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Pedicled Extranasal Flaps in Skull Base Reconstruction

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Abstract

Cerebrospinal fluid (CSF) leaks most commonly arise during or after skull base surgery, although they occasionally present spontaneously. Recent advances in the repair of CSF leaks have enabled endoscopic endonasal surgery to become the preferred option for management of skull base pathology. Small defects (<1cm) can be repaired by multilayered free grafts. For large defects (>3cm), pedicled vascular flaps are the repair method of choice, resulting in much lower rates of postoperative CSF leaks. The pedicled nasoseptal flap (NSF) constitutes the primary reconstructive option for the vast majority of skull base defects. It has a large area of potential coverage and high rates of success. However, preoperative planning is required to avoid sacrificing the NSF during resection. In cases where the NSF is unavailable, often due to tumor involvement of the septum or previous resection removing or compromising the flap, other flaps may be considered. These flaps include intranasal options—inferior turbinate (IT) or middle turbinate (MT) flaps—as well as regional pedicled flaps: pericranial flap (PCF), temporoparietal fascial flap (TPFF), or palatal flap (PF). More recently, novel alternatives such as the pedicled facial buccinator flap (FAB) and the pedicled occipital galeopericranial flap (OGP) have been added to the arsenal of options for skull base reconstruction. Characteristics of and appropriate uses for each flap are described.

Keywords

CSF leak; endoscopic; reconstruction; skull base; vascularized flap

Introduction

In the last 10 years, anterior skull base reconstruction to repair cerebral spinal fluid (CSF) leaks has evolved tremendously. The primary goal of skull base reconstruction is to obtain a watertight closure, separating the cranium and the sinonasal cavity as a barrier against intracranial infection. Other goals include elimination of dead space, preservation of neurovascular and ocular function, and promotion of wound healing.

Early success with endoscopic reconstructive techniques to repair spontaneous CSF leaks caused by accidental or iatrogenic trauma has led to acceptance of endoscopic transnasal transcranial surgery as the preferred option for managing benign and malignant diseases. Small (<1cm) defects in the skull base, commonly found during CSF fistula closure, are reliably repaired (success rate greater than 90%) using multilayered free grafts [1]. In such

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small defects, merely establishing a tissue barrier is sufficient. However, larger (>3cm) defects such as those commonly caused by tumors (e.g., meningioma) are more difficult to repair. The repair of large defects using free grafts has resulted in rates of postoperative CSF leaks up to 40% [2], which varies by tumor location.

Large defects demonstrate additional challenges including wide resection of the dura, additional dissection of the arachnoid, and greater exposure to high-flow CSF. With advancements in reconstructive techniques using local and regional vascularized flaps, the rate of postoperative CSF leak has been reduced to less than 5% [3]. In this chapter, we discuss the use of pedicled extranasal flaps that may improve management of large skull base defects.

Clinical Presentation

A patient's history is most suggestive of postoperative CSF leak, which may occur spontaneously after trauma or, more commonly, within a week following skull base surgery. Patients may present with complaints of metallic/salty taste and symptoms including rhinorrhea or clear postnasal drip. On physical exam, findings suggestive of CSF leak include a positive reservoir sign (clear rhinorrhea induced by the patient leaning forward) or rhinorrhea elicited by the Valsalva maneuver. Sinonasal endoscopy can help localize the CSF leak. Assay of rhinorrhea fluid for Beta-2 Transferrin, a protein found in CSF, may be used as a confirmatory test [4].

It is less common to experience a postoperative CSF leak beyond a week from surgery. Intermediate timed CSF leaks (2–6 weeks postoperatively) present with intermittent low flow leaks from a small dural opening. Late CSF leaks (more than 6 weeks) are rare and usually seen with hard nose blowing, radionecrosis, and prior surgery [5].

High Risk Factors for Post Operative CSF Leak

Risk for postoperative CSF leak is often dependent on size and location of defect, intraoperative dural violation, and the type of reconstruction employed. Large defects repaired with free grafts are associated with unacceptably high rates of CSF leak, >30%, while small defects have much lower risk of developing postoperative CSF leak regardless of method of repair [6]. In terms of location, anterior skull base defects are much more likely to leak than clival defects [5]. The presence of an intraoperative high-flow CSF leak is the most reliable predictor of developing a postoperative leak [7]. Thus, pathology that requires dissection into the arachnoid cisterns or ventricles is also associated with higher rates of postoperative CSF leaks. However, with the advent of vascularized flap reconstruction, the rate of postoperative leaks has been dramatically reduced to less than 5% [7, 8]. Patient factors that increase the risk of a post-operative CSF leak include [5]:

1) Obesity - Associated with increased ventricular pressure

2) Cushing's disease - Increased circulating cortisol levels can lead to poor tissue healing

3) History of prior surgery or radiation – Limits options for vascularized tissue reconstruction, impaired tissue healing

Management of Skull Base Defects

Endoscopic expanded endonasal approach (EEA) is now widely used to treat a full range of extradural and intradural pathologies. As the skull base defects created by EEAs became more complex, the options for reliable reconstructive expanded as well. Materials for reconstruction now include avasular grafts, pedicled nasoseptal flaps, turbinate flaps, and endoscopic regional flaps from extranasal sources. The choice of appropriate reconstructive option should be guided by the location and size of the defect, type of intraoperative CSF leak after resection, and history of radiation or sinonasal surgery.

Prior to the routine use of vascularized tissue flaps for skull base reconstruction, free grafts of biologic or synthetic material were used as the primary reconstructive technique. The key to a successful repair was use of a multilayer approach. The repair begins with a subdural inlay graft of collagen matrix (Duragen) to obliterate the intradural dead space, followed by an inlay graft of acellular dermis (AlloDerm) in the epidural space. In many cases of EEA skull base defects, especially at the sphenoid or clivus, the bony ledges are limited and cannot support an inlay graft. In these cases, an extracranial onlay graft may be used. The grafts are then bolstered intranasally with absorbable packing, synthetic or biologic glue, and a nasal Foley catheter balloon or expandable sponge packing. This technique can be modified for moderately sized defects by using an onlay free mucosal graft instead of the Alloderm graft. Abdominal fat can also be added to the multilayer reconstruction as an additional bolster or biologic dressing or to obliterate dead space. For small defects (<1cm), the multilayer approach has a success rate of greater than 90% [6]. For defects greater than 3cm, reconstruction with multilayered free tissue grafts results in unacceptably high rates of postoperative CSF leaks of 20–30%, and therefore not recommended [3]. Reconstruction of the bony defect following skull base surgery is controversial. Advocates of reconstruction cite the need to prevent herniation of cranial contents or pulsatile exophthalmos. However, much literature has shown that the bony defect presents no functional or aesthetic consequence [9]. If structural support is needed, titanium mesh, calvarial bone, or split rib grafts have been used in the past. However, introduction of free bone grafts or synthetic material can lead to poor tissue healing [10].

Reconstruction with a vascular pedicled flap is preferred for large defects resulting from wide dural resection with associated extra arachnoid dissection, high flow CSF leaks, and a non-vascularized reconstructive bed. Of the local and regional vascularized flaps, the nasoseptal flap (NSF) has increasingly become the workhorse of endonasal skull base reconstruction. The NSF is a vascular flap composed of mucoperiosteum and mucoperichondrium from the nasal septum, pedicled on the posterior nasoseptal artery [5]. The advantages of the NSF include endoscopic graft harvest avoiding a second incision and the ability to cover a most of anterior skull base defects based on radioanatomic studies [12]. The major disadvantage is that the use of the NSF must be anticipated preoperatively: without this planning, the dissection might compromise vascular supply to the flap during sphenoidotomy or posteror septectomy. This flap may not be available secondary to sinonasal tumor involvement or if prior surgery has used the flap or compromised the pedicle. At its maximum, the NSF can cover from the posterior wall of the frontal sinus to the sella turcica, and from orbit to orbit [5]. The harvest can also be extended onto the nasal floor for a wider flap. Special consideration must be taken in the pediatric population (<10 years of age); the NSF area is often significantly smaller than the age-corresponding skull base defect because septal growth is not completely developed until puberty [13]. The size of the flap is may be limited by whether the lesion involves the area of the plan harvest, if the required dissection may potentially injure its vascular supply, or in the presence of septal spurs that may increase the risk of flap perforation. The NSF should be used in conjunction with a multilayer reconstructive approach as previously described with the flap used as an onlay graft over the bony cranial base defect [5]. As with any vascularized flap, the flap needs to be in direct contact with the margins of the defect for proper healing without interference from any nonvascularized tissue. Finally, it is essential to separate the graft from any nonabsorbable packing with nonadherent material so that the graft is not disrupted upon removal of the packing. Packing is typically left in place for 3 to 5 days.

For patients in whom a NSF is unavailable, an inferior turbinate (ITF) or middle turbinate flap (MTF) can be considered. The ITF and MTF are posteriorly pedicled from the inferior turbinate artery and middle turbinate artery respectively, both of which are branches off the posterior lateral nasal artery (PLNA), a terminal branch of the sphenopalatine artery [5]. The entire medial surface of the inferior turbinate should be harvested to maximize coverage. The harvest can even be extended to include the lateral muoperiosteum for a wider flap. The ITF can cover approximately 60% of the anterior cranial fossa and bilateral flaps can be use for larger defects [5]. Although coverage may be incomplete in some cases, reconstruction can still be successful if augmented with free grafts owing to the vascularity of the flap. Compared to the NSF, the ITF is shorter in length and has a limited arc of rotation. Due to these limitations, the ITF is best suited for small (<1cm) posterior defects of the sella, parasellar and midclival areas [5]. Silicone nasal splints are typically left in place for 10 to 21 days to protect the denuded lateral nasal wall. The MFT is another posteriorly pedicled local flap that can be used small anterior skull base defects. Elevation of the MFT is technically challenging, especially in the setting of anatomic variations, and only produces a small flap of thin layer of mucosa [7]. However, due to the more superior position of its pedicle, the MTF is better suited than the ITF for defects of the planum sphenoidale, sella, and fovea ethoidalis better than the ITF [5]. In general, the MTF is used sparingly as a secondary option if a NSF is not available.

As endoscopic resections for skull base pathology become more complex, the resultant defects require more difficult and extensive reconstructions. In such cases, use of regional tissue flaps, distal pedicled flaps, or even free tissue transfer may be indicated. Extranasal flaps are ideal for endonasal reconstruction because they are not involved in the primary cancer site [8]. Details of regional extranasal flaps such as the frontal or occipital pericranial flap, temporoparietal fascial flap, palatal flap, or facial buccinator flap are described later in the chapter. Distal pedicled fasciocutaneous, muscle, or myocutaneous flaps include pectoralis major, trapezius, latissimus dorsi, or sternocleidomastoid flaps. However, their vascular attachments originate below the clavicle, which limits their reach to the skull base. The use of a vascularized free flap allows for great flexibility in flap content and design, a single stage reconstruction, and the ability to introduce a large quantity of vascularized tissue to eliminate dead space. Pedicled flaps are often limited by length and arc of rotation allowed by the pedicle and the fact that the distal, most tenuous portion of the flap is often positioned over the most crucial portion of the defect. Both of these issues are eliminated with the use of a free flap. Free flaps also have the potential to provide enough tissue for coverage of defects that extend to the middle cranial fossa [11]. Donor sites for free flaps include the radial forearm, rectus abdominis, latissimus dorsi, serratus, scapula, or gracilis [10]. The recipient vessels are often the superficial temporal vessels. Detailed discussion of free vascularized flap reconstruction of skull base defects is covered in a separate chapter. A summary of local and regional vascular flaps options can be found in Table 1.

Pedicled Extranasal Flap Options

Although a pedicled NSF is the reconstructive option of choice for most endoscopic skull base defects, other vascularized flaps may be necessary in some cases to achieve optimal outcomes. This situation arises almost exclusively in cases where the NSF is unavailable, due either to previous surgical resection or to involvement of the nasal septum by tumor or diseased tissue. When the NSF is not a reconstructive option, a regional pedicled flap becomes the preferred reconstructive option. Such flaps are most commonly harvested from the pericranium (pericranial flap, PCF), temporoparietal fascia (temporoparietal fascial flap, TPFF), or from the palatal mucosa (palatal flap, PF). Additionally, novel options such as the pedicled facial buccinator flap (FAB) and the pedicled occipital galeopericranial flap (OGP) have recently been described. All of these alternative vascularized flaps are preferred to avascular or artificial repair options because, as with the NSF, the rate of CSF leak is lower with vascularized repair.

Pericranial Flap

The pericranial flap (PCF) is the most versatile alternative to the NSF and has the potential for the largest area of coverage. Its pedicle is based upon the supraorbital and supratrochlear arteries, and it was commonly used for skull base reconstruction in the era prior to the widespread use of endoscopic resection [5]. At first, it was considered to have little utility for endoscopic skull base surgery. By transposing the flap through a small nasionectomy into the endoscopic field, this flap became a useful alternative to the NSF [5]. In its current form, it is best suited for defects of the anterior skull base: it can cover an extensive area and its pedicle allows extension from the anterior cranial fossa as far as the sella [7]. However, it is unable to reach posterior cranial base defects. Historically, this flap has entailed large external incisions and suboptimal cosmesis; however, endoscopic harvesting of this flap [14] has allowed for minimal adverse effect on cosmesis as well as better visualization during flap rotation to avoid torsion of the flap pedicle [7].

Results of endoscopically-harvested PCF are quite promising: Patel and colleagues [15] described a series of 10 reconstructions by their senior authors. In their series, there were no postoperative CSF leaks, no V1 paresthesia, no facial nerve dysfunction, and no significant cosmetic deformities. Furthermore, frontal sinus patency was preserved in all cases, and all flaps covered 100% of the cranial defect. The flap also proved quite hardy in the face of radiation treatment: they had no cases of late flap complications (>3mo) in their series.

Special considerations while using the PCF include ensuring that the flap passes through the glabellar incision without twisting the pedicle and compromising the vascular supply of the flap. When extending the flap for larger skull base defects, it is critical not to extend the PCF past midline in order not to compromise contralateral structures which could become necessary for revision surgery [15]. Additionally, it is important to note that this reconstructive option becomes more challenging in older patients due to difficulty dissecting within the subperiosteal plane; however, authors have documented successful flap harvesting in patients up to 80 years old [15]. Finally, when using this flap, postoperative treatment must avoid use of a compressive cranial dressing: this intervention may compromise the blood flow through the PCF pedicle [15].

Temporoparietal Fascial Flap

For defects of the sella, parasella, and clivus, the temporoparietal fascial flap (TPFF) provides a good alternative reconstructive option [6, 7]. The superficial temporal artery (STA), a terminal branch of the external carotid artery, comprises blood supply for the flap. The flap is harvested after endoscopic dissection is complete so that the exact dimensions needed for reconstruction are known prior to harvesting. At its largest, the dimensions of the fan-shaped flap can reach 17×14cm [5]. Thus, the TPFF can comprise a large, durable reconstructive option that is especially advantageous for patients who have undergone sinonasal or skull base radiotherapy, as this vascularized tissue lies beyond the irradiated field [5].

The flap is limited by the arc of rotation of its pedicle, which must rotate 90 degrees as it is passed through the pterygopalatine fossa. It therefore is poorly suited for reconstruction of defects of the anterior cranial fossa [7]. Additionally, this flap does require an external incision, leading to a surgical scar and accompanying risk of alopecia [5]. While harvesting the flap, careful attention is necessary to avoid injury to the pedicle, as the STA lies directly below the skin near the hemicoronal incision created. Care must also be taken during flap harvesting not to injure the facial nerve, which courses just below the TPFF after crossing the superficial surface of the zygomatic arch [5].

Palatal Flap

An additional reconstructive option that has recently been described is the palatal flap (PF). For this flap, the vascularized mucoperiosteal tissue of the hard palate is passed through the greater palatine foramen into the nasal cavity to reach defects of the skull base [5]. Theoretically, this flap could prove incredibly useful: its vascular supply derives from the greater palatine artery, providing a 3cm pedicle that could potentially reach any area of the skull base [7]. However, to date the technique has mainly been described in cadaveric studies [7]. This lack of clinical experience and the potential donor site morbidity incurred by removal of the hard palate mucosa have, to date, relegated this flap to use as a reconstructive option of last resort [5].

Pedicled Facial Buccinator Flap

The pedicled facial buccinator flap (FAB) was recently described by Rivera-Serrano and colleagues [16]. This flap, as its name suggests, is pedicled upon the facial artery after it branches off the external carotid artery. In cadaveric studies, the FAB had a length of 7–8cm from pedicle to tip and was able to reach the anterior skull base and planum sphenoidale [16]. Its size is limited by anatomical considerations in the area of harvest. The parotid duct orifice creates a superior limit, although by extending the flap in an “L” or “Boot” configuration around this landmark, the potential size is increased [16].

Two options for harvesting the FAB exist: solely muscular (facial artery musculo-buccinator, FAMB) or combined myomucosal (facial artery musculo-mucosal-buccinator, FAMMB) flaps. When mucosa is used, it becomes necessary to rotate the flap 180 degrees in order to place the mucosal surface within the nasal cavity [16]. Thus, the authors suggest that the FAMB flap is preferable for skull base reconstruction due to the potential for venous obstruction secondary to this rotation [16]. For either option, transposition of the FAB flap takes place through a maxillary window.

Because the FAB flap has only been described in cadaveric studies to date, the risk profile is largely theoretical. One potential complication would be the risk of dental or facial paresthesia [16]. Dissection of this flap does traverse territory close to facial nerve branches; however, because dissection should take place in the plane directly superficial to the vascular pedicle, facial nerve injury should not be expected in these patients [16]. Other potential complications include persistent epiphora and introduction of oral flora into the surgical field. The authors propose to mitigate these risks by installing Crawford silicone tubes to address epiphora and by instituting a protocol of chlorohexedine gargle 4 hours prior to surgery to decrease bacterial counts [16].

Occipital Galeopericranial Flap

Another alternative recently touted by Rivera-Serrano and colleagues for its potential in skull base reconstruction is the occipital galeopericranial flap (OGP) [17]. This flap is an excellent choice for large skull base lesions, as flaps as large as 44cm^2 (11cm × 4cm) were harvested in their cadaveric studies [17]. This expansive flap is pedicled upon the occipital artery, which supplies the majority of the posterior scalp. Use of this large artery is advantageous, providing a long pedicle and thus enhancing the versatility of the flap [17]. Dissection of the pedicle is facilitated by detachment of the overlying neck musculature, including the sternocleidomastoid (SCM) [18]. Furthermore, the anatomy of the blood supply to the OGP shows a high rate of consistency between individuals, facilitating a reliably successful dissection [18]. Transposition takes place through a tunnel along the inferomedial surface of the medial pterygoid muscle requires a wide endoscopic maxillary antrostomy and posterior maxillectomy as well as removal of the inferior aspect of the pterygoid plates[18]. Finally, the distance of the flap from the skull base itself makes the OGP an excellent choice in patients who have previously undergone surgery or radiotherapy [18].

Proposed use for the OGP is largely relegated to lesions of the posterior skull base due to the success of the PCF in reconstructing large lesions of the anterior skull base, as discussed above. In addition, more ventral positioning of the OGP increases the risk of compression of bulkier, more distal portions of the flap, and may pose a threat of venous congestion and flap compromise [18]. Of note, harvesting the OGP does require transection or detachment of several neck muscles, including the SCM and trapezius. However, Dogliotti and colleagues [18] described favorable outcomes with reattachment in their use of this flap for mandibular reconstruction, noting no residual neck muscle weakness. Dissection of the pedicle to its proximal extent might also pose the threat of carotid injury; however, ample pedicle length is available without such extensive dissection [18].

Conclusion

Anterior skull base defects can be successfully and reliably repaired via a purely endoscopic endonasal approach. This chapter provides a comprehensive overview of reconstructive options for skull base repair. With advances of new reconstruction techniques and use of vascularized flaps, postoperative CSF leak rates have been reduced to less than 5%. Pedicled extranasal flaps allow a better reconstructive option for larger and more complex lesions.

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Table 1

Intranasal and regional vascular flaps available for skull base reconstruction

Location	Vascular Tissue Flap	Pedicle	Advantages/Uses	Disadvantages/Limitations
Intranasal	NSF	Posterior septal artery (from SPA)	• Ideal for all skull base reconstructions	• Size limitation in pediatric patients
	ITF	Inferior turbinate artery $^{\Phi}$	• Good for small clival defects	• Cannot reach ACF or sella • Crusting over denuded turbinate
	MTF	Middle turbinate artery $^{\Phi}$	• Good for small ACF or transphenoidal defects	• Small in size • Thin mucosa • Difficult to elevate
Regional	PCF	Supraorbital & supratrochlear arteries	• Hearty flap with versatile dimensions • Extends from ACF to sella	• Does not extend to posterior skull base • Requires external incision
	TPFF	Superficial temporal artery	• Good for clival or parasellar defects • Usually from non-irradiated field	• 90° pedicle rotation limits reconstruction of ACF • Requires external incision
	PF	Greater palatine artery	• Theoretically can reach all areas of skull base • Long (3 cm) pedicle	• Difficult to dissect pedicle • Donor site morbidity • Unproven clinically
	FAB	Facial artery	• Useful for anterior skull base • No facial incision	• Potential paresthesia or persistent epiphora • Potential introduction of oral flora to sterile field • Unproven clinically
	OGP	Occipital artery	• Good for posterior lesions • Potential for very large area of coverage • Long (8+ cm) pedicle • Usually from non-irradiated field	• Potential for carotid injury with proximal dissection of pedicle • Unproven clinically

SPA – Sphenopalatine artery, NSF – Nasoseptal Flap, ITF – Inferior Turbinate Flap, MTF – Middle Turbinate Flap, PCF – Pericranial Flap, TPFF – Temporoparietal Fascia Flap, PF- Palatal Flap, FAB – Facial Buccinator Flap, OGP – Occipital Galeopericranial Flap, ACF – Anterior Cranial Fossa

$^{\Phi}$terminal branch of posterior lateral nasal artery of the sphenopalatine artery