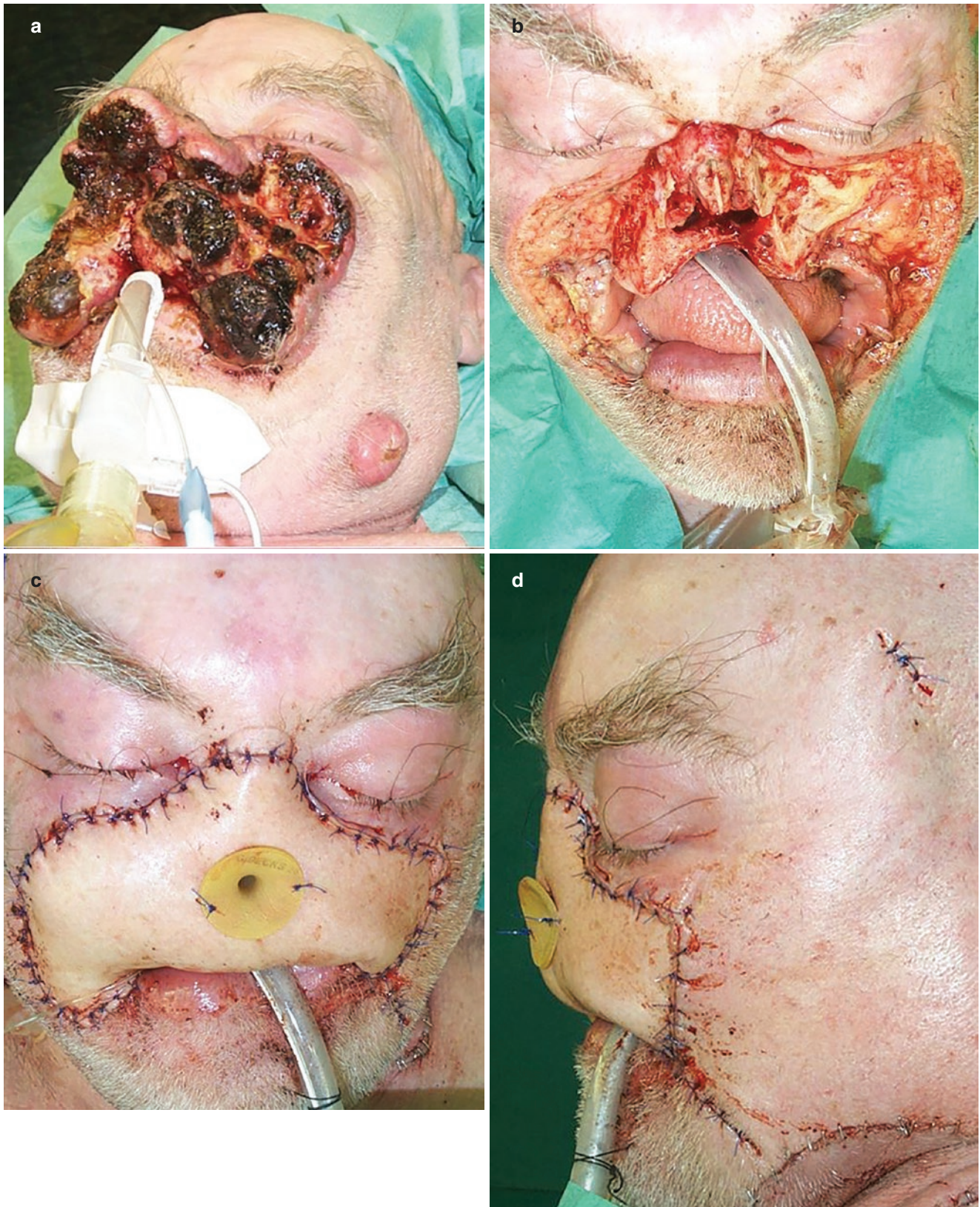


Fig. 1 (a–d) 60-year-old man with advanced squamous cell carcinoma of the midface. Midface resection including premaxillae and reconstruction with a free scapular osteofasciocutaneous flap



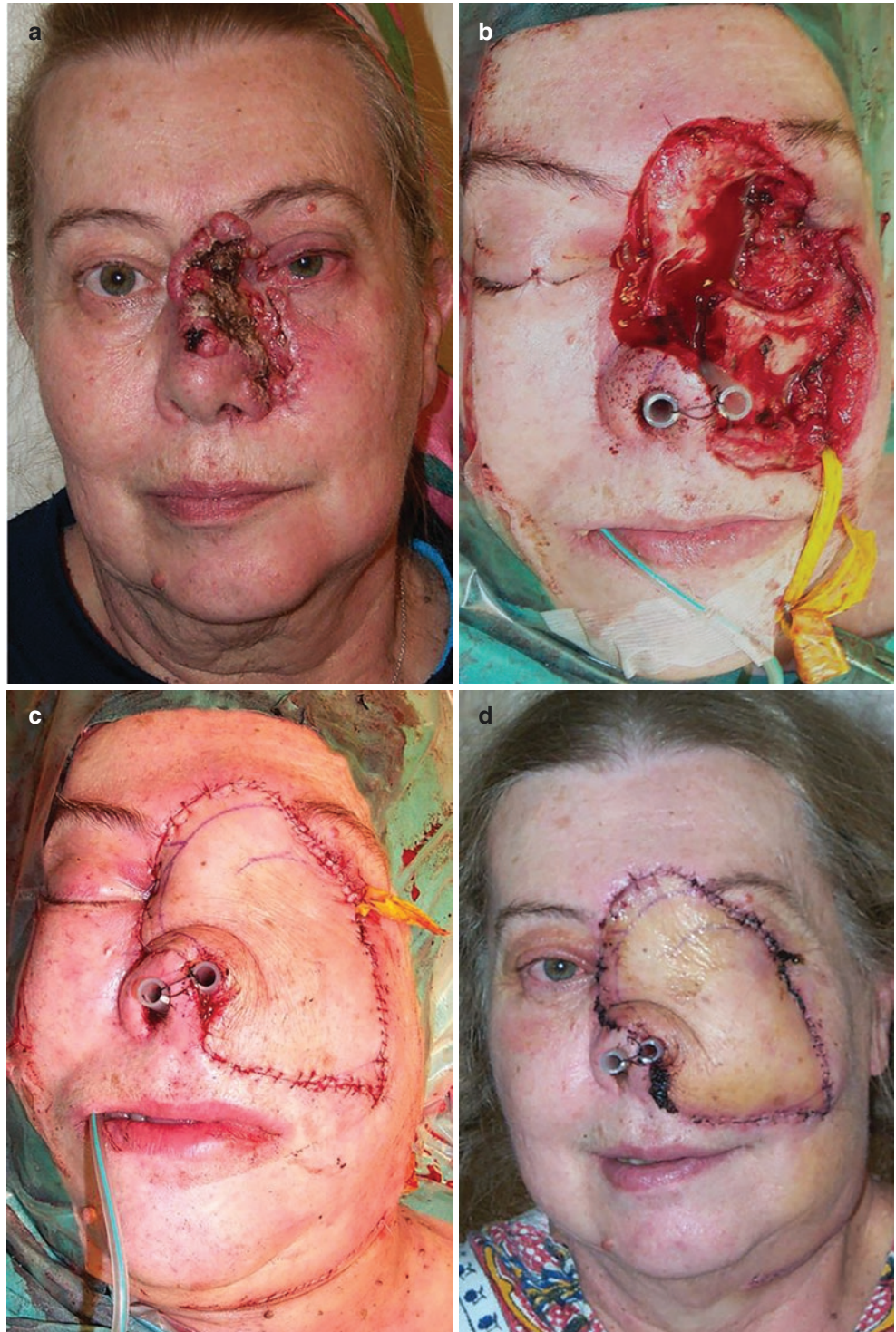
Fig. 2 (a–c) Healed free scapular osteofasciocutaneous flap to midface defect post-cancer resection and donor site, which was complicated by partial dehiscence

3.2 Advanced Basal Cell Cancer of the Naso-Orbital Region

This 65-year-old female patient presented with a large ulcerated lesion on the left side of the naso-orbital region (Fig. 3).

It had started as a lesion on the inner canthus. Radiological studies demonstrated infiltration into the nasal area and medial wall of the orbit. A major resection was performed, and a single-stage free radial forearm flap was used for basic coverage followed by palliative radiotherapy.

Fig. 3 (a–d) A 65-year-old woman with advanced ulcerated BCC of the left orbito-nasal region invading the medial left orbit. Radical resection including left orbital exenteration was immediately reconstructed with a free radial forearm fasciocutaneous flap. This was followed by palliative radiotherapy



3.3 Recurrent Squamous Cell Carcinoma of the Neck Post-surgery and Adjuvant Radiotherapy

This 40-year-old male patient previously had a tonsillar squamous cell carcinoma treated with radiotherapy, complicated by a right neck recurrence (Fig. 4). The recurrence was widely excised, and the defect was

reconstructed with a pedicled pectoralis major myocutaneous flap. A second recurrence occurred later in the irradiated neck field. This was widely excised with exposure of the major neck vessels. A salvage palliative reconstruction was achieved with a free groin flap, with anastomosis to vessels on the left side of the neck. Brachytherapy lines were placed for further palliative radiotherapy. The donor site dehisced and took several weeks to heal by secondary intention.



Fig. 4 (a–d) 40-year-old man with recurrent tonsillar SCC in his irradiated right neck where a previous recurrence had been widely excised and reconstructed with a pedicled pectoralis major myocutaneous flap.

The second recurrence was resected exposing major neck vessels, which were covered with a free groin flap anastomosed to recipient vessels in his left neck

3.4 Recurrent Left Orbital Sarcoma Invading the Hard and Soft Palate

This 35-year-old man presented with a large recurrent sarcoma of the left orbit invading the hard and soft palates

(Fig. 5). Wide local excision was performed and reconstruction with a free musculocutaneous rectus abdominis flap. The skin island was divided into two regions for intra- and extra-oral reconstruction. The anastomosis of flap vessels was to the facial vessels.



Fig. 5 (a–e) A 35-year-old man with recurrent left orbital sarcoma invading the hard and soft palate, widely excised and the defect reconstructed with a free bi-paddled rectus abdominis flap. The flap was divided into 2 paddles, one for the orbital defect and the other for the maxillary defect

4 Conclusions and Summary

As highlighted in Chap. 10 “Basal Cell Carcinoma: A Surgical Enigma”, the philosophy of Dr. Milton Edgerton emphasized in his 1982 Hayes Martin Lecture [1] has much significance in this consideration of palliative surgery. Cancer control and quality of life may be the goal in the most challenging head and neck cancer cases where cure is out of reach. Dr. Edgerton advised: *“Each of us must make judgments about when to try for cure, what to tell the patient, how long to continue palliation. These are never easy questions”*.

Professor Michael Poole MD, FRCS former plastic, craniofacial and head and neck plastic surgeon in Sydney, was always a firm and passionate advocate for palliative surgery in selected patients to improve their quality of life. This was planned and discussed in the St George Hospital, multidisciplinary head and neck cancer team, of which many contributing authors of this Atlas were past or current members.

Although we try to perform curative procedures for our facial cancer patients, it is not always possible to do so. Some patients continue to develop exophytic tumours and metastases that will not be curable. Palliative treatment then plays a crucial role in the management of these cases. The aim is to

provide the patient with comfort, pain relief, tumour debulking and giving him/her dignity during this phase. Although this might involve complex surgical procedures, we consider that the final decision as always will depend on the patient and the treating team.

If microsurgery is to be used, a multidisciplinary approach is highly recommended. When indicated, we suggest taking advantage of all the reconstructive surgical tools available in order to offer the patient quality of life in this situation.

Preoperative planning with digital tools is of great help in assessing the donor site and the receptor site. The use of instrumentation such as anastomosing rings and vascular closure systems (VCS) has reduced operating time. Intraoperative tissue assessment tools and postoperative monitoring systems have improved the observation of reconstructive flap viability.

Every case, however, is a challenge to the treating team.

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Part IV

Form and Function

Metastatic Cancer to the Parotid Region

Robbie S. R. Woods and Nick McIvor

Core Messages

- The presence of lymph node disease is a poor prognostic factor in cutaneous malignancy.
- Cutaneous malignancy of the head and neck can spread to parotid lymph nodes, cervical lymph nodes or both, depending on the location of the primary tumour. Clinical evaluation of the parotid and neck should be performed in patients with cutaneous malignancy.
- Treatment for lymphatic spread of non-melanoma cutaneous malignancy of the head and neck should be surgical resection with adjuvant radiation.
- Oncologic outcomes should be maximised by appropriate management of the temporal bone, external auditory canal, temporomandibular joint, facial and other nerves.

1 Introduction

Regional metastatic disease from cutaneous head and neck malignancy is a common and complicated clinical challenge. Although the region is anatomically complex, lymph drainage from cutaneous malignancies follows somewhat predictable patterns of spread. In contrast to mucosal disease of the head and neck, the parotid and superficial lymphatic systems need to be addressed in cutaneous malignancies. The commonest cutaneous pathology found in parotid nodes is squamous cell carcinoma (SCC), followed by melanoma [1]. Other primary cutaneous malignancies can also present with regional disease in the parotid such as Merkel cell carcinoma, pleomorphic sarcoma or basal cell carcinoma. In cases of SCC, it is possible that, once nodal metastases occur, nodal factors may be stronger predictors of prognosis than primary tumour factors [2].

More than 300 lymph nodes are present in the head and

location, including parotid, postauricular, suboccipital, facial, retropharyngeal and cervical (subdivided into submental, submandibular, jugular chain (upper, middle, lower, anterior), spinal accessory chain and supraclavicular). Pathways of lymphatic drainage that have been described are shown in Table 1. A significant proportion of facial cutaneous disease may drain through the parotid. While it is understood that the majority of lymph nodes within the parotid lie superficial to the facial nerve, a small number of nodes are usually also present in the deeper parotid gland [3, 4].

There are a number of important anatomical structures to consider in managing primary periauricular cutaneous malignancy and regional nodal disease to the parotid gland. These include the facial nerve, external auditory canal, temporomandibular joint (TMJ), lateral temporal bone and sensory nerves such as the greater auricular and auriculotemporal nerves. Particular care must be taken to manage nerves appropriately in cases of squamous cell carcinoma, given the potential for perineural spread of disease. It is worthwhile noting that immunosuppression significantly increases the risk of cutaneous malignancy and immunocompromise is a significant independent risk factor for aggressive behaviour of metastatic cutaneous SCC to the parotid and neck [5, 6].

The commonest primary tumour metastasising to the parotid gland is cutaneous squamous cell carcinoma. The parotid is the initial draining site for cutaneous malignancies on the cheek, pinna, forehead and temple [7]. Rates of regional disease from cutaneous SCC are estimated at approximately 5% [8, 9]; however, higher rates of up to 33–47% are reported in cases with adverse histopathological features such as poor differentiation and perineural invasion [10]. The presence of disease in regional nodes has been associated with five-year survival rates as low as 35% [10, 11]; however, rates are reported at 50–70% after appropriate surgery and adjuvant treatment [12–15]. The management of metastatic SCC to the parotid region is often similar to cutaneous malignancy of the periauricular region. A number of local anatomical factors need to be considered in the man-

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agement of this disease and will be considered in this chapter.

Malignant melanoma is the second most common tumour type that metastasises to the parotid and the proportion of primary cutaneous malignant melanoma metastasising into the parotid gland is higher than squamous cell carcinoma [1]. Lymphatic drainage patterns of the head and neck are challenging in the treatment of melanoma. Likely routes of lymphatic drainage in melanoma have been described [16];

pathways and so the inclusion of parotidectomy in a therapeutic neck dissection for clinically involved cervical lymph node metastasis continues to be controversial [17, 18]. In general, surgery for positive cervical nodal disease from melanoma located in certain head and neck regions, such as the face, forehead, coronal scalp, periauricular area and upper neck, will include superficial parotidectomy [18, 19]. Although surgery for cervical nodal disease contributes to staging and locoregional control in head and neck melanoma, disease-specific survival rates are not affected. Although sentinel lymph node biopsy is a viable tool in head and neck melanoma, there are potential issues such as unpredictable lymphatic drainage, multiple sentinel nodes per patient, proximity of the injection site to the draining basins, a slightly greater risk of false-negative results and mapping to the parotid gland in 19% to 44% of cases, with the potential of morbidity from facial nerve injury [20].

Metastatic basal cell carcinoma (BCC) is rare, but has been associated with size, depth of invasion, gender, history of radiation and perineural invasion [21]. Rates of metastatic disease from BCC are reported at 0.0028–0.55%, and are

mostly associated with head and neck disease, usually to regional lymph nodes [22].

Merkel cell carcinoma is a rare aggressive neuroendocrine carcinoma most commonly occurring in the head and neck, and with a high propensity for regional spread. Even in clinically node-negative cases, the rate of nodal micrometastasis can be 20–50%. Parotid metastases may occur even without the presence of an index primary lesion.

Other rare cutaneous malignancies such as atypical fibroxanthoma or pleomorphic dermal sarcoma may also demonstrate regional spread.

Adjuvant treatment such as radiation or systemic therapy will be discussed in other chapters of this book.

Table 1 Head and neck lymphatic drainage pathways

Site	Lymph drainage
Frontoparietal scalp	Parotid
Posterior scalp and head	Suboccipital, postauricular, jugular chain, supraclavicular
Lateral head and forehead	Parotid, upper jugular
Eyelid and eyebrows	Parotid, facial
Anterior ear and preauricular	Parotid
Helix and lateral auricle	Parotid, postauricular, suboccipital
Cheek, nose, upper lip	Facial, submandibular
Lateral lower lip	Submandibular
Medial lower lip, chin	Submental
Neck	Jugular chain

2 Staging

Staging is important in the management of all cancers. It guides treatment and counselling of patients regarding prognosis. It also facilitates research and international comparisons. Cutaneous carcinoma of the head and neck is usually staged by the American Joint Committee on Cancer (AJCC) TNM classification system, which stages cancers based on features of the primary lesion (T stage), lymph nodes (N stage) and distant metastases (M stage) [23]. The AJCC staging is shown in Table 2.

Staging for melanoma is also carried out according to the AJCC TNM classification system. This is shown in Table 3. For Merkel cell carcinoma, staging systems include the Memorial Sloan Kettering Cancer Center staging system, the AJCC TNM staging system and the system proposed by Yiengruksawan et al. (stage I—local disease, stage II—regional lymphadenopathy, stage III—distant metastases) [24]. The latter system is most commonly used.

Although the AJCC classification is most commonly used, there are a number of issues surrounding its use, particularly in cases of nodal spread from cutaneous SCC. The nodal system is the same as that which is used for mucosal SCC, but it is likely that stratification does not adequately reflect the differences between nodal spread of mucosal and cutaneous SCC [25, 26]. For example, N2c and N3a stages

may be redundant in cases of cutaneous SCC [23, 26]. Alternative staging systems for regional spread of cutaneous SCC have been proposed, such as Clark's N1S3 system [27], O'Brien's parotid and neck node system [28], and the ITEM prognostic score [29]. It has been suggested that incremental increase in nodal disease burden in cutaneous SCC may also impact survival and therefore be a useful prognosticator [30]. Similarly, increasing nodal disease burden has been suggested as a prognosticator in Merkel cell carcinoma [31].

Other staging systems for primary disease have been proposed. For example, the Brigham and Women's staging system identifies four high-risk tumour features found to be statistically independent prognostic factors associated with adverse outcomes (poor histological differentiation, perineural invasion, tumour diameter ≥ 2 cm and invasion beyond the subcutaneous fat). However, while it has been suggested that patients staged T3 or higher in the AJCC or Brigham and Women's staging systems should undergo neck dissection, neither of these staging systems significantly stratified tumours in a manner that predicted the presence of nodal disease [32]. Imaging or sentinel lymph node biopsy in clinically node-negative cases that are staged T3 or higher may be alternatives to elective neck dissection and parotidectomy.

For tumours involving the temporal bone, the most commonly used staging system is the modified University of Pittsburgh system [33]. This is shown in Table 4.

Table 2 AJCC staging system for cutaneous carcinoma

Primary tumour (T)	
TX	Primary tumour cannot be assessed
Tis	Carcinoma in situ
T1	Tumour smaller than or equal to 2 cm in greatest dimension
T2	Tumour >2 cm but smaller than or equal to 4 cm in greatest dimension
T3	Tumour >4 cm in maximum dimension or minor bone erosion or perineural invasion or deep invasion*
T4	Tumour with gross cortical bone/marrow, skull base invasion and/or skull base foramen invasion
T4a	Tumour with gross cortical bone/marrow invasion
T4b	Tumour with skull base invasion and/or skull base foramen involvement
* Deep invasion is defined as invasion beyond the subcutaneous fat or >6 mm (as measured from the granular layer of adjacent normal epidermis to the base of the tumour); perineural invasion for T3 classification is defined as tumour cells within the nerve sheath of a nerve lying deeper than the dermis or measuring 0.1 mm or larger in calibre, or presenting with clinical or radiographic involvement of named nerves without skull base invasion or transgression.	
Regional lymph nodes (N)	
<i>Clinical N (cN)</i>	
NX	Regional lymph nodes cannot be assessed
N0	No regional lymph node metastasis
N1	Metastasis in a single ipsilateral lymph node ≤ 3 cm in greatest dimension and no extranodal extension (ENE [–])
N2	Metastasis in a single ipsilateral lymph node >3 cm but not more than 6 cm in greatest dimension and ENE (–); Or metastases in multiple ipsilateral lymph nodes, none >6 cm in greatest dimension and ENE (–); Or in bilateral or contralateral lymph nodes, none >6 cm in greatest dimension and ENE (–)
N2a	Metastasis in a single ipsilateral lymph node >3 cm but not more than 6 cm in greatest dimension and ENE (–)
N2b	Metastasis in multiple ipsilateral lymph nodes, none >6 cm in greatest dimension and ENE (–)
N2c	Metastasis in bilateral or contralateral lymph nodes, none >6 cm in greatest dimension and ENE (–)

(continued)

Table 2 (continued)

N3	Metastasis in a lymph node >6 cm in greatest dimension and ENE (–); or metastasis in any node(s) with clinically overt ENE (+)		
N3a	Metastasis in a lymph node >6 cm in greatest dimension and ENE (–)		
N3b	Metastasis in any node(s) with clinically overt ENE (+)		
	Pathological N (pN)		
NX	Regional lymph nodes cannot be assessed		
N0	No regional lymph node metastasis		
N1	Metastasis in a single ipsilateral lymph node ≤3 cm in greatest dimension and ENE (–)		
N2	Metastasis in a single ipsilateral lymph node, 3 cm or smaller in greatest dimension and ENE (+); Or a single ipsilateral lymph node >3 cm but not more than 6 cm in greatest dimension and ENE (–); Or metastases in multiple ipsilateral lymph nodes, none >6 cm in greatest dimension and ENE (–); Or in bilateral or contralateral lymph nodes, none >6 cm in greatest dimension and ENE (–)		
N2a	Metastasis in a single ipsilateral lymph node, 3 cm or smaller in greatest dimension and ENE (+); Or a single ipsilateral lymph node >3 cm but not more than 6 cm in greatest dimension and ENE (–)		
N2b	Metastasis in multiple ipsilateral lymph nodes, none >6 cm in greatest dimension and ENE (–)		
N2c	Metastasis in bilateral or contralateral lymph node(s), none >6 cm in greatest dimension and ENE (–)		
N3	Metastasis in a lymph node >6 cm in greatest dimension and ENE (–); Or in a single ipsilateral node >3 cm in greatest dimension and ENE (+); Or multiple ipsilateral, contralateral or bilateral nodes, any with ENE (+); Or a single contralateral node of any size and ENE (+)		
N3a	Metastasis in a lymph node >6 cm in greatest dimension and ENE (–)		
N3b	Metastasis in a single ipsilateral node >3 cm in greatest dimension and ENE (+); Or multiple ipsilateral, contralateral or bilateral nodes, any with ENE (+); Or a single contralateral node of any size and ENE (+)		
Distant metastasis (M)			
cM0	No distant metastasis		
cM1	Distant metastasis		
pM1	Distant metastasis, microscopically confirmed		
Prognostic stage			
Stage	T	N	M
0	Tis	N0	M0
I	T1	N0	M0
II	T2	N0	M0
III	T3	N0	M0
	T1–3	N1	M0
IV	T1–3	N2	M0
	Any T	N3	M0
	T4	Any N	M0
	Any T	Any N	M1

Table 3 AJCC staging system for malignant melanoma

Primary tumour (T)	
TX	Primary tumour cannot be assessed
T0	No evidence of primary tumour
Tis	Melanoma in situ
T1	Thickness ≤ 1.0 mm T1a: < 0.8 mm without ulceration T1b: < 0.8 mm with ulceration, or 0.8 – 1.0 mm with or without ulceration
T2	Thickness > 1.0 – 2.0 mm T2a: without ulceration T2b: with ulceration
T3	Thickness > 2.0 – 4.0 mm T3a: without ulceration T3b: with ulceration
T4	Thickness > 4.0 mm T4a: without ulceration T4b: with ulceration
Regional lymph nodes (N)	
NX	Regional nodes cannot be assessed
N0	No regional metastases detected
N1	One tumour-involved lymph node or in-transit, satellite and/or microsatellite metastases with no tumour-involved nodes N1a: one clinically occult (detected by sentinel lymph node biopsy [SLNB]); no in-transit, satellite or microsatellite metastases N1b: one clinically detected; no in-transit, satellite or microsatellite metastases N1c: no regional lymph node disease; in-transit, satellite and/or microsatellite metastases found
N2	Two or three tumour-involved nodes; or in-transit, satellite or microsatellite metastases N2a: two or three clinically occult (detected by SLNB); no in-transit, satellite or microsatellite metastases N2b: two or three clinically detected; no in-transit, satellite or microsatellite metastases N2c: one clinically occult or clinically detected; in-transit, satellite and/or microsatellite metastases found
N3	≥ 4 tumour-involved nodes or in-transit, satellite, and/or microsatellite metastases with ≥ 2 tumour-involved nodes or any number of matted nodes without or with in-transit, satellite and/or microsatellite metastases N3a: ≥ 4 clinically occult (detected by SLNB); no in-transit, satellite or microsatellite metastases N3b: ≥ 4 , at least one of which was clinically detected, or presence of any matted nodes; no in-transit, satellite or microsatellite metastases N3c: ≥ 2 clinically occult or clinically detected and/or presence of any matted nodes, with presence of in-transit, satellite and/or microsatellite metastases
Distant metastasis (M)	
M0	No detectable evidence of distant metastases
M1a	Metastases to skin, soft tissue (including muscle) and/or nonregional lymph nodes
M1b	Lung metastasis, with or without M1a involvement
M1c	Distant metastasis to non-central nervous system (CNS) visceral sites with or without M1a or M1b involvement

(continued)

Table 3 (continued)

M1d	Distant metastasis to CNS, with or without M1a or M1b involvement		
Cases of metastasis (beyond M0) in which the lactate dehydrogenase (LDH) level is known are given the suffix (0), for normal LDH level, or (1), for elevated LDH level			
Clinical stage	T	N	M
0	Tis	N0	M0
IA	T1a	N0	M0
IB	T1b	N0	M0
	T2a	N0	M0
IIA	T2b	N0	M0
	T3a	N0	M0
IIB	T3b	N0	M0
	T4a	N0	M0
IIC	T4b	N0	M0
III	Any T, Tis	N1, N2 or N3	M0
IV	Any T	Any N	M1
Pathologic stage	T	N	M
0	Tis	N0	M0
IA	T1a, T1b	N0	M0
IB	T2a	N0	M0
IIA	T2b, T3a	N0	M0
IIB	T3b, T4a	N0	M0
IIC	T4b	N0	M0
IIIA	T1a/b, T2a	N1a, N2a	M0
IIIB	T0	N1b, N1c	M0
	T1a/b, T2a	N1b/c, N2b	M0
	T2b, T3a	N1a/b/c, N2a/b	M0
IIIC	T0	N2b/c, N3b/c	M0
	T1a/b, T2a/b, T3a	N2c, N3a/b/c	M0
	T3b, T4a	Any N ≥N1	M0
	T4b	N1a/b/c, N2a/b/c	M0
IIID	T4b	N3a/b/c	M0
IV	Any T, Tis	Any N	M1

Table 4 Modified University of Pittsburgh staging system

T stage	Imaging or pathologic findings
T1	Tumour limited to the external auditory canal without bony erosion or evidence of soft tissue involvement
T2	Tumour with limited external auditory canal bone erosion (not full thickness) or limited (<0.5 cm) soft tissue involvement
T3	Tumour eroding the osseous external auditory canal (full thickness) with limited (<0.5 cm) soft tissue involvement, or tumour involving the middle ear and/or mastoid
T4	Tumour eroding the cochlea, petrous apex, medial wall of the middle ear, carotid canal, jugular foramen or dura, or with extensive soft tissue involvement (>0.5 cm), such as involvement of temporomandibular joint or styloid process, or evidence of facial paresis

3 Extent of Parotidectomy/Neck Dissection

Crucial to surgical planning for patients with parotid and cervical nodal disease is thorough clinical examination. Involvement of overlying skin, deeper structures, and facial or sensory nerves are important to identify prior to planning surgical extent. Investigation of patients with suspected parotid nodal metastases usually includes ultrasound-guided fine-needle aspiration and computed tomography (CT) scanning of the parotid gland, neck and chest. Figure 1 demonstrates an example of CT imaging of a patient with parotid nodal metastases. Magnetic resonance imaging (MRI) is useful in patients with suspected perineural invasion or parapharyngeal involvement, while the role of PET/CT imaging in cutaneous SCC and melanoma of the head and neck is limited. Figure 2 demonstrates an example of MRI of a patient with parotid nodal metastases.

Although the role of elective neck dissection or elective neck irradiation in cutaneous SCC is controversial, some research has suggested its use in certain circumstances [34]. Rates of metastatic spread from the superficial parotid nodes to the cervical lymph nodes range from 13 to 35% [28, 35–37]. It has also been suggested that elective parotidectomy is considered for T3 or T4 lesions or for lesions with high-risk features [38–42]. However, no prospective study has demonstrated a clinically substantial survival benefit to elective neck dissection compared to therapeutic neck dissection after nodal metastasis has developed [43].

Approximately 75% of nodal metastases from cutaneous squamous cell carcinoma of the head and neck are present in the parotid gland, as shown in Fig. 3, followed by 40% presenting in level II nodes [44]. Surgery with adjuvant radiation is usually the standard of care for these patients [45]. For patients presenting with cervical metastatic disease from a cutaneous primary in regions at high risk of parotid disease discussed above, parotidectomy should be carried out alongside the neck dissection. As well as parotidectomy, it is important to adequately manage the region of the external jugular lymph node in these cases [7, 46].

The extent of surgery required to manage parotid nodal metastases depends on the extent of disease, and it has been

reported that locoregional control rates are equivalent when advanced disease is treated more aggressively [47]. In addition to involvement of parotid lymph nodes, cutaneous SCC frequently exhibits extranodal extension into parotid gland tissue [43]. When parotid disease is present, the extension of surgery to include deep lobe tissue in the form of a total parotidectomy will give prognostic value, but may also improve local recurrence rates [48]. Therefore, patients with clinical metastatic disease to any intraparotid lymph nodes may benefit from total parotidectomy [43, 49]. However, this is controversial and may only be beneficial in cases with a high suspicion of, or confirmed, deep lobe involvement [28, 50, 51].

For patients with parotid nodal metastases who are otherwise clinically node-negative, options include elective selective neck dissection along with the parotidectomy, or elective neck radiotherapy, assuming adjuvant radiotherapy will be administered to the parotid region. It has been suggested that elective nodal irradiation is equivalent to elective neck dissection with adjuvant radiation [52]. However, a pathologically negative neck dissection would avoid subsequent toxicity from radiation to the neck. Indeed, cases with a single positive node of less than 3 cm in size with no extranodal spread may be treated with single modality therapy [53]. In cases of selective neck dissection, suggested levels to include are levels I–III for anterior facial primaries, levels II–III for anterior scalp and external ear primaries and levels II–V for posterior scalp and neck primaries [46].

The circumstances in which radical or extended radical parotidectomy are required are considered in further sections of this chapter. Extended radical parotidectomy is carried out when the parotid disease invades adjacent structures such as the temporal bone, the mandibular bone or the skin [48]. Radical parotidectomy involves removal of all parotid tissue and sacrifice of the facial nerve, usually in cases where the nerve has been invaded or if preoperative function was impaired in the presence of malignant disease [48]. Concurrent procedures such as mandibulectomy, skin resection, infratemporal fossa dissection, and skull base or temporal bone resection may be necessary and will be discussed further; however, prognosis is typically poor in these more advanced cases.

Regarding melanoma, although pathways of drainage are less predictable, parotid nodes are commonly the first-echelon nodal drainage basins for cutaneous melanomas of the anterior scalp, temple, forehead and pinna. Sentinel lymph node biopsy has been advocated in the management of clinically node-negative melanoma to determine prognosis, but elective neck dissection does not provide survival benefit [44]. If presenting with nodal disease in the parotid, appropriate staging imaging investigations should be carried out. When clinically evident neck disease is present, surgery is the treatment of choice for nodal areas that are at risk, which is usually more comprehensive than for squamous cell carcinoma. Depending on primary site, level I nodes may not require dissection, while facial, external jugular, postauricular and occipital nodes, as well as sternocleidomastoid muscle, may require dissection [44]. For primary melanoma of the scalp, pinna and posterior face with established nodal metastases in the neck, it is recommended that superficial parotidectomy be performed concurrently with neck dissection. In melanoma arising posterior to a vertical line through the external auditory canal, neck dissection of levels II–V along with the postauricular and suboccipital lymph nodes is recommended. In cases anterior to this vertical line, parotidectomy and levels II–IV neck dissection are recommended, while neck dissection of at least levels I–III is suggested for patients with anterior facial lesions.

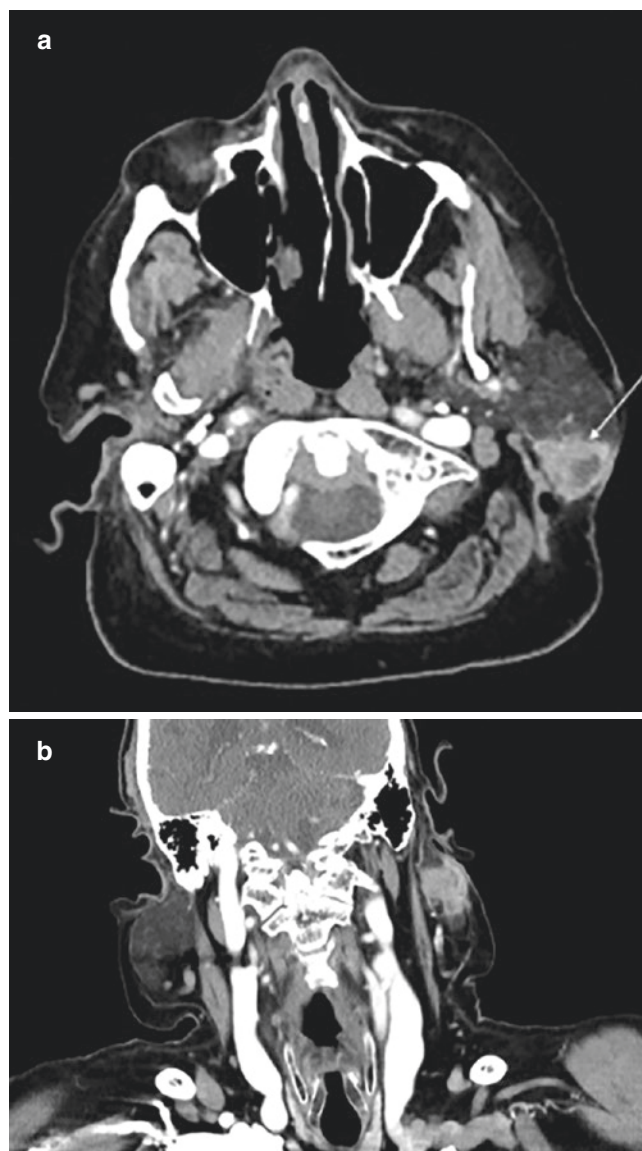


Fig. 1 (a and b) Computed tomography imaging (axial and coronal) of nodal metastasis in posterior parotid with central necrosis and overlying skin thickening

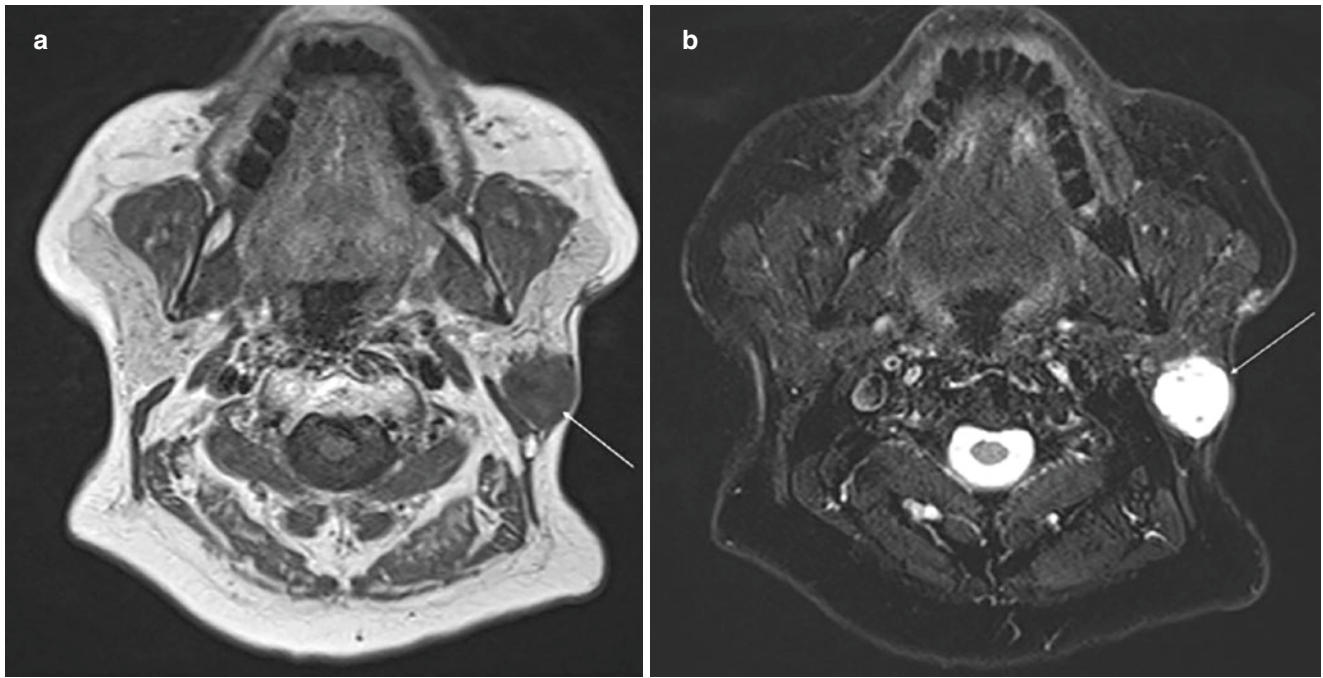


Fig. 2 (a and b) Magnetic resonance Imaging, T1 and T2 fat suppression axial showing parotid nodal SCC against normal parotid



Fig. 3 (a and b) Patient with parotid nodal SCC on a background of previous cutaneous SCC

4 Management of the External Auditory Canal, Temporal Bone and Temporomandibular Joint

Just as some form of mandibular resection is mandated in the treatment of oral SCC when the tumour is adherent to the mandible, it has been suggested that some form of lateral temporal bone resection is mandated when metastatic cutaneous SCC is adherent to the temporal bone [47]. Tumours involving the temporal bone can either arise from cells within the temporal bone itself or, more commonly, invade the temporal bone from surrounding soft tissue [54]. Cutaneous SCC in the periauricular region is particularly associated with locoregional invasion of the temporal bone [43]. The majority of malignancies involving the temporal bone are squamous cell carcinoma, accounting for 60–80% [55].

One known route of invasion of the temporal bone is via perineural invasion, which will be discussed further later in this chapter. It can involve over 80% of cases of higher stage tumours of the external ear that undergo temporal bone resection [38]. This carries a poor prognosis [56]. When disease is found to involve the facial nerve at the stylomastoid foramen or identified on preoperative imaging, lateral temporal bone resection should be considered to fully resect the disease to its proximal extent [57].

There is a high rate of locoregional recurrence of over 30% in cases of temporal bone involvement [54]. Recurrences are often not amenable to further surgery [58, 59]. Therefore, when surgically resectable, combined aggressive surgery with adjuvant radiation is the primary treatment modality of choice in most advanced cases of temporal bone malignancy [54].

The extent of bone resection can be determined by the clinical and radiological extent of disease, the objective being to resect sufficiently to achieve clear margins [47]. Figure 4 demonstrates a case that requires bony resection. Data on margin status are conflicting [57, 60, 61], which could reflect that the deep margin is often given by burring of bone. Recent guidelines for pathological assessment of temporal bone malignancy should enable more uniform data collection, thus assisting the development of a universally accepted staging system [62, 63].

Lateral temporal bone resection consists of removal of the bony and cartilaginous external auditory canal with or without partial or complete pinnectomy, as well as removal of the tympanic membrane, malleus and incus with identification and preservation of the facial nerve along its vertical segment. Extended lateral temporal bone resection includes the

above plus resection of other structures such as the facial nerve or mandibular condyle. Subtotal temporal bone resection additionally removes the bony labyrinth, sacrificing sensorineural hearing and often facial nerve function [64]. For disease that extends past the tympanic membrane into the middle ear or mastoid, the use of subtotal temporal bone resection has shown a survival benefit [65]. Total temporal bone resection includes resection of all bony structures and the carotid artery, sigmoid sinus and jugular foramen contents.

Regarding extent, clinical or radiological suspicion of tumour involving the mastoid tip could be treated with a limited mastoidectomy [47]. In cases with advanced T stage, such as in Fig. 5, lateral temporal bone resection is preferred, to reduce morbidity, for example, by preservation of the facial nerve, if not involved by disease, while extended or subtotal resections can be performed when necessary due to disease extent [54]. Invasion of the external auditory canal usually necessitates en bloc excision and lateral temporal bone resection [43]. In general, the degree of tumour extension does not impact on whether surgery is performed, except when tumour extends to involve the meninges [61]. It should be noted that parotidectomy is generally recommended in the management of patients with external auditory canal SCC [66].

While extensive surgery in these cases can be disfiguring and cause functional disturbance, to hearing for example, it is ongoing physical symptoms, communication difficulties and social disturbances that have been associated with poorer quality of life [67]. Long-term survival is often poor in patients requiring temporal bone resection as part of an extended parotidectomy. However, aggressive management to ensure satisfactory oncologic clearance can result in high locoregional control and can mitigate the poor prognosis associated with advanced disease in the parotid gland [47, 54]. Extending the operation to include the temporomandibular joint (TMJ), facial nerve or an infratemporal fossa resection may be necessary to obtain a clear margin and will be discussed further [57].

Although involvement of the temporomandibular joint in cutaneous malignancy is rare, it is important to manage appropriately. When invasion of the joint is managed appropriately, joint involvement does not affect prognosis, although invasion beyond the joint into the pterygoid muscle can affect prognosis [68]. A thorough patient history, a detailed clinical examination and proper radiographic imaging are important for making an accurate diagnosis [69]. Partial or segmental mandibulectomy, including the joint,

may be necessary in cases undergoing lateral temporal bone resection to ensure clear margins [70]. This can be the case in up to 4–58% of patients, depending on the stage of disease [55, 57, 70]. Debate exists as to the appropriate circumstances that necessitate condylectomy [64]. Most surgeons would advocate for it in stage T3 and T4 disease, but some have gone further to suggest even resection in T1 and T2 disease should include condylectomy [71].

Involvement of the joint by tumour will likely lead to trismus postoperatively, as a result of either surgical management or radiation treatment [72]. Reconstruction of the TMJ depends on the extent of resection and can include custom-made TMJ prostheses, fibula free flap, calvarial bone and full-thickness rib graft, but the benefit may not be significant as, without reconstruction, symptoms are often not troublesome [72].

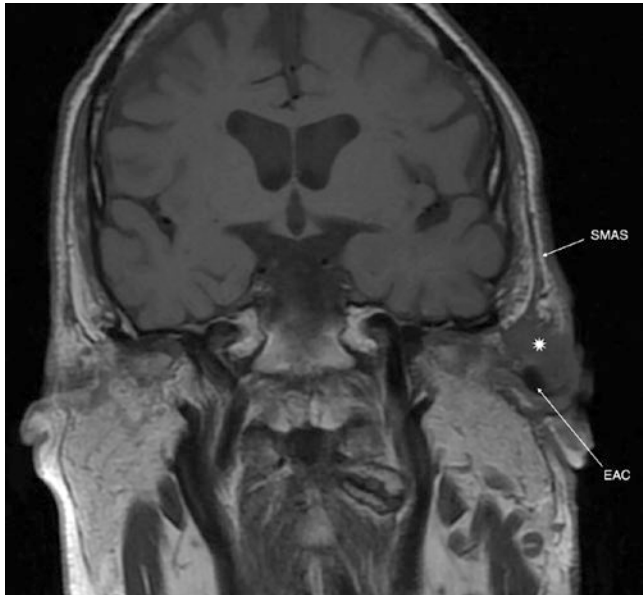


Fig. 4 Magnetic resonance imaging, T1 coronal, showing SCC of the external auditory canal (EAC), tumour (asterisk) and superficial musculoaponeurotic system (SMAS) in the temporal region



Fig. 5 T4 basal cell carcinoma of the periauricular region requiring bony resection

5 Management of Nerves

The head and neck region is highly sun-exposed and has a rich neural network. Therefore, involvement of the trigeminal and facial nerves in cutaneous malignancies is common, as well as cervical plexus nerves, and even multiple nerves can be involved in the same tumour. Nerve sacrifice may be necessary for disease control either due to the location of the tumour in proximity to the nerve, or due to perineural invasion (PNI). The potential for PNI is highest for squamous cell carcinoma but may also occur in melanoma and basal cell carcinoma.

Another form of perineural involvement, perineural spread, is a pathological event where a malignant cell gains access to a nerve and then spreads centripetally away from the primary tumour within the perineural and endoneurial spaces, with eventual failure in the brainstem if left untreated [73]. Although only 30–40% of these patients will have preoperative manifestations of neurotropicism, there is evidence that long-term survival will be approximately 20–30% once patients become symptomatic [57, 74, 75]. It can occur after treatment of a primary cutaneous malignancy or if the tumour has been resolved by the body's immune system [76]. Distinct types of nerve involvement include cases where tumour has invaded into nerves and cases where tumour accesses nerve endings and spreads along the nerve, while tumour can also involve the nerve without causing dysfunction [73]. Perineural spread in head and neck tumours involves larger nerves beyond the site of primary tumour and reduces overall survival, but, unlike histologic PNI, it does not predict local tumour recurrence or increased risk of lymph node metastasis [77]. Figure 6 demonstrates cases with significant facial nerve perineural spread.

It is important to differentiate clinical and histologic PNI. Histological PNI is found incidentally by the pathologist and gives prognostic information along with other standard pathological criteria that are relevant to staging, whereas clinical PNI manifests as a clinical sign such as dysaesthesia or paralysis and almost always can be identified on a dedicated MRI [73, 78]. This is important to determine as patients with radiological evidence of clinical PNI have a poorer prognosis than those whose scans are negative [79]. Follow-up imaging with baseline MRI post-treatment is also helpful to later identify recurrent disease, which could be resected [73].

Once appropriately imaged, large nerve PNI can be staged according to a zonal system as shown in Table 5 [73]. In general, disease that is present in zones 1 and 2 can be considered amenable to surgery [80]. This system does not account for the greater auricular nerve or cervical plexus branches but is limited to trigeminal and facial nerve involvement.

For patients with clinical PNI, there is a reasonable body of evidence to suggest that survival is improved by surgical resection if feasible, followed by postoperative radiation [80–83]. Although it has been suggested that “skip lesions” characterised by discontinuous spread of tumour cells along the nerve, potentially via perineural lymphatic vessels, can reduce ability of surgery to effectively clear margins, high-quality studies now suggest that tumour spread is continuous along nerves [77, 80]. Although every attempt is made to preserve nerves, clinical PNI has been shown to significantly affect survival, and the treatment philosophy should be based on the extent of PNI along the nerve, and surgical resection with clear margins followed by radiation optimises the patient's chance for cure [57].

Anterograde spread of disease along nerves is also possible, but whole dermatome resection is not recommended, rather the use of radiation to manage disease with excision of recurrences when presenting as a subcutaneous mass [80].

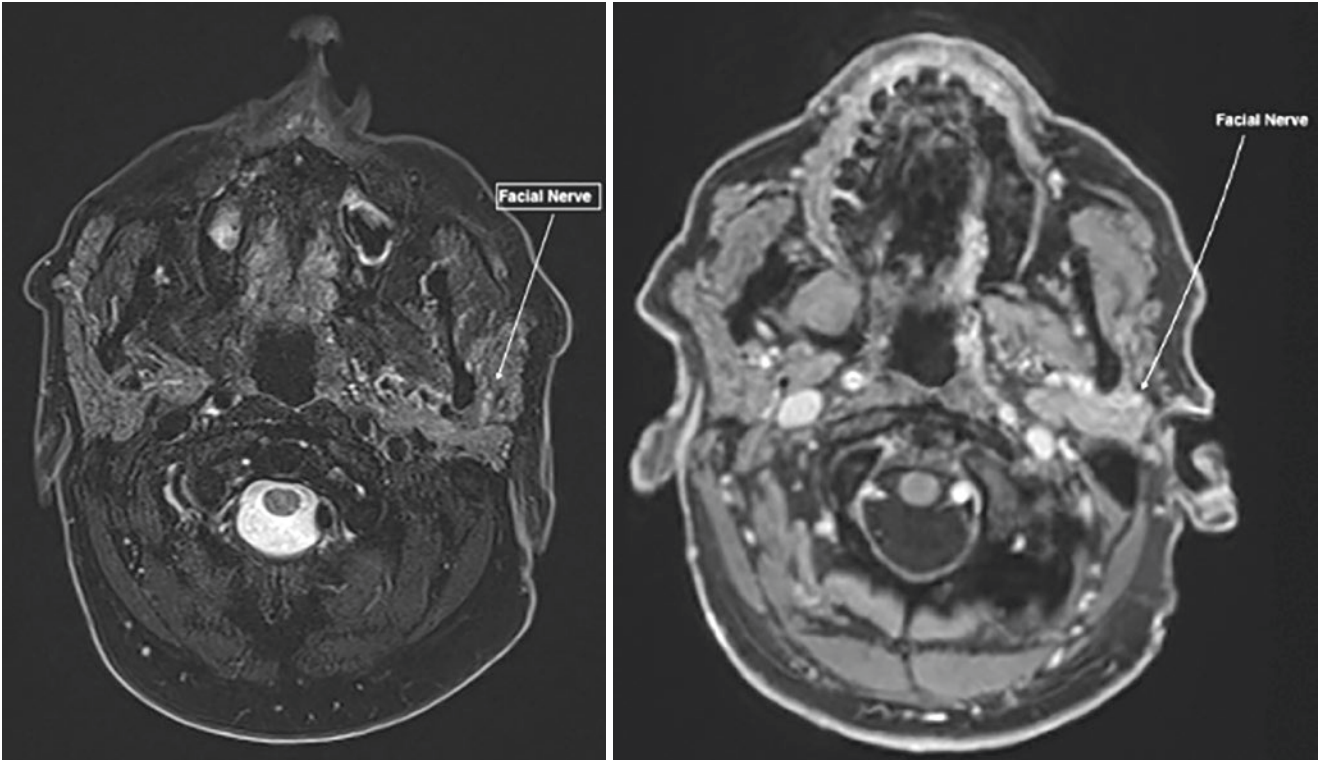


Fig. 6 Magnetic resonance imaging, T2 fat suppression, axial, showing increased signal in facial nerve in parotid gland and T1 fat suppression post-contrast axial showing enhancing facial nerve in parotid gland

Table 5 Zonal staging of perineural spread describing limit of extension

	Zone 1	Zone 2	Zone 3
V1	Superior orbital fissure	Trigeminal ganglion cistern	Cistern and brainstem
V2	External aperture of the foramen rotundum	Trigeminal ganglion cistern	Cistern and brainstem
V3	External aperture of foramen ovale	Trigeminal ganglion cistern	Cistern and brainstem
VII	External aperture of the stylomastoid foramen		Cistern and brainstem

6 Facial Nerve

One of the most crucial elements to appropriately managing parotid metastatic disease is consideration of the facial nerve. The extent of surgery for metastatic disease to the parotid region generates considerable debate. Facial nerve function is an important outcome for patients with cancer of the parotid/temporal bone region [67].

National Comprehensive Cancer Network Guidelines recommend a superficial parotidectomy with the intent of sparing the facial nerve, sacrificing it only when it is directly compromised by the tumour [43, 50]. In one study, disease-specific survival has been shown to be equivalent in facial nerve-sparing parotidectomy followed by adjuvant radiation compared to more aggressive surgical therapy [60]. As discussed above, there may be added benefit to total parotidectomy. In cases where preservation of the nerve is attempted, a facial nerve monitor is a useful adjunct.

The facial nerve is rarely sacrificed if it is functioning preoperatively, but if disease location risks satisfactory oncologic resection or tumour encircles the nerve, then it would be most appropriate to sacrifice the facial nerve with immediate or delayed facial reanimation [84]. For example, tumours that are adherent to bone at the stylomastoid foramen, even when the nerve is clinically intact, usually require a full lateral temporal bone resection with facial nerve resection as clear margins necessitate a radical excision [47].

In cases where nerve dysfunction is present preoperatively, sacrifice of the nerve is necessary with radical parotidectomy. To ensure clear margins, it is helpful to carry out frozen section of the nerve. This can be done both proximally and distally, particularly in cases where dynamic facial reanimation may be considered. When disease is present in Zone 1, treatment with a radical parotidectomy, including the peripheral branches of the nerve, along with resection of the mastoid segment of the nerve has been suggested [80]. For Zone 2 involvement, the nerve should be followed up to the second genu by mastoidectomy. Lateral temporal bone resection can be used to access disease extending beyond this to the first genu, but a posterior tympanotomy including the mastoid portion of the fallopian canal can extend access allowing resection to the first genu without a full lateral temporal bone resection if not required for the rest of the disease.

Research on the topic of survival in facial nerve involvement is conflicting, but some suggest that facial nerve involvement does not necessarily affect disease-specific survival on multivariate analysis [47, 54, 85, 86]. In terms of temporal bone tumours, the proposed alteration of the original Pittsburgh staging system by Moody et al. was not because an association with poorer survival was demon-

strated in the study, but because facial nerve involvement, by definition, meant a tumour must be T4 [33, 54]. Ensuring clear facial nerve margins by intraoperative frozen section facilitates satisfactory oncologic management of the nerve, thereby potentially removing any individual effect on survival [54]. Higher recurrence rates in cases with facial nerve involvement are likely a reflection of higher stage disease, rather than the nerve involvement itself being a risk factor [6].

7 Trigeminal and Cervical Plexus Nerves

The trigeminal nerve is occasionally involved by disease extending to the parotid region via the auriculotemporal branch, which provides sensation to the auricle and preauricular region. Numbness and pain in this distribution can be presenting features of clinical involvement by disease. When this is suspected, or present on imaging in Zone 1, an en bloc resection of the infratemporal fossa is recommended [80]. After detaching the masseter, a mandibular osteotomy can be performed from the mandibular notch to the angle of the mandible. The mandibular condyle is freed from the glenoid fossa, removing the attached pterygoid musculature and tak-

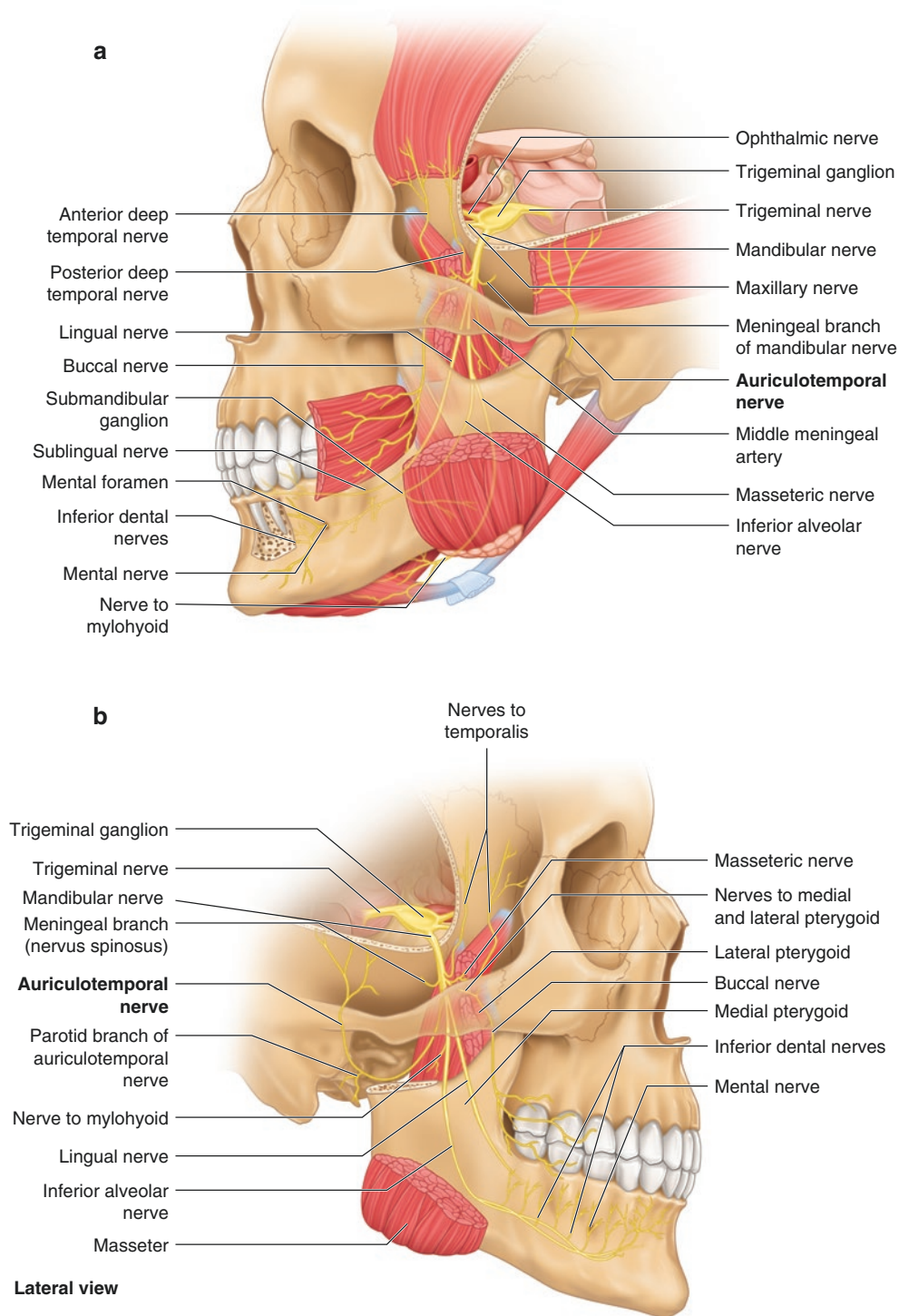
is involved, which can be in a significant proportion of these cases, a lateral craniotomy is necessary to access the skull base or else treatment with adjuvant radiation may be effective [80, 87].

Alternatively, good access to the auriculotemporal nerve can be obtained by removal of the mandibular condyle alone, as shown in Figs. 7 and 8. Frozen section histopathology can facilitate surgical management of this nerve and its resection through the infratemporal fossa as appropriate.

The auriculotemporal nerve has anastomoses with the upper division of the facial nerve and so tumours involving the parotid gland have a route by which they can travel along the facial nerve into the infratemporal fossa and skull base [87–89], such as the case shown in Fig. 9. If trigeminal and facial nerves are involved simultaneously, which can be frequent [87], this can be managed by radical parotidectomy with ascending mandibulectomy along with removal of the infratemporal fossa contents.

Although rare, spread from cutaneous malignancy to the greater auricular nerve or other cervical plexus nerves does occur and can extend in a retrograde fashion [90–93]. MRI should be utilised to determine extent for surgical planning, and spinal foraminotomy may be necessary to clear the margins in cervical plexus nerve roots, depending on frozen section analysis. Figures 10, 11 and 12 demonstrate a case with involvement of the greater auricular nerve.

Fig. 7 Illustrations demonstrating the approach to the auriculotemporal nerve and infratemporal fossa pre- and post-resection of the mandibular condyle



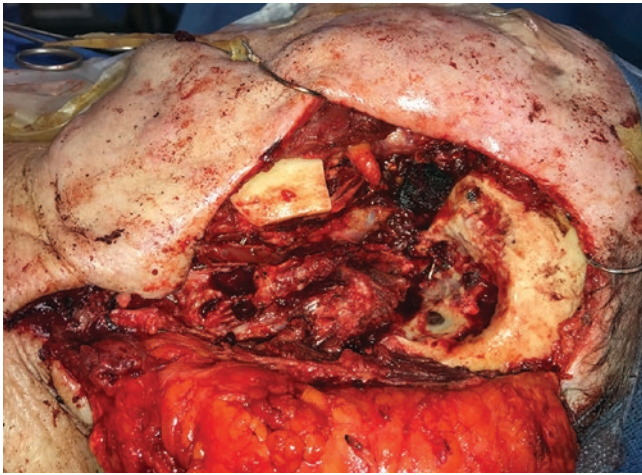


Fig. 8 Left mandibular condyle resection for access to the infratemporal fossa for resection of auriculotemporal nerve

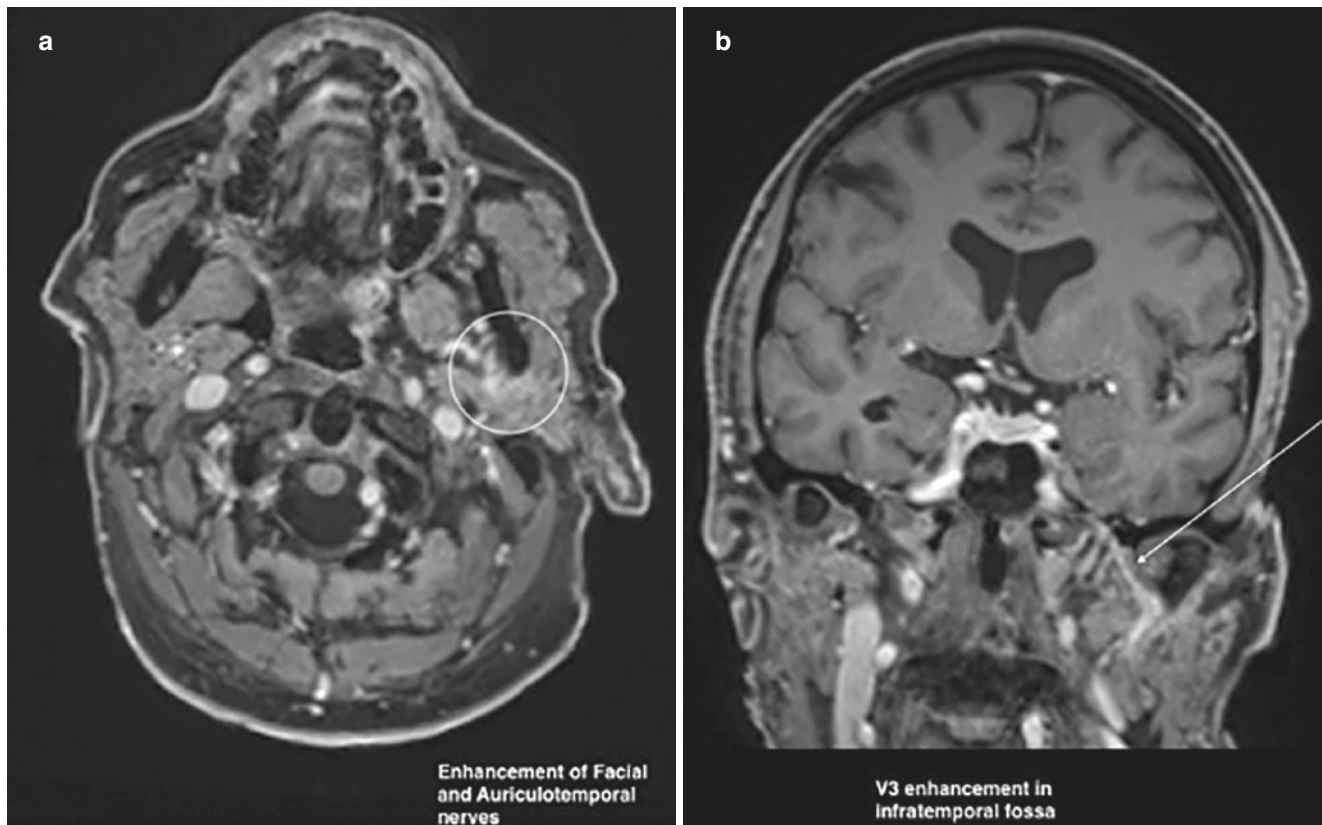


Fig. 9 (a and b) Magnetic resonance imaging, T1 fat suppression post-contrast, axial showing circled facial nerve behind mandibular ramus where joins V3 as auriculotemporal nerve, and coronal with arrow showing enhancing V3 in infratemporal fossa

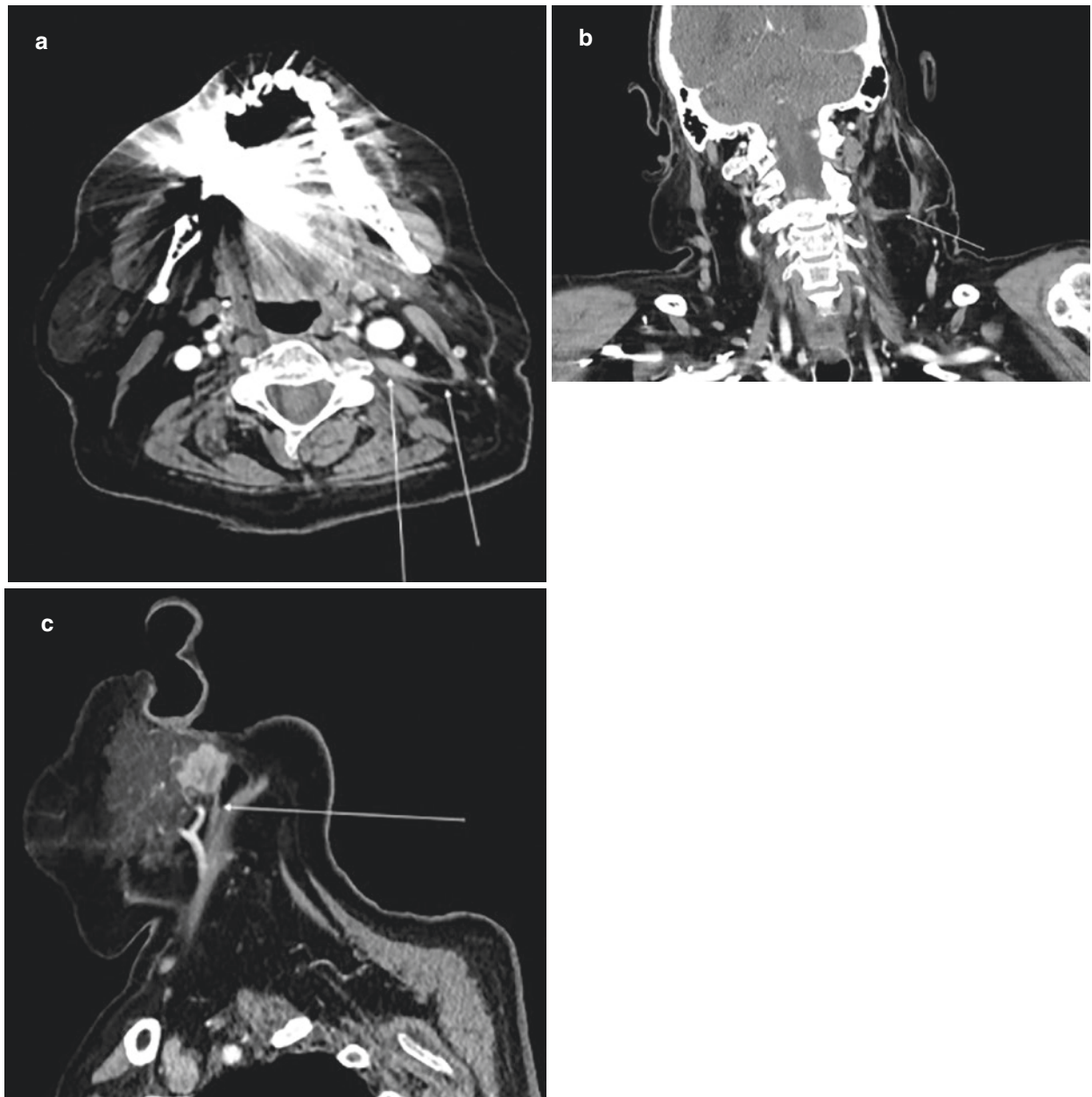


Fig. 10 (a–c) Computed tomography imaging showing thickening and enhancement of greater auricular nerve in axial, coronal and sagittal planes

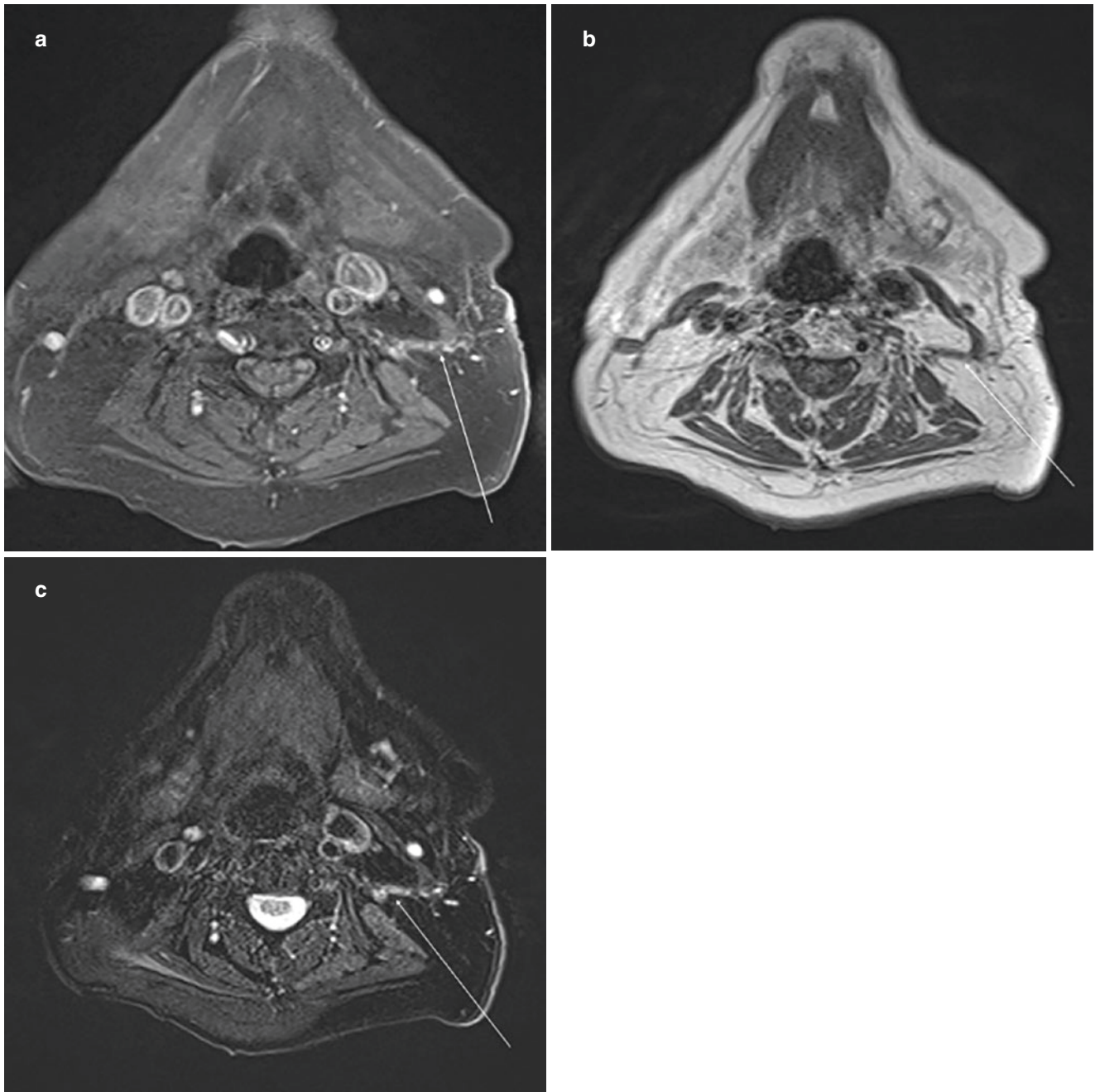


Fig. 11 (a–c) Magnetic resonance imaging, T1 fat suppression post-contrast axial, T1 axial, T2 fat suppression axial demonstrating a thickened and enhancing greater auricular nerve involved by SCC that is traversing the neck

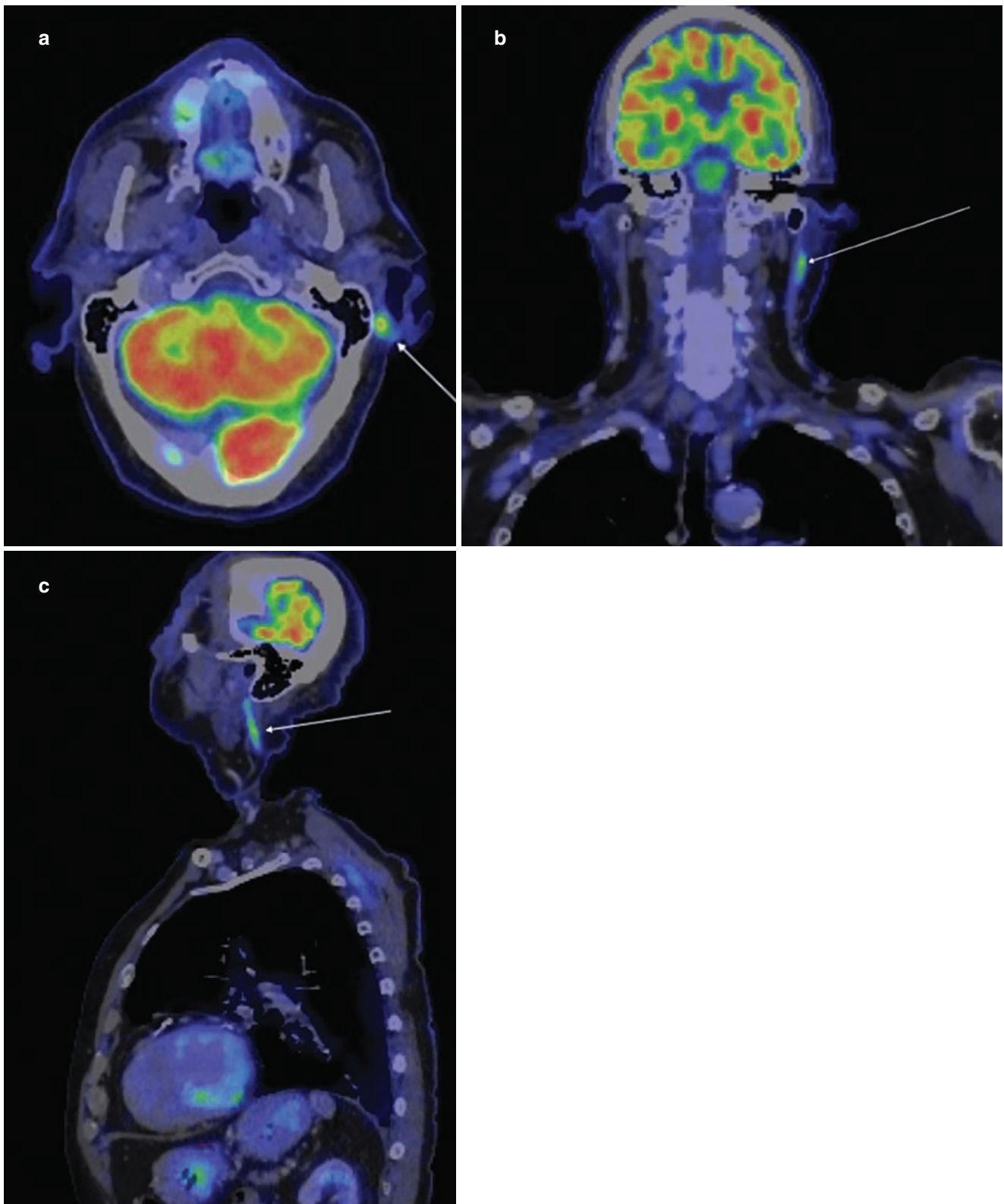


Fig. 12 (a–c) Positron emission tomography/computed tomography, axial, coronal and sagittal views, demonstrating uptake in the greater auricular nerve due to involvement by SCC

8 Reconstruction

In general, small defects in the parotid and temporal bone region are suitable for local tissue closure and the use of local flaps such as the cervicofacial flap is appropriate in these cases. Larger defects, however, may require a pedicled or free flap [72]. The tissue used should be reliable and well vascularised, with bulk required to fill dead space. Surgical closure of the skull base is usually done in layers to try and prevent a CSF leak and close dead space [94].

In defects (class I) where the external auditory canal is spared and no mastoidectomy is necessary, a cervicofacial or other thin local flap is appropriate [95]. In defects (class II) involving a lateral temporal bone resection but with preservation of part of the auricle, a radial forearm flap has been suggested, while in defects (class III) that include complete auriculectomy, lateral temporal bone resection, parotidectomy and neck dissection, an anterolateral thigh flap is suggested [95].

An alternative algorithm that can be used includes the use of primary closure or local tissue transfer in defects less than 5 cm, or free flap reconstruction in defects more than 9 cm with the aim of skin closure and adequate dural coverage [54].

Pedicled flaps that can be considered in reconstruction of the parotid region are the temporalis muscle flap or supraclavicular island flap, both of which can provide bulk to improve contouring in certain defects or in cases where free tissue transfer may be contraindicated. Alternative local flaps include a scalp flap, preauricular flap or temporoparietal fascia flap, depending on the defect.

In the setting of facial nerve resection, the role for dynamic reconstruction is limited when extensive perineural spread is present, as are recipient functional nerves, so a static facial reanimation is often used and this can frequently be incorporated into the flap of choice [94]. Where nerve grafts are used, donor nerves could include the greater auricular nerve, if not involved by disease. For more length, a sural nerve graft can be raised and utilised for multiple anastomoses. Success rates of nerve grafting will vary depending on patient factors such as age and co-morbidities (e.g. diabetes), as well as treatment factors such as extent of nerve resection or need for adjuvant therapy such as radiation.

9 Conclusion

Multiple aspects need to be considered in the management of patients with parotid metastatic disease from cutaneous malignancy. Parotid surgery is the mainstay of treatment, but cervical nodes, temporal bone, mandible and nerves must be

all be managed appropriately to ensure the best outcomes. Patient factors such as immunocompromise need to be considered. Management in a multidisciplinary setting is recommended.

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Modern Maxillofacial Rehabilitation

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Core Messages

- Prosthetic reconstruction is an important option in the reconstructive ladder for patients with challenging facial defects post-cancer resection.
- Careful preoperative planning and teamwork are the key.
- Prosthetic retention is an important principle determining success or failure of the rehabilitative phase.
- The face has complex anatomy with both extraoral and intraoral specialized physiological functions.
- Cancer patient expectations for cure and rehabilitation.
- Digital and osseointegration technology combined with microvascular flap reconstruction.

1 Introduction

Maxillofacial prosthetics is the discipline within dentistry involved with the prosthetic rehabilitation of patients who have acquired and/or congenital defects of the jaws and face. This includes patients who have undergone surgical resection ± reconstruction of a facial defect due to cancers of the face and jaws so can be split into two sections, intraoral and extraoral. The first section of this chapter considers the traditional prosthetic techniques to reconstruct defects contrasted with the new paradigm of digital technology. It also covers the role of osseointegrated implants and their use in facial

prosthetic rehabilitation. The new digital imaging tools using anatomical data from helical CT scans are described for modern facial prosthetics. The second section of this chapter considers modern maxillofacial surgical methods for planning and execution of reconstruction for the extraoral and intraoral challenges.

Although autologous reconstruction with pedicled or free flaps is ideal in some anatomical regions, e.g. the orbit, this is still not possible to an aesthetic standard acceptable to most patients. Prosthetics have a definite place in the reconstructive ladder and are more appropriate for many patients either definitively or as a temporary measure with delayed reconstruction, which allows time for oncologic monitoring. Maxillofacial Technicians/Prosthetists, Anaplastologists and Prosthodontists are important members of the multidisciplinary team dealing with the facial cancer patient. Good communication, collaboration and presurgery workup are important principles that must be shared by the surgeon and the maxillofacial technicians in the team. It is important for the prosthetist to understand the impending facial defect before surgery and whether existing facial structures can be saved or should be sacrificed. This is because remnant soft tissues may impede optimal prosthetic reconstruction and lead to prosthetic failure. Floppy soft tissues and excessive movement interfere with prosthetic retention.

Presurgical communication between the patient and the prosthetic team is also mandatory in the process of informed consent and for patient confidence in the reconstructive options. The advantages psychologically for the patient are obvious, and in reality, their rehabilitative journey has begun. This is also a time when impressions can be taken to produce facial casts and mouldages for later prosthetic production.

It is critical and important to wait until all tissues are healed from surgery, radiotherapy or chemotherapy before prostheses are provided. The initial assessment of the patient considers the shape of the defect, the morphological quality of the skin or mucosa and how much tissue movement is evident for the underlying supporting skin/structures. The other priority is the type of retention appropriate to successfully retain the prosthesis in situ.

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2 Indications

Traditional methods for retention of facial prosthetics include the following:

1. Medical adhesives (water or silicone based).
2. Spectacle retention (nasal and orbital prosthetics).
3. Natural undercuts within the defect.
4. Combination adhesive acrylic baseplate with keepers and magnets.

The modern and lead author's preferred method of retention is with osseointegrated implants. Craniofacial osseointegrated implants provide a secure, immobile platform for the prosthesis to sit upon. They are patient-friendly and reliable. More technical details about the bar/clip magnetic components of osseointegrated prosthetics are covered later.

Examples of spectacle retention are shown in Fig. 1.

An alternative method is the adhesive base plate with magnets as illustrated in Fig. 2.



Fig. 1 (a–e) Female patient post-right orbital exenteration with a spectacle-mounted orbital prosthesis attached by magnetic coupling. Note the Technovent mini-magnets and keepers bonded into the frames with Dentsply Triad Light Cure gel

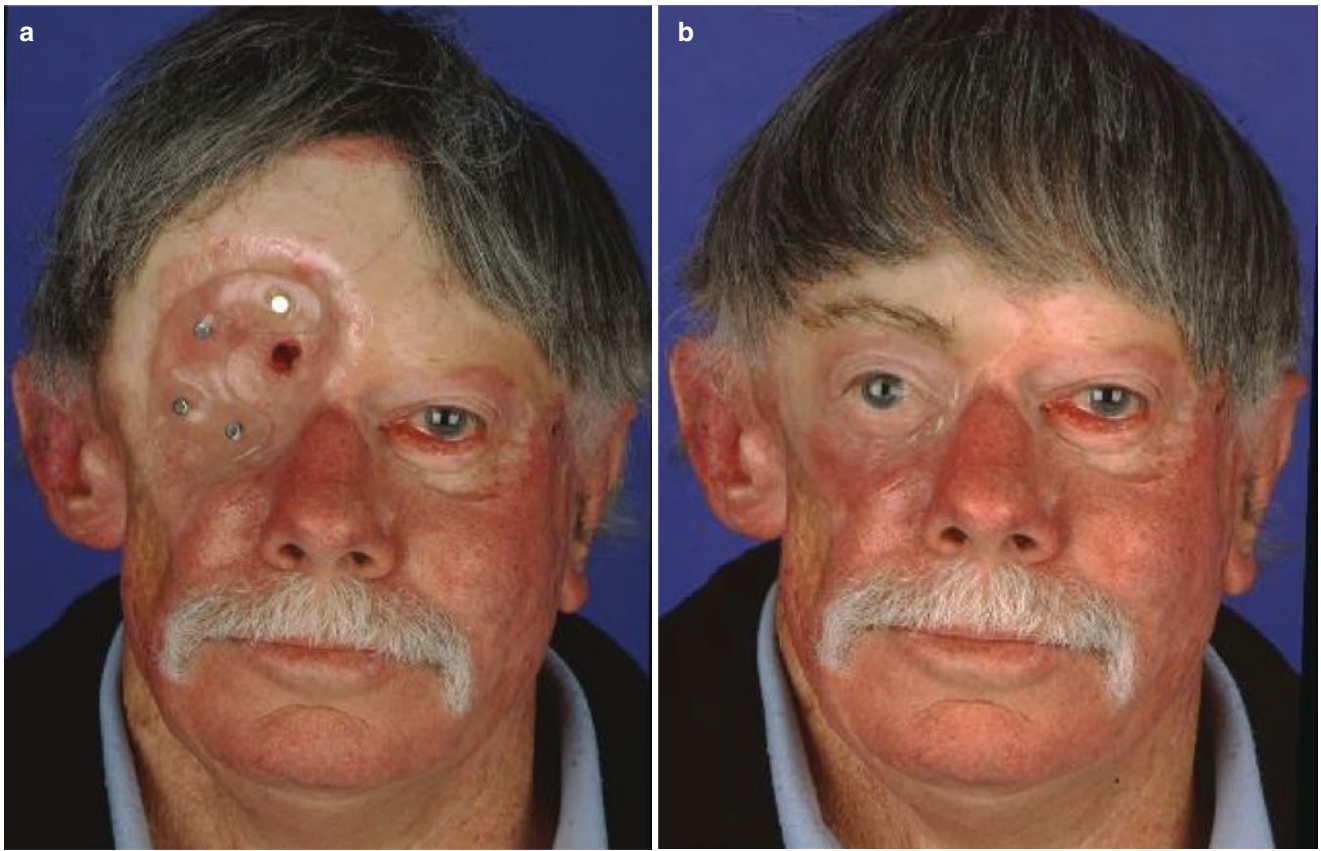


Fig. 2 (a and b) Male patient with right fronto-orbital defect reconstructed with a prosthesis fixed to an adhesive baseplate with Technovent magnets

3 Important Surgical Principles for Prosthetics

Adequate depth of the resection defect for prosthetic placement is a fundamental principle, especially for the orbit and ear. A concave defect is desirable, and a convex defect secondary to a bulky flap is undesirable. The problem with some flaps is that with time they atrophy, and this will undermine a good prosthetic result.

4 Taking the Impression

Ideally, the patient should be in the upright sitting position to avoid distortion of the soft tissues (Fig. 3). The surgical repair should be healed and stable. Fistulae can be plugged temporarily with paraffin-impregnated gauze, and hair around the defect should be removed or lubricated with gel. A variety of materials are used for taking an impression

including alginate, polyvinyl siloxane (PVS) silicone (especially good for auricular and nasal defects). Technique is all important. Once the impressions are completed, they are taken to the dental laboratory for casting up in gypsum stone. Practically, it is wise to make a duplicate model of the master cast.

Impressions of the auricular defect should ideally have the position of the tragus, meatus and angle of the pinna recorded with the use of an indelible pencil or a skin marker pen so that the size, position and angulation of the pinna can be correctly orientated on the resultant cast as the pen marks will transfer to the impression and then to the cast (Fig. 4).

The next stage of the prosthetic construction process is to complete a wax-up of the deficient anatomy of the facial part in question. For ears, an alternative technique is simply to make a cast of the contralateral normal ear and create a mirror wax-up of this. Accurate measurement of the facial zones in the vertical planes will help with precision.

Fig. 3 (a–f) The impression process for a right orbital defect with a fistula exposing the right lacrimal bone. Jelonet covers the fistula, and thick green alginate was applied first (light green) followed by gauze to the setting alginate and plaster of Paris to render the impression rigid. The alginate is kept moist with wet gauze to prevent distortion prior to pouring up the die stone cast in the dental laboratory





Fig. 4 (a–d) Impression of a patient's left ear with polyvinyl siloxane (PVS) silicone, utilizing a plastic ring to control the silicone flow before setting

5 Wax-Up Evaluation

The wax pattern is then tried onto the patient, and the necessary alterations to the shape, position and orientation are completed to the patient's and prosthetist's satisfaction.

Often defects are not perfect in the sense that absolute symmetry can be difficult to achieve, and this is where the artistic flair of the prosthetist is required to get the contour correct with the underlying anatomy and for the prosthesis margins to blend correctly with the skin.

6 Orbital Prostheses

The procedure to construct an artificial eye for an orbital prosthesis requires the use of a mould that has the right shape of the anterior curvature of the eye. The author (MW) uses PMMA-prefabricated iris and corneal units from Oculoplastik, Quebec, Canada. The correct iris size that

matches the patient's own iris size on the contralateral eye is painted using oil paints with monopoly syrup and acrylic monomer (Fig. 5).

On achieving an adequate colour match, the iris and corneal unit can be bonded together. When happy that the characterization of the eye with the second paint is complete, the eye is reprocessed with a layer of clear acrylic to seal the artwork. Waxing up for orbital prostheses can be very challenging, including waxing up of the eyelids to achieve the correct palpebral width and height.

Once the ocular prosthetic is constructed and incorporated into the wax-up ring, measurements are made to determine the correct position of the globe, to ensure that it is not proptosed or enophthalmic and that central pupillary position is correct vertically and horizontally with the correct direction of gaze. Finally, once wax-up is satisfactory to patient and prosthetist, the wax pattern can be sealed to the cast and invested for the construction of the definitive mould (Fig. 6).

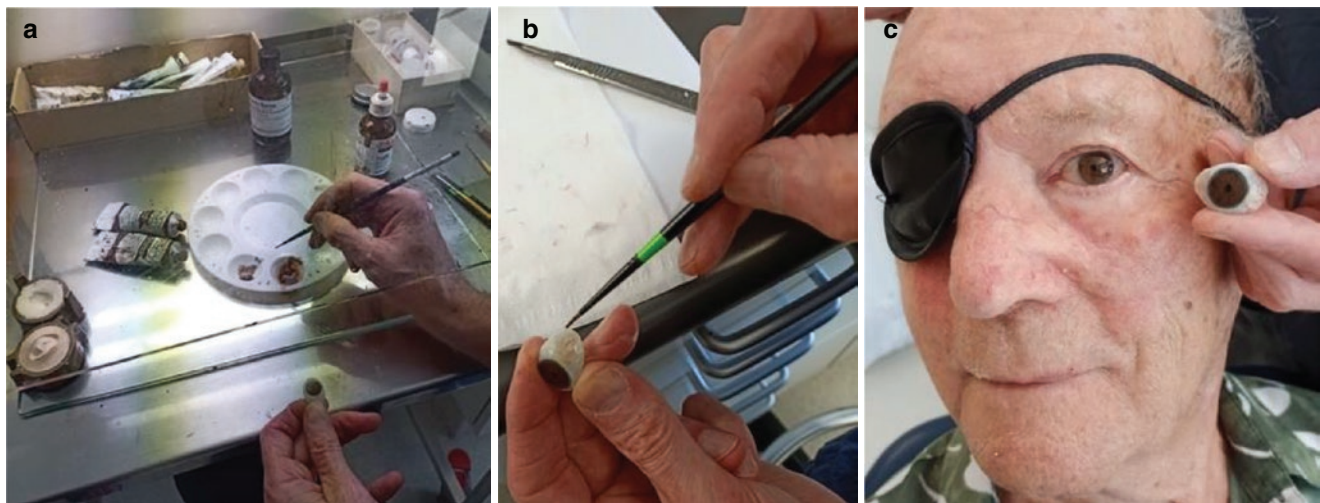


Fig. 5 (a–c) Colour matching and painting the orbital prosthesis



Fig. 6 (a–g) Checking for anatomical congruence, waxing up the prosthesis and final mould construction in silicone. Note the final mould indents for accurate location

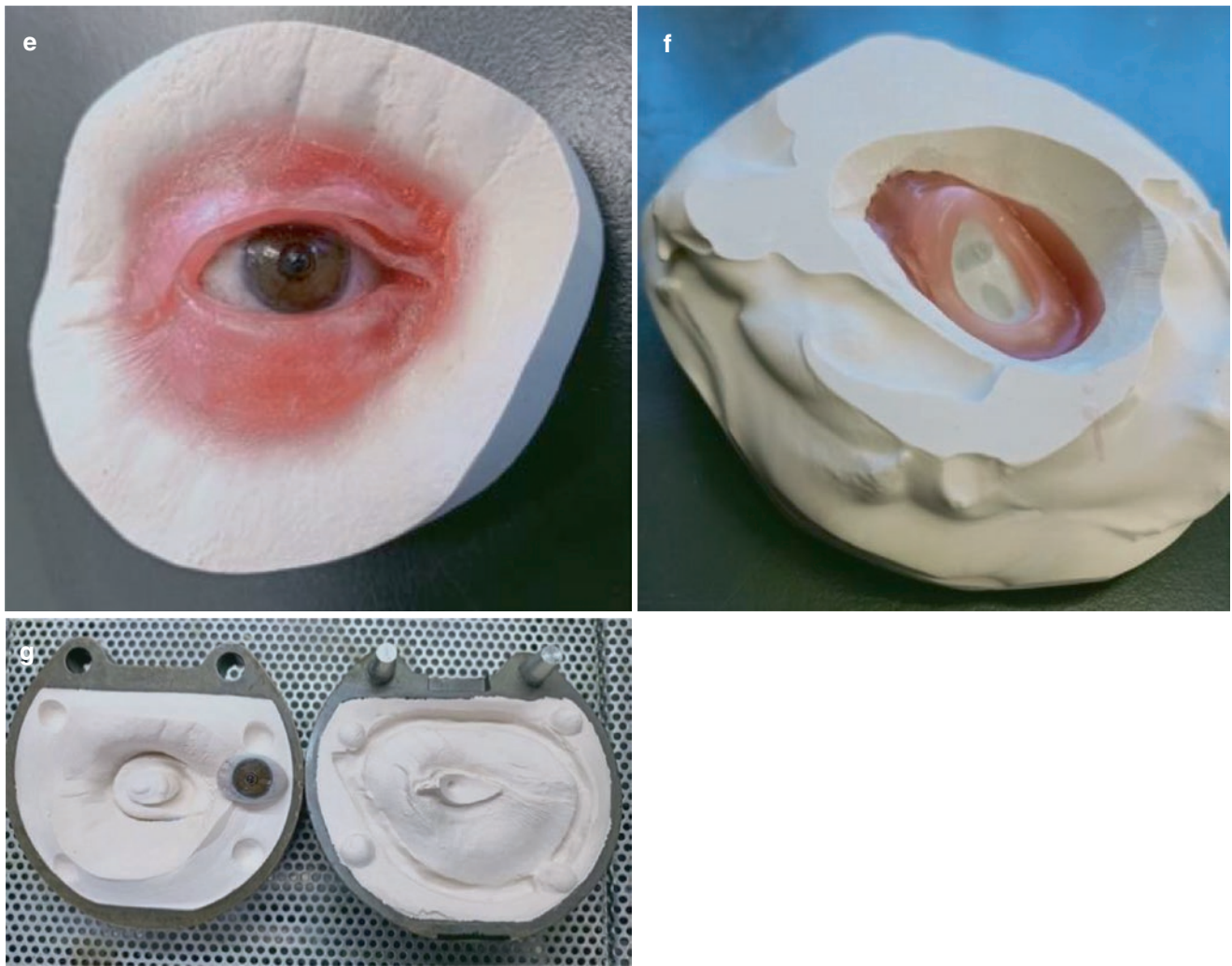


Fig. 6 (continued)

7 Silicones and Intrinsic Colour Matching

Medical-grade silicones are primarily used for the construction of modern facial prostheses. Medical-grade silicone products guarantee a high level of purity and cleanliness. They are also safe to use long term against the patient's skin without leaching or breakdown.

Silicone pigments chemically bind into the elastomer for better long-term pigmentation. Spectromatch E-Skin System (available from Technovent, UK) is a device (Fig. 7) used to electronically scan the patients' skin. This accurately matches the colour of the skin being scanned and enables the prosthetist to accurately mix colours into base elastomer for that skin tone. Recipes for the colouration are obtained online through Spectromatch's website.



Fig. 7 (a–f) Colouration of a right orbital prosthesis using the Spectromatch E-Skin System Kit and the painstaking expertise that may take up to 6–7 colour swatches, intrinsic colouring, curing and finally extrinsic colouring



Fig. 7 (continued)

8 Osseointegrated Implant Retention

The concept of osseointegration was first described by Bothe et al. in 1940 and later by Leventhal et al. in 1951 [1, 2]. Titanium oxide forms on the titanium implant, and the osteoblasts in bone form a bond to it. The term osseointegration can thus be described “the formation of a direct interface between an implant and bone, without intervening soft tissue” [3].

Brånemark coined the term “osseointegration” whilst viewing chambers placed into the lower leg bones of his rab-

bits were fixed solidly after a period of healing. Brånemark then developed and tested a type of dental implant utilizing pure titanium screws, which he termed *fixtures* [4]. Brånemark further realized that this could have implications for not just dental prosthetic rehabilitation but that a secure anchor could be created to lock prostheses into the skeleton, for restoration of limb loss and for hearing through a transducer, i.e. bone-anchored hearing aids (BAHAs).

The author (MW) believes that osseointegrated implants for appropriate candidates are the preferred method of retention for facial prostheses (Fig. 8).

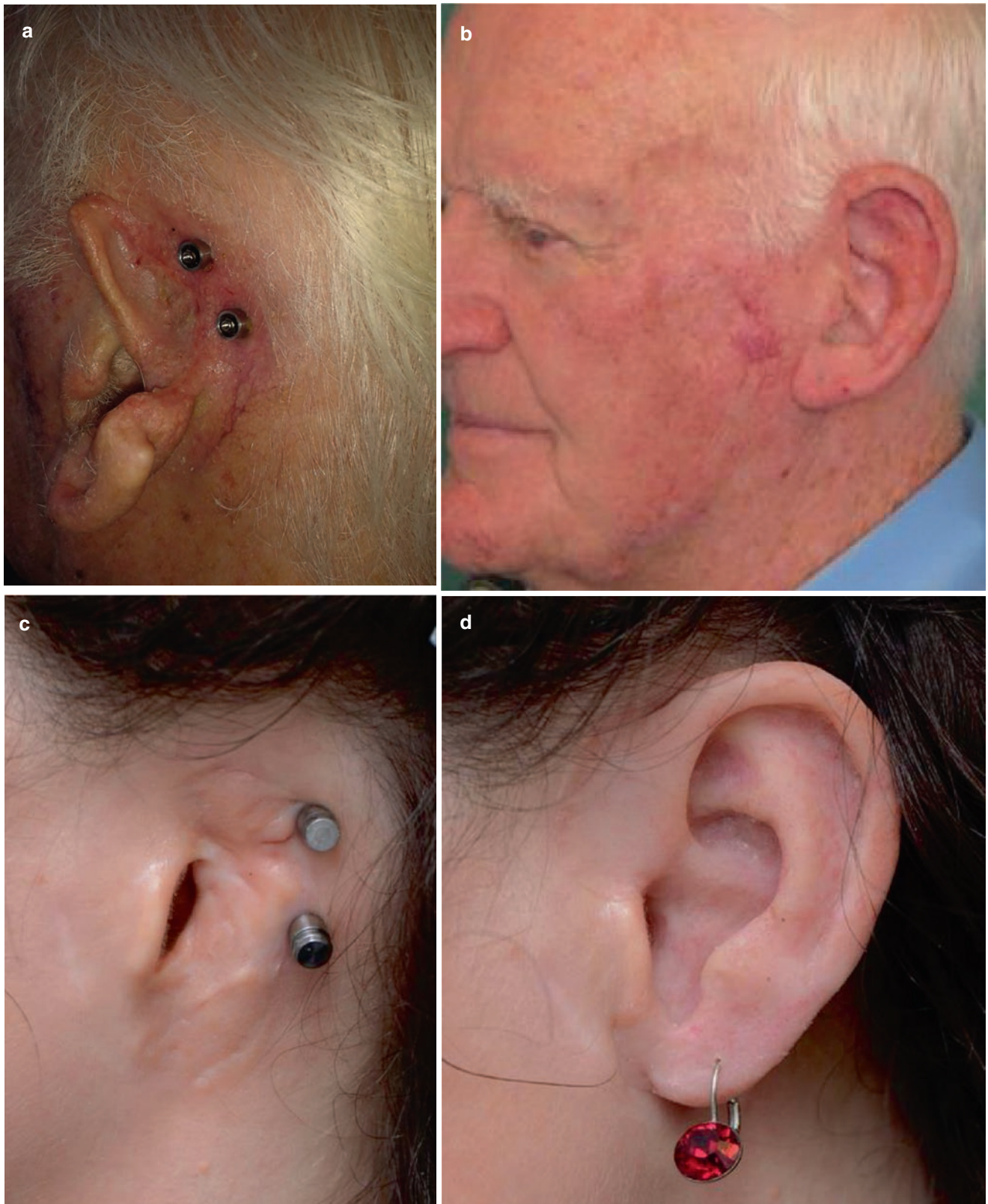


Fig. 8 (a–f) Osseointegrated partial and total left ear prostheses

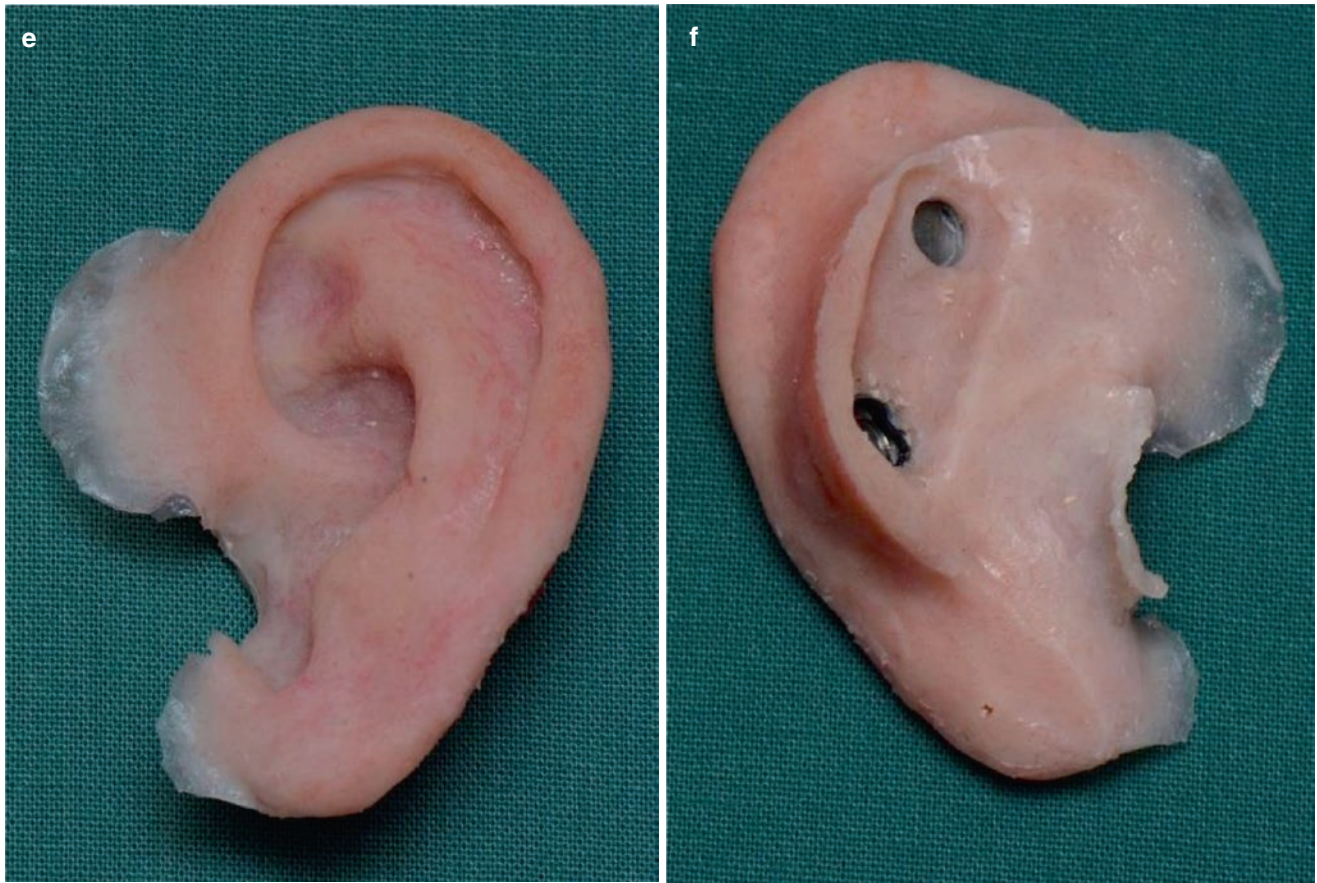


Fig. 8 (continued)

9 Selection Criteria of Patients for Implant Therapy

As a general rule, patients should have been disease-free for 18 months to 2 years before being offered osseointegration prosthetic therapy. It is expensive and patients with low chances of survivability after cancer surgery are contraindicated. Patients taking bisphosphonate drug therapy are also contraindicated. Patients need to be committed to high standards of peri-abutment hygiene in order for the osseointegrated prosthetic therapy to be successful. Age and psychological factors are also an issue as patients with dementia or psychiatric illnesses should not be considered for implant treatment.

Old age is not in itself a contraindication, and our oldest patient was 93 years of age when treated with implants for the provision of a partial auricular prosthesis and is still going strong 3 years later.

10 The Vistafix Implant System

The system consists of fixtures constructed from commercially pure titanium, of 3 and 4 mm in length $\times$ 4 mm in diameter with either machined, smooth surfaces or a moderately rough, treated surface for integration (Fig. 9). The Cochlear Vistafix 3 VXA300 and BAHA BI300 implants have a TiOblast surface treatment, which means it has been blasted with an abrasive agent to create the roughened textured surface, which under testing has been shown to improve the quality and speed of successful osseointegration when compared to the original machined implants. The Cochlear BAHA implants are able to be loaded within 2–3 weeks of placement once skin has healed, whereas we normally wait about 12 weeks with Vistafix fixtures.

Typical set-up for Vistafix one-stage surgery (4 mm)

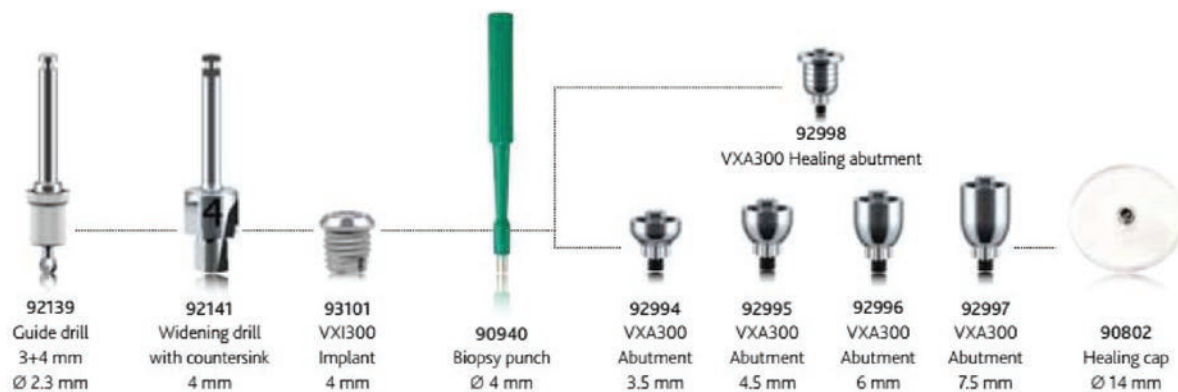


Fig. 9 Vistafix implant system (© Cochlear Limited 2012. This material is reproduced with the permission of Cochlear Limited)

11 Planning for Implant Surgery

Usually, most patients have been a recipient of a prosthesis already before progressing to implant treatment and this is valuable as the existing prosthesis will help with planning the ideal position of the implants for the retention of the prosthesis (Fig. 10).

The implants ideally should be placed and angled such that they will not compromise the end aesthetic result of the prosthesis; i.e., implant positioning is optimized from the prosthetic platform down, so it is within the existing prosthetic form, and fixtures are placed preferably parallel, if possible.

With implant placement, the procedure may be single-staged or in two stages. The fixtures provide the secure anchorage within bone, but the connection to the prosthesis is achieved via the connection of the prosthetic retentive superstructure to the top of the abutment through to the fixture.

Single-stage surgery is usually chosen for patients who have not undergone radiation therapy and usually for the provision of auricular prostheses. Midface defects tend to have much thinner bone and therefore are more suitable to a 2-stage procedure. Patients who are irradiated are always managed in 2 stages as are children receiving implants for prostheses.

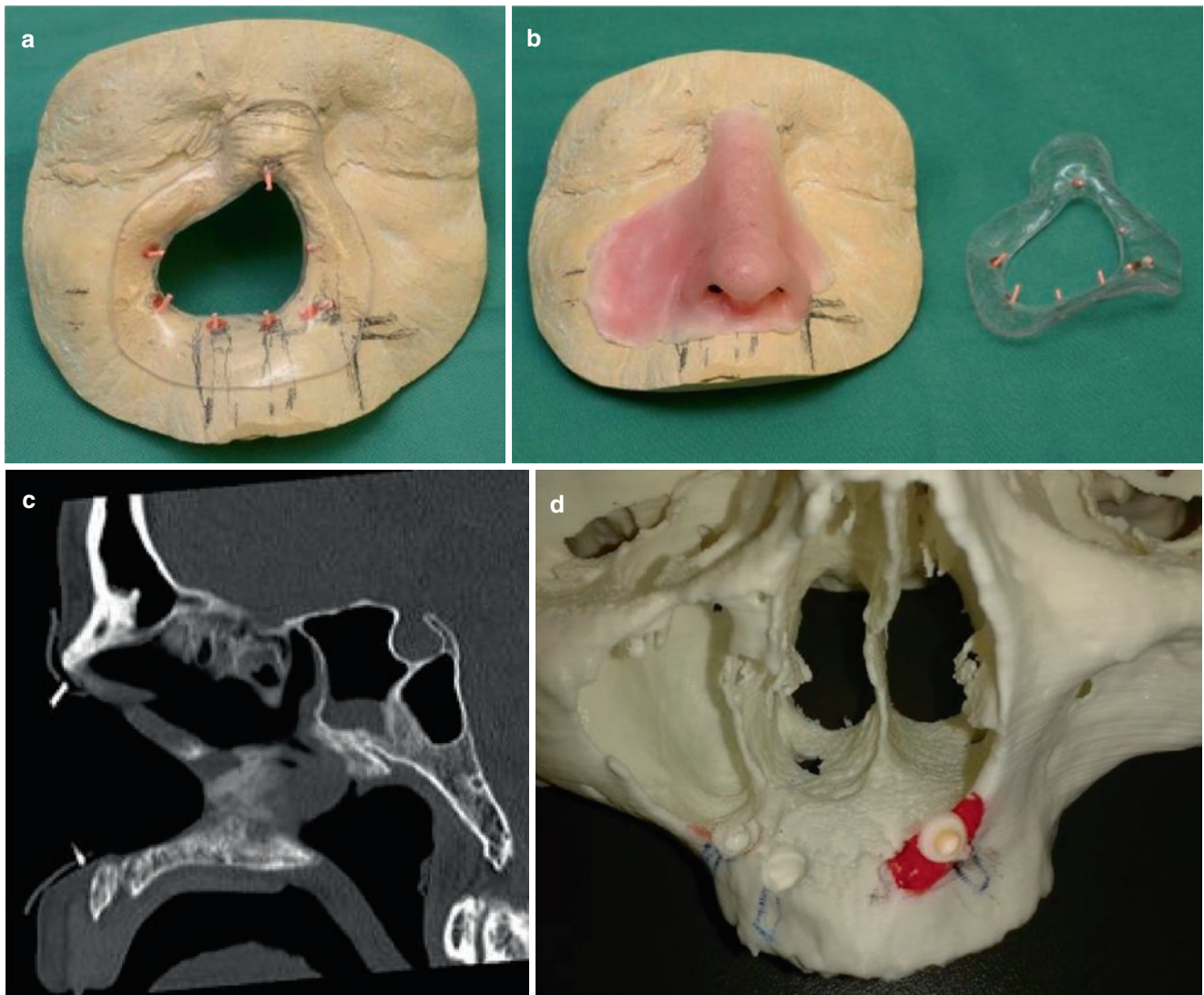


Fig. 10 (a–d) Planning for an osseointegrated replacement of a previous nose prosthesis

12 A Key Osseointegration Principle Is that the Peri-abutment Skin or Mucosa Should Be Immobile to Reduce the Risk of Infection and Implant Failure

The patient requiring a new nasal prosthesis with osseointegrated technique is shown with his final prosthesis (Fig. 11). This had followed presurgical planning, with the final prosthesis on Ti-milled bar framework and gold clips inside the prosthesis. This patient had extended total rhinectomy for SCC with removal of the lateral nasal wall and the antrolateral wall of the maxilla exposing the right maxillary sinus. Two Cochlear vistafix 2 implants were placed to retain the prosthesis. Placement of more implants was not possible due

to poor quality bone and soft tissues due to previous surgery and adjuvant radiotherapy treatment.

Another patient with a right ear and periauricular defect secondary to wide excision of recurrent malignant melanoma is shown (Fig. 12).

Analogue techniques for the construction of prosthetics, like those above, are how many practitioners around the world produce prostheses. Technologists need to be fairly artistic and have a good eye for detail as well as being able to mirror and replicate 3-dimensional shapes accurately to produce high-quality prostheses. We recommend at least annual review of the patients with prostheses for colour maintenance, upgrades and oncological follow-up by the maxillofacial team.

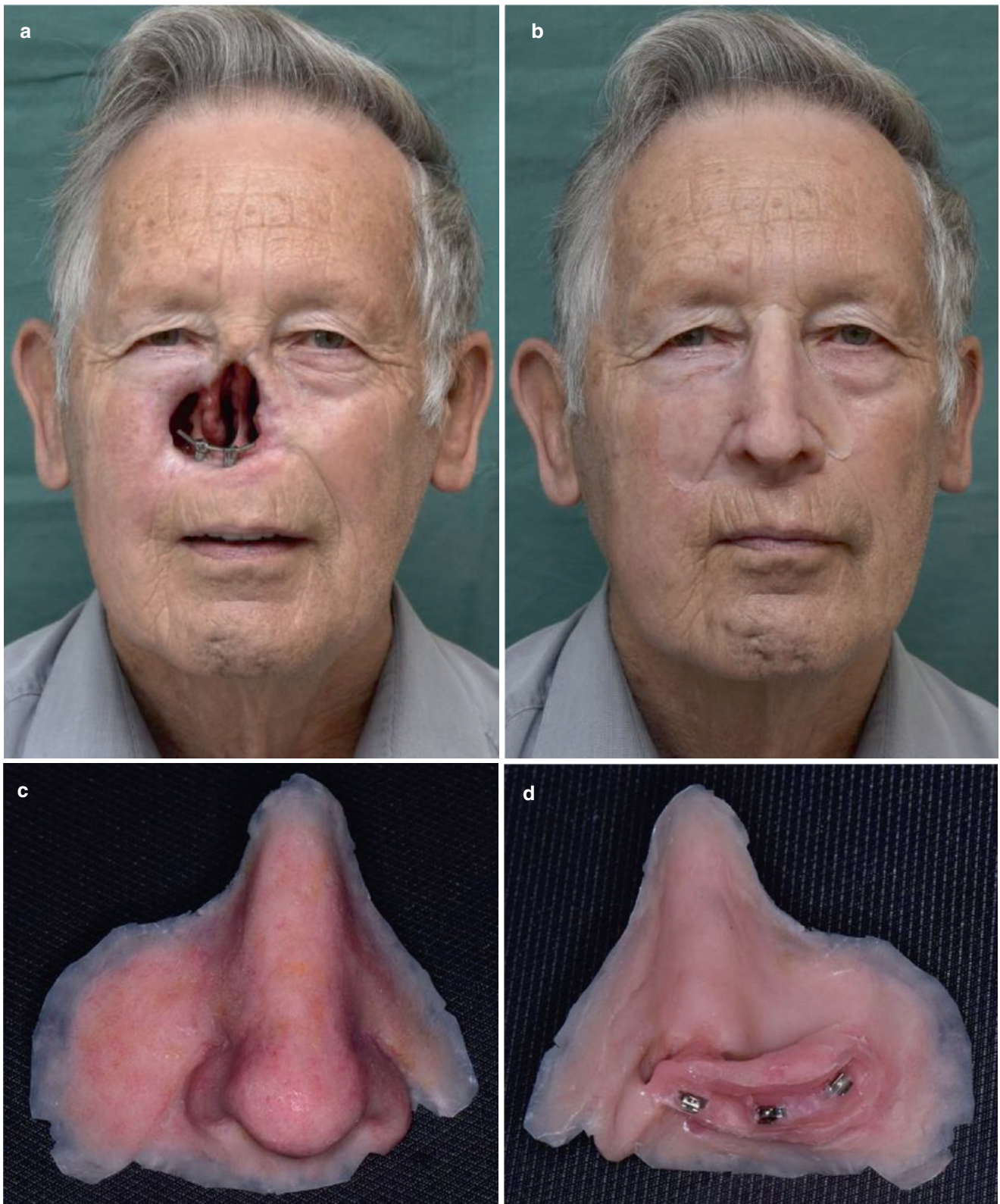


Fig. 11 (a–d) Patient shown in Fig. 10 with his final osseointegrated nose prosthesis following radical rhinectomy for SCC



Fig. 12 (a–f) Recurrent malignant melanoma of the right auricular region, showing surgical plan for wider margins and the osseointegrated ear prosthesis that was constructed

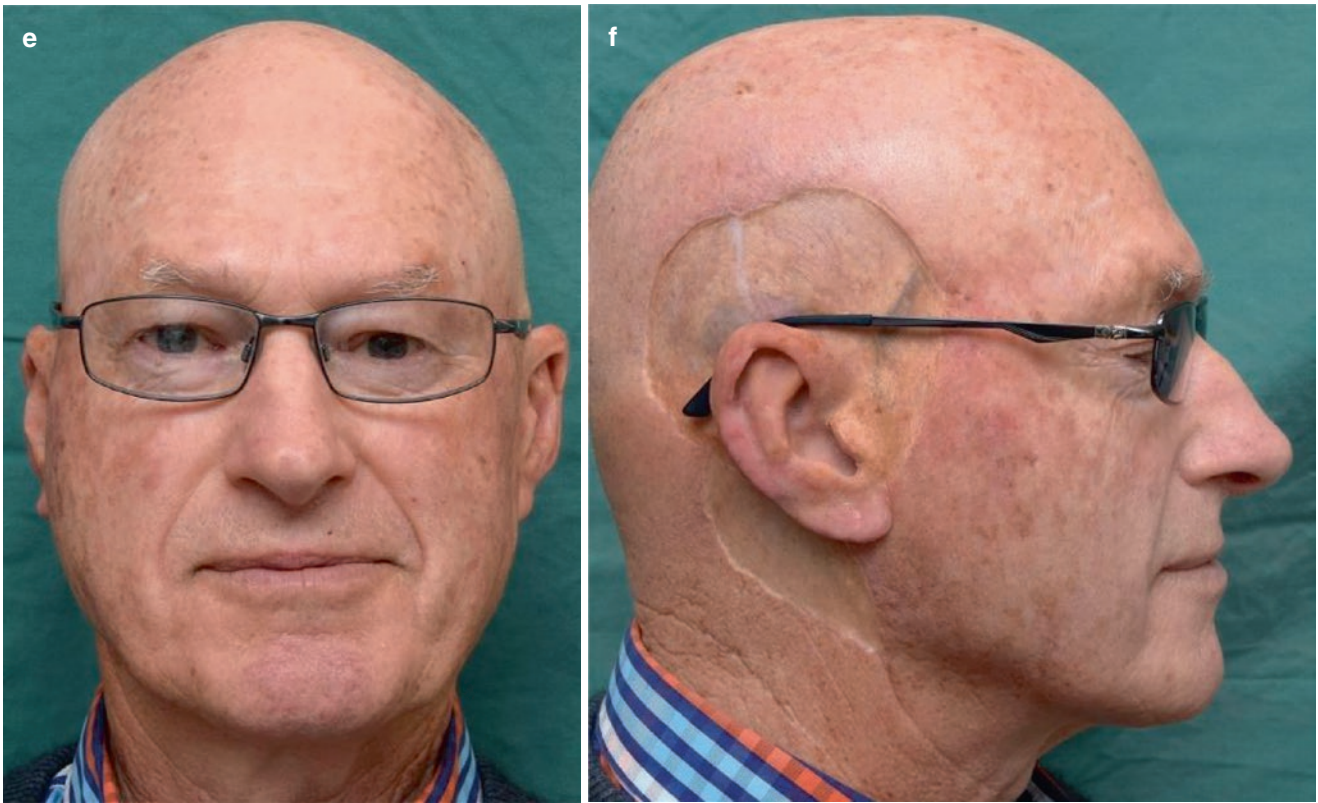


Fig. 12 (continued)

13 Digital Imaging for Facial Prosthetics

The digitalization of investigative anatomical data has created huge opportunities for the planning, treatment and post-operative rehabilitation.

It is important to gather the right level of information at the right time and under the appropriate protocols.

The main imaging modalities useful to the maxillofacial prosthetist are as follows:

1. Helical CT scan.
2. Surface capture technology.
3. Model scanning technology.
4. MRI.

The most useful of these is the helical CT scan as it provides both accurate hard tissue data and excellent soft tissue data including fine detail of the external anatomy. It is useful to establish set protocols with the radiology department as often they will be taken at 3 mm or 5 mm slice distance. The ideal requirement is a 0.5 mm slice distance with a 50% overlap. This is especially important for orbital reconstruction due to the thin nature of the orbital bones.

Surface capture technologies are essentially a 3D photograph, are noninvasive and are either mobile or static. Static scanners such as the 3DMD face system (3DMD Ltd) are studio-based and have a fixed focal distance and are excellent at fast capture but fail to capture hair, shiny objects such

as the eye and deep areas of defects. Mobile systems such as the Artec Spider (Artec Ltd) are handheld and take longer to capture their subject requiring a degree of skill and practice but are better for undercut areas such as the auricle.

Model scanners are desktop-based and are more accurate than the aforementioned systems, down to micron level, but they only have a small capture area and are usually designed specifically for plaster dental models. If you are looking to plan for osteotomies or implant position, this type of scanner is essential.

13.1 Software

To be of any use, digital data need to be imported into software that can reform digital information communication in medicine (DICOM) data from CT and MRI into 3D representations.

13.2 Indications for Digital Imaging

13.2.1 Case Example 1

A 22-year-old woman with an exenterated orbit following rhabdomyosarcoma underwent a CT scan for the digital planning of implants. By requesting the patient to keep the eye open during the scan, the data can be used to design and print the prosthesis prototype (Fig. 13).

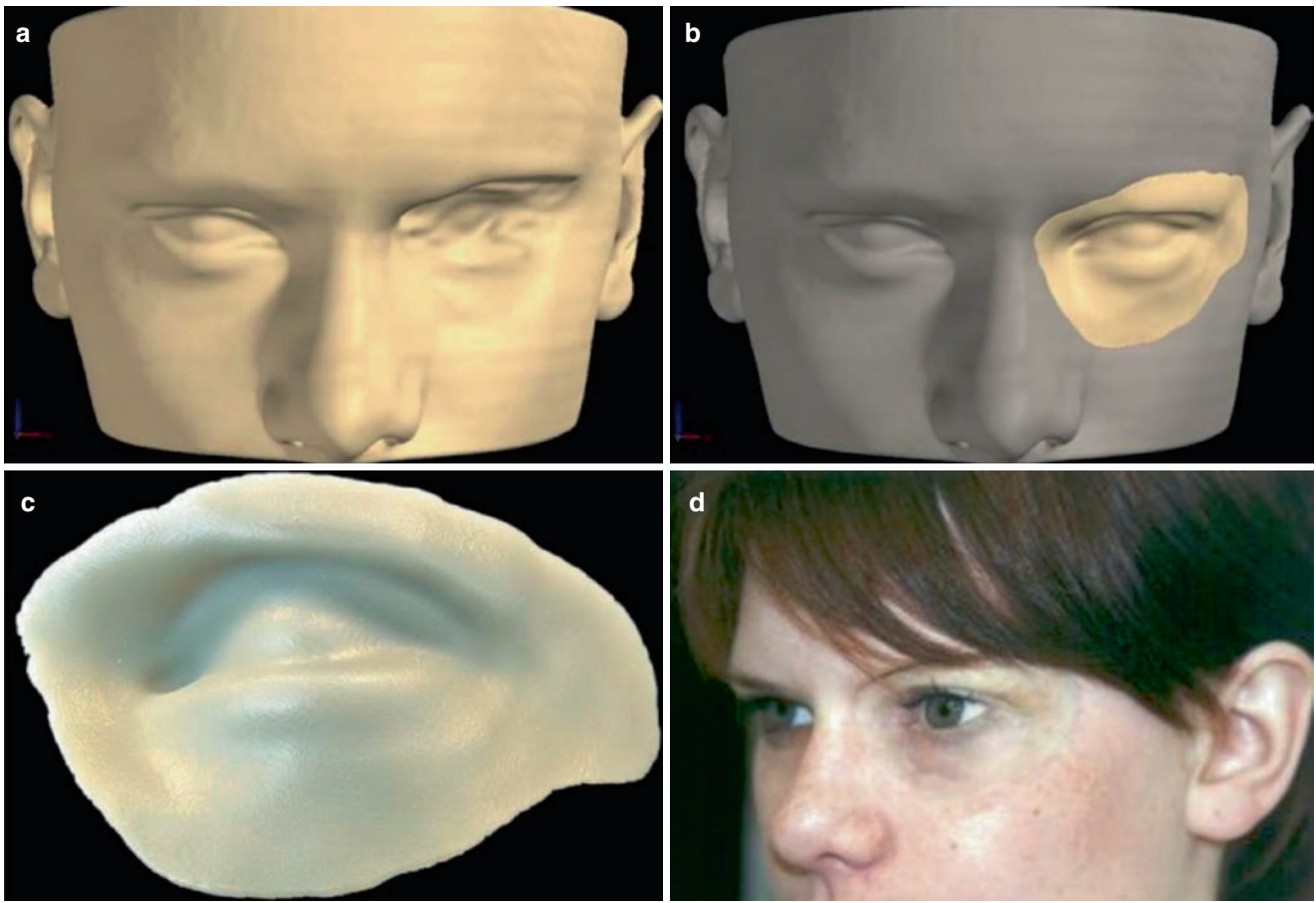


Fig. 13 (a–d) Digital imaging for the construction of a left orbital prosthetic following exenteration for rhabdomyosarcoma

13.2.2 Case Example 2

A 78-year-old man underwent subtotal rhinectomy for the removal of a squamous cell carcinoma. The digital data are used to plan the position of the zygomatic implants (MIMICS

Medical), but the CT data of the soft tissue can be used for the creation of the postoperative prosthesis (Fig. 14).



Fig. 14 (a–c) Digital imaging for the construction of a nasal prosthesis post-total rhinectomy for SCC

13.2.3 Case Example 3

For a 25-year-old woman who required craniofacial implants for the retention of an auricular prosthesis for congenital atre-

sia, 0.5 mm helical CT data were acquired. The opposing ear is mirrored for planning of the implant position. The same data can be used for the creation of the prosthesis (Fig. 15).

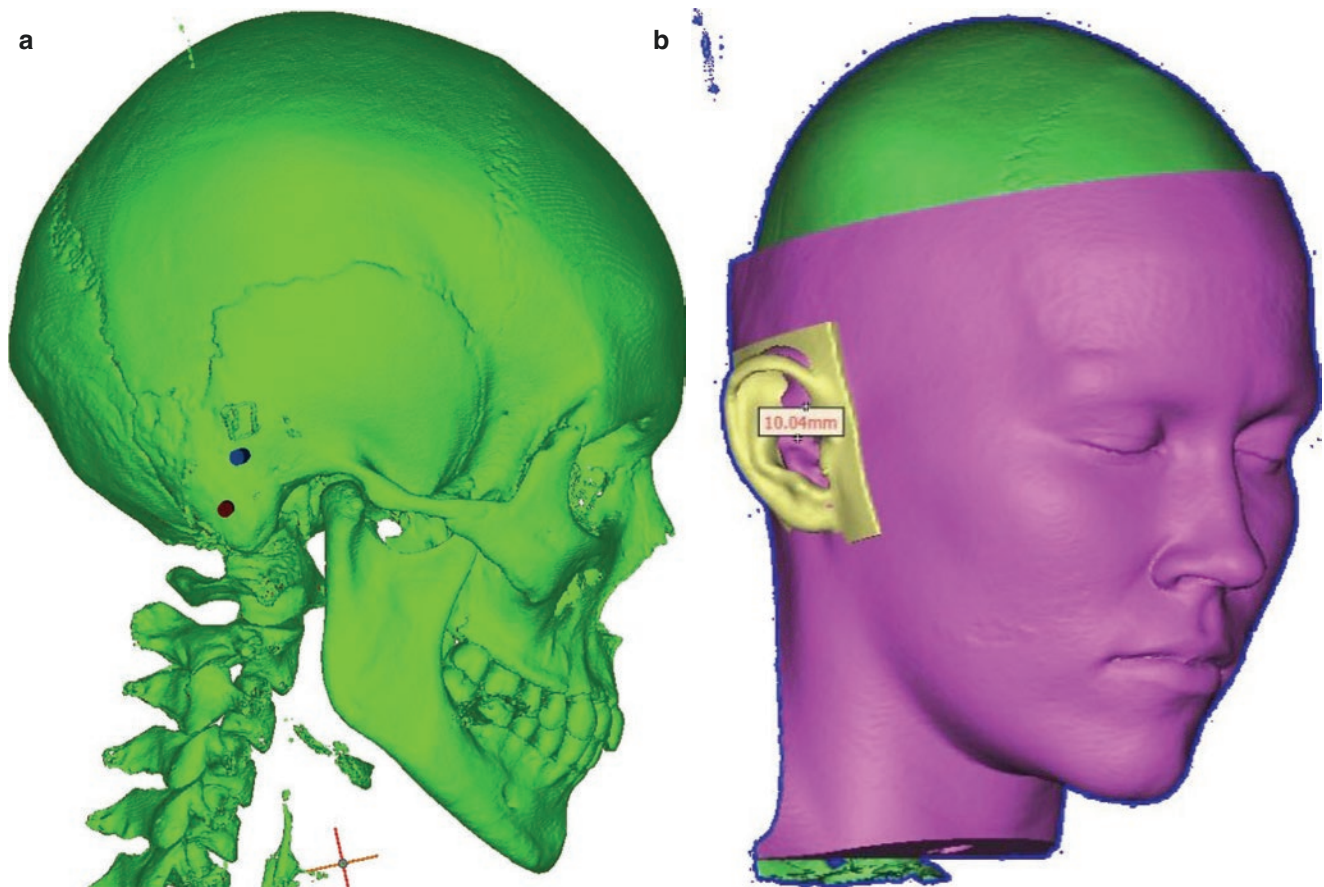


Fig. 15 (a and b) Digital imaging for the planning and construction of a right ear prosthesis designed from the shape of the contralateral ear and positioned on the CT scan data

14 Surgical Considerations for Oral and Facial Rehabilitation Post-cancer Resection

Orofacial defects are deforming, unique and challenging to manage. As detailed in Chap. 4 “Applied Facial Anatomy”, facial anatomy is complex with the presence of the eyes, ears and cavities (oral, pharyngeal and paranasal sinuses), which serve highly specialized functions. The goals of surgery are to cure or control the cancer and prolong survival. Restoring form and function are the bedrock principles of this approach. Modern maxillofacial surgery is also driven by the patient’s expectations for improvement in their quality of life post-cancer ablation. This can be measured in the clinical setting as is covered comprehensively in Chap. 19 “Assessment of Function Post-cancer”.

Overall, the survival from head and neck cancer is approximately 60% and has not changed significantly in the last 70 years. Chap. 2 “Cancer Stem Cells in the Head and Neck Cancers” addresses some of the new science of cancer stem cells, which may explain why there has been little change in survival. There will be paradigm shifts in the way we approach cancer in the future, but the concept of rehabilitation of the patients to normal health remains a noble goal. The multidisciplinary collaboration has been reiterated in this Atlas again and again. A key modern concept for maxillofacial surgery is the occlusal-based planning for oral rehabilitation, following segmental resection of the mandible and maxilla. With the advent of 3D imaging and virtual surgical planning, it is now possible to place oral rehabilitating implants immediately into free flap reconstructions. In well-selected patients, this can achieve outstanding orofacial rehabilitation including better mastication, speech and swallowing.

14.1 Timing of Surgery and Prosthetic Rehabilitation

The likelihood of adjuvant radiation should be considered in the team approach because research shows that the success of osseointegrated dental implants is higher when the implants are placed prior to radiotherapy as opposed to after radiotherapy. Craniofacial implants placed in irradiated bone of the face are more likely to fail. Furthermore, reconstruc-

tive surgery on irradiated soft tissue is slower to heal and carries a higher risk of complications. Real-time surgical planning with advanced imaging and three-dimensional (3D) printing, and soft laser intraoral and facial scanning make the complex planning of these challenging orofacial defects a much simpler and efficient process.

14.2 3D Model-Assisted Surgery

This technology enables the surgeon and prosthetist to optimize reconstructive flap surgery and orofacial rehabilitation implant placement. 3D printing requires printing one or more materials in a layer-by-layer manner, and by adjusting the shape of each layer, a complex solid object can be formed from a digital model. This allows for simulated model surgery rehearsal, bone plate blending, 3D positioning of osseous reconstruction (AP, transverse and vertical positioning) and determining the site, length and angulation of osseointegrated implants (Fig. 16).



Fig. 16 A 3D model of a mandible outlining the extent of tumour resection (from the right ascending ramus to the midline). The model was used to bend the reconstruction plate, and the blue dots mark the site of two osseointegrated implants on the native mandible. The osseointegrated implants were placed at the time of fibular flap harvest, with one on the fibular flap and two on the left native mandible

14.3 Indications

In a similar case (Fig. 17), a pre-bent bone plate is shown with an ex vivo inset of a free chimeric osteocutaneous scapular flap used to reconstruct a composite defect of the mandible, floor of mouth, tongue and skin of the anterior chin.

The next case involved a patient with an SCC of the mandibular alveolus, extending from the right second premolar (45) to the left second premolar (35). After wide segmental mandibular resection, the pre-bent bone plate was applied, and a myo-osseous fibular free flap inset and the microvascular anastomoses were completed (Fig. 18). The muscle provided lining for the floor of the mouth and the new mandibular alveolus. A total of 6 oral rehabilitation implants were placed, and their position was determined with 3D implant planning software. Sulcoplasty was then performed 6 months later, and a split skin graft was secured with a stent applied to the titanium cylinders.

Subtotal midface and maxillary 3D positioning is a more challenging reconstructive proposition. The relationships of the maxilla with the mandible, zygoma and the cheek soft tissues add to the reconstructive complexity. The next case shows an SCC of the maxilla with labial gingival infiltration, treated with total maxillectomy via an intraoral approach (Fig. 19). Reconstruction was achieved using a 3D model to plan a segmental free fibular flap, with a central segment of vascularized bone to support the nose and lateral segments to support the soft tissues of the cheeks. Later, 6 osseointegrated implants were placed, a sulcoplasty was resurfaced with a split skin graft and finally titanium cylinders were attached. These supported an upper denture restoring the patient's normal facial appearance, speech and ability to eat normally.

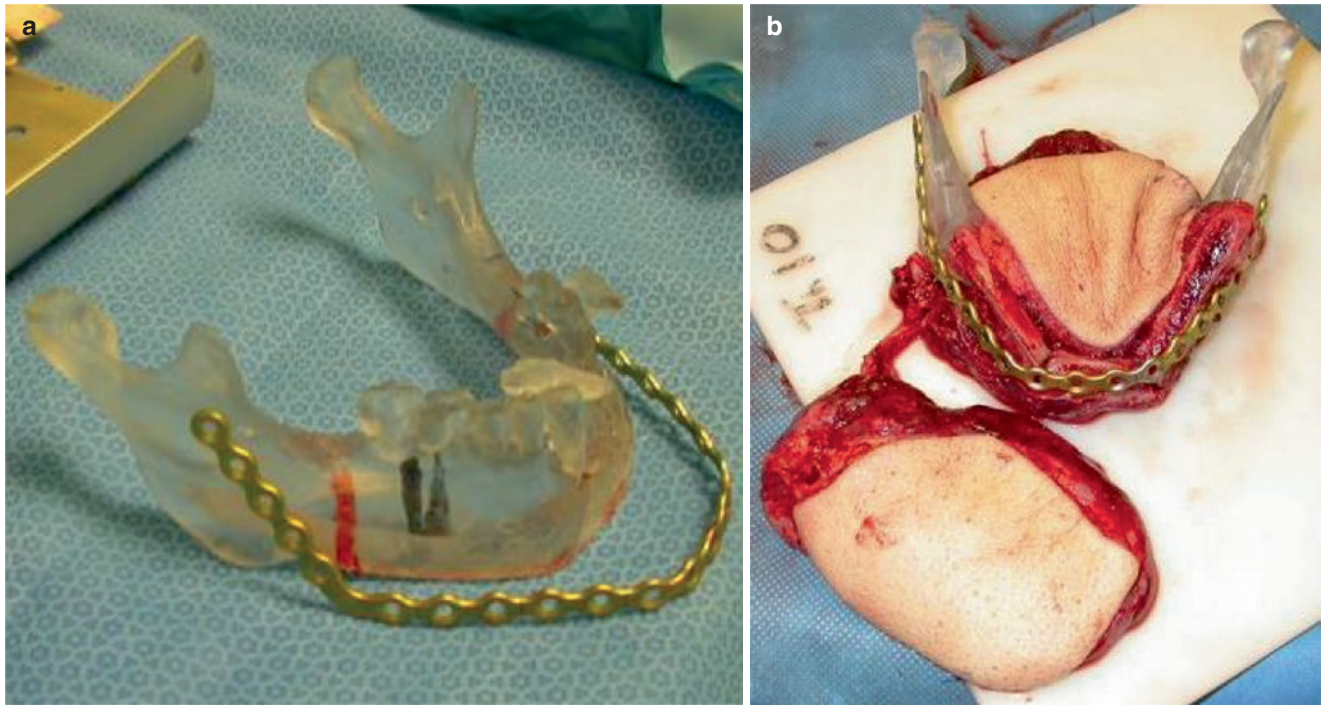


Fig. 17 (a and b) 3D modelling for composite mandible/floor of mouth defect reconstructed with a free osteocutaneous scapular flap

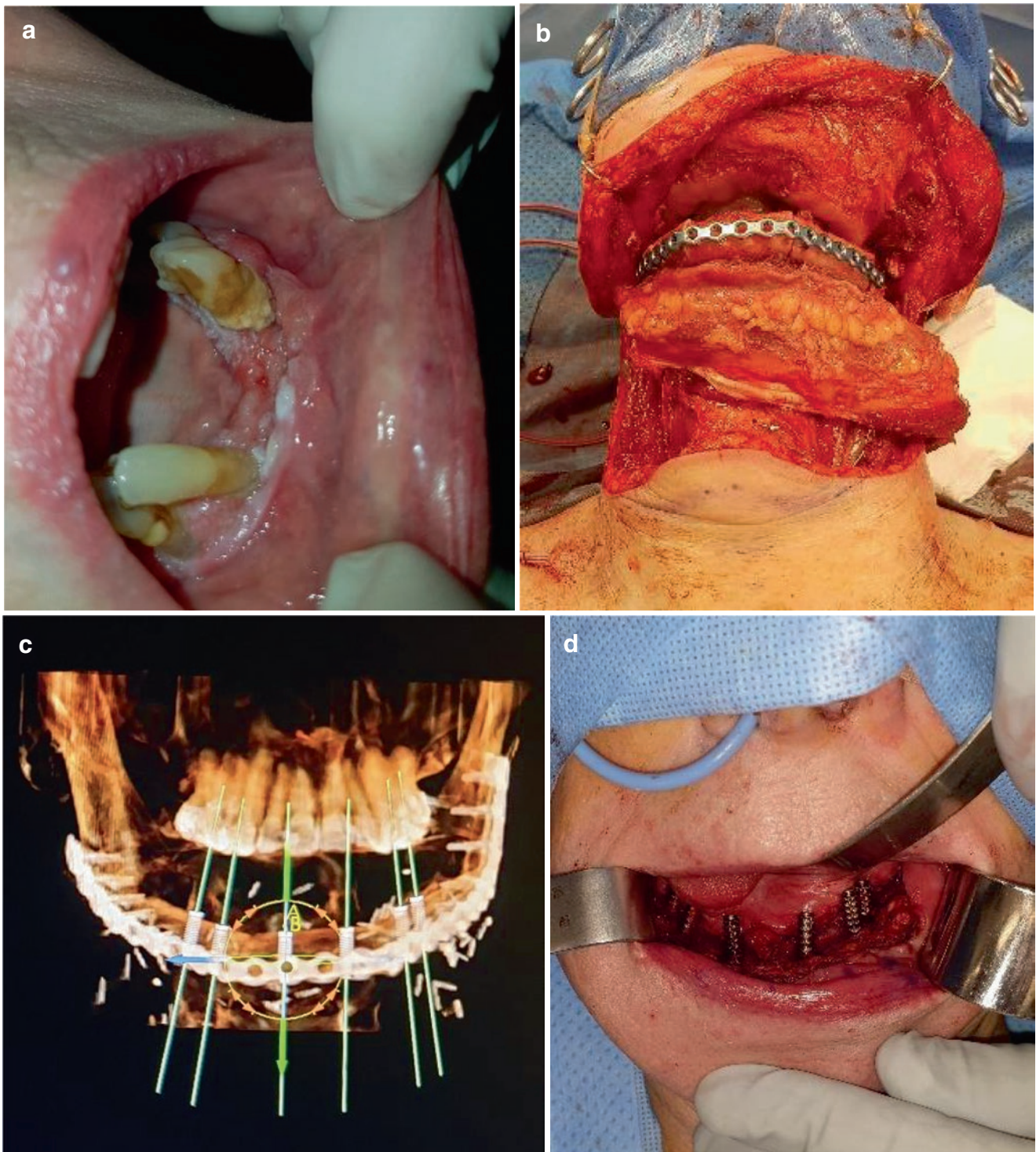


Fig. 18 (a–f) Angle-to-angle composite mandibular resection in a female with extensive SCC, reconstructed with a free fibular flap and dental implants using 3D planning and modelling. Final appearance of patient with restored facial profile and projection shown



Fig. 18 (continued)

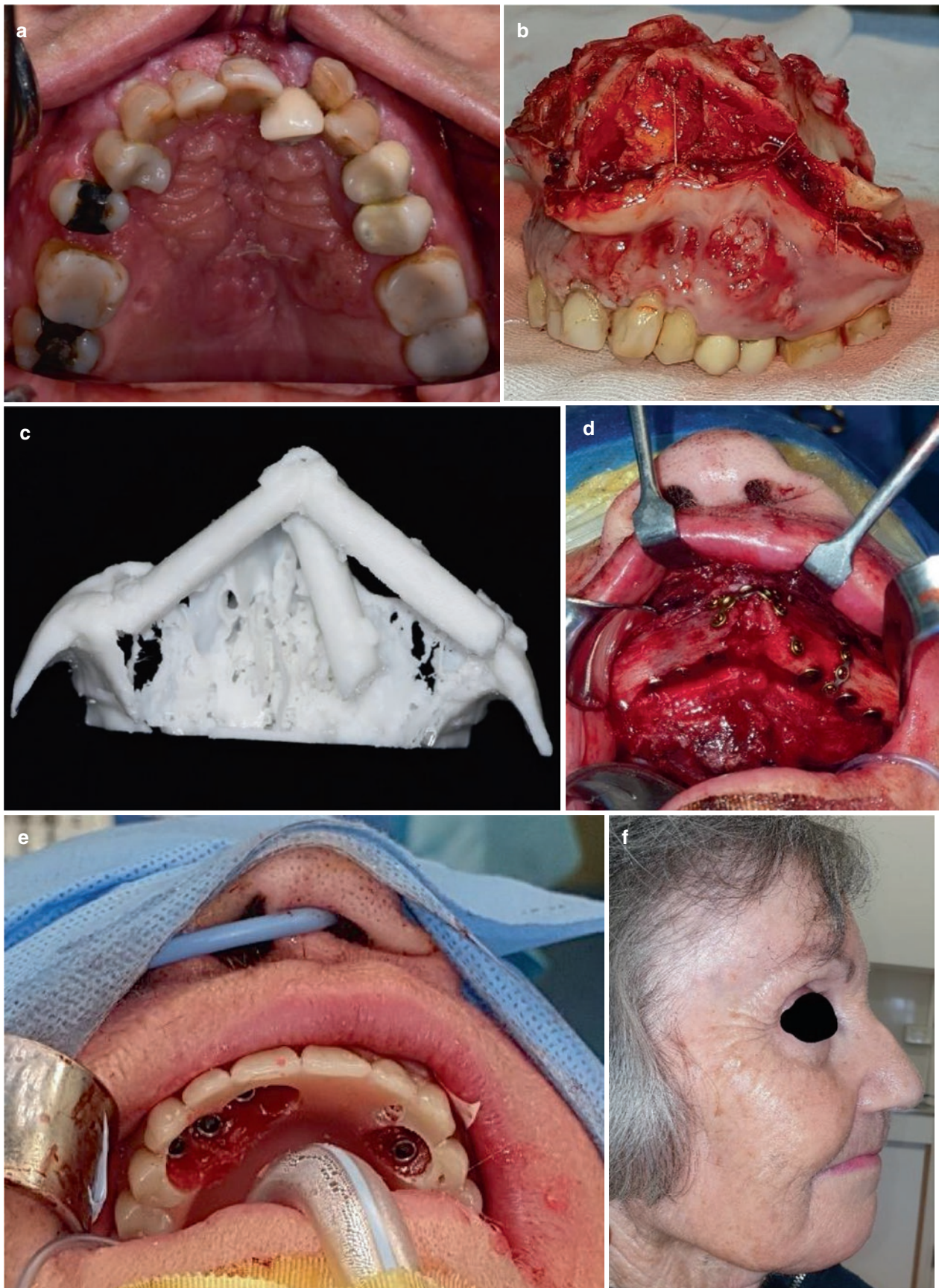


Fig. 19 (a–h) Total maxillectomy case reconstructed with segmental free fibular flap and later an upper denture fixed with osseointegrated implants. Final appearance with restored profile shown

14.4 3D-Guided Placement of Osseointegrated Implants

Printed 3D models are very helpful to decide on the 3D position of the newly reconstructed jawbone and implants. Placement of osseointegrated implants is achieved by either freehand (Fig. 20) or 3D-guided imaging, the latter with more accuracy and with both static and dynamic options. This new technology allows the precise placement of

implants including the selection of correct length, diameter and angulation. The optical scan of the mouth or the defect is superimposed on the CT scans of the patient. Using special software, a digital file can then be prepared for 3D printing (Fig. 21).

The dynamic 3D-guided implant placement is a recent innovation. It is real-time surgical navigation used specifically to place implants, and no 3D printed model guide is needed (Fig. 22).

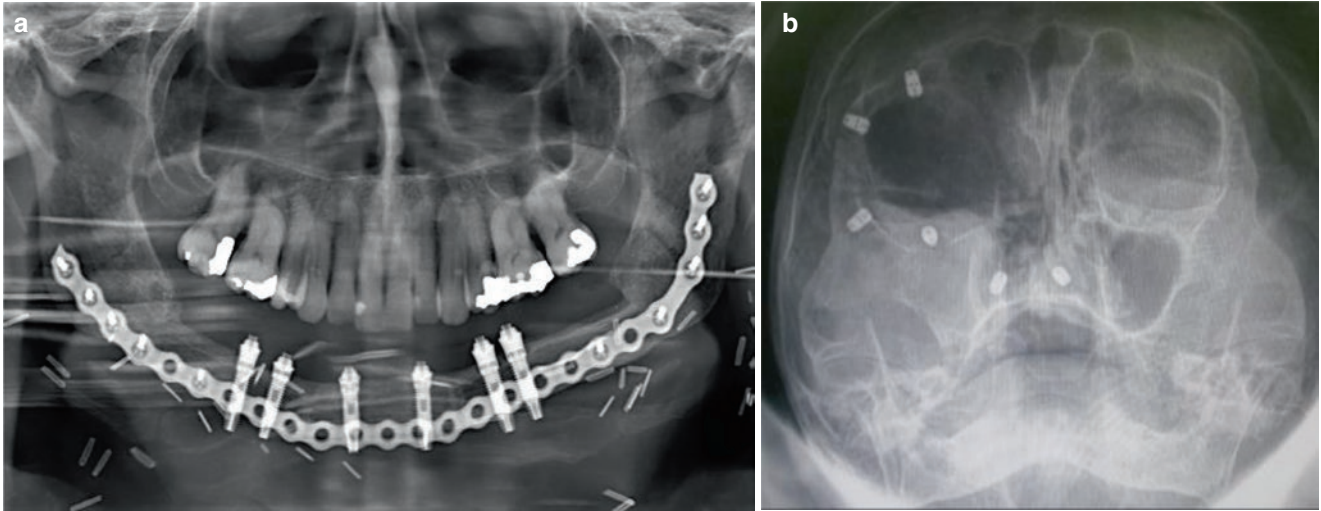


Fig. 20 (a and b) Freehand placed bone plates and implants

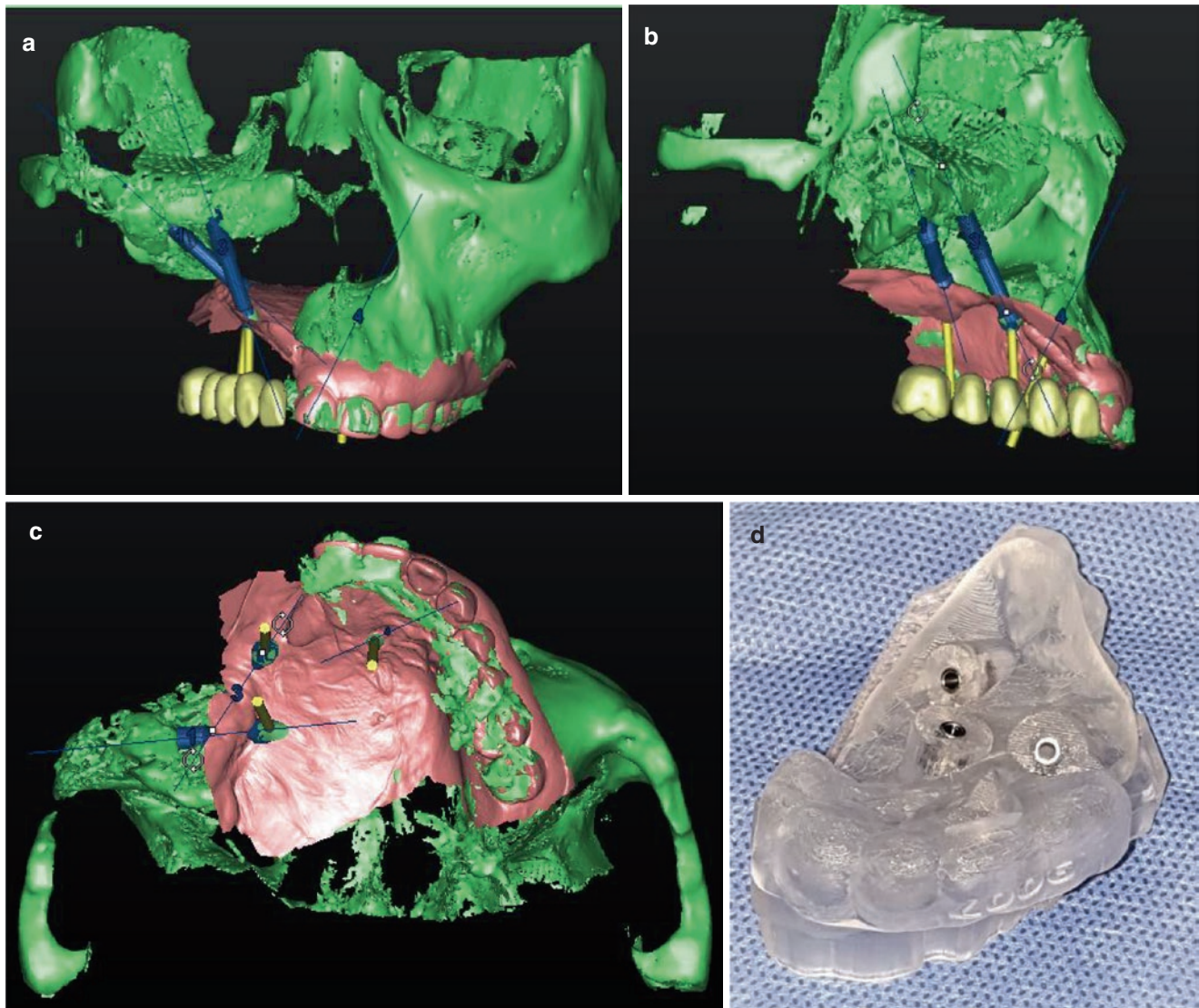


Fig. 21 (a–f) Female patient after free fibular flap + rectus abdominis free flap reconstruction of her right maxillary defect for a giant cell tumour. 3D-guided planning, with the fabricated grey guide for the pre-

cise placement of 2 × zygomatic osseointegrated implants for the retention of her right hemimaxillectomy prosthesis



Fig. 21 (continued)

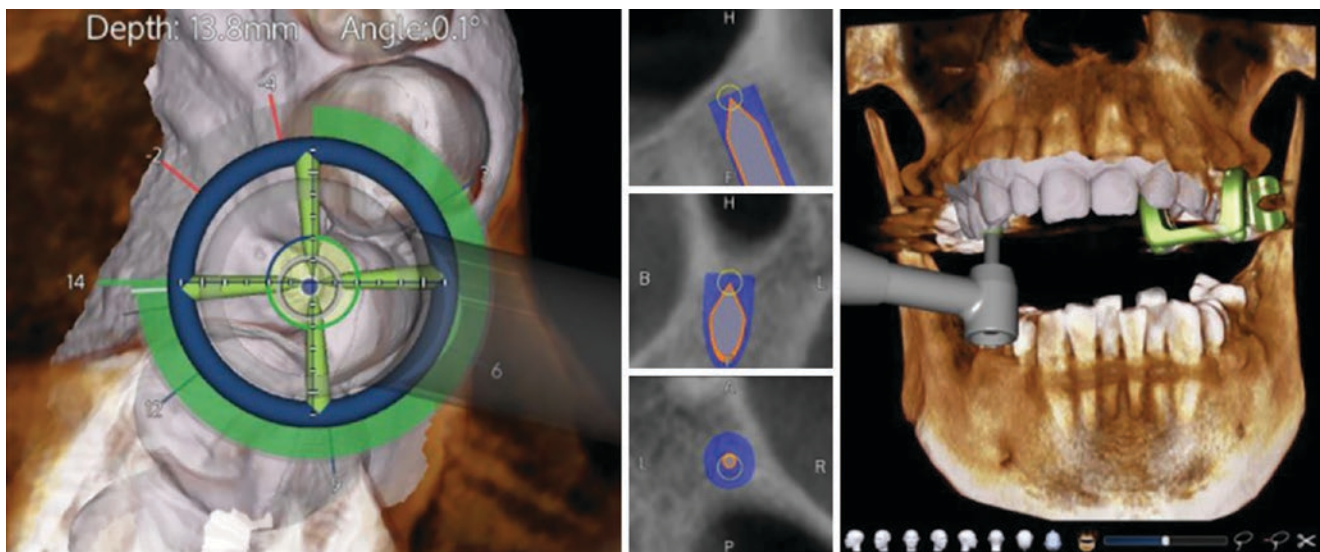


Fig. 22 Dynamic 3D-guided implant placement with surgical navigation

15 Virtual Surgical Planning (VSP)

3D printed cutting guides can be produced for the precise osteotomies required for osseous flap design, and this is illustrated in Fig. 23 for the harvest of a free DCIA flap from the iliac crest for a partial maxillectomy defect. The resected tumour was a mucoepidermoid carcinoma.

Another clinical example is the use of virtual surgical planning for reconstruction of a complex left orbitozygomatic defect using a free scapular osteocutaneous flap based on the thoracodorsal pedicle (Fig. 24).

Using advances in virtual surgical planning, it is now possible to place dental implants at the time of free flap recon-

struction. The extent of the cancer resection is determined and then the position of the tooth crowns was planned followed by the corresponding implants. The bone reconstruction is then virtually positioned to support the implants. This is the occlusion-first approach and is illustrated in Fig. 25, for a posterior maxillary defect reconstructed with a free fibular flap. The dental implants have been placed in the vascularized bone graft with a temporary implant-retained bridge, which will be applied with intermaxillary fixation for perfect occlusion.



Fig. 23 (a–c) Precise design of a free DCIA myo-osseous flap for partial maxillectomy reconstruction using the 3D-printed cutting guides

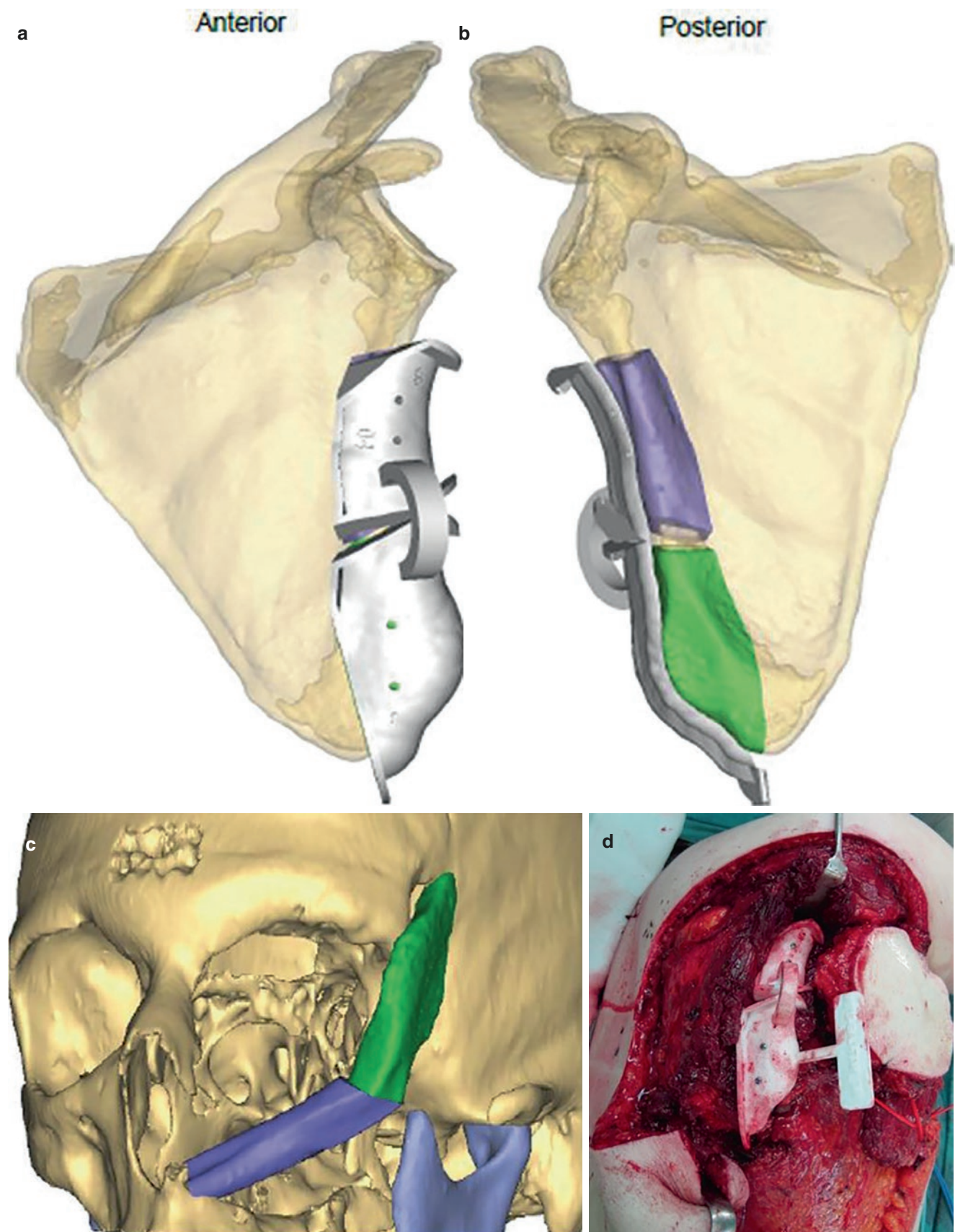


Fig. 24 (a–d) Virtual surgical planning for a left orbitozygomatic reconstruction with an osteotomized free scapular flap

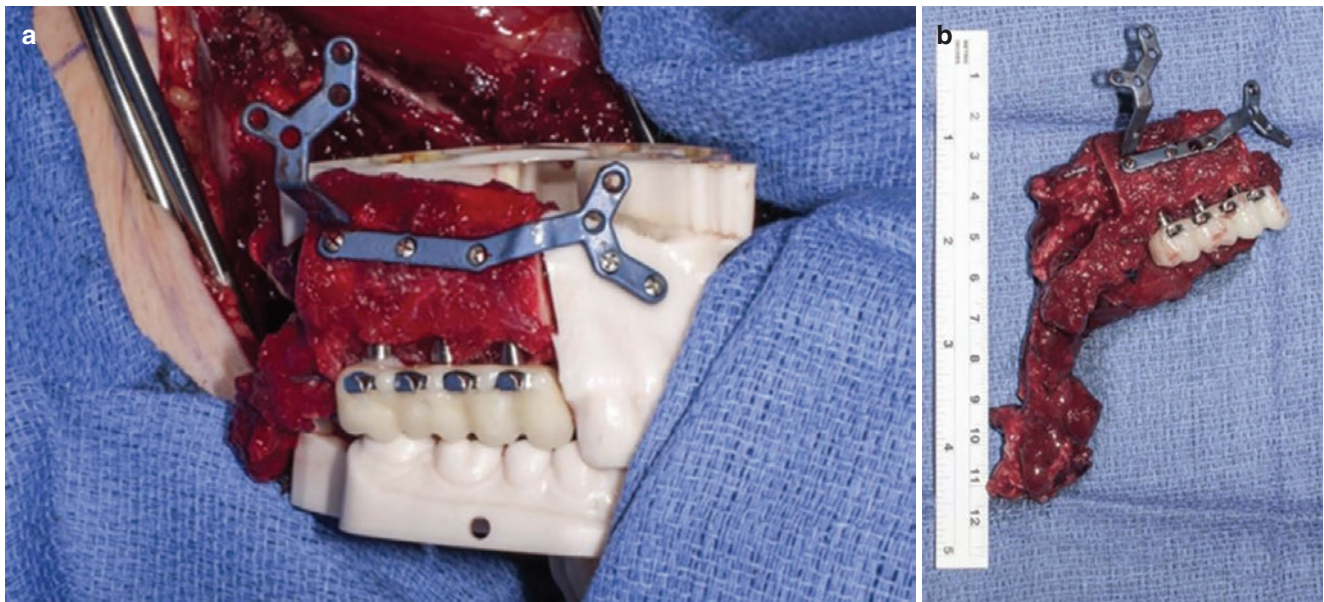


Fig. 25 Occlusion-first approach with VSP for a posterior maxillary defect reconstructed with a free fibular flap and osseointegrated implants already place. Note the hooks attached to the bridge for IMF (adapted from Patel et al., 2019)

16 Immediate Implant Placement

Immediate implant placement is a technique that can be used in patients who are likely to need postoperative adjuvant radiotherapy.

17 Soft Tissue Adjustments

These include flap debulking around osseointegrated orofacial implants to reduce shear forces at the implant/soft tissue interface, which may lead to implant failure. The other common adjustment is replacing non-keratinized epithelium intraorally with either palatal mucosal or split skin grafts.

Sulcoplasty (vestibuloplasty) is also a common surgical adjustment to recreate the buccal/lingual sulcus following intraoral reconstruction. Again, palatal mucosal or split skin

grafts are used and immobilized for graft take with a temporary stent. If volume is needed to rebulk flap repairs in the head and neck, the use of autologous stem cell-rich fat grafts is an option.

18 The Cheesecake Flap for Total Glossectomy

The head and neck surgical service at Mercy Hospital in Auckland has developed a reconstructive option to replace the tongue prosthesis in rare cases of total glossectomy [Abu-Serriah et al. in press]. The new cheesecake flap, a free rectus abdominis myocutaneous flap, eliminates the need for permanent tracheostomy and feeding tube (Fig. 26). Intelligible speech is also achieved.

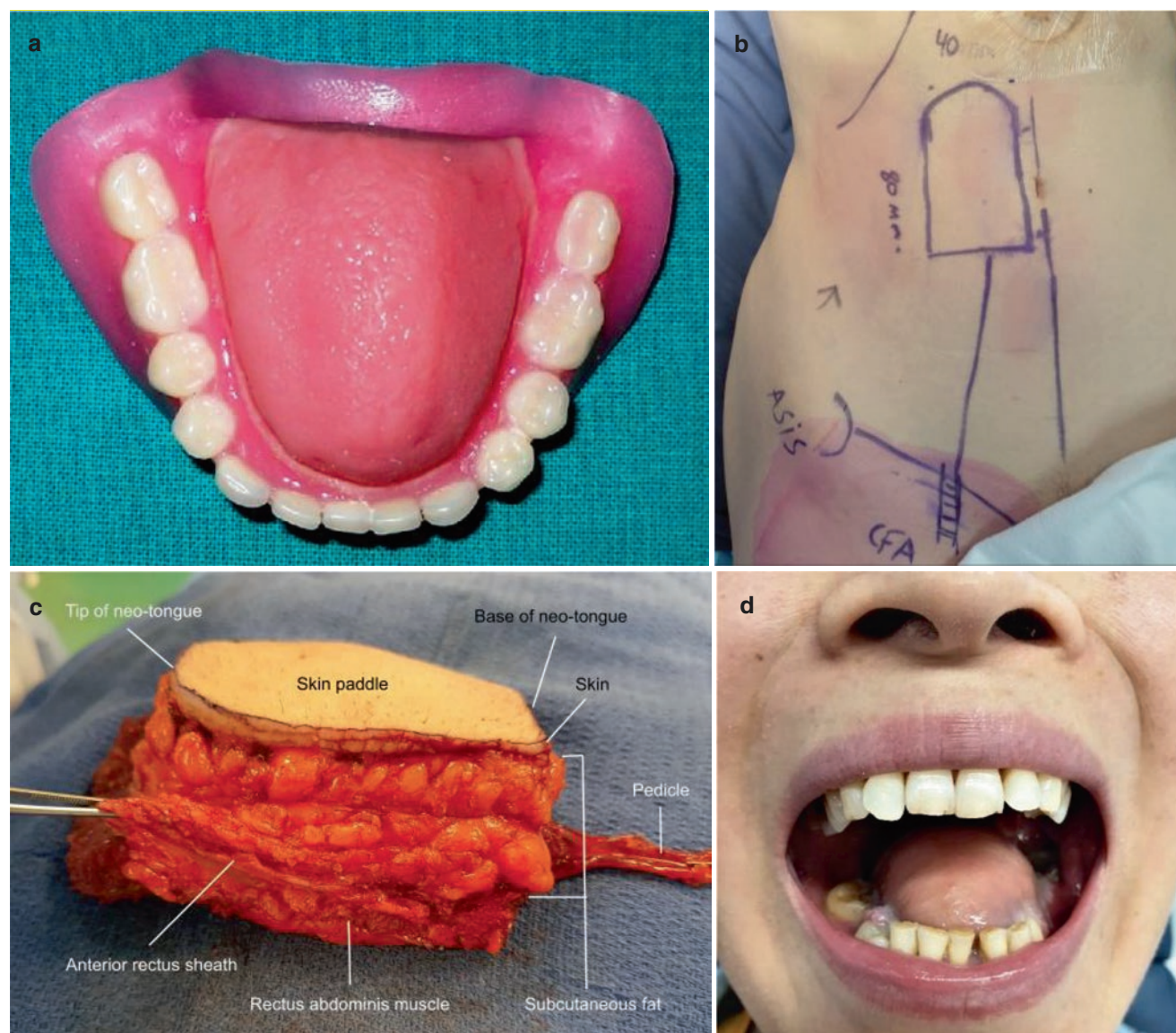


Fig. 26 (a–d) A traditional tongue prosthesis and the innovative “cheesecake” rectus abdominis myocutaneous free flap alternative developed in Auckland by the Mercy Head and Neck Surgical Service.

The patient is shown 9 weeks post-total glossectomy and “cheesecake” free flap reconstruction of his tongue

19 Maintaining Alveolar Ridge Height in the Dentate Patient

This is best achieved with a DCIA free flap or a double-barrelled free fibular flap (Fig. 27). However, in cases where only a single barrel is possible (e.g. long resection), improv-

ing the vertical height of the neo-alveolar ridge may be achieved by vertical distraction osteogenesis.

Vertical cuts are made in the free fibular flap, and a vertical distractor was placed to augment the vertical height of the neo-alveolus.

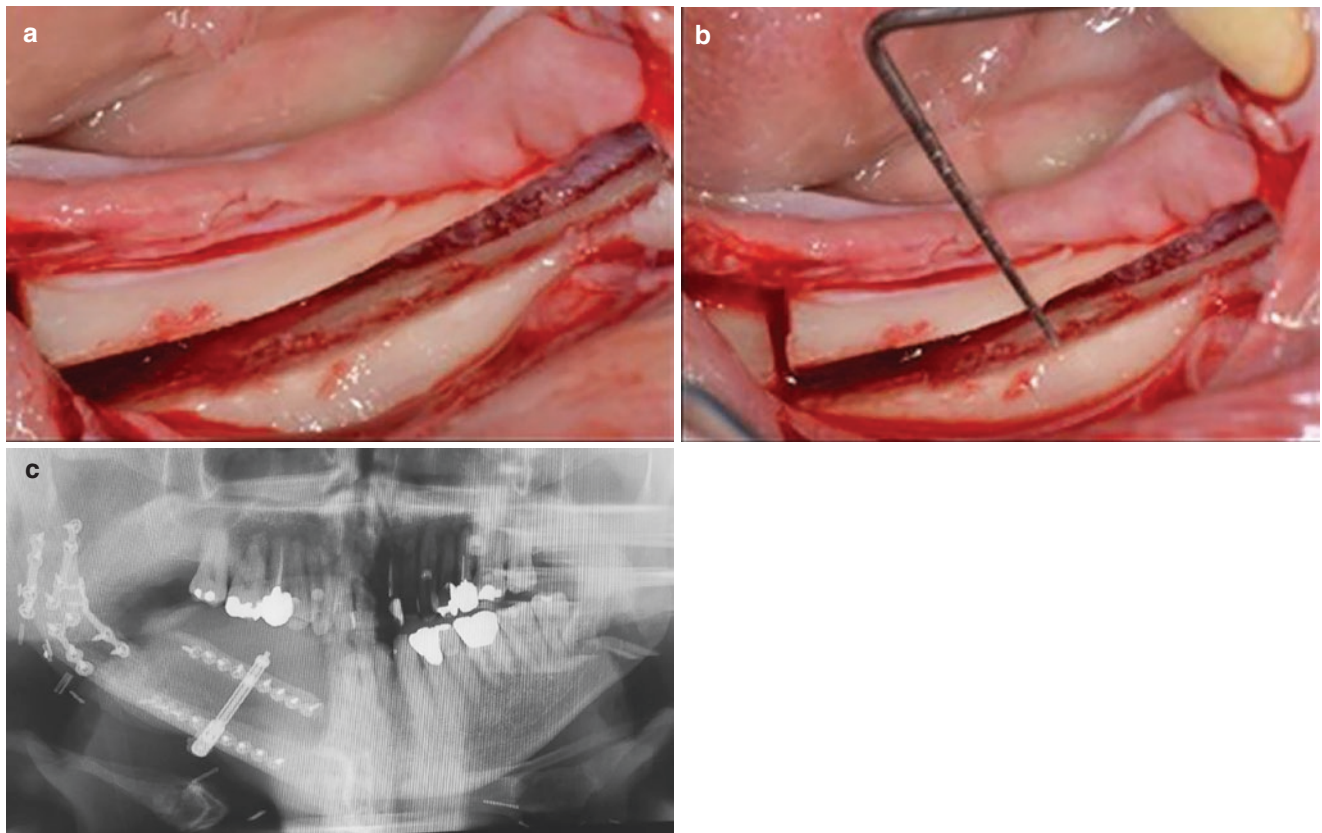


Fig. 27 (a–c) Double-barrelled free fibular flap with vertical distractor for neo-alveolus right hemi-mandibular reconstruction

20 Controversies

There is an obvious controversy in the timing of complex oral and facial prosthetic rehabilitation; immediately at the time of free bone flap reconstruction or later when survival from the extreme facial/intraoral cancer is confirmed. Arguments can be made for either case, but generally this would be an individualized decision for treatment considered by the multidisciplinary team, the patient and their family. Many factors would be considered, not least the patient's personal wishes based on proper informed consent.

21 Conclusion/Summary

Prosthetic rehabilitation is an excellent alternative either definitively or temporarily to surgical reconstruction for many patients. With education and guidance from presurgery and throughout the remaining course of a patient's life, prosthetics if done well can be incredibly realistic and life-changing for the patient. With restoration of appearance comes improved body image and confidence, enabling patients to resume their lives without fear of looking different and standing out from the crowd. A lifetime relationship can develop between prosthetist and patient, and as patients

age and change, their prostheses will also need to be regularly updated to reflect those age-related changes.

Modern maxillofacial surgical techniques have been refined by an increasingly sophisticated technology including modern radiological imaging, improved resection methods and microvascular flap reconstruction. 3D model-assisted surgery, planning and precise placement of osseointegrated implants all contribute to better clinical outcomes in terms of function and aesthetic form. The collaborative team approach focussed on the right care for each patient is a key principle and early surgical intervention when complications arise.

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Perioperative and Anaesthetic Care in Head and Neck Cancer Surgery

Su S. Thon

Core Messages

- An appreciation of the evolution of modern anaesthesia recalls the advances that have been made to enable effective surgery.
- The symbiotic role of anaesthesia and surgery epitomises the team approach to this field of head and neck cancer, including extreme facial cancer.
- The broader anaesthetist's role of perioperative care, based on the sentinel principles of optimising the patient's physiology to achieve safe and satisfactory surgical outcomes.
- The mechanics of anaesthesia pharmacology, airway management and intraoperative vital sign monitoring are shared including the protocols for managing anaesthetic crises.

1 Introduction

The word “anaesthesia” means “loss of sensation”. The traditional anaesthetist's role, as part of a multidisciplinary surgical team, is to provide anaesthetic care for the surgical patient. Types of anaesthesia include local anaesthetic infiltration, regional anaesthesia, general anaesthesia and sedation. For the purposes of this chapter, only general anaesthesia will be discussed. The latter procedures are done specifically under the supervision of a trained anaesthetist. Many modern surgical techniques today could not be undertaken without their involvement.

2 A Brief History and Development of Anaesthesia in the Western World [1, 2]

16 Oct 1846	William Morton and Dr. John Warren (Surgeon at Massachusetts General Hospital) used ether vapour for removal of a tumour in a patient's neck (The Ether Monument)
19 Dec 1846	First anaesthetic in Britain
1847	James “Young” Simpson discovers the anaesthetic properties of chloroform
1853	Dr. John Snow, a London physician, administers the first chloroform anaesthetic to Queen Victoria during the labour and birth of her first child
	Joseph Clover continues forwarding advances in anaesthesia after Dr. John Snow's death, refining techniques on dose delivery and monitoring the unconscious patient. Both these pioneer British anaesthetists appear on the crest of the Royal College of Anaesthetists, UK
	Sir Benjamin Ward Richardson advances new anaesthetic drugs and introduces ether (then ethyl chloride spray) for local anaesthesia
1862	In the USA, Colton discovers nitrous oxide speeds up the induction of ether anaesthesia, and this progresses to the modern approach of anaesthetic drug combinations rather than single, larger dose of one agent (with the potential for side effects and toxicity)
1884	Sigmund Freud, along with ophthalmologist, Karl Koller, studies the systemic effects of cocaine (an alkaloid plant, coca discovered in South America and known for its numbing properties since 1860)
Sept 1884	Peripheral nerve blocks are described. Halstead and Hall inject cocaine to numb the ulnar nerve
1898	Spinal anaesthesia developed
1921	Epidural anaesthesia developed
1934	Introduction of fast-acting intravenous anaesthetic (thiopental)
1935	First formal postgraduate qualifications for anaesthetists introduced

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1942	Muscle relaxants based on curare, a South American arrow poison, introduced by Harold Griffith and Johnson in Montreal and developed in the UK by Jack Hatton in Liverpool. Muscle relaxation of diaphragm and abdominal muscles is beneficial for optimising conditions during thoracic and abdominal surgery
	Use of muscle relaxants becomes a driver for anaesthetists to develop techniques for intubation and mechanical ventilation in order to control breathing and gas exchange
1942 onwards	Specialist anaesthetists with airway skills and ability to manage seriously ill patients and underlying diseases lead to the development of intensive care units
Jun 1947	In Australia, the first successful operations under ether anaesthesia are conducted—William Ross Pugh in Launceston, and dental extraction by Sydney dentist, John Bellisario
Sept 1947	In NZ, Colonial Surgeon James Patrick Fitzgerald performs the first anaesthetic for dental extraction on an inmate in the Wellington jail
1948 onwards	Introduction of the first modern local anaesthetic (lignocaine) leading to development of skills in nerve blocks to supplement general anaesthesia
	Increasing role of anaesthetists in the management of acute and chronic pain
1950s	All specialties given equal status in the NHS

3 Modern Anaesthesia

Anaesthesia has morphed since its inception. Initially administered by surgeons, the role of the anaesthetist has evolved separately into a specialty independent of surgery, but with an intimate, collaborative and supportive relationship with the surgeon. The team of anaesthetist and surgeon is pivotal to the team approach. The interface between the two roles has allowed for innovation in surgical techniques and thus increasing complexity of surgery that can be offered. The more sophisticated the surgery, the greater the requirement for skilful anaesthetists with better equipment, improved drugs and better techniques. Modern surgery would not exist without one specialty spurring on advances in the other, and the cycle has driven progress ever since. The safety gains achieved in anaesthesia in the last century have been due to the improvement in equipment, monitoring and knowledge, and the recognition of anaesthesia as its own specialty with specialist postgraduate training.

The volume of surgery is increasing worldwide, and advances in surgical techniques naturally lend to pushing the surgical boundaries of what can be achieved. New surgical innovations, like microsurgery, robotic surgery and radiology-guided navigation of the operative field, have allowed for increasingly complex and precise technical work. More people have access to surgery, especially in high-income countries. However, population data in these countries have reflected changes producing an “inverted pyr-

amid”, where people are living longer and those over 65 years of age are increasing as a proportion of the total population. This means more people are also living for longer periods with chronic medical conditions.

4 Perioperative Care and Communication

This is especially important in the patient population undergoing head and neck surgery. This can range from surgery for head and neck tumours of both malignant and non-malignant origin, to cosmetic procedures to correct anatomical and inherited defects. As major head and neck surgery is considered relatively superficial compared with body cavity surgery, people with greater comorbidity can be treated. There are also implications for communication and planning between the surgical and anaesthetic teams in relation to the shared decision-making in high-risk patients and shared airway management.

The modern anaesthetist is now increasingly involved in the broader aspects of perioperative care—from preoperative assessment and optimisation, liaising with other medical specialists, to postoperative care and pain management (both acute and chronic) [3]. The emphasis is on collaboration and safety in health teams as well as gains in patient safety and outcomes. The aim is to get “the right operation, for the right patient, in the right place”. Recent system pathway changes have focused on enhanced recovery programmes to decrease variation in care, with buy in from patients, nursing staff and allied health. The aim is to encourage rapid return to normal function—eating and drinking and early mobilisation post-operatively. Alongside this would be an expectation around the pain experience. Although extreme pain after head and neck surgery is uncommon, some pain can be expected after any surgical procedure and will relate to the complexity of the procedure. The experience of pain is multifactorial, individualized and subjective. Pain can also pre-exist before surgery due to cancer or the patient may have painful pre-existing medical conditions, e.g. arthritis and fibromyalgia, and can already be taking analgesics. The preoperative period is a time to discuss not only the process and the technical aspects of anaesthesia, along with side effects, risks and potential complications, but also focus on expectations of recovery in the immediate postoperative period and patient-centric pain management. A multimodal approach to acute pain management during and after surgery is standard. The traditional paradigm has opioids as an integral part of pain management, but newer techniques involve opioid-sparing regimes including lignocaine, alpha-1 agonists (clonidine, dexmedetomidine) and ketamine, as well as regional anaesthetic techniques. This minimises the known side effects of opioids (nausea and vomiting, sedation and respiratory depression,

constipation and ileus, pruritus, cognitive effects and limiting the potential for discharging patients on long-term opioids, which have been implicated in the current opioid epidemic). It has been noted that after cosmetic day-surgery procedures, preoperative education can reduce postoperative opioid requirements and pain intensity and duration [4]. This study involved two meetings with the patient by the surgeon and involved both verbal information and written information about the benefits, risks and side effects of opioids, and led to most patients declining opioids post-discharge. This may not be entirely reproducible within another institution due to time, financial and systemic constraints, but pre-surgical education and knowledge may still be beneficial for patients.

Communication, with both the surgeon (who still takes the lead in care due to their relationship and bond with their patient) and the patient, is an intricate and important one. It is also important that the surgical/anaesthetist relationship is one based on trust and mutual respect. In an ideal world, there should be consistency in the makeup of the team. For patients with complex medical needs and considered high risk, the pathway of progression to surgery is being evaluated, with the anaesthetist being brought in earlier at multi-disciplinary planning and possibly prior to offering surgery. This is to enable discussions about individual risk and expected benefit and outcomes with input from the anaesthetic point of view and a chance for both specialties to present a consistent plan to the patient. Rather than focus on the traditionally technical and narrow definition of the anaesthetist as the individual administering anaesthesia, and surrounding intraoperative care, the preoperative period is an important time to identify, prevent and mitigate potential complications in head and neck cancer surgery, which can lead to morbidity such as return to the operating theatre, prolonged hospitalisation, disability, loss of function and mortality. Information should be provided both verbally and in the written form, and where possible be reiterated as this allows for improved retention.

capacity, state of one's teeth and limitations to mouth opening. Not all institutions have this step in their pathway, but this form is a very helpful start and helps guide the conversation between anaesthetist and patient. Pre-anaesthetic clinics for head and neck cancer surgical patients provide an ideal environment for the identification, investigation and optimisation of chronic conditions (e.g. coronary artery disease, chronic obstructive airways disease, renal impairment, endocrine disease, hypertension), and management of medications in the perioperative period. There is also opportunity to encourage and implement smoking cessation, instigate improvement in nutrition, treat and correct anaemia, and improve glucose control in diabetics and potentially health restoration, to improve physiological resilience to the stress of major surgery. However, this will depend on the lead time to surgery, as well as institutional processes and pathways.

With health advances and improved medical care, people are living better for longer. However, ageing is associated with a well-recognised decline in functional reserve. This can result in a less-effective response to the surgical insult, even if surgery is considered relatively superficial. There is increasing interest in frailty (not just elderly) as a predictor for 30-day mortality. There is no gold standard measure for frailty, but criteria include unintentional weight loss equal to or more than 5% of body weight in the past year, weak grip strength, self-reported exhaustion and slow gait speed. Aspects of these may be noted in any cancer patient due to the disease process, and an element of deconditioning may be expected in head and neck cancer patients. Pre-existing cognitive dysfunction (even if mild) will complicate perioperative outcomes and is commonly associated with postoperative delirium, cardiovascular events, increased length of stay and mortality [5].

Risk assessment can be divided into patient factors and comorbidities, and surgical factors like the type and complexity of surgery, as well as the acuity of surgery.

5 Preoperative Assessment

5.1 Risk Assessment and Stratification

As stated above, there is opportunity in the preoperative period to impact on the course of a patient's surgical journey. Pre-anaesthesia assessment, risk assessment and shared decision-making can identify patients at risk and improve quality of care. Early information gathering starts at the completion of a pre-anaesthetic questionnaire, which has focused on information relevant to anaesthesia—previous surgery and anaesthesia experiences, medical history and medications, allergies, exercise tolerance and functional

5.2 Types of Risk Assessment Tools

1. Risk scores—provides an overall score and classifies the patient into a risk category that allows comparisons to other patients, but cannot be individualised, e.g. American Society of Anaesthetists (ASA).
2. Risk prediction models—provides an individualised risk based on patient information into a validated multivariate model based upon a similar patient population. It requires multiple input variables, which can be preoperative and/or postoperative, and can be individualised. These models provide a quantitative percentage risk probability of an outcome. Examples of risk prediction models commonly used are the P-possum, ACS-NSQUIP calculator and SORT score. Discussion about these risk models is

outside the scope of this chapter, but can be freely accessed online [6–9].

3. Biomarkers—troponin, NT-BNP.

The ASA Physical Status Classification System (ASA) (Table 1) was developed in 1941. It has been used for over 60 years and was developed by the American Society of Anesthesiologists. The purpose of the system is to assess and communicate a patient's *pre-anaesthesia* comorbidities. It was initially not designed as a risk tool although is now used as such. As a classification system alone, it does not predict perioperative risk. Assigning a physical status classification is a clinical decision based on multiple factors and is subjective as it is based on clinical judgement. But, the ASA score is also important as it is an input variable in risk models like the Surgical Outcome Risk Tool (SORT) and American College of Surgeons National Surgical Quality Improvement Programme (ACS-NSQIP) calculator.

Risk assessment forms an integral part of the anaesthetic perioperative plan and ensures there is consideration if further investigations are required, for example cardiac investigations like exercise stress tests, echocardiograms or angiograms for patients with coronary artery disease. Some institutions perform cardiopulmonary exercise testing

(CPET) to determine the patient's anaerobic threshold and other parameters in order to risk stratify for major surgery. Planning will include intra- and postoperative care processes like consideration of invasive monitoring, and utilisation of appropriate postoperative facilities like intensive care. These are the more procedural aspects of an anaesthetist's role and are important for quality care. Risks and complications specific to major head and neck reconstruction surgery would include infection, sepsis, haematoma, bleeding, airway emergencies and flap failure. As part of a shared decision-making model, the multidisciplinary team (including but not limited to surgeons, anaesthetists, oncologists, pathologists, speech/swallowing therapist, nurse practitioners and allied health professionals) need to communicate and arrive at a consensus about the goals of treatment, and where the benefits and risks of each treatment option proposed are based on good scientific evidence. In addition, there is a holistic role anaesthetists can play, in helping inform discussions and document expectations of the patient and family/carers regarding their goals of care—quality of life, independence and return to pre-surgery function, freedom from pain and suffering and the prevention of morbidity. This should be patient-centred and revolve around the patient's and family's values.

Table 1 ASA physical status classification and definitions

ASA PS classification	Definition	Notes
ASA I	A normal healthy patient	Healthy, non-smoking, no or minimal alcohol use
ASA II	A patient with mild systemic disease	Mild diseases without substantive functional limitations
ASA III	A patient with severe systemic disease	Substantive functional limitations; one or more moderate to severe diseases
ASA IV	A patient with severe systemic disease that is a constant threat to life	Including but not limited to recent (<3 months) MI, CVA, TIA or CAD/stents, ongoing ischaemia, impaired ejection fraction, severe valvular disease, ESRD
ASA V	A moribund patient who is not expected to survive without the operation	Examples: AAA rupture, intracranial haemorrhage with mass effect, ischaemic bowel
ASA VI	A brain-dead patient for organ removal and organ donation	

[asa-physical-status-classification-system9](#)

“The addition of “E” denotes emergency surgery: (an emergency is defined as existing when delay in treatment would lead to significant increase in the threat to life or body part)

6 Airway Assessment and Plan

Airway assessment and management are a fundamental part of anaesthetic care and especially so in patients having major craniofacial reconstruction and cancer resection, with the focus on the shared airway, along with intubation and extubation planning. The airway anatomy can be grossly abnormal. A comprehensive history and, where available, documentation of previous airway interventions and surgery are required prior to the induction of anaesthesia. Careful physical examination and investigations should be performed for risk factors for a difficult airway. A difficult airway is defined as a clinical situation in which a trained anaesthetist experiences a range of the following events—difficulty with facemask ventilation, or in placing a supraglottic device in the upper airway, difficult laryngos-

attempts) or failed intubation. The difficult airway can vary from situation to situation and represents a complex interaction between patient factors, clinical setting and the anaesthetist's skills. Poor management of the airway is also the most significant cause of anaesthetic morbidity and mortality (anaesthesia-related deaths are very rare <1 in 50,000 mortalities, of which ~30% are attributable to loss of airway). Other adverse outcomes include, but are not limited to, cardiopulmonary arrest, hypoxic brain injury, oropharyngeal and airway trauma (including dental) and unnecessary surgical airways.

Evaluation of a patient's airway comprises careful history taking and reviewing previous airway interventions, physical examination and further investigations as required. The intention is to detect medical, surgical and anaesthetic factors, which may indicate or contribute to a difficult airway. Although certain risk factors may not be direct prognosticators of a difficult airway, there are recognised associations. A heightened awareness of potential problems allows for planning and preparation. A stepwise plan with a team structure allows for a controlled progression in the management of the airway and aims to reduce the likelihood of adverse outcomes.

6.1 Basics of Airway Assessment

6.1.1 History

A patient's history of interest can be divided into patient-related factors and pathology. The aetiology of the head and neck cancer is important as it relates to structures, invasion and relationship with airway structures. Previous head and neck surgery and subsequent radiotherapy can lead to distortion in normal anatomy and restriction in head and neck movement. Previous airway documentation and management (including tracheostomy) is vital information. Patient

factors include a history of snoring, which could underscore obstructive sleep apnoea (OSA), with its known associations with difficulty in most aspects of the airway and obesity, chronic diseases associated with difficult airway management or restriction in head and neck movement. Examples are diabetes mellitus, rheumatoid arthritis and ankylosing spondylitis. Previous cervical spine surgery can also cause limitations in neck movement. Temporomandibular joint dysfunction should be identified.

6.1.2 Physical Examination

Risk factors for difficult airway include facial hair or beard, micrognathia, state of dentition, obesity, increased neck circumference, airway anatomy relative to previous surgery, head and neck burns, radiotherapy to neck, restrictive scars, craniofacial syndromes (e.g. Pierre Robin, Treacher Collins, Goldenhar), some congenital syndromes (Down, Klippel Feil).

Evaluation and documentation of a patient's airway pre-anaesthesia include the following tests [10].

1. Inter-incisor distance or gap—This is an indicator of extent of mouth opening. A gap less than 3 cm correlates instrumentation.
2. Thyromental distance (Patil test)—This is performed by asking the patient to extend their head and neck as far as possible, and then measuring from the upper border of the thyroid cartilage to the tip of the jaw/chin (mentum). A normal distance is greater than 7 cm. A TMD distance of less than 6 cm is said to predict 75% of difficult laryngoscopies. The TMD ratio is calculated by taking into account the patient's height.
3. Assess for limitations to head and neck extension—To see if the traditional "sniffing the morning air" position is achievable. This involves cervical flexion and atlanto-occipital extension. Limitations of greater than 30% can
4. Grade of mandibular protrusion—Assessment of temporomandibular joint function and prognathic ability. The different grades are described below:
 - Grade A—able to protrude the lower incisors anterior to the upper incisors.
 - Grade B—able to protrude lower incisors but not beyond level of upper incisors.
 - Class C—cannot protrude lower incisors to the upper incisors.
 Classes B and C are associated with increased diffi-
5. The Modified Mallampati Classification (Fig. 1)

The original Mallampati classification consisted of 3 classes [11]. Samson et al. [12] described a modified 4 grade classification that is now widely used. The classifi-

cation is a simple scoring system that assesses the oral pharyngeal cavity size in relation to the size of the tongue and is used as an indicator of potentially difficult airway management. Assessment is made by asking the sitting patient, head in a neutral position, to open their mouth widely and protrude their tongue out as much as possible, without phonation. At eye level, the assessor then looks at the anatomical structures visible, which is then scored. Structures of specific interest are the hard and soft palates, the uvula and the faucial pillars. Limited movement including tongue protrusion could indicate adherence to underlying structures secondary to scarring, radiation or connective tissue disease. A higher Mallampati (III, IV) score is associated with difficult mask ventilation and higher intubation failure rates.

- Class I—the entire palatal arch and bilateral faucial pillars are visible down to their base.
- Class II—the upper part of the faucial pillars and most of the uvula are visible.
- Class III—only the hard and soft palates are visible.
- Class IV—only the hard palate is visible, and soft palate is not visible.

6. Cormack and Lehane classification [13]

The classification is broadly used to describe the laryngeal view achieved.

- Grade 1—full view of glottic aperture.
- Grade 2—only posterior commissure visible.
 - 2A Posterior vocal cords visible*
 - 2B Only arytenoids visible*

- Grade 3—only tip of epiglottis visible.
 - 3A Epiglottis visible and liftable*
 - 3B Epiglottis adherent to pharynx*
- Grade 4—no visible structures, only soft palate.

However, Cook* [14] suggests a new grading system modified from Cormack and Lehane where the laryngoscopic view is graded into EASY (grade 1, 2A), RESTRICTED (grade 2B, 3A) and DIFFICULT (3B, 4), where a DIFFICULT grade view has better practical value, and greater specificity and predictive value compared with a description of a Cormack and Lehane view 3 or 4 [15].

The laryngoscopic view is normally diligently documented on the anaesthetic chart, as well as airway equipment used and adjuncts required. Careful documentation conveys important information to the next anaesthetist upon review.

Unfortunately, there is no single simple test that predicts a difficult airway reliably. Using multiple tests may point to a greater likelihood for difficulties during airway management and therefore lead to a heightened awareness in the anaesthetist to prepare for a difficult airway management strategy. However, it is also important to realise that an unanticipated difficult airway can still occur despite the lack of red flags on assessment [16].

Further information may be required to guide planning [17]. This may include imaging for the degree of tumour intrusion into upper and lower airways, assessment for

taining a patent airway.

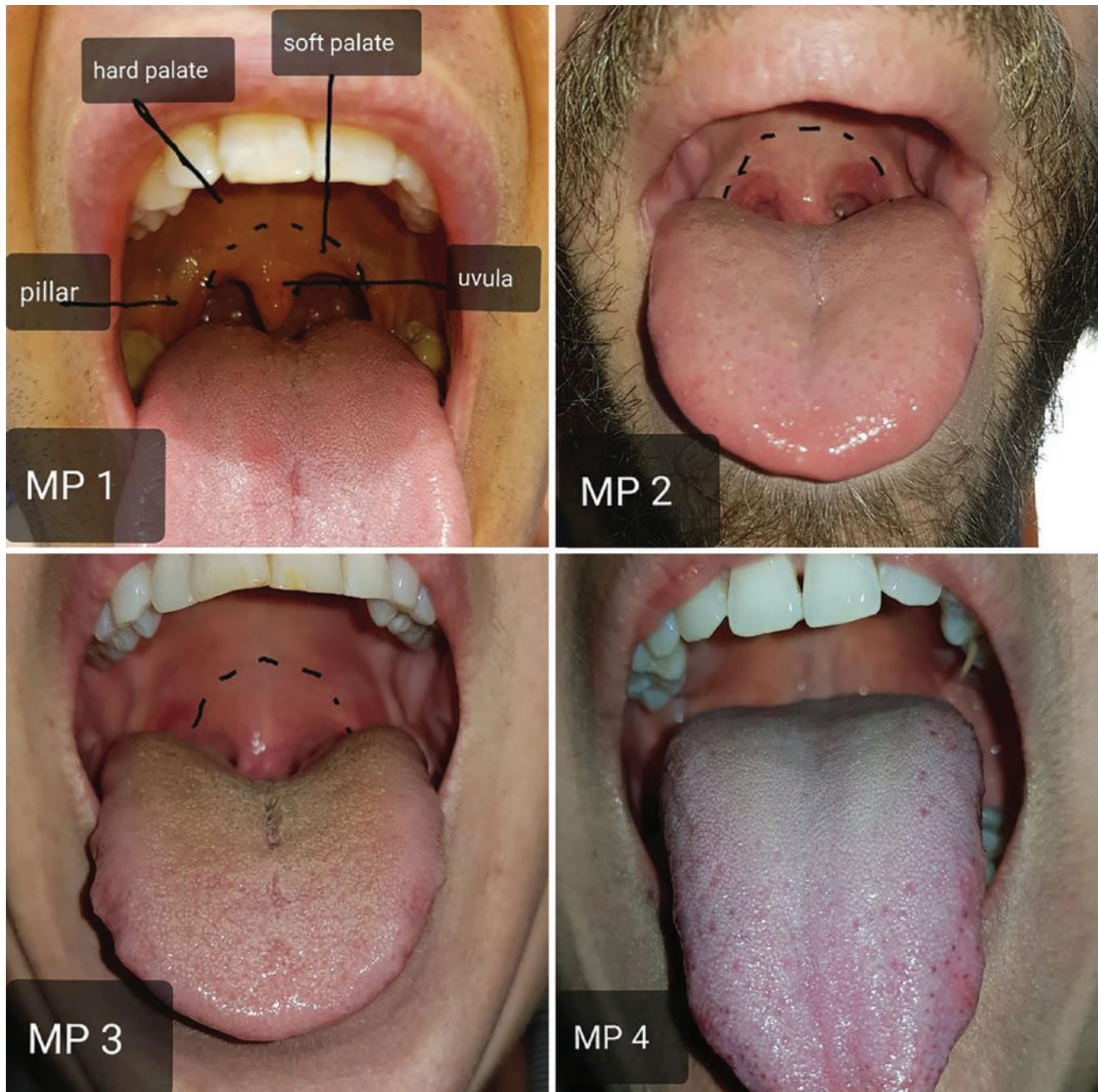


Fig. 1 Modified Mallampati classification views

7 Intraoperative Care

The type of anaesthesia required is specific to the surgical procedure. Generally, the purpose of anaesthesia is to provide the optimal environment for surgery to be performed safely. Most complex and extreme head and neck reconstruction will involve a general anaesthetic to provide amnesia/hypnosis, analgesia and paralysis.

7.1 Preoperative Considerations

Communication is vital between team members and individual specialties should not operate in silos. Choice of airway will depend on the type of surgery, surgical access required, duration and extent of the operation. There is always a risk of surgical complications including intraoperative bleeding and swelling that necessitates a change in strategy and postoperative care. Some of these issues can be identified preoperatively, where we have discussed optimising patients and perioperative care requirements in multidisciplinary meetings—for example difficult airway, maintaining normoglycaemia in diabetics and perioperative management of anticoagulants, all of which directly impact surgery due to wound healing and perioperative bleeding. Other aspects of care can only be decided intraoperatively due to changes in conditions, which can be

unexpected. Therefore, ongoing communication between the operating surgeon and anaesthetist is vital at the start of anaesthesia, during the procedure and in formulating a postoperative plan. The WHO surgical safety checklist has been developed with the aim of promoting patient safety (Fig. 2) [18]. It is used as an aide-memoire to prompt verbalisation of potential safety issues to be shared by the entire operating team (and for postoperative handover). The checklist is divided into periods—before induction of anaesthesia, before “knife to skin” and before leaving theatre (“sign out”). Some institutions have modified the template checklist to fit local practice, but in essence, the checklist is to increase communication and teamwork in surgery, and decrease the incidence of adverse events and errors.

Some institutions have also introduced a “team brief” at the start of an operating list where the operating team meet for a rundown of the workload for the day, check that all the required equipment is available, talk about potential complications and communicate expectations. This is a good time to discuss airway requirements and surgical access to the operating field. Individualised care can also be discussed including antibiotics and chemical or mechanical thromboprophylaxis postoperatively. Specific patient-related medical concerns can also be flagged. Thus, team briefings allow for prospective planning for expected events, and preparation for known anticipated complications.

Surgical Safety Checklist



World Health
Organization

Patient Safety

A World Alliance for Safer Health Care

Before induction of anaesthesia	Before skin incision	Before patient leaves operating room
(with at least nurse and anaesthetist)	(with nurse, anaesthetist and surgeon)	(with nurse, anaesthetist and surgeon)
Has the patient confirmed his/her identity, site, procedure, and consent? ☐ Yes Is the site marked? ☐ Yes ☐ Not applicable Is the anaesthesia machine and medication check completed? ☐ Yes Is the pulse oximeter on the patient and functioning? ☐ Yes Does the patient have a: Known allergy? ☐ No ☐ Yes Difficult airway or aspiration risk? ☐ No ☐ yes, and equipment/assistance available Risk of >500ml blood loss (7ml/kg in children)? ☐ No ☐ yes, and two IVs/central access and fluids planned	☐ Confirm all team members have introduced themselves by name and role. ☐ Confirm the patient's name, procedure, and where the incision will be made. Has antibiotic prophylaxis been given within the last 60 minutes? ☐ Yes ☐ Not applicable Anticipated Critical Events To Surgeon: ☐ What are the critical or non-routine steps? ☐ How long will the case take? ☐ What is the anticipated blood loss? To Anaesthetist: ☐ Are there any patient-specific concerns? To Nursing Team: ☐ Has sterility (including indicator results) been confirmed? ☐ Are there equipment issues or any concerns? Is essential imaging displayed? ☐ Yes ☐ Not applicable	Nurse Verbally Confirms: ☐ The name of the procedure ☐ Completion of instrument, sponge and needle counts ☐ Specimen labelling (read specimen labels aloud, including patient name) ☐ Whether there are any equipment problems to be addressed To Surgeon, Anaesthetist and Nurse: ☐ What are the key concerns for recovery and management of this patient?

This checklist is not intended to be comprehensive. Additions and modifications to fill local practice are encouraged.

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8 Airway Management and Airway Equipment

Airway management, these days, is synonymous with the anaesthetist. However, modern airway equipment has its origins in surgery, especially in head and neck surgery. The first elective endotracheal intubation was performed in 1878 by the Scottish surgeon, William Macewen for the resection of an oral tumour. In 1885, O'Dwyer, an American paediatrician and obstetrician, developed the first metal endotracheal tubes. Americans, Guedel and Waters attached an inflatable cuff to the endotracheal tubes to provide a better seal in the trachea. Insufflation of the lung in animals by Meltzer and Auer in Germany was trialled in 1909, and this technique was then brought to the UK by Kelly and applied in humans. During World War I at the Queen's Hospital in Sidcup, Kent, anaesthetists Sir Ivan Magill (1888–1986) and Stanley Rowbotham used endotracheal tubes for reconstructive surgeries on injured soldiers (especially facial and jaw injuries), enabling more successful surgery (and decreased mortality) by securing and thus protecting the airway. Magill also invented the technique for nasal intubations using the “red rubber tube” and pioneered numbing the airway with cocaine to prevent coughing and spasm. David S. Sheridan, an American inventor, is credited with creating the first disposable endotracheal tube, where its use has superseded the reusable red rubber tube thus limiting the risk of cross-infection. With the use of muscle relaxants, airway management evolved from slow inhalational inductions to rapid intravenous inductions, induced apnoea and paralysis, securing the airway via intubation and commencement of positive pressure ventilation.

Another important piece of airway equipment is the laryn-

Albert Kerstein, after building on a long history of indirect methods of viewing the glottis through reflective mirrors or intubation via “blind” techniques. German laryngologist, Gustav Killian and Philadelphian, Chevalier Jackson, pioneered and improved on using hollow tubes for illumination and setting the foundation for bronchoscopes and gastroscopes. Jackson designed the first laryngoscope that was further modified by Magill, Macintosh and Miller. Henry Harrington Janeway (New York 1912) attached a battery-powered light source to the blade and made it portable. Many of these names are immortalised in modern-day anaesthetic equipment, including Magill's forceps that are still used today for nasotracheal intubations. The curved Macintosh blade (introduced by Sir Robert Macintosh in 1943), known as “the Mac”, is the most commonly used laryngoscope blade in the Western world. The most recent significant breakthrough in airway equipment occurred in 1966 when Shigeto Ikeda

duced it into medical practice in 1968 [19].

The modern airway team in its simplest form comprises a trained anaesthetist and an assistant (technician, anaesthetic nurse or operating department practitioner depending where one works in the world). But teams can also be much larger with a team leader overseeing a team of anaesthetists and assistants with different roles as there is recognition that complex airway management can be heavily task-loaded. Surgeons with tracheostomy skills can also be part of the airway team, including specialty laryngologists, plastic surgeons and maxillofacial surgeons.

Generally, the options for an airway for general anaesthesia are either an appropriately sized supraglottic airway or a secured airway with a cuffed endotracheal tube (either oral or nasal depending on surgical access required)—placed tra-

(MAC) blade. There are also other blades like straight blades, and the McCoy blade that has a flexible moveable tip seg-

blades although there are more on the market for specific uses and too many to describe (Figs. 3, 4, and 5).

For the anticipated difficult airway, preparation is key! Additional airway equipment should be available and preferably stored in a portable storage unit and readily accessible. Various devices have been invented for rescue in difficult or failed intubations, for example the intubating laryngeal mask airway (iLMA) with accompanying endotracheal tube, or variations on the concept of railroading an endotracheal tube over a guide (bougie, Aintree intubating catheter, Cook exchange catheter or fibre-optic scope) through a supraglottic airway used as a conduit. Then, the first video laryngoscope (GlideScope), designed by Dr. John Pacey, became commercially available in 2001. Since then, the video laryngoscope has become a part of regular and routine use in anaesthesia, emergency departments and by senior paramedics out in the field. Its use has been incorporated into the Difficult Airway Society (DAS) UK guidelines in its recent 2015 version. A video laryngoscope is now an essential part of the increasing arsenal of airway equipment. Portable versions are available.

However, the original GlideScope incorporated 2 new technologies—video and a hyper-angulated blade. It is important to realise that not all video laryngoscopes are built in the same way, and there is a learning curve with the different brands in the market. Some brands come with an additional hyper-angulated blade along with the standard blade. It is best to familiarise yourself with a chosen brand, rather than to have a range of video laryngoscopes, including

essarily extrapolate well into success for patients with abnormal anatomy (Figs. 6, 7, 8, 9, 10, and 11) [21].

In some cases of craniofacial and neck cancer surgery, the airway may need to be secured before the induction of gen-

eral anaesthesia. Maintaining oxygenation and spontaneous ventilation until the airway is sited is fundamental to prevent the catastrophic and uncontrolled loss of airway. The gold standard remains an awake fibre-optic intubation. This is a technique that requires good preparation, adequate local topicalisation of the airway with local anaesthetic (with or without sedation) pre-procedure, the slick use of a fibre-optic scope and, more importantly, a cooperative and compliant patient [22]. Other options include the use of rigid fibre-scopes and transtracheal jet ventilation (Fig. 12).

Maintaining oxygenation is another fundamental component of airway management. Techniques that prolong the apnoeic window allow the luxury of time and control during airway instrumentation—maintaining arterial oxygen content and preventing desaturation during the apnoeic period. This is traditionally done with pre-oxygenation with 100% oxygen via a well-sealed facemask in an awake, spontaneously ventilating patient prior to induction of general anaesthesia. More recently, trans-nasal high flow rapid insufflation ventilator exchange (THRIVE) has been used in some units to achieve this effect. Oxygen is delivered through a nasal high flow oxygen delivery system, which can deliver flow rates of warm and humidified oxygen of up to 70 L/min, and has been shown to increase apnoea time in head and neck patients by an average of 17 min. This “buys” time for controlled and gentle airway management and a safety buffer as one progresses down the difficult airway algorithm [23, 24].

Other methods include a surgical airway, performed by an ear nose and throat (otolaryngologist) specialist and submen-

tal intubation, which has also been well described in the literature [25, 26]. The editors believe that all surgeons operating in the head and neck field (including plastic surgeons, general surgeons and maxillofacial surgeons) should be trained and skilled in performing both emergency and elective tracheostomy.

A safe and complete airway plan has clear points in the plan to declare a “pause and think”. It is important at these points to consider the safest course, including waking the patient and revising the airway plan, re-evaluating skill sets and equipment for another day. The greater the number of attempts and instrumentation, the worse the visualisation can become due to trauma, bleeding, swelling and potential airway soiling. Emergency “front of neck access” or cricothyroidotomy remains plan D, and there is a greater emphasis on plan C, which is PAUSE and THINK in an unanticipated difficult airway. The safest course is to wake the patient. There are various kits on the market and methods described for performing a cricothyroidotomy or a needle/jet ventilation technique. In the end, these are rescue techniques to maintain oxygenation temporarily until a definitive and secured airway can be achieved. Once the airway is secured, the placement of the endotracheal tube in the trachea should be confirmed with capnography or end-tidal carbon dioxide monitoring.

Below is the Difficult Airway Society (DAS) UK guidelines

lines for managing the unanticipated difficult airway (Figs. 13 and 14) [27, 28].

Fig. 3 Range of supraglottic airways



Fig. 4 Profile of IGEL (supraglottic airway)

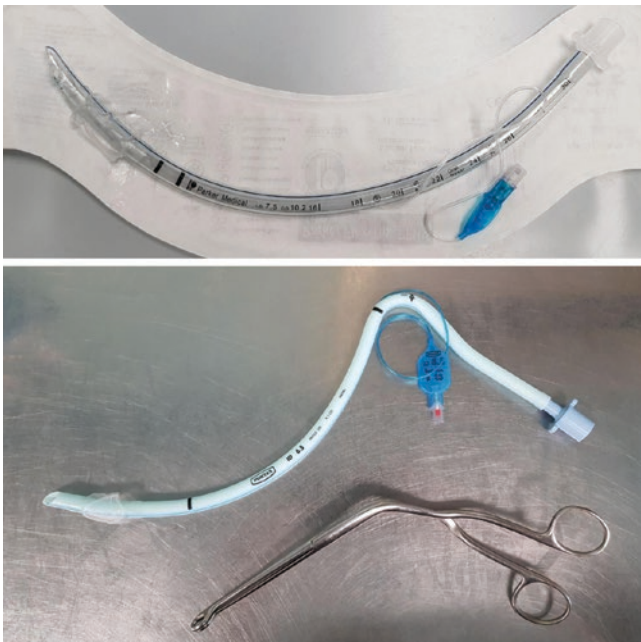


Fig. 5 Oral cuffed endotracheal tube, cuffed nasopharyngeal tube with Magill's forceps



Fig. 6 GlideScope



Fig. 8 Comparison between GlideScope hyper-angulated blade and standard Macintosh



Fig. 7 GlideScope blade

Fig. 9 GlideScope laryngeal views

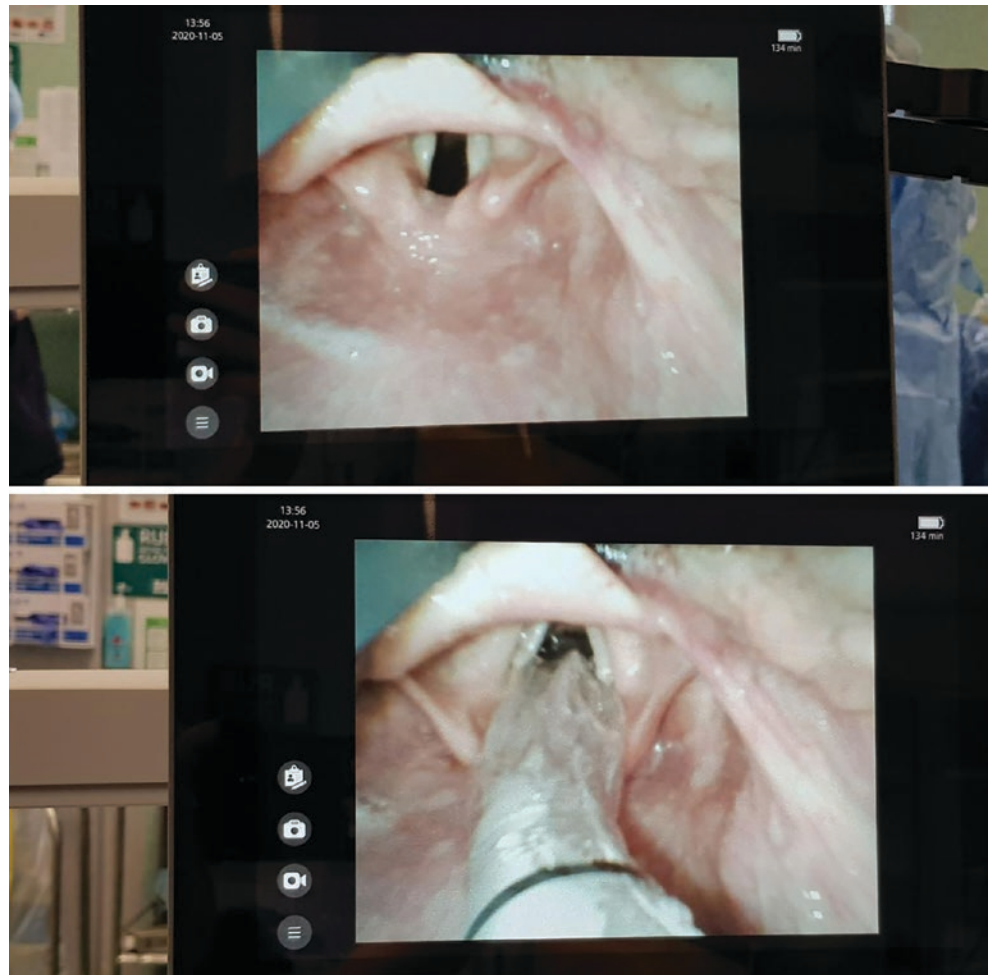


Fig. 10 An example of a portable video laryngoscope



Fig. 11 Handheld video laryngoscope



Fig. 12 Fibre-optic scope with viewing screen

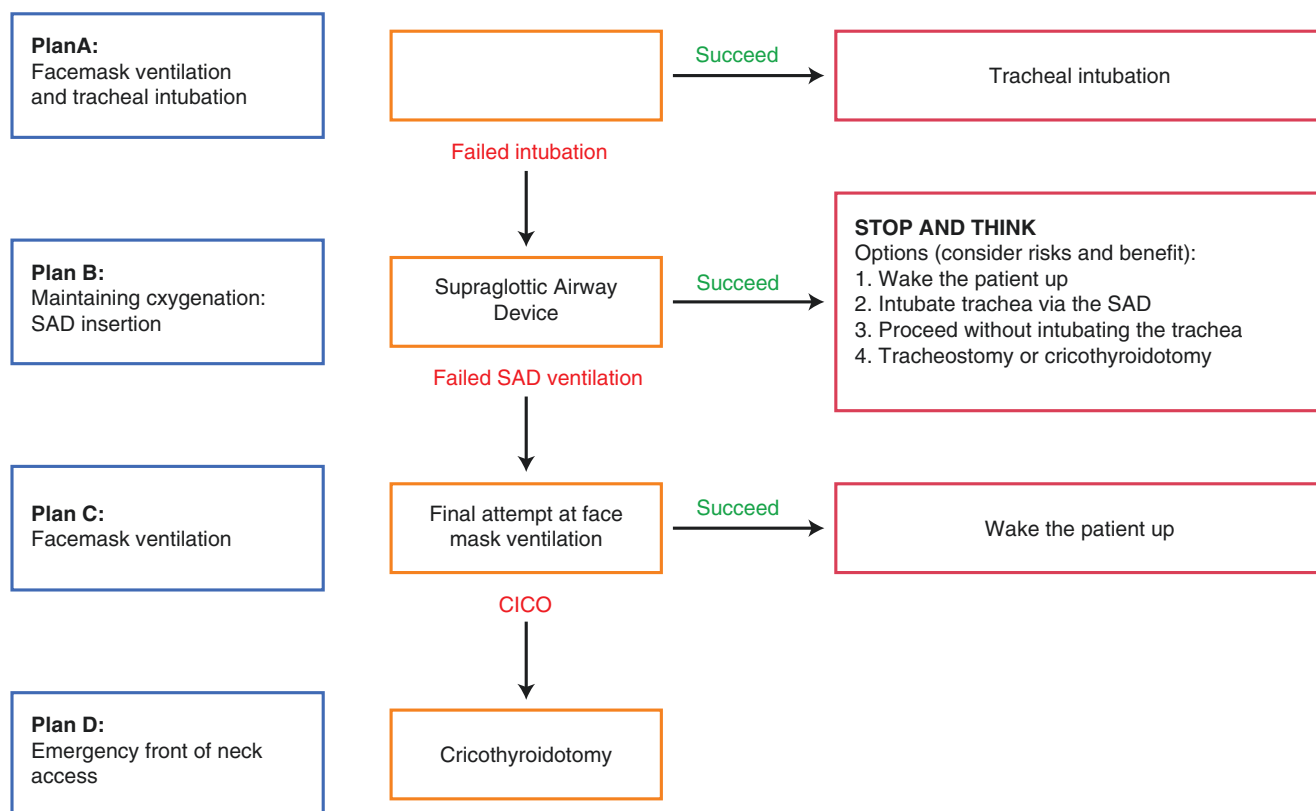


Fig. 13 Difficult Airway Society (DAS), difficult intubation guideline overview



Fig. 14 Difficult intubation trolley with Plan A, B, C and D labelled drawers

9 Intraoperative Monitoring

General anaesthesia can be achieved either intravenously or via inhalation of volatiles. After securing the airway, anaesthesia can be maintained with either technique. The choice is individualised to each patient, aiming to minimise side effects and a rapid and complete emergence at the end of surgery if immediate postoperative extubation is part of the plan. Common side effects of general anaesthesia include postoperative nausea and vomiting, sedation/tiredness, hypotension, headaches and dizziness. Side effects can be dose-dependent (i.e. greater risk with longer anaesthetics and surgery due to increased overall dosage).

Intraoperative monitoring will depend on multiple factors. In Australia and New Zealand, this is guided by the College of Anaesthetists for Australia and New Zealand (ANZCA). All patients having either general anaesthesia or sedation have basic monitoring consisting of ECG (modified 3 lead), noninvasive blood pressure measurement and pulse oximetry to monitor oxygen saturations. Further monitoring is dependent on the type and complexity of surgery and duration of surgery. As discussed above, once the airway is secured, end-tidal carbon dioxide monitoring (ETCO₂) is part of the respiratory monitoring. This has become a necessity as it highlights inadvertent oesophageal intubations, which if not rectified leads to patient morbidity and mortality. ETCO₂ fluctuations can also be a useful surrogate for cardiac output, and the shape of the capnograph can provide useful information about ventilation and lung compliance.

Aims of anaesthesia care include fluid management and managing blood loss as well as maintaining normothermia, thromboprophylaxis and pressure area care. Additional monitoring equipment may be needed to reflect this. However, many head and neck resections and free tissue transfers will not be associated with significant bleeding. Hypotensive conditions ("permissive hypotension") may minimise blood loss and improve the surgical field. For more "beat to beat" and more invasive haemodynamic monitoring, an arterial line can be placed in an artery of choice (usually radial, but also brachial, axillary and dorsalis pedis has been used) and is also useful for repeated blood sampling and blood tests. For surgeries involving large fluid shifts, the arterial line can be married with cardiac output monitors that help guide fluid and blood management, as well as determine if cardiac support is needed. Indwelling urinary catheters are useful, for monitoring fluid balance and preventing urinary retention. Temperature probes are sited in order to monitor temperature, and the patient is kept warm using commercially available warming devices. Maintaining normothermia is vital for patient comfort and reduces shivering, and there is increasing evidence that it

decreases surgical site infections, decreases metabolic stress, postoperative complications and reduces the risk of developing coagulopathy.

Depth of general anaesthesia (DGA) monitoring has become a part of modern anaesthesia with BIS (Bispectral Index Monitor) first introduced in 1992 and approved by the FDA for measuring the depth of hypnosis in 1996. Other devices followed (Narcotrend, auditory evoked potentials (AEPs), entropy, Massimo, SedLine, etc.). The premise of these devices is that EEG signals are measured via a soft sensor on the forehead, and EEG fluctuations are processed and integrated with custom hardware and software to produce a dimensionless number on the scale from 0 to 100—where 100 is an awake patient, and 0—where the EEG is isoelectric. With BIS, depth of anaesthesia is aimed between 40 and 60 to prevent awareness and implicit recall. The risk of awareness decreases with a BIS reading of less than 60, and a number less than 40 being a state of deep hypnosis and may be associated with cardiovascular and haemodynamic instability. Different monitors will have different reference ranges. DGA monitoring allows some guidance for the adjustment of depth of anaesthesia due to changes in requirements (hypnosis vs surgical or painful stimulus), aiming to reduce both overdosage and underdosage of anaesthesia. However, DGA monitoring should only be another indicator with other signs like physiological responses and movement. The sensor placement may interfere with surgical site access, especially in head and neck surgery, and therefore not be able to be used. The monitors cannot be solely relied on due to the effects of artefacts and EMG activity on the "number", and the effects of analgesia and other drug adjuncts, which may be additive or synergistic but not reflect hypnosis and thus not impact on the reading. The use of ketamine and nitrous oxide also impacts the BIS number. Overall, DGA monitoring is not recommended as compulsory monitoring for all general anaesthetics, but can be considered on an individual basis, and can be associated with a reduction in awareness with recall in adults during general anaesthesia and sedation. The use of DGA monitoring has a role in total intravenous anaesthesia with muscle relaxant due to range of individual effects at differing concentrations of propofol [29]. Increasingly, anaesthetists are encouraged to be able to interpret the accompanying EEG (Fig. 15).

We should mention the increasing use of the Fisher and Paykel Optiflow Thrive which is an oxygen delivery device that delivers high flow humidified oxygen nasally. This is managed by the anaesthetic team to maintain safe oxygenation, prevent oxygen desaturation and may allow the safe extension of apnoea times during periods of non-ventilation.

Mechanical and chemical thromboprophylaxis (subcutaneous low molecular weight heparin) and new oral anticoagulants (NOACs) like dabigatran and rivaroxaban are

options in the perioperative period. Mechanical thromboprophylaxis is commonly used intraoperatively, especially in long operations, and may be continued postoperatively if the patient remains bed-bound. The use of LMWH and other anticoagulants needs to be decided in conjunction with the surgeon, along with the timing of dosage post-surgery. Chemical thromboprophylaxis postoperatively will depend on the risk of postoperative bleeding and concerns about surgical haemostasis. The use of LMWH will be guided by the surgeon and risk assessed individually for each patient. Prolonged immobility, obesity, a previous history of deep vein thrombosis, pulmonary embolism or inherited coagulopathies, pregnancy, current use of the oral contraceptive pill and cancer are risk factors for the development of postoperative thrombotic events. During long

surgery, pressure area checks and cares are also conducted on a regular basis to prevent pressure ulcers and nerve impingement. Patient positioning during surgery is important.

10 Commonly Used Drugs in General Anaesthesia

Note: all drugs have side effects, and there is always the potential for drug interactions with others [30].

10.1 Intravenous Vs Inhalational Anaesthetics (Table 2)

Table 2 Intravenous vs inhalational anaesthetics

Intravenous agents	
Propofol	A phenol derivative, used for intravenous induction and maintenance of anaesthesia. Produces a smooth, rapid induction, with suppression of laryngeal reflexes and a rapid and clear-headed recovery. Also used for sedation in intensive care and short procedures
Thiopentone	Thiobarbiturate, used for hypnosis, as an induction agent, and as an anticonvulsant
Ketamine	Phencyclidine derivative. Used for intravenous induction of anaesthesia, especially in high-risk hypovolaemic/septic/hypotensive patients, or in situations to where airway reflexes need to be preserved. Very effective analgesia in acute and chronic pain due to its antagonistic effects at the NMDA receptor
Etomidate	Used for its relative cardiovascular stability; however, some recent data have highlighted safety of use on patients with risk of adrenal insufficiency, although there is no conclusive evidence that anaesthetic doses contribute to morbidity or mortality
Inhalational agents	
Sevoflurane, desflurane (others: Halothane, isoflurane, enflurane)	Fluorinated isopropyl methyl ether (volatiles) used for inhalational induction and maintenance of anaesthesia, with desflurane having a better profile for rapid emergence postoperatively due to its low lipid solubility

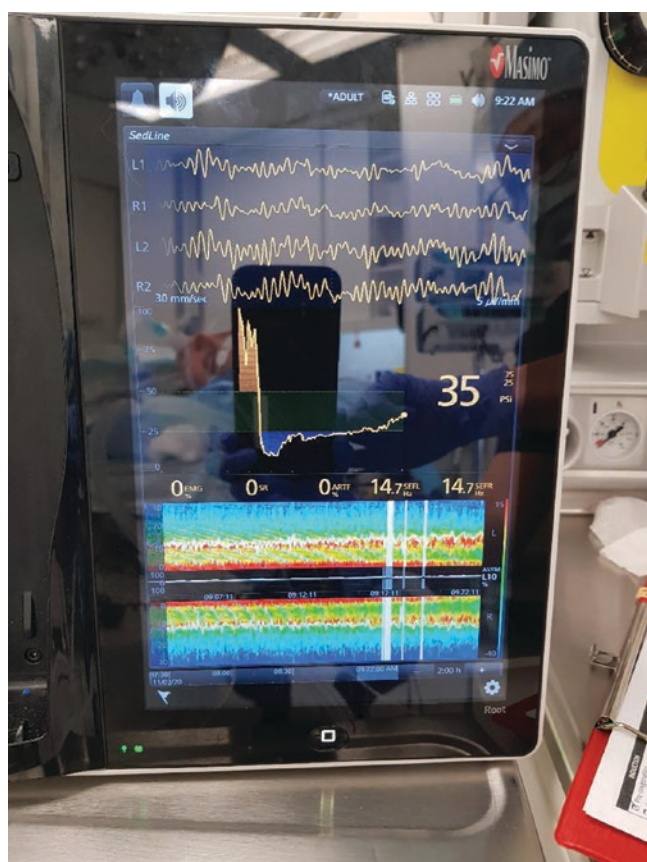


Fig. 15 Massimo SedLine DGA monitor

10.2 Analgesia and Co-analgesia

At the core of intraoperative analgesia is the use of opioids. Different opioids will have different pharmacological profiles that make it suited for a variety of operations depending on duration and degree of noxious stimulation, and expected ongoing pain postoperatively. Opioids range from very short-acting to long-acting. A summary of commonly utilised opioids is listed in the table below.

Natural opioids—morphine, codeine

Semi-synthetic opioids—diamorphine (heroin), hydromorphone, oxycodone, buprenorphine.

Fully synthetic opioids—fentanyl, pethidine, methadone, tramadol, tapentadol.

However, opioids have known side effects and have the potential for opioid-induced hyperalgesia. Common opioid side effects are nausea, vomiting, constipation, ileus, pruritus, urinary retention, sedation and risk of respiratory depression. New techniques have also focused on a multimodal approach to analgesia—regional blocks, neuroaxial blockade, local infiltration, polypharmacy with co-analgesics, pre-emptive analgesia and generally more opioid-sparing techniques, working towards a potential future goal of opioid-free anaesthesia (Table 3).

Table 3 Opioids

Short-acting opioids	
Fentanyl	Highly potent synthetic phenylpiperidine derivative. Highly selective mu-agonist. Provides pain relief for moderate to severe pain, but shorter-acting. Potent respiratory depressant
Alfentanil	Synthetic phenylpiperidine derivative used to provide short-acting analgesia during general anaesthesia. Rapid onset of action with peak effect within 90 s of intravenous administration, with a very short duration of effect (5–10 min)
Remifentanyl	A synthetic phenylpiperidine derivative of fentanyl, only available in intravenous form. Used to provide the analgesic component during general anaesthesia, and also for procedural sedation including awake fibre-optic intubations. It is metabolised rapidly by non-specific tissue and plasma esterases with a fixed context-sensitive half-life of 3–5 min so offset can be reliably depended upon once the infusion is stopped. Reduces volatile and propofol requirement during general anaesthesia when used as a co-agent
Long-acting opioids	
Morphine	A phenanthrene derivative, used as an analgesic for moderate to strong pain. Morphine and active metabolites are secreted via the kidneys, and care needs to be taken in renal impairment
Oxycodone	Semi-synthetic opium alkaloid derivative for moderate to strong pain. Oral formulations of oxycodone have better orally absorbed, have a faster onset of action, better oral bioavailability and longer duration of action compared with morphine. Majority is metabolised in liver, therefore not dependent on renal clearance
Pethidine	Synthetic opioid that acts as an agonist on mu- and kappa-opioid receptors. It is 1/10th the potency of morphine. Its active metabolite, norpethidine, can accumulate and cause neuroexcitatory effects—ranging from agitation, myoclonus to seizures. Low doses are commonly used to treat postoperative shivering in PACU
Hydromorphone	Derivative of morphine, with a potency 5 times of morphine. Strong opioid analgesia with slightly better analgesic effects with similar side effect profile at equipotent doses. Like pethidine, metabolites can accumulate in renal failure and cause neurotoxic effects
Partial opioid agonists	
Buprenorphine	Partial opioid agonist is used as analgesia for moderate to severe pain. It is also used for sequential analgesia, with a longer latency period and duration of action compared with morphine due to high receptor affinity and slow receptor disassociation. It is less likely to cause dependence or respiratory depression compared with pure mu-agonists, but effects of large doses of naloxone may not completely reverse its effects. Buprenorphine can also antagonise the effects of morphine and other opioid agonists
Co-analgesia	
Tramadol	Synthetic opioid. Comprises of a racemic mixture of 2 tramadol enantiomers. It is a non-selective agonist at mu-, kappa- and delta-opioid receptors, as well as inhibits noradrenaline reuptake and enhances serotonin release centrally. It can also be used to treat postoperative shivering and has been shown to be effective for neuropathic pain [31]

(continued)

Table 3 (continued)

Codeine and dihydrocodeine	Naturally occurring phenanthrene alkaloid that is a methylated morphine derivative. It is a weak opioid and has very low affinity for opioid receptors. 10% of drug is metabolised to morphine. It is used to treat mild to moderate pain and has antitussive effects. Effects can also be dependent on individual genetic variability in CYP2D6 enzyme with “fast metabolisers” producing more morphine, and increased risk of respiratory depression has been described Dihydrocodeine is a semi-synthetic derivative of codeine with twice the potency of codeine and 1/6th the potency of morphine
Paracetamol	Simple analgesic and antipyretic, usually given as premedication
Non-steroidal anti-inflammatory drugs (NSAIDs)	Non-selective NSAIDs—e.g. ibuprofen, diclofenac, naproxen, tenoxicam, ketorolac—spectrum of analgesic, anti-inflammatory and anti-pyrexial effects, and act as reversible cyclooxygenase (COX) enzyme inhibitors Coxibs (COX II inhibitors)—etoricoxib, celecoxib, parecoxib (intravenous form)—have been developed to selectively inhibit COX II, with the aim to decrease side effects and complications due to the inhibition of prostaglandins on the protective effects of gastric mucosa, bronchodilation and platelet function Both are effective analgesics in acute postoperative pain and are an integral part of multimodal analgesia. Combination of paracetamol and NSAIDs has been proven to be more effective pain relief than either drug alone [32]
Gabapentinoids	Gabapentin—an acetic acid derivative that is a structural GABA analogue, but acts by binding to voltage-gated calcium also enhances the analgesic effect (and potential side effects) of other opioids Pregabalin—has better oral absorption and bioavailability greater potency and theoretically less side effects compared with gabapentin
Clonidine and dexmedetomidine	Acts by stimulating presynaptic alpha2 receptors and acts as an antihypertensive, analgesic, sedative and anxiolytic
Tricyclic antidepressants (TCAs)	Antidepressant, sedation and first-line therapy in the treatment of neuropathic pain
Lignocaine	Local anaesthetic works by diffusing through neural sheaths and axonal membrane to the inner surface of the sodium decreases Na ⁺ conductance and prevents cell membrane depolarisation Lignocaine can also be used systemically with evidence that perioperative infusions (in a wide range of doses) can have an opioid-sparing effect, reduce pain scores and decrease incidence of postoperative ileus [33]. Its membrane-stabilising effect has been used in the treatment of chronic neuropathic pain and peripheral nerve trauma

11 Local Anaesthetics (Tables 4, 5, and 6)

Used topically, local infiltration, as an agent for regional and neuroaxial blockade.

Classification:

Ester LA—benzocaine, cocaine, tetracaine.

Amide LA—Lignocaine, prilocaine, ropivacaine, bupivacaine.

Signs of local anaesthetic systemic toxicity (LAST) can involve the central nervous system (CNS), with initial excitation followed by depression (lightheadedness, dizziness, tinnitus, perioral numbness or tingling, agitation, auditory and visual hallucinations and seizures followed by drowsiness and coma), on the cardiovascular system (decreased peripheral vascular resistance and depressed cardiac contractility, leading to hypotension, malignant arrhythmias and cardiovascular collapse).

Recognition is important. Stop infusion, declare an emergency, start resuscitation procedures and symptom management.

Treatment: Lipid emulsion therapy (intralipid) is used in the treatment of local anaesthetic toxicity. The mechanism of action of the lipid emulsion may be due to the partitioning of local anaesthetic within the emulsion itself (acting as a “lipid sink”), mitochondrial enhancement in the myocardium and/or a direct inotropic effect. Dose of intralipid (20% emulsion) is an initial bolus of 1.5 mL/kg over 1 min and then an infusion of 15 mL/kg/h. Once stabilised, they are then transferred to a monitored environment.

Anti-emetics and the management of Postoperative Nausea and Vomiting (PONV).

The incidence of postoperative nausea is 50%, and the incidence of vomiting is 30%. Therefore, the prevention of PONV is important, especially in head and neck surgery where the act of retching and vomiting can cause straining and raise head and neck pressures, as well as the risk of aspiration. Risk factors for PONV are female gender, a history of PONV or motion sickness, non-smoker, certain types of surgery (bariatric, laparoscopic and gynaecological procedures) and anaesthetic factors such as the use of volatiles, nitrous oxide and long-acting opioids. Ensure adequate hydration to help minimise PONV.

For patients who are deemed high risk of PONV, a combination of (at least 2) anti-emetics is advocated. Prophylactic use of a 5HT₃ (serotonin) receptor antagonist and dexamethasone is associated with less need for rescue anti-emetics compared with single-agent use [36].

Table 4 Local Anaesthetics

LA	Onset of action (min)	Duration of action (min)	Max dose (mg/kg)
Lignocaine	5	60–90 (intermediate)	3
Lignocaine + adrenaline	5	120–360	7
Prilocaine	5	60–120	6
Bupivacaine, levobupivacaine	10–15	200+ (long)	2
Ropivacaine—benefit of intrinsic vasoconstrictor activity, less cardiotoxic and less motor blockade compared with bupivacaine	5–15	200+	3

Duration of effective analgesia depends on type, volume and concentration of injected local anaesthetic

Table 5 Options for post-op nausea and vomiting (PONV)

Type	Example	Comments
5-HT ₃ receptor antagonists	Ondansetron Granisetron Tropisetron	
Neurokinin(NK) 1 receptor antagonists	Aprepitant	More efficacious than ondansetron, shown to be effective in reducing incidence of vomiting rather than nausea
Corticosteroids	Dexamethasone	Early dosing as takes longer to take effect. Also has opioid-sparing and anti-inflammatory effects. Can be added to regional nerve blocks to prolong duration of action of LA
Antidopaminergics	Amisulpride Droperidol Metoclopramide Prochlorperazine	
Antihistamine	Cyclizine Diphenhydramine Promethazine	Diphenhydramine (unclear efficacy) Promethazine (risk of extravasation, therefore better given intramuscularly)
Anticholinergics	Hyoscine	Can be given transdermally (scopoderm patch)

Table 6 Other commonly used medications

Tranexamic acid (antifibrinolytics)	Synthetic lysine analogue that acts as a competitive inhibitor of plasminogen activation, preventing the dissolution of established thrombi. Its antifibrinolytic activity is utilised in elective orthopaedic and cardiac surgery where it may decrease intraoperative blood loss. It has been shown to decrease risk of death in trauma if given early [34] and it is increasingly used in aesthetic facial surgery, but evidence remains sparse. However, there is evidence that systemic TXA leads to decreased blood loss during rhinoplasty [35]
Midazolam	Water-soluble imidazobenzodiazepine used commonly as a premedication for anxiolysis, and as a co-induction agent for general anaesthesia. Also used for sedation. Effects can be reversed with flumazenil
Antibiotics	Suitable prophylactic antibiotics are chosen to prevent surgical site infection. For head and neck surgery, a suitable antibiotic choice would be a broad-spectrum bactericidal antibiotic with gGram-positive cover like cephazolin (a first-generation cephalosporin). If allergic to penicillin, options include macrolides or vancomycin, but guidelines are usually driven by the guidance of local institution infectious disease specialists
Muscle relaxants	Depolarising neuromuscular blocker (suxamethonium)—short-acting Competitive non-depolarising neuromuscular blockade (variable duration of action—mivacurium, atracurium, rocuronium, vecuronium, pancuronium) causes paralysis and is used to facilitate intubation and ventilation
Reversal agents	Neostigmine is a cholinesterase inhibitor and allows the accumulation of acetylcholine in the neuromuscular junction which then competitively antagonises any residual non-depolarising muscle relaxant present. Neostigmine's side effects Sugammadex was first approved for use in the EU in 2008, but took until December 2015 for full FDA approval for use in the USA. Used for reversal of aminosteroid muscle relaxants (rocuronium and vecuronium). It acts by encapsulating the steroid portion of the aminosteroid molecule, thus decreasing the amount of free drug available for effect
Vasopressors	Phenylephrine, metaraminol, ephedrine. Nnoradrenaline (requires central venous access)

12 Postoperative Management

After successful airway management and surgery, considerations for a safe extubation are vital. The WHO checklist has a “sign out” section where surgery is acknowledged as completed to plan (or otherwise) and any concerns for handover to the next team, be it in the PACU or intensive care. This provokes discussion at the end of surgery between surgeon, anaesthetist and nursing team and adoption of an agreed strategy. This could be either the patient being extubated immediately at the end of surgery, or the patient having a period of prolonged ventilation in intensive care until surgical swelling and airway oedema have resolved. The need for advanced airway protection is to avoid airway obstruction due to haemorrhage and other surgical complications affecting the airway. There should be consideration for the clinical factors that may produce the scenario of the “failed” extubation, where the patient may need reintubation due to the inability to maintain adequate oxygenation and ventilation post-extubation. Placement in higher-level care, for example intensive care units, allows for smaller nurse–patient ratios, close haemodynamic monitoring and careful fluid management and allows for early detection and treatment of the deteriorating patient, thus preventing complications like haemodynamic perturbations, cardiac ischaemia/infarcts and acute kidney injury from hypovolaemia/blood loss or a catastrophic loss of airway. Neck haematoma, flap vascular insufficiency (venous or arterial), fistulas and loss of airway are common reasons for returning to theatre. If the patient remains intubated and ventilated, care remains the responsibility of anaesthetist (or an intensivist with airway training), even if handed over to another team. Proximity to an operating theatre and an on-call team with skills and training is needed, and an institution’s postoperative facilities will dictate the best and safest environment for a patient’s care.

Other aims are to treat anaemia, maintain perfusion pressure, keep the patient normothermic and comfortable, maintain blood glucose within a normal range and prevent postoperative nausea and vomiting.

In the aftermath, airway events need to be discussed with the patient, and documentation is of utmost importance for future care. Patients should be informed of events and have an airway letter describing the airway difficulties and the various airway management techniques used. They can also apply for a medical alert bracelet or tag to keep on their person in case of emergencies. Copies of the airway alert should be forwarded to the patient’s general practitioner and relevant specialists, and it is imperative to be able to flag the airway alert in inter-hospital communications and medical records. Patients may also need follow-up for complications as a consequence of airway trauma.

13 Crisis Management

In the event of perioperative crisis and emergencies, the anaesthetist tends to fall into the lead role of managing the situation. The list of emergencies [but is by no means exhaustive, include cardiac arrest and malignant arrhythmias, anaphylaxis, local anaesthetic toxicity, massive haemorrhage, embolism (air, gas and clot), malignant hyperthermia and fires]. We have already discussed airway emergencies in the section about airway assessment and management and briefly mentioned management of local anaesthetic systemic toxicity (LAST).

We have not discussed management algorithms, as there are subtle variations in guidelines endorsed by collegial bodies in different countries (ANZCA, AAGBI, ASA, NZRC). These can be found on individual college websites and in local hospital protocols, of which all clinical staff should familiarise themselves. However, all are based on the principles of stopping the trigger, declaring an emergency and calling for help, resuscitation and adopting a team-based collaborative approach to treatment and supportive measures. Environments should also be well-designed with equipment and processes in place. There should be appropriate post-event facilities for ongoing monitoring; otherwise, transfer is required for ongoing care.

The ABCD acronym:

A—Airway—secure an airway.

B—Breathing, oxygenate and ventilate with 100% oxygen.

C—Circulation, support circulation including cardiopulmonary resuscitation.

D—Drugs—specific drugs for certain conditions—adrenaline in anaphylaxis and cardiac arrest, dantrolene for malignant hyperthermia, lipid emulsion in treatment of local anaesthetic toxicity.

E—Exposure, electrolytes—seek and correct causes.

A good quality crisis management response relies on good leadership, communication and teamwork. These skills may not be inherent in every person and therefore have to be learned and practised. For every crisis, the first thing is to verbalise the crisis clearly to the rest of the team and declare an emergency. Call for help as crisis management is resource and task heavy, and can be cognitively overwhelming. Identify a team leader who remains hands-off and maintains a helicoptering view. The team leader also needs to mobilise the team, delegate duties to specific team members and coordinate the response. Closed-loop and efficient communication needs to be used, again a skill that may have to be acquired and requires practice. Institutions should have the appropriate emergency equipment and medications. In the heightened and tense environment of a crisis, the use of

index or cue cards for management of different events is helpful. These laminated algorithm or protocol cards should be easy to access and up to date. A dedicated reader should be assigned to the task if possible. Phone numbers for urgent laboratory results and blood bank must be easy to find. Centres that deal with surgery with high risk of rapid and/or large volumes of blood loss have massive transfusion protocols (MTPs) to guide administration of appropriate blood products for resuscitation in a timely manner. This is in collaboration with blood bank, anaesthetists, the operating surgeon, haematology, and supported by rapid and timely blood tests and surgical assessment of haemostasis (thromboelastogram, ROTEM).

Anaesthesia, as a profession, has been quick to recognise the advantages of adopting simulation as an educational concept. Since the first crew resource management (CRM) course was run in 1990 in Stanford, high-fidelity simulation training in crisis management is now recognised as an essential part of the anaesthetic training programme and imparts technical and personal non-technical (communication, leadership, decision-making, prioritisation, task and resource management, situation awareness) skills, the latter which is more difficult to define and measure. Experiential learning can explain how simulation can support and enhance professional capabilities. Simulation training is also essential for all team members and when undertaken in a safe and supportive environment, is perhaps the most effective way of building teamwork and therefore improving safety outcomes for patients. In recent years, performing workplace (in situ) simulation training has been found to have greater efficacy as knowledge pre-exists regarding equipment, drugs, processes and members of the team. Team behaviour can be scrutinised to understand the human factors and address barriers to effective teamwork [37, 38]. Another benefit of in situ training would be to highlight intrinsic system deficiencies that might have otherwise gone undetected until the advent of a real crisis. The RACS has also introduced non-technical skills (NTSS) for surgeon simulation workshops.

Much has been said about the importance of communication. The SBAR was first developed by the military and used for nuclear submarines. It was then adopted in the aviation industry and then introduced into health care in 2002 where it was used in rapid response teams in a hospital in Colorado. It is recognised that different people can have markedly varying communication styles, and thus, a structured, focused and easy-to-use mnemonic was recommended to overcome difficulties in communication. It organises a conversation into the essential elements in the exchange of information from one person to another. It is now one of the most popular systems used for handover in health care the world over and is used in both clinical and non-clinical situations.

The elements of the ISBAR communication tool for handover are as follows:

- I**—Introduction.
- S**—Situation.
- B**—Background.
- A**—Assessment.
- R**—Recommendation.

14 New Technologies/Innovations

What about the future of anaesthesia? The advances over time have been focused on improvement in knowledge and training, medications, equipment and monitoring. Research continues into safety and quality improvements, and shifts in the way the specialty approaches and delivers healthcare to patients. Anaesthesia as a specialty plays an increasing role in patient advocacy and measuring more patient-centric outcomes, also there is greater interest in the understanding on how we communicate and deliver information to patients to best convey risk and outcomes.

New advances in equipment and monitoring have lofty aims to better tailor a more “personalised” or bespoke anaesthetic for each individual patient. The first pharmacogenetic discovery was made more than five decades ago with the discovery of glucose-6-dehydrogenase deficiency in patients who develop haemolysis after being given primaquine in the fight against malaria. The term was first coined by Friedrich Vogel, a German geneticist in 1959. However, advances in the research into pharmacogenetics have only really accelerated in the last 20 years with the completion of the US Human Genome Project in 2003 and the International HapMap project [39]. Research continues into how pharmacogenetics impact an individual’s response to drug pharmacokinetics, drug metabolism and efficacy as there is evidence that genetic variations play a role in pain, response to analgesia (especially studied in opioids), side effects and overall clinical outcomes [40].

New methods of monitoring aspects of anaesthesia are being investigated for functionality, practicality and reliability. An area of interest is the objective assessment of nociception under anaesthesia—the ability to “quantify” pain, and thus titrate analgesia promptly to painful stimuli. One such monitor is the Analgesia Nociception Index (ANI) monitor, but other monitors are available. All use an algorithm to assess various physiological variables to produce a numerical index that estimates the antinociception–nociception balance. The ANI monitor derives a score from 0 to 100, where the numbers indicate the sympathetic/parasympathetic balance, the higher the values, the less nociception. Thus, the target is to keep the index between 50 and 70, where in theory, a low score below 50 indicates the need for more analgesia and that is titrated until the number is within the target range. Additional touted benefits of this technology are the ability to titrate analgesia to noxious stimuli

promptly and accurately, thus potentially decreasing overall drug requirement (and thus side effects) and may prevent postoperative pain and distress. It may also help differentiate between pain and other causes of physiological variability, for example tachycardia and hypo/hypertension from other causes by determining the effect of opioids on the sympathetic response [41]. Unfortunately, two recent meta-analysis studies have not been able to find any benefits of usage of the monitors on intraoperative opioid consumption, but these

incomplete data, and significant heterogeneity [42]. However, some promise has been demonstrated on monitor use and its effects on intraoperative stability (due to the titratability of medication) and possibly its impact on postoperative pain [43]. Studies continue in this area. Note that ketamine, a commonly used co-analgesia medication, does not impact the ANI number.

Other monitors undergoing refinement include depth of general anaesthesia (DGA) with displays of EEG and EMG (to guide interpretation of the index number). We are seeing the impact of artificial intelligence in our monitors and equipment with BIS currently being used to guide closed-loop feedback TIVA delivery systems.

Some new drugs that could potentially be useful in the practice of anaesthesia are longer-acting local anaesthetics. The only commercially available formulation is liposomal bupivacaine [44], and it is only FDA-approved for limited applications—in interscalene brachial plexus blocks, transversus abdominis plane (TAP) blocks and for surgical infiltration. It lasts for 24–72 h, but is not currently widely available, and is prohibitively expensive with a price point 200 times more expensive than plain bupivacaine. At present, there is insufficient evidence supporting its theoretical advantages and the price makes its routine use unattractive.

15 Conclusion/Summary

Anaesthetists inhabit a unique place between surgery and medicine, and take the lead in crisis and emergency management. The profession is closely entwined with the surgical profession for which, without it, would never have existed. Technical skills in airway management and care of the unique patient physiology under anaesthesia, as well as pain management, remain the core skills and knowledge set. Knowledge of anatomy and research into new regional blocks aids in pain management and towards opioid-sparing anaesthesia. Anaesthesia is now a specialty in its own right, and advances in care and patient safety have been driven by training, equipment, monitoring and research. New methods of delivering anaesthesia and analgesia (using artificial intelligence), targeted monitoring and novel drugs will continue to be investigated to allow for safe care, minimise risks, adverse events and

decrease side effects or medication interactions. The digitalisation of health and data collection (anonymised metadata) may drive further changes in targeted and individualised care, but issues related to privacy and legality will be at the heart of changes. Although care is increasingly technology-driven, there is acknowledgement that communication and non-technical skills are also a fundamental aspect of the role.

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Assessment of Function Post-cancer

Julia Maclean

Core Messages

- Pre-surgery assessment and planning are imperative for the complex head and neck cancer patient.
- The speech pathologist and dietitian are critical to this multidisciplinary assessment for the realistic expectations and education of the patient and their family.
- The crucial functions of breathing, speaking and swallowing are frequently impacted by the treatment and are rated as priority quality-of-life concerns.

1 Introduction

Speech pathologists play an integral role in the successful multidisciplinary management of patients with head and neck malignancies. The crucial functions of breathing, speaking and swallowing are frequently impacted by head and neck surgical treatments, and are consistently rated by patients as priority quality-of-life concerns [1, 2].

It is imperative for any patient planned to have surgery for head and neck cancer to undergo a multidisciplinary assessment. As a result, the patient's clinical pathway can be clearly outlined and implemented from the time of diagnosis, through treatment, and beyond into survivorship. The importance of pre-operative assessment and education of the patient and family cannot be overstated, particularly when highly invasive surgeries such as laryngectomy and glossectomy are contemplated. Peer programmes to ensure that the patient and family establish realistic expectations of post-operative function, and to provide support, can be very useful. Close liaison between the surgeon and speech pathologist ensures that accurate and consistent information is provided to patients about likely post-operative outcomes and the benefits of rehabilitation.

Management of the patient's airway is inextricably linked to the treatment of head and neck cancers due to anatomical proximity and the likelihood of short- or long-term complications (Fig. 1). For instance, controlling post-operative oedema, an anticipated side effect of surgery, is usually achieved with a short-term tracheostomy. In the case of a

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total laryngectomy, there is permanent separation of the airway, resulting in the need for a stoma. Information regarding planned airway management should be provided pre-admission, to ensure that patients and their families understand the implications of surgery on the airway.

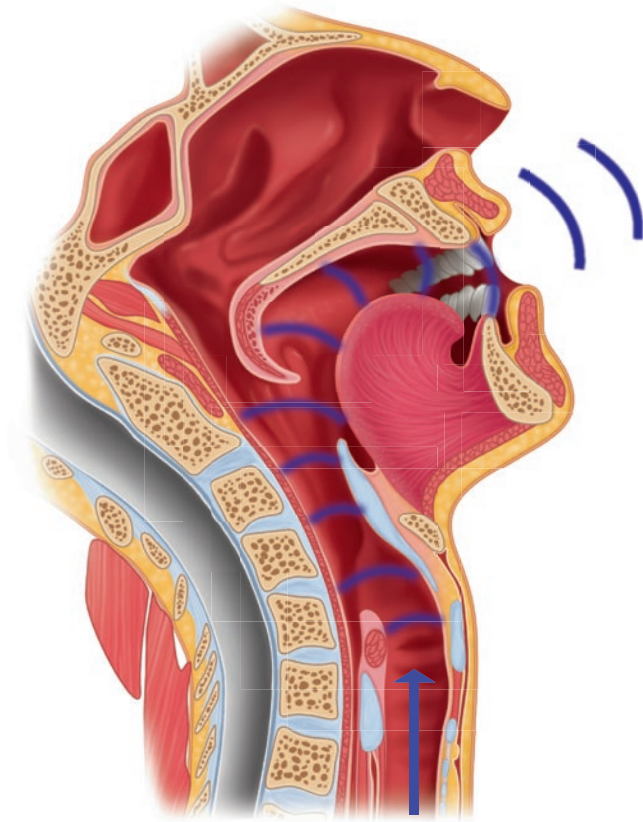


Fig. 1 The human aerodigestive tract and implications for function in the resection and reconstruction of head and neck cancer

2 Breathing/Speaking

The ability to speak so as to be understood is closely linked to a good quality of life and the concept of human identity. Given that major reconstructions (with or without a tracheostomy) may have a major impact on verbal communication, a plan for communication in the post-operative period should be assessed pre-operatively. A tracheostomy is usually required temporarily, and while the cuff is inflated, verbal communication is not possible. For many patients, this period of time is brief and a simple augmentative communication board, or a whiteboard, to assist communicate needs may be sufficient.

If time permits, and the period without voice is likely to be prolonged, a more sophisticated method of communication may be considered. Recent advances in technology allow voice banking as long as pre-operative levels of function are sufficient to facilitate the use of digital technology post-operatively. If a tracheostomy is to be long-standing, while the cuff is inflated, no air passes through the larynx to facilitate voice. In this situation, facilitating periods of cuff deflation and the use of speaking valves should be considered. Speaking valves are used to facilitate speech with the cuff deflated to redirect airflow through the larynx during expiration and may also improve swallowing and assist in respiratory rehabilitation [3]. There is increasing evidence that coordinated tracheostomy care provided by multidisciplinary teams (including medical, physiotherapy, speech pathology, psychology and nursing staff) influences the safety, quality of care and clinical outcomes for patients with tracheostomies and their families [4]. Such was the case for this patient with SCC of the retromolar trigone, resected via a swing mandibulotomy approach, temporary tracheostomy and reconstructed with a free radial forearm free flap (Fig. 2).

Long-term speech function following head and neck surgery is dependent on the size and location of the cancer, the need for reconstruction, the type of reconstruction, the patient's ability to move the reconstructed tongue, the presence of a tracheostomy and, most importantly, patient motivation [5]. Where cuff deflation on a tracheostomy cannot be achieved, or following large oral reconstructions where speech remains unintelligible despite articulation therapy, augmentative communication

aids, text to talk and other computer applications can provide useful options to facilitate communication. For patients who have undergone a total laryngectomy, rehabilitation using tracheoesophageal speech has been the gold standard since its advent in the late 1970s [6]. Depending on the proposed extent of surgery, a prosthesis may be placed at the time of initial surgery as a primary placement to allow oral communication to be commenced as soon as the patient is able (Fig. 3) [7].

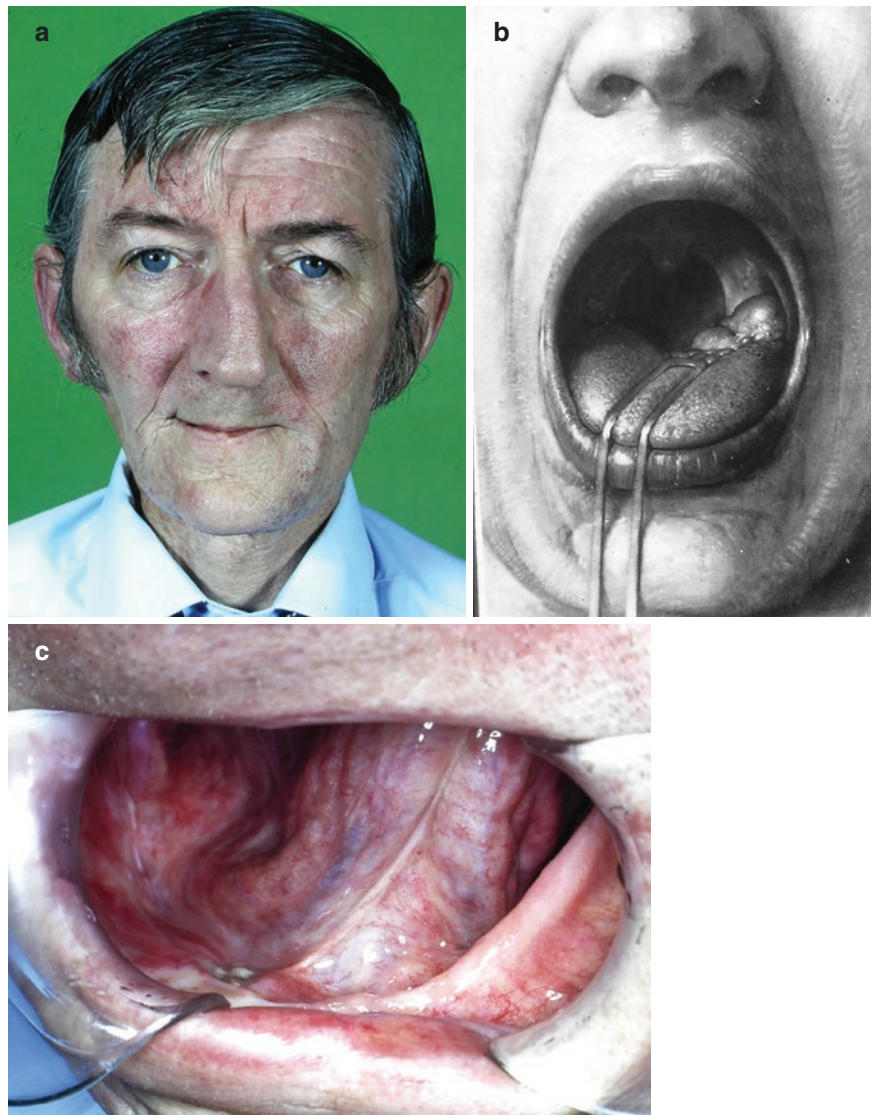


Fig. 2 (a–c) 1983 case of SCC right retromolar trigone, resected and reconstructed with a radial forearm free flap (the first of its kind, at Canniesburn Hospital, Glasgow) (image courtesy of Brent Tanner, FRCS)

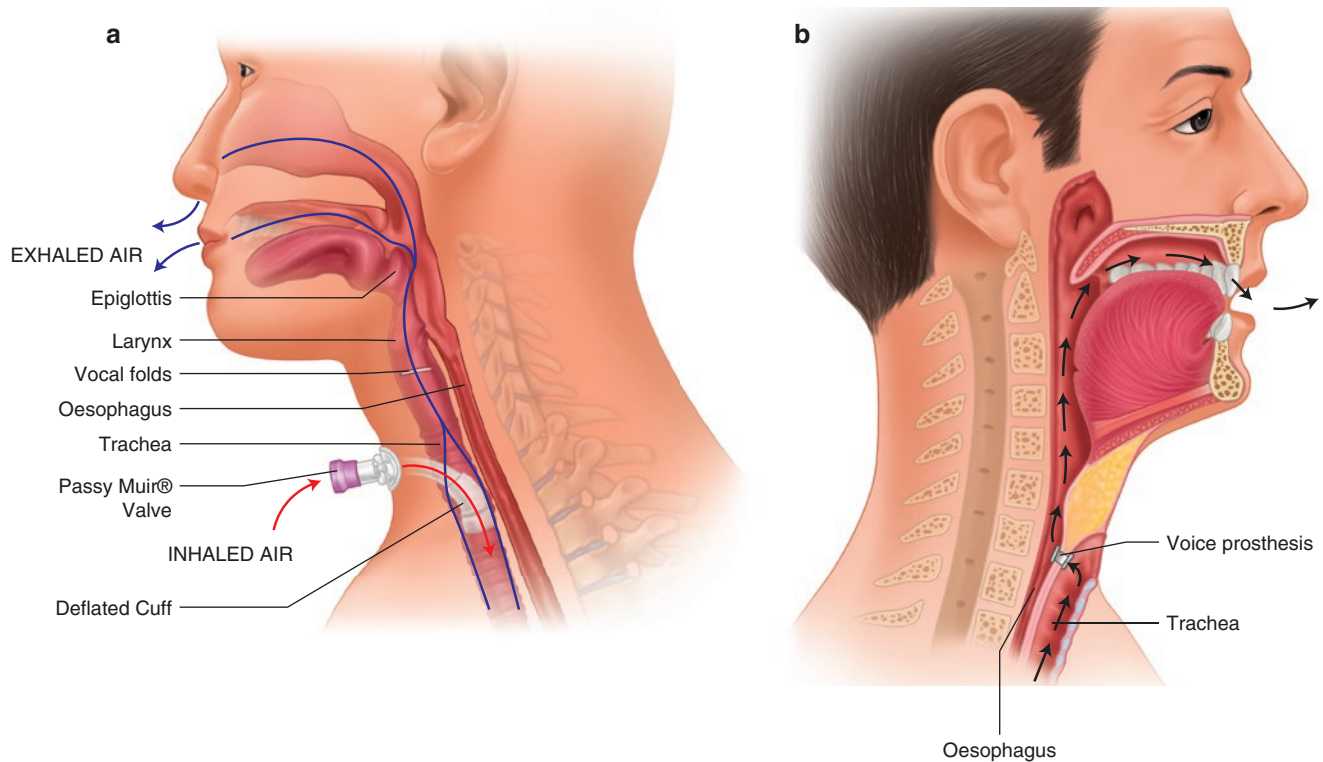


Fig. 3 (a) Passy Muir Speaking Valve (image courtesy of Passy Muir, Inc., Irvine, CA). (b) Laryngectomy patient with voice prosthesis (image courtesy of InHealth Technologies, Carpinteria, CA)

3 Speaking/Swallowing/Nutrition

Speech pathologists work frequently with dietitians to ensure that both swallowing function and nutrition can be optimised following treatments for head and neck cancer. There is well-established evidence that pre-operative assessment of swallowing function is important to establish baseline levels of function prior to head and neck surgery [8]. There is growing evidence that optimising nutrition pre-operatively should be considered as part of a comprehensive pre-admission plan for these patients and that where severe nutritional risk is identified, patients should receive nutritional support for 10–14 days prior to major surgery [9]. There is also good evidence that patients with a low pre-operative albumin and low body mass index are predictive of 5-year mortality [2]. It is then crucial to use a validated nutritional screening tool at diagnosis and at repeated intervals throughout treatment [9].

There is no consensus regarding whether prophylactic feeding tubes should be used, and decisions are often based

on local preferences. When deciding on the type of feeding tube to be used, clinical considerations should incorporate the site of tumour, the treatment intent, the extent of surgery and reconstruction that is needed, the pre-operative nutritional state, the likely period and severity of swallowing dysfunction, nutritional compromise and the requirement for adjuvant treatments [10, 11]. It is common for patients to take a year of rehabilitation to reach optimised recovery to the swallowing mechanism and stability in nutritional status [2].

The impact on oral preparatory, oral propulsive and the pharyngeal phases of swallowing are dependent on the site, stage of tumour, extent of surgical resection, presence of a tracheostomy and the type of any reconstruction. In general, the larger and the more posterior the resection, the greater the likelihood of significant swallowing dysfunction [12]. In particular, resection and reconstruction incorporating the tongue base and pharynx are likely to have the greatest long-term impact on swallow function (Fig. 4) [12].

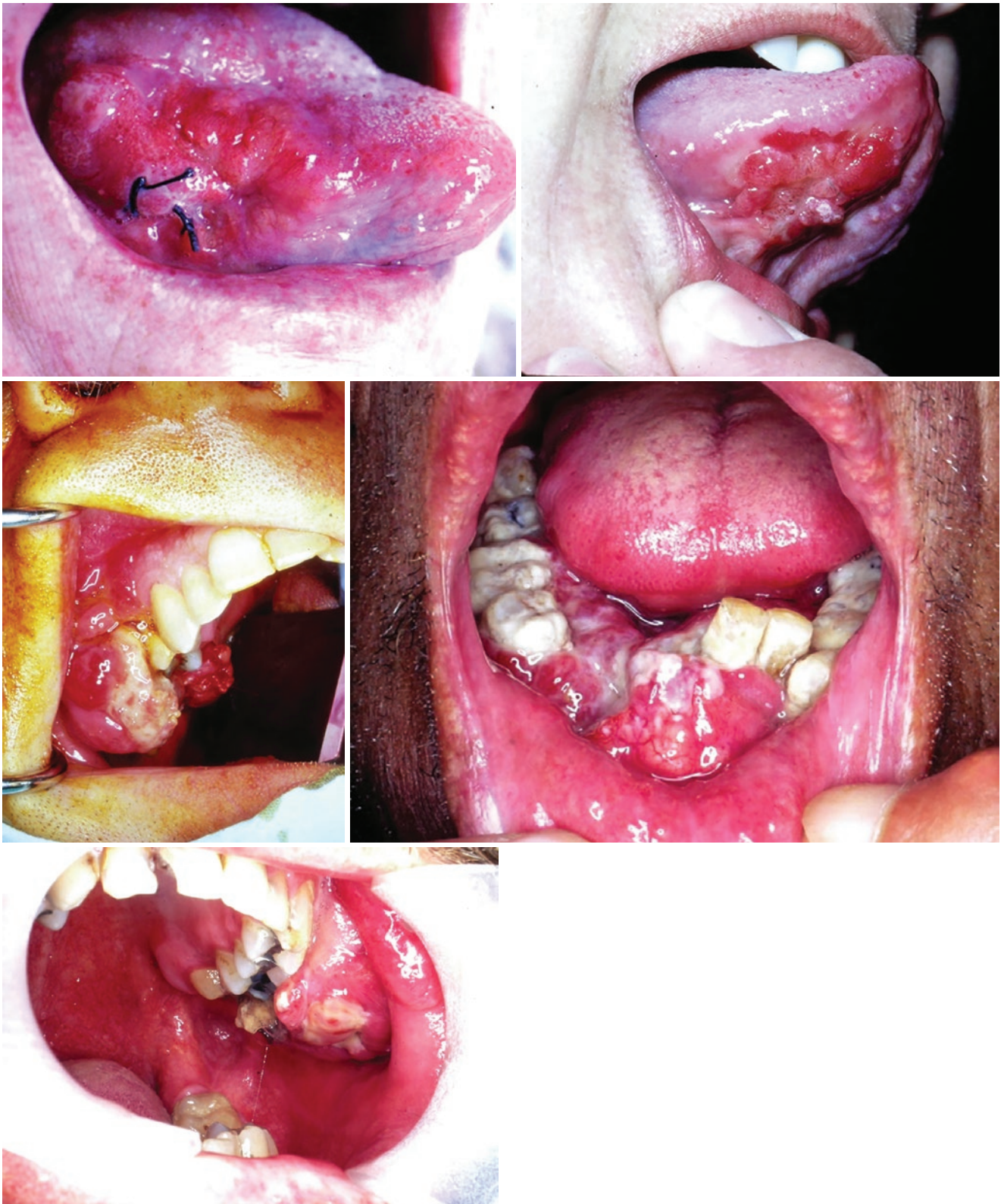


Fig. 4 (a–f) Intra-oral cancers that will require airway diversion and functional rehabilitation as part of the multidisciplinary team management

4 Assessment of Swallowing Function

Clinical assessment of swallowing must incorporate an assessment of the oromusculature including labial, lingual and palatal movement and timing, evaluation of cranial nerve function, hyolaryngeal movement and laryngeal function, paying particular attention to aspiration risk. Penetration refers to the bolus of food or liquid entering the airway but remaining at or above the level of the vocal cords, whereas, in an aspiration event the bolus extends below the vocal cords. The use of objective assessment allows accurate quantification of penetration/aspiration risk, which is important for patients with advanced stage and/or laryngeal/hypopharyngeal tumours [8].

Objective assessment of swallowing can be accomplished using either a videofluoroscopic swallow study (VFSS) (Fig. 5) or fibre-optic endoscopic evaluation of swallow (FEES) (Fig. 6).

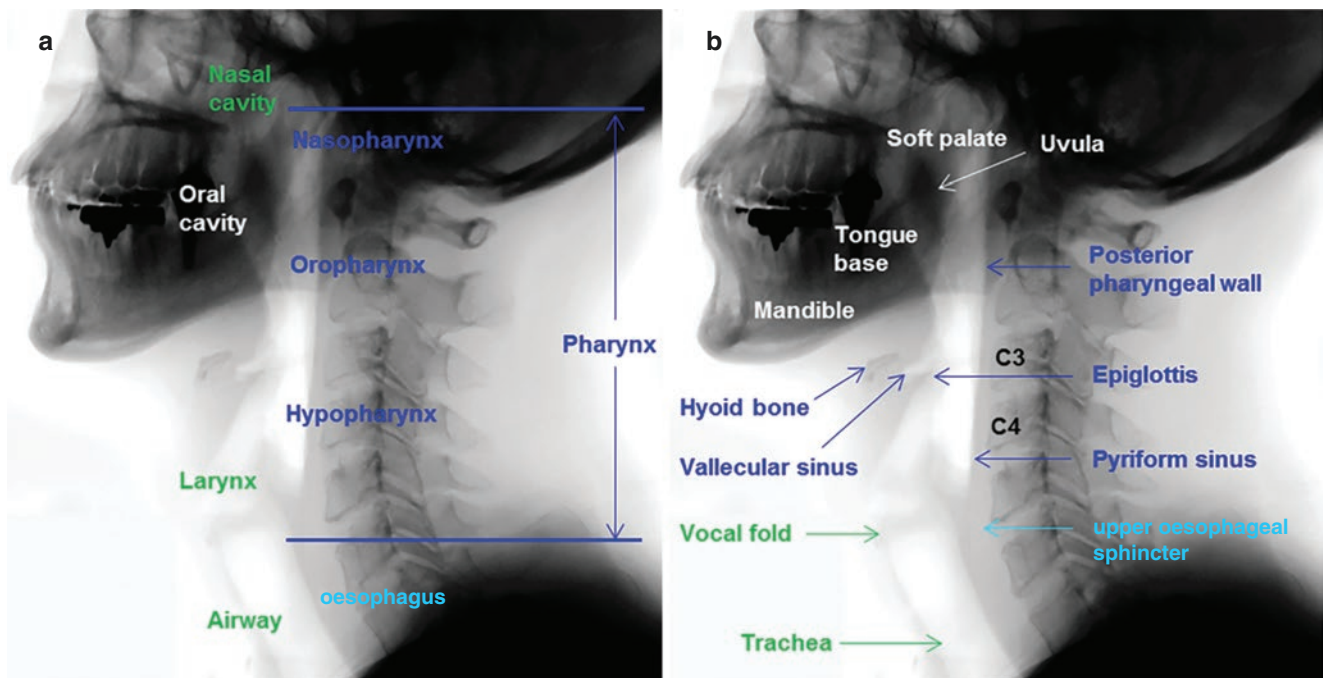
A FEES assessment allows direct visualisation of the structure and movement of the nasopharynx, base of tongue, hypopharynx, larynx and vocal cords. Assessment of swallowing using FEES allows detection of any premature spillage of the bolus from the oral cavity into the pharynx, quantification of residue after the swallow and a direct view of any penetration, aspiration or regurgitation of the bolus. Importantly, during the actual swallow the view is obliterated by the movement of the epiglottis and the function of the upper oesophageal sphincter cannot be seen.

Videofluoroscopic swallow studies are a two-dimensional assessment of the three-dimensional structures involved in swallowing, making quantification of the amount of residue and aspiration more difficult. Importantly, however, video-

low from the oral phase, through the upper oesophageal sphincter into the cervical oesophagus. These assessments should be seen as complimentary, and the choice of which assessment method to be used should be based on the patient's situation and the clinical question needing to be answered [13].

Standardised and validated measures during FEES and both the efficiency and safety of swallowing. The penetration–aspiration scale (PAS) is an eight-point scale that is

FEES to characterise both the location of an airway invasion and the patient's response to the penetration or aspiration [14, 15]. Penetration refers to the bolus of food or liquid entering the airway but remaining at or above the level of the vocal folds, whereas, in an aspiration event, the bolus extends below the vocal cords. When material is aspirated, there is the potential to result in a more serious health sequela; aspiration pneumonia is a common non-cancer-related cause for mortality in the head and neck cancer population [16].



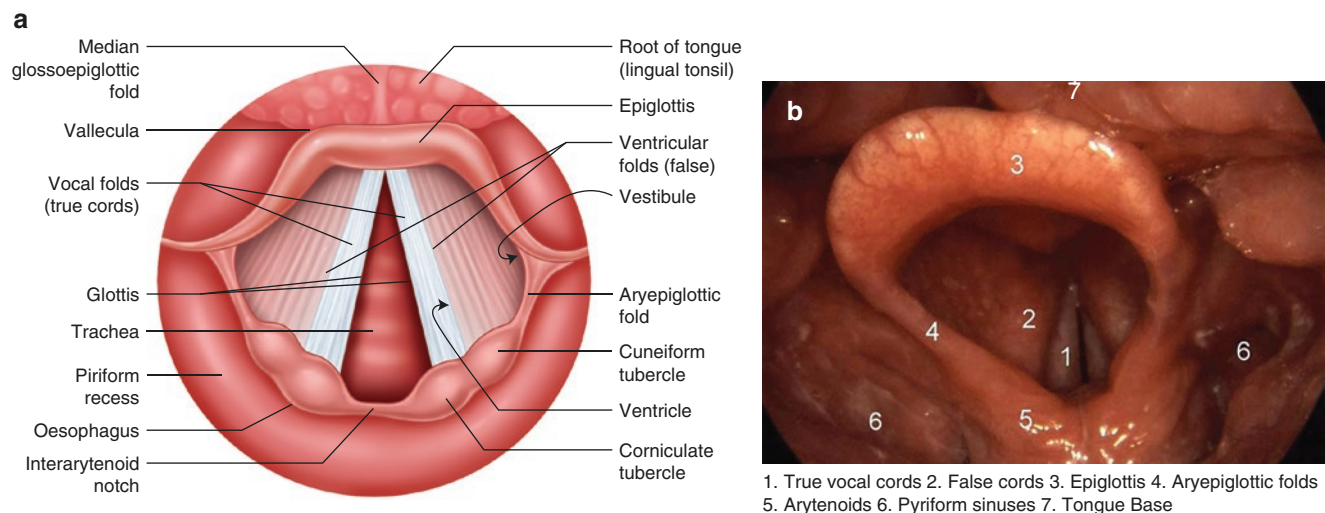


Fig. 6 Anatomy of pharyngolaryngeal swallow in fibre-optic endoscopic evaluation of swallow (FEES)

5 Chemoradiation Effects

Frequently, head and neck cancers require multi-modality treatment incorporating radiotherapy, chemotherapy and immunotherapy. These treatments all have additional and cumulative effects on short- and long-term swallowing functions. Despite advances in chemoradiation, normal tissues are inevitably exposed to high doses of radiation, which invariably lead to early and late treatment effects [17]. One retrospective long-term follow-up study revealed that 25% of patients had long-term treatment toxicity to the pharynx and larynx. Nearly 21% of patients required permanent gastrostomy tube placement, and 47% of patients had oral cavity sequelae including osteoradionecrosis, which is often painful and can have significant effects on the ability to chew [17]. Fibrosis is a common consequence of radiation, and radiographic studies show stricture of the pharyngoesophageal junction occurs in 20% of patients [18]. In patients who experience dysphagia (approximately 60% of head and neck cancer survivors), 80% had reduction in the compliance of the pharyngoesophageal sphincter, suggesting that past estimations have likely underscored the prevalence of this late effect [16]. Radiological assessment of stricturing is not accurate, and where it is suspected, endoscopic assessment should be considered [19].

Although evidence to support the use of prophylactic exercises prechemoradiation is increasing, to date there are insufficient high-level data to uniformly recommend this approach at the present time. The paucity of high-level evidence most strongly illustrates the need for multidimensional assessment pre-treatment (encompassing both instrumental assessment and patient-reported outcome

measures) to allow analysis of altered patient function pre- and post-treatment [20]. Adherence to swallowing exercises during treatment has been shown to independently benefit patients during chemoradiation maintaining both short- and long-term swallow functions. Additionally, maintaining oral intake during chemoradiation treatment has been shown to be independently associated with better long-term swallowing outcomes and having a shorter period of time reliant on enteral feeding [21]. The known risks for developing stricture include twice-daily radiation treatment, female sex and a hypopharyngeal primary site [17]. Additionally, patients who have not maintained an adequate oral intake throughout treatment, or who have a lengthy recovery back to an oral diet, are at an increased risk of late swallowing function [21].

6 Conclusion/Summary

Where long-term swallowing dysfunction is present, objective assessment should be made to determine the mechanism of the dysfunction. For many patients following head and neck treatments, the aetiology of the swallowing dysfunction is multifactorial and may include structural and physiologic changes from surgery, xerostomia from radiotherapy, and altered propulsion of the pharyngeal musculature and stricture from the combined effects of surgery and radiotherapy. Where a stricture is suspected, endoscopic dilatation has been shown to be a safe and effective treatment with short-term response rate of 76%; however, the relapse rate is also high, and 50% of patients require ongoing management of this problem throughout survivorship [22].

Most head and neck cancer patients report both physical and psychosocial impacts in the short and longer terms [23]. Critical to all treatment modalities in head and neck cancer is the use of patient-reported outcome measures pre, post and ongoing during rehabilitation to monitor and record both deficits and improvement. As the acute and late effects may have a profound impact on quality of life, it is critical for the treating clinicians to use measures that encompass a multidimensional and professional view of the deficits including disfigurement, dysphagia, dental caries, feeding tube dependence, lymphoedema, voice and xerostomia [24]. Recent advances involving predictive prognostic models that are individually tailored to patients may enable a better understanding of outcomes, response to treatment and future disease progression [25].

The high symptom burden across the fundamental human functions of breathing, communicating and swallowing requires comprehensive and coordinated multidisciplinary care to harness the varied expertise and drive personalised care with speech pathologists and dietitians central to successful multidisciplinary care (*see Fig. 5*) [24].

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Modern Morphing Technology in Facial Reconstruction

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Core Messages

- Technological advancement has transformed medical practice. Facial features analysis required for surgical planning is not alien to this evolution.
- Modern 3D imaging methods have been used in research studies and could soon become the standard practice for craniofacial assessment in reconstructive procedures, improving doctor–patient communication and aiding surgical planning and follow-up processes.

1 Introduction

A great interest in three-dimensional surface imaging (3DSI) has arisen during the last decades. Improvements in computer and imaging technologies have played an important role in the development and popularization of these tools introducing them into medical practice. Their use in cosmetic surgery has been championed by the industry but the potential benefits that can be obtained by their application in reconstructive procedures have been scarcely explored [1, 2].

Several companies offering different software and equipment to obtain patient 3DSI coexist at the present. Their medical use has mostly focussed on the face, chest, and breast areas. The capturing of high-fidelity three-dimensional images in real time has been enhanced by the possibility of modifying their shape through computer software with the intention of simulating the result of the suggested surgical procedure. This process is known as Morphing.

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In this chapter, we describe the possible uses and benefits that the introduction of 3DSI may have in the performance of reconstructive procedures in the face, head, and neck area.

2 Technique

3DSI is a novel imaging modality that provides objective information about the patient's soft tissue characteristics in the face, head, and neck area. Generation of this imaging varies between the providing companies. Most of them require specific equipment and software to capture the required data. Once obtained, this information is processed and displayed as a digital three-dimensional image. Technologies used to obtain the images include structured light, stereophotogrammetry, and 3D reconstruction from two-dimensional image analysis [3].

Structured light consists of the projection of a known light pattern (usually in the form of grids or lines) onto the surface of an object. The object will alter the projected light direction and intensity. These changes are captured by a calibrated camera, which converts it into a 3D coordinate. The data are processed and turned into a 3D image showing the surface of the analyzed object.

Stereophotogrammetry employs two or four cameras, depending on whether a 180° or 360° 3D image is to be created. Each camera is positioned at a specific angle and distance from the studied object and will obtain an image that can be broken down into points. Each point will be captured by at least two cameras, and through the principle of triangulation, each point will be assigned a spatial position into the x , y , and z axes. The conjunct analysis of all the points will finally provide a three-dimensional image.

or hybrid. Active stereophotogrammetry utilizes a structured light pattern projected over the surface of the studied object, whereas passive stereophotogrammetry determines the 3D structure of the studied body by direct imaging. Hybrid ste-

reophotogrammetry relies on a combination of both to achieve a more accurate 3DSI [4].

Three-dimensional reconstruction from two-dimensional image analysis relies on three digital pictures of the studied object taken from different angles, in order to recreate a 3D image. Once the 3DSI has been created, it can be digitally displayed in real time on a computer screen by the use of specific software. This allows navigation and movement throughout the image with the possibility of viewing from different angles and zooming in and out, allowing the volumetric and position evaluation. Most software is equipped with tools that will allow the surgeon to simulate surgical procedures on the projected image. These features may assist during surgical planning and display the expected surgical outcomes to the patient, which can enhance their understanding and has been shown to increase patient conversion rate in aesthetic procedures.

The generation of several 3DSI of the patient along their follow-up improves documentation and may precisely evaluate a patient's evolution with time, impact of growth, and aging on their craniofacial soft tissues.

Some software allows the super-interposition of 3D reconstruction of CT or cone-beam CT images with the obtained 3DSI. This image fusion permits the assessment of bone structures and soft tissues, further increasing the possible areas of clinical application [5].

More recently, a 4D system has evolved, which introduces the possibility of recording movement of the 3DSI [6]. This is of great interest for the gaming and movie industries but can also be applied in the medical field. This is relevant when studying a dynamic structure like the face, which is constantly subject to changes in soft tissue position with expression.

Characteristics of the ideal 3DSI capturing systems are described in Table 1.

Table 1 Ideal 3-dimensional surface imaging capturing systems

Noninvasive
Fast (real-time data processing and image display)
User-friendly with short learning curve
Portable
No additional or special equipment needed
System validated for medical use
High spatial resolution with high accuracy allowing quantitative analysis of craniofacial features
Accurate color and texture mapping
Low distortion and motion artifacts
Low cost
Data encryption complying with patient privacy
Small file size and cloud storage readily available.
Supported by portable technology devices (tablets and smartphones)
Allows navigation within the image and visualization from various angles
Permits morphing simulation of aesthetic and reconstructive procedures over the 3DSI

3 Innovation

The use of 3DSI in plastic surgery has been promoted as a means of engagement with the patient during an aesthetic consultation. The patient's digital image projection allows the surgeon to provide better education to the patient. Instead of being shown before and after procedure pictures performed in other patients, the patient is able to visualize themselves and recreate the results of the surgery over their own image (Figs. 1 and 2). Undoubtedly, this attracts the patient and has shown to increase the consultation to surgery conversion rate [7].

Although 3DSI has received less application by the industry in the field of reconstructive surgery, surgeons have explored its application in diverse areas in search of the benefits this novel technique may provide. This has indications not only during surgical planning, but also during surgical execution and patient follow-up.

The use of this technology to aid the treatment of deep lacerations of the face represents a challenging scenario since shear forces and hematoma formation may hinder skin graft take at the recipient site. In order to overcome these difficulties, after tangential escharotomy of the burned facial area, a 3DSI of its contour was obtained using Crisalix [Virtual Aesthetics, Crisalix™, Lausanne, Switzerland] 3D sensor in combination with a Face Simulator software on a tablet [iPad™, 5th Generation, Apple Inc., Cupertino, California]. The possibility of 3DSI acquisition with a portable home device, which was available with no need for calibration, turned it into a practical and economic alternative in our practice. Image capture was performed on the ward while the patient was hospitalized without further need for patient transfer (Fig. 3).

The use of a cloud-based program for image storage provided additional benefits in our experience, thus making the data accessible from a portable computer from where the image was processed and a negative was acquired. The image negative was utilized to print a personalized 3D face mask of polylactic acid [Ultimaker 3 Extended™, Ultimaker, Geldermalsen, The Netherlands], which perfectly matched the shape of the patient's face (MIRAI 3D, Buenos Aires,

silicone, and elastic straps were added on its sides to ensure homogeneous pressure was applied over the graft. The custom face mask was used to fix the skin grafts in position, allowing the integration of the graft and prevention of hypertrophic scarring (Fig. 4).

A similar use is possible, when planning surgical treatment of giant congenital melanocytic naevi of the face [9, 10]. Through the surface scan of the patient's face, a custom-

made face mask could be made, which could help to hold the grafts in position improving the surgical outcomes.

Skin disease monitoring over time has traditionally been done by direct inspection and photographic comparison. 3D systems applied focally over the lesions may obtain a detailed shape and volumetric image. Objective assessment of variations and evolution of the structure may be performed exceeding the capacity of the human eye to determine changes in elevation, surface topography, and size with a submillimeter accuracy [11].

The use of 3DSI could further help simulate and predict the surgical outcome in resection of malignant lesions, aiding in the design of local flaps required for closure. Similarly, objective measurement of infantile hemangioma dimensions and follow-up of their progression along the infant's first year of life may be a difficult task. Interpersonal measurement variations may arise leading to misleading information. The usefulness of 3DSI has been presented in these situations by allowing the objective measurement of the tumor's involution after treatment with β -blockers, guiding the need for further treatment of this prevalent disease [12].

In the field of orthognathic surgery, 3DSI has proven to be a valuable resource. Several studies have compared surgical planning guided by 2D and 3D imaging of the bony structures, showing the benefits the latter technique has regarding its precision to predict outcomes [13, 14]. However, few studies have centred on soft tissue response to surgery [15]. Bony structures and soft tissues are intrinsically correlated in the facial structure, and their dissociation seems unnatural. New software allows overlapping of 3D CT or cone-beam CT images with the 3DSI, which adds the possibility of modifying the virtual models to help predict and objectively quantify the changes in soft tissue generated by the mobilization of bony maxillofacial structures during surgical planning [16, 17]. Moreover, this technology improves patient education by allowing the patient to imagine the results of the proposed surgery. The capturing of sequential images preoperatively and during postoperative follow-up helps to accurately quantify the modification of facial soft tissues along different time periods.

A similar setting is encountered when treating patients with unilateral cleft lip and palate. Typically, surgical treatment of this population involves procedures performed on both bony and soft tissue structures and planning includes the use of 2D cephalometric measurements or more recently 3D computer-assisted planning and simulation in conjunction with the patient's picture records. However, soft tissue characteristics on the affected side, which contribute to facial asymmetry, are occasionally overlooked or underestimated by these methods leading to decreased patient satisfaction and the need for revision surgery. Recent research has intro-

duced the use of 3DSI to improve the evaluation of soft tissue when performing orthognathic surgery and rhinoplasty procedures, aiding in the precision of pre- and postoperative evaluation [15, 18].

Facial gender reassignment procedures involve the modification of both soft tissue and skeletal components, with each procedure uniquely tailored for the individual patient. As in orthognathic surgery, the use of 3DSI may be beneficial in postoperative follow-up and documentation, although its use for surgical planning has not been extensively explored [19]. Capturing of 3DSI of symmetrical body structures, such as the breast, can be used to create 3D printed biomodels to aid in the precise shaping of flaps for autologous breast reconstruction [20, 21]. The novel use of Crisalix for this purpose has been

be applied to restore complex craniofacial tissue defects caused by severe trauma or previous surgery. Through the application of image mirroring, an objective assessment of the deformity may be performed and volumetrically quantified. The obtained information may help to assist in the manufac-

turing of a customized prosthesis [23]. A representative case of a patient with a craniofacial defect is presented in Fig. 5.

Some systems allow the analysis of dynamic and static images of the face. This has permitted the broadening of its applications to accurately evaluate the results of reanimation procedures in patients with facial palsy [24]. There is actually no consensus on which is the best method for the evaluation of the surgical outcomes, but undoubtedly dynamic 3DSI analysis may soon turn into the new standard, since it provides valuable information that traditional pictures or video recordings cannot. The analysis of the position of each structure at every moment during facial animation is possible through this method. By superimposition of the patient's facial 3DSI at rest, the grade of recovery can be quantified and even compared to the normal side [25]. However, what is more relevant is the ability to evaluate the recovery of movement produced by reanimation surgery. Through this technology, the dynamic appraisal may help objectively evaluate the recovery of facial movement and the spontaneity gained by the reanimation procedures.



Fig. 1 A 66-year-old female patient interested in a face-lift procedure. A simulation of face-lift result showing improvements in her jawline using Crisalix was done. The center image is a cross-fading image showing the smooth transition from the original image and the face-lift simulation

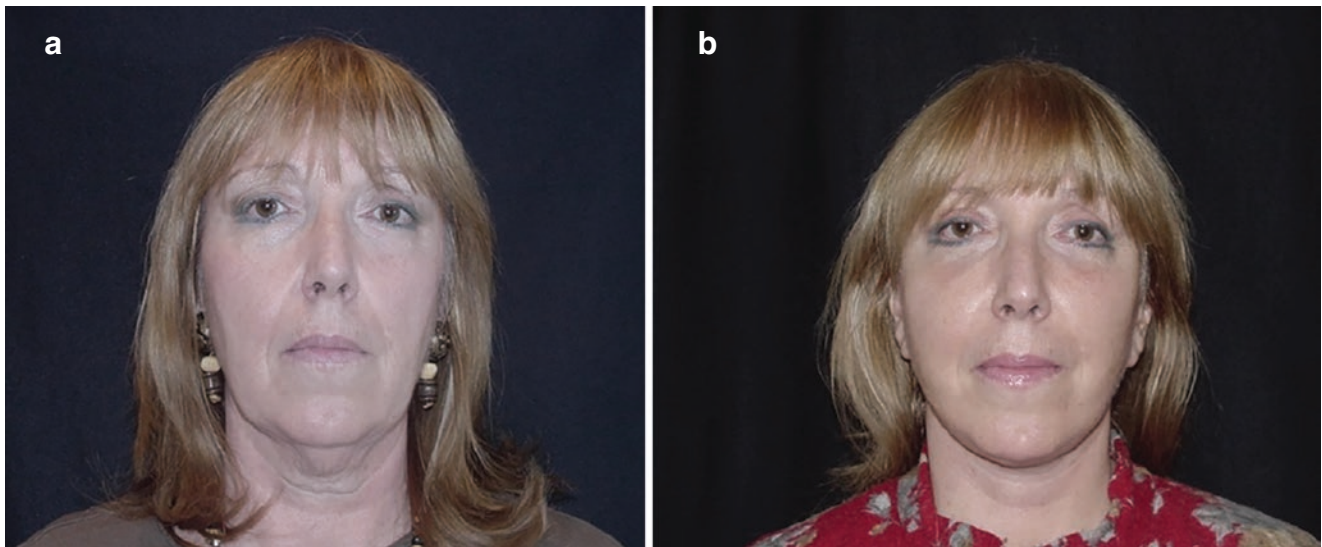


Fig. 2 (a and b) Same face-lift patient as above: (a) preoperative anterior view; (b) postoperative view at 3 months showing a very similar result as obtained through simulation

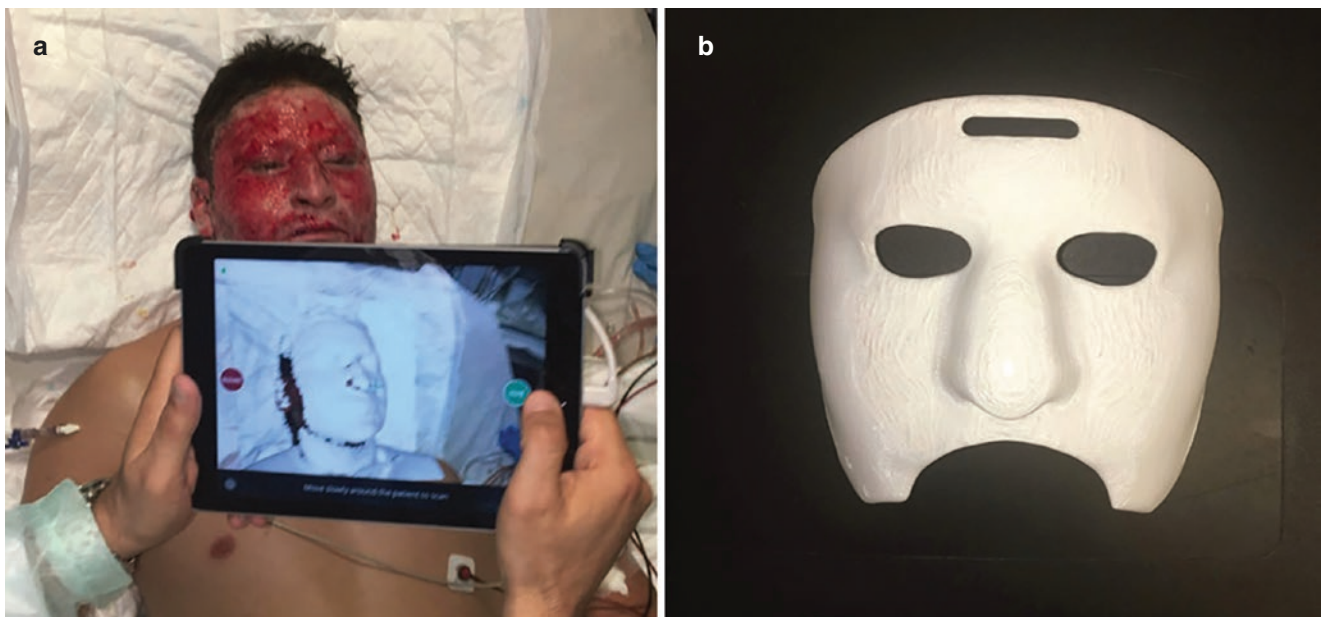


Fig. 3 (a and b) A 38-year-old patient was admitted to our burns unit with third-degree flame burns of the hands, forearms, and legs. Also exhibiting extensive facial damage including forehead, eyelids, nasal region, and both cheeks: a) The patient's facial features are scanned

with Crisalix and a portable 3D scanner; (b) the scanned image is then edited to create a custom facemask that is directly printed out using a 3D printer. (reproduced with permission from Aguilar and Mayer [8]; with permission)



Fig. 4 (a–f) Immediate postoperative view with both cheeks covered using a dermal substitute and both eyelids grafted with full-thickness skin grafts; (b) the grafted area was covered with dressings containing nanocrystalline silver and the 3D facemask; (c) postoperative view at day 21 showing full integration of the dermal substitute; (d) partial-

thickness skin grafts are placed on the integrated dermal substitute; (e) postoperative view at day 7 showing total integration of skin grafts; and (f) postoperative view at 4 months showing acceptable skin color match (*reproduced with permission from Aguilar and Mayer [8]; with permission*)



Fig. 5 (a–c) A 59-year-old female patient interested in restoring a temporoparietal defect resulting from resection of a meningioma; (b) the patient's face is scanned with Crisalix and a portable 3D scanner; and

(c) simulation of surgical results showing the temporoparietal defect and its restoration by mirroring her left facial side along a vertical axis

4 Complication Management

Image acquisition is made through noninvasive, radiation-free methods. Few complications have been reported by the use of 3DSI in the performance of most types of reconstructive procedures. The images obtained are precise and reproducible with a reported error rate that is lower than that obtained with direct anthropometry [26].

5 Limitations and Controversies

Several limitations may be pointed out regarding the systematic use of 3DSI for facial reconstructive procedures. To begin with, the high cost of the systems and the need for special equipment in most of the available technologies seem to be a major drawback impeding the broadening of its application. This makes it partially prohibitive for small practices or economically developing countries. Moreover, reconstructive procedures frequently do not produce such significant revenue as cosmetic procedures will, turning these technologies into a low cost-effective tool in this field.

In addition, since most of the 3DSI technologies require large and delicate equipment, its portability is impractical and usually it is placed in a room exclusively dedicated for its storage and use. The existence of many different hardware/software systems in the marketplace and the learning curve for correct use depending on the complexity of the selected system are also limitations.

In our practice, we use Crisalix, which is a user-friendly simulator software designed for use in aesthetic plastic surgery that offers high-resolution 3DSI. Crisalix only requires a tablet with a portable 3D sensor to plug in representing a practical option to other technologies that require significant resources, including training, equipment, and office space. Its annual subscription cost ranges from USD \$1,761 to \$6,082, making it an affordable alternative to more expensive technologies [3].

Regarding the setting for the image capture, some interference has been reported with the ambient lighting setup, and offices without windows or direct sunlight are usually preferred. Relying on the systems flash is recommended. Recent research has shown that patient skin tone does not influence the accuracy of image capture with hybrid or passive stereo-photogrammetry [27]. Image artifacts should be reduced as much as possible. The capturing of areas with hair, like the beard or scalp, represents a real challenge. The use of wig caps during image capture attenuates this effect and has been extensively applied. Reflective objects and accessories like earrings and jewellery should also be removed [28].

Finally, even though we try to mathematically scrutinize the different variables and analyses we perform on the

human face with the idea of improving the accuracy, predictability, and reproducibility of our interventions we as plastic surgeons aim to harmonize facial structures, and the challenge of numerically analyzing aesthetic facial features as a whole seems an impossible task to attain [29]. Establishing a cutoff point to consider a change to be significant or not after a facial surgery may be difficult. No other structure like the face experiences such great variation with movement, expression, and morphological changes throughout the day influenced by tiredness, feelings, etc. All these factors could reduce the possibility of obtaining a neutral facial expression during evaluation. This would compromise the results obtained with such an accurate study. In children especially, this could be a challenging and time-consuming task [30].

6 Informed Consent

As with other medical images, it is prudent and necessary to obtain the patient's informed consent in order to reproduce patient images for educational purposes. As opposed to two-dimensional photographs, display of 3DSI is more fruitful when done in a digital manner or by the use of 3D printing, which allows navigation and/or visualization from multiple angles. For this reason, preserving the patient's anonymity by covering the patient's eyes, similarly to what is done in traditional two-dimensional photographs may be complicated in 3DSI. This fact should be explained to the patient and should be stated on the written consent as well as a detailed description of the possible uses that may be given to the recorded images.

Most available software allows procedures to be simulated over the digital image, which, when observed by the patient without adequate counselling, may give false expectations. Care should be taken regarding this aspect. Post-op complications that may alter the final result or will grant the need for revisional procedures will inevitably arise in a subset of patients. This should be explained to the patient in a straightforward manner during the consultation and must be clearly addressed by the informed consent.

7 Future Perspectives

Although most of the available software today has a user-friendly interface requiring a short learning curve, the anatomical landmark positioning required for image analysis is user-dependent. Future technology will probably be able to accurately detect the position of the facial landmarks and perform an automatic 3D facial analysis, providing quantitative data of surface distance, area, and volume that the surgeon can employ for surgical planning.

Intraoperative navigation with virtual and augmented reality by the use of a wearable lens may give the surgeon access to real-time information that can aid decision-making during surgical procedures [31]. The projection of holographic 3DSI during surgery might be attractive for plastic surgeons since it could help compare preoperative and intraoperative modifications of facial soft tissue structures as they occur. The combination of 3DSI for surgical planning and virtual reality projection could be a powerful tool in the future.

8 Conclusions

Anthropometric measurements and clinical photography have been plastic and reconstructive surgeons' long-term allies. However, with the continuous advancement of imaging and computer technology, combined with the surgeon's continuous quest for surgical refinement and improved outcomes, an evolution of the assessment techniques employed is a natural step.

Even though 3DSI is not a routinely employed technology in plastic surgery, the reported benefits of its use may convert it into an attractive tool for reconstructive procedures. While numerous publications have investigated the role of 3DSI in research studies, further studies are still needed to validate its use in the reconstructive field. While there is always some resistance to the application of new technology, it has been extensively proven that through this technique, benefits for both the patient and the surgeon can be attained.

3DSI systems could soon turn into the standard of care, allowing a more in-depth evaluation of prospective patients for different reconstructive craniofacial procedures.

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Index

A

Aesthetic reconstruction, 93, 98, 108
Airway equipment, 426, 430–437
Airway management, 422, 425, 426, 430–437, 443, 445
Anaesthesia head and neck surgery, 422, 425, 430, 437, 441
Avoiding the stigma of deformity, 109
Awake fibre-optic intubation, 431

B

Biopsy and excision specimens, 31, 40
Breathing, 447–450, 454

C

Cancer growth, 55, 80
Cancer stem cells (CSCs), 17–20, 22–26
Carcinoma, 121–125, 139
Chin, 332, 336, 337
Circulating tumour cells (CTCs), 20–22
Clinical observations, 143
Complete and adequate wide local excision plus staging, 275, 298, 311
Complete local excision and aesthetic reconstruction (CLEAR) philosophy, 195, 207
Craniofacial analysis, 456, 458, 463

D

Dermatomal alignment, 145

E

Emotion, 381
Extreme facial skin cancer, 4

F

Facial analysis, 462
Facial reconstructive surgery, 117–119, 124, 139, 347, 353, 354
Fine needle aspirate, 32, 33, 35–37, 40
Forehead flap, 119–125, 128–133, 135, 137, 139, 276–285, 287, 289, 290, 294, 308–309
Form and function, 406
Free flaps, 111–118, 347
Frozen section, 32, 38, 39

H

High risk, 188, 190
High-risk scalp cancers, 213

Human face identity, 381
Human factors, 444

I

Immunohistochemistry, 39, 45, 46
Inking, 41, 44

K

Keystone perforator island flap, 142, 148, 167, 169, 171, 172

L

Lateral cheek, 317, 323, 327, 329
Loco-regional recurrence and anatomical implications, 80
Lower eyelid cheek junction, 314, 343, 344
Lymph nodes, 357–359, 363, 364
Lymphatic metastasis, 357, 358, 368

M

Malar and buccal regions, 319, 321, 328, 329
Malignant melanoma, 17, 19, 20, 24, 26
Measuring outcome, 81, 85, 87, 89, 90
Medial cheek, 330
Metastasis, 17, 19–22, 24, 25
Microenvironment, 17, 20, 22–24
Molecular studies, 31, 37, 45–48
Morphing, 455, 456
Multidisciplinary care, 215, 216

N

Nasolabial local flaps, 276–285, 287, 289, 290, 294, 308–309

O

Occlusal-based planning, 406
Orbital and eyelid tumours, 215, 217, 219
Orofacial defects and deformity, 406

P

Palliative, 347–349, 351, 353, 354
Parotid and peri-auricular regions, 145
Parotid gland, 357, 358, 363, 366, 370
Parotid region, 357, 363, 370, 376
Pathology reports, 44, 48, 53
Patient expectations and confidence, 381, 420
Pedicled flaps, 111, 112, 114–117

Periauricular loco-regional flaps, 275, 278, 296
Perioperative care, 422–423, 428
Prefabricated prelaminated osseous free flaps, 388
Preservation of vision, 215
Prosthetic rehabilitation, 381, 393, 406, 420
Prosthetic retention, 381
Protocols, 89

R

Radiological imaging, 200, 204
Reconstruction of major eyelid defects, 215–218, 227–228, 233, 237–251, 271
Renin-angiotensin system (RAS), 17, 23, 25, 26

S

Skin cancer, 24, 25
Skin neoplasms, 363

Soft tissue and bone planes, 80
Speaking, 447–452
Squamous cell carcinoma, 17, 24–25
Staging, 195
Surgeon, 185
Swallowing, 447, 448, 450–454

T

Team work, 81, 85, 89, 90
3D photography, 463
3D surface imaging, 455
Tissue expansion, 119, 133, 137–139
Transport media, 31

U

Upper and lower lips, 314, 332