3 Nasal Flaps and Reconstruction

Cristine Klatt-Cromwell, Brian Thorp, Charles S. Ebert Jr, Deanna Sasaki-Adams, Matthew G. Ewend, and Adam M. Zanation

3.1 Introduction

Endoscopic skull base surgery has become a rapidly changing and innovative area of otolaryngology and neurosurgery. Over recent years, approaches and reconstructive options have dramatically diversified. A broadened anatomic understanding has allowed expansion of endoscopic surgery to include approaches to the median and paramedian skull base, orbit, and upper cervical spine. Techniques are now widely used to treat both extradural and intradural pathology. With these more extensive approaches, reconstructive techniques have concurrently evolved with wide representation in the literature. Previously used cellular and acellular grafts have now been replaced or used in conjunction with a multitude of vascularized reconstruction techniques to continue to improve surgical outcomes. Initially, the bulk of skull base defects were repaired using cellular or acellular free grafts. A meta-analysis of CSF leak repair resulting from trauma or endoscopic sinus surgery using such grafts was studied by Hegazy et al. in 2000 [1]. In this study, 289 patients with CSF leaks were assessed. Patients were repaired with multiple different techniques with 90% success, supporting the success of multiple non-vascularized techniques. Reconstruction techniques then evolved to encompass vascularized flaps for reconstruction. In a 2014 study by Thorp et al., 152 patients were identified that had undergone vascularized skull base reconstructions. This study assessed multiple reconstructive techniques including nasoseptal flap, pericranial flap, facial artery buccinator flap, and inferior turbinate flap reconstruction. Overall, the CSF leak rate in this study was found to be 3.3%, supporting the robust nature of these reconstructions [2]. This chapter will discuss all of these techniques and their role in this rapidly expanding field.

C. Klatt-Cromwell · B. Thorp · C. S. Ebert Jr · A. M. Zanation (✉)
Department of Otolaryngology, University of North Carolina Chapel Hill, Chapel Hill, NC, USA
e-mail: Adam_Zanation@med.unc.edu

D. Sasaki-Adams · M. G. Ewend
Department of Neurosurgery, University of North Carolina at Chapel Hill, Chapel Hill, NC, USA

3.2 Rationale

Skull base surgery has dramatically evolved over recent years. Since its inception, the goals of the surgical team have included not only tumor resection but also watertight skull base reconstruction to separate the nasal cavity from the intradural space. These efforts are directly aimed at preventing postoperative cerebrospinal fluid (CSF) leaks, which have been associated with severe consequences including meningitis, pneumocephalus, and even death.

3.3 Patient Selection

The continued advancement of the field of endoscopic skull base surgery has resulted in diversified patients and pathologies amenable to endoscopic techniques. Expanded approaches necessitate careful preoperative planning for each case. Tumor characteristics are extensively assessed, including the type of tumor and its location in regard to surrounding structures. With these factors in mind, an expected surgical defect is then estimated, as is careful planning of possible reconstructive options. In addition, patient-specific factors affecting wound healing must be identified preoperatively and managed with care. Such factors include underlying medical comorbidities, obesity, prior radiation, or smoking. Select patients with increased risks of CSF leak including those with elevated intracranial pressures or morbid obesity should be identified and optimized prior to surgical resection. While management of patients being treated with endonasal skull base surgery has generally become standardized, exceptions may be made on a case-by-case basis.

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Patients identified as having increased risk for CSF leak may require lumbar drain diversion preoperatively at the discretion of the skull base surgery team. Stoken et al. demonstrated that early in the evolution of skull base surgery over the last decade, lumbar drains were frequently used preoperatively for CSF diversion [3]. Previously discussed in the neurosurgery literature stemming from open cranial cases, the drain was thought to decrease postoperative inflammation and swelling. Once thought to be vital to preserve skull base reconstructions, lumbar drains are not without potential complications. As described by Governale et al., the literature reports a 3% risk of major complications associated with lumbar drains, while the minor complication rate increases to 5% [4]. Recent studies in the literature have shown that lumbar drains in the preoperative period are not required in endoscopic skull base reconstructions. Garcia-Navarro et al. reviewed 46 cases undergoing endoscopic skull base surgery, and in this study, 67% of patients had lumbar drains placed. Of these, only two patients had postoperative CSF leaks. The study determined that there was no significant correlation between the use of lumbar drain and CSF leaks [5]. In a separate study by Ransom et al., 65 patients were retrospectively studied and demonstrated a postoperative CSF leak rate of 6.2%. They also found that the lumbar drain complication rate was 12.3%, leading to a recommendation that lumbar drains should be used judiciously in the setting of skull base surgery [6]. There are populations of patients, however, that may significantly benefit from the intraoperative and even postoperative use of lumbar drains. These include patients with chronic intracranial hypertension and/or patients with recurrent leaks requiring revision reconstruction.

The location and size of the tumor also helps identify patients at risk for CSF leak. Zanation et al. also identified that patients with anterior skull base defects were more likely to leak than clival defects [7]. Furthermore, Patel et al. demonstrated that there was a significant correlation between intraoperative high-flow CSF leaks and postoperative leaks [8]. While there is no consensus on the use of lumbar drains in the perioperative period for endoscopic skull base surgery, the surgical team should use their discretion in the setting of each individual patient's factors to determine when the benefits of CSF diversion outweigh the risks.

3.4 Skull Base Pathology

See Table 3.1.

3.5 Surgical Technique

Careful presurgical planning and preparation is vital to the success of these operations. Patients and their tumors must be evaluated on a case-by-case basis. Underlying health problems should be addressed and optimized prior to surgery. Previous radiation therapy, prior or current smoking, as well as underlying medical comorbidities can significantly affect surgical outcomes and must be identified before surgery. With that in mind, standardization of the process with few modifications allows for consistent and successful surgical outcomes.

Endoscopic skull base surgery begins with a smooth induction of general anesthesia. Due to possible tumor impingement on vascular structures, it is vital to avoid extremes of hypotension or hypertension. Once an adequate plane of anesthesia is established, attention is turned to surgical preparation and meticulous positioning. Skull base procedures involve the use of image guidance; therefore, stereotactic systems with fine cut CT and MRI data are loaded and checked to be functioning. In select patients with risk factors,

Table 3.1 Skull base lesions/conditions

Malignant	Benign	Sellar	Fibro-osseous	Other
Esthesioneuroblastoma	Schwannoma	Pituitary adenoma	Ossifying fibroma	Cerebrospinal fluid leak
Adenocarcinoma	Chondroma	Meningioma	Fibrous dysplasia	Encephalocele
Salivary gland carcinoma (adenoid cystic)	Meningioma	Craniopharyngioma	Osteoma	
Squamous cell carcinoma	Nasopharyngeal angiofibroma	Rathke's cleft cyst		
Sinonasal undifferentiated carcinoma	Hemangiopericytoma	Paraganglioma		
Rhabdomyosarcoma	Hemangioma			
Chondrosarcoma	Petrous apex lesions			
Melanoma	Epidermoid			
Lymphoma				
Metastasis				
Osteosarcoma				

a lumbar drain would be placed at this time. Once confirmation of adequate lumbar drain function is confirmed, the surgical bed is turned 90° away from the care of anesthesia. Depending on surgeon preference, the bed position may be adjusted into a modified beach chair position with the head up or remain flat. Different degrees of reverse Trendelenburg and bed tilt may be used to maximize surgeon comfort. During patient positioning, careful attention is placed on padding pressure points such as elbows and heels, as long surgical procedures can lead to peripheral neuropathies and sores. In order to ensure adequate exposure for reconstruction, additional surgical sites (scalp, abdomen, and/or thigh) are prepped and draped in the standard sterile fashion prior to commencement of the surgical procedure. Immobilization with pins is not commonly used for endoscopic endonasal surgeries unless a concurrent transcranial approach is also expected or if required by the navigation system utilized. Once all positioning and surgical preparation is complete, the image guidance system is brought onto the field, and patient registration is completed in the standard fashion.

Bolstering Technique

Reconstruction of the skull base using a combination of cellular and acellular grafts and vascularized flap techniques requires multilayer closure and proper bolstering to ensure successful outcomes. The repair is most vulnerable during the initial phases of healing, immediately following repair. A standardized approach to bolstering helps produce reliable and predictable results. First, Surgicel (Ethicon US, LLC) is typically used to keep any cellular graft or flap in place. It is placed around the margins of the reconstruction, once the reconstructive tissues are in place. Following placement of Surgicel, the most vital areas of the repair and those most prone to leakage are bolstered using firm NasoPore® (Polyganics, Groningen, the Netherlands). This is typically cut into smaller pieces in order to improve manipulation. Once complete, a biologic glue such as DuraSeal® (Confluent Surgical Inc., Waltham, MA, USA) is placed over the entire repair. NasoPore is then used in multiple layers over the reconstruction to further bolster the repair. The goal of this packing is to prevent any movement at the repair site for optimal healing to occur. This must also remain in place when non-dissolvable packs or the Foley balloon are removed after surgery. Once NasoPore is in adequate position, a 14-French Coude Foley catheter is placed under direct visualization to further bolster the repair. Occasionally, expandable tampon-like sponges may be used instead of a Foley catheter. Such sponges are used when the vector of support lies in the vertical plane when the patient is in standing position. The sponges are placed bilaterally under direct visualization in order to further bolster the underlying repair. Dependent upon patient-specific factors, the Foley catheter or nonabsorbable packs are removed 3–7 days after surgery. Patients require antibiotic therapy while nonabsorbable packing is in place. Nasal irrigations are typically started 1 week postoperatively.

Grafts

Acellular Grafts

Acellular grafts play a large role in skull base reconstruction. These materials may be used in conjunction with a multitude of other techniques, making them vital to the success of endoscopic surgery. As noted by Kim et al., the key for all skull base reconstruction should be a multilayer approach for closure [9]. Should the reconstructive surgeon prefer to use an inlay technique, acellular dermal matrix (AlloDerm®, LifeCell, Branchburg, NJ, USA) is effective, placed in the subdural or epidural plane. The use of onlay technique requires that all surrounding mucosa be removed to prevent delayed mucocele formation. The graft requires adequate saline hydration prior to its use. Should the resection require removal of dura, acellular dermal matrix may be used in conjunction with a collagen matrix (Duragen®, Integra Life Sciences, Plainsboro, NJ, USA). This material is used as an inlay graft either between brain and dura in the subdural plane or between dura and the bony skull in the epidural plane. The placement of this graft in this plane many times eliminates CSF leakage resulting from tumor resection. It must be placed beyond the dural margin with adequate (5–10 mm) margins in order to be effective in CSF leak repair. In certain cases involving the sphenoid or clivus, bony ledges may be limited, thus only supporting an onlay graft. With all acellular techniques, the material must be bolstered into place using a combination of packing as previously detailed.

Cellular Grafts

Cellular grafts encompass a vast array of techniques that may be used in combination or independent of the acellular techniques described above. As noted with acellular grafts, emphasis is placed on a multilayer technique with elimination of CSF leak intraoperatively. In a study by Harvey et al., smaller defects (<1 cm) repaired with multilayer closure using free tissue was found to have a success rate of greater than 90% [10]. Several options for free mucosal grafts are available and are described below.

Free Mucosal Graft

The use of a free mucosal graft in skull base reconstruction is a widely applied technique. Tissue is readily available throughout the nasal cavity for harvest and use, eliminating the need for a second surgical site. Mucosal grafts may be taken from the nasal floor, middle turbinate, or septum for use in skull base reconstruction. Many surgeons prefer to preserve the middle turbinate to optimize postoperative sinonasal function and to reserve the nasal septum mucosa for more complex reconstructions, thus making nasal floor mucosa the most readily available cellular reconstructive option.

Using a needle tip bovie that has been bent 45°, the mucosa along the nasal floor is incised. The incision may be carried onto the inferior nasal septum and extended under the inferior turbinate in order to maximize size. Attention must be noted to the location of the soft palate to avoid an incision in this area. The graft incisions are carried anteriorly along the nasal floor until the desired size is achieved. Careful elevation of the graft is performed with a Cottle elevator, ensuring the mucosal side remains identified throughout the dissection. After removal of the graft, the mucosal surface can be inked with a surgical marker to allow for proper placement during repair. Once completely removed from its donor site, it may be used for reconstruction. As emphasized with acellular techniques, removal of all underlying mucosa at the site of reconstruction must be performed in order to avoid the formation of a mucocele. Likewise, it should be ensured that the periosteal aspect of the graft faces the dural and osseous defect. The free graft may be used with previously discussed acellular techniques and bolstered in a similar fashion. Meticulous hemostasis along the donor site should be achieved prior to the conclusion of surgery. If the middle turbinate is removed as part of the approach for skull base reconstruction, the mucosa lining of this structure may be used as a mucosal graft. Careful removal of the underlying bone must be performed prior to its use. Both techniques serve as an excellent option for smaller defects.

Abdominal Fat

The use of abdominal fat in skull base reconstructions is also widely used. It is typically placed to help obliterate space prior to a multilayer reconstruction, in order to create a less irregular defect for reconstruction. To harvest, the incision is made at a second surgical site in either the periumbilical region, lower abdominal area, or lateral hip. This area is prepped and draped separately at the beginning of the procedure in order to maintain sterility. The fat is then harvested through circumferential dissection. Once an adequate volume has been collected, the wound is irrigated, hemostasis obtained, and it is closed in a multilayer fashion. If the donor defect is large due to the need for significant fat harvest, a suction drain may be used to prevent fluid collection or hematoma. The fat is then typically placed intradurally prior to additional dural and skull base resection. Recently, the use of dermal fat grafts has gained popularity. Contrary to normal fat grafts, typically an elliptical incision is created, but the fat is not immediately harvested. The epidermis is removed leaving dermis attached to fat, and the two are harvested together as a composite graft. A larger volume of fat may be dissected circumferentially around the piece of dermis; however, this must be kept in continuity. Once an adequate volume is collected, the two are removed together and used in the skull base reconstruction. Careful sizing of the graft must be done, in order for the dermal component to rest at the level of the skull base defect, thus allowing a more laminar reconstruction. The use of dermis allows for a more robust bolster for reconstruction and facilitates manipulation or the graft during placement. Both free fat and dermal fat grafts are frequently used with a combination of other techniques, both acellular and/or vascularized reconstructions. They are bolstered with a combination of absorbable packing, biologic glue, and expandable sponges/Foley catheter as previously described. It is important to note that while cellular and acellular techniques provide a robust reconstruction for small skull base defects, Hadad et al. found that in resections greater than 3 cm, multilayered free tissue grafts resulted in unacceptably high rates of postoperative CSF leaks at 20–30%, and consideration of additional techniques, namely, vascularized reconstruction, was recommended [11].

Flaps

Vascularized flap reconstruction has become the mainstay in endoscopic skull base surgery with the ever-expanding complexity of cases and pathology amenable to this approach. Initially described by Hadad et al. in 2006, the nasoseptal flap, comprised of mucoperiosteum and mucoperichondrium from the nasal septum and pedicled on the posterior septal artery, has become the preferred technique for skull base reconstruction [11]. It is characterized by a long robust pedicle that makes it ideal for use in a multitude of defects and locations. The harvest of the nasoseptal flap can be extended onto the nasal floor, allowing it to expand from orbit to orbit and from sella to frontal sinus [7]. In addition to its robust pedicle and expansive reach, the endoscopic harvest of the nasoseptal flap prevents the need for a second surgical site and the potential associated morbidity. The primary disadvantage of the nasoseptal flap is that its use must be expected preoperatively. Because of the location of the pedicle, its harvest must be performed prior to sphenoidotomy and posterior septectomy in order to ensure its viability. The "rescue" technique will be further described below and has largely offset this disadvantage. In certain settings, the nasoseptal flap may be unavailable for use due to tumor involvement or vascular compromise due to prior surgery. Prior septoplasty is not a complete contraindication to nasoseptal flap use, although the flap must be elevated with great care to preserve its integrity without tears. If it is unclear as to whether the vascular pedicle to the nasal septum is viable, a Doppler probe can be utilized to confirm its presence.

Technique for the Nasoseptal Flap

The patient is positioned in the standard fashion as previously described. To improve visualization, the inferior turbinates may be outfractured bilaterally, and the middle turbinate on the side of the nasoseptal flap (NSF) harvest is removed at the discretion of the surgeon. Meticulous hemostasis is performed after middle turbinate removal to have clear visualization; however, caution is used posteriorly in order to preserve the pedicle from nondirected cautery. The superior turbinate is then gently lateralized until the natural os of the sphenoid sinus is identified. The flap is harvested based on a prediction of the surgical resection made prior to surgery. When in question, an overestimation of size is always preferred. Using needle tip extended length monopolar cautery that is bent 45°, two parallel incisions are made. The inferior incision is made across the posterior choana margin and then onto the nasal septum at its junction with the nasal floor. The superior incision begins at the natural os of the sphenoid sinus and then extends superiorly. In order to preserve the olfactory epithelium, the incision is placed 1–2 cm from the superior portion of the septum. A vertical incision is then placed anteriorly connecting the previously performed inferior and superior limbs and can extend as far as the mucocutaneous junction. A Cottle elevator is then used to begin the elevation. Careful separation of all incisions anteriorly should be performed before proceeding with more posterior elevation, as incomplete elevation at the incision lines can lead to tearing, reducing the functionality of the flap. Once the flap is elevated, it is then placed into the nasopharynx or ipsilateral maxillary sinus until the extirpative portion of the procedure is complete (Fig. 3.1a–d).

Once attention is turned to the reconstruction, the flap is lifted out and rotated into place along the skull base ensuring the pedicle remains untwisted. It is important to ensure that the perichondrial aspect of the flap is in contact with the cranial base rather than its mucosal aspect to allow the graft to adhere and prevent delayed mucocele formation. As these can sometimes be difficult to distinguish at the end of the procedure, it is sometimes helpful to mark the mucosal aspect of the flap with a surgical marker immediately after harvesting. After placement over the cranial base defect, the flap is then used as part of a multilayer reconstruction of the skull base defect in combination with other cellular and acellular techniques. Careful attention to placing the flap in direct contact with the bony margins of the defect is critical. In addition, as described with free mucosal grafts, all underlying mucosa must be removed to prevent mucocele formation. The flap is then bolstered into place as previously described. As discussed before, patient characteristics including underlying medical problems, previous radiation, presence of high-flow CSF leak, or revision procedure affect the duration of the use of nonabsorbable packs and/or Foley catheters postoperatively. Reconstruction bolsters including nonabsorbable packs and/or Foley catheters may remain in place anywhere from 3 to 7 days.

Nasoseptal "Rescue" Flap Technique

Extirpative procedures that require large skull base defects allow for the preoperative expectation that a nasoseptal flap or other pedicled flap will be required for reconstruction. However, in some cases, the need for the nasoseptal flap may not be known at the beginning of the case. In this specific patient population, a nasoseptal "rescue" flap may be elevated at the beginning of the case. This procedure allows for the preservation of the vascular pedicle but does not eliminate the opportunity to leave the flap in its native position should its use not be necessary. Rivera-Serrano et al. describe a technique in which partial harvest is done at the beginning of the case. In this technique, the superior incision is performed as with the nasoseptal flap. It begins at the sphenoid os and extends approximately 2 cm anteriorly along the same incision a traditional NSF would follow [12]. Rawal et al. further describe the technique in which a Cottle elevator is then used to expose the sphenoid rostrum by reflecting the flap inferiorly. By displacing this area prior to sphenoidotomy and septectomy, the vascular pedicle of the flap is protected for further reconstruction [13]. If a nasoseptal flap is required for reconstruction, the remainder of the NSF incisions are then placed, and the flap is harvested in the same fashion. The flap is then placed as part of a multilayer closure as previously described. If a nasoseptal flap is not required, the inferior reflected "rescue" flap is then returned to its native position (Fig. 3.2a–c).

Endoscopic-Assisted Pericranial Flap

While the nasoseptal flap remains the workhorse of skull base reconstructions, the pericranial flap (PCF) provides an option for reconstruction when this is either not available or inadequate. As described by Zanation et al., the PCF is a very robust flap pedicled on the supraorbital and supratrochlear arteries [14]. Because of its large size, it allows for reconstruction of the entire skull base especially in defects following more extensive and difficult resections. The reconstructive surgeon may choose to harvest the flap through an array of techniques including an endoscopic-assisted, hemicoronal, or coronal approach with or without a small glabellar incision for intranasal introduction. The noted glabellar incision allows for a bony window through the nasion to be utilized for nasal introduction of the flap [14]. The PCF also provides an important extranasal option for reconstruction, a valuable alternative for previously radiated patients requiring extensive

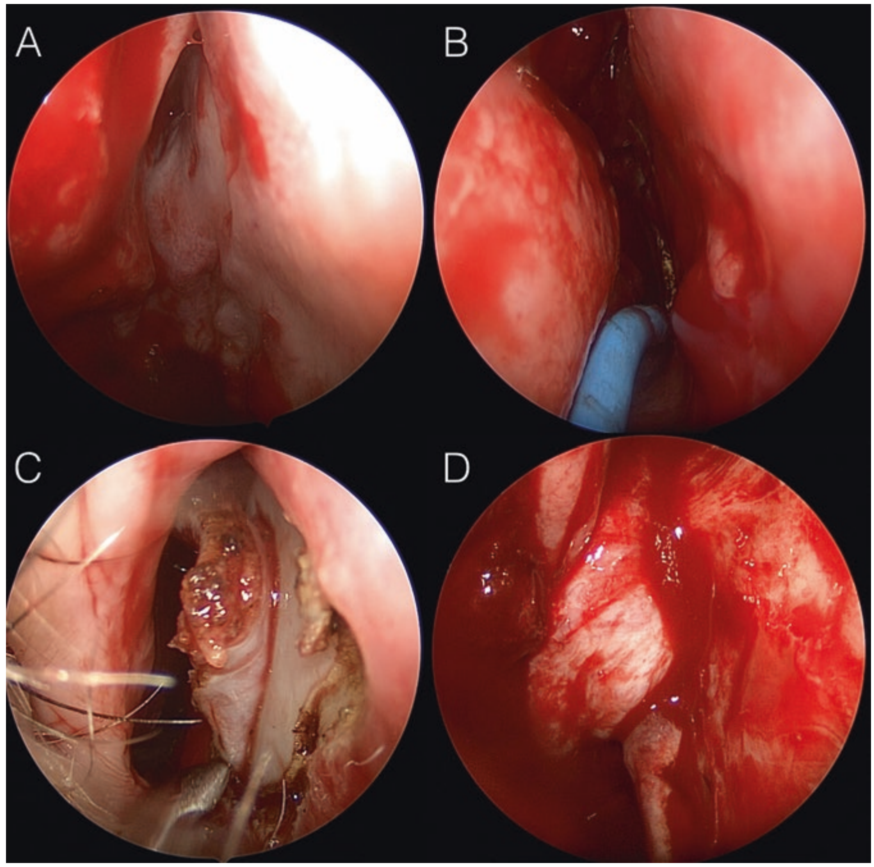

Fig. 3.1 (**a**–**d**) Nasoseptal flap. (**a**) Prior to incision, the superior turbinate is lateralized to visualize both the choana and the natural ostium of the sphenoid sinus. These landmarks are confirmed prior to incision. (**b**) Inferior incision made with the needle tip bovie. This incision can be modified to widen the flap. (**c**) Careful elevation with a cottle in the mucoperichondrial plane protects the integrity of the flap. (**d**) Nasoseptal flap elevated off the septum and tucked into the nasopharynx

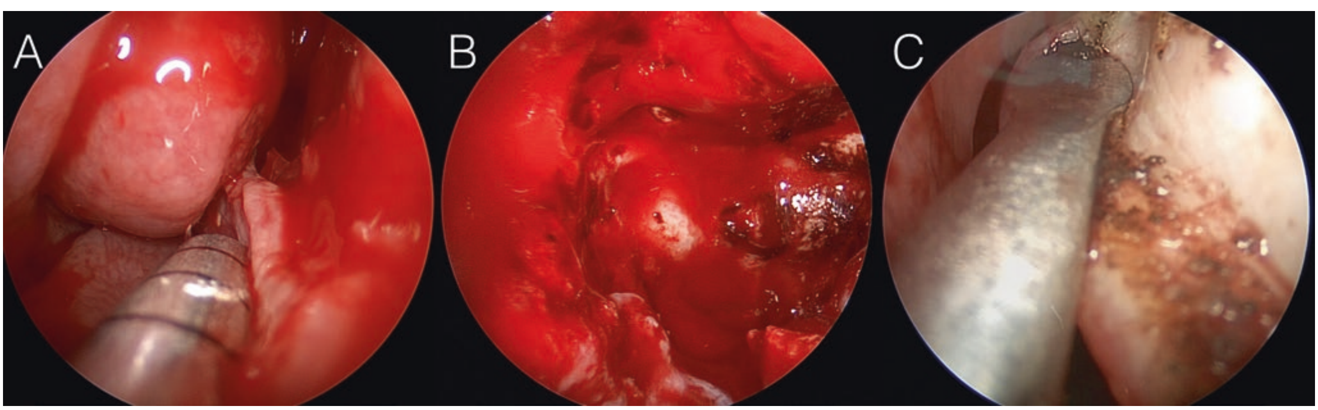

Fig. 3.2 (**a**–**c**) Rescue flap. (**a**) Middle turbinate is removed, and superior turbinate is lateralized prior to incisions. Confirm the location of the natural ostium of the sphenoid sinus. Superior longitudinal incision beginning at the sphenoid ostium is extending anteriorly along the expected nasoseptal flap trajectory without full extension anteriorly. (**b**) Rescue flap use still allows for wide exposure and access for tumor dissection. (**c**) After placement of the incision, release is performed in the mucoperichondrial plane

resection or those for whom the nasal septum is unavailable due to tumor involvement or prior surgery.

In a radioanatomic study by Patel et al., imaging studies for ten patients were assessed preoperatively to determine ideal PCF incisions. From this study, the average length from the nasion to the sphenoid sinus was 4.51 cm, nasion to posterior wall of the sella was 7.57 cm, and nasion to the inferior clivus was 12.10 cm. The average external pedicle length was measured to be 4.36 cm, a combination of distances measured from lateral supraorbital notch to the mid-forehead plus the mid-forehead to the nasion. These values were used to obtain average PCF lengths needed for reconstruction of defects in these areas. The following measurements were obtained with a 3 cm correction factor accounting for flap transposition through the nasionectomy: 11.31–12.44 cm for anterior fossa defects, 14.31–15.57 cm for sellar defects, and 18.3–20.42 for clival defects. All patients in this study had no evidence of postoperative CSF leak [15].

Endoscopic-Assisted Pericranial Flap Technique

The patient is prepped and draped in the same fashion as previously described for skull base surgery. The hair is stapled away from the planned surgical site but not shaved. The planned scalp incision is then marked, and its location is at the discretion of the reconstructive surgeon. The supraorbital notch is then identified, and 1.5 cm are marked on either side. During planning, the midline should be marked as the contralateral PCF may be used for revision surgery. After the extirpative portion of the procedure is complete, attention is turned to elevation of the PCF. The skin incision is performed, and dissection is then carried out in a subgaleal plane using direct visualization aided by the endoscope. The endoscope allows improved visualization anteriorly and posteriorly to ensure a large flap may be harvested (Fig. 3.3a–c).

Once this dissection is complete, a needle tip extended length cautery is used to make an incision in the pericranium at the most posterior aspect of the field. Bilateral lateral incisions are then placed ensuring the pedicle is preserved. Once this is complete, the pericranial flap is elevated with endoscopic assistance to help prevent tearing in the flap. As noted with the nasoseptal flap, it is important that all incisions are complete prior to elevating to prevent damage to the integrity of the flap. Attention is then turned to the glabella incision. This is dissected down to the periosteum, which is incised using bovie electrocautery at the level of the nasion. A drill is used to transgress the bone of the nasion and enter the nasal cavity. Once this area is opened adequately to prevent pressure on the flap or its pedicle, the flap is introduced through this area into the nasal cavity. Caution must be taken during this translocation to not twist the pedicle, as the vascular supply could be compromised. Once within the nasal cavity, the PCF is moved into position, ensuring direct contact with defect margins to ensure adequate healing (Fig. 3.4a–f). Patency of the frontal sinus outflow can be maintained with steroid-eluting stents (PROPEL Sinus Implant, Intersect ENT, Menlo Park, CA) placed alongside the PCF, but the primary concern should be cranial base repair. Once healed, the PCF can always be surgically dissected/divided in a delayed fashion to reestablish sinus drainage and prevent mucocele formation. After placing the PCF, a multilayer reconstruction and bolstering is used as previously noted. The external incisions are then copiously irrigated with normal saline and closed in a multilayer fashion. The scalp wound typically requires a small suction drain to prevent the formation of hematoma or seroma in the wound bed. The surgical drain is monitored until appropriate for removal prior to hospital discharge.

Temporoparietal Fascia Flap

Traditionally, the temporoparietal fascia flap (TPFF) was used extensively in head and neck cancer reconstructions. As reviewed by Patel et al., this widely versatile flap is based on the more anterior branch of the superficial temporal artery (STA), a terminal branch of the external carotid system [16]. This fan-shaped flap provides a reliable extranasal reconstructive option, when the flaps listed above are not available [7, 8]. Like the PCF, the TPFF provides a valuable extranasal option for patients with previous skull base or sinonasal radiation. Due to the location of its pedicle, it is best suited for reconstruction of the sellar region extending down into the clivus. As noted by Patel et al., this limits its use for anterior cranial fossa defects [8]. Careful patient selection must also be used as history of temporal artery biopsy or scalp radiation can lead to vascular compromise or donor site morbidity. An advantage to this flap is it provides large size and bulk for patients requiring extensive resection. Disadvantages include donor site necrosis, alopecia, scarring, frontal branch of the facial nerve weakness or dysfunction, and cosmetic deformity. The dissection for transposition of the flap also involves the infratemporal fossa, putting the internal maxillary artery at risk.

Temporoparietal Fascia Flap Technique

The patient is positioned and prepped for endoscopic skull base surgery in the standard fashion as previously described. In addition, the patient is also prepped for an ipsilateral scalp hemicoronal incision. The TPFF harvest is not started until completion of tumor resection and wide ipsilateral maxillary antrostomy and complete ethmoidectomy. Following adequate exposure, the sphenopalatine artery (SPA) and posterior septal artery are identified and clipped endoscopically. The SPA is then followed into the pterygopalatine fossa (PPF), and the posterior and lateral walls of the maxillary sinus are removed to expose the infratemporal fossa. Once the internal maxillary artery (IMA) is fully visualized, the descending palatine artery may be identified and dissected. Once these vessels are identified and dissected, the contents of the PPF may be protected and moved laterally until the pterygoid plates are fully visualized. At this location, the vidian nerve is typically sacrificed to allow displacement, but the pterygopalatine ganglion may be preserved. Attention is then turned to the external flap harvest. An ipsilateral hemicoronal incision is made with care to ensure preservation of the STA, which lies in the subcutaneous tissues. The incision and elevation should be in the subfollicular plane. An aggressive incision in this area can lead to compromise of the vascular pedicle. Once exposure of the flap of desired size is complete, an incision is placed through the fascia laterally. The flap is then elevated from the temporalis muscle fascia superiorly and superficial layer of the deep temporal fascia below the level of the temporal line of fusion including elevation of the periosteum from the zygomatic arch.

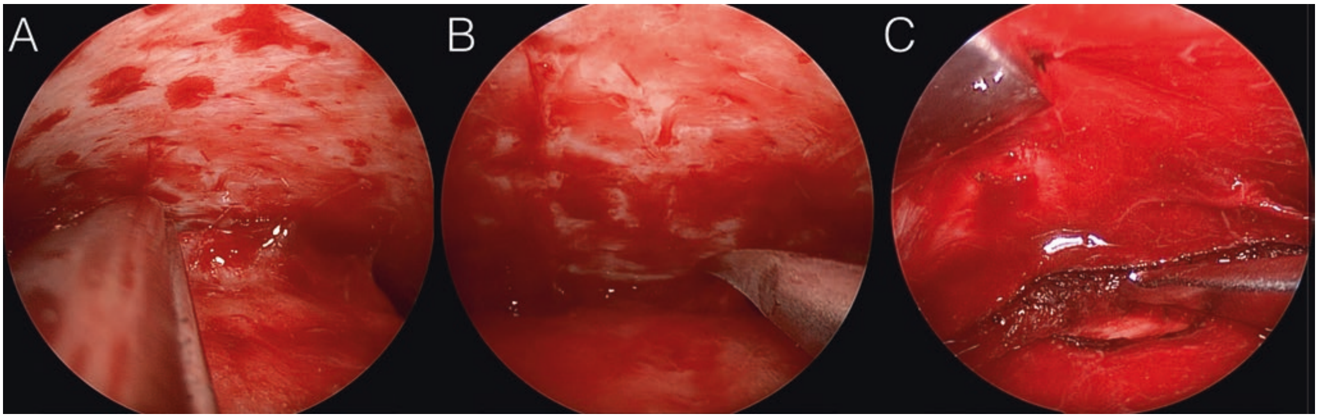

Fig. 3.3 (**a**–**c**) (**a**) After skin incisions, elevation is performed in the subgaleal plane. This is done with sharp instrumentation to ensure preservation of a thick pericranial flap. (**b**) Generous elevation is performed prior to incisions with monopoly cautery. (**c**) After incisions have been placed with preservation of a 3 cm vascular pedicle, progressive elevation of the flap is performed with a periosteal elevator

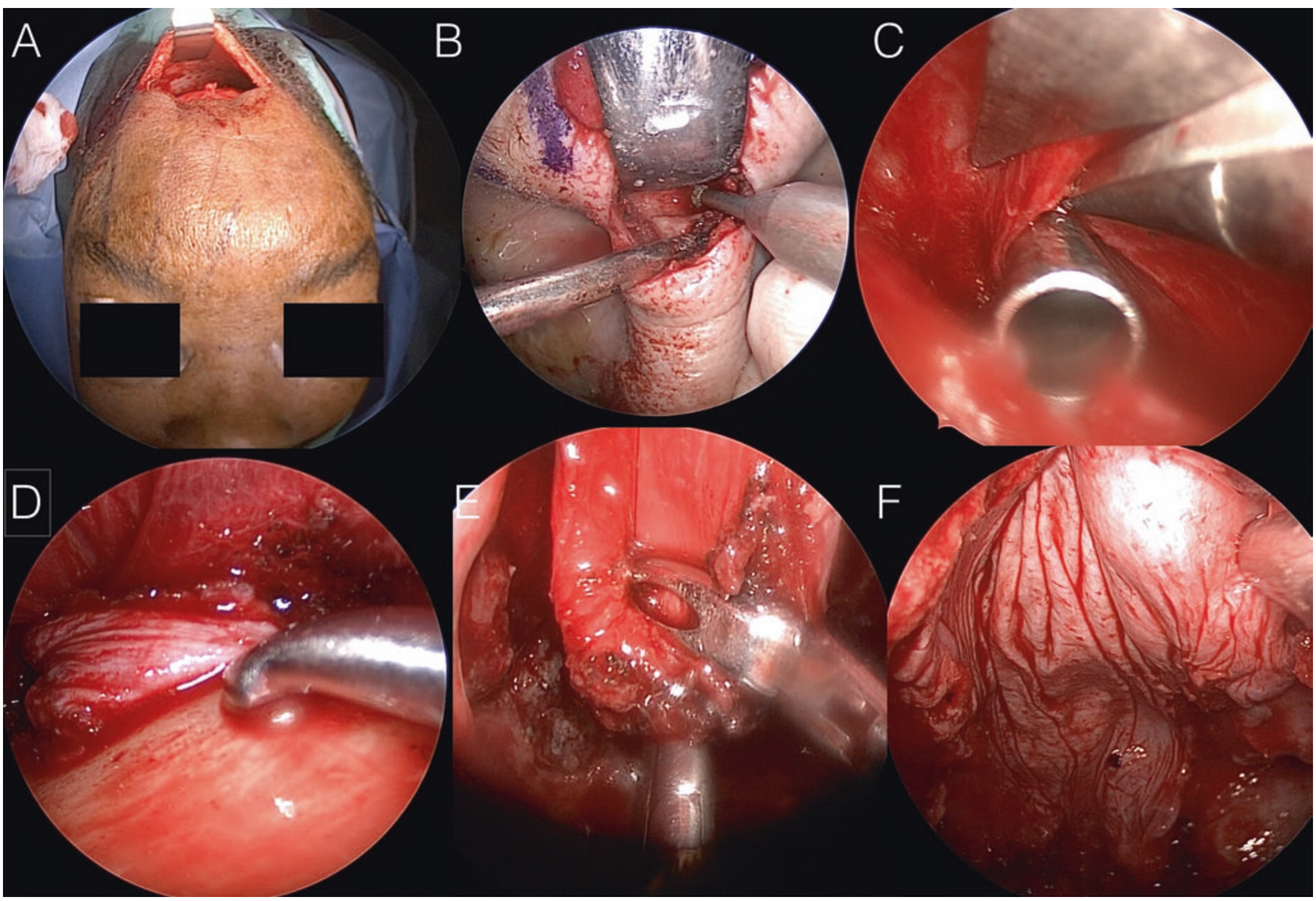

Fig. 3.4 (**a**–**f**) Progressive pericranial flap elevation. (**a**) Trichophytic superficial incision used without need for complete hemicoronal. Elevation performed through this incision in the subgaleal plane. (**b**) Horizontal glabellar incision carried to the level of the nasal bones. The periosteum is dissected, and a nasionectomy is performed to obtain access to the nasal cavity. (**c**) Communication between the subgaleal and subperiosteal planes are confirmed prior to movement of the flap. (**d**) Progressive elevation of the flap down to the nasionectomy is performed to ensure preservation of the pedicle. (**e**) Transposition of the pericranial flap into the nasal cavity performed under direct visualization. (**f**) Pericranial flap used for anterior skull base defect prior to packing

A wide tunnel is then formed in this area down to the infratemporal fossa. This can typically be done with commercially available percutaneous tracheostomy dilators. A lateral canthotomy incision can occasionally help at this point to help expose the pterygomaxillary fissure to help in full transposition of the flap. Once the tract is complete, a guide wire is placed through the largest tracheal dilator. The dilator is then removed, and the flap is attached to the guidewire and pulled into the nasal cavity. Meticulous attention to over-rotation of the flap in this area is important to minimize the potential for vascular compromise to the flap. Once in the nose, the TPFF is placed overlying the defect. This can be used in conjunction with other reconstruction techniques and is bolstered into the place in the standard fashion. External incisions are again copiously irrigated and closed in a multilayer fashion with a surgical drain in place.

Turbinate Flaps

Less commonly used intranasal options for patients in which the NSF is not available for skull base reconstruction exist. Zanation et al. discussed two flaps, the inferior turbinate flap (ITF) and the middle turbinate flap (MTF), each pedicled on their respective arteries and branches of the posterior lateral nasal artery, a terminal branch of the sphenopalatine [7]. The ITF has a shorter length and arc of rotation when compared to the NSF but provides an option for smaller skull base defects. Zanation et al. discussed its use for the sellar, parasellar, and midclival areas [7]. This flap can be combined with a contralateral ITF for better skull base coverage. To harvest, incisions should include the entire medial surface of the turbinate and can be extended onto the lateral wall mucoperiosteum for wider coverage. With a posterior pedicle, care must be taken to not avulse this area during harvest or transposition. After use, nasal splints are used to prevent scarring within the nose. Patel et al. described the elevation of the MTF but noted limited utility given its technically difficult harvest and thin mucosa [8].

3.6 Postoperative Care and Complications

Extensive endoscopic endonasal skull base resections and reconstructions are not completed without risk for complications. Cautious standardized postoperative care following these procedures helps ensure the optimal results. Immediately after surgery, patients have packing in their nose supporting complex multilayer closures. This typically includes nonabsorbable packing or a Foley catheter used to bolster the repair and depends on intraoperative factors. As previously discussed by Patel et al., intraoperative high-flow CSF leak is the most reliable predictor of developing a postoperative leak [8]. Following skull base surgery, all patients keep a urinary Foley catheter overnight to monitor urine output and rule out concerns for diabetes insipidus. Patients with extensive tumor resections, intradural or intra-arachnoidal resections go to the neurosurgical intensive care unit overnight for close observation. In patients with high risk of postoperative leak, bedrest may be implemented for up to 48 h, at which time activity is still significantly limited. An aggressive bowel regimen is also implored to prevent significant straining postoperatively. Patients with no to low-flow intraoperative CSF leaks have nonabsorbable packing or Foley catheter removed prior to discharge on postoperative day 3. Those with high-flow leaks do not have packing removed until postoperative day 5 and sometimes postoperative day 7. When used, lumbar drains are initially kept open and then slowly tapered until appropriate for removal. All patients require antibiotic therapy while packing is in place for prophylaxis to reduce the risk of meningitis. Commencement of nasal saline irrigations is typically determined by intraoperative leak status reconstruction type.

As with all surgeries, complications exist with endoscopic endonasal skull base surgery reconstruction. Kassam et al. describe these as postoperative CSF leak, meningitis, pneumocephalus, and/or graft failure or displacement [17]. To further assess these complications, a meta-analysis by Harvey et al. reviewed 38 studies. Overall the study found that endonasal skull base reconstruction techniques revealed a postoperative CSF leak rate of 11.5% (70/609) [18]. In this study, analysis of patients reconstructed with free grafts revealed a CSF leak rate of 15.6% (51/326), while the vascularized flap rate was 6.7% [18]. In a separate study by Thorp et al., 152 flaps were assessed and only 5 (3.3%) were found to have CSF leaks (3 NSF, 1 PCF, 1 ITF) [2]. In this study, the majority of leaks were in patients with high-flow CSF leaks. The average time to leak in this study was 43.6 days, as CSF leaks typically occur in the immediate postoperative period. This study did not find an association between complications and radiation therapy. Pneumocephalus is typically an immediate postoperative concern that presents with mental status changes, headache, and vomiting. Expeditious clinical and radiologic evaluation is vital for identification and management of this complication. Reconstructive flaps that have tears present the possibility of CSF leakage as well. With the exception of large tears, small areas of damage typically do not restrict the use of the flap due to the underlying multilayer closure. However, if the surgeon has concerns for intraoperative CSF leak due to lack of flap integrity, a separate reconstruction technique should be used at the time of surgery. Even with the meticulous use of bolstering materials intraoperatively, very rarely flaps may shift. Should this occur and result in CSF leakage, expedited surgical revision should be undertaken. If changes to flap position are only noted on postoperative imaging but no clinical concerns are present, no further revision should be performed.

Overall, review of studies, such as Zanation et al., reveal excellent results using a variety of techniques for skull base reconstruction [7, 18]. In a separate study by Zanation et al., 70 skull base reconstructions for high-flow CSF leaks were assessed, and the CSF leak rate was found to be 5.7% [18]. In a further study by Zanation et al., NSF previously used were revised, taken down, and reused, and postoperative CSF leak rates were no higher. There was also no evidence of flap death in this group [19]. With expanding skull base surgery techniques, the NSF remains the primary option for vascularized skull base repair. However, a study by Patel et al. demonstrated that secondary vascularized flaps beyond the NSF (PCF and TPFF) had a success rate of 97%, compared to that of the NSF (95%) [15]. In a separate study, Patel et al. assessed 34 patients in which the NSF was not available for use. Here, the success rate was greater than 95%, demonstrating new techniques provide consistent and robust repairs in the face of ever-increasing complex pathology [16].

3.7 Surgical Pearls

Nasoseptal Flap

- Meticulous surgical planning is vital to adequate NSF harvest. Overestimation is always preferred.
- The superior incision must be placed 1–2 cm below the superior border of the septum to save olfaction.
- When making nasoseptal flap cuts, do not move too quickly as this will leave areas attached, risking flap tearing. Ensure all anterior elevation has occurred along all three incision lines prior to posterior elevation.
- Standardized multilayer closure including cellular, acellular, and flap techniques is vital to consistent outcomes.

Pericranial Flap

- Very robust flap that offers reconstruction of the entire skull base, especially anterior skull base defects.
- Do not taper the pedicle too much as this can lead to vascular compromise.
- Perform extensive dissection circumferentially prior to incising pericranium or the size of the flap can be significantly truncated.

Temporoparietal Facial Flap

- This flap provides robust reconstruction in patients with very limited options for further skull base repair.
- Dissection in the infratemporal fossa is extensive and has a different risk profile than other reconstructive efforts.
- Over-rotation of the pedicle can lead to flap compromise.

Postoperative Care

- Postoperative activity should be very conservatively managed.
- Patients at increased risk for CSF leak should progress through postoperative care with extreme caution.
- Any concerns for early CSF leak should be revised and repaired if possible before significant complications arise.

References

1. Hegazy HM, Carrau RL, Snyderman CH, et al. Transnasal endoscopic repair of cerebrospinal fluid rhinorrhea: a meta-analysis. Laryngoscope. 2000;110:1166–72.
2. Thorp BD, Sreenath SB, Ebert CS, et al. Endoscopic skull base reconstruction: a review and clinical case series of 152 vascularized flaps used for surgical skull base defects in the setting of intraoperative cerebrospinal fluid leak. Neurosurg Focus. 2014; 37(4):1–7.
3. Stoken J, Recinos PF, Woodard T, Sindwani R. The utility of lumbar drains in modern endoscopic skull base surgery. Curr Opin Otolaryngol. 2015;23(1):78–82.
4. Governale LS, Fein N, Logsdon J, et al. Techniques and complications of external lumbar drainage for normal pressure hydrocephalus. Neurosurgery. 2008;63:379–84; discussion 384.
5. Garcia-Navarro V, Anand VK, Schwartz TH. Gasket seal closure for extended and endonasal endoscopic skull base surgery: efficacy in a large case series. World Neurosurg. 2013;80:563–8.
6. Ransom ER, Palmer JN, Kennedy DW, et al. Assessing risk/benefit of lumbar drain use for endoscopic skull-base surgery. Int Forum Allergy Rhinol. 2011;1:173–7.
7. Zanation AM, Thorp BD, Parmar P, Harvey RJ. Reconstructive options for endoscopic skull base surgery. Otolaryngol Clin N Am. 2011;44(5):1201–22.
8. Patel MR, Stadler ME, Snyderman CH, Carrau RL, Kassam AB, Germanwala AV, Gardner P, Zanation AM. How to choose? Endoscopic skull base reconstructive options and limitations. Skull Base. 2010;20(6):397–404.
9. Kim GG, Hang AX, Mitchell C, Zanation AM. Pedicled extranasal flaps in skull base reconstruction. Adv Otorhinolaryngol. 2013;74:71–80.
10. Harvey RJ, Parmar P, Sacks R, Zanation AM. Endoscopic skull base reconstruction of large dural defects: a systematic review of published evidence. Laryngoscope. 2012;122(2):452–9.
11. Hadad G, Bassagasteguy L, Carrau RL, et al. A novel reconstructive technique after endoscopic expanded endonasal approaches: vascular pedicle nasoseptal flap. Laryngoscope. 2006;116:1882–6.
12. Rivera-Serrano CM, Snyderman CH, Gardner P, et al. Nasoseptal "rescue" flap: a novel modification of the nasoseptal flap technique for pituitary surgery. Laryngoscope. 2011;121(5):990–3.
13. Rawal RB, Kimple AJ, Dugar DR, et al. Minimizing morbidity in endoscopic pituitary surgery: outcomes of the novel nasoseptal rescue flap technique. Otolaryngol Head Neck Surg. 2012;147:434–7.
14. Zanation AM, Snyderman CH, Carrau RL, et al. Minimally invasive endoscopic pericranial flap: a new method for endonasal skull base reconstruction. Laryngoscope. 2009;119:13–8.
15. Patel MR, Shah RN, Zanation AM, et al. Pericranial flap for endoscopic anterior skull-base reconstruction: clinical outcomes and radioanatomic analysis of preoperative planning. Neurosurgery. 2010;66(3):506–12.

16. Patel MR, Taylor RJ, Zanation AM, et al. Beyond the nasoseptal flap: outcomes and pearls with secondary flaps in endoscopic endonasal skull base reconstruction. Laryngoscope. 2014;124:846–52.
17. Kassam AB, Thomas A, Carrau RL, et al. Endoscopic reconstruction of the cranial base using a pedicled nasoseptal flap. Neurosurgery. 2008;63:ONS44–52.
18. Zanation AM, Snyderman CH, Carrau RL, et al. Nasoseptal flap reconstruction of high flow intraoperative CSF leaks during endoscopic skull base surgery. Am J Rhinol Allergy. 2009;23:518–21.
19. Zanation AM, Carrau RL, Snyderman CH, et al. Nasoseptal flap takedown and reuse in revision endoscopic skull base reconstruction. Laryngoscope. 2011;121(1):42–6.