Paparella: Volume IV: Plastic and Reconstructive Surgery and Interrelated Disciplines

Section 1: Plastic and Reconstructive Surgery

Chapter 5: Microvascular Surgery for Head and Neck Reconstruction

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Modern head and neck surgery is characterized by its emphasis on reconstruction and rehabilitation. Over the past 20 years there have been dramatic improvements in the treatment of head and neck cancer. Before the 1960s the drive to ablate head and neck cancer, seemingly at all costs, frequently resulted in radical ablations with horrendous deformities and significant morbidity. Aesthetic and functional considerations were thought to be secondary since, at that time, maximal cure rates had not yet been achieved. During the 1960s and 1970s combination therapy, including radiotherapy with surgery, proved in many circumstances to yield higher cure rates than aggressive ablative surgery alone. At about the same time, very radical surgical and radiotherapeutic treatment regimens were brought under close scrutiny by some surgeons who pioneered a new revolution in conservation therapy. They showed that, frequently, less tissue could be removed without compromising the cancer cure rates. Since the 1970s there has been a virtual plateau in the cure rates for tumors of most regions in the head and neck. Currently, head and neck surgeons find themselves paying much more attention to reconstruction and rehabilitation in their treatment of the patient with head and neck cancer. They no longer view the often horrendous deformities created by radical ablative surgery around the head and neck as an inevitable consequence of tumor control. Now the focus is on functional and aesthetic restoration.

Over the past two decades there has been a steady advance in the available surgical techniques for reconstruction of head and neck defects. Before that time most defects, irrespective of size and location, were closed either with local tissues or with random pattern skin flaps that were pedicled and "walked" to the head and neck from the trunk in long, tedious staged procedures. Very rarely was much effort expended in an attempt too replace missing tissue other than skin. The first major advance in this modern era of reconstructive surgery came with the delineation by McGregor (1963) of the axial pattern skin flap. His forehead flap was initially used for reconstruction of oral defects. The increased predictability of this axial pattern skin flap provided a dramatic improvement in functional restoration within the oral and facial region, and a much more predictable and successful surgical outcome than had been entertained before this time. However, the donor site left by this flap was quite deforming, with a skin graft over the forehead pericranium. A second axial pattern skin flap was introduced by Bakamjian (1965), whose deltopectoral flap became another standard for head and neck reconstructive surgery over the ensuing decades. The donor site on the shoulder provided a much more acceptable donor defect from an aesthetic standpoint. These flaps, however, were limited in their arc of rotation by the pedicle length. They required staged procedures with split-thickness skin grafts to the donor site on the chest and shoulder. The deltopectoral flap provides thin, pliable skin, but many head and neck defects demand more than this for adequate reconstruction. Although limited, these two flaps were the standard optimal flaps available for reconstruction during the late 1960s and early 1970s.

Microvascular transfer of free tissue grafts to the head and neck was performed as early as 1959 by Seidenberg and associates, who used revascularized free jejunal segments to repair defects of the pharyngoesophagus. McLean and Buncke transferred omentum as a free flap pedicled on the gastroepiploic vessels to cover a cranial defect in 1972. His omental vascular pedicle was anastomosed to the superficial temporal artery and vein.

Daniel and Taylor described a free cutaneous flap in 1973 and Panje and colleagues first published a description of the use of such a free cutaneous flap for head and neck reconstruction in 1976. Panje transferred the groin flap pedicled on its direct cutaneous artery, the superficial circumflex iliac artery, to repair an intraoral defect. This groin flap enjoyed an early success for head and neck reconstruction but there were significant associated technical difficulties. The vascular pedicle was inconsistent and the vessels were very small in diameter, with a short pedicle. The flap itself was usually bulky and thick, and provided a poor color and texture match for reconstruction of most head and neck defects.

The evolution of free cutaneous flaps continued. A lateral axillary free cutaneous flap was also described about this time. This was based on an inconsistent cutaneous artery arising from either the lateral thoracic or subscapular arteries in the axilla. The pedicle was inconsistent and not very reliable. A free cutaneous flap from the dorsum of the foot was also described, based on the dorsalis pedis artery, which supplies the skin of this region together with the second metatarsal and second toe. This flap provided a much more reliable vascular pedicle and a much more appropriate match of tissues for reconstruction of certain head and neck defects, specifically mandibular and intraoral defects. The second metatarsal could be used for certain limited mandibular defects, while the thin, pliable skin of the dorsum of the foot provided a close match for intraoral tissue replacements. The vessels were large, and transfer of these flaps was much more reliable and successful. Enthusiasm for this flap remained limited, however, in large part owing to the relatively complicated harvesting procedure and, perhaps more important, to the significant associated donor morbidity. The dorsum of the foot required skin grafting, and these grafts frequently became unstable with normal footwear.

During this period, an extremely reliable and valuable free flap was developed. The latissimus dorsi musculocutaneous flap, pedicled upon the thoracodorsal artery and vein, which branched from the subscapular vessels in the axilla, was transferred as a free flap to the head and neck as early as 1976 by Harii and colleagues. By the middle to late 1970s the microvascular transfer of free flaps to the head and neck become relatively commonplace. However, only a limited number of surgeons were performing these procedures, and the technique in general did not capture widespread support. A limited number of flaps were available at this time and they failed to adequately address the needs of many head and neck reconstructions. The tissue requirements of many head and neck defects included bone, skin, muscle, or combinations of these tissues. These newer free flaps provided much more latitude than the pedicled axial pattern skin flaps, but the price was high. The vascular pedicles on the available flaps at that time were usually short, with vessels of very small diameter. This led to significant technical difficulties in microvascular anastomoses, with predictable rates of complications and flap failure. These factors, most particularly the perceived difficulty of the microvascular anastomotic technique, seemed to constitute an insurmountable barrier for most head and neck surgeons.

Many investigators were looking for new and improved donor sites for free tissue transfer. This quest and the aggressive investigation of cutaneous vascular supply over the body ironically lead in the late 1970s to the rediscovery of the pedicled musculocutaneous flap. Tansini had described the pedicled latissimus dorsi musculocutaneous flap for breast reconstruction in the late nineteenth century, but it was not until 1976 Olivari rediscovered and published this most exciting concept. These pedicled musculocutaneous flaps provided the next major breakthrough in head and neck reconstructive surgery, and seemed for a time to almost totally eclipse free tissue transfer by microvascular technique for such reconstruction. The pectoralis major and trapezius musculocutaneous flaps joined the latissimus dorsi flaps as the principal reconstructive tools for the head and neck surgeon by the end of the 1970s. Sternocleidomastoid and platysmal musculocutaneous flaps were described, and composite flaps involving bone were also produced. Ariyan (1979) reported the harvest of the fifth or sixth rib along with the pectoralis major flap, and Demergasso and Piazza (1979) described the harvest of the spine of the scapula in continuity with the trapezius musculocutaneous flap. These pedicled musculocutaneous flaps were reliable, quick, and easy to harvest and provided one-stage repair for most defects of the head and neck. They also provided more bulk than had been available with the pedicled axial pattern skin flaps, with more attendant latitude in decision making regarding reconstruction of any given defect. The composite flaps, most notably the trapezius osseomusculocutaneous flaps, also provided the ability to tailor the donor tissue more closely to the requirements of the head and neck defects. Enthusiasm for microvascular free flaps for head and neck reconstruction declined as it appeared that they had little to offer in regard to better tissue match or improved function over the available and more easily performed musculocutaneous flaps.

Over the past decade two interesting factors have influenced head and neck reconstructive surgery. First, the limitations of the pedicled musculocutaneous flaps have become apparent. Second, and perhaps more important, the search for new and better donor sites for reconstructive flaps had not stopped during the revolution produced by musculocutaneous flaps. Investigators found many more free flap donor sites that possessed longer vascular pedicles with very large vessels and were made up of various tissues, including skin, muscle, bone, and nerve, allowing far greater choice for reconstruction of any given defect. In addition to the free transfer of latissimus dorsi musculocutaneous flaps, Harii and colleagues (1976) described the free transfer of a gracilis muscle flap with revascularization and microneural anastomosis for facial reanimation. The Chinese surgeons Yang and colleagues described the radial forearm fasciocutaneous flap as early as 1981. Taylor and Watson had harvested portions of the iliac crest based on the superficial circumflex iliac artery and attendant groin flap in 1978. In 1979 Taylor and colleagues described the superiority of the iliac crest composite flap based on the deep circumflex iliac artery. This has continued to be a standard reconstructive technique for very large defects of the mandible. The revascularized osseous or composite iliac crest flap is extremely reliable and provides such a large amount of bone that reconstruction of mandibular defects from the condyle to the opposite angle is possible. These large bone flaps can accommodate osseointegrated implants, and provide the ultimate in functional restoration after mandibulectomy. The scapular skin flap was described by dos Santos (1980) and the parascapular skin flap by Nassif and colleagues (1982). Both of these flaps are based on terminal cutaneous branches of the circumflex scapular artery. Swartz and associates (1986) expanded upon the scapular flap and described the osseous and osseocutaneous flaps based on these circumflex scapular vessels. Baek (1983) introduced the lateral cutaneous thigh flap. The rectus abdominis muscular and musculocutaneous flaps, which had been used as pedicled flaps, became popular about this time as free flaps based on the deep inferior epigastric artery and vein. There was a cascade of descriptions and elaborations of various new and improved free flap donor sites. Now, many more options for reconstruction of any given defect were available to the surgeon facile not only with pedicled musculocutaneous flaps but with free tissue transfer techniques.

Patient Selection

With the expanded scope of options available to the head and neck surgeon, the job of decision making becomes more interesting and fruitful (Table 1). The surgeon must consider the type and amount of each tissue required for proper restoration of form and function. He must assess the need for motor or sensory reinnervation of replaced muscle or skin, respectively. He must assess the anticipated functional gain from the replacement of each missing tissue. Defects within the head and neck pose special problems for patient and surgeon. Aesthetically and emotionally the patient meets the world with his or her face. A careful replacement of tissue loss with like tissue, with similar static and dynamic properties to the tissue lost, is desirable. Because of the association with the aerodigestive tract and special sensory systems, functional rehabilitation is especially important with head and neck defects. The need for different tissues in composite tissue transfer can vary dramatically among patients. Restoration of oral competence often demands a thin and pliable skin flap or a mucosal flap for superior reconstruction instead of a thick and bulky flap. The mobility of surrounding structures, ie, the tongue and pharyngeal walls, must always be considered in the functional goals of such reconstructions. Mandibular resections may require small amounts of bone with very large soft tissue requirements for closure of both intraoral and external skin coverage, or in selected patients may require very large bony components with minimal, if any, soft tissues.

The surgeon must be cognizant of the potential morbidity associated with each donor flap harvested. The expected success rate of a transposition must be weighed against the difficulty of performing each procedure, which translates into operative time for the surgeon and patient. The patient's general medical status is a necessary consideration in each decision. The prolonged operative time often associated with many free flap reconstructions may be contraindicated in certain patients. On the other hand, the distant donor sites far removed from the head and neck provide an opportunity for synchronous double team surgery and actual shortening of operative time, unlike the situation with many regional flaps.

Table 1. Criteria for Selection

Amount(s) of tissue required
Innervation required
Anticipated functional gain
Anticipated donor morbidity
Success rate
General medical status
Patient position
Donor location
Operative time
Surgical skills required.

Microvascular free flap transfer once again provides a major and leading role in the reconstruction of head and neck defects. Its preeminent position as the reconstructive approach of choice in the repair of many complex defects facing the head and neck surgeon is no longer in question. No other surgical technique offers such a wide choice of potential donor tissues. The surgeon is now free to choose from multiple donor options for reconstruction of any given defect. This flexibility permits the surgeon to make a much more critical appraisal of the tissue requirements for each patient and makes it possible thereby to provide a superior tissue match. If the defect requires a thin and pliable skin flap, skin donor sites should be considered before a bulky musculocutaneous flap is harvested. If anterior mandible is sacrificed with or without soft tissues in a patient who has been radiated, a revascularized bone flap is the only means of providing reliable and optimal reconstruction. An added advantage is found with the greater latitude provided in tailoring and positioning of free flaps relative to pedicle flaps in many difficult areas, such as defects in the medial skull base.

Free Flaps

There is now available a wide spectrum of microvascular free flaps for head and neck reconstruction. A variety of the most commonly employed flaps will be described with examples of their clinical applications. This is not intended as a comprehensive review of all available flaps but rather an overview of the more important flaps in use at this time.

Free Cutaneous Flaps

Skin is the most expendable organ in the body. Free cutaneous flaps are a primary choice for defects of skin but also some are thick enough after deepithelialization to be ideal for providing bulk, since the revascularized subdermal tissues and fat will not atrophy. Free cutaneous flaps should always be considered also when deciding on the appropriate flap for reconstruction of mucosal defects. It is frequently inappropriate to sacrifice a muscle simply as a carrier for a skin flap, as with a musculocutaneous flap, when the defect requiring reconstruction involves only the loss of skin or mucosa. Various free cutaneous flaps are now available with long and attractive pedicles. The flaps vary in size, thickness, hair-bearing qualities, and donor defects. The surgeon's ability to harvest more than one free flap of any given tissue type allows much greater latitude in choosing the most appropriate flap for each defect.

Lateral Thigh

The lateral cutaneous thigh flap is a fasciocutaneous flap based on the third perforator of the profunda femoris artery and its attendant venae comitantes. The third perforator exits the intermuscular septum between the firm vastus lateralis anteriorly and the more fleshy biceps femoris muscles posteriorly. The artery arborizes in the subdermal fascia to provide a rich vascular supply to the skin of the lateral thigh.

This flap can be very large and is very often thin and pliable with little hair, even in male patients. In obese patients, especially females, the flap thickness may be considerable in the area of "saddlebags". The vascular pedicle is long, measuring up to 15 cm, and the vessels may be very large with arterial diameters of 2 to 4 mm and venous diameters of 2 to 4 mm. With such large diameters, microvascular anastomoses between these donor vessels and the recipient vessels in the neck are relatively easy to perform. The lateral thigh flap possesses excellent vascularity and comes from a nonradiated site. The donor site is far removed from the head and neck, and synchronous two-team surgery is possible. The donor site is closed primarily with no significant functional loss and an easily camouflaged linear scar.

The versatile lateral thigh flap has many applications in the head and neck. It is particularly useful in the reconstruction of large circumferential defects of the pharyngoesophagus. The thin, pliable nature of the flap allows for easy contouring and insetting of the flap at the distal anastomosis in the root of the neck behind the trachea. By use of a staggered anastomosis with the esophagus, the risk of annular scar formation with subsequent stricture is reduced. The large amount of skin available (often 10 x 20 cm) can provide excellent coverage for large skin defects anywhere in the head and neck. This thin, pliable flap may be ideal for reconstruction of oropharyngeal and oral cavity defects in selected patients. For more obese patients this flap can be used for facial augmentation such as in facial microsomia. In these cases the flap is deepithelialized and buried under facial flaps.

This flap may be harvested as a sensate flap if the lateral femoral cutaneous nerve of the thigh is maintained as it enters the anterosuperior aspect of the flap. There are few disadvantages to this flap. The most notable is the difficult dissection deep in the leg near the profunda femoris artery. This requires an assistant for retraction of the vastus lateralis. Very rarely the dominant pedicle to the skin of the lateral thigh is the fourth perforator of the profunda femoris artery. Allowance for this can be made by always raising a long ellipse of skin down to the intermuscular septum. Once the dominant vascular pedicle has been identified, trimming of the flap is possible. The flap may be hair bearing, but this is only a relative contraindication in patients who are to receive postoperative radiotherapy, since such treatment usually obliterates the hair follicles.

Radial Forearm

The radial forearm flap is another fasciocutaneous flap, this time supplied by the radial artery with venous drainage by means of the venae comitantes accompanying the radial artery as well as through the subcutaneous veins of the forearm. This flap has become one of the workhorse flaps for head and neck reconstruction. It is easy to harvest by a second team owing to its remote location from the head and neck. The radial artery runs in the lateral intermuscular septum separating the flexor and extensor compartments of the forearm. Multiple perforators through this intermuscular septum supply the skin over the volar aspect of the forearm from the elbow to the wrist, as well as a portion of the radius. Consequently one can harvest this flap as a fasciocutaneous or osseofasciocutaneous flap. The skin of the forearm is some of the thinnest and most pliable skin on the body and is frequently hairless. This flap has one of the longest vascular pedicles available at present, measuring up to 18 cm. The vessels can be extremely large. Unlike most flaps, the pedicle vessels can be identified and marked out on the forearm before flap elevation. This flap can also be harvested as a sensate flap if the medial or lateral cutaneous nerves of the forearm are taken with the skin. It is very important to perform an Allen's test before harvesting the flap, because the radial artery is necessary for perfusion of the hand in a limited number of patients.

The major disadvantage of this reliable flap is cosmetic. The donor site in all but the very smallest flaps requires skin grafting. In the case of a positive Allen's test, there is a potential threat to the hand when this flap is harvested, even if interpositional vein grafts are inserted.

This flap has become one of the most popular tools for reconstructing skin defects or mucosal defects in the head and neck. Its thin, pliable nature allows easy placement for intraoral and pharyngeal defects.

Scapular and Parascapular Flaps

The circumflex scapular artery has a terminal cutaneous branch that exits through the triangular space bounded by the teres major, teres minor, and long head of triceps lateral to the scapula. This terminal cutaneous branch of the artery bisects in the subdermal fascia, sending a horizontal branch toward the midline and an oblique branch down the lateral border of the scapula. Both of these direct cutaneous vessels will carry a flap. The horizontally running artery supplies the scapular flap, and the oblique artery the parascapular flap. These flaps are extremely reliable and can be raised as a double-paddled single flap. The vascular pedicle is long, measuring up to 14 cm if the vessel is dissected all the way back to the subscapular artery and vein. Alternatively the vascular pedicle can be sectioned before the takeoff of the thoracodorsal vessels, providing vessels of smaller diameter (the artery usually measuring 2 mm and the vein 2 to 3 mm) and a slightly shorter pedicle of approximately 11 cm. The skin of the back is usually the thickest skin on the body. However, there is often limited subcutaneous tissue, providing, overall, a relatively thin and pliable flap that is hairless in many patients. The dissection of the vascular pedicle down through the triangular space demonstrates the direct osseous branches of the circumflex scapular vessel entering the lateral border of the scapula. These allow a composite osseocutaneous flap to be developed. It is usually possible to close the donor site primarily with a scar on the posterior shoulder and back, which is easy to cover.

A relative disadvantage of this flap is that it requires special positioning of the patient. Synchronous two-team surgery is possible but difficult. It necessitates the use of a bean bag on the operating room table and a special neurosurgical headholder. The patient can be placed in a 45- to 60-degree lateral-oblique position with the ipsilateral arm retracted on an armholder. The head can then be positioned for synchronous head and neck surgery.

The scapular and parascapular skin flaps provide very large paddles for coverage of large head and neck soft tissue defects. The flaps are rarely thin and pliable enough to be primary contenders for intraoral or pharyngeal reconstruction. The major application for the skin flaps appears to be in facial augmentation, since the deepithelialized flap is of appropriate thickness and conformity for buried augmentation in this area.

The primary application of scapular flaps is as composite flaps with bone for mandibular reconstruction with soft tissue defects (see below).

Free Muscle or Musculocutaneous Flaps

Rectus Abdominis

The rectus abdominis free flap is pedicled upon the ipsilateral deep inferior epigastric artery. This artery originates from the medial side of the external iliac artery at about the same level that the deep circumflex iliac artery originates from its lateral side. The artery courses under the lateral border of the rectus muscle inferior to the arcuate line, and travels along the undersurface of the muscle to anastomose with the superior epigastric artery on that side. A very rich vascular supply to the muscle is provided, and multiple perforators supply the overlying skin. The greatest concentration of perforators are found in the periumbilical region and tend to radiate out to the skin over the entire abdomen. The largest skin paddles currently available are those pedicled upon the rectus abdominis muscle. These cutaneous paddles can be transversely oriented as the TRAM (transverse rectus abdominis musculocutaneous) flap or elevated obliquely in a superolateral direction, radiating from the umbilicus as far as the midaxillary line. The vascular pedicle can be long, up to 15 cm, if the muscle below the umbilicus is trimmed to follow the pedicle closely until it lies free between the lateral muscle border and the external iliac vessels. The vessels are large in diameter, arterial sizes measuring 2 mm and the associated deep inferior epigastric veins 3 to 4 mm. The long pedicle permits an anastomosis with recipient vessels far removed from the recipient site without the need for vein grafts. This flap is extremely easy to elevate, with a very reliable vascular supply. The patient is in the supine position and does not require repositioning. The donor site is far enough removed from the head and neck for teams of ablative and reconstructive surgeons to operate synchronously.

Since the rectus flap can provide the largest of available skin flaps (20 x 40 cm), it is capable of providing excellent coverage for very large facial and scalp defects. In many patients this flap may be too thick to be effectively tubed for pharyngoesophageal reconstruction, or too bulky for oropharyngeal defects.

An innervated flap is not available, since the rectus muscle is innervated by segmental nerves entering its lateral border. The rectus abdominis muscle flap is extremely useful for reconstruction of skull base defects. It provides an appropriate amount of well-vascularized muscle with a long vascular pedicle, and harvesting is quick and easy. The fibrous intersections along the rectus muscle provide excellent suspension points for suture placement when securing the flap in difficult recipient beds.

Since the rectus abdominis muscle provides a major component for support of the anterior abdominal wall, care must be taken to avoid the formation of ventral hernia. This risk can be minimized by careful reconstitution of the anterior rectus sheath inferior to the arcuate line.

Latissimus Dorsi

The latissimus dorsi is a large, fan-shaped muscle originating from the lower thoracic spinal processes, the thoracolumbar fascia and the iliac crest. It inserts into the humerus. The muscle receives a primary blood supply from the thoracodorsal artery, a large terminal branch of the subscapular artery. Venous drainage is provided by attendant venae comitantes draining through large thoracodorsal and subscapular veins into the axillary vein. Musculocutaneous perforators provide a rich vascular supply to the overlying skin, especially proximally, and a very predictable musculocutaneous flap. The latissimus dorsi muscle is innervated by the thoracodorsal nerve, which offers the possibility of a revascularized and reinnervated muscle or musculocutaneous flap. The flap can be harvested with the patient in the 30- to 45-degree lateral-oblique position, which does not compromise synchronous head and neck surgery. Dissection along the anterior border of the latissimus dorsi muscle provides access to the thoracodorsal pedicle, which enters the undersurface of the muscle just behind the anterior border in its proximal third. Once the vascular pedicle has been identified, axillary dissection is relatively simple, the branches of the thoracodorsal system to the serratus muscle and the more proximal circumflex scapular vessels being apparent. Once the pedicle has been isolated, an appropriate-sized muscle or musculocutaneous paddle is developed. If reinnervated muscle is required, the thoracodorsal nerve is preserved. A decision is then made as to the length and diameter of vascular pedicle required. Pedicle lengths of 7 to 10 cm are available, depending on the level of section. Specifically, the thoracodorsal vessels can be sectioned distal to the origin of the circumflex scapular vessels from the subscapular system. Alternatively, the circumflex scapular vessels can be sacrificed and the vascular pedicle dissected all the way up to the subscapular vessels to the axillary system. This provides greater length and extremely large vessel diameters, 2 to 3 mm for the artery and 3 to 5 mm for the vein.

The latissimus dorsi provides the second largest skin paddle available in the body. Unlike the rectus abdominis musculocutaneous flap, however, all the skin of the latissimus dorsi is centered over the muscle. This provides a more bulky flap than the rectus abdominis in most situations. This extremely large flap is available for covering very large defects. It is frequently too thick to allow tubing or for the provision of thin intraoral coverage. The muscle flap can be reinnervated and provide functional muscle for facial reanimation. The reinnervated, revascularized latissimus dorsi musculocutaneous flap can provide reconstruction of the total glossectomy defect when the larynx has been preserved with the assurance that the reinnervated muscle, although not mobile, will not atrophy and thereby maintain bulk and help prevent aspiration.

The functional morbidity associated with sacrifice of the latissimus dorsi muscle is minimal. The scar is placed in the posterior axillary line, swinging onto the back posteriorly and inferiorly. Extremely large flaps can be harvested with primary closure of the skin defect.

Composite Free Flaps (Including Bone)

It is now recognized that ablative surgery around the mandible and associated soft tissues in patients who have received or will receive high-dose radiotherapy presents special problems for reconstruction. Nonvascularized bone grafts and alloplastic implants have limited success in these radiated fields. It has been amply shown that vascularized bone is essential to the predictable reconstruction of mandible in these patients. No other currently available technique of pedicle flaps can provide the range of options for revascularized bone and soft tissue replacement that is available with microvascular free flap transfer. The ultimate restoration of form and function now includes the placement of osseointegrated implants in the neomandible. This requires vascularized bone of sufficient dimensions to accept osseointegration.

Scapula

The bone of the lateral scapula is fed by osseous branches of the circumflex scapular artery. As the artery comes up through the triangular space, it sends short branches into the lateral border of the scapula as a leash of vessels fanning out up and down the lateral border over a distance of approximately 2 cm. This provides a rich vascular supply to the bone, both endosteal and periosteal. As mentioned above, the scapular and parascapular skin flaps receive their blood supply from terminal cutaneous branches of the same circumflex scapular artery as it continues toward the skin. These cutaneous branches are quite separate from the osseous branches. This allows the bone flap and skin flap(s) to be harvested as a composite flap and rotated about each other without concern for vascular compromise, since both the bone and the skin are on separate vascular stalks. The vascular pedicle is lengthy, and the very large vessel diameters make for easy and reliable microvascular anastomoses.

The bone flap is harvested from the lateral border of the scapula from just below the glenoid fossa to the tip of the scapula. In the average-sized adult, at least 11 to 12 cm of bone is available. The thicker lateral border of the scapula mimics the size of the edentulous mandible. The bone is inset in the mandible with the lateral rim of the scapula inferior and the thin blade of the scapula superior for reconstruction of an alveolar ridge. Since the major component of the bone supply is periosteal, preservation of the periosteum is essential if bone distal to any osteotomy is to be viable. For this reason, both vertical and horizontal bends in the straight lateral rim of the scapula can be created by elevation of the periosteum and attendant soft tissues from both aspects of the scapular graft. With the periosteum retracted and protected, a cutting bur is used to create an ostectomy at the chosen site. The bone is then gently positioned in its new alignment and fixed mechanically in that position. If soft tissue lining is required within the oral cavity, the scapular or parascapular skin flap can be draped over the scapular bone. After complete healing, a second-stage vestibuloplasty is required to secure firm adherence of scapular skin to the new "alveolar ridge". This allows tissue-borne denture placement and proper function. Since two skin flaps are available, adequate soft tissue can be harvested for closure of very large intraoral and extraoral soft tissue defects.

Harvesting of the scapular bone flap requires detachment of the teres major muscle, which must be reattached to the remaining scapular bone. Donor morbidity is relatively low with this procedure so long as proper muscle reattachment is carried out and postoperative physiotherapy is instituted. Synchronous double-team surgery is possible with the patient placed in a lateralized position, the head twisted on a neurosurgical head-holder. This is tedious and one of the major shortcomings of this technique. The length of bone is limited to a maximum of 15 cm in extremely large individuals. The volume of bone is also less than is available from the iliac crest flap.

Ilium

The nutrient supply for the iliac crest is the deep circumflex iliac artery. This vascular pedicle will carry huge amounts of the iliac crest, sufficient to reconstruct the average mandible from the condyle to the opposite angle. As an osseous flap, it is without comparison; it not only provides a very large amount of bone, but because the vascular pedicle is running along the internal aspect of the iliac bone, osteotomies can be performed on the external cortical table, permitting accurate tailoring of the donor bone. The bone has sufficient width and depth to easily accommodate osseointegrated implants as well. Historically, the shortcomings associated with this flap have involved the soft tissue paddle. The skin over the iliac crest does receive some blood supply from perforators that traverse the internal and external oblique muscles and subdermal fat. However, the dominant cutaneous supply to this region actually comes from the superficial circumflex iliac artery. Maintenance of reasonable vascularity to this skin paddle requires preservation and delicate handling of the mesentery containing these cutaneous perforators. This mesentery consists of a cuff of transversus, internal and external oblique muscles with intervening soft tissue between the muscle and overlying skin. This translates into a sometimes very thick and bulky soft tissue skin paddle. Furthermore, this skin paddle must be kept in close alignment over its bone so as not to sheer the cutaneous perforators during flap harvest. For these reasons, the skin paddle may often be too large for intraoral coverage and may be somewhat unpredictable. Urken and colleagues (1989) described a modification of the flap in which a large paddle of internal oblique muscle is used to wrap the iliac crest bone flap intraorally and accept a skin graft. The bulky skin paddle usually associated with the flap is left externally as a marker and can be removed at a later date. This technique eliminates the relative unpredictability of the cutaneous portion of the flap.

Donor morbidity is relatively low in the long term. In the short term, patients complain of considerable pain at the donor site. Most important, the donor site is far removed from the head and neck and the patient is supine, allowing for synchronous two-team surgery. The pedicle is of moderate length, with moderate-sized vessels. The outstanding feature of this flap is the very large amount of predictable bone available.

Radial Forearm

The distal radius received a blood supply from the radial artery. A portion of this distal radius, as much as 10 cm, can be harvested as an osseous flap or, as described above, an osseocutaneous flap. Soutar and colleagues (1983) popularized this composite flap for the reconstruction of mandibular and oral lining defects. It provides a close match of tissues for such defects. The narrow segment of bone is hard and strong and can be curved with osteotomy. It is secured at the superior margins of the mandibular stumps. In this way the very thin and pliable skin flap of the forearm can be draped over the bone to provide the equivalent of an alveolar ridge for denture placement. This flap cannot provide adequate bone or soft tissue for large defects involving mandible and oral structures as well as external soft tissues.

This flap has many advantages, including the remote donor site, which permits double-team surgery, and its relatively easy harvesting. It does, however, carry the potential for significant donor morbidity. In spite of beveled ends on the bony donor site and plaster casting after surgery, pathologic fractures have been reported secondary to weakening of the radius. The risks of vascular compromise to the hand must be assessed with a preoperative Allen's test. None except the very smallest skin donor sites on the forearm can be closed primarily and require skin grafts.

Dorsalis Pedis

The second metatarsal and toe receive a nutrient supply from the dorsalis pedis artery, as does the skin over the dorsum of the foot. The volume of bone available with this flap is comparable with the radial forearm flap, and the thin, pliable nature of the somewhat smaller skin flap is also comparable with the forearm donor. Inset of the metatarsal for mandibular reconstruction is similar to that described for the radius, and an "alveolar ridge" can be produced to support a denture. This is a reliable flap but more difficult to harvest than others mentioned above. It has a quite predictable blood supply and a predictable, sizable vascular pedicle. The distant donor site allows two-team surgery. The most outstanding shortcoming of this flap relates to the donor morbidity associated with skin grafting the dorsum of the foot. Normal footwear can often render the skin grafts unusable, exposing the underlying extensor tendons. This has resulted in a limited surgical following for this flap.

Free Visceral Flaps

Gastro-Omental Flaps

The greater curvatures of the stomach and of the omentum are supplied by the anastomosis of the right and left gastroepiploic arteries. A gastro-omental free flap is available pedicled on either of these arteries, but usually the right side provides a longer pedicle with vessels of larger diameter. The mucosa of the greater curvature of the stomach contains no acid-secreting cells. A flap of this portion of the stomach provides a thin, pliable, smooth, mucosa-lined donor flap with mucus production. The vascular pedicle also supplies the omentum, which can be harvested with the segment of stomach or sacrificed before flap transfer to the head and neck defect. Harvesting of this flap involves a routine laparotomy and delivery of the stomach. The omentum is delivered and the gastroepiploic pedicles evaluated. The coalescence of the right and left gastroepiploic vessels is sectioned and ligated after the desired size of the gastric component is decided. Using a stapling device, a segment of the greater curvature of the stomach is removed after cross stapling and sectioning. All the omentum on the right gastroepiploic system is delivered with the flap. The vascular pedicle, if dissected back to the origin of the right gastroepiploic artery, can be extremely long (up to 25 cm), and the vessel diameters are large, the artery measuring 2 to 3 mm and the vein 3 to 4 mm. The vascular pedicles supplying visceral flaps almost always contain very thin-walled vessels.

The free gastro-omental flap is versatile in that it provides the availability of as much or as little bulk as is required for reconstruction of a given defect. Specifically, the omentum can be trimmed away almost completely by careful sectioning of the nutrient vessels from the gastroepiploic system. Alternatively, almost the entire omentum can be harvested with this flap, providing for significant bulk when necessary. This flap is particularly applicable to reconstruction of defects of the oral cavity and oropharynx in which the mandible has been retained. Access to these defects is usually provided through mandibular-swing procedures. Other, thicker flaps frequently fail to allow closure of the mandibular osteotomy without significant compression and subsequent vascular compromise of such flaps. The thin gastro-omental flap conforms nicely to defects of the oral cavity and oropharynx, including the palate, while still allowing enough room for mandibular closure. When bulk is required, eg, in reconstruction of oropharyngeal lesions together with tongue base resections, or in radical neck dissection when great vessel coverage is desirable, as much omentum as needed can be maintained. The mucosa is smooth and does not trap food particles. In patients who have received ablative surgery for second tumors or for lesions that have already received radiotherapy, and in whom xerostomia has been a problem, a particular bonus of this form of reconstruction is the restoration of secretions in the oral cavity and oropharynx.

This flap is relatively easy to harvest. It provides almost ideal tissue match in selected mucosal defects and has demonstrated very low morbidity.

Of course, the choice of any visceral donor site necessitates a violation of the abdomen, and the attendant morbidity and potential mortality associated with such procedures. In the authors' opinion, if free cutaneous flaps are available that conform to the space and area requirements of the resection, they are usually preferable to visceral donors for this reason. Skin is the most expendable organ in the body, and its harvesting results in significantly lower morbidity than that of any other organ.

Jejunum

Microvascular transfer of the jejunum was first presented for experimental pharyngoesophageal repair in 1958. The second loop of the jejunum is supplied by the mesenteric arteries through an arcade system. Harvesting of this flap is relatively easy. After routine laparotomy, the second loop of the jejunum is delivered, and with backlighting of the mesentery the mesenteric arcade system can be evaluated. An appropriate length of jejunum is identified upon a continuous arcade, and careful sharp and blunt dissection through the mesentery, with ligation and section of appropriate branches of the mesenteric arcades, isolates a segment of jejunum upon a branch of the mesenteric artery and its associated vein. At this time the distal portion of the jejunum is marked with a suture in the serosa. With a stapling device the segment of jejunum is sectioned free. Dissection back to the origin of the mesenteric vessels allows a moderate length of vascular pedicle. The vessel diameters at this point usually measures 2 mm for the artery and 3 to 3.5 mm for the vein. Once the free segments of jejunum has been harvested with section of its vascular pedicle, the cut ends of the jejunum are reapproximated again with a stapling device. Transfer of the free segment of jejunum to the head and neck allows anastomosis of the pedicle vessels with recipient vessels in the neck.

The jejunum is most frequently used as an interpositional graft after total laryngopharyngectomy for reconstruction of the pharyngoesophageal defect. This free segment of jejunum is interposed between the oropharynx and the esophagus. The caliber of the jejunum closely matches that of the proximal esophagus. The proximal anastomosis with the oropharynx is usually carried out after a split in the wall of the antimesenteric border of the jejunum has fishmouthed the bowel to allow a closer approximation with the size of the oropharyngeal outlet. It is important to align the free jejunal segment in an isoperistaltic direction. It is also important to preplan the position of the vascular pedicle relative to the length of the jejunal segment, since the short to moderate length of the pedicle must be considered if tension-free anastomosis with available recipient vessels is to be possible without need for interpositional vein grafts.

This form of reconstruction of the pharyngoesophagus currently enjoys status as the first choice for reconstruction of this defect in a large number of centers. However, morbidity and potential mortality are associated with the necessary abdominal surgery. Postoperative complication rates from this form of reconstruction may exceed 30 per cent when graft necrosis, distal anastomotic stricture, and fistula formation are included with the abdominal complications.

The jejunal free segment may also be used for internal lining of the oral cavity or oropharynx as a patch graft if the jejunum is opened along its antimesenteric border. This flap is mucus producing, and in a previously irradiated and xerostomic patient may provide an excellent reconstruction in that it restores secretions in this area. However, there are horizontal irregularities in the mucosa of the jejunum that, although they tend to flatten somewhat over time, often present a problem with trapping of food. The uncoordinated peristalsis of the free jejunal segment may often provide a functional dysphagia, especially in the early postoperative period. This is because its peristaltic activity is not coordinated with the swallowing reflex initiated in the oral cavity and oropharynx. The free gastric mucosal graft, in the authors' opinion, provides a superior patch graft for reconstruction of oral and oropharyngeal defects. It possesses a longer and larger vascular pedicle, and has the potential for providing much larger (especially wider) donor flaps. Although significant lengths of jejunum are available, the width of open graft is limited by the diameter of the bowel.

Head and Neck Reconstruction

Various defects are presented to illustrate examples wherein microvascular transfer of free tissue flaps represents the obvious best choice for reconstruction.

Pharynx

This section addresses the reconstruction of circumferential defects created by total laryngopharyngectomy. In patients who have undergone laryngectomy with partial or subtotal pharyngectomy, and in whom a strip of pharyngeal mucosa has been preserved, a pedicled pectoralis or latissimus musculocutaneous flap is recommended, since, these techniques provide equally good reconstruction with less effort.

In the circumferential defect, the goal is the reconstitution of an epithelium-lined conduit from mouth to esophagus. An adynamic conduit is acceptable so long as it is of sufficient diameter not to impede the bolus of food propelled by the tongue and constrictors in the remaining proximal oropharynx. The ideal reconstructive techniques would replace this conduit as a one-stage procedure with a high probability of success, low complication rates, and low donor morbidity. Hospitalization should be minimized, since patients undergoing this radical surgery are at high risk for recurrent disease and an abbreviated life span.

None of the historical techniques fulfills all these criteria. Local cutaneous flaps require multi-stage procedures with poor success rates and high local complication rates of skin slough, stenosis, fistula formation, and so forth. These problems are particularly acute when the local cervical skin has been heavily irradiated. Hospitalizations are frequent and often prolonged.

The same can be said for the two-stage deltopectoral flap reconstructions in which a tubed deltopectoral flap is anastomosed end to end with the oropharynx while at the first stage the proximal esophagus is anastomosed end to side to this tube. The donor site is skin grafted and a salivary fistula runs onto the chest until, at a second operation weeks later, the end-to-side anastomosis is taken down and converted to an end-to-end closure of the esophagus with the tubed deltopectoral flap. The remaining deltopectoral pedicle is replaced on the chest. Closure of the distal anastomosis at this second stage is often difficult, and fistula and subsequent stricture formation at the distal anastomosis is common.

The pedicled musculocutaneous flaps provide a reliable one-stage procedure, but the flaps are so thick that tubing them deep in the root of the neck for end-to-end anastomosis with the esophagus is almost impossible. The result is less than a watertight closure with fistula formation. The blood supply to the musculocutaneous flap is so good that these leaks usually close without the need for further surgery, but healing is by secondary intention, with increased scar formation around the distal anastomosis with the esophagus. Stenosis from scar contracture is very common. Deepithelialized pectoralis flaps have been tried with skin grafts, but the natural behavior of skin grafts and of denervated muscles is to contract, and this phenomenon again results in relatively high local complication rates of fistula formation, stricture formation, and stenosis. When a strip of mucosa has been preserved, this dilemma necessitating complete tubing of a thick flap in a confined space is avoided. Therefore, stricture formation is rarely seen when these subtotal defects are repaired with pedicled musculocutaneous flaps. The gastric pull-up provides a one-stage procedure with a short hospital stay in which there is no distal anastomosis, so fistula formation and stenosis are much less of a worry at that site. This procedure is the technique of choice for patients in whom the cancer has invaded the proximal esophagus and in whom a total esophagectomy is indicated for cure. Very significant complication rates are associated with this procedure, however, and it cannot be recommended for reconstruction of all segmental circumferential defects of the pharyngoesophagus. A review of the world literature reveals a collective mortality of 4 to 6 per cent with this procedure, as well as a high incidence of serious gastrointestinal complications. It is an excellent tool when necessary, but should not be used unless truly required.

Microvascular surgery provides the two techniques that currently most closely fulfill the criteria laid out for reconstruction of this defect. The free jejunal transplant has wide popular acceptance and a proved track record. However, it still presents a relatively high complication rate when the experiences of multiple centers are pooled. Part of this is due to the necessary violation of the abdomen. A laparotomy cannot be viewed lightly in this patient population requiring pharyngoesophageal reconstruction. A second area of concern is the relatively high stricture rate at the distal anastomosis.

The authors feel that a free cutaneous flap when available provides the ideal tool for this reconstruction. It alleviates the need for laparotomy. A thin, pliable skin flap can be tailored easily and carefully in the close quarters surrounding the proximal esophagus. A staggered-line closure with the esophagus can be effected, breaking up the annular line of closure seen with most tubes. Scars contract and, moreover, contract in straight lines. The natural history of an annular scar is contraction leading to stricture at that site. The jejunal segment can likewise be tailored in this area, but the edema encountered with the cutting and trimming of bowel results in a more difficult anastomosis than with a skin flap. Flap necrosis with both jejunal and skin flaps should be rare in light of their large and reliable vascular pedicles. The donor morbidity associated with the harvesting of a purely cutaneous free flap is minimal, and hospitalization is abbreviated.

Mandible

When the posterior mandible, the angle, and the ascending ramus are removed, the defect can be dealt with in a variety of ways with about equal restoration of form and function. Free flaps show no demonstrable superiority in the reconstruction of this defect.

The "Andy Gump" deformity produced by removal of the anterior mandibular arch, on the other hand, presents the surgeon with one of the most horrendous deformities seen in the head and neck. Oral competence suffers from the patient's inability to manage oral secretions, speak, eat, or swallow. This defect produces a horrible and often debilitating aesthetic problem. Furthermore, surgical tumor ablation and trauma frequently result in the loss of both intraoral and extraoral soft tissues.

The need for bone, intraoral soft tissue, and external skin coverage must be assessed carefully, with attention paid to the relative amounts of each tissue required. The amounts of donor tissue required are determined by the length of missing mandible and the size of the soft tissue defect(s). The timing of the ablation and reconstruction also influence the amounts of tissue required. With immediate and delayed reconstructions, the bony requirement is the same; however, with late-stage reconstruction, the soft tissue requirements are much greater, since remaining soft tissues will be markedly contracted. Functional goals include the restoration of a competent oral sphincter and of the ability to speak intelligibly and swallow. A number of reconstructive options are available, many of which enjoy similar success rates.

Very often, cancers of this region are treated with both surgery and high-dose radiotherapy. The radiotherapy accounts for the fact that use of alloplastic materials and free nonvascularized bone has met with limited success in these patients.

Pedicled latissimus and pectoralis major musculocutaneous flaps have become the standard workhorse tools for head and neck reconstructive surgery. Ariyan (1979) described the use of the pectoralis major flap together with the underlying fifth or sixth rib for mandibular reconstruction. This technique provided a poor match of donor tissues with those required by the defect. If bone alone is required, the rib is at best a poorly revascularized donor because of its tenuous collateral blood supply from the overlying pectoralis major muscle. That portion of the sixth rib underlying the most distal origin of the pectoralis major muscle is usually composed of cartilage an not bone. This flap may provide inadequate amounts of bone replacement, but it simultaneously provides excessive soft tissue bulk of the pectoralis muscle, breast, and subcutaneous fat in the mouth. Functional gain is compromise by this large soft tissue mass in the anterior floor of the mouth, which hampers speech, mastication, and deglutition.

The trapezius osseomusculocutaneous flap incorporating the spine of the scapula was popularized by Demergasso and Piazza (1979) for mandibular reconstruction. The trapezius muscle can be pedicled on the transverse cervical artery or on its superior vascular supply, and serves as the carrier of the spine of the scapula. This flap provides well-vascularized bone that does not resorb. The skin overlying the trapezius muscle is available for intraoral or extraoral coverage. The muscle must, however, be included as a vascular carrier for the skin. Once again, the match between tissue needed and those available is less than ideal, although somewhat better than in the pectoralis major flap. There may be significant donor morbidity with this flap, since the arc of rotation is only just sufficient for the spine to reach the anterior mandibular segment, and only with the patient's head sometimes uncomfortably rotated toward the donor sit. Two-team surgery is possible, but only with special positioning of the patient, the flap team seated under an elevated patient.

Various free flaps are used for mandibular reconstruction. The iliac crest flap based on the deep circumflex iliac artery (DCIA) is probably the flap of choice when bone alone is required or when very large amounts of bone, with or without soft tissue, are needed. It is also preferable in patients in whom the surgeon anticipates denture placement with osseointegration. The supine position and synchronous surgery make this flap a standard for reliable free bone transfer.

The scapular composite flap is preferred when there are large soft tissue defects combine with anterior mandibular defects, since the generous and easily positioned skin pales provide a real advantage for simultaneous reconstruction of internal and external soft tissue defects. The scapular flap is also preferred for smaller mandibular defects (less than 12 cm), especially in patients who can reasonably expect to wear dentures on a reconstructed alveolar ridge, alleviating the need for implants.

Facial Reanimation

Microsurgical techniques provide the only reliable method for reanimating the chronically paralyzed face. After years of denervation, facial muscles have atrophied and reanimation is impossible without the transfer of new muscle to the face. Revascularized and reinnervate free muscle transfer can be accomplished by using such muscle donors as latissimus dorsi, serratus anterior, pectoralis minor, and, most important, gracilis.

At a first stage a crossfacial nerve graft is anastomosed to enough fascicles of the functioning facial nerve to provide sufficient motor fibers for stimulation of a free muscle graft. After sufficient time for nerve growth to reach the distal extent of the crossfacial nerve graft, the second stage is possible. This nerve growth may take many months; clinical assessment using Tinel's sign can be used to monitor progress. Once there is sufficient motor nerve activity crossing to the paralyzed side, a free innervated muscle flap is transferred and microvascular microneural anastomoses are performed to recipient vessels and to the crossfacial nerve graft. The transferred muscle is tailored and inset in such a way as to mimic normal facial tone and movement as closely as possible. The muscle that seems to provide the best functional results in the lower face is the gracilis. Secondary procedures are usually required to optimize muscle pull.

Facial Contouring

Another area where microsurgical free tissue transfer unquestionably represents the superior reconstructive technique is in the treatment of patients with large contour defects in the face. These can be congenital defects such as hemifacial microsomia or acquire defects from trauma or tumor ablation. The transfer of nonvascularized autologous fat grafts or dermal-fat grafts is limited to the treatment of small defects and has a relatively unpredictable absorption rate. Such transfer is almost never successful in a radiated be. Free revascularized tissue, on the other hand, is not dependent on the vascularity of the recipient bed and does not atrophy. Muscle flaps transferred by microvascular or pedicled techniques atrophy if denervated. For this reason, free muscle flaps or musculocutaneous flaps are not primary contenders for this form of reconstruction. Instead, the transfer of omentum or deepithelialized skin flaps is the best form of augmentation for very large facial or scalp defects.

Omentum has a tendency to remain lumpy under the skin after transfer. It also requires a laparotomy for harvesting. A large number of cutaneous and fasciocutaneous flaps are now available and represent the tools of choice. The surgeon can choose a donor flap that will provide appropriate bulk and also a vascular pedicle long enough to reach from the recipient site to vessels in the neck. No pedicled flap allows the accurate placement and restoration of form that is available with these free flaps.

Although pedicled cutaneous and myocutaneous flaps have been the workhorses of head and neck reconstruction for many years, it is now apparent that they no longer provide the optimal reconstructive technique for many defects. The wide variety of free flaps now available, with long vascular pedicles containing large-diameter vessels, allow the reconstructive surgeon skilled in free tissue transfer to match the reconstructive flap much more appropriately to the needs dictated by the defect. As often repeated, "If all you have is a hammer, everything you see will look like a nail". If the surgeon possesses only skills with musculocutaneous flaps, or often will make these reliable tools fit every circumstance, often to the detriment of the patient. Microvascular surgical skills are not difficult to acquire, especially for the otolaryngologist and head and neck surgeon already facile with microsurgery. The modern array of free flaps possess in many cases large pedicle vessels measuring greater than 2 mm in diameter, making anastomoses technically easy. These free flap reconstructions do require special skills and increased surgical commitments both in operative time and perioperative care. Such skills are readily attainable by the head and neck surgeon, and the increased commitment yields benefits to the patient in the form of improved restoration of form and function. This is a dynamic field with new techniques evolving constantly. The future of head and neck surgery, especially of reconstruction, is intimately intertwined with microvascular surgery at this time.