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Research Article

The Nasoseptal Chondromucosal Flap: A Rigid Reconstructive Technique for Skull Base and Orbital Defects

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Keywords
Nasoseptal flap · Skull base reconstruction · Orbital wall reconstruction · Chondromucosal nasoseptal flap · Composite septal graft · Endoscopic endonasal surgery

Abstract
Introduction: The pedicled mucoperichondrial nasoseptal flap serves as the predominant reconstructive option for anterior skull base defects. Its use has also been described for repair of the lamina papyracea following orbital tumor removal. Large skull base or orbital defects may benefit from a more rigid reconstruction to reduce the risk of herniation of orbital or intracranial contents into the sinonasal cavity, which could result in enophthalmos, diplopia, or an encephalocele. ***Objective:*** This study aims to test the feasibility of using a vascularized rigid composite nasoseptal chondromucosal flap for increased structural support in repairing skull base or orbital defects. ***Methods:*** The study was conducted in a cadaver model in a surgical skills laboratory. ***Results:*** We demonstrate a novel technique for harvesting and insetting a pedicled vascularized autologous rigid composite nasoseptal chondromucosal flap to repair both orbital and anterior skull base defects. The graft is harvested with intact mucosa, cartilage, and bilateral perichondrium to preserve a contiguous vascular supply. Confirmation of successful reconstruction is achieved via transcranial and transorbital access to visualize the graft from above. ***Conclusion:*** The cartilaginous support with associated perichondrium adds to the structural integrity of the reconstruction and may serve as an alternative to devascularized autologous grafts or synthetic materials, which may be particularly advantageous in patients with large defects or those requiring adjuvant radiation.

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Introduction

Since its description by Hadad et al. [1] in 2006, the pedicled mucoperichondrial nasoseptal flap (NSF) has become the mainstay of anterior skull base repair. Its use has been applied more broadly to repair orbital wall defects and even oroantral fistulas [2–5].

Failure rates of NSF for cerebrospinal fluid (CSF) leak repair are 5–7% [1, 6]. Complex skull base defects may require fat, fascia, or bilateral NSFs to bolster the reconstruction. Rigid reconstruction is at times preferred to reduce the risk of herniation of orbital or intracranial contents into the sinonasal cavity, which could result in enophthalmos, diplopia, or an encephalocele. In certain higher-risk patients, we hypothesize that a pedicled vascularized composite nasoseptal chondromucosal flap (NSCF), harvested with cartilage and bilateral perichondrium, may afford greater structural integrity. This vascularized autologous graft could reduce the risk of infection or extrusion associated with synthetic or free grafts.

NSCFs have previously been described in repairing lateral nasal wall, palatal, and orbital floor defects [7–10]. While free cartilage grafts risk necrosis when their size exceeds 1 cm, pedicled composite grafts are not restricted by size because their blood supply comes from the overlying perichondrium [11]. The objective of this study was to assess whether the NSCF is a feasible technique to add to the armamentarium of skull base and orbital reconstruction.

Methods

The study was conducted in a surgical skills laboratory at the Columbia University Irving Medical Center using a fresh cadaveric head obtained from Science Care (Phoenix, AZ, USA). Because no live human subjects were affected, this study was exempt from Institutional Review Board approval.

Harvest Technique

Routine endoscopic sinus surgery is first performed to skeletonize the skull base and medial orbital wall. For the purposes of this study, an iatrogenic 1.5-cm skull base defect was created in the ethmoid roof.

A posteriorly based NSF is harvested as follows. The superior mucoperichondrial incision is made just inferior to the sphenoid os and carried anteriorly 1 cm below the superior aspect of the septum to the anterior limit of the inferior turbinate. At this point, the incision is carried inferiorly in a vertical fashion. The inferior incision is made along the arch of the choana, down the vomer, and along the nasal floor anteriorly.

The mucosal flap is elevated in an anterior-to-posterior fashion, preserving a 1.5-cm caudal strut. A curved round knife is then used to carefully incise the septal cartilage without violating the contralateral mucosa. A Cottle elevator is used to elevate the contralateral mucosa off of the cartilage graft, while leaving perichondrium intact bilaterally. A sickle knife and Cottle elevator are then used to harvest the remainder of the cartilage graft. The cartilage is sized to be just smaller than the defect and is maintained centrally in the paddle of the NSF to ensure a mucosal cuff circumferentially. The remainder of the flap is elevated posteriorly to the sphenoid os. The resulting NSF contains an adherent cartilaginous button at its distal end (Fig. 1).

Results

Following appropriate harvesting, as described above, the flap is then rotated on its pedicle towards the skull base. The cartilaginous portion is positioned by palpation into the bony defect, with the outer mucosal lip covering the perimeter of the defect. Transcranial access was obtained to visualize the reconstruction from above and demonstrated complete defect closure (Fig. 2).

Next, a 1.5-cm defect was created in the lamina papyracea and periorbita to create fat herniation, simulating a defect following the endonasal removal of an orbital lesion. The flap

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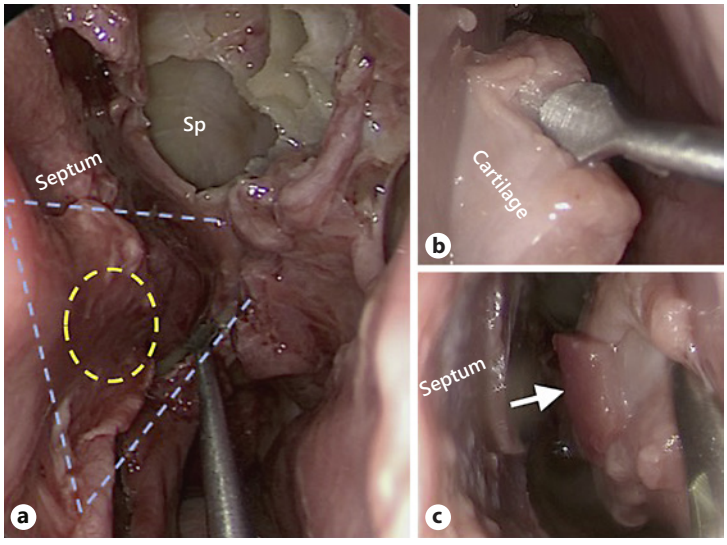

Fig. 1. a Left nasal cavity. The blue line marks the outline of NSCF; the yellow line marks the planned cartilage component. **b** Cartilage dissected away from contralateral mucosa. **c** Harvested NSCF (arrow). Sp, sphenoid os.

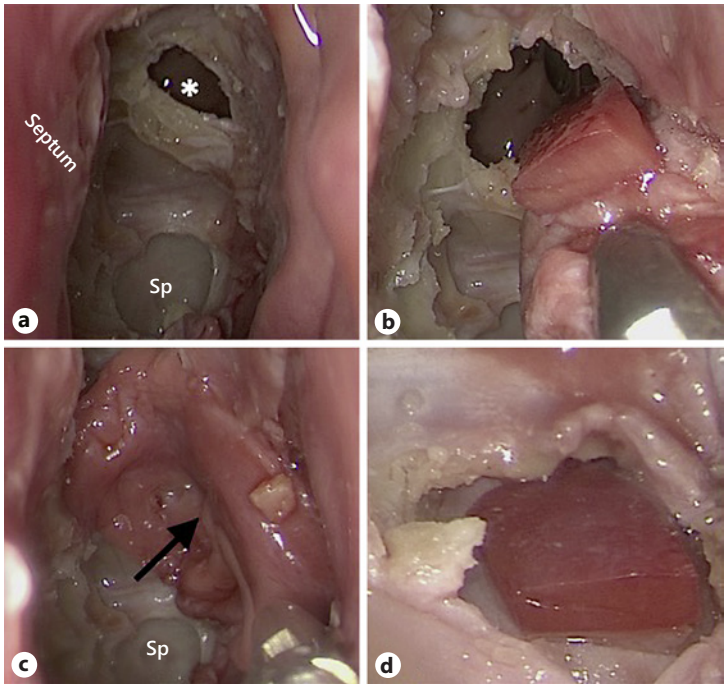

Fig. 2. a Right nasal cavity. The asterisk (*) marks the ethmoid roof defect. **b** NSCF inset approximating cartilage to defect. **c** Repaired defect with NSCF (arrow). **d** Transcranial view demonstrating repaired skull base defect. Sp, sphenoid os.

was used to repair the medial orbital wall in similar fashion. A Lynch incision was made to visualize the repair transorbitally. The cartilaginous portion of the graft was appropriately positioned, maintaining the orbital contents well within the orbit (Fig. 3).

Discussion

This study demonstrates excellent closure of ethmoid roof and medial orbital wall defects using a pedicled vascularized NSCF based on the posterior nasal septal artery. The viability of this flap has been demonstrated in lateral nasal wall and orbital floor reconstruction [9,

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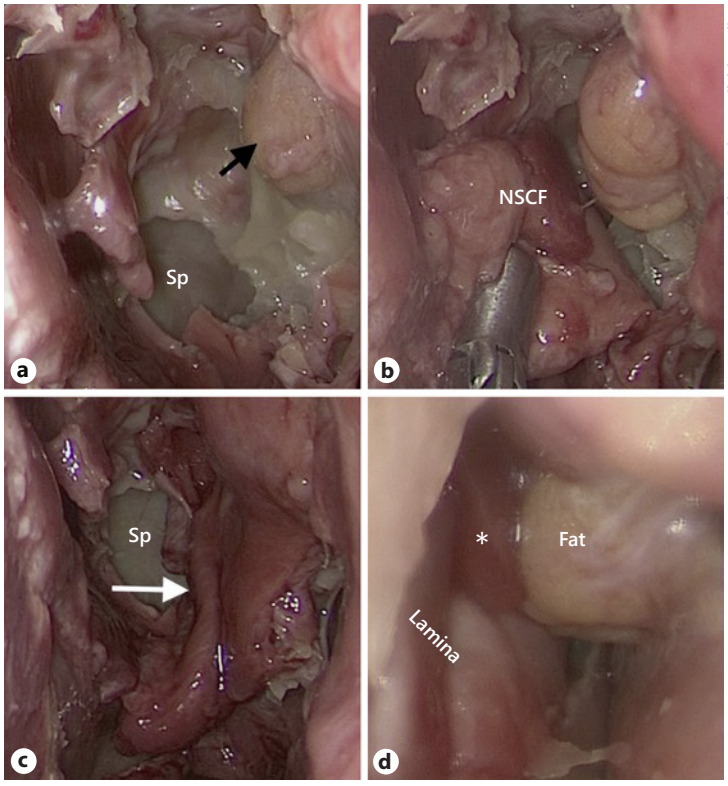

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Fig. 3. Left nasal cavity. **a** Orbital fat herniating through the lamina papyracea defect (arrow). **b** NSCF inset approximating cartilage to defect. **c** Repaired defect with NSCF (arrow). **d** Transorbital view. The asterisk (*) indicates NSCF. Fat, orbital fat; Sp, sphenoid os.

10]. Before the advent of endoscopic sinus surgery, Weisman [9] described the use of a superiorly or posteriorly based chondromucosal septal graft utilized in an open approach, carrying greater morbidity. In contrast to our NSCF, that flap did not reliably follow the angiosome of the posterior nasal septal artery. More recently, Kalyoussef et al. [10] reported an encouraging case using a similar technique for orbital floor repair following tumor excision.

While the standard mucoperichondrial NSF results in excellent clinical outcomes, this NSCF modification offers an alternative rigid reconstruction to be considered in cases with larger defects, elevated intracranial pressure, herniation of orbital contents, or need for radiation [1]. The need for greater and more durable reconstructive options will continue to grow as the utility of extended endoscopic approaches expands. This technique may prove to be especially useful in large skull base or orbital wall defects. In this proof of concept study, the viability of this technique was tested using the cartilaginous portion as a floating graft. An underlay graft may provide additional structural support. However, it is technically challenging to underlay the cartilaginous portion of the NSCF. Nevertheless, the graft is likely to provide significant added support even in the "floating" or overlay fashion when properly placed with supporting packing to overcome the intracranial pressure exerted on the flap.

It is important to recognize that other rigid reconstructive techniques exist, including titanium hardware, polydioxanone flexible plates, free bone or cartilage grafts, and hydroxyapatite cement [12–15]. Synthetic implants are thought to have a higher risk of extrusion and infection, particularly in patients who require adjuvant radiation, although this has not been sufficiently investigated in large-scale trials. Soudry et al. [16] report successful endoscopic repair of CSF leaks with vascularized pedicled flaps in 94% of patients. Zanation et al. [17] found dural defect size and radiation therapy to be predictors of NSF failure. Prior studies have described the use of two vascularized flaps in especially high-risk patients [18]. We

hypothesize that the NCSF provides similar added support without the risks of synthetic graft material or the use of two separate donor sites.

When harvesting the flap, care must be taken to prevent perforation of the contralateral septal mucosa. Given the relatively high rate of donor site morbidity from the standard mucoperichondrial NSF at 18%, it is important to recognize the likelihood of higher morbidity rates with this technique [6]. As such, its investigation should be restricted to patients who are prone to failure with the standard mucoperichondrial NSF.

This study is limited by the cadaveric nature of this model. Additional research is necessary to test the viability and outcomes of this flap in vivo.

Conclusion

This study demonstrates a novel technique utilizing the NSCF to repair large anterior skull base or orbital wall defects requiring rigid structural integrity. The use of a composite cartilage graft is technically feasible and may provide necessary support for patients with large bony defects or those undergoing adjuvant radiation.

Statement of Ethics

This study is exempt from Institutional Review Board approval because no live human subjects were affected.

Disclosure Statement

The authors have no conflicts of interest to declare.

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No sources of funding were acquired for this study.

Author Contributions

Study design: D.B.S., D.A.G. Study implementation: D.B.S., D.A.G., M.K. Manuscript composition: J.B.O., D.B.S., M.K., D.A.G. Manuscript revision: J.B.O., D.B.S., M.K., D.A.G.

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