Posterior Pedicle Lateral Nasal Wall Flap: 
New Reconstructive Technique for Large Defects of the Skull Base

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Abstract

Background: Indications for expanded endoscopic approaches continue to grow, resulting in larger and more complex skull base defects. Reconstructive developments, however, have lagged our extirpative capabilities. As the complexity of clinical scenarios continues to escalate, challenging our current reconstructive strategies, we are compelled to develop alternative techniques to prevent CSF leaks and protect neurovascular structures.

Objectives: In this article we demonstrate the anatomical basis for a new posterior pedicled flap from the lateral wall of the nose (Carrau-Hadad or C-H flap) for the reconstruction of median skull base defects, and present our early clinical experience.

Methods: Using a cadaveric model we designed a posterior pedicle flap comprising the nasal inferolateral wall mucoperiosteum. We applied this information clinically, to reconstruct transmural skull base defects.

Results: In our cadaveric model, we harvested and transposed C-H flaps into various defects of the planum sphenoidale, sella turcica, clivus and nasopharynx. Then, we used the C-H flap in four patients, successfully reconstructing their clival (n=3) and sellar (n=1) surgical defects. All patients healed uneventfully.

Conclusions: Our anatomical study and early clinical experience support the use of the posterior pedicle lateral nasal wall flap to reconstruct large cranial base defects resulting from endoscopic skull base surgery in properly selected patients.

Level of Evidence: 2B
INTRODUCTION:

A favorable outcome is expected following the endoscopic reconstruction of small defects of the skull base, regardless of which technique or tissue is used; therefore, vascularized flaps do not appear to be essential for the reconstruction of limited defects.\textsuperscript{1} In contrast, the use of vascularized flaps for the reconstruction of large skull base defects, regardless of the surgical approach (open or endoscopic) seems to be advantageous. Some have obtained adequate results with the use of free tissue grafts such as fat, acellular dermis or fascia lata. Free grafts still are an important part of our armamentarium (specially when a pedicle flap is not available). However, vascularized flaps lead to faster and more reliable healing; thus, they are associated with a lower risk of postoperative CSF leaks and their associated complications.\textsuperscript{2-9}

Skull base defects resulting from expanded endonasal approaches (EEA) can be extremely challenging to reconstruct due to their complexity and extent. Development of reconstructive strategies have lagged that of extirpative techniques; thus, presenting a major hurdle toward standardization and popularization of EEA.\textsuperscript{2-5} During the last five years, various endonasal pedicled flaps have been developed, including the Hadad-Bassagasteguy nasoseptal flap, and middle and inferior turbinate pedicled flaps.\textsuperscript{6-8} These flaps represent important advancements that helped to decrease the incidence of postoperative CSF leaks to less than 5%.\textsuperscript{10}

Availability, versatility and reliability have propelled the rapid popularization of the Hadad-Bassagasteguy nasoseptal flap; however, tumor extension or prior surgery, involving the nasal septum, rostrum of the sphenoid sinus or pterygopalatine fossa, may preclude its use. In addition, the extent of the defect may require the use of multiple flaps, or a hybrid technique combining vascularized flaps and free tissue grafts.\textsuperscript{2-5} Hence, current reconstructive algorithms demand alternative reconstructive strategies.
Following the patterns of nasal blood supply (“vascular tree”) one can design other potential pedicled vascular flaps. We have benefited from the work of others, who have characterized the vascular anatomy of the lateral nasal wall. Blood supply of the postero-lateral nasal wall mainly originates from the sphenopalatine artery, a terminal branch of the internal maxillary artery. The inferior turbinate, however, has a dual anterior and posterior blood supply; although, its main blood supply arises posteriorly from the posterolateral nasal artery (a branch of the sphenopalatine artery). We have taken advantage of this anatomical attribute that serves as the foundation of our new reconstructive technique. In this article, we describe an innovative pedicled flap comprising the mucoperiosteum of the infero-lateral wall and floor of the nasal cavity, the Carrau-Hadad (C-H) flap, based posteriorly on branches of the sphenopalatine artery. We demonstrate its anatomical basis using a cadaveric model and further establish its feasibility with our early clinical experience.

**MATERIALS AND METHODS**

Our anatomical dissections were, completed at the Medical School of Rosario (Province of Santa Fe, Argentina) and were reproduced at the Minimally Invasive Neurosurgery Center (MINC) anatomy labs at the University of Pittsburgh Medical Center (approved by the Committee for Oversight of Research Involving the Dead or CORID). Three fresh and five preserved cadaveric specimens were used to design, harvest and transpose several modifications of the C-H flap into various defects of the median skull base (see following description). To better evaluate the vascular anatomy, we injected the specimens with colored silicone, using red for the arterial system and blue for the venous system. Anatomic details and technical variations revealed by the cadaveric model provided us with enough confidence to use the C-H
flap clinically. Therefore, we used the C-H flap to reconstruct four patients, who required EEAs at the John Wayne Cancer Institute (Santa Monica, CA) and the Instituto de Diagnostico y Cirugia: Cabeza y Cuello, Nariz y Senos Faciales, Base Anterior de Craneo (Rosario, Argentina); and, whose clinical presentation prohibited the use of the Hadad-Bassagasteguy nasoseptal flap (HBF). Pertinent clinical data was reviewed retrospectively (IRB exemption granted).

Surgical Technique

Endonasal incisions can be made with a unipolar electrocautery fitted with an extended, insulated needle tip (Valleylab, Boulder, Colorado) or a Colorado tip (Stryker Corporation, Kalamazoo, MI). However, any sharp instrument may be adequate. Anteriorly, the mucoperiosteum is incised along the anterior border of the ascending maxillary process, starting at a level that corresponds to the most caudal aspect of the nasal bones and extending inferiorly to the level of the head of the inferior turbinate (Figures 1 and 2). A second vertically oriented incision is made along the posterior aspect of the lacrimal bone, starting at a level that is superior to the anterior insertion (“axilla”) of the middle turbinate, and extending inferiorly to a level near the upper aspect of the inferior turbinate. A third incision connects the most superior aspect of the first two incisions.

According to the needs of each case, the anterior incision may extend further inferiorly along the lateral nasal wall, just anterior to the inferior turbinate, and continue over the floor of the nasal cavity to harvest a wider flap (Figures 1 and 2D). At its most infero-medial level, it joins another incision (oriented in the sagittal plane), which extends posteriorly to a point that is at the level of the sphenopalatine foramen (in the coronal plane; Figures 1, 2D). As previously mentioned, this latter incision can be placed at the lateral nasal wall or carried medially over the floor of the nose, to harvest a wider flap. The incision over the lacrimal bone (antero-posterior)
joins a sagittal incision that extends posteriorly, over the superior aspect of the inferior turbinate, to reach the sphenopalatine foramen. Some of the mucosa of the maxillary sinus fontanelle can be incorporated into this incision to widen the surface area of the flap. Alternatively, this incision can be part of a wide maxillary antrostomy. Resection of the middle turbinate greatly facilitates the visualization and harvest of the flap, but is not mandatory. Another horizontal incision crosses the floor of the nose at the level of the sphenopalatine foramen (in the coronal plane) to connect the superior and inferior sagittal incisions, (Figures 1).

The head of the inferior turbinate is incised vertically and the incision is extended to intersect the most anterior incision. This incision at the head of the turbinate is critical to harvest the meatal aspect of the inferior turbinate mucoperiosteum (Figure 2E). The mucoperiosteum is dissected with a Cottle or Freer periosteal elevator (Figure 2B), continuing its dissection along the medial (nasal) aspect of the inferior turbinate bone. The bone may be sequentially removed with true-cut and Kerrison rongeurs or any other preferred instrument (Figure 3A); and the mucoperiosteum of the lateral (meatal) side is elevated, until it curves laterally at the level of the opening of the nasolacrimal duct (Figures 3B and C). The opening of the nasolacrimal duct and Hasner’s valve is preserved by incising around its periphery; thus, preserving it in situ (Figures 3D-F).

The mucoperiosteum is elevated further posteriorly along the lateral nasal wall (inferior meatus and fontanelle) and the remaining floor of the nose component. (Figure 4). Special care should be taken at the most posterior aspect of the flap, as the branches of the sphenopalatine artery, especially the postero-lateral nasal artery, should be identified and preserved (Figure 4A). Once elevated, the flap may be rotated posteriorly or superiorly with a pivot point at the sphenopalatine foramen, or preserving a wider base that extends to the inferolateral nasal wall to
the junction of the hard and soft palates (Fig 5). Due to its pivot point, its pedicle may need to be freed from the sphenopalatine foramen. This facilitates a rotation of up to $180^\circ$ from its original position.

A temporary bolster using nasal packing helps to fixate the flap. As long as the pedicle is free, its rotation does not cause significant retraction of the flap away from the defect. However, a wider pedicle (extended to the floor of the nose) produces more torque and retraction. The C-H flap dimensions were adequate to reconstruct the expanse from nasopharynx to planum sphenoidale (antero-posterior), and from orbital apex to orbital apex or ICA canal to ICA canal (latero-lateral).

**RESULTS**

In the cadaveric model, all C-H flaps were harvested using the previously described technique and modifications, and were uneventfully transposed into a myriad of defects of the median skull base. The PLNA and its inferior turbinate branch were routinely identified and preserved during the harvesting of the flap. The C-H flap appeared to be adequate to reconstruct defects of the planum sphenoidale, sella, clivus and nasopharynx. The only challenge was a tendency for the inferior turbinate portion of the flap to return to its original shape.

Clinically, C-H flaps were used for the reconstruction of four patients whose presentation prohibited the use of the Hadad-Bassagaisteguy nasoseptal flap. Three patients underwent a trans-clival resection for recurrent clival chordomas that had been previously treated with surgery and radiotherapy. One patient underwent an expanded endonasal resection for a recurrent pituitary extrasellar adenoma that produced a large CSF leak. Harvesting of the flaps proceeded in a fashion similar to our experience in the anatomical laboratory. All flaps appeared viable after
harvesting, without discoloration or congestion. All four surgical defects were successfully reconstructed with C-H flaps, which were transposed in place and fixated with a multilayer bolster using gelatin sponges, tissue sealant, and strip-gauze or sponge packing (removed five days after surgery). No perioperative lumbar spinal drain was used in any of the patients. Postoperative viability and uneventful healing of the C-H flaps and nasal cavity were monitored during the postoperative follow up visits. All patients required daily nasal toilette that included self-administered saline lavages and moisturizing sprays; and, weekly or bi-weekly office debridement for 6-8 weeks postoperatively. However, all four patients healed uneventfully with no CSF leak or any other postoperative complication (Figure 6).

DISCUSSION

During the past two decades, we have witnessed the evolution of endoscopic endonasal approaches, from trans-sphenoidal surgery for sellar lesions to expanded endonasal approaches (EEA) for a variety of pathologies located along the ventral skull base.\textsuperscript{2-5} Their use to manage skull base lesions has increased exponentially. Reconstructive developments, however, have lagged our extirpative capabilities, and increasingly complex clinical scenarios continue to challenge current reconstructive strategies.

Reconstructive objectives after resection of the skull base include protection of critical neurovascular structures and separation of the cranial cavity from the sinonasal tract\textsuperscript{2-4}; therefore, decreasing the risk of postoperative cerebrospinal fluid (CSF) leaks and ascending bacterial infections.\textsuperscript{1} An hermetic separation of cranial cavity and sinonasal tract also protects major vessels against desiccation and infection that could lead to a vascular blow-out or pseudoaneurysm.
It has been demonstrated that repair of small CSF fistulas is successful in over 95% of cases, independent of which biological tissue or surgical technique is used. Some have obtained good results with the use of free grafting for the reconstruction of defects after endoscopic skull base surgery. However, others have reported that the incidence of postoperative CSF leaks increases significantly when free grafting techniques are used to reconstruct large cranial base defects.

Pedicled mucosal and fascial flaps provide the most reliable, reproducible and optimal reconstruction of large skull base defects. Reconstruction of skull base surgery defects using vascularized tissue is associated with a significantly lower incidence of postoperative CSF leaks. In our experience, the HBF posterior pedicle nasoseptal flap lead to a dramatic improvement in our postoperative CSF leaks rate, currently less than 5%. However, the HBF is frequently not available in patients who have undergone previous posterior septectomy or wide sphenoidotomies, which compromise its pedicle; or when the donor site (nasoseptal mucosa) is infiltrated by tumor. As a result, alternative endonasal reconstructive flaps have been developed; however, these are yet not sufficient to provide an encompassing solution to the increasing size and complexity of the defects, and the variability of clinical situations. Free grafting remains as a viable alternative, however, as previously mentioned vascularized tissue alternatives seem superior alternatives. Various extranasal pedicled flaps can also be used for the reconstruction of large defects of the anterior skull base, such as the transfrontal pericranial flap, the transpterygoid temporoparietal fascia flap, the palatal flap, the facial artery buccinator flap (FAB), and the occipital galeopericranial flap. These offer reconstructive alternatives in select patients, but they may be technically challenging and are associated to some donor site morbidity. Furthermore, in some patients, these flaps may not be available due to
compromise of their pedicle or donor site by tumor or prior surgery. A posterior pedicle inferior turbinate flap has been previously described for reconstruction of clival and sellar defects. In contrast to the posterior pedicle inferior turbinate flap, the C-H flap incorporates the mucosa anterior to the middle turbinate, extending beyond the lateral wall to the mucosa covering the nasal bones, as well as the mucoperiosteum of the inferior nasal lateral wall, inferior meatus and nasal floor. This results in a flap with a potential surface area that is three times the surface area of that of the inferior turbinate flap, and a superior reach.

The ideal candidate for the C-H flap is a patient with a large surgical defect resulting from a transplanum, transsellar, transclival or middle cranial fossa EEA, in whom the Hadad-Bassagaisteguy nasoseptal flap is not available. Contraindications to the C-H flap include the need to sacrifice its mucosal surface, pedicle or proximal blood supply to achieve oncologic margins, and prior surgery or embolization of its main blood supply. Prior high dose radiotherapy or chemoradiotherapy should be taken into consideration; however, the lateral nasal wall is not within the usual radiation fields of tumors originating or extending to the clivus, sella or planum sphenoidale. In the rare instance where the flap has been irradiated we anticipate a tolerance similar to the nasoseptal flap.

Harvesting of the C-H flap is not difficult assuming that the surgeon has experience with endonasal endoscopic surgery. However, meticulous attention to its technical harvesting is paramount for a favorable outcome. The absence of the posterior nasal septum greatly facilitates the harvesting process, as it provides more working space. We expect that this scenario will not be uncommon as the lack of nasal septum (compromised HBF donor site) is one of the indications for C-H flap.
Based on our early clinical experience with the C-H flap and our acquaintance with other endonasal flaps, we expect minimal morbidity in the vast majority of the patients. Initial morbidity is mostly associated to temporary, albeit significant, nasal crusting, which lasts until re-mucosalization of the donor site is complete. It has been our observation that mucosalization of the donor site progresses more rapidly than that of the nasoseptal flap. It does require, however, nasal toilette and endoscopic debridement (every 1-2 weeks for about 6 weeks). We have not encountered problems with lacrimal outflow despite harvesting mucosa very close to the opening of the nasolacrimal duct in the inferior meatus.

CONCLUSION

Our anatomical cadaveric dissections and early clinical experience support the use of the posterior pedicle lateral nasal wall and floor flap for vascularized reconstruction of large ventral cranial base defects in select patients.
REFERENCES:


FIGURES:

Figure 1. Incisions for the C-H flap.

Dashed lines represent the incisions. Ant-Sup incision (large black arrow) = Antero-superior incision. Ant-Inf incision = Antero-inferior incision. IT = Inferior Turbinate. MT = Middle turbinate. ST = Superior turbinate. Small curved black arrows = blood supply of the flap. White arrow = Nasolacrimal duct opening. Dashed black (circles) line and small black arrow = an incision can be made at the nasal floor to increase the arc of rotation of the flap. Please note that the antero-inferior incision is directed laterally (from the head of the inferior turbinate) towards the meatal side of the inferior turbinate / nasolacrimal duct opening (correlate with figure 2), in order to incorporate the lateral-inferior nasal mucosal wall of the inferior meatus. The medial aspect of the inferior turbinate is not incised.

Figure 2. Harvesting of the C-H flap from left side.

A. Incisions. Gray arrow = stump of middle turbinate. B. Incision (white arrow) at the head of the inferior turbinate. C. Incision and elevation of the flap from the ascending process of the maxilla (apm). F = flap. Nv = nasal vestibule. D. Dashed line = Extension of the incision across the nasal floor. Small white arrow = Direction of the sagitally oriented incision along the floor of
the nasal cavity, just lateral to the nasal septum (which extends posteriorly to a point that is at the level of the sphenopalatine foramen in the coronal plane).  

E. Harvesting of the meatal aspect of the inferior turbinate mucoperiosteum (black arrow).  

F. Elevation of the most anterior aspect of the flap (dashed line represent incisions – correlate with figure 1 and 2a).

**Figure 3. Harvesting of the C-H flap from left side.**

A. Residual inferior turbinate bone is removed with Kerrison rongeurs.  

B. The mucosa of the lateral aspect of the middle turbinate is elevated until it turns laterally towards the opening of the nasolacrimal duct.  

Gray arrow = residual bone of inferior turbinate.  

White asterisk = mucosa from the meatal side of the middle turbinate is reflected laterally.  

White arrow = approximate location of the opening of the nasolacrimal duct in the middle meatus.  

C. Scissors are used to cut the meatal mucosa towards the opening of the nasolacrimal duct.  

D. White arrow points the nasolacrimal duct opening.  

Dashed line = incision line towards the nasal floor (just inferior to the nasolacrimal duct opening).  

E. Incision is carried down towards the nasal floor / nasal septum in the coronal plane.  

F. The the mucoperiosteum is elevated from the middle meatus and reflected medially.  

White arrow = nasolacrimal duct opening.

**Figure 4. Harvesting of the C-H flap from left side.**

The nasal septum has been removed in this specimen.  

A. The mucoperiosteum is further elevated posteriorly along the lateral nasal wall and the floor of the nasal cavity.  

Branches of the sphenopalatine artery (black arrowhead) should be identified and preserved.  

B. Lateral (wall) aspect of the flap completely elevated.  

White arrow = nasal choana.  

C. Nasal floor component of the flap completely elevated.  

Dashed line represents the sagittally oriented incision along the
floor of the nasal cavity (correlate with Figure 2D). **D. Harvested flap.** Black asterisk = nasal floor component of the flap.

**Figure 5. Transposition of the C-H flap.**

A. Surgical defect. Gray arrow = clival defect. White arrow = residual nasal septum. Black asterisk = Left inferior turbinate. White asterisk = Sphenoid sinus. **B and C.** The flap is approximated to the defect. **D.** Flap completely covering the sphenoid sinus and clival defect

**Figure 6. Postoperative MRI.**

Sagittal T1 weighted contrasted MRI demonstrating the vascularized C-H flap (arrows) combined with a free abdominal fat graft (arrowheads) to reconstruct a clival defect.
a  
b  
c  
d  
e  
f