Lack of Sphenoid Pneumatization Does Not Affect Endoscopic Endonasal Pediatric Skull Base Surgery Outcomes

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**Objectives/Hypothesis:** Currently, due to the rarity of pathology, there are limited data surrounding outcomes of pediatric skull base surgery. Traditionally, surgeons have proceeded with caution when electing endonasal endoscopic transsellar/transplanum approaches to the skull base in pediatric patients due to poor sphenoid pneumatization. In this study, we review outcomes of endoscopic pediatric skull base surgery based on sphenoid pneumatization patterns.

**Study Design:** Retrospective chart review.

**Methods:** A review of all cases of pediatric (age < 18 years) craniopharyngioma managed via an endoscopic endonasal approach at a tertiary academic medical center.

**Results:** A total of 27 patients were included in the analysis. The median age was 8 years. Nineteen (70%) patients were male. Presellar, sellar/postsellar, and conchal sphenoid pneumatizations were found in 6, 11, and 10 patients, respectively. There was no significant association between sphenoid pneumatization pattern and extent of resection (gross vs. subtotal, \( P = .414 \)), postoperative cerebrospinal fluid (CSF) leak (\( P = .450 \)), intraoperative estimated blood loss (\( P = .998 \)), total operative time (\( P = .540 \)), and length of stay (\( P = .336 \)). On multivariate analysis, after accounting for age, sex, preoperative cranial nerve involvement, and cavernous sinus invasion, there remained no significant association between sphenoid pneumatization pattern and extent of resection (\( P = .999 \)) and postoperative CSF leak (\( P = .959 \)).

**Conclusions:** Sphenoid pneumatization pattern does not appear to affect outcomes in endoscopic skull base surgery in the pediatric population. Importantly, lack of sphenoid pneumatization does not impede gross total resection or increase complications. Thorough knowledge of the anatomy during the endoscopic approach is critical to optimize outcomes.

**Key Words:** Skull base surgery, outcomes, sphenoid, sella, cerebrospinal fluid leak, craniopharyngioma.

**Level of Evidence:** 4

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**INTRODUCTION**

Pediatric skull base tumors are a rare entity, presenting only 5% to 6% of all skull base tumors. The most common benign pathologies include craniopharyngiomas, nerve sheath tumors, and juvenile nasopharyngeal angiofibroma, whereas the most prevalent malignant pathologies include chondrosarcoma, chordoma, and rhabdomyosarcoma. Typically, treatment of pediatric skull base tumors is accomplished via surgical resection, historically carried out through an open approach. More recently, the expanded endoscopic approach (EEA) has gained in favor due to improved endoscopic techniques and the benefits of minimizing several potential morbidities associated with open procedures. Serious intraoperative complications of EEA to the skull base are rare, but can involve damage to critical neurovascular structures including the internal carotid artery, optic nerves or chiasm, or other cranial nerves.

A unique aspect of applying EEA to pediatric skull base tumors is the variable degree of sphenoid sinus development. The sphenoid sinus is often filled with solid bone at birth, but begins the process of pneumatization as early as 4 months of age (generally around age 3 years) but does not reach maturity until approximately age 10 to 14 years. An incompletely pneumatized sphenoid sinus necessitates drilling of the sphenoid bone to access the sella and parasellar region, decreasing working room and potentially increasing operative time. Additionally, a poorly developed sinus precludes intraoperative visualization of bony landmarks (i.e., opticocarotid recess) for locating crucial neurovascular structures. This has led many to...
propose that incomplete sphenoid sinus pneumatization represents a relative contraindication to the EEA due to the theoretical increased risk of major intraoperative complications. However, more recent proficiency with endoscopic access and widespread adoption of intraoperative navigational imaging appears to have augmented the skull base surgeon’s ability to safely perform skull base resection in even the youngest of patients.

As surgeons become more adept in utilizing the EEA in skull base tumor resection, it is important to assess whether incomplete sphenoid sinus development poses a clinically significant barrier to employing this approach for pediatric patients. This study aimed to evaluate the relationship between the extent of sphenoid sinus pneumatization and intraoperative and postoperative outcomes. It is the hope that this analysis will provide further clarity on the relative risks and benefits of utilizing an EEA for resection of skull base tumors in pediatric patients.

MATERIALS AND METHODS

Institutional review board approval was obtained for this study. A retrospective chart review of all cases of pediatric (age < 18 years) craniopharyngioma managed via EEA at a tertiary academic children’s hospital was performed. The study period spanned from May 2011 through December 2017. Cases where open approaches to the skull base were utilized, or when the intent of resection was sub-total (e.g., decompression to prevent endocrinopathies), were excluded. All surgeries were performed by a multidisciplinary team of two rhinologists/skull base surgeons (J.N. P., N.D.A.) and a pediatric neurosurgeon (P.B.S. and/or J.Y.K.L.). Cranio-pharyngioma is a benign cystic tumor arising from epithelial cells within the remnant Rathke’s pouch (embryonic anterior pituitary gland) (Fig. 1). They tend to be expansile and may undergo cystic change and formation of calcium deposits, and general management recommendations including complete surgical removal of the tumor, with radiation and chemotherapeutic agents (e.g., BRAF inhibitors) playing a more adjunctive role. It was selected as the skull base lesion for comparing transsphenoidal approaches to the sella due to its consistent anatomic primary site (suprasellar area), presentation across the entire spectrum of pediatric age ranges, and need for wide endoscopic access for complete resection. All cases included use of a real-time, intraoperative, image guidance navigation system (Fusion ENT Navigation; Medtronic Inc., Fridley, MN). No lumbar drains were used in the perioperative and postoperative periods. By design, all cases required creating a surgical corridor to the suprasellar region, leading to a high-flow intraoperative cerebrospinal fluid (CSF) leak, which was, in all cases, repaired using a multilayer strategy involving synthetic dural substitute (Duragen; Integra Life Sciences, Plainsboro, NJ), fat graft, fascia lata graft, and a pedicled vascularized nasoseptal flap.

For each case, age at diagnosis, sex, preoperative cranial nerve involvement (visual changes, extraocular movements restriction), and the presence of cavernous sinus invasion were collected. Sphenoid pneumatization pattern (conchal, presellar, sellar, post-sellar) as previously described by Hamberger et al. was determined through review of each patient’s preoperative high-resolution computed tomography scan (Fig. 2). In cases of poorly pneumatized sphenoid sinuses, wide access to the planum sphenoidale, tuberculum sella, and sellar floor was accomplished through removal of sphenoid bone using a powered high-speed drill. For purposes of analysis, sellar and post-sellar pneumatization patterns generally do not require additional drilling for access, and thus are categorized together. Outcomes assessed included intraoperative estimated blood loss (in milliliters), total operative time (in minutes), extent of resection (gross total vs. subtotal), length of hospital stay (in days), and the presence of a postoperative CSF leak.

Comparisons between categorical and continuous variables were performed using the Fisher exact test or $\chi^2$ test and two-tailed Student $t$ test, respectively. Correlations were calculated using the Spearman coefficient. Multivariate regression was performed to identify correlations between covariates and outcome variables, followed by multivariate logistic regression to determine independent predictors of any given outcome. All statistical testing was performed using SPSS 21 (IBM, Armonk, NY). A significance level of $P = .05$ was used for all comparisons.

RESULTS

A total of 27 patients were included in the analysis. Table I summarizes the baseline characteristics of the

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Laryngoscope 129: April 2019

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Kuan et al.: Sphenoid Pneumatization Skull Base Outcomes

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833
study cohort. Conchal, presellar, and sellar/postsellar, sphenoid pneumatizations were found in 10 (37%), six (22%), and 11 (41%) patients, respectively. No carotid artery or optic nerve injuries, as well as unanticipated intraoperative CSF leaks, were encountered in any case.

Table II summarizes frequency tables for sphenoid pneumatization patterns as they relate to extent of resection and postoperative CSF leak. On bivariate analysis, there was no significant association between sphenoid pneumatization pattern and extent of resection (gross vs. subtotal, \( P = .414 \)), postoperative CSF leak (\( P = .450 \)), intraoperative estimated blood loss (\( P = .098 \)), total operative time (\( P = .540 \)), and length of stay (\( P = .336 \)). On multivariate analysis, after adjusting for age, sex, preoperative cranial nerve involvement, and cavernous sinus invasion, there remained no significant association between sphenoid pneumatization pattern and extent of resection (\( P = .999 \)) and postoperative CSF leak (\( P = .959 \)).

**DISCUSSION**

With improved powered instrumentation and developments in high-definition imaging, the frontiers of what can be achieved with endoscopic techniques have been pushed over the last few years. Surgeons’ ability to work effectively within the endoscopic endonasal corridor has been drastically expanded, with pediatric skull base surgery now being performed safely and oncologically at centers with specialized expertise. Pediatric craniopharyngiomas were traditionally thought to be a difficult disease to surgically manage in a minimally invasive manner. Although its location in the suprasellar area would appear to make it amenable to endonasal resection, the incomplete pneumatization of the sphenoid in the pediatric population gave many surgeons pause. Our case series, the largest of its kind to explore this topic, presents convincing data that the degree of sphenoid pneumatization should not impact choice of surgical approach. Specifically, presellar or conchal pneumatization had no impact on intraoperative blood loss,

![Fig. 2. Examples of variability in pediatric sphenoid pneumatization patterns, including conchal (left), presellar (middle), and postsellar (right) patterns.](image-url)
postoperative CSF leak rates, hospital admission length, and the ability to perform a complete resection, thereby showing the safety and validity of this approach.

The poorly pneumatized sphenoid sinus, specifically the presellar and conchal patterns, is characterized by encasement of the normally visible posterior and lateral sphenoid wall landmarks (i.e., sellar bulge, opticocarotid recess) by thick, dense bone (Fig. 3). It is not surprising that earlier reports of transnasal, transsphenoidal access to the sella and parasellar region in these cases were met with some trepidation, as the bony wall itself provides no visualization of landmarks and therefore no cues as to the extent of posterolateral dissection. Furthermore, the bone tends to be predominantly marrow-rich, and tends to bleed significantly upon instrumentation. Thus, it is critical to proceed with caution through this portion of the dissection, and intraoperative image guidance is extremely helpful for orientation. Use of the Doppler probe to identify the parasellar carotids may be indicated.10

In the adult literature, the prevalence of the conchal and presellar patterns is much lower, together accounting for less than 10% to 20% of cases.15,16 However, in the pediatric population, sphenoid pneumatization begins around age 3 years and is generally complete around age 10 to 14 years.4 The growth pattern seems to proceed in a temporal and posterior fashion.17 Similarly, in the current study cohort, 19 of 30 (63%) of patients had poorly pneumatized sphenoid sinuses, suggesting that the likelihood of encountering challenging sphenoid anatomy is high in this population.

The key to successful access is slow, methodical dissection, with reliance on extrasphenoid landmarks (e.g., maxillary sinus, ethmoid skull base) for orientation. Adequate lateral access is important to facilitate a two-surgeon, four-hand approach, whereas superior access is necessary to gain exposure of the anterior extent of the tumor within the suprasellar cistern.18 Furthermore, complete exposure of the planum and sellar floor are essential in accommodating reconstruction using a nasoseptal flap, as there needs to be enough room for the flap

![Fig. 3. Triplanar image of conchal sphenoid pneumatization pattern in a pediatric patient. Note that there is dense bone filling the sphenoid sinus without discernable landmarks.](image)

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<thead>
<tr>
<th>TABLE II. Frequency for Sphenoid Pneumatization and Extent of Resection and Postoperative CSF Leak</th>
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<tbody>
<tr>
<td>Extent of Resection</td>
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<td>Sphenoid pneumatization</td>
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CSF = cerebrospinal fluid.
to lay over bone edges without being furled on itself, risking pedicle compression or poor surface adherence. In a series of 296 patients with pituitary adenomas, Hamid et al. reported that dissection through a conchal sphenoid required a significantly longer operative time, reflecting the additional care surgeons should be mindful of while proceeding through this part of the case. In the current study, we found that, despite wide variations in patient age, corridor size, and sphenoid pneumatization patterns, by employing the strategies above, there was no impact upon tumor resection and reconstruction outcomes. Furthermore, no differences were found in perioperative blood loss, total operative time, or length of hospital stay, suggesting that, overall, dissection through a non-pneumatized or poorly pneumatized sphenoid sinus is safe and effective for accessing the skull base.

Possible explanations for the lack of differences in outcomes based on sphenoid pneumatization pattern were reviewed. No significant differences in estimated blood loss more likely reflects variability of the surgical cavity itself, namely mucosal bleeding from the sinuses, especially as some children with allergic inflammation of the nose tend to exhibit more oozing. No large-caliber vascular injury was encountered. In addition, though drilling the conchal sphenoid exposes marrow that can bleed readily, the use of a diamond burr with some thermocauterative properties, as well as topical hemostasis using thrombin gelatin and microfibrillar collagen, tends to minimize the severity of these bleeds. Despite more effort required to drill open the sphenoid bone (anecdotally, adding approximately 5–30 more minutes as compared to a pneumatized sphenoid sinus), total operative time more likely reflects differences in time needed for dissecting the tumor itself. Finally, lack of differences in hospital stay is more dependent on medical issues that arise postoperatively, such as hyponatremia and diabetes insipidus, rather than surgical factors.

CONCLUSION

Sphenoid pneumatization pattern does not appear to affect outcomes in endoscopic skull base surgery in the pediatric population, including the youngest of patients. Importantly, lack of sphenoid pneumatization does not impede the ability to attain gross total resection or increase perioperative or postoperative complications, and is thus not a contraindication for the endoscopic endonasal approach in pediatric patients.

BIBLIOGRAPHY