Operative Techniques in Otolaryngology (2010) 21, 74-82

ELSEVIER

Operative Techniques in
Otolaryngology

Reconstruction of the cranial base after endonasal skull base surgery: Local tissue flaps

Amol M. Bhatki, MD,[a] Harshita Pant, MD, PhD,[c] Carl H. Snyderman, MD, FACS,[a,b] Ricardo L. Carrau, MD, FACS,[a,b] Amin B. Kassam, MD, FRCSC,[d] Daniel M. Prevedello, MD,[b] Paul Gardner, MD[b]

From the [a]Department of Otolaryngology—Head and Neck Surgery, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania;
[b]Department of Neurosurgery, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania;
[c]Department of Otolaryngology, University of Adelaide, Adelaide, Australia; and
[d]Saint John's Health Center & John Wayne Cancer Institute, Santa Monica, California.

KEYWORDS
Skull base reconstruction;
Endoscopic endonasal skull base surgery;
Nasoseptal flap;
Middle turbinate flap;
Inferior turbinate flap

Advances in endoscopic techniques and technology have substantially increased the scope of endonasal skull base surgery. Large dural defects after expanded endonasal approaches (EEA) present a challenge for reconstruction and have revealed the limitations of conventional reconstructive methods. Initial reconstructive attempts using nonvascularized free tissue grafts resulted in unacceptably high rates of cerebrospinal fluid fistulae. The advent of vascularized, pedicled flaps has substantially improved these outcomes. These flaps also have the advantage of a large surface area and can be mobilized over a large arc of rotation. Vascularized tissue heals quickly and can tolerate postoperative radiation therapy. We have developed 3 nasal vascularized flaps that can be used for skull base reconstruction after EEA. The anatomy, technique, and reconstructive considerations for the nasoseptal flap, the inferior turbinate flap, and the middle turbinate flap will be reviewed in detail in the following report.

Over the past decade, indications for expanded endonasal approaches (EEA) for resection of skull base and intradural lesions have grown substantially. The progressive acquisition of surgical experience and understanding of endoscopic anatomy, coupled with significant advances in technology and instrumentation, has provided endonasal access to the entire ventral skull base. As a result, many lesions that were previously resected using traditional craniofacial approaches are currently managed with EEA.[1-3]

All skull base reconstructions strive to recreate a separation of the cranial cavity from the sinonasal cavity to prevent cerebrospinal fluid (CSF) leakage, pneumocephalus, and intracranial infection. Small skull base defects and CSF fistulas can be reconstructed with a variety of free grafting techniques resulting in a success rate of >95%.[4,5] However, free grafts are associated with unacceptably high rates of postoperative CSF leak for large dural defects. The lack of supporting structures and the high flow of CSF in cisterns and ventricles pose further challenges to the reliability of reconstruction.

Initial adaptations of endonasal reconstruction consisted of buttressing the dural repair with free fat grafts, suturing of allografts, and supporting the reconstruction with balloon stents.[6] The greatest advance, however, has been the development of vascularized, pedicled local tissue flaps that provide several advantages, including a large area of tissue to reconstruct a sizeable dural defect. This is an important consideration when a patient has received prior radiation therapy or when postoperative radiation therapy is anticipated. In comparison with rotation or advancement flaps that recruit a random blood supply from a wide-based pedi-

Address reprint requests and correspondence: Carl H. Snyderman, MD, FACS, Department of Otolaryngology, Eye and Ear Institute, Suite 500, 200 Lothrop Street, Pittsburgh, PA 15213.
E-mail address: snydermanch@upmc.edu.

1043-1810/$ -see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.otot.2009.10.003

cle, an axial blood supply allows the flap to be mobilized over a larger arc of rotation and conform better to irregular surfaces. Finally, vascularized flaps heal quickly, shortening the healing period and allowing early institution of adjunctive therapies. In our experience, the incidence of postoperative CSF leaks has reduced significantly, from about 25% to <5%, with vascularized tissue reconstruction.[7]

Several endonasal axial flaps have been developed to provide the benefits of vascularized reconstruction without compromising esthetics or adding morbidity associated with external incisions. This manuscript will review in detail the anatomy and surgical techniques of 3 local endonasal tissue flaps: the Hadad-Bassagasteguy nasoseptal (NS) flap, the posteriorly pedicled inferior turbinate (IT) flap, and middle turbinate (MT) flaps.

The NS flap

The Hadad-Bassagasteguy NS flap is the workhorse for endonasal skull base reconstruction. Its large surface area and arc of rotation coupled with a robust blood supply and technical ease make for a reliable, versatile, and hardy reconstruction.

Surgical anatomy

The reconstructive paddle of the NS flap incorporates the mucoperichondrium and mucoperiosteum of the nasal septum. This axial flap is supplied by the NS arteries derived from the posterior nasal artery, one of the terminal branches of the sphenopalatine artery (SPA). The SPA is a continuation of the internal maxillary artery after it passes through the sphenopalatine foramen (or foramina) from the pterygopalatine fossa into the nasal cavity. The SPA typically divides into the lateral and posterior nasal arteries. The posterior nasal artery courses across the sphenoid rostrum between the level of the sphenoid os superiorly and the superior choanal margin inferiorly to supply the septum. Closer to the posterior septum, several branches may arise from the posterior nasal artery, termed NS arteries. These vessels then diverge and form a highly vascular submucosal arcade that anastomoses with septal contributions from the ethmoidal arteries, the superior labial artery, and the artery of the incisive foramen (derived from greater palatine artery).

The perichondrium and periosteum of the septum are adherent to the underlying cartilage or bone in 3 main locations. Anteriorly, anterior to the mucocutaneous junction, several fibrous bands from the mucoperichondrium firmly adhere to the underlying quadrangular septal cartilage. Perichondrial and periosteal fibers also adhere at the bony-cartilagenous junction of the nasal septum and at the junction of quadrangular cartilage and maxillary crest. The vascular arcade lies within the submucosal plane, and the flap is thus elevated deep to the perichondrium. Fibrous adhesions to the underlying cartilage and bone must be meticulously dissected to maintain this plane of dissec-

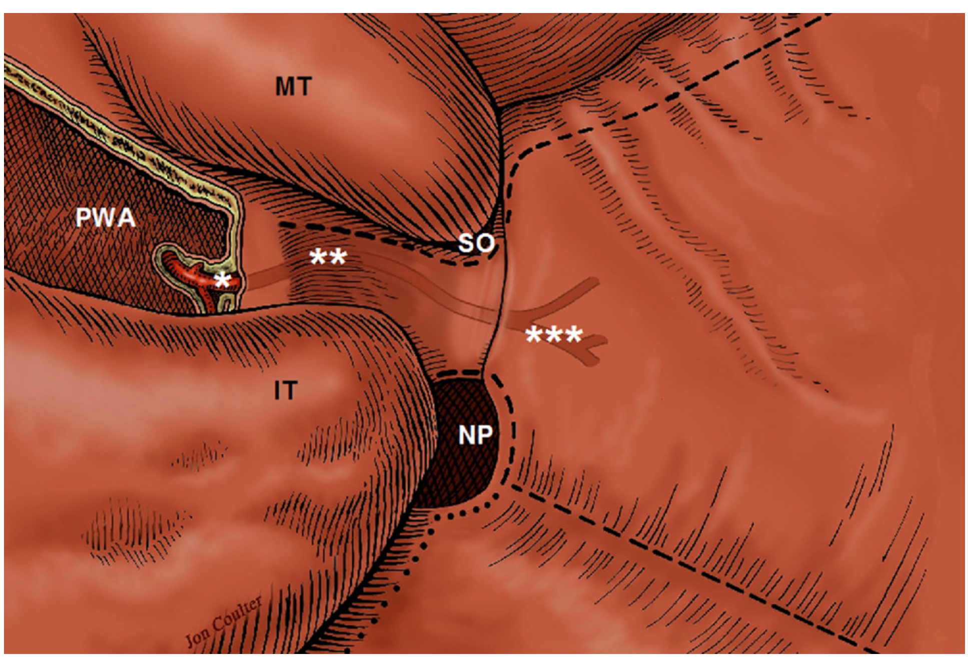

Figure 1 Schematic representation of endoscopic view of right nasal cavity. The dashed lines depict the superior and inferior incisions for the nasoseptal flap. The superior incision begins at the level of the sphenoid os (SO), extending laterally to the lateral nasal wall and medially to the nasal septum. The superior incision is carried forward on the nasal septum in a line that corresponds to the level at which the middle turbinate attaches to the lateral nasal wall. The inferior incision begins at the level of the choana and curves laterally toward the upper margin of the eustachian tube laterally (not shown) and medially to the posterior edge of the nasal septum. This incision then curves forward, approximately 1 cm anterior to the posterior edge of the nasal septum, onto the nasal floor and carried forward in a line corresponding to the junction of the nasal floor and septum. The dotted line represents a lateral extension of this inferior incision onto the nasal floor to maximize the surface area of this flap. MT indicates middle turbinate; PWA, posterior wall of antrum; IT, inferior turbinate; NP, nasopharynx; *, sphenopalatine artery; **, posterior nasal artery, ***, nasoseptal arteries. (Color version of figure is available online.)

tion, and avoid laceration of the flap and disruption of the blood supply.

Operative technique

The nasal cavity is decongested with topical application of pledgets soaked in 0.5% oxymetazoline. The septum is infiltrated with lidocaine 0.5%-1% with epinephrine 1:100,000 to 1:200,000 into the subperichondrial layer, thus hydrodissecting the surgical plane. Mucosal incisions are made using monopolar electrocautery with an extended, insulated needle tip set on a low current. Beginning posteriorly, an incision is made from the apex of the posterior choana below the level of the sphenoid floor along the posterior free margin of the septum to the nasal floor (Figure 1). The vascular pedicle includes the mucosa from this incision inferiorly to the sphenoid os superiorly. The inferior incision is extended anteriorly along the junction of the nasal septum with the nasal floor, until the most anterior projection of the IT. A superior incision starts at level of the sphenoid os and extends across the front of the sphenoid sinus to the nasal septum where it continues anteriorly parallel to the skull base approximately 1 cm below the olfactory sulcus to preserve the olfactory epithelium. The upper incision is flared superiorly to the NS junction and extended anteriorly along the septal aspect of the internal nasal valve (Figure 2) to maximize the surface area of the distal flap. This maneuver does not affect olfaction because olfactory epithelium is not significantly present anterior to the cribriform plate. Endoscopically, this region lies anterior to the attachment of the MT. Sometimes it can be difficult to perform the superior incision in this region under direct vision because of the anterior septal swelling. The superior and inferior septal incisions are now joined anteriorly by a vertical incision that is approximately 1 cm from the nasal columella.

Elevation of the flap begins anteriorly in the subperichondrial plane with a Cottle elevator (Figure 3). A suction elevator is helpful in maintaining visualization, and the superior and inferior septal mucosal cuts may be completed with endoscopic scissors as necessary. It is prudent to complete all incisions before flap elevation because it is often technically challenging to maintain tissue tension and to access the posterior nasal cavity after flap elevation has begun. The dissection proceeds posteriorly and the flap is raised completely when the vascular pedicle is elevated off the sphenoid rostrum. At this point, the flap may be transposed into the nasopharynx to allow for unfettered access for transcribriform, transplanum, or transellar endonasal skull base approaches (Figure 4A). However, for transclival or transpterygoid approaches, the flap is best protected by mobilization into the ipsilateral maxillary sinus through a wide middle meatal maxillary antrostomy.

After the tumor is removed and hemostasis achieved, our standard multilayered reconstruction commences with the placement of a collagen matrix graft (DuraGen; Integra Neurosciences, Plainsboro, NJ) subdurally in an inlay manner. The NS flap is then transposed to cover the defect (Figure 4B). Before positioning, the surgeon must ensure that all the mucosa along the skull base defect has been removed. Furthermore, dead space between the flap and underlying tissue must be obliterated and all aspects of the flap, including the pedicle, must be in direct contact with tissue (bone and dura). Failure to do so will result in contracture of the flap and a CSF fistula either at the distal aspect of the defect or deep to the pedicle. Cellulose strips are placed along the edges of the flap and dural sealant (Duraseal; Confluent Surgical, Inc, Waltham, MA) is applied followed by pieces of gelfoam. Nasal tampon or a balloon catheter (12F Foley urinary catheter) filled with saline is placed to apply indirect pressure onto the NS flap against the defect (Figure 5). Care must be taken because overinflation of the balloon catheter may compress intracranial neural and vascular structures, and may also compromise flow through the vascular pedicle. Silicone septal splints are placed to protect the exposed septal cartilage during wound healing for approximately 3 weeks.

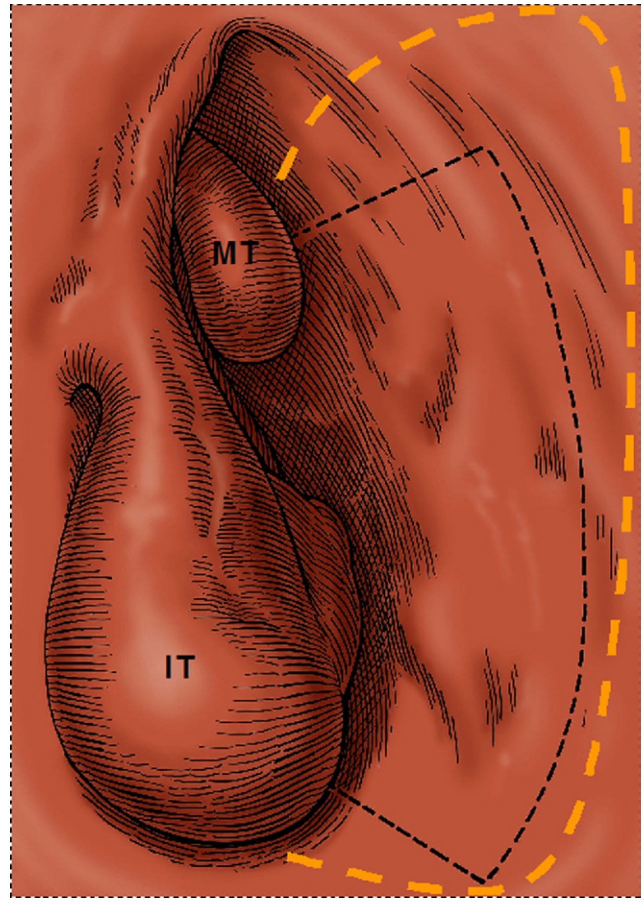

Figure 2 Schematic representation of right nasal cavity showing incorrect (black dashed line) and correct (yellow dashed line) incisions for the nasoseptal flap to include nasal mucosa from the anterior-superior area of the nasal septum. MT, middle turbinate; IT, inferior turbinate. (Color version of figure is available online.)

Modifications of the NS flap

The area of the flap and length of the pedicle may be tailored to the size of the anticipated defect. It is always best

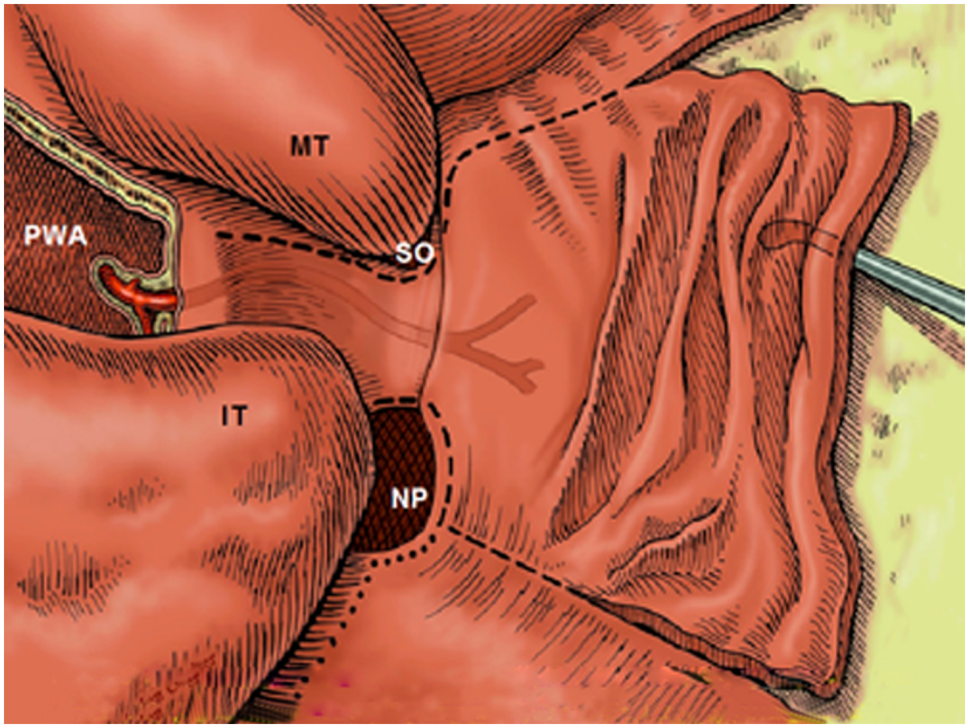

Figure 3 Diagram of the right nasal cavity depicting elevation of the nasoseptal flap in the subperichondrial and subperiosteal plane with a Cottle elevator. SO, sphenoid os; MT, middle turbinate; PWA, posterior wall of antrum; IT, inferior turbinate; NP, nasopharynx. (Color version of figure is available online.)

to overestimate the needs of the reconstruction because the flap is usually elevated before creation of the skull base defect. A wide flap may be harvested by extending the inferior incision laterally to incorporate the mucoperiosteum of the nasal floor and, if necessary, the inferior meatus (Figure 1). This technique compensates for superior septum that may be absent (septal perforation) or involved with tumor.

Technical considerations

Harvesting the NS flap before commencement of the EEA precludes inadvertent transection of the pedicle and protects the mucosa from injury from passage of instruments. With the flap elevated and protected, the posterior septum may be resected to provide binarial exposure. When an intraoperative CSF leak is not anticipated and the surgical exposure is limited (small pituitary tumor), a NS flap is not elevated at the beginning of the surgery. Rather, the vascular pedicle is preserved on one side, and the NS flap is elevated at the completion of tumor resection only if a dural reconstruction is necessary.

Whether the NS flap is harvested on the right or left nasal cavity is based on several factors. First the endonasal corridor needed to approach the tumor must be considered. If ligation of the SPA is required, the flap should be harvested on the contralateral side to protect its blood supply. Similarly, the flap should also be elevated on the contralateral side for unilateral or eccentric tumors. For lesions without laterality or vascular involvement, NS flap elevation can be performed on either side, depending on the preferences of the surgeon or existing septal deviation.

The large surface area of the nasal septum results in a flap that is capable of reconstructing virtually any skull base defect. In a radioanatomical study of the cranial base and flap dimensions, our group demonstrated that the NS flap could adequately reconstruct any single segment of the ventral skull base, including sella and/or planum, clivus, or cribriform.[8] In its largest dimensions, the NS flap can reconstruct an entire anterior craniofacial defect from the frontal sinus to the planum sphenoidale and from orbit to orbit (Figure 6). The flap length, however, may not be adequate to cover defects resulting from combined approaches (eg, from frontal sinus to sella turcica). In such cases, adjuvant flaps, free fat grafts, or a shorter contralateral NS flap may be necessary to provide adequate reconstruction. The reach of the flap is maximized when it is on a planar surface instead of following the curves of the sinuses and skull base. Obliteration of a sphenoid or clival defect with a fat graft will allow the NS flap to reliably reach the posterior table of the frontal sinus.

Preoperative planning is essential in determining whether the NS flap will be available for reconstruction. Prior endonasal surgery (eg, large sphenoidotomy, transseptal sellar surgery) may violate the pedicle or result in septal perforations precluding its use. Also, in the setting of sinonasal malignancy, the septum may be extensively involved and, thus, resected to obtain clear margins. Such cases should ideally be identified preoperatively so that adjunctive reconstructive options are discussed with the patient.

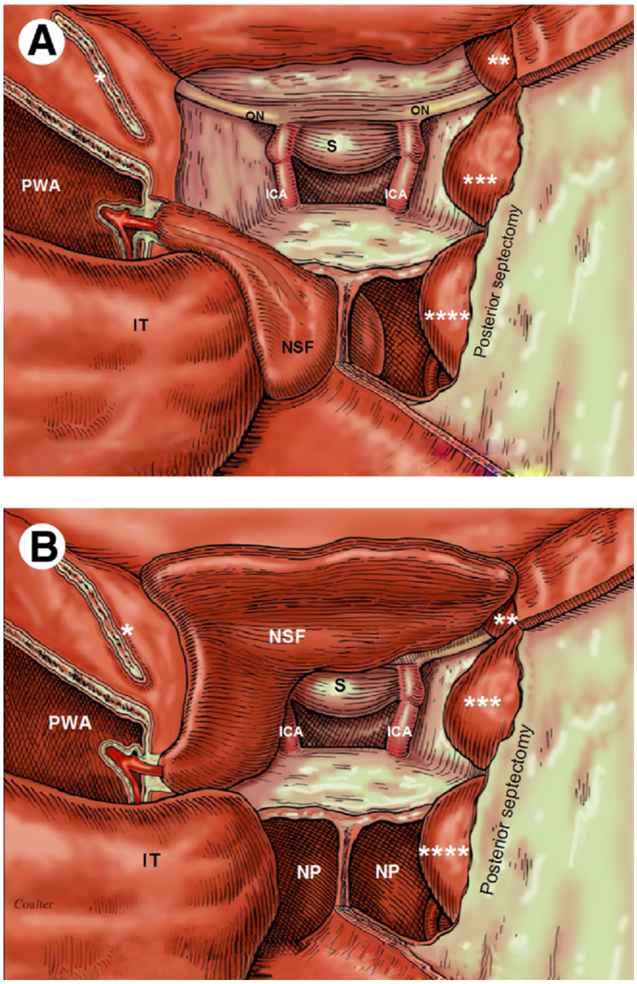

Figure 4 Schematic diagram of an endoscopic view from the right nasal cavity. The right middle turbinate is removed and its remnant attached to the lateral nasal wall is shown (*) and the sphenoid sinus is opened widely to expose the sella (S), bilateral paraclival and cavernous segments of the internal carotid arteries (ICA), and optic nerves (ON). A posterior septectomy is shown, and posterior edges of the contralateral superior turbinate (**), middle turbinate (***), and inferior turbinate (****) can be seen. (A) The nasoseptal flap (NSF) is transposed into the nasopharynx (NP) temporarily to allow access to the sella. A posterior bar of nasal septum is preserved to prevent the NSF from frequent anterior dislodgement during surgery. (B) Schematic representation showing the nasoseptal flap in position on the skull base. PWA, posterior wall of antrum; IT, inferior turbinate. (Color version of figure is available online.)

Inferior turbinate flap

The posteriorly pedicled IT flap is another endonasal vascularized pedicled flap that may be used for skull base reconstruction. It may be used alone or as an adjunct to the NS flap.

Surgical anatomy

The IT flap is pedicled posteriorly on the IT artery. This artery is a branch of the posterior lateral nasal artery (PLNA), which arises from the SPA medial to the sphenopalatine foramen. The PLNA descends in an oblique manner over the perpendicular plate of the palatine bone. The branch to the IT enters on the superior aspect of its lateral attachment, 1.0-1.5 cm from its posterior tip.[9] Hadar et al[10] have reported that the artery often lies within the bone (50%), but may be entirely within the soft tissue (14%) or may present a mixed pattern (36%). After traveling a mean distance of 1.2 cm, the IT artery divides into 2 to 5 branches.

Operative technique

As with the NS flap, the nose is decongested and the lateral nasal wall is infiltrated with lidocaine plus epinephrine solution anterior to the IT. The turbinate is gently medialized to allow visualization of the inferior meatus. The flap is then harvested from the entire IT (Figure 7). A wider flap may be harvested by extending the lower incision onto the nasal floor.

It is best to first dissect the SPA as it emanates from its foramen and identify the PLNA as it is the sole pedicle for the flap. Two parallel incisions are made in the sagittal plane: the upper incision is placed just above the IT in the middle meatus (along the fontanelle of the maxillary antrum) and the lower one is inferior to the turbinate in the inferior meatus.[11] These incisions are connected by a vertical incision around the anterior head of the turbinate (Figure 7A). The flap is then carefully elevated from the lateral nasal wall and inferior concha in the subperiosteal plane in an anterior-to-posterior direction. Care must be taken during posterior dissection to avoid injury to the vascular pedicle located at the superior aspect of the lateral attachment of the turbinate (Figure 7B).

The flap may then be transposed into the defect and applied either directly to bone or dura, or to a free fat graft (Figure 7C). As previously explained, the flap must be in contact with all margins of the defect and must directly appose tissue throughout its length to minimize flap con-

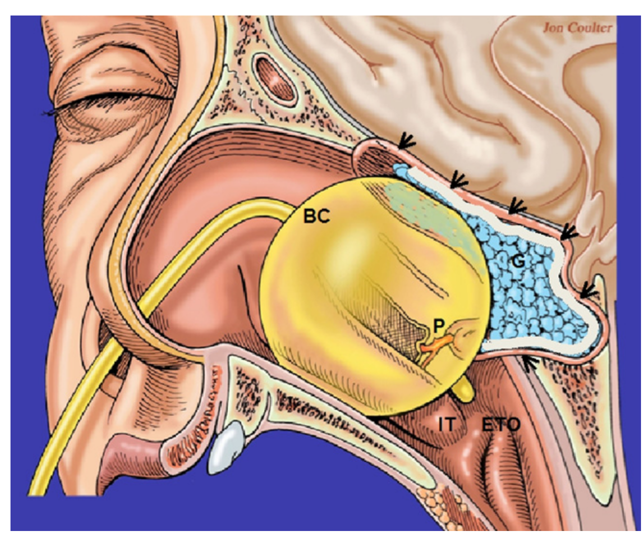

Figure 5 Schematic representation of nasal packing after nasoseptal flap (arrows) is in place. Cellulose strips are placed along the edges of the flap, followed by a dural sealant (white line), gelfoam pieces (G), and balloon catheter (BC). P, pedicle of nasoseptal flap; ETO, eustachian tube orifice; IT, inferior turbinate. (Color version of figure is available online.)

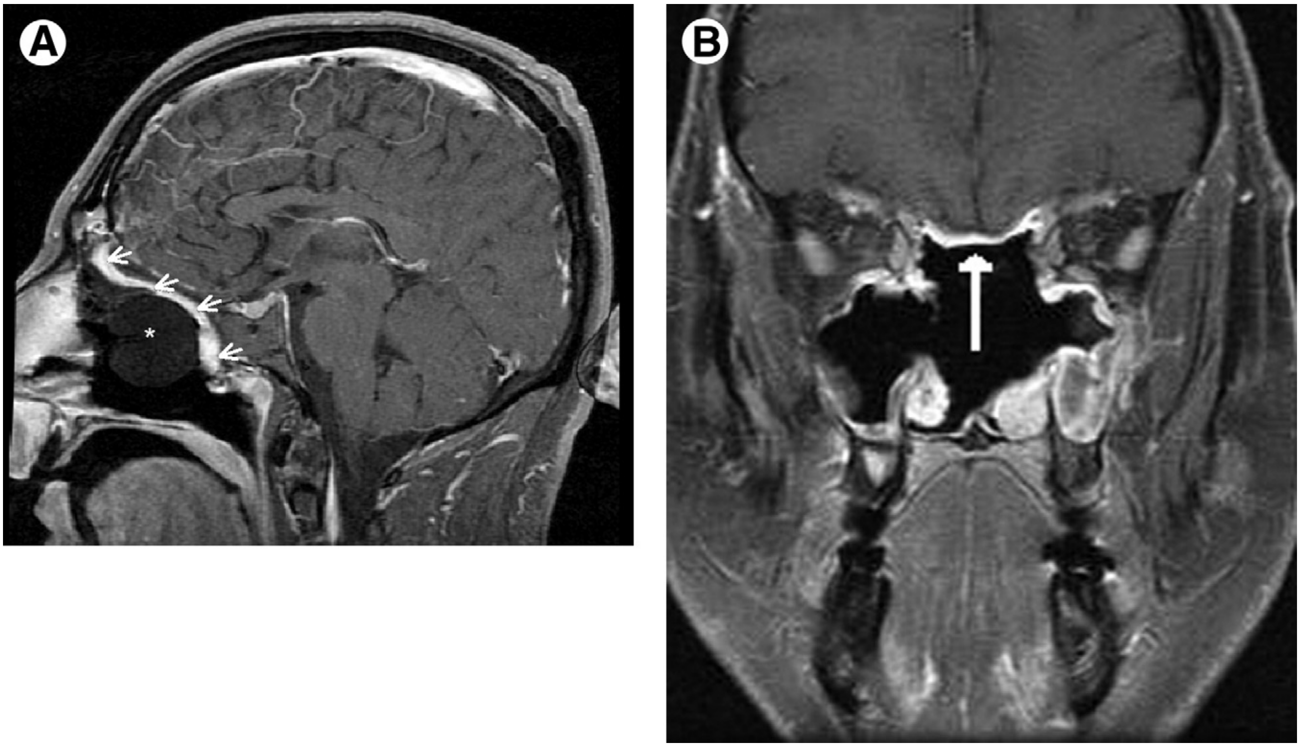

Figure 6 A postoperative computed tomography scan following an endonasal transcribriform approach showing the nasoseptal flap (arrows) in place. (A) The anterior-posterior extent of the nasoseptal flap is shown. The balloon catheter (*) is also seen in place. (B) The lateral extent of the flap is shown, spanning orbit to orbit.

tracture. A layered placement of dural sealant, gelfoam, and nasal packing or a balloon stent provide a stable buttress.

Technical considerations

Contrary to the NS flap, the IT flap is harvested after the EEA is performed. This allows the surgeon to contour the flap to the defect and minimizes trauma during skull base exposure and extirpation. The IT flap is often harvested ipsilateral to the skull base defect. This maximizes the reach and coverage of the flap. However, the IT flap has several major limitations. First, although the flap is long, it is substantially narrower than the NS flap. The average surface area of an IT flap[12] is 5 cm^2 compared with 25-cm^2 area of the NS flap.[8] This naturally limits the width of dural defects that can be reconstructed. As an adjuvant technique, a NS flap or bilateral IT flaps may be positioned to accommodate larger defects. Second, because the flap is pedicled just posterior and inferior to the sphenopalatine foramen, the IT flap has a limited reach and arc of rotation. It is best suited for reconstruction of inferior skull base defects (eg, clivus, sella). Finally, the IT flap is difficult to dissect from the bone of the inferior concha and has a tendency to retain its convex, convoluted shape when elevated and transposed onto the dural defect.

Middle turbinate flap

The MT flap provides another option for endonasal cranial base reconstruction. Although it is pedicled posteriorly like the IT flap, the superior position of the pedicle makes it a better option for sellar, planum, and fovea ethmoidalis defects.

Surgical anatomy

The MT is attached to the lateral nasal wall at its anterior and posterior aspects, as well as at the basal lamella. The vertical plate is attached superiorly to the skull base at the vertical lamella of the cribriform plate. Anatomical studies reveal that there is a consistent artery that emanates posteriorly from the SPA that supplies the MT via its posterior attachment.[13]

Operative technique

After decongesting the nasal cavity with oxymetazoline, the anterior head of the MT is infiltrated with a lidocaine solution containing epinephrine. The lateral nasal wall along the superior aspect of the uncinate process and the vertical lamella of the MT may also be infiltrated. First, a vertical incision is made along the anterior aspect of the head of the MT and a horizontal incision continued horizontally and posteriorly, just below the skull base (Figure 8). Subperiosteal elevation of the medial aspect of the turbinate proceeds from superior to inferior, and is followed by a meticulous and careful removal of the MT bone in a piecemeal manner. The vertical attachment of the MT to the skull base should be sharply transected to avoid inadvertent skull base fracture and CSF leak.

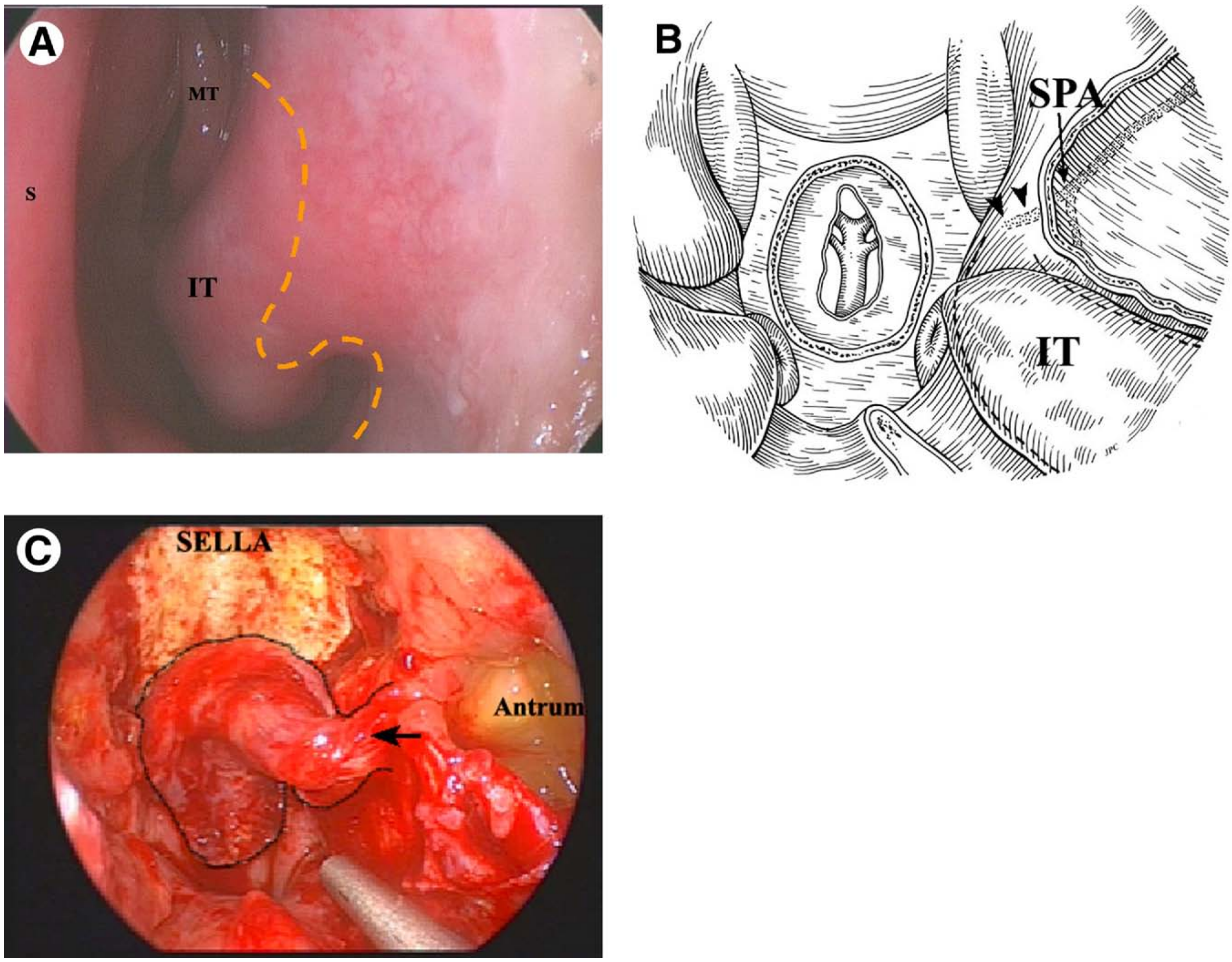

Figure 7 (A) The mucosal incision starts at the maxillary ostium in the middle meatus and follows the edge of the inferior turbinate (IT) anteriorly. It incorporates the mucosa of the inferior meatus and terminates posteriorly at the Eustachian tube. (B) An IT flap is pedicled on a branch from the SPA and is best suited for small clival defects. (C) Intraoperative photo of a clival defect that was reconstructed with a left IT flap. MT, middle turbinate (Color version of figure is available online.)

After all the bone is removed, the lateral mucoperichondrial flap is incised sharply, again, along the plane of the skull base. Thus, the flap unfolds from the underlying bone as if opening a book. Elevation of the flap proceeds posteriorly as the basal lamella is transected. While preserving the vascular supply, it is best to dissect the pedicle to the sphenopalatine foramen to gain the maximum length and arc of rotation for the flap. A layered reconstruction then proceeds following the same principles as noted previously.

Technical considerations

The MT flap may be harvested at the onset or the conclusion of EEA. Because the right MT is often transected for exposure, harvesting this flap may be best accomplished at the outset. Similar to the NS flap, the flap may be stored in the nasopharynx or ipsilateral maxillary sinus until required for reconstruction.

One of the major limitations of the MT flap is its high degree of technical difficulty. Destabilization of the bony attachments and anatomical variations, such as a concha bullosa, make the flap harvest more technically demanding. Moreover, the anatomy of the MT is commonly variable, including[14] concha bullosa, paradoxical turbinate, and hypoplasia. The dimensions of the MT are also highly variable.[14,15] A smaller turbinate may be limited in its reach, especially to the sella turcica, which requires an estimated length of 4 cm[13] Also, as seen with the IT flap, the smaller mucosal paddle results in a mean surface area of only 5.6 cm^2.[13] These limitations make the MT flap best suited for reconstruction of the planum, fovea ethmoidalis, and, depending on the turbinate's dimensions, the sella.

Revision surgery

Some patients will require revision surgeries. This may be due to intentional staging of surgeries because of extensive bone work before tumor resection, long duration of surgery, surgeon fatigue, intraoperative blood loss, lack of tumor descent, or the need to update image guidance as a result of tumor shift. In such cases, the second stage is preformed

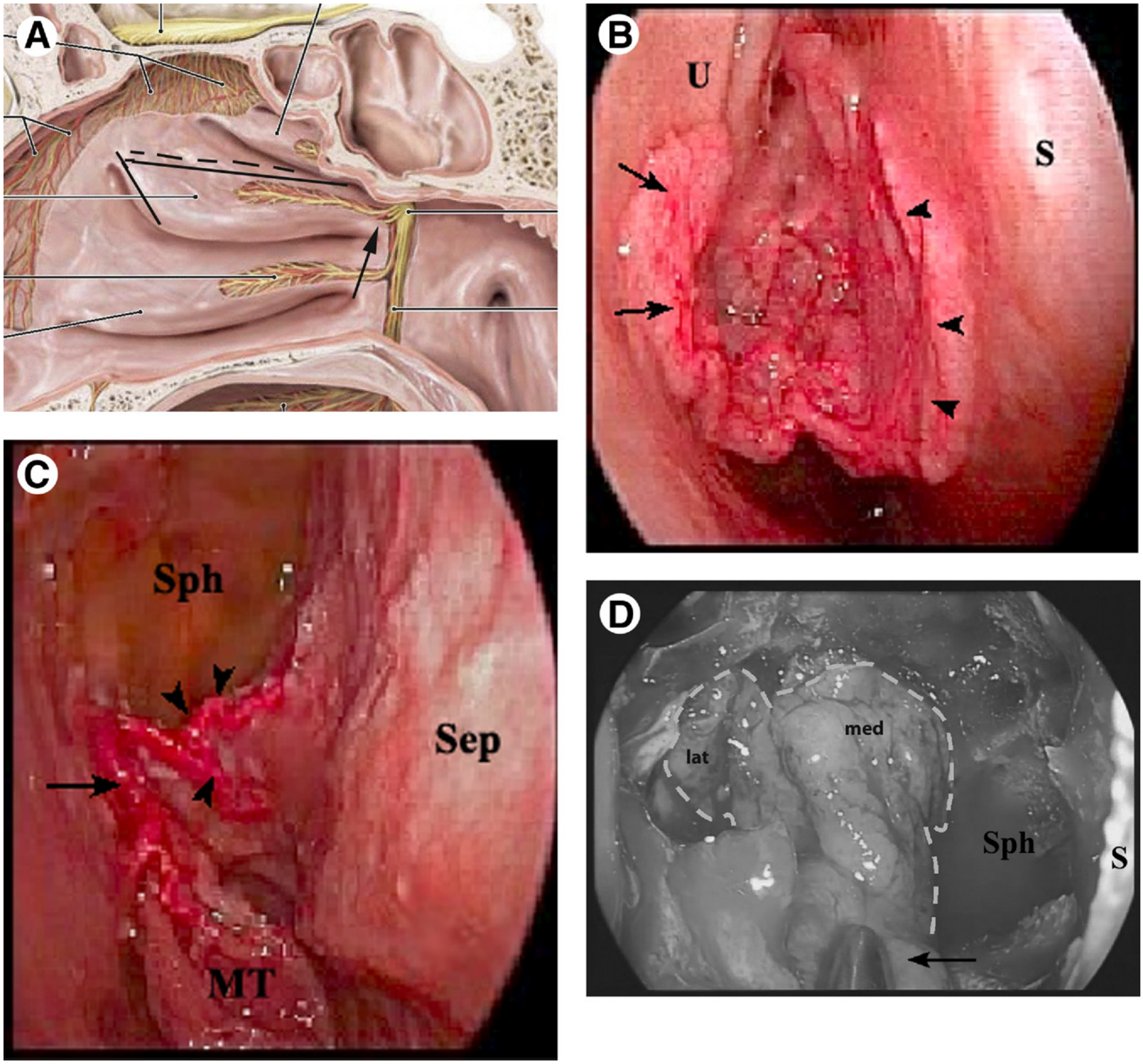

Figure 8 (A) Mucosal incisions (solid lines) are made on both sides of the turbinate parallel to the skull base attachment (dashed line) and along the anterior projection (vertical line). (B) The middle turbinate (MT) has been opened like a book and the bone has been removed from the two mucosal surfaces. (C) The MT flap is pedicled on medial (arrowheads) and lateral branches (arrow) of the sphenopalatine artery. (D) The medial and lateral surfaces of the flap have been transposed to cover a skull base defect. (Color version of figure is available online.)

days to weeks later. Other revision surgeries are due to tumor recurrence, most frequently seen with pituitary adenomas, meningiomas, and craniopharyngiomas. A favorable attribute of the NS flap and other mucosal flaps is that they can be reused multiple times. A mucosal incision is made around the periphery of the flap and a plane of dissection can be easily developed deep to the flap. The vascular pedicle is preserved and the flap is displaced for later reconstruction. In revision surgeries, the flap retains its shape and immediately conforms to the surgical defect if the surgical exposure is not modified extensively. Preservation and reutilization of flaps is not always possible in the event of recurrent surgery for a malignancy. The flap should be resected if the recurrence is in proximity to the flap. In such cases, an alternative reconstruction (regional flap) should be considered.

Reconstructive failures

There are many reasons why a flap reconstruction can fail, resulting in a CSF leak. High-flow leaks from a large defect or entry into a CSF cistern or ventricle pose a greater risk for a postoperative leak, and prophylactic lumbar spinal drainage should be considered. Elevations of CSF pressure are also seen in patients with occult hydrocephalus and obesity. Transient elevations in CSF pressure also occur during emergence from anesthesia and because of patient activities. Nasal packing or a balloon catheter helps to counteract these fluctuations in pressure. Flap necrosis rarely occurs but could be a consequence of overdissection of the flap pedicle, kinking of the pedicle during a long surgery, or excessive compression from a balloon. Other causes of failure are inadequate placement of the flap—migration of the flap during reconstruction and reversal of the flap with its mucosal surface apposing the skull base. A flap that is too small or short for the defect will result in tension, bridging of the flap pedicle, or failure to overlap avascular areas of reconstruction. An inadequate recipient bed can interfere with revascularization—large dead space from tumor resection or encephalomalacia, retained mucosa and foreign bodies (bone chips, bone wax), prior irradiation, and a positive tumor margin. Finally, disruption of the repair can occur with removal of packing, improper placement of a balloon catheter, or excessive postoperative debridement. The optimal duration for postoperative packing is undetermined, but is probably in the range of 4-7 days.

Conclusions

Vascularized pedicled flaps are the best option for providing a reliable and robust reconstruction after endonasal skull base surgery. Because it is a versatile flap with a good arc of rotation and a large surface area, the NS flap is the workhorse in our reconstructive algorithm. Secondary flaps, such as the IT flap and the MT flap, are less versatile and have limited roles in skull base reconstruction. With appropriate planning and meticulous dissection technique, even large dural defects can be reliably reconstructed.

References

1. Kassam AB, Gardner P, Snyderman C, et al: Expanded endonasal approach: Fully endoscopic, completely transnasal approach to the middle third of the clivus, petrous bone, middle cranial fossa, and infratemporal fossa. Neurosurg Focus 19:E6, 2005
2. Kassam A, Snyderman CH, Mintz A, et al: Expanded endonasal approach: The rostrocaudal axis. Part I. Crista Galli to the sella turcica. Neurosurg Focus 19:E3, 2005
3. Kassam A, Snyderman CH, Mintz A, et al: Expanded endonasal approach: The rostrocaudal axis. Part II. Posterior clinoids to the foramen magnum. Neurosurg Focus 19:E4, 2005
4. Hegazy HM, Carrau RL, Snyderman CH, et al: Transnasal endoscopic repair of cerebrospinal fluid rhinorrhea: A meta-analysis. Laryngoscope 110:1166-1172, 2000
5. Zweig JL, Carrau RL, Celin SE, et al: Endoscopic repair of cerebrospinal fluid leaks to the sinonasal tract: Predictors of success. Otolaryngol Head Neck Surg 123:195-201, 2000
6. Kassam A, Carrau RL, Snyderman CH, et al: Evolution of reconstructive techniques following endoscopic expanded endonasal approaches. Neurosurg Focus 19:E8, 2005
7. Hadad G, Bassagasteguy L, Carrau RL, et al: A novel reconstructive technique after endoscopic expanded endonasal approaches: Vascular pedicle nasoseptal flap. Laryngoscope 116:1882-1886, 2006
8. Pinheiro-Neto CD, Prevedello DM, Carrau RL, et al: Improving the design of the pedicled nasoseptal flap for skull base reconstruction: A radioanatomic study. Laryngoscope 117:1560-1569, 2007
9. Padgham N, Vaughan-Jones R: Cadaver studies of the anatomy of arterial supply to the inferior turbinates. J R Soc Med 184:728-730, 1991
10. Hadar T, Ophir D, Yaniv E, et al: Inferior turbinate arterial supply: Histologic analysis and clinical implications. J Otolaryngol 34:46-50, 2005
11. Fortes FS, Carrau RL, Snyderman CH, et al: Transpterygoid transposition of a temporoparietal fascia flap: A new method for skull base reconstruction after endoscopic expanded endonasal approaches. Laryngoscope 117:970-976, 2007
12. Murakami CS, Kriet JD, Ierokomos AP: Nasal reconstruction using the inferior turbinate mucosal flap. Arch Facial Plast Surg 1:97-100, 1999
13. Prevedello DM, Barges-Coll J, Fernandez-Miranda JC, et al: Middle turbinate pedicled flap for anterior skull base reconstruction: A cadaveric feasibility study. Laryngoscope 119:2094-2098, 2009
14. Perez P, Sabate J, Carmona A, et al: Anatomical variations in the human paranasal sinus region studied by CT. J Anat 197:221-227, 2000
15. Bodino C, Jankowski R, Grignon B, et al: Surgical anatomy of the turbinal wall of the ethmoidal labyrinth. Rhinology 42:73-80, 2004