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The evolution of head and neck reconstruction

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Introduction

Like most areas of plastic surgery, head and neck reconstruction has evolved considerably over the past half century, incorporating new techniques and innovations. In many parts of the world it has become part of the specialty of head and neck surgery, which itself evolved from general surgery, plastic surgery and otolaryngology, such that it is no longer thought of as part of plastic surgery alone. This discipline now includes new techniques, new flaps and new approaches. In addition, we have seen the blending of hitherto unrelated subspecialties, so that microsurgery and craniofacial surgery are now often practiced by a new breed of practitioners who are trained in both techniques. We have also seen a blending of resection and reconstruction, often by the same surgeon, which though it may seem like a new approach, is how it was done originally. The sheer scope of the subject prevents this paper from being exhaustive, so we attempt to give a broad overview of the changes and to give some background on how and why these advances happened. Such an overview is considered timely and useful for an early issue of this journal. Key references are cited to provide further reading.

Microsurgery and flaps

Before the era of microsurgery, tubed pedicle flaps were used in head and neck surgery. This approach was very morbid and disfiguring but it was the best that was available at the time. The deltopectoral flap was introduced by Bakamjian in 1965[1] and became the standard flap for reconstruction of many defects in the head and neck. Bakamjian made many contributions to head and neck reconstruction and is considered a pioneer of the modern era. In 1979, Ariyan introduced the pectoralis major flap[2] for reconstruction of the head and neck, though the flap first appeared in Russian literature in 1961.[3] The pectoralis major flap is still used today and the deltopectoral flap, while still occasionally used, has morphed into the internal mammary artery perforator (IMAP) flap.[4]

The introduction of microsurgical techniques to the head and neck revolutionised this area of surgery and made possible many procedures that were hitherto fraught with major complications or impossible to perform safely. This saw the end of the tubed pedicle flap and significantly reduced the morbidity seen with these procedures.[5] The groin flap was one of the initial common flaps in microsurgery as it was the first flap recognised to have an axial blood flow.[6,7] Many microvascular free flaps of every region of the body were then described in quick succession, although not all are suitable for head and neck reconstruction.

Flap surgery has undergone an evolution as our anatomical knowledge increased over the years. Mathes and Nahai opened the door to the rapid evolution of flaps in the 1980s by classifying muscle blood supply.[8] What was originally known as the 'Chinese flap' and more commonly known now as the radial forearm flap was introduced by Song in 1982.[9] This flap was revolutionary in that it brought us for the first time a thin pliable flap, with a long vascular pedicle and the potential for innervation. Despite its suboptimal donor site, it is ideal for many applications in the head and neck, and is still widely used 36 years later. Admittedly, many alternative fasciocutaneous free flaps are now available for situations where the radial forearm free flap is deficient (such as in donor site cosmesis and morbidity, or insufficient flap surface area and volume), including the anterolateral thigh (ALT), medial sural artery perforator, and scapular and thoracodorsal artery perforator free flaps.

The ALT flap in particular has many attributes that make it an unsurpassed option in head and neck reconstruction today. Apart from relative anatomical consistency and a donor site with little morbidity, it is highly versatile—with multiple skin paddles, as a chimeric flap with separate skin and muscle components, and as a conjoint flap with the anteromedial thigh flap or tensor fascia lata flap.[10] Flaps from the subscapular axis also allow a wide variety of configurations, including the latissimus dorsi and serratus anterior muscles, and the scapular borders and angle, but a major limitation is the difficulty it presents in a two-team simultaneous resection-reconstruction approach.

Taylor described the first osseocutaneous deep circumflex iliac artery flap in 1979,[11] paving the way for Urken to describe the internal oblique-iliac crest osseomyocutaneous free flap for head and neck reconstruction.[12] The muscle component has superior conformity for reconstruction of the intraoral mucosal defect to the osseous component. Hidalgo brought mandibular reconstruction to the present era when he introduced the fibular osseocutaneous flap in 1989.[13] Though not the only reconstruction method available, it remains ideal for mandibular reconstruction by allowing us to perform complex reconstructions elegantly and reproducibly. The addition of the technique of osseointegrated dental implant reconstruction by Branemark allowed for a complete and functional reconstruction, with reasonable success nowadays even in the setting of adjuvant radiotherapy.[14,15]

We see that our knowledge of flaps has advanced so much in the past 50 years that we have gone from the era when flaps were virtually random, through axial flaps, myocutaneous flaps, fasciocutaneous flaps to our current use of perforator flaps, which we can now use in a freestyle manner to customise our reconstructions and minimise the morbidity of our donor sites.[16] In fact, perforator flaps have expanded our reconstructive choice for many defects of the head and neck. Hofer first introduced the facial artery perforator (FAP) flap[17] and, though not often used, is nevertheless a very useful flap to have in our armamentarium as it adheres to that basic principle of replacing like with like.

The submental flap[18] is an excellent flap for soft tissue reconstruction in the head and neck, providing excellent skin quality and colour where metastasis to the submental and submandibular nodal basins is not a consideration. Some might argue that perforator flaps are merely refinements of pre-existing flaps—for example, the superficial circumflex iliac perforator flap (SCIP) is the 'new' groin flap, just as IMAP is to deltopectoral, and FAP is to the nasolabial flap. The development and acceptance of perforator flaps, however, required a complete paradigm shift in how we approached the vascular pedicle and perforators—from avoidance to virtual skeletonisation, albeit with finesse. Despite these wonderful new flaps, we still regularly use the earliest flap—the forehead flap—as well as other tried and true traditional techniques such as the Abbe and Estlander lip-switch flaps. We therefore have a much-expanded choice of reconstructive options, all of which have advantages and disadvantages.

Many other innovations have made microsurgery more reliable. Devices such as microclips and the microvascular anastomotic coupler are time-efficient and cost-effective.[19] There are also ever-increasing adjuncts to conventional clinical assessment of microvascular free flap viability, with variable efficacies, including the implantable Doppler, laser Doppler flowmetry, near infrared (IR) spectroscopy and IR thermography[20-22] and fluorescent angiography.[23] These technological advances further remove the mystique of microsurgery, and enable it to be widely practiced.

Skull base surgery

No single area better illustrates how our methods have changed and how evolutions and innovations have influenced our current practice than the skull base. Skull base surgery was once associated with such high morbidity and mortality that it was a last resort. The surgery was made possible in the first place by the application of craniofacial principles developed by Tessier and others. The lethal complications that were all too often seen were meningitis, cerebrospinal fluid (CSF) leak and brain abscess. This changed with the introduction of microsurgery. The use of free flaps allowed the intracranial contents to be reliably separated from the upper aerodigestive tract and we saw significant reductions in the number of lethal complications.[24]

As the field developed and newer techniques became available, we saw the introduction of endoscopic approaches to the skull base.[25] At first, we began to see the reappearance of the earlier complications because the free flaps we had previously used were no longer applicable in the endoscopic approach. This led to the development of new flaps and new techniques to separate the cranial contents from the upper aerodigestive tract. So we saw the introduction of the nasoseptal flap,[26] the endoscopic application of the pericranial flap[27,28] and the transpterygoid approach for introduction of the superficial temporoparietal fascia to the skull base.[28]

While this phenomenon is best illustrated in the skull base, there are several other examples in the head and neck where an innovation in one area drives an evolution in another. Indeed, enhanced knowledge of intranasal vascular anatomy has led to the refinement of other flaps, such as the inside-out septal mucoperichondrial flap.[29]

Craniofacial surgery

We have already mentioned that skull base surgery was born from advances made in craniofacial surgery. One important advance in craniofacial surgery originated from the field of musculoskeletal surgery—that of bone lengthening first introduced by Ilizarov.[30] This was adapted to the craniofacial skeleton by McCarthy and radically changed craniofacial surgery.[31] Congenital deformities once treated with staged open procedures are now addressed with distraction osteogenesis. Distraction can also be applied to other situations and has simplified our approach to many difficult situations.

In some respects, less has become more in craniofacial surgery. Pioneered by Lauritzen, spring-assisted cranioplasty is now favoured by some centres over total cranial vault remodelling in cases of non-syndromic sagittal craniosynostosis due to its superior morbidity profile.[32,33] The introduction of structural fat grafting by Coleman, despite initial concerns for its safety, has experienced a surge in popularity either as an alternative or an adjunct to microvascular free flaps in correcting facial contour deformities in oncology, trauma and developmental abnormality,[34] with the added benefit of tissue rejuvenation.[35] For better or for worse, the medical industry is increasingly involved with the medical profession. It is sometimes difficult to ascertain which is the driving force but we are also seeing an ever-expanding array of synthetic implants and injectables, which are favoured by some over traditional osteotomy and bone advancement procedures, such as genioplasty and malar augmentation. Only time will tell whether or not they provide the longevity we hope for.

Facial reanimation

Using functional muscle transfer for facial reanimation has been performed since Harii first reported it in 1976.[36] The contralateral normal facial nerve was and remains the ideal way for driving the transferred muscle through a cross facial nerve graft (CFNG), though other nerves, such as the accessory nerve, were first reported for anastomosis with the facial nerve in 1950.[37] Manktelow and Zuker reported using the nerve to the masseter muscle to animate patients with Möbius syndrome having a free functioning muscle transfer.[38]

A controversy arose as to whether the CFNG or the nerve to the masseter is the superior donor nerve for functional free muscle mid-face reanimation. The better spontaneity of smile and muscle resting tone offered by the CFNG is weighed against greater number of motor axons and smile excursion attributed to the masseter option. Dual coaptations are now not uncommonly performed using both the ipsilateral nerve to masseter and the contralateral facial nerve with a CFNG.[39] Further, a sensory nerve—that is, a branch of the infraorbital nerve being coapted to the CFNG—has recently been shown to provide pathway protection of the CFNG by increasing the number of motor axons that successfully traverse the CFNG to ultimately be available for the target muscle.[40] Koshima has introduced supermicrosurgery into this area and has reported repairing up to 3cm facial nerve gaps with vascularised fascicular turnover flaps with good results.[41]

Direct neurotisation of an anaesthetic cornea with the contralateral supratrochlear/ supraorbital nerve first described by Terzis[42] is another revolutionary concept, where nerve fascicles of the donor nerve are sutured directly to the corneal limbus.

Stereolithography and 3D printing

Computers have improved our precision, particularly in designing osteotomies and placing implants. With the aid of stereolithography[43] we can produce models derived from CT scans that allow us to plan and execute reconstruction (and resection) precisely. On mandibular reconstruction, for example, using computer-designed jigs to make accurate osteotomies in a fibula allows us, ahead of time, to be confident in the knowledge that everything will fit almost exactly.[44] Virtual surgical planning has also shifted the paradigm of dental rehabilitation for oncology patients. Pioneered by Urken and popularised by Levine, primary placement of osseointegrated dental implants into free flaps in the same operative setting as tumour resection (prior to radiotherapy) is rapidly gaining traction.[45,46]

Robotic surgery

Because so much of the head and neck is difficult to access, the application of robotics in this area is intuitive, and transoral robotic surgery (TORS) is a reality.[47] This organ-preserving technique allows the surgeon to remove tumours of the upper aerodigestive tract without external incisions. Such an approach reduces morbidity and improves quality of life for patients.[48] As with all innovations, this has demanded further evolution of our reconstructive techniques,[49] a process that is ongoing. While the DaVinci system is so far ubiquitous, robots designed for microsurgery are currently in development that will further change the landscape.

Tissue engineering

Despite ongoing optimism, unfortunately tissue engineering has not entered clinical practice beyond skin cell regeneration for application to burns. Despite the advent of decellularised extracellular matrix from human donor organs, three-dimensional bioprinting scaffolds and human pluripotent stem cells, we are still not close to producing a human organ analogue.[50]

Vascularised composite allotransplantation

A review of head and neck reconstruction would not be complete without mention of facial transplantation. Facial transplantation, although not 'life-saving', is without doubt life-changing—but comes at the steep price of a life-long requirement of immunosuppression. For this reason it has, for the most part, been confined to those patients who could not be reconstructed by conventional means. This controversial area is nevertheless being practiced, albeit in a very limited way, and it is interesting to note that the three most recent units approved for vascularised composite transplantation by UNOS (united network for organ sharing) in the US, being the Mayo Clinic, the University of Michigan and the University of Washington, received their approval on the basis of 'state of practice' and not on the basis of an institutional review board-approved research proposal (the equivalent in Australia would be a human research ethics application). In other words, for purposes of approval, facial transplantation is no longer considered experimental. While more than 38 facial transplantations have been carried out worldwide, this procedure is not without risk since several recipients, including the world's first transplant patient, have died, either from rejection, sepsis or malignancy.

Conclusion

Head and neck reconstruction is a complex area of practice that seems to become more complex as surgical techniques evolve. However, it must be remembered that evolution and development is not just happening in surgery but also in fields such as radiation and medical oncology, both of which have a major impact on what reconstructive surgeons do and how the field will change with time.

The history of plastic surgery has been one of innovation regardless of the area of reconstruction. As a specialty, we tend to develop novel techniques for addressing difficult problems, and not infrequently new approaches are adopted and sometimes taken over by other specialties to the exclusion of plastic surgery. We are vulnerable to this because of the fact that this specialty is often not the 'gatekeeper' for patients with the particular problem being addressed. Head and neck surgery is one such area. Continuing to innovate, adapt and introduce new techniques and approaches is our best protection in ensuring that head and neck reconstruction remains in our domain.

Disclosure

The authors have no financial or commercial conflicts of interest to disclose.

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