Principles of Head and Neck Reconstruction: An Algorithm to Guide Flap Selection

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ABSTRACT

Advances in head and neck reconstruction have resulted in improved outcomes with single-stage repair of defects ranging from intraoral to pharyngoesophageal to skull base defects. Key to success of surgery is choosing an appropriate reconstructive option based on the patient's wishes and fitness for major surgery. Where possible, free tissue transfer provides the best functional and aesthetic outcomes for the vast majority of defects. In this article, we present an algorithm to guide choice of flap selection and review principles of reconstruction and secondary surgery for head and neck defects.

KEYWORDS: Flap selection, free tissue transfer, integrity-function-form, reverse reconstructive ladder

Reconstruction of defects in the head and neck poses a unique challenge. Unlike other areas of the body, which may on occasion be temporized by dressing changes or even allowed to heal by secondary intention without major complications, immediate or early closure of head and neck defects is vital for several reasons. Maintaining the integrity of the alimentary tract, and as such the patient's ability to eat, is an issue of paramount importance. Reconstruction of the face is essential for a person to communicate through facial expression. Last but not least, coverage of the neck and maintenance of an intact intraoral seal prevents life-threatening complications such as blowout of the great vessels of the neck. Here we present an algorithm to guide choice of reconstruction in the head and neck and also present a current and historical review of reconstructive options.

APPROACH TO RECONSTRUCTION

When approaching options for reconstructing a defect of the head and neck, it is helpful to decide the goals of reconstruction. A useful way of doing this is to decide if the patient requires reconstruction only to restore the *integrity* of the alimentary tract, face, and neck or if the patient is fit enough for reconstruction aimed at restoring *function* as well as *form* for organs in the head and neck.

Many patients requiring reconstruction present after extirpative oncologic surgery and may not be the fittest candidates for major surgery. First and foremost, restoring the *integrity* of the alimentary tract, face, and neck must be a priority for all patients, for reasons mentioned above. If not performed adequately, complications such as an orocutaneous fistula compromise the patient's ability to feed and can even lead to a

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Figure 1 A pedicled pectoralis major flap was used to reconstruct a right hemiglossectomy and floor-of-mouth defect in a patient with squamous cell carcinoma. Due to tethering resulting from the pedicled flap, there was limited tongue mobility. This reconstruction was aimed at, and successfully restored, *integrity* but not *function*. (A) Preoperative image showing lesion. (B) Flap is well healed and mucosalized 10 months after surgery.

life-threatening event such as carotid artery blowout. Although reconstruction using free tissue transfer would be ideal, in extremis a simple pectoralis major pedicled flap to plug a hole (Fig. 1; see also Fig. 2) or to restore the continuity of the pharynx or esophagus may be sufficient to achieve this goal for most patients. Another example where restoration of *integrity* is vital is separation of the intracranial contents from the sinuses and alimentary tract in skull base reconstruction as well as obliteration of dead space with vascularized tissue to prevent meningoenitis and cerebrospinal fluid leak.

Next, restoring *function* in the patient is an important consideration if the patient can tolerate major surgery. The head and neck area is responsible for several vital functions such as mastication, swallowing, speech, and facial expression. As an example, reconstruction of a partial glossectomy defect is not essential for the survival of a patient, as the defect can be closed primarily. However, restoration of the bulk of the tongue through free tissue transfer allows the neotongue to contact the palate and hence facilitate swallowing (Fig. 3). Another example is speech rehabilitation through such methods as tracheoesophageal puncture¹ or free ileocolon flap.² Although a person can survive after total laryngectomy without this procedure, restoration of speech facilitates communication and enhances quality of life. Similarly, whereas a large mandibular bony defect can be repaired using just a reconstruction plate or nonvascularized bone graft, this results in a suboptimal reconstruction in the long term. To allow continued function of the mandible in mastication and to allow placement of osseointegrated implants, vascularized bone is essential. Restoration of *integrity* and *function* in the head and neck should be the minimal goal in all patients who are not critically ill.

Lastly, where possible, *form*, or aesthetics, should be a consideration in head and neck reconstruction. As an example, maxillary defects can be reconstructed using an obturator or a purely soft tissue free flap such as a

scapular flap. However, using a segmented free fibular flap would allow one to reconstruct the buttresses of the face, restoring facial projection, and also allow for placement of osseointegrated implants for dental rehabilitation.³ Reconstruction of the soft tissue defect after total parotidectomy is another example where a de-epithelialized parascapular free flap has been used.⁴ Facial nerve reconstruction after total parotidectomy allows restoration of smile and prevention of stigma associated with nerve palsy.⁵ On a more limited scale, considering the aesthetic subunits of the face^{6,7} and respecting these boundaries when planning the reconstruction allows optimization of the cosmetic outcome after surgery. Replacing a defect with like tissue, for example in sensitive areas such as the lip and nose, allows an optimal aesthetic outcome. *Form* may also be restored secondarily in a patient who may not be fit initially for extensive surgery (Fig. 2).

Considering whether *integrity*, *function*, and *form* should be the goals of the reconstruction alone or in combination will depend on the patient's state of health, comorbidities, and wishes. Preoperative work-up of patients should be extensive, taking into account factors that affect risks of anesthesia and surgery and that would potentially affect the outcome of the reconstruction. If a patient has extensive coronary artery disease, with a correspondingly high surgical risk, and is also malnourished and cachectic due to tumor progression in the head and neck, he or she may not be the best candidate for a free tissue transfer. In this context, restoration of *integrity* alone using a pedicled locoregional flap may be sufficient. However, if a young, fit patient presented with a benign tumor in the mandible and required reconstruction after resection, it would certainly be appropriate if *integrity*, *function*, and *form* are taken into account when planning the reconstruction.

Having decided the aims of reconstruction, it is then prudent to analyze the *components* of the defect. The defect may involve skin, soft tissue, or bone, alone or in

Figure 2 (A) A 73-year-old man presented with a large ulcerated squamous cell carcinoma invading the superficial and deep lobes of the parotid necessitating total parotidectomy with facial nerve sacrifice, with (B) a large resultant skin defect. (C) A pedicled pectoralis major flap was used to "fill the hole." This reconstruction successfully restored *integrity*. The patient did well postoperatively and had further interventions 4 months after the initial surgery aimed at restoring *form*. These included a static sling procedure using tensor fascia lata for elevation of the oral commissure and suspension of the lower lid to the temporalis fascia. (D) Postoperative image 5 weeks after secondary surgeries. Botox injections can be used on the contralateral face to obtain more symmetry.

combination. It may also require two or more separate skin paddles, for example in reconstruction of an intraoral and extraoral skin defect. The tissue *components* and *volume* of tissue required would dictate the choice of reconstruction.

WORK-UP OF PATIENTS UNDERGOING RECONSTRUCTION

Many patients requiring reconstruction of head and neck defects also require extirpation of malignant lesions, with a large number of these patients being of middle age or older, with comorbidities. Routine work-up should

therefore be extensive and include at least a thorough history and physical examination, laboratory investigations, chest X-ray, and electrocardiogram. Other investigations may include computed tomography (CT) of the head and neck and positron emission tomography scan. Patients with head and neck cancer may also have undergone evaluation with direct laryngoscopy, bronchoscopy, or esophagoscopy under anesthesia to assess for spread of the lesion and synchronous lesions. Patients with comorbidities such as coronary artery disease may require further cardiac evaluation and work-up with an echocardiogram or exercise stress test. As many patients with head and neck cancer also smoke, pulmonary

Figure 3 (A) A 63-year-old man presented with a large ulcerated cancer involving the left tongue and floor of the mouth. This was reconstructed with a radial forearm flap, with neurotization of the lateral antebrachial cutaneous nerve using the hypoglossal nerve. This reconstruction restored *function*. (B) The patient 6 months after surgery was free of disease, with good tongue movement and intelligible speech.

function tests and a pulmonary consult may be in order. Interestingly, advanced age has not been found to lead to worse outcomes in patients undergoing free tissue transfer.^{8–10} Age should therefore not be a contraindication for use of free tissue transfer for reconstruction in elderly patients without other significant comorbidities.

Other investigations that may aid in deciding the choice of reconstruction include the use of CT angiography¹¹ or magnetic resonance angiography¹² to assess the arterial anatomy prior to harvest of a free fibular flap. CT angiography and CT-guided stereotaxy have been described for preoperative imaging of perforators in anterolateral thigh (ALT) flap reconstruction.¹³ Prefabricated mandible templates based on CT scan data are also used to aid in shaping the neomandible from fibula, scapula, and radius bone after extirpative surgery.¹⁴

RECONSTRUCTIVE OPTIONS: THE REVERSE RECONSTRUCTIVE LADDER

The reconstructive surgeon should be familiar with all aspects of the reconstructive ladder. In the head and neck, however, aside from some small and superficial defects, free tissue transfer should be the first choice for reconstruction of large or composite defects involving bone, soft tissue, and skin. There are several reasons for this.

1. Free tissue transfer brings in robust new tissue with its own blood supply, providing enough volume to restore function in critical areas such as the mandible or tongue. Use of locoregional flaps in most cases will not be sufficient to restore integrity and function for many defects or may not be aesthetically pleasing. An example of this is the bulge in the neck and loss of function necessitated by use of pectoralis major pedicled flaps for reconstruction of intraoral defects.
2. Many patients with head and neck cancer will require radiation. As such, vascularized tissue, which is resistant to radiation, is essential in many reconstructions. An example is the use of vascularized bone for

reconstruction of mandibular defects. Use of non-vascularized bone or a reconstructive plate for repair of these defects leads to suboptimal outcomes and higher complications such as osteoradionecrosis.

3. Use of free tissue transfer to achieve an optimal reconstruction during the first surgery also reduces the cost and morbidity often associated with repeat surgeries due to failure of suboptimal reconstructions using locoregional flaps.¹⁵ Where free tissue transfer is not a good option in a critically ill patient, and the aim is to restore only *integrity*, without *function* and *form*, then regional flaps such as the pectoralis major and deltopectoral flaps would provide options for reconstruction.

The evolution of head and neck reconstruction in many ways parallels this trend. Early reconstructive techniques, such as the Wookey flap¹⁶ for pharyngoesophageal defects, involved the use of local tissue in a staged fashion for reconstruction. However, these were plagued with complications and unpleasant for the patient. The necessity for immediate reconstruction in the head and neck was advocated by Edgerton in 1951.¹⁷ Subsequent descriptions of the deltopectoral flap by Bakamjian in 1965¹⁸ and the pectoralis major flap by Ariyan¹⁹ in 1979 and Theogaraj et al²⁰ in 1980 (for pharyngoesophageal reconstruction) were milestones that allowed single-stage reconstruction of head and neck defects with much greater success and less morbidity. These regional flaps are still an important component of the armamentarium of the reconstructive surgeon today.

The development of free tissue transfer facilitated unparalleled outcomes in head and neck reconstruction, allowing for single-stage reconstruction of composite and large defects with a marked decrease in morbidity and higher success rates. Free jejunal flaps for esophageal reconstruction were described in 1959.²¹ Free fasciocutaneous flaps were later described for intraoral reconstruction in 1976.^{22,23} The description of the radial

forearm flap by Yang et al²⁴ in 1981 provided surgeons with easily accessible pliable tissue that could be used for reconstruction in many areas in the head and neck. Reconstruction of osseocutaneous defects was facilitated by introduction of the deep circumflex iliac artery flap by Taylor et al²⁵ in 1979 and the fibular flap by Hidalgo²⁶ in 1989 for mandibular reconstruction.

Recent developments have included the use of perforator flaps in head and neck reconstruction. The ALT flap was first described by Song et al in 1984²⁷ and subsequently popularized by Wei et al.²⁸ In many centers, this has become the flap of choice for skin and soft tissue reconstruction in the head and neck, providing an unparalleled quantity of soft, supple tissue, with a concealed donor site. Another advantage of the ALT flap is the possibility to use it as a chimeric flap,²⁹ allowing simultaneous resurfacing of intraoral and extraoral defects with different skin paddles based on different perforators. Chimeric flaps based on ALT, anteromedial thigh, and vascularized iliac bone graft have also been used to repair massive defects in the head and neck,³⁰ and combined ALT and fibular flaps based on the chimeric principle have been used to reconstruct large through-and-through oromandibular defects.³¹

Clearly, the field of head and neck reconstruction has developed exponentially and continues to advance daily. Recently, pedicled flaps have experienced a resurgence with some authors. The supraclavicular artery island flap³² and submental artery flap³³ are examples of regional flaps that provide alternatives to free tissue transfer in selected cases.

SECONDARY SURGERY

Reconstruction of the head and neck defect does not end at the primary surgery. Unfortunately, every surgeon will experience several free flaps that cannot be salvaged by reexploration or conservative measures such as the use of leaches. The question that arises is what to do next. Keeping tissues moist with regular dressing changes prevents desiccation and weakening of such critical structures as the carotid artery and internal jugular vein. Early debridement and coverage of exposed vital structures is critical. Pooling of secretions and infection in the neck can lead to life-threatening complications such as carotid artery blowout.

In a review of 1235 flaps in the head and neck with 42 failures (3.4%), Wei et al³⁴ performed a second free flap in 40% of patients, regional flaps in 36% of patients, and treated conservatively in 24% of patients. The mean time between failure and second free tissue transfer was 12 days. They noted that 47% of regional flaps failed, and 40% of patients treated conservatively developed complications that required additional procedures, often in the form of free tissue transfer. These

authors concluded that, in the head and neck, a second free tissue transfer was a more reliable and effective procedure for treatment of flap failure. Okazaki et al,³⁵ in a series of 502 free flaps with 19 failures (3.8%), arrived at the same conclusion, recommending a second free flap where possible, and pedicled flaps or direct closure in small defects. It was noted in this series that patients who underwent reconstruction with pedicled flaps such as pectoralis major and deltopectoral flaps for secondary esophageal reconstruction had a poorer outcome than those who were reconstructed with free jejunal flaps, being able to eat only gruel, as opposed to a normal soft diet. Clearly, where possible, early coverage with a second free tissue transfer should be the option of choice in most cases of flap failure in the head and neck.

Patients may also require secondary surgery to enhance function after reconstruction. An example is tracheoesophageal puncture for voice rehabilitation.¹ Debulking of flaps results in enhanced facial contour, symmetry, and aesthetic outcome and can be performed under local anesthesia.³⁶ Secondary vestibuloplasty allows for delayed osseointegrated implants. Other procedures may include scar revision or resurfacing of an unsightly skin-grafted donor site using modalities such as tissue expanders.

As many patients requiring head and neck reconstruction are also cancer patients, a significant number may present with a recurrence requiring further reconstruction. Salvage surgery with free flap reconstruction has been reported to have the best outcomes in patients with recurrent T1 and T2 tumors.³⁷ However, limited application in recurrent advanced (T3 and T4) cancer³⁸ has also been reported, with a reported mean survival of 27.3 months in a series of 48 patients. As salvage surgery is often the only curative option for recurrent head and neck cancer, a significant proportion of patients presenting for reconstruction will have previously undergone treatment.

In this subgroup of patients, the neck is often scarred due to previous surgery and radiation. Recipient vessels for free flaps are hard to find and are often encased in scar. Often, vessels from the contralateral neck or vein grafts may have to be used. Unfortunately, the use of vein grafts has been reported to be associated with an increased incidence of thrombosis.³⁹ The transverse cervical vessels have been advocated for use as recipient vessels in previously treated head and neck patients by Yu et al,⁴⁰ as they are often outside the field of radiation and previous surgery. Other options include the thoracoacromial artery⁴¹ and cephalic vein dissected distally and transposed for venous drainage when no other veins are available.⁴² Unusual applications of free flaps may be required, such as the use of a tubed ALT flap for tracheal reconstruction in parastomal recurrence after total laryngectomy.⁴³

CONCLUSION

Head and neck reconstruction is perhaps one of the most challenging and progressive areas in plastic surgery, with new advances virtually every day. The treatment of many cancer patients extends beyond a single surgery and is often a lifelong process, with secondary surgery required for rehabilitation and recurrence. Key to achieving the best long-term outcome is an optimal reconstruction performed at the first stage. Paradoxically, as a result, free tissue transfer should often be the first choice for reconstruction, with a "reversed" reconstructive ladder helping to guide flap selection based on patient wishes and components of the defect.⁴⁴ The plastic surgeon is only one member of a multidisciplinary team comprising the resecting surgeon, medical oncologist, radiation oncologist, prosthetist, speech pathologist, dietitian, and social worker, all of whom work together with the aim of reconstructing the head and neck based on requirements for restoration of *integrity, function, and form*.

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