TITLE: Free Flap Reconstruction of Head and Neck Defects
SOURCE: Grand Rounds Presentation, UTMB, Dept. of Otolaryngology
DATE: May 22, 2002
RESIDENT PHYSICIAN: Christopher Muller, M.D.
FACULTY PHYSICIAN: Shawn Newlands, M.D., PhD. and Ann M. Pou, M.D.
SERIES EDITORS: Francis B. Quinn, Jr., MD and Matthew W. Ryan, MD

Introduction

Over the past three decades, many advances have been made in the treatment of head and neck cancer. These include the combination of radiation therapy and chemotherapy with surgery, conservation laryngeal surgery, and modifications of the classic radical neck dissection. The desire to improve postoperative outcomes by focusing on preservation of tissue and function led to these advances and resulted in more rapid recovery and decreased cosmetic deformities while maintaining equal cure rates to prior techniques. Despite the fact that these changes have decreased morbidity, overall survival rates for patients with head and neck cancer has reached a plateau over the past several decades. Because of this, the focus of many head and neck surgeons in the past 20 years has been directed at further decreasing morbidity from surgery and improving functional and reconstructive outcomes.

The use of free tissue transfer and microvascular re-anastomosis for the reconstruction of head and neck defects from extirpative oncologic surgery is a relatively recent practice. Prior to the past 3 decades, the majority of head and neck defects were closed with either local tissue or random skin flaps that were pedicled and “walked” up to the head and neck region from other sites such as the trunk. Very rarely were large soft tissue and bony defects replaced with anything other than skin. In 1963 McGregor first introduced his forehead flap for reconstruction of oral defects. This was an axial pattern skin flap and was much more reliable than random flaps. In addition it did not require the tedious relocation from distant sites. The problem with this flap was that it left a large skin defect on the forehead and scalp requiring a skin graft, which was rather deforming. Subsequently in 1965, Bakamjian introduced the deltopectoral flap based on the perforators of the internal mammary artery. The donor site was the shoulder and chest, which was much more cosmetically acceptable. The shortcomings of the flap, however, were that its reach was limited by its pedicle. McGregor’s forehead flap and Bakamjian’s deltopectoral flaps were the standard flaps available for head and neck reconstruction during the 1960s and 70s.

Although microvascular transfer of free tissue grafts did not gain favor until the mid 1970s it was performed as early as 1959 when Seidenberg used revascularized free jejunum segments to repair pharyngoesophageal defects. McLean and Buncke used omentum pedicled on the gastroepiploic vessels to cover a cranial defect in 1972. In 1973, Daniel and Taylor described the first free cutaneous flap and in 1976, Baker and Panje was the first to publish the use of free cutaneous flaps for the reconstruction of head and neck defects. He followed this in 1977 with a free groin flap based on the superficial circumflex iliac artery to reconstruct an intraoral defect. This flap was met with some favor during this time and was performed by other surgeons, however it was a bulky flap and its vascular pedicle was inconsistent and the vessels were very small in diameter.

Other flaps such as the axillary free flap and dorsalis pedis flap were also described but had short-comings such as an inconsistent pedicle and significant donor site morbidity respectively. In 1976, Harii and colleagues developed the latissimus dorsi musculocutaneous flap. This was a very reliable flap based on the thoracodorsal artery and vein. It has remained a favorable flap for certain head and neck defects to this date.

During the 70s limited numbers of surgeons were performing free flaps for a number of reasons. First, there were only a few to choose from. In addition they did not always provide all the tissue needed to reconstruct head and neck defects requiring combinations of bone, skin, and muscle. Most importantly, the majority of flaps at this time had inconsistent small pedicles making them technically difficult to perform. Towards the end of the 1970s free flaps grew out of favor and an old technique was revisited. In 1896, Tansini had described the pedicled latissimus dorsi flap. In 1976, Olivari brought this back into favor. Subsequently other pedicled cutaneous and myocutaneous flaps arose such as the pectoralis and trapezius flaps. The pectoralis myocutaneous flap was considered the "work Horse" flap of head and neck reconstruction during this time. In 1979, Ariyan used the pectoralis flap in combination with rib and in the same year Demergasso and Piazza described harvest of the spine of the scapula with the trapezius musculocutaneous flap. These pedicled flaps became the choice of most head and neck surgeons over the next decade. They were reliable, quick, and easy to harvest. They also required only one stage, had minimal donor site morbidity, and provided more bulk than the free flaps available at that time. They required only one surgical team, were technically easier, and provided nonirradiated tissue (Chepeha and Teknos, 2001).

In the past fifteen years, limitations of pedicled flaps and desire by surgeons for new and better donor sites has lead to a resurgence of free tissue transfer. Pedicled flaps were not well suited for reconstruction of defects requiring very large bulk or those needing thin pliable tissue. In addition their reach was constrained by the length of their pedicle. As further investigations continued new donor sites for free flaps emerged that possessed longer and larger vascular pedicles and were made up of various tissues including skin, muscle, bone, and nerve. This allowed for much more refined tailoring of harvested tissue to the recipient site. Free flaps can provide a much wider range of skin characteristics that can match the host site well. In addition microvascular transfer makes much more efficient use of harvested tissue as nearly all is used directly in the reconstruction. Pedicled flaps require less efficient use of tissue as entire muscles are defunctionalized in order to safely transfer enough tissue to fill a defect. Because free flap donor sites are often located at a distant location from the extirpative site, a two team approach can be used to decrease operating room time. The excellent perfusion of free flaps significantly improves wound healing and serves to protect against wound breakdown and osteoradionecrosis when postoperative radiotherapy or brachytherapy is utilized. Free flap reconstruction also affords the ability for water-tight closures in skull base defects to prevent CSF leaks. Because revascularized tissue transfers maintain their independent blood supply, they are not as subject to resorption, providing for greater long-term stability and cosmesis to the reconstruction. Resorption, which plagued non-viable bony transfers in the past, is virtually eliminated with free flap reconstruction. Finally, many of free flaps have the potential for functional neurosensory and motor innervation from recipient nerves as well as the ability for primary placement of osseointegrated implants for improve oromandibular function

In 1979, Taylor and colleagues described the iliac crest composite flap based on the deep circumflex iliac artery. This was followed by the radial forearm fasciocutaneous flap (Yang, 1981), the scapular skin flap (dos Santos, 1980), the parascapular skin flap (Nassif, 1982), the lateral arm fasciocutaneous flap (Song, 1982), the scapular osseocutaneous flap (Swartz 1986), the lateral cutaneous thigh flap (Baek 1983), and the rectus abdominis myocutaneous flap (Drever, 1985).

Today microvascular free-tissue transfer to the head and neck has become an accepted method of reconstruction. This is due primarily to increased success rates for free-flap surgery (93 to 94%, Schusterman, 1993 and Urken, 1994 respectively) and superior aesthetic and functional results. Increasing numbers of surgeons have become adept at this surgical subspecialty for a number of reasons: (1) widespread application of microvascular techniques by a variety of different surgical disciplines; (2) Advances in technique and instrumentation; and (3) expanding number of dedicated training fellowships.

PREOPERATIVE EVALUATION AND PATIENT SELECTION

Planning for reconstruction of head and neck defects after ablative surgery for cancer requires an enormous amount for foresight. Each patient must be evaluated on an individual basis and a number of factors considered in determining what will be the best reconstructive option for them. Those factors include the following: (1) amount and type of tissue that will be required; (2) if innervation is required; (3) anticipated functional gains; (4) anticipated donor morbidity; (5) success rate; (6) patient positioning and donor location; (7) operative time; (8) surgical skills required and most importantly (9) patient factors including general medical status and the patients wishes and expectations. Patients should be thoroughly counseled in the preoperative period of all options for reconstruction after extirpation (including secondary intention, primary closure, skin grafting, regional flaps, and free tissue transfer). The experienced reconstructive surgeon should have a plan in mind as to which surgical procedures will likely be used however there is never any guarantee as to what the best options will be until the tumor is removed and the final defect is analyzed. In addition the quality of vessels for chosen flaps will be evaluated only after they are isolated. Instances have arisen where a flap was not used because of vessels that were too small, requiring use of flaps from other donor sites. The patient must be aware of these factors.

Successful free tissue transfer begins with proper patient selection. There are a number of patient characteristics which can additively increase the likelihood of failure. Diabetes and other systemic illnesses such as hypercholesterolemia can increase the likelihood of microvascular disease and muscular artery atherosclerosis. In addition, poorly controlled diabetes often impairs proper wound healing. Microvascular disease delays healing and neovascularization between the flap and surrounding tissues. It also increases the likelihood of infection with potential flap loss. Atherosclerosis is most problematic when using lower extremity vasculature such as in fibula flaps and the dorsalis pedis flap. Atherosclerotic disease is less problematic with upper extremity, truncal, and visceral vasculature. Within the head and neck, the facial artery is the peripheral branch of the external carotid system which is most susceptible to atherosclerotic plaques. Still, this vessel is frequently used as a recipient vessel for anastomosis because of its close proximity and good vessel caliber. It should also be taken into account that patients who have had previous radiation therapy are at increased risk of atherosclerosis.

Patients with existing cardiac disease have increased morbidity and mortality with any large operation requiring anesthesia. This is particularly true in the treatment of head and neck cancer where surgeries run for extended periods of time. Free flaps significantly increase the operating time for these surgeries (4 to 6 hours), although at many institutions this is no longer an issue secondary to the development of an increased number of distant donor sites which allow for a two team approach. Postoperative cardiac complications pose a major threat to the viability of free-flaps, which are dependent on adequate blood flow. Cardiac function should be optimized in these patients in the perioperative period through invasive monitoring and appropriate medical management by cardiac and anesthetic specialists.

Decreased flap perfusion, hypercoagulation, and impaired wound healing have been associated with smoking. Thus, smoking should be discontinued for at least one week prior to surgery and forbidden in the postoperative period. Obesity may also decrease the success of free tissue transfer as the increased adipose tissue makes dissection of the vascular pedicle more difficult and interferes with the microvascular anastomosis, insetting, and flap tailoring after transfer.

Collagen vascular diseases are another relative contraindication to free flap transfer. These diseases can compromise the cardiovascular system, particularly in individuals with an active vasculitic process. These individuals have a much higher incidence of anastomotic thrombosis and thus may not be candidates for free tissue transfer.

Coagulopathies are another relative contraindication. Most are secondary to coumadin therapy for those who have a history of cerebrovascular disease, deep vein thrombosis, or mechanical heart valves. As such, most can be modulated with cessation of the coumadin, and the use of replacement blood products such as fresh frozen plasma. However, patients with a history of ethanol-induced hepatic insufficiency will often have a less easily controlled coagulopathy and the risk for severe intraoperative bleeding, postoperative hematoma, and consequent risks to the vascular anastomosis are greater. The only absolute contraindication for free tissue transfer is a hypercoagulable state. In these persons (i.e. polycythemia, sickle cell disease), the risk of anastomotic thrombosis is too great to justify the use of free tissue transfer.

INTRAOPERATIVE MANAGEMENT

The details of the microvascular technique will not be covered in this text but selected important principles will be mentioned. The operating microscope needs to be checked prior to the case to ensure it is in working order. All necessary instruments, including the proper suture materials, should be readily available. The operating room nurse should have warm physiosol, 1% lidocaine without epinephrine, heparin, and papavarine available for immediate irrigation. No systemic pressor agents (i.e. dopamine or phenylephrine) should be used by anesthesia. The use of various anticoagulants and vascular expanders is employed by some to reduce the probability of vascular thrombosis. Some have been shown to produce an advantage in experimental models, and also potential clinical benefit in retrospective analysis. However, because the rate of thrombosis is quite low with good techniques, detection of a difference between groups is difficult. The three most commonly used substances include heparin, aspirin, and low molecular weight dextran (a volume expander). Heparin (5000 units) may be given during the last quarter of the venous anastomosis and continued as a low continuous rate of infusion to achieve a PTT of approximately 1.5 times normal value. Aspirin is often given at 5 to 10 grains per day (per rectal or per NGT). Low molecular weight dextran is usually given at a low rate of infusion (20-30 cc/hr) either continuously or as a serial infusion (i.e. 12 hours on and 12 hours off).

Patency of an anastomosis can be tested in various ways. Venous patency is easily evident when the vessel is translucent. Direct observation of expansive pulsation is a reliable indicator of vessel patency, whereas longitudinal pulsation usually indicates a partial or complete obstruction. The Doppler ultrasound can be also used as an indicator of vessel patency. The chances of thrombosis are greatest at the site of anastomosis 15-20 minutes following closure. Therefore, it is customary to observe the anastomosis and test its patency during this period of time. If partial obstruction occurs, gently squeezing the vessel with forceps or massaging the vessel may break up the thrombus. A complete thrombus necessitates resection of the damaged segment and reanastomosis.

Vascular thrombosis is most commonly due to technical error in suture placement or pedicle kinking, or the use of a vessel with a damaged intimal layer. Thrombosis at the venous anastomosis accounts for 9 of 10 thromboses and is more likely due to the slower venous flow and relative stasis of blood at this site. After the first 20 minutes, the next critical period is within the first 3 postoperative days as 90% of vascular thromboses occur during this time. After this time, vascular thrombosis is more often associated with the late development of a hematoma, infection, or fistula. Although neovascularization may be complete in a short period of time in thin flaps, which have a large surface to volume ratio, thicker flaps may take several weeks before they are independent of their anastomosed blood supply.

FREE FASCIOCUTANEOUS FLAPS

Radial forearm

The radial forearm free flap (RFFF) has become one of the work horse flaps for reconstruction in head and neck surgery. It is primarily used defects in the oral cavity, oropharynx, and hypopharynx. Its vascular supply is based on the radial artery and paired venae comitantes (which accompany the radial artery). The cephalic vein can also be used for venous anastomosis. It has many advantages including the following: (1) consistent vascular anatomy (2) long vascular pedicle – up to 18-20cm; (3) vessels are large – up to 2.5 mm in diameter; (4) location allows for a two team approach; (5) pedicle can be outlined on the skin prior to incision; (6) it can be raised as a composite graft including bone and nerve; and (7) has acceptable donor site cosmesis. The forearm has some of the thinnest, most pliable skin in the whole body making it an excellent donor for reconstruction of the oral cavity and pharynx. The flap may include skin from the antecubital fossa to the flexor crease at the wrist.

Disadvantages of the RFFF include potential donor site morbidity (hand ischemia), limited bulk, and requirement of a split thickness skin graft (STSG) to cover the donor site. An Allen’s test should be performed on all patients considered for a RFFF. The nondominant hand should be chosen first. This involves having the patient squeeze their fist tightly to expel blood from the hand. Pressure is then placed over the ulnar and radial artery and the patient is asked to release their fist. The hand should appear pale. The ulnar artery is then released and the hand is watched for capillary refill. It may take up to 60 seconds to see adequate refill. If there is uncertainty, doppler of the digital artery should be performed (Chepeha, Teknos, 2001).

The steps of the surgical procedure can be learned from most head and neck surgical atlases and will not be discussed here. There are some considerations to keep in mind. Venepuncture should be avoided from the antecubital fossa of the forearm selected for harvesting the flap. If possible, skin should not be elevated over the ulnar artery. The paratenon of the flexor tendons (flexor carpi radialis tendon) should be left down as this provides blood supply to the STSG. If paratenon is violated, muscle flaps may be created to increase vascular supply to the graft. A volar splint should be used with the wrist in 10-15 degrees of extension and the digits in the “position of function.” The splint is left on for 2 weeks.

Lateral Arm

The lateral arm flap may be raised as a fasciocutaneous flap or as a composite graft with bone (humerus), and two nerves, one of which (posterior cutaneous nerve of the arm) serves as sensory supply and the other (posterior cutaneous nerve of the forearm or posterior antebrachial cutaneous nerve) as a vascularized nerve graft. The skin flap that is raised is similar in texture, pliability and size as the RFFF but it has distinct advantages. First, the donor site can be closed primarily and does not require a skin graft if the skin flap is limited to 6-8 cm, or one-third the circumference of the arm. Second, its vascular supply is based on the profunda brachii, which is not essential to the vascularity of the distal upper extremity. There is no risk of ischemia to the arm with this flap.

The pedicle to this flap is based on the terminal branches of the profunda brachii artery and the posterior radial collateral artery (PRCA) and its venae comitantes. These vessels travel in the spiral groove with the radial nerve. As the PRCA enters the lateral intermuscular septum, its average diameter is approximately 1.55mm. The blood supply to the skin is derived from four to five septocutaneous perforators that arise from the PRCA. The maximum length of the vascular pedicle is 8-10mm. This length can be achieved by extending the dissection proximally between the lateral and long head of the triceps muscle. This involves creating a tunnel underneath the triceps insertion to gain access to the spiral groove to access more of the vessel. This maneuver can risks the muscular branches of the radial nerve to the triceps muscle. There are several disadvantages to the lateral arm flap. The donor site requires a pressure dressing postoperatively which has been associated with radial nerve palsies. If a large flap is required, a STSG may be required.

Lateral Thigh

The lateral thigh flap is a fasciocutaneous flap whose blood supply is based on the third perforator of the profunda femoris artery and its venae comitantes. This flap, like the RFFF is used primarily used in reconstruction of oral cavity and pharyngeal defects. It has many advantages including: (1) a long vascular pedicle (up to 15cm); (2) large vessels (2-4mm); (3) large skin paddle (up to 10X20cm); (4) distant from the head and neck allowing for a two team approach; (5) donor site can be closed primarily with minimal functional loss; (6) the skin is pliable and usually hairless; and (7) the flap may be harvested as a sensate flap if the lateral femoral cutaneous nerve of the thigh is preserved. In obese patients, particularly women, these flaps may be very bulky. Other disadvantages include the difficulty of dissection deep in the leg near the profunda femoris artery requiring an assistant to retract the vastus lateralis. The vascular pedicle is often inconsistent. The most common variation is for the pedicle to arise from the fourth perforating branch of the profunda femoris artery.

FREE MUSCLE AND MUSCULOCUTANEOUS FLAPS

Rectus Abdominis

The rectus abdominis is an extremely versatile free flap used for reconstruction of multiple soft tissue defects in the head and neck. Most commonly it is used for large defects in the midface and cranial base region. It has also been used on the scalp and in the oral cavity (particularly for patients undergoing total or subtotal glossectomy). The flap may either be raised as a muscle flap or a musculocutaneous flap. The blood supply to the rectus abdominis muscle is based on the deep superior and inferior epigastric arteries while the skin overlying it is based on musculocutaneous perforators arising from these arteries within the muscle belly. The muscle is very large and can fill in large defects and can reliably separate the oral from the cranial cavity in cranial base surgery. There are a large numbers of musculocutaneous perforators that supply the overlying skin making it possible to create spatially separated skin paddles. This allows for closure of defects involving more than one epithelial site such as the cheek and the oral cavity or the buccal mucosa and the palate.

Other advantages of the rectus abdominis free flap include: (1) constant anatomy; (2) ease of flap elevation; (3) change of position is not necessary allowing simultaneous elevation with extirpation of the primary; (4) large diameter vessels (mean of 3.4mm) with a pedicle up to 8-10cm in length.

Patients should be evaluated preoperatively for any previous abdominal surgery. If so, it should be determined whether or not there may have been disruption of blood supply to the flap. If uncertain, another donor site should be chosen. In addition, the amount of abdominal wall fat will determine the bulk of the flap if skin and subcutaneous fat is to be taken as well. If it is too bulky, the muscle can be transferred alone and a skin graft can be used. This is often why other donor sites such as the forearm, are chosen for reconstruction of smaller defects particularly in the oral cavity.

A multitude of flap designs have been described. Each flap should be tailored to the patient's particular defect

In order to successfully elevate the rectus abdominis free flap, a thorough understanding of the rectus sheath is required. It is composed of different layers of facial extensions from the external oblique, internal oblique, and transverse abdominis muscles depending on the location along the abdominal wall. The rectus abdominis muscle originates from the pubic symphysis and extends cephalad to insert on the costal cartilage syncytium of ribs 8 to 11. In the upper two thirds of the muscle, the anterior sheath is formed by the aponeurosis of the external and internal abdominal oblique muscles. The posterior sheath is formed by the aponeurosis of the transverse abdominis muscle and the transversalis fascia. At approximately the level of the anterior superior iliac spine and important transition occurs. The aponeurosis of the transverse abdominis muscle courses anterior to the rectus muscle interdigitating with the external and internal oblique muscles. This area is called the arcuate line. Below this point the posterior sheath is composed of the transversalis fascia only.

When designing a flap, it is important to preserve the anterior rectus sheath to prevent herniation or bulging of the abdominal contents. This is of particular concern below the arcuate line. There is usually no need to remove the anterior rectus sheath below this level. The only portion of this sheath that is routinely removed is in the periumbilical area where the major musculocutaneous perforators surface. Some authors have advocated preserving the anterior rectus sheath in the periumbilical area as well by making fascial cuts to isolate the perforators (Taylor et al., 1984).

Latissimus Dorsi

The latissimus dorsi flap (LDF) has long been a useful flap to reconstruct very large defects of the head and neck. The latissimus dorsi muscle is a large fan shaped muscle that originates from the thoracolumbar fascia, lower thoracic spinous processes, and the iliac crest and inserts onto the humerus. Its neurovascular supply is based on the thoracodorsal artery with its paired vena comitantes, and the thoracodorsal nerve. The thoracodorsal artery is a terminal branch of the subscapular artery. The pedicle based on this artery ranges from 7 to 10 cm. Additional length can be obtained by ligating the circumflex scapular artery and including the subscapular artery with the pedicle. The diameter of the artery in this area is 2 to 3 mm. The vein is approximately 3 to 5 mm. The thoracodorsal nerve can be reanastomosed to a recipient nerve in the neck to reinnervate the muscle and prevent wasting.

The vascular supply to the skin paddle of the LDF is provided by musculocutaneous perforators branching from the thoracodorsal artery which span a large surface area of skin. The skin flap that can be elevated is the second largest available in the body next to the rectus abdominis flap. The difference between these two flaps is that the skin of the latissimus flap is centered over muscle. This makes the flap extremely large. It is great for filling very large defects but usually to thick to tube or use in the oral cavity. Multiple skin paddles can be designed with this flap.

The donor site for the latissimus flap is usually easily closed primarily with little cosmetic deformity. Functional deficits from removing this muscle are prevented by the compensatory action of other muscles that act across the glenohumeral joint. It is important to note that progressive morbidity to the shoulder does occur with the sacrifice of the latissimus dorsi is combined with loss of either the trapezius muscle or the pectoralis major muscle. To harvest this flap, the patient must be in a 30 to 45 degree lateral oblique position. Although synchronous head and neck surgery can be performed, there may be some difficulty, especially if bilateral neck dissections must be performed..

COMPOSITE FREE FLAPS

Radial forearm

The RFFF free flap may be raised with a segment of bone from the radius to reconstruct mandibular or midface defects. A segment of bone up to 10cm may be harvested. The segment of radius that can be taken is vascularized by the vessels passing from the radial artery through the lateral intermuscular septum and perforating vessels through the muscle belly of the flexor pollicis longus. Only 30% of the cortex of the radius may be removed. If more is taken there is a high risk of developing a pathologic fracture. Compared to other osseocutaneous flaps such as the iliac or fibular free flaps, the amount of bone that can be raised with the RFFF is much less. The radius is best suited for reconstructing lateral defects in the mandible. If the periosteum is preserved on the volar and radial aspects of the bone, 2 or 3 osteotomies can be made through the medullary side to reconstruct symphyseal and parasymphyseal defects. Reconstruction in this manner, however, does not allow for dental rehabilitation. Prior to the operation, posterior and lateral x-rays should be taken of the forearm to assess the cross-sectional area of the radius. The rest of the preoperative evaluation is the same as for the cutaneous flap.

Fibula

The fibular free flap (FFF) can be an osseus or osteocutaneous flap. Its blood supply is based on the peroneal artery and the accompanying vena commitantes. The fibula can provide up to 25cm of vascularized bone for grafting. This is why it has become the preferred technique for reconstruction of segmental defects in the long bones of the upper and lower extremities. The peroneal artery provides a dual blood supply to the fibula via endosteal and a periosteal vasculature. Because multiple segments of this bone can receive enough blood supply from the periosteal component, their viability can be maintained after multiple osteotomies. This makes the fibular free flap an ideal donor site for mandibular reconstruction which requires contouring of bone. Other advantages of the FFF include the following: (1) it provides the longest and strongest bone stock of any other osseus free flap; (2) low donor site morbidity; (3) easy positioning and two team approach; (4) easily supports osseointegrated dental implants; and (5) its thickness roughly approximates the body of the mandible.

The length of the vascular pedicle to the FFF is limited proximally by the bifurcation of the posterior tibial artery. Additional length can be gained by harvesting a more distal segment of bone. With this technique, pedicle length as long as 12cm has been attained (Hidalgo, 1994). The variability in blood supply to the FFF is one reason this flap may not be acceptable in certain patients. Aberrations in blood supply to the feet can occur in up to 10% of the population with the peroneal artery being the dominant supply to the entire foot. In order to verify that this in not the case, it is necessary to perform an imaging study of the lower extremity vasculature (i.e. an angiogram or MRA). Peripheral vascular disease can also affect the normal circulation of the foot thereby necessitating a preoperative imaging study. Other disadvantages include a limited cutaneous paddle and soft tissue bulk often requiring a second free flap or pectoralis flap for extensive soft tissue defects, slight reduction in ankle strength and limited great toe flexion, and slight risk of chronic ankle pain. The skin paddle has an unpredictable blood supply and may be lost in up to 5 to 10% of patients. This can only be determined after the harvest. The patient must be informed that a second cutaneous flap may be needed.

Loss of the lateral mandible (posterior to the mental nerve foramen), will result in a concavity of the cheek, mandible rotation to the defect side with cross bite malocclusion, remnant rotation superiorly and medially, and mental nerve loss. These losses are much easier to adjust to than anterior loss. However, in a relatively fit patient with or without dentition, the advantages of reconstruction compared to primary closure without reconstruction can be dramatic. The iliac bone is often chosen over the fibula for these defects because of the close approximation of the shape of the anterior iliac spine to the angle and body of the mandible.

Operative considerations in raising the FFF are as follows: (1) leave a 1 mm cuff of soleus and peroneal muscle attached to the fibular during dissection to protect the periosteum; (2) leave 6 cm of distal and proximal fibula preserve the stability of the ankle and knee joint and to help avoid injury to the common peroneal nerve; (3) the bone should be oriented so that the vascular pedicle is located on the lingual surface of the neomandible. This places the skin paddle at the inferior border. It can be wrapped over the buccal surface allowing for coverage of the fixation hardware; (4) the lateral sural nerve can be harvested to provide a sensate flap.

Postoperative care should include splinting of the leg and non-weight bearing until postoperative day three.

Scapular and Parascapular Free Flaps

The subscapular system of flaps is unique in that it can provide a wide range of tissue types based on a single pedicle. The branching pattern of the subscapular artery and vein permits the transfer of the following flaps: scapular fasciocutaneous flap, parascapular fasciocutaneous flap, scapular-parascapular osteofasciocutaneous flap, latissimus dorsi flap, latissimus dorsi musculocutaneous flap, latissimus dorsi rib osteomusculocutaneous flap, serratus anterior flap, serratus anterior musculocutaneous flap, and the serratus anterior rib flap. Advantages of all these flaps include a long pedicle (10-14cm) with large diameter vessels, abundant surface area of relatively thin hairless skin, and separation of the soft tissue and bone flaps, which allows for freedom in three dimensional insetting.

The scapular and parascapular free flaps are both fasciocutaneous flaps which can be harvested independent of bone or as a composite graft and have the circumflex scapular artery as their pedicle. The accompanying vena commitantes drain the flap. As the circumflex scapular artery emerges from the triangular space bounded by the teres major and minor muscles and the long head of the triceps, it branches into horizontal and vertical fasciocutaneous branches (the tranverse cutaneous branch and descending cutaneous branch respectively) overlying the scapula. Scapula (horizontally oriented) or parascapular (obliquely oriented) fasciocutaneous or osteofasciocutaneous flaps can be harvested from these two branches. Up to 10 cm of bone can be removed from the lateral aspect of the scapula. This bone is thick enough to allow for osseointegrated implants for dental reconstruction.

The main disadvantage to this donor site is positioning, which may prevent a two team approach, increasing operative time substantially. The lateral decubitus positioning has also been associated with morbidity to the brachial plexus. Injuring to the glenoid fossa has also been reported. Harvesting of bone necessitates detachment of the teres major and minor muscles, which may result in shoulder weakness and decreased range of motion.

Ilium

The ilium free flap is usually raised as an osseomusculocutaneous flap which is usually used in head and neck surgery for reconstruction of mandibular defects. The most reliable vascular supply for free tissue transfer of iliac crest is the blood supply from the deep circumflex iliac artery and vein. The rich vascularity of the ilium allows for great flexibility in the size and shape of the segment of bone that is harvested. The amount of bone that can be taken from the ilium provides the greatest cross-sectional surface area compared to the fibula, scapula, and radius. Its thick bone stock can easily support osseointegrated bone implants. The bone can be harvested by incorporating the anterior iliac spine which can nicely reconstitute the mandibular angle when this is taken with the resection. When symphyseal defects are present, a straight piece of iliac bone is harvested that requires osteotomies to achieve a gentle curvature that matches the anterior mandible. Care must be taken to maintain continuity of the inner perichondrium to preserve its vascular supply. When insetting the flap, the pedicle should always be oriented so that it is on the lingual side of the oral cavity. This requires careful planning so that the correct donor side is chosen. This also depends on the desired location of the pedicle (angle, mid-body or parasymphyseal) so that it easily reaches the chosen recipient vessels in the neck.

The size of the skin paddle must be large enough to incorporate a sufficient number of musculocutaneous perforators. Unfortunately, the skin component is often too thick and immobile to allow good intraoral coverage. Increased mobility can be obtained by placing the skin paddle more cephalad on the abdominal wall. Care must be taken to include the cutaneous perforators in the inferior portion of the skin paddle. If the skin is thin enough it may be used for oral cavity reconstruction of soft tissue defects. Again, the donor side chosen should be planned depending on where the recipient vessels are (ipsilateral or contralateral to the defect). The skin should always be oriented in its original anatomic position to avoid any torsion on the delicate musculocutaneous perforators. The internal oblique muscle component is usually harvested with the flap and draped into the oral cavity and allowed to mucosalize by secondary intent or can be skin grafted.

Review of the favorable characteristics of the iliac free flap include; thick bone stock, easy positioning and two team harvest, defect can be closed primarily, and minimal donor deformity. Disadvantages include; bulky soft tissue component, poor reliability of skin paddle, pelvic pain and the risk for hernia formation, decreased postoperative ambulation, possible risk to peritoneum and bowel, and paralysis of the rectus abdominus muscle.

Postoperative care should include progressive mobilization, which should begin on the third or fourth postoperative day and is followed by assisted ambulation on the seventh day. Stair climbing should not be performed until 3 weeks after surgery.

FREE VISCERAL FLAPS

Jejunum

In the history of free tissue transfer with microvascular reanastomosis, the jejunal flap holds particular importance because it was the first tissue to be transplanted in humans. In 1959 Seidenberg et al. reported their experience in one patient where they used a free jejunal autograft to reconstruct a patient who had undergone a pharyngoesophagectomy for recurrent cancer. Although this patient did not fair well (survived 5 days) this flap has since become a standard reconstructive method for pharyngoesophageal defects. Interestingly, this first report of free tissue transfer with microvascular reanastomosis in a human was done before the advent of the operating microscope. The first successful transfer of a free jejunal flap was performed by Roberts and Douglas in 1961 in which their patient survived and was able to resume swallowing.

Although in the past the jejunum was used as a pedicled flap to reconstruct the thoracic esophagus, it is now primarily used as a free flap. It is most commonly used as a mucosal tube or a mucosal patch for functional reconstruction of the pharyngoesophagus. Prior to the jejunal free flap, reconstruction of the pharyngoesophagus had been tried with a number of techniques including tubed pedicled skin flaps (pectoralis, deltopectoral), gastric pull-up, and colonic interposition grafts. Each of these had definite disadvantages compared to the jejunal free flap. Pedicled skin flaps were often too bulky. When the gastric pull-up was used in heavily radiated tissues, its weight and the effect of gravity led to problems with wound healing. In addition it was often unable to reach more cephalad defects extending into the oropharynx. The colonic interposition graft also had limited reach and because of its natural flora would often result in abdominal and chest infections.

The vascular supply to the jejunum is based on branches from the superior mesenteric artery (SMA). There are 12 to 15 jejunal arteries that arise from the left side of the SMA. These arteries divide into two smaller arteries which unite to form vascular arcades. The arcades give off smaller straight branches called vasa recta, which enter the small intestine on its mesenteric border. The venous supply comes from paired vena commitantes which accompany each artery and drain into the superior mesenteric vein. The particular segment of jejunum used must be supplied by a single vascular arcade (usually the second or third) with nutrient vessels of sufficient size for microsurgical transfer.

Performing free transfer of the jejunum requires a two or three team approach. A general surgery team isolates a segment of jejunum which is left attached to its vascular supply in the abdomen. After extirpation of the tumor has been completed in the neck, evaluation the exact size and shape of the defect is carried out. The jejunal segment is then harvested and insetting into the defect is carried out in an isoperistaltic fashion. This is followed by microvascular reanastomosis to recipient vessels. Sewing of vessels is performed after insetting of the flap for two reasons: (1) it provides more accurate geometric arrangement of the vessels based on the final positioning of the flap to reduce tension and (2) prevents excessive bleeding from the edges of the flap which can make insetting very difficult particularly if the distal end of the defect is low in the thorax.

Use of the jejunal free flap is contraindicated in a number of situations including patients with ascites, history of extensive abdominal surgery, involvement of cancer in the thoracic esophagus (gastric pull-up should be used), and history of chronic intestinal disease such as Crohn's disease.

Disadvantages of the jejunal free flap include: (1) requires laparotomy with potential complications; (2) lacks neovascularization resulting in total depends on anastomosed blood supply; (3) short pedicle; and (4) results in gurgly voice when voice restoration procedures are performed.

HEAD/NECK RECONSTRUCTION BY SITE/RECONSTRUCTIVE PLANNING

The basic goal in reconstruction of head and neck defects is to maximize cosmesis and function while minimizing the complexity and risk involved. Free tissue transfer is not only expensive and many times difficult to perform, the donor site morbidity and more complex postoperative care make it an option that must be considered carefully. Therefore, for each reconstructive problem, one must always consider all forms of reconstruction from simple to complex. In many instances, a non-free flap option should be employed. There is almost always more than one form of reconstruction available and only after carefully weighing the potential added advantage of free tissue transfer as compared to more simplistic methods, should it be employed. Options that should be considered in each patient include 1) healing by secondary intent, 2) primary closure, 3) skin grafts, 4) local flaps, 5) myocutaneous flaps, and finally 6) free flaps. Although reconstruction is often approached in an algorithmic fashion, it is important to realize that exceptions do arise and not all patients with similar defects would be best suited to one particular reconstructive option.

Oral Cavity and Oropharynx Reconstruction

Within the oral cavity and pharynx, thin pliable mucosa is found. The goal in reconstructing these sites include a watertight seal as well as minimal wound contracture to maintain mobility of the tongue so that function may be preserved. All reconstructive options should be considered. Methods that result in contracture and reduced mobility of the tongue should be avoided. Myocutaneous flaps are often too bulky to reconstruct the thin resected surfaces. Therefore, fasciocutaneous free flaps and split jejunum would be possibilities. The radial forearm is used most often.

Tongue Reconstruction

The tongue is one of the most specialized tissues within the oral cavity. Reconstructive efforts for the tongue should be focused on preserving what has not been lost and preserving an adequate shape, volume, sensation, and motion. The extent of the defect, coupled with the adjacent tissues lost (i.e. floor of mouth) and neural integrity of remaining tongue, should dictate what reconstruction may be appropriate. For mobile tongue defects, most forms of reconstruction are adequate as long as they prevent tethering of the remaining tongue. Free tissue transfers may be useful when it is anticipated that contracture with primary closure or skin graft will make speech or bolus manipulation difficult. This is particularly true with defects involving over one-third to one-half of the oral tongue. Reconstruction of the entire anterior 2/3's of the tongue may be best accomplished with a tubed or coned fasciocutaneous.

For reconstruction of the tongue base and for total glossectomy defects, one must consider the patient's pulmonary reserve and ability to tolerate aspiration. Criteria used for supraglottic laryngectomy should be used to determine this. The goal with total glossectomy defects is to create an adequate oral mound such that the patient can have some approximation of the flap tissue with the palate. Only in this way will they have the potential for intelligible speech and some ability to move a food bolus into the oropharynx. Once in the oropharynx, the bolus must initiate the pharyngeal phase of swallowing and be transferred into the cervical esophagus without significant aspiration. This requires an intact pharynx and an anteriorly based larynx.

Rectus abdominus and latissimus dorsi musculocutaneous free tissue transfers for total tongue reconstruction offer abundant subcutaneous tissue to create the oral mound. The rectus flap has an added advantage of allowing suspension of the anterior rectus sheath to the mandible to prevent gravitational drop of the oral flap tissues. If the larynx is preserved additional measures such as laryngeal suspension to the mandible should be carried out to reduce aspiration. If patients are too sick to undergo a free tissue transfer, a pectoralis major myocutaneous flap is a reasonable alternative.

Hypopharynx and Cervical Esophageal Reconstruction

Because pharyngeal and laryngopharyngeal carcinomas often have significant submucosal spread beyond the obvious tumor boundary, the extent of surgical defect can be greater than anticipated preoperatively. Therefore, with the exception of the smallest tumors, a plan for reconstruction of a complete circumferential defect should be considered preoperatively. Typically, if 3 centimeters or more of mucosa remains, primary closure is advocated. If less than 3 centimeters remain, consideration for a pectoralis major regional flap or radial forearm free flap could be considered. For total loss above the thoracic inlet, a tubed pectoralis major flap, fasciocutaneous free flap, or free jejunum flap could be considered. Currently, in relatively healthy patients, the free jejunal flap remains the reconstructive technique of choice for these defects. If total loss occurs below the thoracic inlet, a gastric pull-up is the reconstruction of choice.

Mandibular Reconstruction

Loss of the anterior mandibular arch results in loss of chin and lip support and sensation, malocclusion, and retrognathia. These result in severe cosmetic deformity and functional deficits, including lack of oral competence and extreme difficulties with eating and speaking. Reconstruction of this portion of the mandible is considered by some as one of the few absolute indications for a free tissue transfer. Other methods of reconstruction such as the use of reconstruction plates and nonvascularized bone grafts result in much poorer functional and cosmetic results, and are associated with much higher rates of failure. Reconstruction with regional bone containing flaps is much less optimal as all such flaps have a tenuous blood supply to the attached bone and usually result in some bone resorption. Regional flaps such as the sternocleidomastoid muscle with clavicle, pectoralis major with rib, trapezius with spine of scapula, and latissimus with rib have been utilized but do have a higher likelihood of flap failure. The usual candidates for bone containing free flaps used for mandibular reconstruction include the fibula, iliac crest, scapula, and radius as discussed previously.

Skull Base Reconstruction

Skull base reconstructions are usually accomplished with bulky, well vascularized flaps such as the rectus or latissimus flaps. These flaps are positioned against the skull base with the flap muscle packed into the orbital, nasal, paranasal, infratemporal, or temporal skull base defects. Thus, the contaminated extracranial space can be separated from the dural repair.

POSTOPERATIVE MANAGEMENT AND CARE

Proper care after surgery requires nursing and surgical personnel who understand the principles behind free tissue transfer. With this knowledge, it is common sense to avoid any pressure in the vicinity of the pedicle or flap. An anastogram at the bedside can illustrate the sites of anastomosis to those not present during the procedure. Supplemental oxygen and cool humidified air can cool a superficial flap and inhibit its blood flow. Strict orders to keep the head in neutral position will limit the tension placed on the anastomosis. Hemodynamics and blood volume should be monitored closely. Although there is little scientific evidence supporting the ideal hematocrit in free flap patients, the consensus among experienced surgeons is somewhere between 27-29, with 30 an appropriate goal. Close surveillance for hematoma formation is necessary to avoid vascular compression and blood pressure needs to be maintained appropriately for tissue perfusion. As stated previously, systemic pressure agents should be strictly avoided in managing blood pressure fluctuations in these patients.

Pharmacotherapy has become routine is free tissue transfers. As discussed earlier, aspirin is initiated after surgery using 5-10 grains daily for 2-3 weeks in order to inhibit platelet and endothelial cyclooxygenase. Dextran is used for its viscosity lowering properties and inhibition of rouleaux formation. Heparin is continued as part of some postoperative protocols for at least the first 3 postoperative days but its use increases the risk of hematoma. Antibiotics are given as usual for head neck procedures and delirium tremens prophylaxis should be administered for at risk individuals.

As the majority of free tissue transfer fails secondary to vascular anastomosis problems, early detection and timely repair can often salvage the flap. Although many different methods exist, the current standard is clinical evaluation. This is accomplished by visually inspecting the flap color, turgor and capillary refill, dopplering the pedicle frequently during the first 3 days, and performing the prick test daily. A healthy flap will be pink, warm, minimally edematous, and will have a capillary refill time of 1-3 seconds.

The prick test will produce 1-3 drops of bright red blood. Venous anastomotic thrombosis, implicated in over 90% of flap failures, is clinically evident with a dark blue congested appearance of the cutaneous portion of the transferred tissue and often with concurrent hematoma within the operative site. This occurs as thrombosis of the venous outflow causes a high-pressure buildup within the flap, and consequent diffuse bleeding from the flap soft tissue. This is usually obvious clinically and recognition is followed by immediate return to the operating room for exploration, thrombectomy, and revision anastomosis. Using established techniques, over 50% of those flaps developing venous thrombosis can be salvaged. If the anastomosis cannot be salvaged, heparinization and the use of medicinal leeches can occasionally buy enough time for peripheral revascularization to occur so as to result in partial or total flap salvage. This is very costly, however, and usually results in multiple blood transfusions for the patient. However, these later measures never replace exploration unless there is some reason the patient is unfit to return to the operating room. Arterial anastomotic thrombosis is uncommon but produces a pale, cold flap with no bleeding after pricking. Treatment is immediate return to the operating room with reanastomosis.

Because early detection of flap compromise allows for earlier intervention and higher chances for successful salvage, numerous adjuncts to clinical assessment have been devised. Temperature measurements have demonstrated reliability with a sensitivity of 98% and a predictive value of 75%. However, thin skin flaps and those placed intraorally have negligible temperature drops, especially with venous thrombosis. In addition, fluctuations in surface, peripheral, or core temperature can provide misleading data about the viability of the flap. Technetium scanning within the first week after surgery can be valuable for evaluating the perfusion of composite bone grafts, however its use after the first week is unreliable. Single-photon emission computed tomography (SPECT) may be a useful indicator of flap viability, however few centers have such technology. A recently introduced technique utilizes infrared spectroscopy to noninvasively monitor the concentrations of oxy- and deoxy-hemoglobin in the flap. Transcutaneous and intravascular devices which measure oxygen tension, pH, and carbon dioxide levels have met with great enthusiasm however may not live up to its lofty goals. The laser Doppler flowmeter also holds promise, however it is not applicable to deep flaps in the oropharynx. At present, as there is no perfect objective device that accurately indicates flap failure consistently, clinical assessment remains the standard.

References

Ariyan, S.: The pectoralis major myocutaneous flap. Plast. Reconstr. Surg. 63:73, 1979

Chepeha, D. B., Teknos, T. N.: Microvascular free flaps in head and neck reconstruction in Head and Neck Surgery – Otolaryngology, Editor Bailey, B. J., Lippincot Williams and Wilkins, 3rd ed., 2001, pgs 2045-2065

Baek, S. M.: Two new cutaneous free flaps: The medial and lateral thigh flaps. *Plast. Reconstr. Surg*. 71:354, 1983

Bakamjian, V. Y.: A two-stage method for pharyngoesophageal reconstruction with a primary pectoral skin flap. *Plast. Reconstr. Surg*. 36:1732, 1965.

Daniel, R. K., and Taylor, G. I.: Distant transfer of an island flap by microvascular anastomoses. *Plast. Reconstr. Surg*. 52:111, 1973

Demergasso, F., and Piazza, M. V.: Trapezius myocutaneous flap in reconstructive surgery for head and neck cancer: an original technique. *Am J. Surg*. 138:533, 1979

Drever, J.: Closure of the donor defect for breast reconstruction with rectus abdominus myocutaneous flaps. Plast Reconstr Surg 76:558-567, 1985

dos Santos, L. F.: Retallro escapular: um novo retalbro livre microcirurgico. *Rev. Bras. Cir*. 70:133, 1980

Harii, K., Ohmori, K., and Torri, S.: Free gracilis transplantation with microneurovascular anastomoses for the treatment of facial paralysis. Plast. Reconstr. Surg. 57:133, 1976

Hidalgo, D.: Discussion of "Fibula osteoseptocutaneous flap for reconstruction of composite mandibleular defects" by Wei F, Seah C, Tsai Y, Liu S, Tseu M. *Plast Reconstr Surg*. 93:305, 1994

McGregor, I. A.: The temporal flap in intraoral cancer; its use in reforming the postexcisional defect. *Br. J. Plast. Surg*. 16:318, 1963

Panje, W. R., Bardach, J., and Krause, C. J.: Reconstruction of the oral cavity with a free flap. *Plast. Reconstr Surg*. 58:415, 1976

Roberts, R. E., Douglas, F. M.: Replacement of the cervical esophagus and hypopharynx by a revascularized free jejunal autograft: report of a case successfully treated. *N Engl J Med* 264:342, 1961

Scusterman, M. A. et. al.: A single center's experience with 308 free flaps for repair for head and neck cancer defects. *Plast Reconstr Surg*. 93(3):472-478, 1993

Seidenberg, B., Rosznak, S. S, Hurwittes, et al: Immediate reconstruction of the cervical esophagus by a revascularized isolated jejunal segment. Ann Surg 149:162, 1959

Song, R., Song, Y., Yu, Y., Song, Y.: The upper arm free flap. Clin Plast Surg. 9:27-35, 1982

Swartz, W. M., Banis, J. C., Newton, E. D., et al.: The osteocutaneous scapular flap for mandibular and maxillary reconstruction. *Plast. Reconstr. Surg*. 77:530, 1986

Taylor, G., Corlett r. J., boyd, B.: The versatile deep inferior epigastric)inferior rectus abdominis) flap. *Br J Plast Surg*. 37:330-350, 1984

Taylor, G. I., and Watson, N.: One-stage repair of compound leg defects with free revascularized flaps of groin skin and iliac bone. *Plast. Reconstr. Surg*. 61:494, 1978

Urken, L. M. et. al.: Microvascular free flaps in head and neck reconstruction. *Arch Otolaryngol Head Neck Surg*. 120:633-640, 1994