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Endoscopic Pedicled Nasoseptal Flap Reconstruction for Pediatric Skull Base Defects

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Objectives/Hypothesis: A prospective study of endoscopic expanded endonasal approaches (EEA) with nasoseptal flap reconstructions revealed anecdotal evidence of less available relative septal length in pediatric patients. Our goal is to use radioanatomic analysis of computed tomography (CT) scans to determine limitations of the nasoseptal flap in pediatric skull base reconstruction and to describe clinical outcomes after using the nasoseptal flap in six pediatric patients.

Study Design: Six pediatric patients who underwent EEA with nasoseptal flap reconstruction were prospectively analyzed for flap coverage and postoperative cerebrospinal fluid (CSF) leak. Fifty maxillofacial CTs of individuals <18 years of age and 10 adult images underwent radioanatomic analysis.

Methods: Measurements included potential nasoseptal flap dimensions and dimensions required to reconstruct an anterior skull base defect, a trans-sellar defect, and a transclival defect. Measurements were compared to determine if flap size would be sufficient to cover independent EEA defects within different age groups.

Results: Two out of three patients <14 years of age had inadequate flap coverage; one had a postoperative CSF leak. Patients >14 years of age had adequate flap coverage. Average potential flap length is less than average anterior skull base length until age 9 years to 10 years, and less than average trans-sellar defect length until age 6 years to 7 years. Septal growth is most rapid between 10 years and 13 years.

Conclusions: The pedicled nasoseptal flap may not be a viable option for EEA reconstruction in children <10 years of age. This flap is a reliable option in patients >14 years of age, as their septums are comparable to adults. Patients 10 years to 13 years of age require careful consideration of facial analysis and preoperative radioanatomic evaluation on an individual basis.

Key Words: Nasoseptal flap, endoscopic skull base surgery, skull base reconstruction, pediatric skull base surgery.

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INTRODUCTION

Over the past decade, a full endoscopic expanded endonasal approach (EEA) has been more frequently employed for exposure and resection of intradural lesions. Significant advances in instrumentation, understanding of anatomy, and surgical technique has led to endoscopic management of both benign and malignant diseases of the skull base.[1,2] As our understanding of endoscopic skull base surgery has evolved, we have moved into performing more complex resections and even resections in pediatric patients.[3]

Effective and consistent reconstruction following endoscopic expanded endonasal approaches requires complete separation of the cranial cavity from the sinonasal tract, obliteration of dead space, preservation of neurovascular and ocular function, and reconstruction of tissue barriers.[4] A neurovascular pedicled flap of the nasal septum mucoperiosteum and mucoperichondrium based on the nasoseptal artery is gaining wider acceptance for reconstruction following anterior skull base, trans-sellar, and transclival EEAs.[5,6] The flap is harvested at the beginning of the case and displaced into

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the nasopharynx until completion of the resection. In the sagittal plane of the septum, two parallel incisions are made on the septum, one inferiorly over the maxillary crest and the other 1cm below the skull base to preserve olfactory epithelium. These incisions are joined anteriorly by a vertical incision. Posteriorly, they cross the rostrum of the sphenoid sinus. Elevation of the flap spares a posterolateral neurovascular pedicle. The multilayer reconstruction includes an inlay subdural graft, an onlay fascial graft (or abdominal free fat), the septal mucosal flap, and nasal packing or a 12-French foley catheter. This technique has been shown to reduce cerebrospinal fluid (CSF) leaks after EEA by 50%.[6] Use of the nasoseptal flap requires anticipated use and design prior to resection since the pedicle must be raised and preserved prior to the skull base approach.

A recent pilot study developed a method using computed tomography (CT) images to measure potential dimensions of EEA defects and potential dimensions of the nasoseptal flap in four adults. In this study, the potential length of the nasoseptal flap proved adequate to cover defects from anterior skull base, trans-sellar, and transclival approaches independently.[5] Although the use of the nasoseptal flap for skull base reconstruction is gaining popularity in adults, little is known about its use in children. Anecdotal data from the senior authors (A.Z., C.S., R.C., A.K.) suggest that the size of the nasoseptal flap area in children is more limited than adults for large skull base reconstructions.

Growth trends in craniofacial measurements based on CT scans show that cranial growth is rapid in the first few years of life, followed by a leveling off.[7] The skull base continues to develop for at least 10 years after birth.[8] In contrast to the cranium, the upper midface does not show a dramatic increase in size early in life. This region continues to grow later in life at a more rapid rate than the cranium.[7]

Based on normal growth trends and our experience, we hypothesize that the potential dimensions of the nasoseptal flap are insufficient to cover some larger skull base defects early in childhood, and it is not until adolescence when septal length approaches full size and is adequate for EEA reconstruction. Using a method similar to the previous pilot study, we compare potential nasoseptal flap length and width to skull base defect dimensions in 50 pediatric patients and 10 adult controls. These comparisons are stratified by age group to optimize reconstructive planning in children.

MATERIALS AND METHODS

Clinical Outcomes Methods

One hundred fifty patients undergoing expanded EEAs for skull base surgery with primary nasoseptal flap reconstruction at the University of Pittsburgh Cranial Base Center were prospectively studied from July 2007 to June 2008. Only approaches and reconstructions that the principal investigator (A.Z.) was involved with and able to be graded at the time of the operation were included. Twelve potential risk factors for postoperative CSF leak were determined for study by both anecdotal data by the authors and also by retrospective review of prior nasoseptal flap outcomes. We report six pediatric patients (under the age of 18 years) that were included in the 150 patient prospective cohort. These 12 factors were graded at the time of the operation to reduce any grading biases that may result from a postoperative CSF leak.

The twelve factors were:

- Corridor of resection (e.g., trans-sellar vs. transclival vs. transcribriform)
- Tumor pathology
- Intraoperative CSF leak
- High flow leaks (cistern/ventricle opened during resection)
- Large dural opening (estimated >2 cm^2)
- Functional pituitary adenoma
- Cushings disease patients
- Morbid obesity (BMI >30)
- Complete defect coverage by the flap
- Lumbar drainage postoperatively
- Prior radiation therapy
- Alloderm or fat augmentation of the reconstruction

Radioanatomic Methods

Institutional review board approval was given to review CT scans after identifying data were removed for skull base anatomic protocols. Scans were stratified by age groups only. Patients <18 years of age who obtained a maxillofacial or sinus CT scan in the last two years were identified through the IMPAX system (Agfa Healthcare, Mortsel, Germany). All of the CT scans were performed using 0.75 mm to 3 mm axial section protocols with coronal and sagittal reconstructions. Patients with preexisting conditions altering skull base anatomy (including trauma), previous sinus or skull base surgery, congenital midface anomalies, nasal polyposis, or premature birth were excluded. Remaining images were stratified according to age. Six pediatric age groups (<24 months, 3–4 years, 6–7 years, 9–10 years, 12–13 years, and 15–16 years) were chosen and 50 images were analyzed. Ten adult images with similar inclusion and exclusion criteria were analyzed for comparison. The measurements included dimensions required to reconstruct defects secondary to 1) transcribiform approach/anterior skull base approach, 2) trans-sellar approach/transplanar approach, and 3) transclival approach, and potential nasoseptal flap dimensions. All measurements were performed by a neuroradiologist and an otolaryngologist on a PACS system (Agfa Healthcare).

Measurements

The sphenopalatine foramen (SPF) was used as a point of reference for skull base and septal lengths. The SPF was first identified in axial and coronal planes. Using the 3D localization feature of the PACS system, the projection of the SPF on the septum could be identified in the midsagittal plane (Fig. 1). A summary of all measurement abbreviation definitions and corresponding figures are shown in Table I. Measurement definitions are comparable to the method developed by Pinheiro-Neto et al. for reconstructive design of skull base defects.[5]

Flap length required to reconstruct a defect after a transcribiform/anterior skull base approach is defined as the distance from the posterior wall of the frontal sinus to the planum sphenoidale plus the distance from the planum to the SPF projection in the midsagittal plane (SPF-SKB, Fig. 2C). Two measurements represent the flap width required to cover an

Fig. 1. Identification of sphenopalatine foramen (SPF) projection on the posterior nasal septum. (A) Identification of SPF on axial plane. (B) Identification of SPF on coronal plane. (C) Corresponding SPF projection in midsagittal plane using axial and coronal planes and 3D localization.

anterior skull base defect; these were performed in the coronal plane. Anterior width is defined as the distance between both lamina papyracea at the level of the anterior ethmoidal artery (SKB-AEA, Fig. 2A). Posterior width is defined as the distance between both lamina papyracea at the sphenoethmoidal junction (SKB-PES, Fig. 2B).

TABLE I.
Definitions of Skull Base and Nasoseptal Flap Measurements.

Abbreviation	Measurement	Representative Figure
SPF-SKB	Posterior frontal sinus to planum sphenoidale to SPF projection	Figure 2C
SPF-S	Planum sphenoidale covering inner sphenoid sinus to SPF projection	Figure 3A
SPF-C	SPF projection to clival point tangent to sellar floor to inferior border of clivus	Figure 4A
SKB-AEA	Between both lamina papyracea at level of anterior ethmoidal artery	Figure 2A
SKB-PES	Between both lamina papyracea at sphenoethmoidal junction	Figure 2B
SKB-OA	Between both optic apices	Figure 3B
SKB-CA	From medial to medial border of carotid arteries at their second genus	Figure 4B
FL-SPF-NB	Flap length from SPF projection to anterior projection of nasal bone	Figure 5D
AFW	Flap width at level of anterior ethmoidal artery	Figure 5B
PFW	Flap width at midpoint between AFW and sphenoethmoidal junction	Figure 5C

SPF = sphenopalatine foramen.

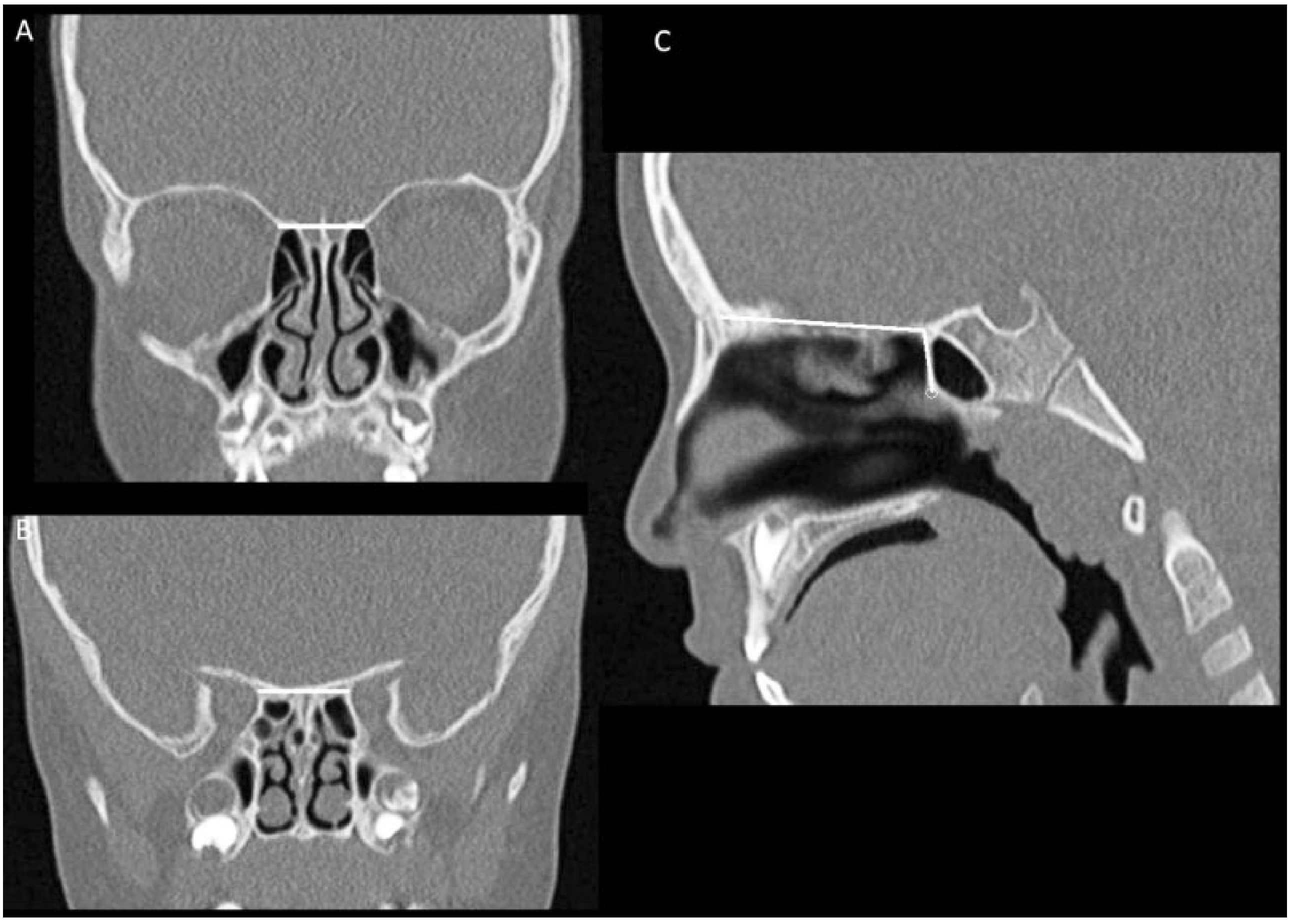

Fig. 2. Measurements of flap dimensions required to reconstruct a transcribiform or anterior skull base defect. (A) Anterior width (SKB-AEA)—distance between both lamina papyracea at the level of the anterior ethmoidal artery in coronal plane. (B) Posterior width (SKB-PES)—distance between both lamina papyracea at the sphenoethmoidal junction in coronal plane. (C) Flap length required to cover anterior skull base defect (SPF-SKB)—distance from posterior frontal sinus to planum sphenoidale to projection of sphenopalatine foramen in mid-sagittal plane. A summary of all measurement abbreviation definitions are shown in Table I.

The trans-sellar or transplanar approach produces a defect approximately equal to the distance from the planum sphenoidale to the anterior superior sella to the inferior dorsum sella. This distance is measured in the midsagittal plane and added to the distance from the inferior dorsum sella to the SPF projection to give the flap length required to reconstruct a trans-sellar approach defect (SPF-S, Fig. 3A). Flap width required to cover the latero-lateral aspects of this defect is measured in the coronal plane and is equal to the distance between both medial aspects of the optic nerves at their apices (SKB-OA, Fig. 3B).

Flap length required to reconstruct a transclival defect is defined as the distance from the SPF projection to the clival point tangential to the inferior border of the sella to the inferior border of the clivus (SPF-C, Fig. 4A). The width of a transclival defect corresponds to the distance between both medial aspects of the carotid arteries at their second genu demonstrable in the axial plane (SKB-CA, Fig. 4B).

Measurements of the potential nasoseptal flap include flap length, anterior flap width, and posterior flap width. In the midsagittal plane, the distance between the SPF projection and the most anterior border of the nasal bone parallel to the hard palate defines the flap length (FL-SPF-NB, Fig. 5D). The anterior and posterior flap widths were measured in the coronal plane as the craniocaudal septum minus 10 mm of the most cephalic nasal septum (AFW, PFW, Fig. 5B, C). During flap harvest, approximately 10 mm of cephalic septum is preserved in order to spare olfactory epithelium. Anterior and posterior coronal slices are shown in Figure 5A. The anterior cut is at the level of the anterior ethmoidal artery, whereas the posterior cut is the midpoint between the anterior ethmoidal artery and sphenoethmoidal junction.

RESULTS

Pediatric Clinical Outcomes Results

Six pediatric patients were included in a recent 150-patient prospective CSF leak outcomes trial performed by the senior author (A.Z.). These six patients were analyzed separately, specifically to evaluate the adequacy of the nasoseptal flap size and for CSF leak outcomes. The clinical data and outcomes for all six pediatric nasoseptal flap patients are included in Table II. There was one postoperative CSF leak in a 10-year-old

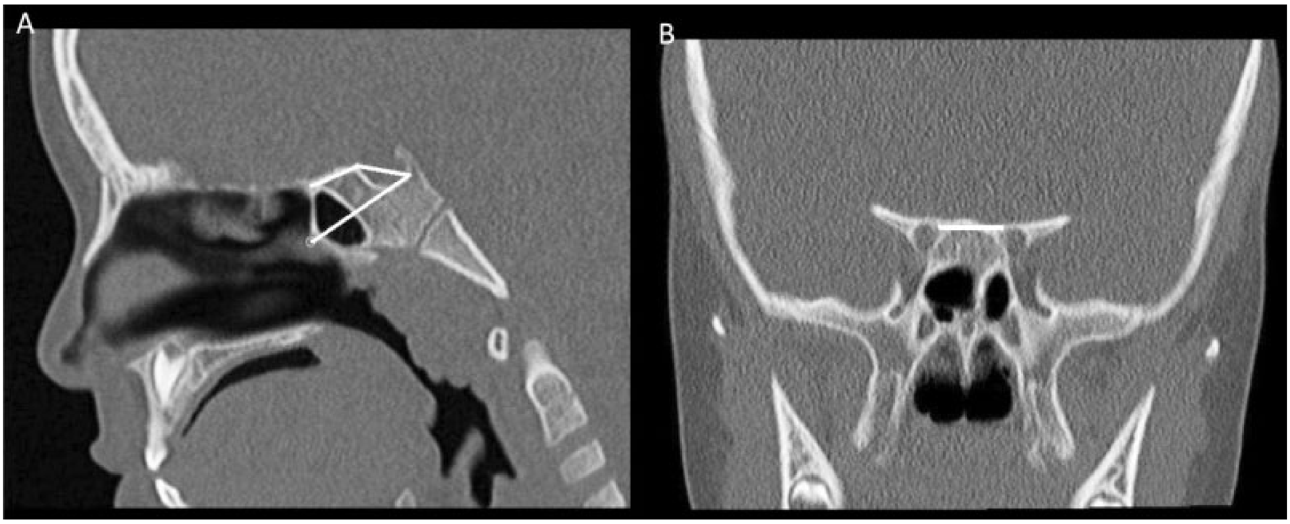

Fig. 3. Measurements of flap dimensions required to reconstruct a trans-sellar or transplanar approach defect. (A) Flap length required to cover trans-sellar approach defect (SPF-S)—distance from planum sphenoidale to anterior superior sella to inferior dorsum sella to sphenopalatine foramen projection in midsagittal plane. (B) Width of trans-sellar approach defect (SKB-OA)—distance between both medial aspects of optic nerves at their apices in coronal plane. A summary of all measurement abbreviation definitions are shown in Table I.

patient after trans-sellar and transdorsal resection of a craniopharyngioma with a large dural opening and cistern and ventriculotomy. The flap in this patient was taken to the limits of the septum size, but only provided 80% defect coverage. This patient was revised with an endonasal bolstering of the CSF fistula with fat and a lumbar drain. In the three patients less than 14 years of age, two of three (66%) did not have sufficient septal flap size to completely cover the defect. In those over 14 years of age, all three (100%) had sufficient flap coverage, and two of those three had defects that extended all the way to the posterior wall of the frontal sinus.

Radioanatomic Results

A total of 50 pediatric scans and 10 adult scans underwent all of the measurements as explained previously. The images were grouped according to the age of the patient at the time of the scan: <24 months (n = 8), 3 years to 4 years (n = 8), 6 years to 7 years (n = 9), 9

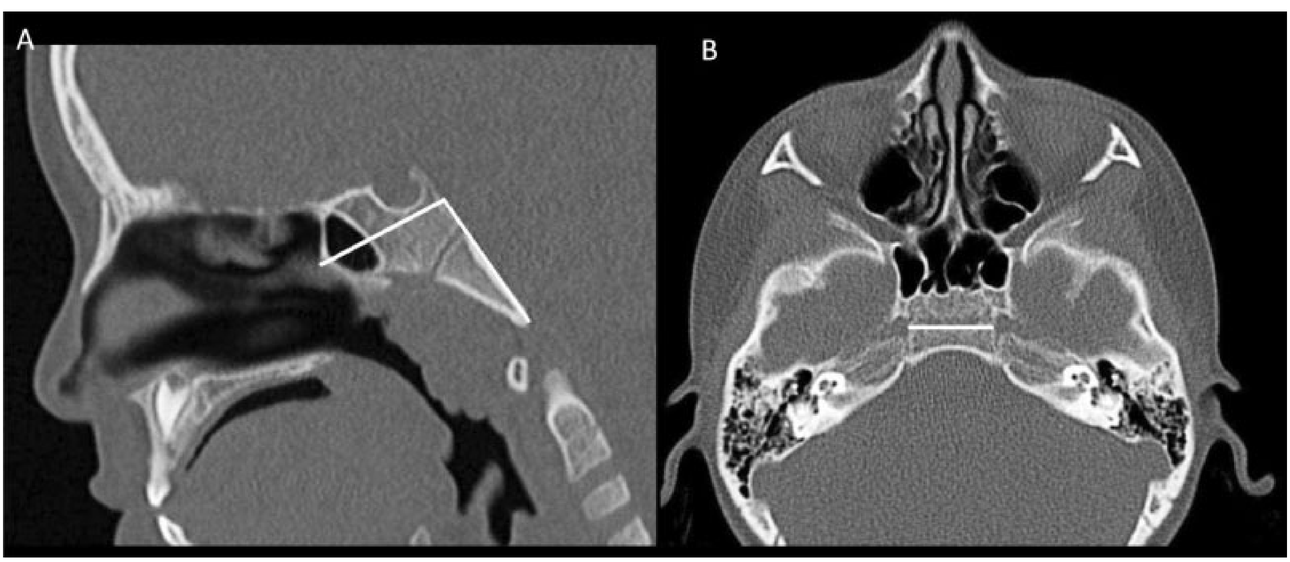

Fig. 4. Measurements of flap dimensions required to reconstruct a transclival approach defect. (A) Flap length required to cover transclival approach defect (SPF-C)—distance from sphenopalatine foramen to clival point tangential to sella floor to inferior clivus in midsagittal plane. (B) Width of transclival approach defect (SKB-CA)—distance between both medial aspects of carotid arteries at their second genu in the axial plane. A summary of all measurement abbreviation definitions are shown in Table I.

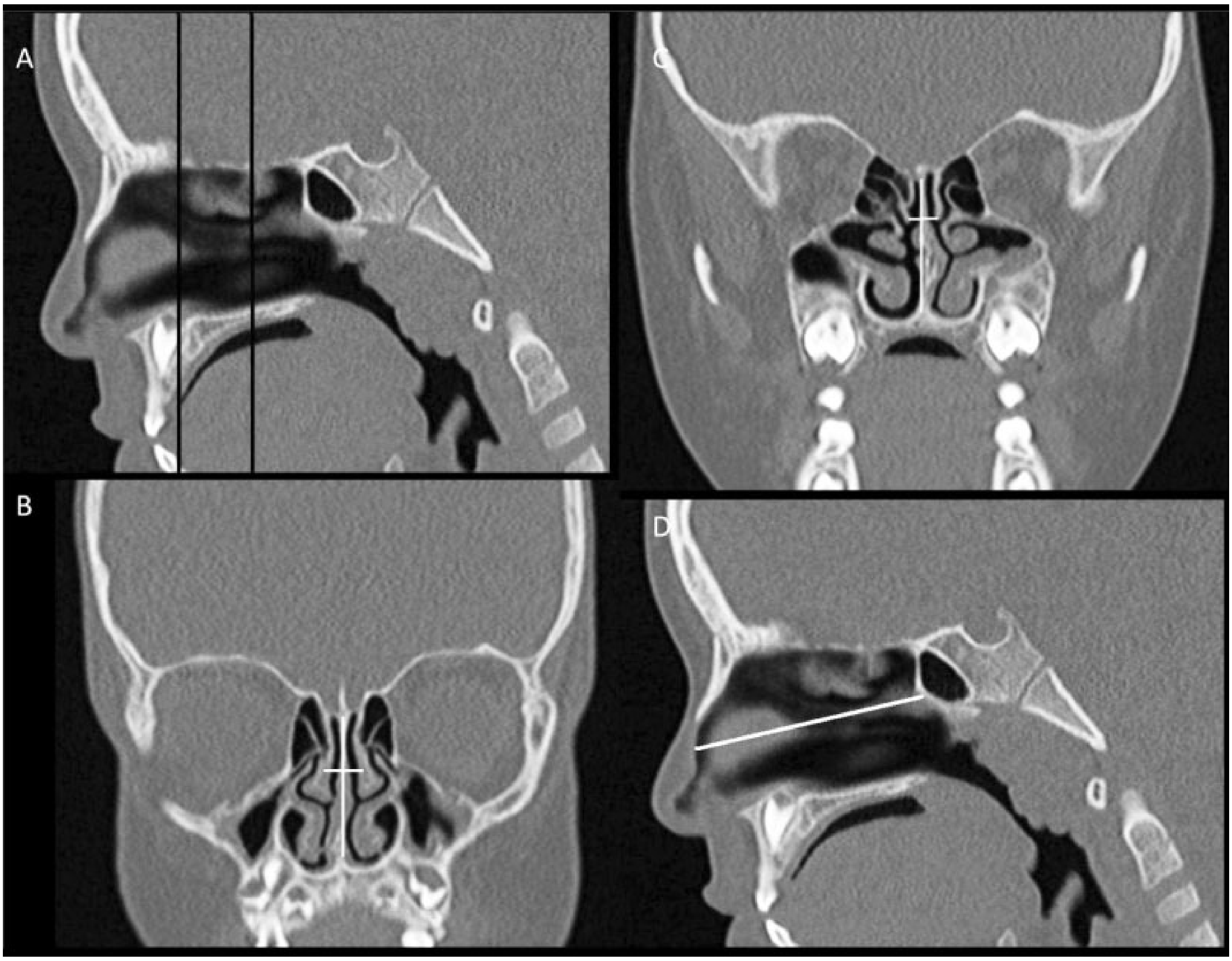

Fig. 5. Measurements of potential nasoseptal flap. (A) Anterior and posterior coronal slices indicated on midsagittal view for flap width measurements. (B) Anterior flap width (AFW)—craniocaudal septum minus 10 mm of cephalad septum in coronal plane at the level of the anterior ethmoidal artery. (C) Posterior flap width (PFW)—craniocaudal septum minus 10 mm of cephalad septum in coronal plane at midpoint between anterior ethmoidal artery and sphenoethmoidal junction. (D) Flap length (FL-SPF-NB)—distance from sphenopalatine foramen projection to anterior border of the nasal bone in a line parallel to the hard palate in the midsagittal plane. A summary of all measurement abbreviation definitions are shown in Table I.

years to 10 years (n = 8), 12 years to 13 years (n = 8), 15 years to 16 years (n = 9), and adults ages 21years to 64 years (n = 10). Measurements were averaged according to age group, and 95% confidence intervals were calculated (Table III). Within each age group, measurements are compared to determine if the anteroposterior (A-P) dimension of the flap (length) would be sufficient to cover A-P defects of each approach, and to determine

TABLE II.
Pediatric Nasoseptal Flap Outcomes.

Patient	Age, y	Pathology	Approach/Module	Flap Coverage	Postoperative Leak
1	10	CP	Trans-sellar, transdorsal	80%	Yes
2	14	GSW to cribriform	Transcribriform	100%	No
3	14	Olfactory meningioma	Transcribriform	100%	No
4	17	PA	Trans-sellar	100%	No
5	11	CP	Trans-sellar, transplanar	90%	No
6	12	CP	Trans-sellar, transplanar	100%	No

CP = craniopharyngioma; GSW = gunshot wound; PA = pituitary adenoma.

TABLE III.
Measurements of Skull Base Lengths (Including Flap Pedicle), Skull Base Widths, and Nasoseptal Flap Length and Width Stratified by Age Group.

Measurement	<24 mo (n = 8)	3–4 y (n = 8)	6–7 y (n = 9)	9–10 y (n = 8)	12–13 y (n = 8)	15–16 y (n = 9)	Adults (n = 10)
SPF-SKB	3.50 (3.27–3.73)	4.69 (4.52–4.85)	5.11 (4.74–5.48)	5.12 (4.74–5.51)	5.15 (4.96–5.34)	5.35 (4.89–5.80)	5.44 (5.29–5.59)
SPF-S	3.83 (3.55–4.10)	4.78 (4.40–5.16)	4.98 (4.52–5.44)	4.98 (4.73–5.22)	5.78 (5.40–6.19)	5.92 (5.56–6.28)	5.84 (5.47–6.22)
SPF-C	4.06 (3.76–4.36)	5.44 (4.19–5.68)	5.93 (5.66–6.20)	5.98 (5.70–6.25)	6.63 (6.35–6.90)	6.92 (6.61–7.24)	6.89 (6.48–7.29)
SKB-AEA	1.28 (1.22–1.34)	1.66 (1.46–1.87)	2.03 (1.89–2.17)	2.27 (2.09–2.44)	2.41 (2.29–2.52)	2.44 (2.32–2.56)	2.05 (1.79–2.31)
SKB-PES	1.14 (1.03–1.25)	1.59 (1.43–1.74)	2.04 (1.86–2.21)	1.95 (1.80–2.10)	2.23 (2.04–2.41)	2.51 (2.32–2.56)	2.47 (2.32–2.61)
SKB-OA	1.15 (1.11–1.20)	1.33 (1.23–1.44)	1.57 (1.41–1.72)	1.55 (1.35–1.73)	1.91 (1.76–2.07)	1.94 (1.80–2.08)	1.93 (1.78–2.07)
SKB-CA	1.26 (1.17–1.36)	1.72 (1.65–1.79)	1.80 (1.68–1.93)	1.83 (1.63–2.02)	1.98 (1.85–2.10)	2.06 (1.93–2.19)	1.76 (1.58–1.93)
FL-SPF-NB	3.38 (3.13–3.63)	4.59 (4.43–4.75)	5.05 (4.84–5.26)	5.20 (4.99–5.41)	5.81 (5.49–6.12)	6.03 (5.84–6.22)	6.22 (5.86–6.58)
AFW	0.98 (0.78–1.16)	2.08 (1.92–2.23)	2.20 (1.97–2.44)	2.86 (2.68–3.03)	3.00 (2.76–3.23)	3.15 (2.93–3.37)	3.02 (2.75–3.28)
PFW	1.01 (0.83–1.19)	1.85 (1.65–2.05)	2.00 (1.72–2.28)	2.36 (2.20–2.53)	2.63 (2.42–2.84)	2.88 (2.65–3.11)	2.96 (2.68–3.23)

See Table I for abbreviation definitions. Averages are in centimeters. 95% confidence intervals are in parentheses.

if flap width would be adequate to cover the latero-lateral aspects of each skull base defect. Figure 6 shows septal growth compared to skull base growth.

Transcribiform/Anterior Skull Base Approach

After a transcribiform EEA, reconstruction would require covering a defect that extends from the posterior frontal sinus to the anterior wall of the sphenoid sinus from lamina papyracea to lamina papyracea. In patients <24 months of age, a nasoseptal flap would be insufficient in length and width to cover this skull base defect. Adults, however, have septal lengths and widths that would cover an anterior skull base defect by over 5 mm in each dimension. In order to evaluate when septal growth allows for sufficient coverage of transcribiform approach defects, potential nasoseptal flap length was compared to anterior skull base defect length; ratios are graphically represented (Fig. 7). Septal length is insufficient to cover the length of the defect in this approach until the age of 9 years to 10 years (ratio >1). After the age of 13 years, septal length approaches full adult size. Septal width provides adequate coverage of the latero-lateral defect of the transcribiform approach in most patients, except those very young.

Trans-Sellar/Transplanar Approach

The trans-sellar approach for skull base lesions results in a defect that approximates the size of the inner surface of the sphenoid and spans the distance between optic nerves. The 6- to 7-year-old age group and above have sufficient septal length to reconstruct this defect with the pedicled nasoseptal flap. The nasoseptal flap would be wide enough to cover the defect width in all but the youngest age group.

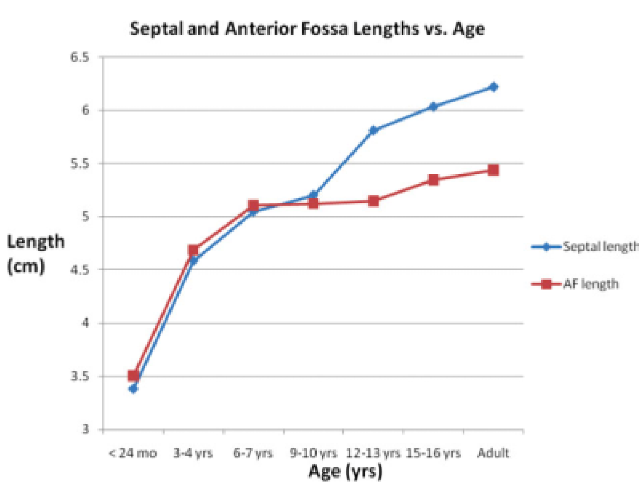

Fig. 6. Graphical representation of flap length (FL-SPF-NB) growth and anterior skull base (SPF-SKB) growth. Rate of septal growth is most rapid between the ages of 10 years and 13 years. AF = anterior fossa. A summary of all measurement abbreviation definitions are shown in Table I. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

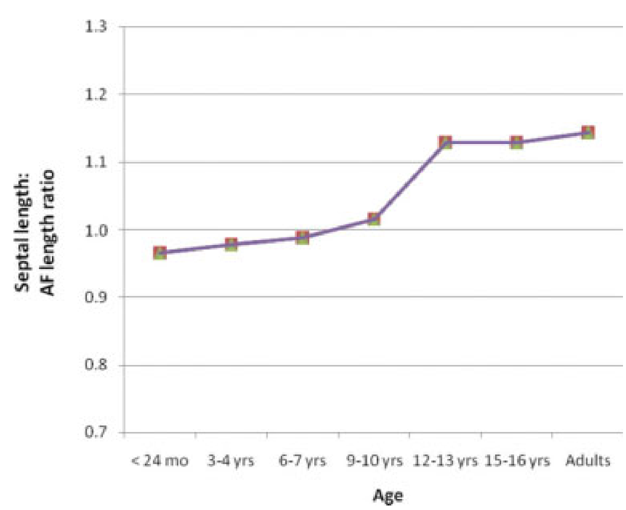

Fig. 7. Graphical representation of the ratio of flap length (FL-SPF-NB) to anterior skull base approach defect (SPF-SKB) according to age. AF = anterior fossa defect. A summary of all measurement abbreviation definitions are shown in Table I. [Color figure can be viewed in the online issue, which is available at www.interscience.wiley.com.]

Transclival Approach

The nasoseptal flap must be long enough to cover the inferior two-thirds of the clivus and its distance to the SPF after a transclival approach. In only three adult patients was the nasoseptal flap length sufficient to cover a transclival approach defect. Septal lengths of all pediatric patients were too short for adequate reconstruction of transclival approach to skull base lesions. Again, flap width was greater than defect width in all age groups except the youngest.

DISCUSSION

The nasoseptal flap has become the work horse for vascularized endoscopic skull base reconstruction. It has been shown to be a highly reliable technique that has reduced the incidence of postoperative CSF leaks after EEA.[6] The main goal of reconstruction is isolation of the cranial cavity from the sinonasal tract. Preoperative anticipation of its use and optimal design is essential to its success. The area of the skull base defect and the potential dimensions of the nasoseptal flap are important when considering reconstruction. Radioanatomic analysis of four adults has shown that the potential length of the nasoseptal flap is adequate to cover anterior skull base, transsphenoidal, and transclival defects independently.[5]

In children, open craniofacial resection followed by regional flap reconstruction (pericranial or temporalis muscle) is the traditional approach to skull base disease.[9] Considering the impact on craniofacial growth and the morbidity of an open approach, minimally invasive endoscopic resection is gaining popularity in the pediatric population. Regional flap reconstruction after EEA would require a separate external approach and add to the morbidity of the procedure. The pedicled nasoseptal flap is a desirable option in these cases; however, its use in children is not well described.

It has been well established that the rate of cranial growth exceeds the rate of facial growth early in life. Scott's craniofacial analysis showed that at 10 years, cranial measurements reached or exceeded 95% of adult size, whereas facial measurements had only reached 85% of adult size.[10] Because the nasoseptal flap must be harvested before resection, its use must be determined prior to surgery, and the dimensions must be adequate to cover the anticipated defect. Determination of potential flap and skull base dimensions at various ages will aid the surgeon in choosing the reconstructive technique for individual patients.

Prospective analysis of six pediatric patients who underwent EEA and nasoseptal flap reconstruction showed that children less than 14 years of age were more likely to have inadequate skull base defect coverage, whereas patients greater than 14 years of age had adult-sized septums and successful flap coverage. Our radioanatomic results confirm this observation.

Waitzman et al. used CT scans to analyze growth trends of the craniofacial skeleton in 525 patients ages 0 years to 17 years. Mean anterior interorbital distance at 3 years was 19.3 mm (95%CI, 15.6–23.0), and at 15 years was 23.5 mm (17.8–29.2).[7] Our mean anterior skull base width at the level of the anterior ethmoidal artery (SKB-AEA) at ages 3 years to 4 years and 15 years to 16 years lie within the confidence intervals calculated by Waitzman.

In the method determined by Pinheiro-Neto for potential nasoseptal flap dimensions, the mean potential flap length in four adults was 72 mm.[5] We found a mean length of 6.22 cm (95%CI 5.86–6.58) for 10 adults. The small difference in results may be a result of our conservative choice in the anterior most aspect of flap length. Mean anterior skull base defect length (53 mm) and transclival length (66.7 mm) in the pilot study lie within our confidence intervals. Mean trans-sellar length (63.7 mm) lies only 1.5 mm outside of our confidence interval.[5] This may be due to a our slight variation in the measurement technique.

Our results regarding skull base and potential flap measurements are in accord with previous literature, thus validating the method of radioanatomic analysis by CT. The main objective of this study was to determine if the nasoseptal flap is a viable option for skull base reconstruction in pediatric patients. We show that children <9 years to 10 years had inadequate septal length to cover anterior skull base defects. Septal lengths in children <6 years to 7 years were also insufficient to adequately cover defects following a trans-sellar approach. Potential flap lengths in all pediatric patients were too small to reconstruct transclival defects. It should also be considered that some flap contraction occurs, and flap design should overestimate the size of the defect.

CONCLUSIONS

The pedicled nasoseptal flap may not be a viable option for reconstruction after EEA in children <10 years of age. Septal growth is most rapid between the ages of 10 years and 13 years. Use of the nasoseptal flap in these patients requires careful consideration of individual facial analysis and skull base and septal measurements of preoperative imaging. Prospective clinical data and radioanatomic analysis show that septal length approaches adult size in patients >13 years to 14 years of age.

Although this study attempts to provide normative values and growth trends of the nasal septum and skull base, individual variation in anatomy may make this impossible. Preoperative measurements for each patient should be undertaken when considering the nasoseptal flap for reconstruction to prevent inadequate coverage of the defect and to avoid having to choose another reconstructive technique intraoperatively. The minimally invasive endoscopic pericranial flap may provide another option for endonasal reconstruction when the nasoseptal flap cannot be used. Preliminary data shows reliability, good outcome, and minimal morbidity with this technique (unpublished data).

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