MICROSURGICAL FREE FLAP IN HEAD AND NECK RECONSTRUCTION

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Abstract: Microsurgical free flaps are today considered state of the art in head and neck reconstruction after composite tumor resections. Free flaps provide superior functional and aesthetic restoration with less donor-site morbidity. This article details our approach to this challenging and complex procedure. Free tissue transfer can be viewed as consisting of 4 essential stages: (1) defect assessment, (2) preparation of recipient vessels, (3) flap selection and harvest, and (4) flap inset and microsurgical anastomoses. The essential details of each step are highlighted. Meticulous attention to each step is important because each plays a crucial role in the overall success of the procedure. Workhorse flaps in our practice are the anterolateral thigh, radial forearm, fibula, and jejunum flaps. Unique issues related to postoperative care and monitoring of head and neck free flaps are discussed. The management of complications, in particular those threatening flap survival, are reviewed in detail. © 2009 Wiley Periodicals, Inc. *Head Neck* **32:** 1236–1245, 2010

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The field of reconstructive surgery has been revolutionized by the advent of microsurgery. Prior to the mid-1970s, pedicled flaps—such as the pectoralis major musculocutaneous flap, laterally based forehead flap, and deltopectoral flap—were the workhorses in head and neck reconstruction.[1–3] The development of free tissue transfer and microsurgical techniques in the 1980s heralded in a new age for head and neck cancer surgery. Surgeons were better able to design flaps that meet exact reconstructive demands. The volume and type of tissues that can be brought into the head and neck region are substantially increased with free flaps. Previously unreconstructable defects can now be reliably replaced with free flaps to achieve primary wound healing.[4–8] These developments have enabled head and neck surgeons to be more aggressive in tumor resections. This in turn has enabled better local control of disease compared with the era before the routine use of free flaps.[9,10] Today, microsurgical free flap is the accepted standard of care for head and neck reconstruction after tumor extirpation.[11–14] Flap selection, techniques, and outcomes of free tissue transfer have continuously been improved and refined with experience gained in the past decades. This review provides an update on the

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state of the art in head and neck microsurgical free flaps.

EVALUATION OF DEFECT

Defects in the head and neck can be classified into 6 anatomical subareas for reconstructive considerations: intraoral, mandibular, midfacial, cranial, cutaneous, and scalp.[15]

Intraoral defects comprise the tongue, floor of mouth, oropharynx, hypopharynx, larynx, and cervical esophagus. Depending on the site of the lesion and its extent, speech, swallowing, or both can be significantly impaired. Defects of the tongue and pharynx most profoundly affect these functions. Thin and pliable flaps are needed in this area because of the limited space and the need to maintain tongue mobility.[16–18] Defects of the tongue of <50% can be primarily closed. Defects of 50% to 70% should be reconstructed with a free flap, taking particular attention to re-create the gingivobuccal sulcus to optimize function of the residual tongue[17,18] (Figures 1A and 1B). Total glossectomy defects are difficult to reconstruct. Neither the use of muscle or skin flaps nor the use of innervated skin flaps has been demonstrated to deliver superior outcomes.[19,20] The reconstructed tongue is unable to replicate the motion of the native tongue,[21–23] and acts mainly to enhance contact with the palate for propulsion of food.[24,25] The results of tongue reconstruction are therefore dependent mainly on the amount of residual native tongue. Circumferential defects of the oropharynx, hypopharynx, and cervical esophagus can be reconstructed with free jejunum,[26] colon, radial forearm, or anterolateral thigh flaps.[27,28]

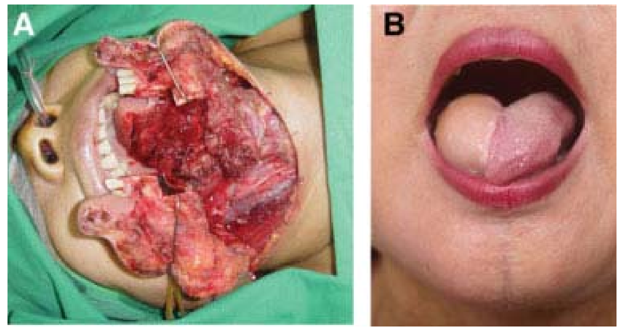

FIGURE 1. Hemiglossectomy defect reconstructed with a free anterolateral thigh flap. (**A**) Tongue defect involving the mouth floor. (**B**) Postoperative result at 4 years' follow-up. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Segmental mandibular defects are best reconstructed with vascularized bone, especially when involving the anterior portion, to prevent collapse of the mandibular arch (Figures 2A–2D).[29–31] The use of free vascularized bone, in particular the fibula osteoseptocutaneous flap, has revolutionized bony reconstructions in the head and neck. The bone can be secured by either the 2.4-mm reconstruction plate or miniplates. For lateral defects or posterior mandibular defects, a more selective approach can be adopted.[32–35] Young healthy patients should

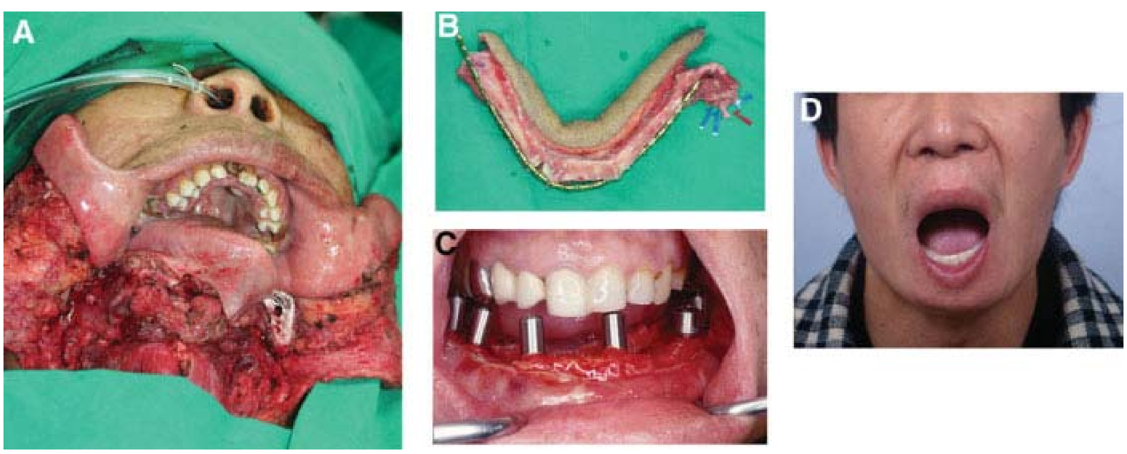

FIGURE 2. An angle-to-angle composite mandibular defect after excision of ameloblastoma and reconstructed with a fibula osteoseptocutaneous flap and subsequently osteointegration teeth implantation for total rehabilitation. (**A**) Angle-to-angle segmental mandibular defect. Note the associated mouth floor defect. (**B**) A fibula osteoseptocutaneous flap and reconstruction plate ready for mandibular reconstruction. (**C**) Secondary osteointegration teeth implanted at the fibula reconstructed neomandible. (**D**) Postoperative result at 4 years' follow-up. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

undergo reconstruction with vascularized bone. On the other hand, elderly debilitated patients with poor prognosis, plate reconstruction or even leaving the mandible free floating with only soft-tissue reconstruction is well tolerated.

Midfacial defects may involve the maxilla, orbit, nasal, and perinasal structures and the hard and soft palate. The small space and complex 3-dimensional relations in this area make accurate inset difficult. The goals of reconstruction here include the separation of the oral from nasal cavities, provision of support for the eye if the orbital walls are breached, and obliteration of dead space. In addition, the use of bone, allowing rigid reconstruction and the placement of osteointegrated implants, is preferred (Figures 3A–3D).[36–39] The hard and soft palate can be reconstructed with a skin flap or palatal obturator. The orbital walls should ideally be replaced by bone grafts. Dead spaces can be obliterated with muscle or deepithelialized skin flaps.

Cranial base defects result from resections involving the anterior, middle, or posterior cranial fossae. The principal reconstructive contingency here is to separate the contaminated aerodigestive tract from the brain with vascularized tissue to prevent infections (Figures 4A and 4B). Small cutaneous and scalp defects are best

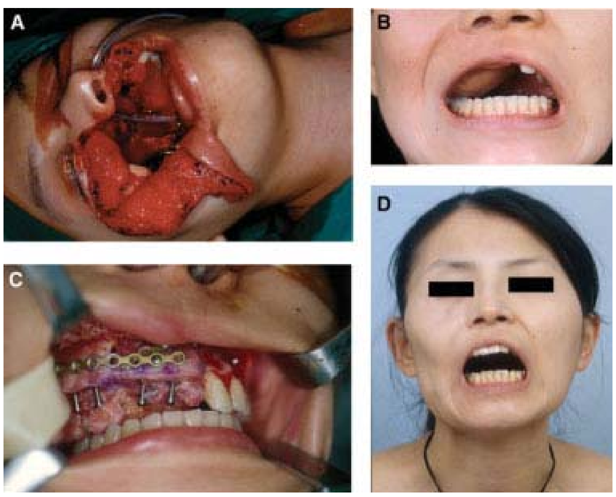

FIGURE 3. Maxillary defect resulted from excision of mucoepidermoid cancer, initially reconstructed with an anterolateral thigh flap and subsequently a fibula osteoseptocutaneous flap. (**A**) Maxillary defect involving medial, anterior, and lateral wall. (**B**) Appearance after first-stage reconstruction with an anterolateral thigh flap. (**C**) Second-stage reconstruction of maxilla bone defect with a fibula osteoseptocutaneous flap and simultaneous osteointegration teeth implantation. (**D**) Final appearance at 4 years. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

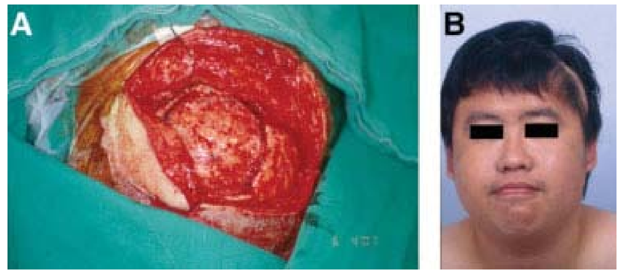

FIGURE 4. Post-traumatic epidural abscess with wound infection, dural defect, and scalp defect reconstructed with an anterolateral thigh fasciocutaneous flap. The vascularized fascia was used to repair the dural defect, and the skin flap was used to reconstruct the scalp. (**A**) Defect after debridement. (**B**) Postoperative result at 1-year follow-up. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

closed by local flaps. Free flaps, however, are indicated for extensive defects.[40–42]

APPROACH TO FREE TISSUE TRANSFER IN THE HEAD AND NECK

Upon completion of the resection, the resected specimen and the defect are examined. The size of the defect, tissue components excised (skin, soft tissue, or bone), and the compartments involved (skull base, orbital, maxilla, and mandible) are noted. Parts of the wound that can be primarily closed are done at this juncture to ensure accurate defect assessment. The neck is then explored for suitable recipient vessels. At least 1 artery and 1 vein are prepared for microsurgical anastomosis. The vessels are completely mobilized, and the approximate location at which the microsurgical anastomosis is to be performed is estimated. The needed pedicle length is estimated, and the need for interpositional vein grafts is determined. Upon completion of vessel selection, it is important to prevent dessication of these fragile vessels, which are irrigated with vasodilators (lignocaine and papaverine) and covered with heparin impregnated gauze. The wound is then covered with moist gauzes while the flap is harvested.

The flap is harvested, and the obtained pedicle length is measured. Upon confirmation of the adequacy of the length and size match, the pedicle is divided. The flap is partially inset into the defect, thus ensuring its proper positioning and reach of the pedicle to the recipient vessels. Watertight closure of defects involving the oral cavity—especially in the dependent areas of the tongue, floor of mouth, and the buccal mucosa—is important. The most inaccessible areas are sutured first. The inset is therefore started at the most difficult to reach location or the deepest extent of the resection and progresses toward the more superficial and easy to reach location of the defect. The inset can be partially or largely completed before microsurgical repair of the vessels. This prevents accidental dislodgement of the flap during microvascular anastomosis and allows the surgeon to further tailor and accurately orientate the flap and confirm the sites of microanastomoses. In particular, tension and twisting of the pedicle must be avoided, with the head in the neutral position. The neck is then passively taken through its functional range of motion to ensure that the pedicle is tension-free. To facilitate microsurgical repair, the head can be turned slightly to the contralateral side. A drain can be placed in dependent portions of the wound, away from the site of microanastomoses, usually in the posterior triangle of the neck. Suction is then applied to prevent pooling of blood and exudate. The recipient artery is ligated with a hemoclip and divided. It is important to ensure that the artery has a good, pulsatile flow, and the vein has an unobstructed outflow. Both the artery and especially the vein should be checked for either tension or redundancy before anastomosis. Except for visceral flaps such as the jejunum, we routinely perform the arterial anastomosis first. The advantages are 2-fold. First, the completion of the arterial anastomosis allows the immediate evaluation of the venous return through the veins. A good return ensures that the vein is orientated correctly with no twists or kinks. This is particularly important for perforator-based flaps because the pedicle is relatively small, fragile, and easily compressed.[43] Second, when 2 vena comitantes exist and only 1 recipient vein is available, this allows the surgeon to visually determine which vein is the better flowing one. Usually the return of 1 of the veins is more brisk, and this is the vein that should be used. In cases of moderate redundancy in the pedicle, multiple tagging sutures can be placed to secure the pedicle to prevent it from folding on itself and kinking. The flap inset is then completed. Excess flap can either be excised or deepithelialized and buried. The latter is useful in providing additional tissue for soft tissue augmentation, which in turn is beneficial in preventing tissue contractures to which these patients are prone, especially after postoperative irradiation. If necessary, additional drains are placed in other dependent areas and the wound is closed. The flap is checked for its color and bleeding again upon completion of the surgery.

Table 1. Flaps performed at Chang Memorial Hospital from 1999 to 2007.

Type of flap	Case no.	%
Anterolateral thigh (ALT) flap	2480	52.51
Radial forearm flap	733	15.52
Fibula osteoseptocutaneous flap	712	15.08
Others	798	16.90
Total	4723	100.00

Note: The ALT, radial forearm, and fibula osteoseptocutaneous flaps are our workhorse flaps and collectively accounted for 83% of flaps performed during this period.

FLAP SELECTIONS

We have used every conceivable flap in the past for head and neck reconstructions. It is difficult, however, for an individual surgeon to be comfortable with the whole spectrum of flaps described. Over the past 10 years, we have consolidated our approach, and have relied on a limited number of "workhorse" flaps for the majority of our reconstructive needs.[14] Currently, our workhorse flaps are the anterolateral thigh, radial forearm, fibula osteoseptocutaneous, and jejunum free flaps (Table 1). These flaps were selected because they allow the versatility of harvesting a variable amount of soft tissue of various components, and they reliably provide a long and sizable vascular pedicle. The fibula provides an unparallel quantity and quality of bone when bony reconstruction is needed. These workhorse flaps have enabled us to reconstruct virtually all types of head and neck defects. Furthermore, because of our familiarity with these flaps, the flaps can be harvested more quickly and more reliably, despite anatomical variations that may be present.

Soft Tissue Flap

Anterolateral Thigh Flap. The anterolateral thigh (ALT) flap is our workhorse soft tissue flap.[14,44] It can be harvested as a skin flap or as a myocutaneous flap by inclusion of the vastus lateralis muscle, thus significantly increasing the bulkiness of the flap. The flap can also be designed as a chimeric flap. A tough layer of deep fascia, particularly in the more proximal extent of the flaps where the tensor fascia lata is located, can also be included. This strong layer of vascularized fascia is very useful as a fascial sling or for dura reconstruction. Including the lateral cutaneous nerve of the thigh with the flap yields a sensate flap. When a thin flap is needed, it can be thinned to 3–4 mm.[45–47] The pedicle of the flap, usually the descending branch of the lateral circumflex femoral artery (LCFA) system, is reliably long (up to 18 cm) and of good caliber.[49] This allows the pedicle to comfortably reach vessels in the lower neck and even the contralateral neck without the need for interpositional vein grafts.[48]

The ALT flap, however, is notorious for its so-called anatomic variations. Based on our current understanding of the ALT flap, the potential variations that one may encounter when harvesting the flap can simply be classified into 2 types: (1) The course of the skin vessel supplying the anterolateral thigh, which can be either musculocutaneous (87%) or septocutaneous (13%)[44] and (2) the pedicle of the flap, which can be either the descending or oblique branch of the LCFA.[49] Such variations, however, do not affect its reliability, and the ALT flap can be safely harvested with meticulous technique.[50,51] The only contraindication to the harvest of the ALT flap is a "true" absence of sizable (>0.5 mm at the subfascial level) skin vessels in the anterolateral thigh. This occurrence is exceedingly rare (1%).[49]

Free Radial Forearm Flap. The radial forearm flap remains one of the most commonly used free flaps in head and neck reconstruction.[8,15] It has been noted that the radial forearm is the best option when a thin, pliable flap with a long pedicle and a sizable caliber is needed, although its unsurpassed characteristic is its reliability. In our practice, the radial forearm would be our choice flap when reliability and safety are the primary considerations, such as in situations of previously failed free flaps. Its limitations are well known and include the relatively small amount of soft tissue available and donor-site morbidity.[52,53] Nonetheless, donor-site morbidity can be appreciably reduced with the suprafascial harvest technique as described by Webster and Robinson[54] and Wei et al.[55] The suprafascial technique preserves the deep fascia of the forearm. This vascular and relatively immobile bed provides a more favorable bed for skin grafting, and the retained deep fascia has the effect of binding the tendons in its place, minimizing tenting of tendons during excursion.[57] Its superiority over the conventional "subfascial" technique has been clearly demonstrated.[55–57]

Bone Flap

Fibula Osteoseptocutaneous Flap. The fibula osteoseptocutaneous flap is our choice flap for vascularized bone transfer to the head and neck. Bone and skin components can reliably be harvested as a single composite flap, thus allowing simultaneous replacement of bone and soft tissue.[60,61] The vascular pedicle is the peroneal artery and its vena comitantes, which is constant and has sufficient length and size. The bone is of exceptional quality, allowing for multiple segmental osteotomies for contouring, and is of sufficient thickness for dental implantation. The donor-site morbidity is minimal.

Primary insertion of osseointegrated implants can be reliably performed in selected patients.[58,59,62,63] Our indications for primary implantation include patients with benign disorders, who are not going to receive postoperation irradiation, are in good health, and are of good prognosis and motivated. The fibula, however, is usually unable to establish adequate alveolar height. In patients in whom osseointegrated implants are planned, as either a primary or a secondary procedure, several maneuvers should be considered. The fibula should be placed about 0.5 to 1 cm above the inferior border of the native mandible, closer to the superior alveolar edge to facilitate placement of implants.[63–65] In most cases, the overlying soft tissue is able to camouflage the inferior border irregularities. A double-barrel fibula can also be used.[66] With this approach, care should be taken to ensure an adequate skin paddle because more soft tissue is often needed to accommodate the extra bony volume. Finally, vertical distraction osteogenesis of the fibula segment can be used to increase its height.

Visceral Flap

Jejunum Free Flap. The jejunum free flap is a reliable and effective option for reconstruction of pharyngoesophageal defects.[26,67] This flap is technically demanding and is noted for its intolerance to prolonged ischemia because of its high metabolic demand. The ability to reconstruct partial or circumferential defects not involving the thoracic esophagus in a single stage, rapid

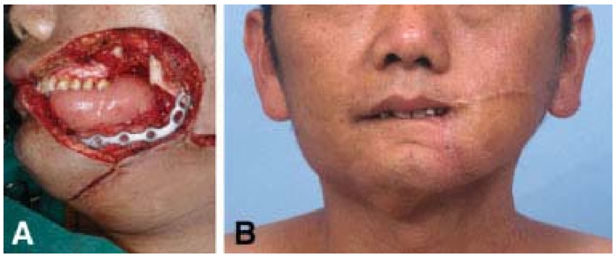

FIGURE 5. Extensive composite mandibular defect reconstructed with double flaps: the fibula osteoseptocutaneous flap for intraoral lining and the mandible, the anterolateral thigh flap for external face, and cheek bulk. (**A**) Defect. (**B**) Postoperative result at 7 years' follow-up. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

return of swallowing attributed to the exceptional motility of the jejunal segment, and the low stricture and fistula formation rates have made this flap the choice flap in defects of the cervical esophagus.

Double Free Flap. Extensive composite oromandibular defects involving bone, oral mucosa, external skin, and soft tissue may requires the use of 2 free flaps for adequate reconstruction[68,69] (Figures 5A and 5B). With the fibula osteoceptocutaneous flap, the volume of soft tissue is often inadequate for extensive defects. This is poorly tolerated in the head and neck region and will be aggravated by postoperative irradiation.[69] Dead space from the extirpation of the masseter muscle, floor of mouth muscles, parotid gland, and buccal fat if not obliterated will develop seroma that promote infection—even threatening flap survival. Even if healing ensues, the reconstructed site rapidly becomes contracted, leading to a sunken appearance and trismus. Patients will have difficulty opening the mouth, swallowing, chewing, and speaking. Such a suboptimal outcome can be avoided by providing adequate soft tissue replacement that can often be achieved only by a second soft tissue flap. Currently, our preferred second soft tissue flap is the anterolateral thigh flap because it can provide a large quantity of soft tissue to achieve volume replacement.

The use a double free flap is more technically demanding. To minimize operative time and optimize outcome, a 2-team approach should be used. While the ablative surgeons are performing the resection, the first team starts by harvesting the fibula osteoseptocutaneous flap. Upon completion of the resection, the first flap is detached from the donor site and the first team proceeds to contour, plate, and inset the flap followed by microsurgical anastomosis. Meanwhile, the second team starts to harvest the second soft tissue flap. Once the microsurgery for the first flap is completed, the second flap is detached, and the inset and revascularization of the second flap can commence. With such an approach, the average operative time was 14 hours and 25 minutes in a series of 130 consecutive double free flaps.[69]

POSTOPERATIVE CARE

Patients should be kept well hydrated and pain free to maintain a stable blood pressure. The head should be maintained in a neutral position. Although small amounts of neck movements are tolerable and probably safe, excessive turning toward and away from the side of the microsurgical anastomotic site can result in kinking and tension on the pedicle, respectively. Any mechanical compression in the neck must be strictly avoided. This is particularly important in patients with tracheostomies. The tracheostomy tube should be secured with sutures. Ties and oxygen mask elastic bands that encircle the neck must be strictly prohibited.

The flap should be left exposed to allow regular inspection. Hourly monitoring should be done for the first 72 hours, with increasing intervals between inspections subsequent for the first 5 postoperative days. Flaps rarely fail after 5 days.[69] Clinical examination is our primary modality of flap monitoring (Table 2). Various devices such as implantable and percutaneous Doppler and laser Doppler scanners have been used as adjuncts for flap monitoring. We do not routinely use these devices because we have found clinical assessment to be adequate, and allowed for timely identification of microanastomotic problems.

We do not routinely use anticoagulants such as dextran, heparin, low-molecular-weight heparin, or aspirin in the perioperative period. Although the use of such agents has not been conclusively demonstrated to increase anastomotic patency, it does not seem to increase perioperative bleeding and hematomas.[71,72] We use anticoagulants in selected cases in which the benefits are deemed to outweigh the risks of its use, such as when anastomotic patency is threatened, when a clot appears at the

Table 2. Clinical flap monitoring.

Characteristic	Arterial compromise	Venous compromise
Flap color	Pale, mottled, or bluish	Cynotic, dusky, or bluish
Capillary refill	Sluggish (>3 seconds)	Brisk
Tissue turgor	Flacid with decreased turgor	Tense with increased turgor
Temperature	Cool (>2° lower than control)	Cool (>2° lower than control)
Pin-prick	Small amount of dark blood	Copious dark blood
Doppler signal	Absence of pulsatile signal	Absence of continuous venous hum

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anastomosis intraoperatively, or in salvage cases after revision of the venous or arterial anastomosis.[73] Intravenous heparin and dextran are used in these cases. Feeding through a nasogastric tube can be introduced progressively from the first postoperative day once active bowel sounds are present. Oral feeding can be started with clear liquids after 7 days.

IDENTIFICATION AND MANAGEMENT OF COMPLICATIONS

Free tissue transfer has high overall success rates of 91% to 99% reported consistently by many centers.[8,70,74,75] However, 5% to 25% of free flaps will require reexploration. In our experience of 1142 consecutive free flaps, the overall flap survival rate was 96.4%. In all, 113 flaps (9.9%) developed vascular compromise and required reexploration.[70] Of these, the vast majority (84%) can be successfully salvaged. The key to successfully salvaging a failing flap is early detection, accurate identification of causative factors during exploration, and correction of these problems. Venous thrombosis accounts for the majority of these problems noted at exploration (58%). This may be related to rheology (low flow and low intraluminal pressure) and biophysical properties (thin-walled and fragile) of veins. Nonthrombotic vascular events account for 46% of flap vascular compromise. These events include vessel vasospasm, problems related to flap inset, compression of the pedicle (by hardware such as the reconstruction plate, bone, or even hemoclips), or pedicle or perforator injury. This will need to be addressed accordingly at exploration including reinset of flap and revision of pedicles that are under tension, if necessary with the use of interpositional vein grafts. If venous outflow is insufficient and there are 2 veins available, performing a second venous anastomosis (if not done at initial surgery) may be beneficial in relieving congestion. Interpositional vein grafts are needed more commonly during reexploration, and the patients should be informed accordingly. The thrombosed segments of the vein or artery often need to be excised together with the clot because intima injury resulting from the clot predisposes to further thrombosis if the segments are preserved.

Infections should be treated aggressively. Necrotic, infected tissue should be debrided to prevent the spread of infection that may compromise the flap pedicle. Also, in the head and neck, infections that are not quickly treated and resolved may erode into necks vessels, resulting in carotid blow-out, which can be dramatic and devastating. The cause of infection should also be addressed at debridement. The most common cause is salivary fistula, resulting in saliva pooling in the neck. In such instances, the unhealthy, dehisced portions of the flap and oral mucosa should be debrided and a watertight closure should be achieved by meticulous suturing, to separate the oral cavity from the neck.

A failed free flap can be managed by 1 of 3 options: (1) a second free flap; (2) a pedicled flap; or (3) conservative wound care followed by closure by either secondary intention, skin graft, or delayed local flap.[76] The management of failed free flaps in the head and neck, however, is dictated by certain time-sensitive constraints. An exposed carotid artery or dura is potentially life-threatening, leading to complications of carotid blow-out and meningitis, respectively, if not expediently covered by well-vascularized tissue. Furthermore, patients after tumor ablation need to have their wound primarily healed so that they can move on to their next phase of treatment, which may include the use of chemotherapy or radiotherapy. Delayed healing may thus adversely affect the oncologic outcomes in these patients. Such considerations therefore exclude a conservative approach in most instances. The use of a second free flap versus a pedicle flap has been previously investigated, and the latter is associated with higher risk of both major and minor complications.[76] Thus, an important consideration for the surgeon when contemplating available options is whether he/she is willing to downgrade the quality of the reconstruction. If the answer is no, then a second free flap will probably offer the most tenable solution. A failed vascularized bone flap can be replaced only by a second vascularized bone flap, to achieve an outcome that was desired at the first surgery. Technically, the second free flap is more difficult and has a higher failure rate (5.8%) than that of primary cases.[76] The contralateral neck may be needed for recipient vessels (35%) and the use of interpositional vein grafts is needed more frequently (30%). It should be stressed, however, that whereas the second free flap is more difficult, in most instances it also represents the best option for the patient.

CONCLUSION

Advancements in reconstructive techniques have given surgeons greater ability to clear malignancies and thus to improve the chances of survival. Functional and aesthetic outcomes also improve the patients' quality of life. Indeed, microsurgical free flap is today the standard of care for patients with large, composite defects after tumor resections. Although workhorse flaps used today are more versatile, donor-site morbidity is at the same time much reduced. Such improvement came about by continuous refinement of surgical techniques, better understanding of anatomy, and critical selection of flaps that provide the requisite tissues with minimal donor morbidities.

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