INTRODUCTION
The adoption of vascular pedicled flaps to reconstruct skull base defects following endoscopic endonasal skull base surgery is a significant milestone in the development of endoscopic endonasal approaches (EEAs). In 2006, Hadad and Bassagaisteguy1 introduced the pedicled nasoseptal flap (NSF). The NSF decreased initial postoperative cerebrospinal fluid (CSF) leak rates from >20% to <5% overall, with a 94% success rate following reconstruction of high-flow intraoperative CSF leaks.1–3 It is a robust, relatively straightforward to harvest flap that provides a large surface area, and can be rotated to cover a wide variety of skull base defects. Currently, the NSF is widely used and is considered the workhorse for skull base reconstruction following EEAs. In addition, it heals quickly, can be modified to better address complex or multiple defects, and can be reused in revision cases.4

In a similar fashion to endonasal skull base surgery, the NSF has evolved over time. One product of this evolution was the development of the nasoseptal rescue flap (NSRF).5,6 This technique protects the pedicle of the NSF while obviating the need to fully dissect its paddle. A NSRF is indicated in cases where a CSF leak is possible, but not likely. The specific technique for raising the NSRF has been previously described. The salient aspects of the NSRF are the use of the posterior-superior limb of the NSF incision, followed by the inferior reflection and retraction of the pedicle. If the NSF is required for reconstruction, the harvest can be completed following the tumor resection. Otherwise, the mucosa containing the pedicle is repositioned at its original site.5

Based on our experience, we found the NSRF efficacious in preserving septal mucosa and in eliminating the time and donor site morbidity associated with raising the entire flap. However, we noticed that too often the pedicle required constant retraction and still impeded dissection and exposure of the floor of the sphenoid sinus and lower aspect of the clival recess. Furthermore, the continuous and significant retraction often results in tearing of the pedicle or avulsion of the vessels. Therefore, we modified the technique to include inferior incisions that allow for a greater degree of freedom of the pedicle. This modification successfully improved the ability to transpose the pedicle out of harm’s way.

MATERIALS AND METHODS
We retrospectively reviewed the clinical data of all patients who underwent a modified NSRF from April 1, 2012 to March 1, 2013. Data related to the approach and the use of the modified NSRF was noted specifically, including indications for surgery, the presence of intraoperative and postoperative CSF leaks, and complications.

Surgical Technique
Surgical techniques related to harvesting the NSF1,2 and NSRF5 and the surgical landmarks of the sphenoid sinus and sellar region7,8 are well described and will not be discussed in detail. In all of our cases, intraoperative surgical dissection was performed using paranasal sinus and skull base endoscopic instruments (Karl Storz Endoscopy, Tuttlingen, Germany; KLS “Angelina” line instruments, Tuttlingen, Germany). Incisions were made using electrocautery equipped with a single use arthroscopic electrode (ValleyLab, Boulder, CO). Photographs were taken with a 0° rod lens endoscope coupled to a light source and high-definition camera and monitor (Karl Storz Endoscopy, Tuttlingen, Germany).

Preparation and initial steps are identical to those described for the NSRF5. In brief, the nasal cavity is decongested and inferior and middle turbinates are out-fractured. Commonly, one of the middle turbinates (usually the right) is removed to facilitate visualization and four-hand technique during the resection. A unipolar electrocautery with an extended, insulated, arthroscopic hook electrode (ValleyLab, Boulder, CO)
is used to perform two horizontal incisions. The first (inferior) incision starts laterally at the level of the posterior choana, extends medially following the free edge of the posterior nasal septum, and then continues anteriorly along the maxillary crest (Fig. 1 and 2). The anterior limit of the incision varies, but commonly extends to the midportion of the middle turbinate. The pedicle may also shift to a more horizontal plane, increasing exposure of the sphenoid contents. C = choana; CR = clival recess; IT = inferior turbinate; MT = middle turbinate; P = pedicle; PS = posterior septum; S = sella; SF = septal flap. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Using a Cottle dissector and a ball-tipped probe, the entire posterior aspect of the flap is raised in a submucoperiosteal/perichondrial plane extending laterally to the posterior choana. This allows the pedicle and posterior flap to fall away from the sphenoid face (Fig. 1A). This downward displacement, coupled to the transposition of the pedicle from a coronal oriented plane (vertical) to an axial plane (horizontal), provides improved access to the sphenoid. Insufficient anterior dissection may prevent the plane shift of the pedicle. Further extension of the inferior incision will allow for additional pedicle displacement and maximal visualization (Fig. 1B). A wide ipsilateral sphenoidotomy is now possible with much less risk to the pedicle as it moves downward and it has superior freedom of movement. The technique is completed bilaterally, and a posterior septectomy and contralateral sphenoidotomy are performed. Then intrasphenoidal dissection and sellar tumor removal may proceed. If a significant CSF leak is encountered and the NSF is deemed necessary for reconstruction, its harvesting can proceed by extending incisions and elevating anteriorly as previously described.1,2 If the NSF is not needed, the bipedicled modified NSRF is advanced toward the sphenoid sinus floor to cover exposed bone.

**RESULTS**

Our pedicle sparing-transposition technique allows for unhindered two-surgeon, three-to-four-handed technique identical to that experienced when a flap is raised at the commencement of the procedure. Compared to the original description of the NSRF, this modification...
allows the pedicle to displace more inferiorly and to rotate into a more horizontal plane (Fig. 1B). Greater mobility of the pedicle allows for easier dissection of the inferior sphenoid sinus, improves instrument access (above and below the pedicle), and maximizes visualization of the sellar and clival region. Increased freedom of the pedicle also provides more options in the event that the flap is not used. The mobility provided by the pedicle sparing-transposition technique, allows the mucoperiosteal strip to be easily replaced to its original position or draped onto the floor of the sphenoid sinus to cover exposed bone as a bipedicle flap. From a surgical standpoint, the technical skills required to perform the procedure is equivalent to the NSF or NSRF.

We identified 64 patients who underwent a total of 108 modified NSRF. Indications for surgery included pituitary adenomas (n = 57), Rathke’s cleft cysts (n = 2), meningiomas requiring decompression of the superior orbital fissure/optic nerve (n = 4), and clival chordoma (n = 1). Forty-four patients underwent a bilateral harvesting. In four patients the modified NSRF was raised in the right side and a standard NSRF was raised on the left side. These four patients had a nasal septal deviation and/or nasal septal spur that interfered with instrumentation through the left nasal cavity; thus, we raised a standard NSRF from the right side after performing a posterior bony septectomy. In 16 patients, a right unilateral modified NSRF was combined with a vertical incision of the left posterior septum and partial resection of the posterior-most left mucoperiosteum as part of the posterior septectomy (no rescue flap technique). The vertical incision is placed as posterior as possible to preserve olfaction while affording bilateral visualization of the sphenoid.

Fifteen patients (23%) had an intraoperative CSF leak. Fourteen patients had grade 1 or 2 CSF leaks (Esposito/Kelly Classification) that were repaired using intradural collagen matrix followed by free abdominal fat or mucoperiosteal grafts. Only one patient (2%) presenting with apoplexy of a pituitary adenoma and requiring decompression of a large suprasellar hematoma required a full harvesting of the NSF for the repair. We encountered three complications in these 64 patients. A patient without an intraoperative CSF leak developed one 5 days after surgery. He was repaired with a layered collagen matrix and free abdominal fat graft (exploration revealed a pin point defect). One flap was accidentally transected with the shaft of the high-speed drill. The stumps were cauterized and transposed to cover the floor of the sphenoid sinus without consequence. A final patient had a delayed posterior epistaxis 2 weeks after surgery requiring posterior packing and subsequent angiography and embolization. The exact point of bleeding was never determined.

**DISCUSSION**

As originally described, the NSF requires preemptive harvesting as most extended EEA procedures will place its pedicle at risk. This required a NSF to be raised for all cases when an intraoperative CSF leak was possible. Despite the versatility and reliability of the NSF, it is associated with some morbidity, including crusting; additional pain related to anterior dissection of the flap; and the potential loss of olfaction.

These sequelae prompted the creation of the NSRF technique, where a NSF is partially raised so that the pedicle is protected in case that an unexpected CSF leak occurs (Fig. 2B). When using a NSRF, the pedicle requires downward displacement with a suction tip or an endoscope, thus occupying a hand or instrument for the majority of the case. In addition, Rivera-Serrano et al. noted that in cases requiring a translational approach, a NSRF pedicle becomes an impediment to a lower dissection, thus requiring the conversion to a standard flap. Our modification of the NSRF incorporates the release of the inferior aspect of the pedicle, thereby eliminating the need for pedicle retraction. Furthermore, this modification allows for the dissection of the inferior sphenoid sinus and clival recess owing to the increased mobility and more horizontal orientation of the pedicle.

An alternative approach would be to raise a NSF in every case and return it to its original position, if at the end of the extirpative surgery it is deemed not needed. This approach, however, is inefficient and contraction of the flap may lead to exposed cartilage, increased crusting, and longer healing time. Thus, we believe that any technique that helps to preserve the NSF pedicle without having to harvest the flap paddle offers distinct advantages. Rawal et al. described their experience in 26 consecutive patients undergoing a NSRF, proceeding to harvest a full nasoseptal flap in only seven patients (27%). Our series has a significantly lower incidence; however, this may be due to differences in CSF grading technique or in the preference for repair of grade 1 and 2 defects. Regardless, both series demonstrate effectiveness in preserving the pedicle of the NSF. In our experience, the NSRF as previously described is an expedient technique, and we still use it in cases requiring minimal inferior dissection (i.e., pituitary microadenomas, Rathke’s cleft cysts). However, when exposure of the sphenoid floor or extended clival dissection is necessary, we utilize the pedicle sparing-transposition technique.

**CONCLUSION**

In comparison to the NSRF, our modification using a pedicle sparing-transposition technique provides improved access to the inferior aspect of the sphenoid sinus and clivus by shifting the pedicle inferiorly and allowing it to assume a more horizontal position. In the case that the NSF is not needed, the improved maneuverability of the pedicle also allows its use as a bipedicled flap for coverage of exposed bone. By elevating only the posterior extent of the NSF, we still capitalize on decreased donor site morbidity in patients without an intraoperative CSF leak.

Our modification expands on the NSRF concept, offering a means in which to decrease patient morbidity.
from elevation of a complete nasoseptal flap even when extended inferior resection is necessary along the floor or clival recess of the sphenoid sinus.

BIBLIOGRAPHY