Surgical Distance to the Sphenoid Ostium

A Comparison of Healthy Patients and Patients With Cystic Fibrosis

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Objectives: To establish and compare the distance and angle from the limen nasi to the sphenoid ostium in pediatric patients with normal sinonasal anatomy vs pediatric patients with cystic fibrosis (CF).

Design: Retrospective review of computed tomographic images.

Setting: Tertiary university-based medical center.

Participants: Patients (newborn to age 20 years) with normal sinonasal anatomy (n=117) or CF (n=15).

Main Outcome Measures: We used a fourth-degree polynomial to curve-fit the distance to the sphenoid ostium vs age for patients with normal sinonasal anatomy, producing a coefficient of determination (R²) of 82%. With this regression curve, we produced a normative distance equation and a normative distance graph using age to predict the distance (95% confidence interval). We validated the normative distance curve fit among 30 new pediatric patients.

Results: No significant difference in the distance to the sphenoid ostium was found between healthy patients and patients with CF. There was no correlation between age and angle in either patient group. The mean (SD) angle was statistically different between healthy patients (37.5° [7.5°]) and patients with CF (41.4° [7.4°]).

Conclusions: Using a normative distance graph and the mean angle, surgeons performing pediatric endoscopic sinus surgery can predict the distance to the sphenoid ostium for healthy patients and for patients with CF. These findings may decrease complications of endoscopic sinus surgery among the pediatric population.


Endoscopic sinus surgery (ESS) has become the standard management of sinus diseases such as chronic and acute recurrent sinusitis after failure of maximal medical treatment. The goal of ESS is to reestablish normal sinus mucociliary clearance for allergic, infectious, or irritant factors.

Symptoms of chronic sinusitis in children include purulent nasal discharge, irritability, congestion, obstruction, headache, increased nighttime coughing, and halitosis. Approximately 13% to 33% of pediatric patients referred for chronic sinusitis to a tertiary care center undergo ESS.1,2 A meta-analysis3 of pediatric ESS showed that positive outcome rates (mean, 88.7%) in children are comparable to those in adults. However, the percentage cure varies substantially among studies depending on variables such as the type of study conducted, criteria for cure, and duration of follow-up.1,4,5

Major complications from ESS occur in approximately 0.6% of children.3 Possible complications include blindness, orbital hematoma, cerebrospinal fluid leak, carotid artery damage, and death. In contrast to the well-documented adult sinonasal anatomy, pediatric patients may be more prone to complications, as their sinonasal anatomy is generally smaller, is not properly documented, and varies with age.

Exploration beyond the sphenoid sinus may be especially dangerous because of its precarious position relative to vital structures such as the optic nerve and internal carotid artery. To prevent unwanted transgression past the sphenoid boundary, our primary objective was to establish the distance (D₀) and angle (A₀) from the limen nasi to the sphenoid ostium in pediatric patients with normal sinonasal anatomy. Using these normative data, we aimed to create a reference graph for surgeons to predict the D₀. Our secondary objective was to examine whether our normative data could be applied to patients with cystic fibrosis (CF). Such a comparison would allow us to determine if early-onset sinus disease is associated with altered nasal cavity development.
This retrospective study was conducted at the London Health Sciences Centre (London, Ontario, Canada) and comprised 2 main components. Part 1 was aimed at determining D0 and A0 in pediatric patients with normal sinonasal anatomy. Part 2 was designed to determine the effect of early-onset sinus disease on D0 and A0 by comparing normative data in part 1 vs CF data. This study was approved by the London Health Sciences Centre research ethics board.

COMPUTED TOMOGRAPHY

Head and neck, facial, and sinus thin-section computed tomographic (CT) images were obtained from the London Health Sciences Centre radiology database from December 1, 2004, to June 26, 2008. There was no difference in resolution among the 3 types of images. Patients underwent CT for various reasons, including vascular disorders, facial fractures, orbital injury, hydrocephalus, and brain tumors.

Normative Data

The CT images of 117 patients (82 male and 35 female [age range, newborn to 20 years]) were examined. Although pediatric patients were classified as being younger than 18 years, patients up to age 20 years were included to determine the age at which D0 matures. Patients with craniofacial abnormalities and sinus disease (eg, chronic sinusitis and CF) were excluded.

CF Data

Preoperative and postoperative CT images from 15 patients with CF (8 male and 7 female [age range, 3-15 years]) who underwent sinus surgery were examined. Patients with craniofacial abnormalities were excluded.

D0 AND A0 MEASUREMENTS

The CT images were examined using measurement software. The D0 was measured in the sagittal plane (Figure 1). For younger patients with immature sphenoid sinuses, a bilateral indentation in the expected position of the sphenoid ostium was used. The A0 was measured between D0 and a line parallel to the horizontal plane. To test for interrater reliability in measurements, the same radiologist (J.R.) remeasured 5 images, and the intraclass correlation (ICC) was determined for D0 and A0. Higher ICCs correspond to greater concordance between measures in the same patient.

VALIDATING THE NORMATIVE D0 GRAPH

A mathematical program (MATLAB; MathWorks Inc, Natick, Massachusetts) was used to curve-fit D0 vs age to a fourth-degree polynomial and to calculate a 95% confidence interval (CI). Residuals for the curve fit were calculated using the same program. Heteroscedasticity in the standard error was determined by correlating residuals of prediction with age using Pearson product moment correlation. Correlation between age and D0 was determined using the same statistical method. Statistical difference in male vs female A0 was determined by t test.

DETERMINING THE EFFECT OF CF ON D0 AND A0

A t Test was used to determine if there was a significant difference in D0 and A0 between normative data and CF data. The D0 CF data were plotted on the normative D0 graph to determine if these data fell within the 95% CI. Using the fourth-degree polynomial, the ICC was calculated between predicted and measured D0.

ESTABLISHING D0 AND A0 NORMATIVE DATA

We measured D0 in 117 patients (age range, newborn to 20 years) with normal sinonasal anatomy using sagittal CT images (Figure 1). We used a fourth-degree polynomial to curve-fit our data ($R^2=0.82$) and calculated a 95% CI (Figure 2). This graph is called the normative D0 graph. The equation of the normative D0 curve fit is as follows:

$$D_0 = -0.001566(age)^4 + 0.07043(age)^3 -1.069(age)^2 + 7.323(age) + 31.51.$$ 

This equation is called the normative D0 equation. Residuals for the normative D0 curve fit were mostly symmetric (Figure 2). There was significant heteroscedasticity, indicating that age-dependent variance in D0 is likely. D0 plateaus (approximate value, 65 mm) at about age 18 years. Scatterplot examination of A0 vs age showed no clinically significant relationship, and this was confirmed by a Pearson product moment correlation coefficient of -0.044 (Figure 3). The mean (SD) A0 among healthy patients was 37.5° (7.5°). No statistical difference was noted in male vs female A0. As determined by ICCs, interrater reliability was 0.864 ($P<.001$) for D0 and 0.910 ($P<.01$) for A0.

VALIDATING THE NORMATIVE D0 EQUATION AND GRAPH

We measured D0 using CT images of 30 new pediatric patients (age range, 2-20 years) with normal sinonasal anatomy. Data from 1 of 30 patients fell outside of the 95% CI on the normative D0 graph (Figure 4). This 16-year-old patient was diagnosed with CF at age 9 years. He underwent sinus surgery at age 11 years; however, residual sinus disease and early-onset CF sinus surgery prevented his D0 from plateauing.

Figure 1. Sagittal computed tomography image of the head and neck. Distance (D0) was measured from the limen nasi to the sphenoid ostium. Angle (A0) was measured between D0 and a line parallel to the horizontal plane.
old girl underwent facial CT for trauma to the orbit. Using the fourth-degree polynomial, there was high concordance (ICC, 0.892; \( P < 0.001 \)) between predicted and measured \( D_0 \).

**COMPARING NORMATIVE AND CF DATA**

Data (not shown) from all 15 patients with CF fell within the 95% CI of the normative \( D_0 \) graph. Concordance was high (ICC, 0.845; \( P < 0.001 \)) between predicted and measured \( D_0 \) of patients with CF using the fourth-degree polynomial derived from healthy patients. The mean (SD) \( A_0 \) among patients with CF was \(+1.4^\circ (7.4^\circ)\). \( t \) Test revealed no significant difference in \( D_0 \) between healthy patients and patients with CF but showed a significant difference in \( A_0 \) (\( P < 0.05 \)).

**COMMENT**

Literature about sinonasal development is scarce. Most investigations have focused on growth of the paranasal sinuses in pediatric patients, with few researchers commenting on changes to the nasal cavity.\(^6-9\) To our knowledge, no studies have examined \( D_0 \) in children, although \( D_0 \) is well established in adults.\(^10,11\) Our primary objective was to establish \( D_0 \) and \( A_0 \) in pediatric patients with normal sinonasal anatomy. We chose the sphenoid sinus because of its proximity to vital anatomical structures such as the internal carotid artery and optic nerve, which may be minimally protected depending on pneumatization. Although rarely injured, the pituitary gland and trigeminal nerve are also in proximity. Furthermore, the sphenopalatine artery runs anterior to the face of the sphenoid sinus, and damage at this location is a common cause of peri-operative bleeding.\(^12\) For younger patients with incomplete or no pneumatization of the sphenoid sinus, we used a bilateral indentation in the expected position of the sphenoid ostium as a danger boundary.

Major complications of ESS can lead to significant and sometimes irreversible morbidity. These complications include blindness, ocular motility dysfunction, orbital hematoma, nasolacrimal duct injury, cerebrospinal fluid leak, damage to brain tissue or vessels in the anterior cranial fossa, carotid artery or cavernous sinus fistula, and death.\(^13\)

Comparing an initial ESS cohort with a subsequent cohort, Stankiewicz\(^14\) highlighted the learning curve in ESS, showing that complication rates dropped from 29% to 2% for major complications and from 5% to 0.7% for minor complications. Other factors increasing complication risk include depth of visualization, extensive disease, altered
anatomy from previous surgical procedures, and poor visibility from excessive bleeding. In contrast to the well-documented sinonasal anatomy in adults, many of these risk factors are greater for ESS in pediatric patients, as sinonasal anatomy is generally smaller, not properly documented, and variable with age. After performing ESS in more than 200 pediatric patients, Parsons and Phillips found that the thin and small bones of children are more easily damaged. The literature indicates that major complication rates are similar between children and adults. One possibility is that more conservative endoscopic surgical procedures are performed in pediatric patients. In a survey of 175 pediatric otolaryngologists examining ESS trends for pediatric chronic sinusitis, almost 66% perform middle meatal antrostomy and anterior ethmoidectomy, 12% perform middle meatal antrostomy and total ethmoidectomy, and 8% perform middle meatal antrostomy alone. This is in contrast to adults, among whom there is substantially more exploration into the posterior ethmoid and sphenoid sinuses. In a study examining 237 cases of adult ESS, 72% of posterior ethmoid sinuses and 54% of sphenoid sinuses were opened.

To establish a reference for surgeons to predict D₀, we curve-fit D₀ vs age to a fourth-degree polynomial (R² = 0.82) and calculated a 95% CI (Figure 2). A 1996 study by Smith et al examined the distance (measured during surgery) from the anterior nasal spine to the anterior sphenoid wall in patients aged 1.5 to 76 years and found that height and age were the best predictors of this distance for patients younger than 13 years. Their study showed no significant difference in distance past that age, while our normative D₀ curve fit continues to increase until approximately age 18 years. Mature D₀ was approximately 65 mm, similar to published data on D₀ in adults (range, 56.5-66 mm). The age-dependent increase in D₀ variance indicates that the normative D₀ graph is more accurate in predicting D₀ in younger patients. However, the graph may be clinically useful for older pediatric patients with larger variations, as D₀s to vital structures likewise increase with age. Enatsu et al showed that the approximate distance in adults from the sphenoid ostium to the carotid artery was 25 mm and to the optic canal was 16 mm. To validate the normative D₀ graph in our study, D₀ was measured in 30 new pediatric patients. Almost 97% (29 of 30) of these patients fell within the 95% CI of the normative D₀ graph. The fourth-degree polynomial derived from the normative D₀ curve fit closely predicted measured D₀ as reflected by the high ICC. There was no correlation between age and A₀. The mean (SD) A₀ among healthy pediatric patients in our study was 37.5° (7.5°), similar to the mean A₀ of 35.9° measured in adults. Variation in A₀ seems greater in the pediatric population, as a cadaver study in adults showed that the stan-
standard deviation of $A_0$ was approximately 10% of the mean. $t$ Test revealed no difference in male vs female $A_0$. We were unable to determine the significance of sex on $D_0$ because of differences in the male vs female data range, especially among older age groups. The overall ratio of male patients to female patients in our normative data was approximately 3:1, likely skewed by the higher male incidence of facial fractures. A study examining CT use in New Mexico found a similar ratio for head and neck images, and Mettler et al speculated that this was related to a higher male incidence of blunt and penetrating trauma.

Our secondary objective was to determine whether early-onset sinus disease affects $D_0$ or $A_0$ by comparing normative data with CF data. Almost all patients with CF have sinus disease in early childhood, and many have sinus hypoplasia or aplasia. Such anatomical variations may predispose these patients to increased risk of complications secondary to ESS. Our study showed no statistical difference in $D_0$ between normative data and CF data. Despite possible insufficient power in our study, data from all 15 patients with CF fell within the 95% CI of the normative $D_0$ graph, and there was high concordance between predicted and measured $D_0$ using the fourth-degree polynomial. Our study showed a significant difference in $A_0$ between normative data and CF data.

In conclusion, we established $D_0$ and $A_0$ in healthy patients and patients with CF using CT images. Because sphenoid pneumatization begins at age 3 years, there is theoretically a greater risk of penetration into vital structures in younger patients. We recommend that surgeons performing ESS use the 5% CI of the normative $D_0$ graph as a boundary line in pediatric patients and proceed with caution when exploring past this point (Figure 5). The statistical difference in $A_0$ observed herein between healthy patients and patients with CF may not be clinically significant, as there was considerable overlap in the standard deviations of the 2 patient groups. Relative to the hard palate, $A_0$ of 37.5° in healthy patients and 41.4° in patients with CF should be used. Future directions may include equalizing the male vs female range of data to more accurately determine the significance of sex on $D_0$ and including sex as a variable in the normative $D_0$ equation if significant. Another useful study would be to validate these results with intraoperative measurements. Although accuracy, skill, and knowledge are paramount, surgeons performing pediatric ESS may find the data in this study useful when exploring the nasal cavities of healthy patients and patients with CF. These data should decrease complications of ESS by minimizing the risk of penetration into the sphenoid sinus and vital structures.

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Author Contributions: Mr Zhao had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Zhao, Husein, and MacRae. Acquisition of data: Zhao, Chandarana, Rogers, and MacRae. Analysis and interpretation of data: Zhao, Husein, and MacRae. Drafting of the manuscript: Zhao and Chandarana. Critical revision of the manuscript for important intellectual content: Zhao, Husein, Rogers, and MacRae. Statistical analysis: Zhao. Administrative, technical, and material support: Chandarana, Husein, and Rogers. Study supervision: Chandarana, Husein, Rogers, and MacRae.

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REFERENCES