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# Microvascular Free Tissue Transfer in Head and Neck Reconstruction

**Mourad MW[1]*, Sami P. Moubayed[1], Inman J[2] and Ducic Y[3]**

[1]Department of Otolaryngology-Head and Neck Surgery, New York, NY, USA

[2]Department of Otolaryngology-Head and Neck Surgery, Loma Linda, CA, USA

[3]Otolaryngology and Facial Plastic Surgery Associates, Fort Worth, TX, USA

***Corresponding author:** Moustafa Mourad, Department of Otolaryngology and Head & Neck Surgery, New York Eye and Ear Infirmary of Mt. Sinai, 310 E 14th Street, New York 10003, USA, Tel: (212) 979 4000; Email: mousmourad@gmail.com

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## INTRODUCTION

In 1907 French surgeon Alexis Carrel first introduced the concept of microvascularized autotransplantation when he transferred a segment of jejunum to the cervical esophagus in a canine model. In 1972, Drs. Harry Buncke and Donald McLean were the first to successfully autotransplant omentum with its own segmental blood supply to cover a cranial defect. Throughout the 1980's, there was a rapid expansion in the study and advancement of surgical techniques relating to free tissue transfer. Now, with more than 40 recognized sites of possible tissue donation, most flap surgeons have many robust tissue matching options (Table1). Surgical techniques and technology have led free tissue transfer to be a widely accepted reconstruction option within the head and neck leading to better functional and aesthetic results. Most large centers currently cite more than 95% flap success rate.

**Table 1:** Some representative commonly utilized free flaps utilized in head and neck reconstruction.

| Flap | Artery | Vein | Nerve |
|---|---|---|---|
| | *Muscle and Myocutaneous Flaps* | | |
| **Rectus Abdominus** | Deep Inferior Epigastric | Deep Inferior Epigastric | Intercostals |
| **Gracilis** | Branch from Medial Femoral Circumflex | Venae comitantes | Obturator |
| | ***Fascial and Fasciocutaneous*** | | |
| **Radial Forearm** | Radial | Venae Comitantes or cephalic | Medial or lateral antebrachial cutaenous |
| **Lateral Arm** | Posterior radial collateral | Posterior radial collateral | Posterior cutaneous nerve of the forearm |
| **Temporoparietal Fascia** | Superficial temporal | Superficial temporal | none |
| **Anterolateral Thigh** | Descending Branch of lateral circumflex femoral | Venae comitantes | Lateral femoral cutaneous |
| | ***Composite Flaps*** | | |
| **Scapula** | Subscapular | Subscapular | none |
| **Latismus Dorsi** | Subscapular | Subscapular | Thoracodorsal |
| **Serratus** | Subscapular | Singe venae comitantes | Long thoracic |
| **Iliac Crest** | Deep circumflex iliac | Deep circumflex iliac | none |
| **Fibular Osteocutaenous** | Peroneal | Peroneal | Lateral sural cutaneous |
| **Radial Osteocutaneous** | Radial | Venae comitantes or cephalic | Medial or lateral antebrachial |
| | ***Visceral Flaps*** | | |
| **Free Jejunal** | Superior mesenteric | Superior mesenteric | none |
| **Free Omentum** | Gastroepiploic | Gastroepiploic | none |

The purpose of this chapter is to provide a general overview of the various reconstructive options available for repair of head and neck defects. We will discuss contemporary management issues with regards to perioperative management, monitoring, and future directions.

## Muscle and Myocutaneous Flaps

Various muscular and myocutaneous flaps have found a role in head and neck reconstruction, particularly when bulk or extensive skin coverage or lining is required. These flaps are frequently utilized in the reconstruction of the skull base, nasal and paranasal sinuses, oral cavity, or scalp. The rectus abdominus free flap is one such flap that can be harvested as a myocutaneous flap based on the deep inferior epigastric artery and vein. Advantages to this flap are its reliability, long pedicle length, minimal donor site morbidity, and ease of harvest in the supine position. Furthermore, due to the rich vascularized subcutaneous perforator network large skin territories can be harvested and utilized for lining of nasal and oral cavity defects [1]. Flap utilization however may be limited by patient related factors, including body habitus with extensive subcutaneous tissue that may limit pliability and design in the head and neck, as well as abdominal weakening that may predispose to ventral herniation—hence the need for adequate prophylactic supporting augmentation of the rectus sheath. Overall, the rectus abdmominus flap has been utilized in oral cavity reconstruction, as well has gained most widespread use in the reconstruction of skull base defects [2-4].

The gracilis flap is a muscular flap used in the reconstruction and rehabilitation of head and neck patients. It is based on branches to the gracilis from the medial femoral circumflex system with two venae comitantes. Its major advantage is its ability to be reinnervated through the obturator nerve, allowing for restoration of dynamic muscular function for patients with facial nerve paralysis.

When large amounts of tissue bulk is needed for coverage, or complex composite chimeric flaps are needed, a subscapular system flap (most commonly represented through the basic subunit of the latissimus muscle) can also be harvested as a muscle, myocutaneous, or composite flap—incorporating the lateral border of the scapula bone or a segment of rib. The serratus muscle can also be incorporated into this flap. Its major advantages include: a large amount of muscular area may be harvested for scalp and skull base defects, its large caliber vessels, and its long pedicle length. The options, chimeric nature, of this flap makes it one of the most commonly used free flaps in head and neck reconstruction for complex defects, especially where composite tissues are required and there is a large area or volume to reconstruct. Its disadvantages include patient positioning in the semi-lateral decubitus position (>30 degrees) which makes simultaneous two team approaches difficult, but not impossible, and patient donor site pain.

## Fascial and Fasciocutaneous flaps

The most commonly encountered defects in the head and neck usually involve skin, mucosa, or other soft tissues. Most T1 and T2 cancers have limited depth, preserving bone and deeper structures, making fascial and fasciocutaneous flaps one of the most used flaps in head and neck reconstruction. The face and neck superficial subunits are predominantly thin making the radial forearm fasciocutaneous free flap, based on the radial artery and the cephalic or comitante veins, the preferred flap for many defects. Its major advantages include long pedicle length, large caliber vessels, and minimal donor site morbidity. Furthermore, its thin pliable tissue is incredibly well-vascularized, allowing for its applicability to a diverse set of defects within the oral cavity withstanding the many facets of these complex wounds. Its pliability allows it to be folded vertically or horizontally to varying degrees, allowing for reconstruction of tongue and floor of mouth defects, cheek defects, hard and soft palatal defects, and occasionally can even result in a mobile velopharynx [5]. Furthermore, the radial forearm free flap has been increasingly used as a tubed flap in the reconstruction of the larynx, pharynx, and esophagus [6]. A disadvantage of the radial forearm is its donor vessel, the radial artery, precludes future a-line monitoring, and places the hand with only one major supplying artery, the ulnar. Surgeons check the ulnar artery for patency and distal perfusion flow through an intact palmar arch before harvesting this flap. An ulnar based flap can also be harvested similarly to a radial based one. This flap usually has thinner skin and less donor morbidity; however, its area is smaller.

A thin anterolateral thigh works especially well in areas where a radial forearm is ideal however a larger area or volume is needed for the defect. The anterolateral thigh free flap has gained widespread use and acceptance with diverse applicability to reconstruction of the head and neck, likely due to its very limited donor site morbidity compared to other flaps. The anterolateral thigh free flap provides more tissue bulk than that provided by a radial forearm free flap, as well as allows for large skin territories to be harvested. Furthermore, it has the added advantages of long pedicle lengths, large caliber size, as well as minimal donor site morbidity. Its major disadvantage and limitation to its applicability in the West however is the excessive subcutaneous thickness and added tissue bulk, limiting its pliability [7]. The ALT free flap is most commonly used for reconstruction of oral cavity defects, but also used in pharyngoesophageal, skull base, scalp, and midface reconstruction [8]. The difference in area and volume between the radial forearm and the ALT provides a good example of the importance of defect matching to patient body habitus. One flap may be preferred over the other—consider a patients forearm size limiting the defect size it can cover precluding its use because of dimensions, and the thickness of the patients ALT precluding its use because of excess bulk. Can one of these less than ideal flaps be modified and still used or are neither acceptable and another flap donor site must be considered? A flap surgeon must occasionally work towards different flaps, despite preferences, based on patient defect or body habitus specifics. Ideally, flap surgeons should have multiple flap or defect augmenting 'tricks' which can be used to allow the harvest of routine flaps, as these are typically more robust and successful (due to their common use), than flaps used less often.

Similar to the radial forearm, the lateral arm free flap offers well-vascularized thin and pliable tissue with potential for sensory innervation. Its vascular supply is based off of the posterior radial collateral artery and vein. It offers a distinct advantage over the radial forearm flap of allowing for primary closure of the donor site in correctly chosen patients. Furthermore, sensory reinnervation of the oral cavity has been restored through the use of the posterior cutaneous nerve of the arm [9]. There is controversy over which cases benefit from sensory reinnervation in the oral cavity and oropharynx—to our knowledge, in most practices, this is not seen to change clinical swallow outcomes, therefore it is not a routine goal to apply flaps with potential sensory reinnervation. The flap is limited due to its smaller caliber artery, shorter pedicle length, and flap skin area encompassed.

A fascial free flap that is rich in vascularity is the temporoparietal fascia free flap, based off of the superficial temporal artery and vein. Although commonly used as a pedicled flap, it has also gained widespread use as free tissue for distant defects. It provides the distinct advantages of providing pliable, durable, well-vascularized tissue that can contour to complex three dimensional defects—such as the nose or the larynx. Its rich vascularity allows it to be used in infected fields, or in regions that require sterility to prevent detrimental outcomes (i.e. skull base). Its rich vascularity also enables it to be utilized in bone and cartilaginous coverage or in free graft coverage.

## Composite Flaps

Due to the complexity of dealing with post-ablative, congenital, or traumatic defects of the head and neck, often composite flaps which incorporate bone or rib are required for reconstruction. The osteocutaneous fibular free flap is one of the most utilized vascularized bone flaps in head and neck reconstruction. It can allows for donation of up to 25 cm in length of bone that can be contoured using osteotomies for reconstruction of total mandibular defects. Furthermore, it provides adequate bone stock for dental implantation, enhancing functional outcomes. Furthermore, it may be harvested with thin pliable skin which can be used in oral cavity resurfacing. The donor site also permits two-surgeon team approaches. In most practices, it is the workhorse flap for mandibular and maxillary reconstruction. The osteocutaneous radial forearm free flap is also a flap that can be utilized for composite defects. Although it may provide up to 12 cm of bone length, only about 40% of the bone circumference can be harvested, with greatly increased risk of pathological fractures. Consequently the composite forearm flap may not provide sufficient bone stock for re-implantation. It is not a commonly used flap, except when only very small bone struts are needed, for example, the midface, orbit, or nose.

The osteocutaneous scapular and parascapular system is another donor site that has widespread applicability in the complex landscape of head and neck reconstruction. The primary advantage to the scapular and parascapular system is the three-dimensional freedom provided by the independent vascularization of the bony and soft tissue components if it is harvested as a chimeric flap. This can allow for modification and application of the flap to difficult oromandibular defects—such as ones involving large resection of the temporal bone, temporal mandibular joint, and soft tissue. This flap can be utilized with latissmus or serratus flap to provided adequate bulk and muscle when needed. The serratus flap may also be harvested with a segment of rib, further facilitating composite reconstruction. It however does not provide the same amount of bone length as the fibular free flap, is greatly limited due to its lack of robust cortex making implantation less than ideal, even with subsequent on lay grafting.

Finally, the iliac crest free flap is another valuable composite flap often utilized by the reconstructive surgeon. Based of the deep circumflex iliac artery, the iliac crest free flap provides high quality bone, up to lengths of 14 cm, that provides good bone stock for reimplantation. Furthermore, the nature curvature of the ilium is excellent in recreating the contour of the mandible. However, the associated skin territory is often thick and bulky, which precludes it from being an ideal donor site for mandibular reconstruction. However, it becomes increasingly valuable as a site of bone donation in patients whereby fibular free flaps are contraindicated (peripheral vascular disease, previous surgery). Pain and donor site morbidity, namely hernias, are common if with adequate donor site reconstruction.

## Visceral Flaps

Although not commonly utilized by most reconstructive head and neck surgeons, two visceral flaps available include the jejunal and mental flap. The free jejunal flap was the first free tissue autograft ever transfered in the human body. Its natural tubed structure and intrinsic motility, has popularized it in the reconstruction of paryngoesophageal defects. The free jejunal flap can also be split along its antimesentric side to allow for resurfacing of larger areas (e.g. pharyngeal inlet, floor of mouth). However, it is limited by donor site morbidity, as well as its intolerance to ischemia time. Moreoever, it fell out of favor with most head and neck reconstructive surgeons due to mucous regurgitation and speech and swallowing issues. The tubed fasciocutaneous flaps and thin musculocutaneous flaps replaced this visceral flap early in flap dissemination training. It is rare that a tubed flap, weighing risks and benefits, would be needed that a gastric pull-up or more commonly used tubed radial forearm would not suffice. The mental flap is a visceral flap that has unique attributes including rich vascularity, promotion of fibroblast and capillary ingrowth, and strong absorptive properties due to its rich lymphatic network [5]. Its primary uses in the head and neck include resurfacing of nonviable, ischemic, infected, or avascular structures. Furthermore, the omentum is thin and pliable and can be folded on itself, and used for resurfacing as well as contouring head, neck, and facial defects. However, this flap is effectively limited in its donor site morbidity, and as such has fallen out of favor when compared to other available flaps. It is still an ideal flap for someone meeting the criteria for subcutaneous fat/volume restoration of the neck, face, or temporal fossas where other implants or free fat are not options due to vascular damage or other variable healing risk factors.

## Free Flap Management Considerations

### Anticoagulation

Maintaining perfusion of vascularized free tissue autografts is of utmost importance for all reconstructive surgeries. This has led to the use of various pharmacological agents to help ameliorate the possibility of thrombosis or attenuate any hypercoagulable states. Despite routine use of such agents, there exists a paucity of literature based high level evidence demonstrating the effectiveness, dosing, or ideal agent utilized for these purposes. Undoubtably, flap ischemia time and surgeon technical abilities surpasses these pharmacologic variables. With free flap success rates >95% in most practices, and >98% in high volume tertiary centers, it is unlikely evidence based studies on humans will ever solve this issue due to the unethical nature most flap surgeons see in augmenting their routine practices and the number needed to treat being too high to reach even in multi-institution trials. This difficulty in establishing evidence based studies can be represented with the deep venous thrombosis (DVT) prevention literature, where thousands of patients are pooled to show varying risks which are barely statistically significant. To standardize this many flap patients with surgeon preferences would take a national effort.

Asprin is an antiplatelet pharmacological agent that works by irreversibly targeting and blocking the cyclooxygenase pathway decreasing arachidonic acid metabolites, overall preventing arterial platelet aggregation. Although its antiplatelet activity is attractive, it has yet to be shown in retrospective studies to be beneficial in preventing adverse flap outcomes, with some studies demonstrating an increased risk of complications [10]. Surgeons seem to follow training patterns in regards to aspirin use and defending its use for greater flap success is not possible through the currently available evidence. That being said, a flap surgeon with 98% success rate would likely never change his or her aspirin use if it has been part of their post-flap protocols.

Dextran is a colloid solution that consists of polysaccharides that acts by inhibiting the formation and promoting the degredation of fibrin, as well as by inhibiting von Willibrand factor, ultimately preventing platelet activation. Many authors have proposed various dosing protocols, the majority of which are anectodal with no evidence substantiating its use. Furthermore, due the intravascular volume expansion, dextran protocols may cause pulmonary edema.

Heparin is an anticoagulant that targets and prevents the formation and propagation of thrombus. It acts by targeting the coagulation cascade by inhibiting thrombin, overall decreasing fibrin formation. Low molecular weight heparin (LMWH) is another formulation of heparin that targets Factor Xa, with a higher bioavailability and half life than regular heparin. The benefits of using both formulations of heparin in preventing thrombus in traumatized vessels have been demonstrated in rat models, but have yet to be susbstantiated in prospective clinical trials [11,12]. Ideally, general post-operative DVT prophylaxis should take place in all patients without a specific contraindication. This has been well borne out in the general surgery literature for patients who meet risk stratification criteria—of which, almost all head and neck free flap reconstruction patients do. The question in most practices is what day to start the heparin. It is ideal to start the day of surgery, or the day after at the latest. Some surgeons state post-operative hematoma as a reason to delay, however, most head and neck surgeons attempt a dry field before closure and use suction drains which help greatly decrease this risk. Slow venous ooze building-up placing flaps under tension, pedicle or tunneled flaps with inadequate drainage places fear in some surgeons who want to delay heparin, which is an understandable concern and requires vast experience before most flap surgeons would even consider changing their historic practice patterns or in-training idiosyncracies.

In-artery heparin irrigation is an under-reported, less studied, mechanism by which many flap surgeons believe will help negate most flap micro ischemic minor technical issues. Concentrated heparin irrigation directly into the flap, during the anastomosis directly places heparin in the most specific location to its need at the the most critical time. Once flow is re-established clotting factors likely need a technical issue to continue to propagate, hence most surgeons success rates. No amount of pharmacologic endeavors can save a poorly executed anastomosis with white clot collecting on the suture line due to tissue damage or irregularity and, similarly, a kinked vessel at nearing the anastamotic suture line is also a harbinger for demise. This is why, above all, training and experience lead to better success rates in individual surgeons and their expertise should not be out-weighed by insufficient literature based recommendations in regards to flap pharmacologic agents.

Tissue plasminogen activator factor, or other anti thrombotic agents are used in flaps which are compromised or have failed to break-up clots or help possibly re-establish the microcirculation thrombi.

## Monitoring

Free tissue transfers are at greatest risk in the first week of autotransplantation, with most failures occurring in less than 48 hours. Flap failure has immense detrimental effects to patient outcomes and health related costs, almost always requiring flap salvage or a second flap. The most failures occur early in the flaps viability course, usually in the first day. Arterial failure occurs earlier than venous, occasionally being caught in the operating room right during skin closure. This is usually a result of a recognizable, at take down, technical issue. Fortunately, these arterial failure flaps are mostly salvaged by redoing the arterial anastomosis, fixing the artery lie to be more inline or gently curving, or choosing a different artery with higher flow or better diameter match. Cutting back damaged arteries is also key in salvage surgery. In contrast, arterial failure that occur later than 48 hours are usually not technical, but propagate from a fistula bathing the anastomosis or the pedicle vessels and resulting infection. Infection alone can cause thrombotic arterial failure. Therefore, routine flap monitoring is integral in successful autografting to allow for flap salvage in the rare setting that is needed. Artery, vein, and wound breakdown issues should all be monitored very closely with decreasing intensity and frequency until time to independent vascular survivability has been reached. Most believe this to be in 5-10 days; however, this variable survival also requires experience to predict as some flaps never obtain complete non-pedicle dependent survival. For example, a large radial forearm flap directly on skull or a flap separating a cavity which cannot fully integrate into surrounding tissues. Various surgeons have implemented different monitoring protocols in order to allow identification of those flaps requiring salvage. Some surgeons utilize surface doppler signals at sites of identified perforators. However, within the head and neck, this can be complicated by signals transmitted from the carotid artery, or other major arteries in the region reducing reliability. This has led some surgeons to use implantable dopplers. These however have been reported to cause pedicle strangulation, anastamotic breakdown, and have been known to become dislodged also reducing reliability. However, with adequate care and training, implantable dopplers are safe in our opinion. Other surgeons prefer to utilize direct physical examination of the flap, assessing flap color, temperature, capillary refill, as well as bleeding from pinprick to assess viability. This becomes problematic for buried flaps, leading some authors to utilize exteriorized monitoring paddles or implantable dopplers. Finally, current investigations are underway determining the role of fluorescent perfusion angiography to determine flap viability. It has been established as predicting underlying blood flow. In the future, flap monitoring is an area for potential technical advancement. For example, with high resolution processed video or picture technology it is now possible to detect minute color changes which correspond to underlying blood flow and likely can be correlated to arterial and venous components leading to a beat-by-beat determination of blood flow through the flap. Another area for potential development is in the standardization of post-operative timing of monitoring. Practices differ in who monitors flaps and how often this monitoring is performed. This is one area where the implantable doppler has made a difference providing 'constant' monitoring easily discernible by nursing staff or even the patient themselves. The cost-benefit analysis of flap monitoring is also an area where further study is needed. For example, in some arenas, no flap monitoring is performed and a 'flap loss' rate is accepted. This may work well for surgeons, groups, or countries, with limited monitoring resources who's flap success rate is so high that the flap monitoring question approaches the benefit cut-off. This may sound counterintuitive if a flap surgeon desires very high success rates, but in the case of late flap failures from infection these are almost never salvaged and need to be re-done. Therefore, one possible future discussion is at what day post operatively does flap monitoring and subsequent attempted salvage fail routinely and require another free flap, thus calling into question strict monitoring protocols which are costly at that cut off where salvage is abysmally low.

Despite the myriad of monitoring options available, there fails to be a consensus on the ideal or optimal monitoring solution with most surgeons relying on their training or flap experience protocols to keep success rates high in their individual practice.

## FUTURE DIRECTIONS

1. Collaborative multi-institutional studies on flaps to increase power of studies
2. Development of universal protocols to decrease hospital days and cost
3. Consolidation of free flap care for better outcomes through experience, volume, protocols, and cost containment strategies
4. Management by set teams with enhanced experience in head and neck
5. Continued development of computer based 3-D surgical planning
6. Delineating which patients qualify for post-operative antibiotic prophylaxis
7. New technological advancements in post-operative flap monitoring
8. Development of new anastomosis coupling techniques
9. Wider acceptance of venous coupler, implantable doppler, doppler couplers though decreasing cost as the technology ages
10. Continued development in bio-printing and alloplastic materials

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