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Special considerations for nasoseptal flap use in children

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The introduction of the vascularized pedicled nasoseptal flap has revolutionized endoscopic skull base surgery, providing a highly versatile option to repair even the most complex skull base defects. Though demonstrated with outstanding results in adult patients, there is limited experience in the pediatric population. Early investigation found that there are limitations in utilization of the nasoseptal flap in children due to craniofacial restrictions. More recently, these concerns have been mitigated, and nasoseptal flaps are reliably used in reconstructing even the largest skull base defects in the youngest patients. Preoperative planning and review of imaging and meticulous intraoperative dissection are essential for successful reconstructive outcomes.

Introduction

Endoscopic endonasal approaches have revolutionized the field of cranial base surgery, obviating the need for open craniofacial resection in many instances.[1-4] This minimally invasive approach to skull base lesions has been effectively applied to pediatric patients, but overall there is less experience in this demographic.[5,6] There are a variety of techniques and options for repair of pediatric and adult skull base defects which depend on the size and complexity of the defect, among other factors. The objective of any skull base repair is to provide a barrier between the intracranial and sinonasal regions, minimize dead space, maintain neurovascular function, and prevent postoperative cerebrospinal fluid (CSF) leaks.[7,8]

The pedicled nasoseptal flap (NSF), comprised of septal mucoperiosteum and mucoperichondrium, is supplied by the posterior septal branch of the sphenopalatine artery, and is a versatile and reliable option for repairing more complex and/or high-flow defects of the anterior and ventral skull base.[7,9] This well-vascularized flap can be customized to fit different defect dimensions, and its reach extends as far anteriorly as the most anterior portion of the anterior cranial fossa. Due to its robust pedicled blood supply, the NSF typically promotes rapid healing and decreased rates of CSF leak. In the event that a revision surgery is necessary, the NSF can often be deconstructed and reused.[10]

Even with increased comfort and dexterity in the endoscopic arena, skull base reconstruction in the pediatric population is limited. Early experiences of endoscopic repair of high-flow CSF leaks suggest that pediatric patients are considered a high-risk group for postoperative repair failure,[11] though more recent evidence suggests otherwise.[13] We review special considerations in utilizing the

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NSF in pediatric skull base surgery, including preoperative assessment, technical highlights, postoperative care, and outcomes.

Preoperative planning

Preoperatively, imaging is reviewed to carefully evaluate the lesion and potentially determine the anticipated post-surgical defect. In the pediatric patient, attention should be paid to assessment of the nasal septum length (potential flap length) in context of the anterior skull base length (anticipated maximal skull base defect). An earlier radioanatomic series of craniofacial dimensions in 6 patients by Shah et al found that children under the age of 10 generally had inadequate flap length, while those patients age 14 and above had reliable and predictable flap length for skull base coverage.[12] However, a follow-up study of 16 patients found that preoperative estimate flap length was adequate for coverage of even large suprasellar defects, with no postoperative CSF leaks encountered in any patients age 10 and younger.[13] Purcell et al similarly found through radioanatomic assessment of the computed tomography scans of 125 children that sellar defects are uniformly encompassed by anticipated flap length, suggesting that sellar reconstruction is feasible.[14]

Special consideration is always necessary for pediatric patients, especially those with a history of nasal or septal trauma, septal perforation, and prior nasal or endoscopic sinus surgery. The NSF is not an option for children with tumor involving the sphenoid face or septum. Though other methods of skull base reconstruction are available, 1 consideration is that patients requiring postoperative radiation therapy may benefit from coverage the skull base and surrounding structures (eg, carotid arteries and optic canals) with vascularized tissue. It is important to discuss risks, benefits, alternatives of flap harvest to the patient and family, specifically the possibility of postoperative CSF leak requiring additional interventions, crusting, septal perforation, bleeding, chondritis, and nasal deformities.[15]

Operative technique

After induction of general anesthesia, the patient is draped in typical sterile fashion. The image guidance system should be registered using the patient's 3-dimensional reconstructed computed tomography scan of the face. The technique for endoscopic endonasal access to the sella and parasellar regions is reviewed in a different section.

At the start of the case, the nose is decongested with oxymetazoline-soaked nasal pledgets. The side selected for NSF harvest is determined after examination for bony spurs, septal deviation, and septal mucosa defects. We conventionally favor the right nasal cavity for dissecting instruments during the 2-surgeon/binostril approach, and as such frequently employ the right side for flap harvest. For some lesions, deliberate choice of flap laterality is determined early; for instance, a left-sided NSF may be more suitable for a right-sided petrous apex or middle cranial fossa lesion due to less twisting of the pedicle.

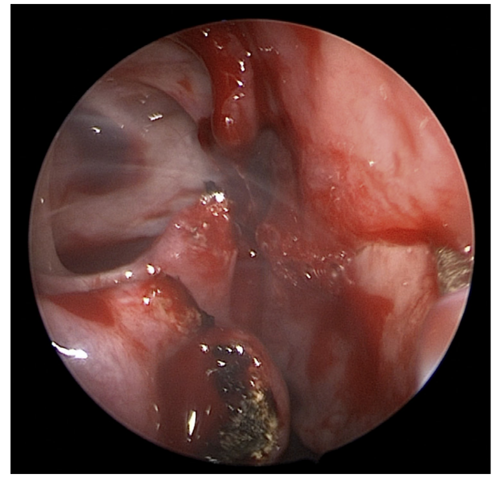

Figure 1 The initial cut extends from the inferior edge of the sphenoid ostium anteriorly along the posterior septum, with care to stay 1.5-2 cm below the skull base to preserve the olfactory strip. This cut is carried anteriorly to the level of the anterior head of the middle turbinate.

Following sphenoidotomy on the side of flap harvest, the anterior septal mucosa is marked with a blue pen to indicate the mucosal side, and flap incisions are made with monopolar electrocautery using an extended length, angled, needle tip Bovie cautery on a low-power setting. In many young children, the sphenoid sinus is not yet pneumatized, and this incision should carry across the approximate anatomic location of the natural ostium (ie, posteromedial to the inferior one-third of the superior turbinate). Having an assistant suction the cautery smoke during flap harvest is helpful for visualization. In many cases of pituitary surgery, we do not harvest a NSF upfront, and instead make only this first incision as part of the "rescue" flap.[16] This first incision is started posteriorly, just below the sphenoid ostium, and is extended anteriorly over the sphenoid rostrum and then carried along the posterior nasal septum to approximately the anterior head of the middle turbinate (Figure 1). To prevent injury to the olfactory strip, the incision should be approximately 1.5-2 cm below the cribriform plate.[17] If the surgery has not committed to requiring NSF for skull base reconstruction, then no further cuts are necessary at this point.

If an NSF is chosen for reconstruction, then a superior incision connecting from the anterior extent of the prior septal incision is made anterior to the olfactory strip and carried as anteriorly as possible. Oftentimes, this superior cut is out of view as it is high in the nasal vault. The third incision is vertically oriented, much like a Killian incision for septoplasty, at the squamo-mucosal junction of the anterior nasal septum; the location of this cut determines the flap length and ideally connects to the anterior limit of the superior incision (Figure 2).

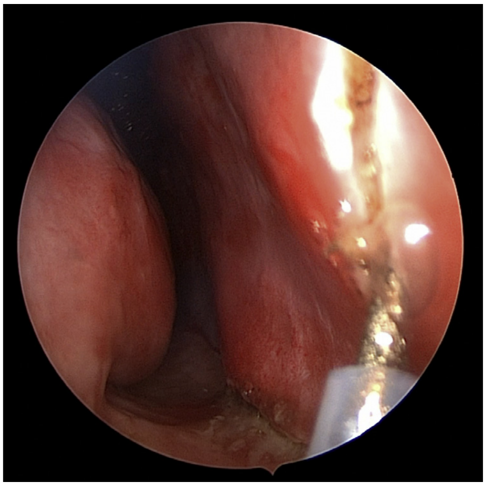

Figure 2 The anterior vertical incision is much like that used in a Killian incision for septoplasty and should extend down to the quadrangular cartilage in a submucoperichondrial plane.

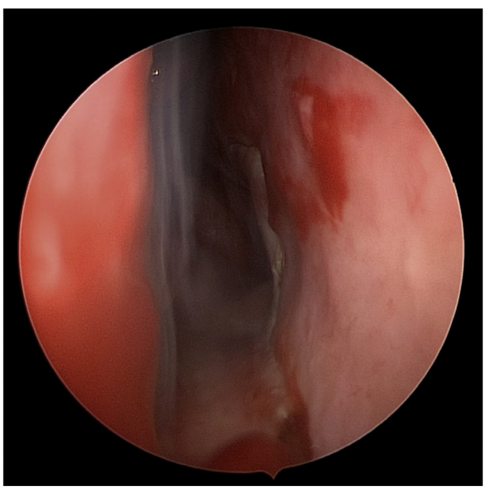

Figure 3 In a standard flap, the posteroinferior cut along the choana is carried anteriorly between the junction of the nasal floor and septum to connect to the anterior vertical incision.

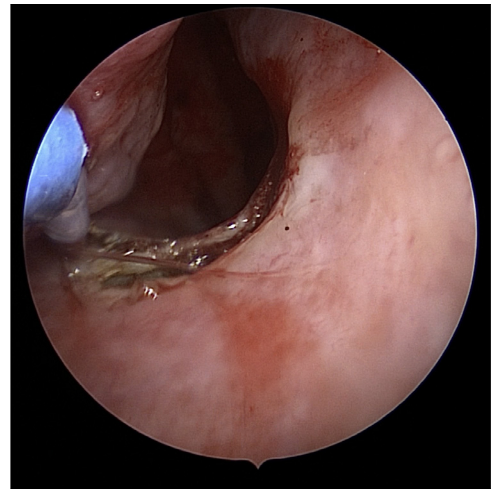

Figure 4 In an extended NSF, the inferior cut along the choana is then carried laterally toward the lateral nasal wall. NSF, nasoseptal flap.

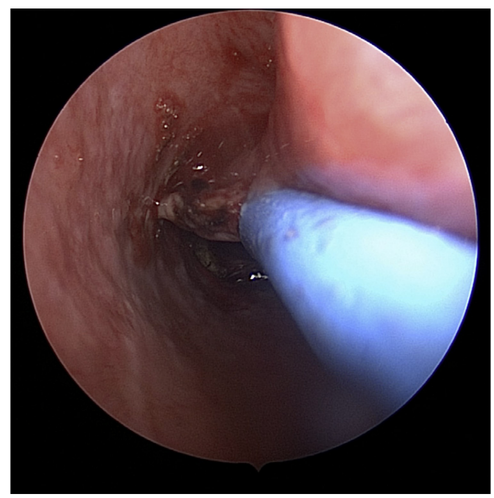

Figure 5 The inferolateral cut is then carried anteriorly over the lateral nasal wall below Hasner's valve, then medially to the anterior vertical incision to incorporate the entire nasal floor and part of the lateral nasal wall mucosa.

At this point, the surgeon has the choice of harvesting a standard NSF, or using the extended nasoseptal and floor flap. The standard NSF involves a posterior incision below the first incision along the arch of the choana, which is then carried along the curvature of the posterior nasal septum down toward the nasal floor (Figure 3). Once at the nasal floor, the incision is carried anteriorly along the junction of the nasal floor and septum and connected to the anterior vertical incision.

The extended NSF incisions start the same way along the choana, but instead of carrying the incision along the junction of the nasal floor and septum, the incision continues laterally along the nasal floor, into the inferior meatus, and, if applicable, up to the lateral nasal wall below the level of Hasner's valve (Figure 4). This incision is then continued from posterior to anterior, incorporating part of the lateral nasal wall, and then turns medially once anterior to the anterior head of the inferior turbinate to transverse the nasal floor medially and connect with the anterior vertical incision (Figure 5). Hydrodissection of the nasal floor mucosa, usually through infiltration with dilute lidocaine with epinephrine, aids in flap elevation.

The Freer is used to elevate the flap in a submucoperichondrial/submucoperiosteal plane in continuity with the vasculature itself, being careful to not disrupt the pedicle (Figure 6). Elevation begins posteriorly along the sphenoid rostrum and choana. If the extended NSF is harvested, the nasal floor component of the flap is then elevated medially toward the septum starting from the posterolateral corner (Figure 7). The anterior elevation proceeds from the Killian incision and is carried posteriorly to the sphenoid face, then down toward the nasal floor. If the superior incision is not complete, then a curved iris scissors may be used to complete the incision with the tines oriented superiorly in order to incorporate as much septal mucosa as possi-

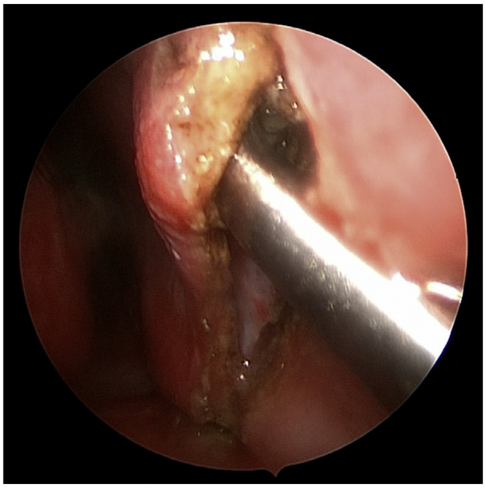

Figure 6 Flap elevation proceeds anteriorly in the submucoperichondrial plane.

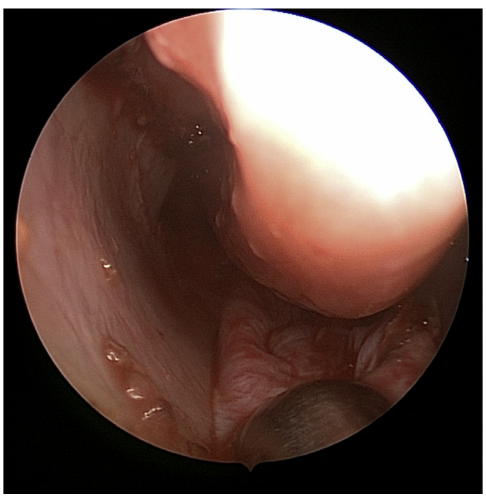

Figure 7 Elevation of the nasal floor mucosa component of the flap proceeds from posterolateral to medial.

ble (Figure 8). After the flap is completely elevated, it is placed into the nasopharynx or maxillary sinus while the other steps of the procedure are completed.

Once it is time to complete the skull base reconstruction, the flap is carefully maneuvered back into the nasal cavity. The NSF should be reoriented, as the pedicle may be twisted on itself when it has been tucked for storage; mucosal markings done previously is helpful for orientation. Mucosa that may be covered by the flap should be removed to prevent delayed mucocele formation. The flap is then placed as an overlay to cover the defect, making sure to contour the flap surfaces directly onto surrounding bone (Figure 9). A small amount of fibrin glue is applied to the flap edges to anchor it in place. We typically place a small amount of iodinated strip gauze packing to apply gentle pressure as the flap heals.

The denuded anterior septum can be covered with either a thin sheet of silastic sutured in place to the membranous septum, or, if wide exposure demanded a posterior septectomy, a reverse NSF.[18]

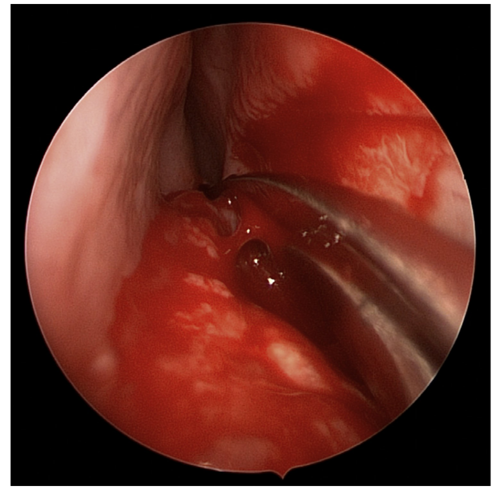

Figure 8 Curved iris scissors are used to complete the superior incision, angling vertically in order to incorporate more of the septal mucosa.

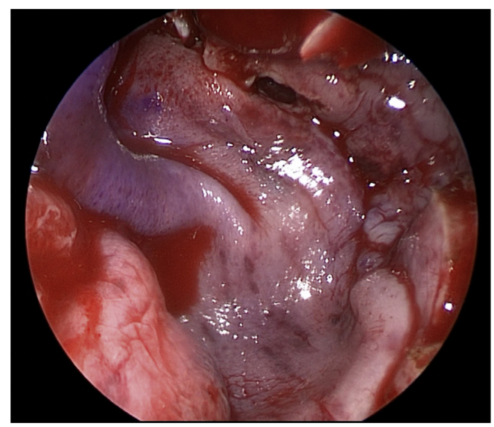

Figure 9 Inset right-sided extended nasoseptal flap over the sella. All flap edges should be in contact with underlying bone.

Postoperative care

Postoperative care related to endoscopic skull base surgery is discussed in a different section. Specific to care of the NSF, the strip gauze packing is gently removed at 2 weeks either in the office or under general anesthesia based on patient tolerance. Gentle debridement in the nasopharynx and anterior nose is performed, but no instrumentation of the flap should occur in the early postoperative period. If the patient has a silastic sheet covering the septum, it may be removed at this time. One of the biggest challenges is postoperative synechiae formation from the denuded septal cartilage to the lateral nasal wall. This is a much larger issue in children both due to the narrow nasal cavity as well the inability to debride the nose of young children in an office setting. The use of thin silastic sheeting has dramatically reduced the rate of synechia formation. Typically, if a child will not allow us to remove the silastic sheet in the office, we employ one additional operative session for removal of the nasal packing against the skull base re-

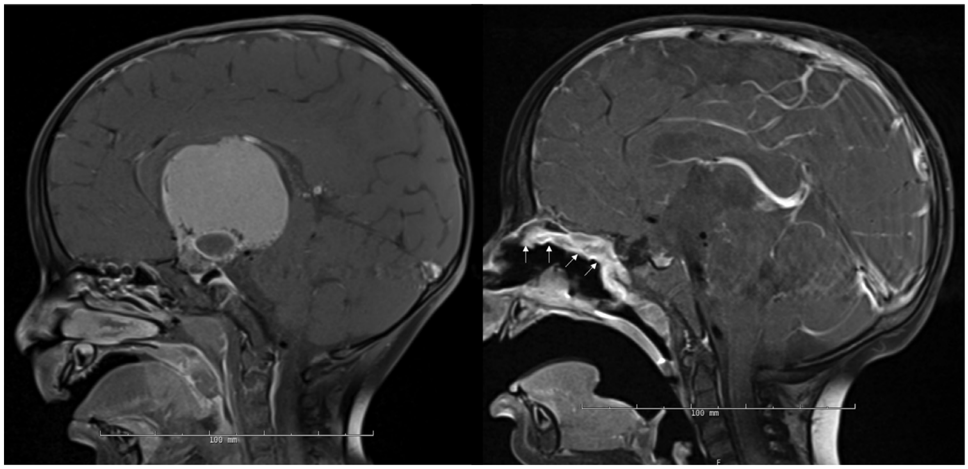

Figure 10 Twenty-two-month-old child who presented with a massive craniopharyngioma (left), with subsequent gross total resection and reconstruction using a vascularized pedicled nasoseptal flap (right, flap indicated by white arrows seen enhancing along skull base defect). No postoperative CSF leak occurred. CSF, cerebrospinal fluid.

construction as well as removal of the silastic sheeting at approximately 2 weeks following the initial procedure.

Outcomes

There are both anatomical constraints and craniofacial growth trends seen in pediatric patients which make skull base repairs more challenging compared to those performed in adults. Specifically, the rate of cranial growth is significantly greater than facial growth in the first 10 years of life, the skull base continues to develop until past at least age 10,[19] and the septum grows most rapidly between ages 10 and 13 years old.[12] From a technical perspective, the confined working space encountered in younger children can make endoscopic approaches and reconstructions more challenging.

Nevertheless, recent literature suggests that even the most complex and advanced skull base defects in extremely young children can be reconstructed successfully using the NSF (Figures 10 and 11). A retrospective study by Giannoni et al reported that of the 9 children in their series that underwent the endoscopic endonasal approach with NSF reconstruction for sellar and suprasellar defects, none developed CSF leaks postoperatively. Additionally, only minor complications including nasal crusting and rhinitis were seen in this cohort, which is within the expected recovery course following flap harvest.[20] Another retrospective analysis of 12 pediatric patients demonstrated an average length of hospitalization of approximately 8 days and no early major postoperative complications such as meningitis or CSF leak; however, 1 child with a craniofacial malformation developed a recurrent encephalocele, CSF leak, and meningitis 2 years after her initial surgery, ultimately requiring revision repair.[21]

Chivukula et al reported their results for endoscopic skull base surgery in 133 pediatric patients from 1999 to 2011, including 55 cases where NSF reconstructions were performed. They demonstrated a reduced postoperative CSF leak rate from 12.5% to 8.9% when the NSF was utilized[22]; however, this improved leak rate after 2008 is undoubtedly impacted by the overall increased experience with endoscopic skull base surgery and technological advances. Today, the NSF is accepted as a safe and technically feasible option even in infants, as demonstrated by

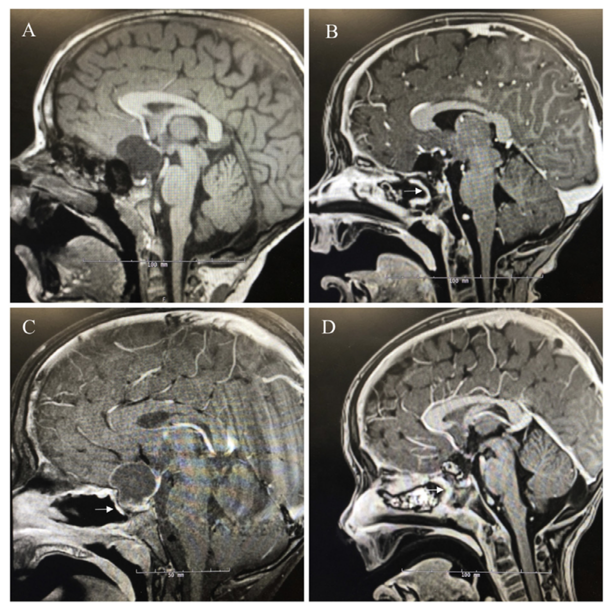

Figure 11 Five-year-old child with cystic craniopharyngioma (A) who underwent endoscopic marsupialization and reconstruction using a vascularized pedicled nasoseptal flap (B, flap indicated by white arrow seen enhancing along skull base defect). Three months later, the cyst reaccumulated with anterior displacement of flap (C, flap indicated by white arrow), and the patient underwent revision surgery with gross total resection and flap takedown and re-coverage of the skull base defect (D, flap indicated by white arrow seen enhancing along skull base defect in a subtly different position). The patient did not develop postoperative CSF leak after either surgery. CSF, cerebrospinal fluid.

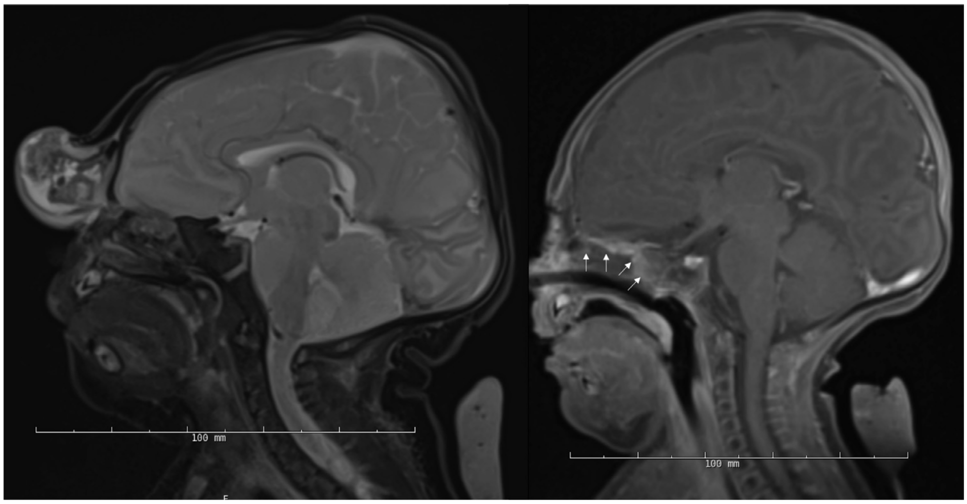

Figure 12 Ten-day-old neonate with congenital frontoethmoidal encephalocele (left). The patient underwent combined open and endoscopic resection and reconstruction of the anterior skull base defect with a vascularized pedicled nasoseptal flap (right, flap indicated by white arrows seen enhancing along skull base defect). No postoperative CSF leak occurred. CSF, cerebrospinal fluid.

Zeinalizadeh et al's report of successful trans-sphenoidal encephalocele repair in 3 infants ages 8-, 18- and 24-month old.[23] The youngest patient in our experience is a 10-day-old neonate with a congenital frontoethmoidal encephalocele who underwent successful closure of a large anterior skull base defect using the NSF (Figure 12).

There is a paucity of published data for NSF repair in the pediatric population, with the majority of studies from small, single-institution series. Regardless, the most recent data and our center's experience suggest that the NSF is a reliable repair option which is well suited for large anterior and ventral skull base defects, both low- and high-flow CSF leaks. However, longer term follow-up is needed to elucidate how septal dissection in young children affects craniofacial growth and development.

Conclusion

Pediatric skull base reconstruction using the NSF has similar outcomes to adults, with overall low rates of CSF leak. The anatomical differences seen in pediatric patients make the NSF repair more challenging, requiring additional preoperative planning and specific operative techniques. Despite these obstacles, the NSF is the most reliable option for repair of extensive anterior skull base defects in the youngest patients, including infants.

Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article.

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