Nasoseptal Flap Reconstruction of Pediatric Sellar Defects: A Radiographic Feasibility Study and Case Series

Patricia L. Purcell, MD1, Justin R. Shinn1, Randolph K. Otto, MD2, Greg E. Davis, MD, MPH1, and Sanjay R. Parikh, MD1,3

Abstract

Objectives. In this study, we used computed tomography measurements to investigate the feasibility of nasoseptal flap reconstruction of sellar defects in children, and we reviewed our institutional experience with the procedure.

Study Design. Cross-sectional and case series.

Setting: Pediatric tertiary care facility.

Methods. We obtained 10 normal maxillofacial scans for each year of age from birth to 18. Computer-assisted nasal and skull-base measurements were performed. Patients with incomplete pneumatization were excluded from analysis. Reconstruction was presumed feasible if the ratio of nasoseptal flap length to associated sellar defect length was greater than 1. Chart review identified surgical patients.

Results. Of 190 scans, 125 had complete pneumatization. Of these, 120 (96%) displayed a ratio of nasoseptal flap length to sellar defect length greater than 1, suggesting that reconstruction would be feasible. Mean ratio of flap length to defect length for all subjects was 1.47 (SD 0.33; 95% CI, 1.41-1.53). Only 5 of 125 patients (4%) had a ratio less than 1; the median age for these patients was 15 years, which is older than the median age of 12 years for subjects with a ratio greater than 1 (P = .02). An inverse relationship was identified between age and ratio of flap length to defect length (r = -0.49, P < .001). Case series identified 6 children, ages 5 to 17; flap length was never described as a limitation.

Conclusions. Nasoseptal flap length is not a limiting factor for reconstruction of pediatric sellar defects. When compared with older patients, younger patients tend to have greater nasoseptal flap length relative to sellar defect length.

Keywords
endoscopic surgical procedure, nasoseptal flap, skull base surgery, pediatric surgery, computed tomography

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Introduction

Transnasal endoscopic approaches to the anterior skull base spare the morbidity of an open craniofacial resection, offer excellent visualization, and possibly result in increased patient satisfaction.1 Studies have shown that transnasal approaches to sellar lesions can be safely and successfully performed in young patients.2,3

However, it is less clear whether the smaller facial structures of pediatric patients can accommodate reconstruction of surgical skull base defects with vascularized tissue flaps. The most popular flap described for reconstruction in adult patients is the pedicled nasoseptal flap, a flap of nasal septum mucoperiosteum and mucoperichondrium based on the posterior septal artery.4

In 2009, Shah et al5 used computed tomography (CT) measurements to evaluate nasoseptal flap size among pediatric patients. Their findings suggested that children younger than 6 to 7 had inadequate nasoseptal flap length for reconstruction of sellar defects; the investigators also noted that nasoseptal flap width did not appear to be a limiting factor in reconstruction.

The objective of the current study was to use CT measurements to characterize the relationship between nasoseptal flap length, sellar defect length, and patient age so that surgeons better understand reconstructive options for sellar defects in pediatric patients. In addition, we describe the

1Department of Otolaryngology, University of Washington, Seattle, Washington, USA
2Department of Radiology, Seattle Children’s Hospital, Seattle, Washington, USA
3Division of Pediatric Otolaryngology, Seattle Children’s Hospital, Seattle, Washington, USA

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Corresponding Author: Patricia L. Purcell, MD, Department of Otolaryngology, University of Washington, 1959 NE Pacific St, Box 356515, Seattle, WA 98195-6515, USA.
Email: plpurcel@uw.edu
Methods

This investigation received institutional review board (IRB) approval from Seattle Children’s Hospital, a pediatric tertiary care facility. The facility’s pediatric radiology database was queried to identify patients who had undergone CT head, sinus, or maxillofacial imaging from 2009 to 2013 (predominantly CPT code 70486). Studies were initially identified by year in which they were performed. Beginning closest to the present date, a pediatric radiologist reviewed the imaging studies in chronological order until 10 adequate studies were obtained for each year of age from birth to age 18.

The indications and images were reviewed to ensure that each selected case had no immediately discernible pathology involving the maxillofacial structures. Patients with craniofacial defects, anterior skull base pathology, or inadequate imaging were thereby excluded. Among examinations included in the study, the most common indications for CT imaging were headache, history of trauma, and suspected sinusitis.

Nasal and skull base measurements were done with US Food and Drug Administration (FDA)-approved OsiriX MD radiology software, which allows for multiplanar formatting and curvilinear measurements. Figure 1 illustrates how measurements were obtained. Nasoseptal flap length was defined as the linear distance from the sphenopalatine foramen to the nasal sill in the parasagittal plane. Sellar defect length was defined as a curvilinear distance tracking posteriorly from the sphenopalatine foramen along the floor of the sphenoid sinus to rise superiorly over the sella turcica to the posterior aspect of the planum sphenoidale.

Once measurements were obtained, a ratio of nasoseptal length to sellar defect length was calculated for each patient. Nasoseptal flap reconstruction was presumed feasible if the experience of clinicians at this pediatric tertiary care facility with nasoseptal flap reconstruction after transsphenoidal procedures.

Figure 1. Multiplanar measurement technique. (A) Sphenopalatine foramen identified in the axial plane. (B) Potential nasoseptal flap length: linear distance from the sphenopalatine foramen to the nasal sill within a parasagittal plane. (C) Potential sellar defect length: curvilinear distance from the sphenopalatine foramen to the posterior planum sphenoidale.
ratio was greater than 1, indicating that nasoseptal flap length exceeded sellar defect length. Patients who were selected as cases but who had incomplete pneumatization of the sphenoid sinus, as shown in Figure 2, were excluded from analysis because sellar defect measurements could not be obtained in the same standardized fashion. Pneumatization was considered complete based on the radiographic appearance of the endochondral/marrow space. If the thickness of the marrow space anterior to the sella turcica was greater than 2 mm, then the subject was considered to have an incompletely pneumatized sphenoid sinus.

We also performed a retrospective chart review of pediatric nasoseptal flap cases at our institution. One pediatric otolaryngologist performed all pediatric nasoseptal flap reconstruction at our institution from 2011 to 2013. The surgeon maintained records of these cases for clinical follow-up, which made it possible to review all the cases performed. We received IRB approval to review these cases at the same time as our approval to perform the CT scan measurements. Data were collected regarding age at time of surgery, final diagnosis, intraoperative and postoperative complications, and readmission rates.

**Analysis**

We calculated the proportion of subjects who had a ratio of nasoseptal flap length to sellar defect length greater than or less than 1. Statistical comparisons were made between subjects with ratios less than 1 and subjects with ratios greater than 1. Inferential testing was performed using Wilcoxon rank sum test. The correlation between age and ratio of flap length to defect length was calculated using Pearson correlation coefficient. Descriptive statistical analysis defined characteristics of patients with incomplete pneumatization and surgical patients within the case series. Statistical significance was set at \( P < .05 \). All analysis was carried out using STATA 13.1 (STATA, Inc, College Station, Texas).

**Results**

Figure 3 illustrates the classification of the 190 radiologic cases included in the analysis. Of 190 CT scans, 125 had complete pneumatization. Of these, 120 (96%) displayed a ratio of nasoseptal flap length to sellar defect length greater than 1, suggesting that nasoseptal flap reconstruction would be feasible.

The mean ratio of flap length to defect length for all subjects was 1.47 (SD 0.33; 95% CI, 1.41-1.53). Only 5 of 125 patients (4%) had ratios less than 1; the median age for these patients was 15 years, which is older than the median age of 12 years for subjects with ratios greater than 1 (\( P = .02 \)). The minimum ratio calculated was 0.82 in an 18-year-old subject, and the maximum ratio was 2.44 in an 11-year-old subject. Figure 4 is a scatterplot displaying the association between age and ratio of nasoseptal flap length to sellar defect length. An inverse relationship was identified (Pearson correlation coefficient \(-0.49\), \( P < .001\)), indicating
that older patients had smaller nasoseptal flap length in relationship to estimated sellar defect length.

There were 65 children with incomplete pneumatization of the sphenoid sinus. Figure 5 is a boxplot comparing the age ranges of patients with fully pneumatized to incompletely pneumatized sphenoid sinuses. All patients less than 3 years of age had incomplete pneumatization. There were 4 patients over the age of 10 who had incomplete pneumatization of the sphenoid: one 11-year-old, one 12-year-old, and two 17-year-olds.

Retrospective review of the pediatric surgical database identified 6 nasoseptal flap cases performed since 2011 at our institution. Ages for these cases ranged from 5 to 17 years, with a mean of 10.7 years. Table 1 lists characteristics of the surgical patients. No surgical report described flap length as a limitation during the case. Only 2 of the patients had imaging that included the length of the septum: a 10-year-old female and a 17-year-old female. Ratios of 1.37 and 1.01, respectively, were calculated for these surgical patients based on their CT measurements.

Of note, the 10-year-old female developed a low-flow cerebrospinal fluid (CSF) leak following a transsphenoidal biopsy of a suprasellar tumor. The patient developed clear rhinorrhea within a day or two of surgery. Because the initial biopsy was inconclusive, the patient underwent a repeat biopsy at which time the nasoseptal flap was readjusted and a lumbar drain was placed with resolution of the CSF leak. The patient was ultimately diagnosed with a suprasellar germ cell tumor.

A second CSF leak occurred in an 11-year-old male with recurrent craniopharyngioma. The patient developed an intraoperative high-flow leak that required lumbar drain placement before the conclusion of the case. He required readmission for recurrent CSF leak, which resolved following additional lumbar drain placement.

Discussion

Endoscopic approaches are now frequently used for anterior skull base lesions. Reconstruction with vascularized tissue flap has been shown to lower the risk of CSF leak after surgery.\(^7\) Because questions had been raised as to whether children have adequate tissue length to permit such reconstruction, the goal of this study was to use a standardized measurement method to characterize the relationship between potential nasoseptal length and sellar defect length in children. This radiographic feasibility study suggests that nasoseptal flap length is not a limitation in reconstruction of pediatric sellar defects. Due to pneumatization, the volume of the sphenoid sinus expands with age,\(^8\) and our study found that older patients were more likely to have longer sellar defect lengths.

Interestingly, these results differ from previously reported findings of Shah et al.\(^5\) There are several possible reasons for this difference. First, OsiriX imaging software allows for multiplanar reconstruction with the ability to easily identify the sphenopalatine foramen in the axial plane while simultaneously determining the nasoseptal flap length in the parasagittal plane. Additionally, we were able to perform curvilinear measurements of circumferential dimensions such as the contour of the sphenoid sinus.

Incomplete pneumatization remains an obstacle to performing endoscopic approaches to sellar lesions in very young children. In the current study, no patient under the age of 3 had a completely pneumatized sphenoid, a finding

Table 1. Characteristics of Pediatric Nasoseptal Flap Cases.

<table>
<thead>
<tr>
<th>Age at Procedure</th>
<th>Gender</th>
<th>Race</th>
<th>NSF/Sellar Ratio</th>
<th>Pathology</th>
<th>CSF Leak</th>
<th>Readmission</th>
<th>Total Length of Hospitalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Female</td>
<td>Asian</td>
<td>—</td>
<td>Primary craniopharyngioma</td>
<td>No</td>
<td>No</td>
<td>5 days</td>
</tr>
<tr>
<td>9</td>
<td>Male</td>
<td>Asian</td>
<td>—</td>
<td>Primary craniopharyngioma</td>
<td>No</td>
<td>No</td>
<td>4 days</td>
</tr>
<tr>
<td>10</td>
<td>Female</td>
<td>Asian</td>
<td>1.37</td>
<td>Germ cell tumor</td>
<td>Yes (low-flow)</td>
<td>No</td>
<td>14 days</td>
</tr>
<tr>
<td>11</td>
<td>Male</td>
<td>White</td>
<td>—</td>
<td>Recurrent craniopharyngioma</td>
<td>Yes (high-flow)</td>
<td>Yes, for recurrent CSF leak</td>
<td>13 days</td>
</tr>
<tr>
<td>12</td>
<td>Male</td>
<td>White</td>
<td>—</td>
<td>Rathke cleft cyst</td>
<td>No</td>
<td>No</td>
<td>3 days</td>
</tr>
<tr>
<td>17</td>
<td>Female</td>
<td>White</td>
<td>1.01</td>
<td>Pituitary adenoma</td>
<td>No</td>
<td>No</td>
<td>3 days</td>
</tr>
</tbody>
</table>

Abbreviations: CSF, cerebrospinal fluid; NSF, nasoseptal flap.

*Ratio could not be determined for 4 cases due to lack of adequate imaging.
that agrees with previously reported pneumatization patterns.9 There are case reports of successful endoscopic transsphenoidal procedures with nasoseptal flap reconstruction in children under the age of 2 years.10 With the use of image-guided navigation, it is perhaps becoming more feasible to perform endoscopic approaches in the setting of incomplete pneumatization, but this remains an area for future investigation.

Our center recently used nasoseptal flaps to repair sellar defects in 6 pediatric patients, the youngest of whom was 5 years of age. A previous case series of 10 pediatric patients also reported successful nasoseptal flap reconstruction in this age range and noted no difficulties with adequate flap elevation.11

Our flap harvesting technique is similar to that previously described.12 The flap is harvested at the start of the case just after entry into the sphenoid ostium. Flap incisions are carried out parallel to the floor of the nose, superior and inferiorly, and then united anteriorly with a Killian incision. For defect closure, rather than using fascia or abdominal fat, the surgeon places a nasal septal bone graft into the dural defect in the posterior sphenoid wall. The nasoseptal flap is then rotated on top of the defect, and packing is used to secure the graft in place. The nasal packing typically consists of an initial layer of Tisseel, followed by Surgicel to fill the sphenoid sinus.

Of the 6 cases at our institution, 2 (33%) developed postoperative CSF leak, a rate which is similar to some published series.9 Studies have suggested that pediatric cases may be at higher risk of reconstructive failure after endoscopic skull base surgery,14 perhaps due to higher rates of suprasellar lesions, such as craniopharyngiomas, and narrower working space, which may make complex closures more challenging.

In the last year, 2 large craniopharyngioma case series have been published, including a total of 37 pediatric patients with smaller numbers of nasoseptal flap repairs.15,16 Both series attributed an overall reduction in CSF leak rates to advances in reconstructive techniques, including the use of vascularized tissue flaps. Future investigations should continue to investigate endoscopic surgical outcomes in children.

This radiographic feasibility study has several limitations. First, the measurements were primarily obtained from patients with anatomically normal CT scans. Sellar lesions often distort the anatomy of the sphenoid sinus and surrounding structures, so it may not be possible to obtain standardized measurements in a similar fashion in surgical patients. For this reason, patients with anterior skull base pathology were excluded from case selection.

We were only able to measure a flap/sellar ratio in 2 surgical patients. The other 4 patients did not have imaging that included the length of the septum. In both measurable cases, we calculated a ratio greater than 1. The pattern was similar to our previous results, with the ratio closely approaching 1 for the older of the 2 patients, who was 17 at the time of surgery. Interestingly, our data indicate that the ratio of septal length to sellar length initially decreases with age before leveling off around age 14 to 15 years. With such limited case numbers, we do not have sufficient information to recommend this measurement strategy for individual preoperative planning.

In addition, while OsiriX allows multiplanar measurements, there are limitations in the ability of radiologic measurements to capture what is ultimately complex 3-dimensional anatomy and subsequent surgical technique. To our knowledge, no studies have described nasoseptal flap width as being a limiting factor for reconstruction of sellar defects, which are typically quite narrow. In the case of larger anterior skull base defects, flap width might become an important consideration; however, skull base pathology requiring such a defect would be extremely rare among pediatric patients.

One of the 2 surgical patients for whom a flap/sellar ratio was calculated did develop a CSF leak. The 10-year-old female with a calculated ratio of 1.37 developed clear rhinorrhea shortly after surgery. The operative report did not mention flap length as a limitation during reconstruction, and this appears to be confirmed by CT measurements. However, it is possible that additional unmeasured factors, such as flap shrinkage or malposition, could have contributed to the development of CSF leak in this case. Flap shrinkage tends to occur intraoperatively: As the flap sits in the nasopharynx, it may become edematous, slightly reducing overall length. Again, none of the operative reports noted flap length to be a limitation in placement, suggesting that intraoperative shrinkage was minimal.

Despite these limitations, the findings from this study, combined with the experiences at our institution and other reported case series, suggest that nasoseptal flap reconstruction of sellar defects is quite feasible in young children. Our data indicate that as children age, the ratio of nasoseptal flap length to sellar defect length decreases initially, and the ratio typically levels off above 1 around the age of 14 to 15 years.

If concerns remain, a prospective study of this question could be performed; intraoperative measurements could be compared with CT measurements to determine how well radiographic measurements correlate with intraoperative findings. It might be worthwhile to carry out such a study among adult patients to determine whether nasoseptal flap length is truly important in assessing flap adequacy.

Conclusion

The length of nasoseptal flaps in children is not a limiting factor for the reconstruction of pediatric sellar defects. When compared with older patients, younger patients tend to have greater nasoseptal flap length relative to the length of sellar defects. Endoscopic surgical outcomes in children should continue to be investigated.

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Author Contributions

Patricia L. Purcell, study design, data analysis, manuscript preparation, manuscript revision; Justin R. Shinn, data collection, manuscript revision; Randolph K. Otto, data collection, manuscript revision; Greg E. Davis, study design, data analysis, manuscript revision; Sanjay R. Parikh, study conceptualization, study design, data acquisition, manuscript revision.

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