Use of the Hadad-Bassagasteguy flap for repair of recurrent cerebrospinal fluid leak after prior transsphenoidal surgery

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ABSTRACT

The Hadad-Bassagasteguy vascularized nasoseptal pedicled flap (HBF) is an effective technique for reconstruction of skull base defects with low incidence of postoperative cerebrospinal fluid (CSF) leak. Advanced planning is required as posterior septectomy during transsphenoidal surgery can preclude its use due to destruction of the vascular pedicle. We present four cases in which the HBF was successfully used to repair recurrent CSF leaks despite prior posterior septectomy and transsphenoidal surgery. A retrospective chart review was performed on all patients who developed recurrent CSF leak after transsphenoidal surgery over a 7-year period (2006–2013). Data were collected regarding demographics, clinical presentation, intraoperative findings, and surgical outcomes. Four patients who developed recurrent CSF drainage after transsphenoidal surgery were managed with HBF reconstruction during the study period. Two were men and two were women with a mean age of 37 years (range, 24–48 years). All had previously undergone resection of a pituitary macroadenoma via *a transsphenoidal approach, with intraoperative CSF leaks repaired using multilayered free grafts. Recurrent CSF rhinorrhea arose 0.37–12 months (mean, 2.98 months) after the initial pituitary surgery. Active CSF drainage could be visualized intraoperatively with posterior septal perforations present. The HBF was successfully used in all cases, with no evidence of recurrent CSF leak after a mean follow-up of 2.35 years. The HBF may be salvaged for repair of recurrent CSF leaks even in the context of prior posterior septectomy and transsphenoidal surgery. However, longer follow-up is necessary to determine the long-term efficacy of this procedure in such revision cases.*

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Since its inception, the Hadad-Bassagasteguy vascularized pedicled nasoseptal flap (HBF) has emerged as a revolutionary technique in the reconstruction of skull base defects after endoscopic expanded endonasal approaches (EEA).[1,2] Its introduction has dramatically reduced the incidence of postoperative cerebrospinal fluid (CSF) leak after EEAs, from >20 to <5%, a level comparable with that of open cranial base surgery.[1–6] Originally described by Hadad *et al.* in 2006, the HBF is a neurovascular pedicled flap comprised of nasal septum mucoperichondrium and mucoperiosteum.[1] Based on the nasoseptal artery, a branch of the posterior septal artery, the HBF harbors a robust vascular supply, extensive surface area, and broad arc of rotation.[1,2] Such unique characteristics have enabled the HBF to facilitate healing and provide durable, comprehensive coverage of a wide variety of skull base defects. Success rates of 94–99% have been reported with the HBF, even in the presence of high-flow intraoperative CSF leaks.[1–3,7,8] Because of its versatility and reliability, the HBF has become the workhorse for skull base reconstruction after expanded endonasal surgery.

However, the HBF requires preemptive harvesting, because most EEA procedures will compromise the viability of the vascular pedicle.[1–2,9] Posterior septectomy and expanded sphenoidotomy can disrupt the flap's blood supply and render the HBF unusable for subsequent reconstruction. Consequently, elevation of HBFs must be performed at the beginning of surgery to protect the pedicle in all cases where a potential CSF leak may be encountered.[1,2,9–11] To circumvent this, Rivera-Serrano *et al.* developed the nasoseptal rescue flap (NSRF).[9] With this technique, the HBF is only partially raised, permitting access to the sphenoid face without injuring the feeding vessels. If an intraoperative CSF leak occurs, the NSRF can be fully harvested and converted to an HBF. If no leak was obtained, elevated mucosa could be placed back into its original position, minimizing donor site morbidity associated with complete flap retrieval. Therefore, nasoseptal harvest could be conducted after tumor resection, allowing reconstruction to be performed only when necessary.[9]

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Despite these advances, little has been described with regard to application of the HBF in patients who have undergone prior transsphenoidal approaches without an NSRF. In such instances, posterior septectomy and extended sphenoidotomies are still considered contraindications to HBF harvest because of presumed destruction of the pedicle site.[1,2,9–11] The aim of the current study was to illustrate the surgical plausibility of using the HBF in the setting of a previous transsphenoidal surgical defect without the benefit of a prior NSRF. We present a series of four patients with a history of posterior septectomy and transsphenoidal surgery in which the HBF was successfully used in the repair of recurrent CSF fistulas. The clinical presentation, surgical approach, intraoperative findings, and patient outcome are discussed.

MATERIALS AND METHODS

A retrospective chart review was performed on all patients who developed recurrent CSF leak after transsphenoidal surgery over a 7-year period (2006–2013). Four patients who underwent revision CSF leak repair using an HBF in the setting of a prior posterior septectomy were identified. Data collected included age, gender, clinical presentation, prior surgical history, site of involvement, method of repair, intraoperative findings, complications, recurrence, and follow-up. CSF leaks were confirmed by clinical history, endoscopic examination, positive β_2-transferrin, and intraoperative visualization of a CSF fistula. High-flow CSF leaks were defined as those in which brisk CSF drainage through the skull base defect was observed without a Valsalva maneuver.[7] Computer-assisted surgical navigation was used in all cases. Endonasal identification of the site of CSF leakage was achieved by intrathecal injection of fluorescein and blue light filter visualization. The protocol for this study was reviewed and approved by the Southern California Permanent Medical Group Institutional Review Board. The requirement for informed consent was waived.

RESULTS

Four patients who developed recurrent CSF drainage after transsphenoidal surgery were managed with HBF reconstruction during the study period. Two were women and two men, with a mean age of 37 years (range, 24–48 years). All had previously undergone resection of a pituitary macroadenoma *via* a transsphenoidal approach. None of the prior skull base procedures involved harvest of an NSRF. Intraoperative CSF leaks were encountered in all cases, which were initially repaired with multilayered free grafts and fibrin glue. Recurrent CSF drainage subsequently arose 0.37–12 months (mean, 2.98 months) after the initial pituitary surgery and were referred to our facility for revision CSF leak repair. High-flow CSF leaks were observed in all patients, with brisk egress of CSF through the skull base defect visualized using intrathecal fluorescein under blue light filter endoscopy (Figs. 1 and 2). Posterior septal perforations were noted in all cases (Fig. 3), but an intact strip of mucoperiosteum was still present between the pedicle and anterior septal mucosa. The mean height of the residual mucoperiosteal tissue between the prior sphenoid sinusotomy and the superior edge of the choanae was 14.3 mm (range, 12–17 mm). The mean distance between the most inferior aspect of the septal perforation

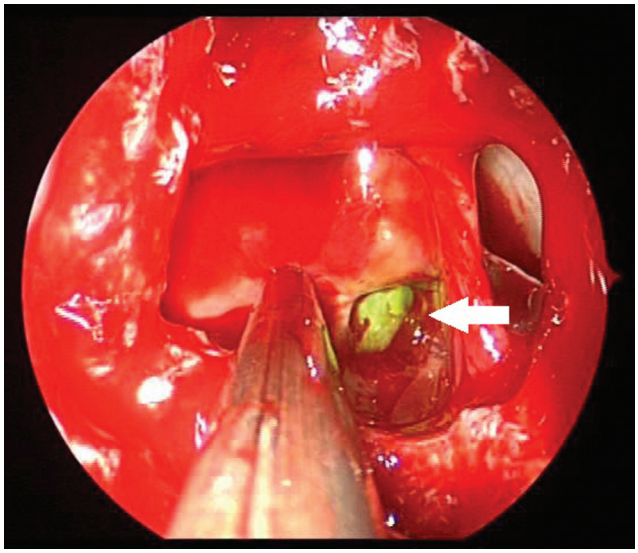

Figure 1. *Intraoperative endoscopic photograph. Fluorescein-stained cerebrospinal fluid (CSF; arrow) can be seen extruding from the skull base defect.*

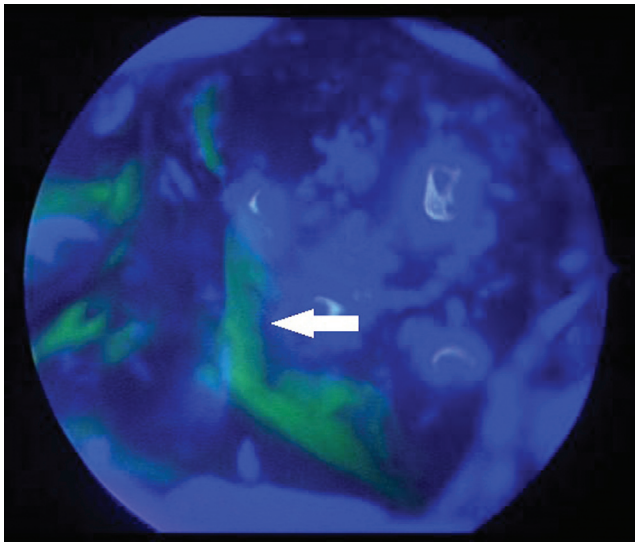

Figure 2. *Intraoperative endoscopic photograph under blue-light filter visualization. Fluorescein-stained cerebrospinal fluid (CSF; arrow) is observed extravasating from the skull base defect toward the nasopharynx.*

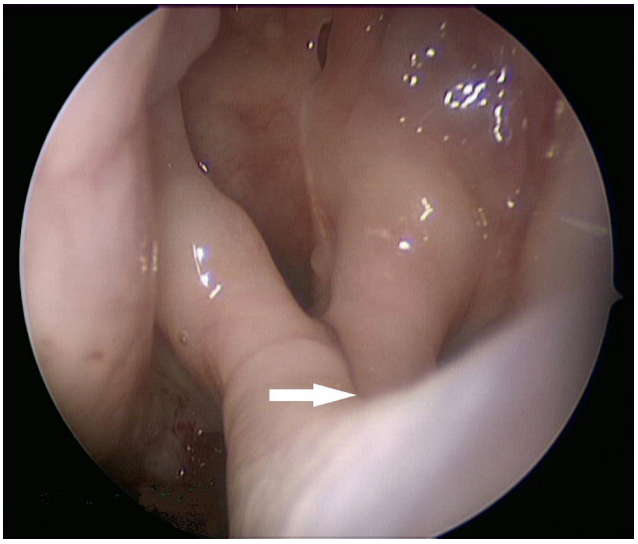

Figure 3. *Intraoperative endoscopic view of the right nasal cavity shows the presence of a posterior septal perforation (arrow at inferior edge) from prior transsphenoidal surgery.*

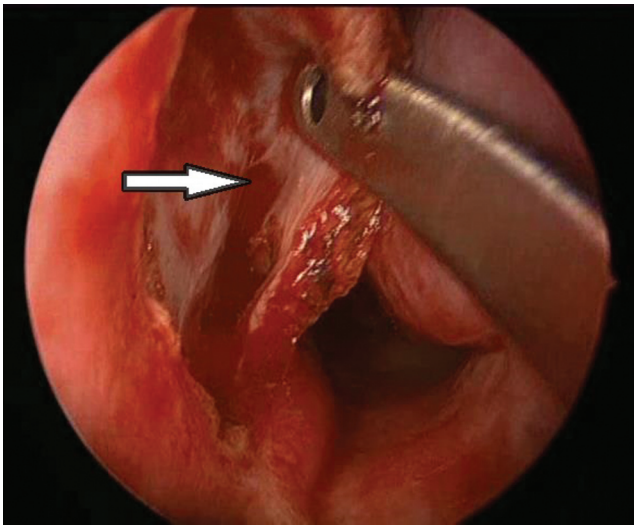

Figure 4. *Intraoperative endoscopic photograph of the left nasal cavity shows initial stages of anterior nasoseptal flap elevation (arrow) using a suction freer elevator.*

and nasal floor was 10.7 mm (range, 9–14 mm). Despite prior partial posterior septectomy, an HBF could be harvested by raising the remaining mucoperiosteal paddle between the inferior aspect of the septal perforation and the nasal floor (Figs. 4 and 5). This intervening tissue served to bridge the pedicle to residual intact septal mucosa anterior to the perforation. The salvaged HBF in conjunction with an abdominal fat graft and fibrin glue were used to repair the CSF leak in all four cases (Fig. 6, *A* and *B*). Lumbar drains were placed in all patients and kept in place for 3–4 days at a rate of 10 mL/hr. No evidence of recurrent CSF drainage has been detected, to date, after a mean follow-up of 2.35 years (range, 1.4–2.9 years). The details of each case are

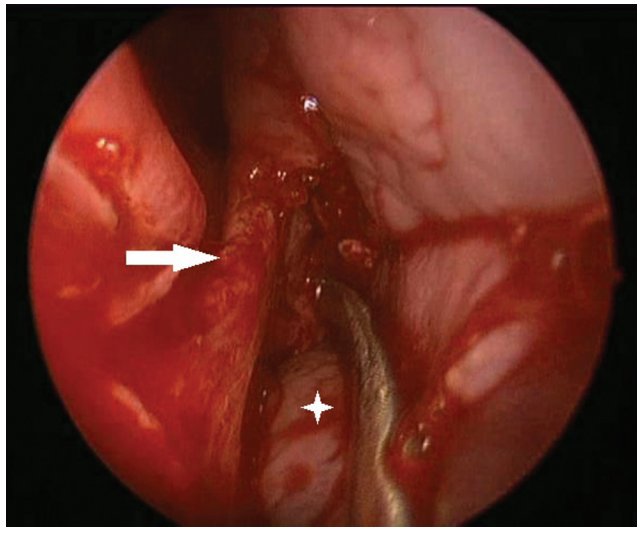

Figure 5. *Intraoperative endoscopic photograph of the left nasal cavity illustrates continuous nasoseptal flap elevation posteriorly to include the remaining mucoperiosteal paddle (star) inferior to the septal perforation (arrow).*

summarized in Table 1, and a representative patient is described in the following subsection.

Case Four

A 48-year-old man presented to the neurosurgery department with a history of bilateral hemianopsia. He was ultimately found to have a pituitary macroadenoma, which was excised *via* an endoscopic transsphenoidal approach in March 2012. An intraoperative CSF leak was repaired using an abdominal fat graft and fibrin glue. Despite the lack of CSF leak symptoms on discharge, the patient presented 12 days later with CSF rhinorrhea after straining during a bowel movement. The patient was admitted by the neurosurgical team and a lumbar drain was placed. Initially, the CSF drainage resolved only to recur again a week after lumbar drain removal. The rhinology service was consulted, and the patient was brought to the operating room for revision endoscopic CSF leak repair. Intraoperatively, fluorescein-stained CSF could be visualized draining through the skull base defect posteriorly toward the nasopharynx (Figs. 4 and 5). Although a posterior septal perforation was present, intact tissue between the inferior aspect of the perforation and the nasal floor was evident bridging the anterior septal mucosa to the neurovascular pedicle. Therefore, an HBF was harvested and rotated into the sphenoid to reconstruct the defect in a multilayered fashion using abdominal fat graft, fibrin glue, and Gelfoam (Baxter, Deerfield, IL) (Fig. 6, *A* and *B*). The patient did well postoperatively without complications and has had no evidence of recurrent CSF leak after 1.4 years of follow-up.

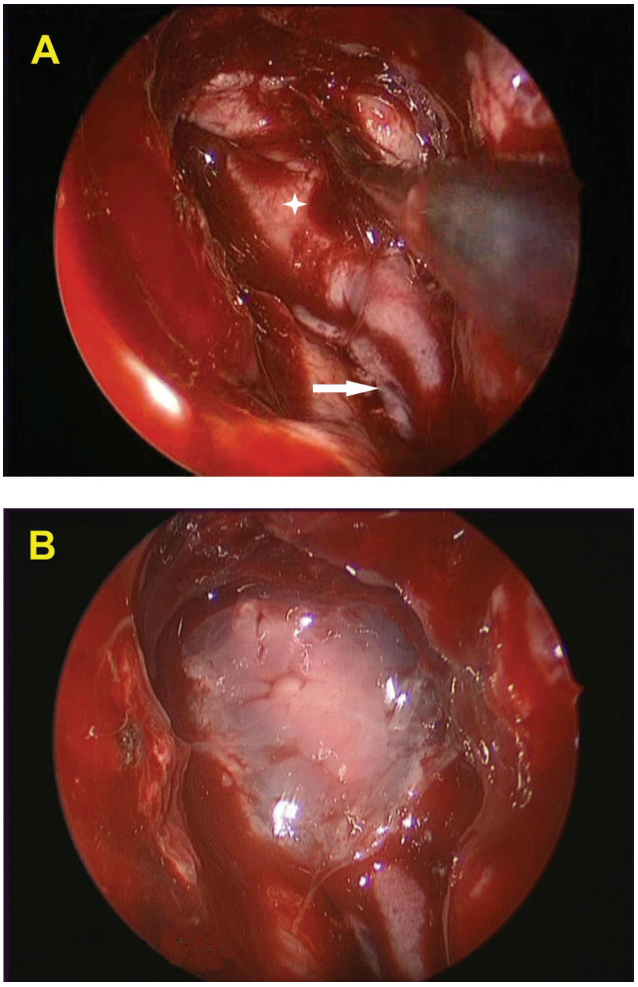

Figure 6. Intraoperative endoscopic photographs depict (A) rotation of the Hadad-Bassagasteguy flap (HBF; star) into place with the vascularized pedicle (arrow) seen inferiorly and the (B) nasoseptal flap in place with addition of fibrin glue.

DISCUSSION

The advent of the HBF represents a significant milestone in the advancement of endoscopic endonasal skull base surgery. With this revolutionary technique, the incidence of postoperative CSF leak decreased significantly after expanded transnasal corridor approaches, from >20 to <5% after adaptation of the HBF.[1–8] Multiple studies have indicated its efficacy in the reconstruction of EEA defects, with overall success rates of 94–99% reported even in the presence of high-flow CSF fistulas.[1,2,7,8] Previous HBFs may also be taken down without pedicle disruption for reuse in revision endoscopic skull base cases.[12] Zanation *et al.* showed that prior HBFs can be dissected away from the original site of surgery and mobilized over the new skull base defect without resultant flap necrosis.[12] Furthermore, the HBF has been found to not only be effective in the treatment of recalcitrant CSF rhinorrhea secondary to EEAs but also after open skull base procedures as well.[13]

Such positive outcomes have been attributed to the flap's robust blood supply, pliability, and superior arc of rotation, which enables the comprehensive coverage of a broad spectrum of anterior, middle, and posterior cranial base defects.[1,2] Depending on the dimensions of the donor septum, the HBF can extend in length from the frontal recess anteriorly to the clivus/C2–C3 posteriorly, and in width from one lamina papyracea to the other.[1,2] The addition of an arterial pedicle is what differentiates the HBF from the initial nasoseptal flap described by Hirsch in 1952, which used a random blood supply in the endonasal repair of two sphenoid CSF leaks.[14] Such random rotational flaps mandated a broad base to preserve their feeding vasculature, limiting their rotational arc and surface area. In contrast, the HBF is based on the nasoseptal artery, a branch of the posterior septal artery, which supplies the entire length of the septum. The nasoseptal artery is situated within a strip of mucoperiosteum between the inferior margin of the natural sphenoid ostium and the superior edge of the posterior choanae. This region comprises the superior and inferior limits of the HBF pedicle.[1,2] Consequently, wide sphenoidotomies extending inferiorly to the sphenoid floor can injure the nasoseptal arteries and compromise the viability of the HBF. Likewise, posterior septectomy can sever the connection between the nasoseptal arteries and residual anterior septal mucoperichondrium, interrupting blood flow to the HBF. As a result, for patients in which an NSRF was not performed during the initial EEA, posterior septectomy and expanded sphenoidotomies have been considered contraindications to use of the HBF because of presumed damage to the vascular pedicle.[1,2,9–11,15]

This quandary has propelled the search for alternative endonasal pedicled flaps that could be used in instances where the HBF was deemed unavailable. To that end, the posterior inferior turbinate flap (PITF), middle turbinate flap (MTF), and lateral nasal wall flap (HB2) have been developed as potential vascularized tissue options for reconstruction in cases where the HBF was no longer a viable option.[10,16–18] The PITF is comprised of inferior turbinate mucoperiosteum and is supplied by the inferior turbinate artery, the terminal branch of the posterior lateral nasal artery.[10] Because its surface area is limited by the dimensions of the turbinate, the PITF has been found to be best suited for reconstruction of moderately sized clival and sellar defects. In the initial study by Fortes *et al.* the PITF was successfully used in two patients with CSF fistulas who had previously undergone posterior septectomies as part of EEAs for clival chordomas.[10] Like the PITF, the MTF is also pedicled posteriorly but receives its blood supply from the middle turbinate artery, another branch of the posterior lateral nasal artery.[17,18] It is most useful for small anterior skull base defects of the

Table 1 **Patient characteristics**

Patient	Age (yr)	Gender	Prior Transsphenoidal Surgery	Initial Closure Technique	Pathology	Recurrent CSF Leak	Our Intervention*	Outcome/ Follow-Up
1	24	F	July 29, 2010: Endoscopic	Fat graft and fibrin glue (Tisseal)	Secreting pituitary macroadenoma	1 mo after initial transsphenoidal pituitary surgery	September 9, 2010: Hadad flap	2.9 yr, no recurrence
2	38	F	October 5, 2006: Open/transseptal October 29, 2009: Open/transseptal	Septal bone and polyethylene glycol (DuraSeal)	Nonsecreting pituitary macroadenoma	12 mo after second trans-sphenoidal pituitary surgery	October 16, 2010: Hadad flap	2.8 yr, no recurrence
3	38	M	May 6, 2011: Endoscopic	Fat graft and fibrin glue	Hemorrhagic pituitary macroadenoma	0.53 mo after initial transsphenoidal pituitary surgery	May 22, 2011: Hadad flap	2.3 yr, no recurrence
4	48	M	March 8, 2012: Endoscopic	Bone graft, fat graft, and fibrin glue	Nonsecreting pituitary macroadenoma	0.37 mo after initial transsphenoidal pituitary surgery	March 25, 2012: Hadad flap	1.4 yr, no recurrence

**All Hadad flap procedures were performed in conjunction with a fat graft, fibrin glue, and a lumbar drain.*
CSF = cerebrospinal fluid.

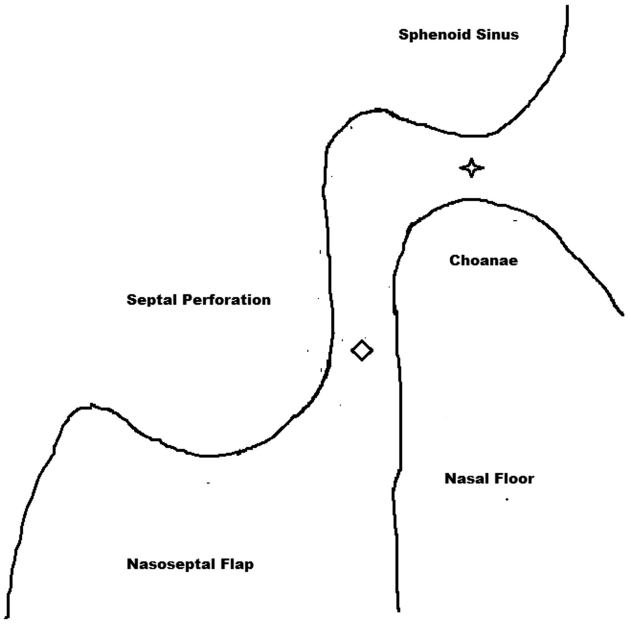

Figure 7. Diagram of the left nasal cavity depicting the relationship between the prior sphenoid sinusotomy, posterior septal perforation, and remaining mucoperiosteal paddle. (Star, the mean height of residual mucoperiosteal tissue between the inferior aspect of the prior sphenoid sinusotomy and the superior edge of the choanae was 14.3 mm; diamond, The mean distance between the inferior aspect of the septal perforation and the nasal floor was 10.7 mm.)

planum sphenoidale or fovea ethmoidalis because of the superior position of its pedicle. However, elevation of the flap is technically challenging, with only a thin layer of mucosa often harvested.[17,18] The HB2 flap is an anteriorly based pedicled flap supplied by branches of the facial (angular and lateral nasal) and anterior ethmoidal arteries.[16] It incorporates mucosa from the lateral nasal wall, turbinates, and nasal floor and has been primarily used in patients with extensive anterior skull base defects after transcribriform EEA. Hadad *et al.* reported the successful use of the HB2 flap in two patients who had undergone EEAs for esthesioneuroblastomas in which the posterior nasal septum had been removed during oncologic resection.[16] It should be noted that in all four cases presented, no mucosal or xenograft overlay was used in the initial surgical repair of the skull base defect. Only fibrin glue was placed over the underlying graft material, which may have contributed to CSF leak recurrence.

A myriad of extranasal pedicled flaps have also been proposed for use in patients where the HBF is not a viable reconstructive option. These include the transpterygoid temporoparietal fascial flap, endoscopic-assisted pericranial flap, facial artery buccinator flap, and palatal and occipital flaps.[11,17–20] However, each of these methods requires osteotomies or tunneling for flap transposition into the nasal cavity, incurring further patient morbidity. The largest series of secondary pedicled flaps published to date was by Patel *et al.*, who presented 34 patients that underwent EEA in which the HBF was unavailable for skull base defect repair.[18] Endoscopic assisted pericranial flaps (16), transpterygoid temporoparietal fascial flap (7), PITFs (3), MTF (2), HB2 (2), palatal (2), occipital (1), and facial artery buccinator flap (1) were performed, with an overall success rate of 97%. A CSF leak was present in 28 of the 34 cases before secondary flap reconstruction, with only 1 of the 28 (3.6%) developing a CSF leak postoperatively.[18]

However, a history of EEA with posterior septectomy should not automatically disqualify use of the HBF and prompt exploration of secondary pedicled flaps, even without the performance of prior NSRFs. Reuse of the HBF during a second EEA after previous application in the initial surgery has been well described.[12] This "reuse" technique implies that the HBF was successfully performed during the first surgery and that the flap pedicle remains intact. It can therefore be taken down, reharvested, and replaced again with maintenance of the same pedicle. However, if prior surgery did not involve use of the "rescue" or the "reuse" technique, the viability of the flap remained unknown. All four patients in the current series underwent transsphenoidal pituitary surgery before the NSRF or reuse techniques were introduced. Nevertheless, HBFs were still salvaged and successfully used for CSF fistula repair in each case. Endoscopic visualization revealed partial posterior septectomies with an intact residual strip of mucoperiosteum present inferior to the perforation, which linked the remaining anterior septal mucosa to the sphenoid rostrum.

Only one other study has previously addressed the feasibility of using an HBF in the context of prior EEA. Pinheiro-Neto *et al.* presented three patients with a history of EEA involving bilateral sphenoidotomies and partial posterior septectomy who required a second EEA for recurrent pituitary/suprasellar lesions.[21] Acoustic Doppler sonography was used to determine the patency of the nasoseptal artery before flap harvest, which revealed audible pulsatile signals in all three patients. No intraoperative CSF leaks were encountered at the time of surgery. HBFs were successfully used in two of the three patients. In the third patient, attempts to raise an HBF failed despite a positive Doppler signal because of insufficient septal mucoperiosteum remaining from the prior EEA. In our series, acoustic sonography was not used to assess nasoseptal artery viability. However, the success rate of the HBF in revision CSF fistula repair after transsphenoidal surgery and posterior septectomy was 100%. HBFs were lifted and placed with excellent postoperative results without the use of an intraoperative Doppler. Endoscopic evaluation showed a residual mucoperiosteal

paddle that served to connect the region of the vascular pedicle to the anterior septal mucosa. Because HBFs were effectively harvested in all four patients who possessed active CSF leaks, such endoscopic inspection may prove critical in analyzing potential flap viability for such revision EEA cases.

In our series, we surmised that the blood supply to the HBF may not have been violated during the initial surgery based on the presence of an intact mucoperiosteal paddle. The mean height of the remaining mucoperiosteal tissue between the prior sphenoid sinusotomy and choanae was 14.3 mm, and the mean distance between the most inferior aspect of the septal perforation and nasal floor was 10.7 mm (Fig. 7). Although it is known that the HBF pedicle courses between the natural sphenoid ostium and the choanae, a review of the literature did not reveal any anatomic studies delineating the precise distance between the nasoseptal artery and the sphenoid ostium or choanae. Consequently, despite the 100% success rate of secondary HBF in the four patients described, it is uncertain what minimum dimensions of the mucoperiosteal paddle are sufficient to preserve flap viability. It is also possible that the vascular pedicle was disrupted during the previous repair and revascularization ensued to the septal mucosa, sustaining flap perfusion. Further investigation is necessary to compare the measurements of the mucoperiosteal paddle observed in this series with the exact location of the HBF pedicle to determine whether preservation or revascularization had actually occurred. Additional studies with longer follow-up and larger patient numbers are also needed to further validate the feasibility for using the HBF in the setting of prior transsphenoidal surgery.

CONCLUSION

The HBF is a robust and versatile reconstructive option that may be salvaged for repair of recurrent CSF leaks even in the context of prior posterior septectomy and transsphenoidal surgery. Although it does not guarantee pedicle viability, endoscopic evaluation of the integrity and dimensions of the remaining mucoperiosteum between the sphenoid rostrum and anterior septum may assist in predicting the feasibility of HBF application. Although the survival rate of the HBF remained 100% in our series, larger patient numbers and longer follow-up are necessary to assess the long-term efficacy of this procedure in such revision cases.

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