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Can sinus anatomy predict quality of life outcomes and operative times of endoscopic frontal sinus surgery?

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Abstract

Purpose—Endoscopic sinus surgery (ESS) can manipulate sinus anatomy, but with limitations due to skull base and orbit anatomy. These anatomical structures dictate the maximal extent of ESS in the frontal recess and may limit surgical extent or operative duration. This study investigates the impact of these anatomical constraints on operative time and quality-of-life (QOL) outcomes.

Materials&Methods—Patients with medically refractory chronic rhinosinusitis undergoing Draf I/IIa frontal sinus surgery were prospectively enrolled. Anatomic measurements of the frontal sinus anatomy were collected during computed tomography review and included: widest distance between the frontal beak and posterior table, narrowest point in the ethmoid bed, Keros height, presence of an anterior ethmoid artery on a mesentery, and presence of inter-sinus septal cells. Primary outcomes included mean operative time and improvement in SinoNasal Outcome Test (SNOT-22) survey scores.

Results—63 adult participants were enrolled and followed 13.8 (5.2) months on average. The ethmoid bed mean width was 7.2 (1.4) mm, the mean distance from frontal beak to the posterior table at widest was 9.0 (2.7) mm, and mean Keros height 5.1 (1.8) mm. 49/63 (77.8%) of participants had inter-sinus septal cells and 30/63 (47.6%) had anterior ethmoid arteries on a mesentery. Mean operative time was 121.5 (44.0) minutes while SNOT-22 scores significantly

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($p < 0.001$) improved 26.1 (21.6) on average. Anatomic measurements were not predictive of operative time or mean QOL change ($p > 0.050$).

Conclusions—Frontal sinus surgery is an effective treatment for a range of frontal and ethmoid sinus anatomy. Further study with larger sample size and measures of more restricted anatomy might elucidate treatment limitations of ESS.

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1. INTRODUCTION

Endoscopic sinus surgery is an effective means to treat chronic rhinosinusitis (CRS) and is predicated on surgically augmenting natural sinus openings.^{1,2} Although there is controversy over the ideal size and extent of anrostomies and sinusotomies,³ there is evidence that larger openings facilitate increased topical therapies and may better accommodate edema.^{4,5} The literature surrounding sinonasal irrigation has demonstrated that larger sinus openings facilitate greater irrigation volume and improved distribution of topical therapies. The sinuses, however, are tightly nestled between the cranial cavity and orbits which both act as strict anatomical limitations to the extent of a sinus opening during surgery. Furthermore, narrow ethmoid beds, diminutive frontal recesses and low-hanging anterior ethmoid arteries add surgical risk and challenge.

These intraoperative challenges may contribute to retained cells around anterior ethmoid arteries, predispose frontal sinus openings to swelling closed, or contribute to prolonged operative time. Retained cells and sinuses occluded by edematous mucosa may lead to diminished gains of quality of life (QOL) improvements after endoscopic sinus surgery. Given the degree to which anatomy impacts the technical challenges of surgical intervention, the present study seeks to investigate if these anatomic constraints negatively impact QOL outcomes and operative times in a surgical subpopulation requiring intervention of the frontal sinuses.

2. MATERIALS AND METHODS

2.1 Inclusion and Exclusion Criteria

All protocols and informed consent were approved by the Institutional Review Board at Oregon Health & Science University (OHSU; eIRB #7198). Adult (> 18 years) study participants were enrolled and followed at OHSU as part of an on-going, prospective, observational cohort study that has been previously reported.^{1,6–10} These subjects were enrolled prospectively between April, 2011 and July, 2013. All subjects had a diagnosis of CRS based on the Rhinosinusitis Task force criteria¹¹ and were enrolled when the subjects elected to pursue ESS after failing either broad-spectrum or culture-directed antibiotics and a trial of oral and topical steroid therapy.

Study participants elected endoscopic sinus surgery (ESS) as the next treatment modality to assist in control of symptoms associated with CRS. Surgical extent was dictated by individual disease processes and the intraoperative clinical judgment of the enrolling physician (TLS). Participants were either primary or revision surgery cases. Surgical procedures included various combinations of the following: unilateral or bilateral maxillary

anrostomy, partial or total ethmoidectomy, sphenoidotomy, middle or inferior turbinate reduction, frontal sinus procedures (Draf I, IIa/b, or III), and septoplasty.

Only subjects undergoing ESS of the frontal sinuses were included for final study analyses. Frontal sinus surgery was defined as removal of all frontal recess cells between the lamina papyracea and the middle turbinate (Draf IIa) or between the lamina papyracea and the nasal septum (Draf IIb). This prospectively collected dataset did not originally include information regarding sinonasal anatomy associated with the frontal region; therefore, this cohort was retrospectively investigated for study participants with a preoperative computed tomography (CT) scan available for review.

Participants with at least six-month postoperative follow-up data were included for final analysis. Any participant presenting with exacerbations of recurrent acute rhinosinusitis or comorbid cystic fibrosis were excluded due to the heterogeneity of those disease processes.

2.2. QOL Evaluation and Objective Testing

Consented participants were administered the 22-item Sinonasal Outcome Test-22 (SNOT-22)¹² at the initial, preoperative enrollment meeting and at least 6 months postoperatively. The SNOT-22 evaluates physical, functional and emotional impact of chronic rhinosinusitis and includes all symptomatic criteria set forth by the Rhinosinusitis Task Force.¹¹ Total scores range from 0 (no impact) to 110 (most severe impact). Baseline scores and mean change scores were used to evaluate post-treatment clinical improvement. Prior study has defined improvement in this population and established the minimal clinically important difference (MCID) of the SNOT-22 score as 8.9 (9.0) in a population undergoing sinonasal surgery.¹²

Objective measures of CRS included conventional CT and visual endoscopic evaluations. Computed tomography scans were obtained preoperatively and evaluated by the enrolling surgeon (TLS) in the coronal plane using the Lund-Mackay scoring system (0–24 point scale).¹³ Rigid sinonasal endoscopy procedures were performed preoperatively and at least 6 months postoperatively when possible. The last available endoscopic exam was used to determine for postoperative changes from baseline. Bilateral endoscopic examinations were quantified using the scoring system described by Lund and Kennedy (0–20 point scale).¹⁴

2.3. Predictive Anatomic Measurements

Computed tomography scans were reviewed using a triplanar view from a picture archiving and communication system (IMPAX, Agfa HealthCare Corp., Greenville, SC., USA) to identify four anatomic parameters related to the frontal recess: anterior-posterior (A-P) distance (mm.), Keros height (mm),¹⁵ narrowest ethmoid width (mm) and presence of either intersinus septal cells or an anterior ethmoid artery on a mesentery. A digital caliper was used for all measurements. The A-P distance was defined as the widest point of the plane at the junction of the frontal recess and the frontal sinus. This plane is defined by the line that forms a tangent simultaneously to the frontal beak and posterior table on the sagittal view (Figure 1). Keros height was measured on the coronal view from the ethmoid roof to the cribriform plate (Figure 2).¹⁵ Ethmoid width was defined and measured at the narrowest distance that begins perpendicular to the lamina papyracea and ends at the lateral lamella of

the cribiform plate (Figure 3). Paired measurements were averaged between both sides to generate a single reportable measure. Presence of an intersinus cell was reported as a dichotomous variable (Yes/No) if the frontal sinus beak was pneumatized (Figure 4).¹⁶ If the anterior ethmoid artery was at any point distinctly inferior to and free of the ethmoid skull base, then it was defined as being on a mesentery in a binary (Yes/No) fashion (Figure 5).

2.4. Operative Time

Total operative time (minutes) was collected using perioperative surgical records. The total operative time was determined from time of day of the primary surgical incision, as marked by the operative nurse, to the time of operative closure. Time associated with intubation and extubation were not included in total operative time evaluations.

2.5. Statistical Analysis

De-identified study data was collected and transferred from standardized clinical research forms into a relational database (Microsoft Access; Microsoft Corp., Redmond, WA, USA). All statistical analyses were performed using a commercially available software program (SPSS v.22; IBM Corp., Armonk, NY, USA). Descriptive analytics were completed for all study subject characteristics and anatomic sinus parameters to assess distribution normality, mean, standard deviations, and data ranges. Matched pairs t-testing was used to evaluate significant improvement in SNOT-22 total scores between preoperative and postoperative assessments. Pearson's correlation coefficients (r_p) were used to evaluate linear associations between mean improvements in SNOT-22 scores (postoperative – preoperative scores) and all continuous measurements of frontal anatomy. Independent t-testing was used to evaluate differences in improvement in SNOT-22 score measures and mean operative time across binary measures of frontal anatomy and extent of frontal surgery. Pearson's chi-square (χ^2) tests and Fisher's exact tests were also utilized to evaluate significant differences in the prevalence of improvement (one or more MCID) in SNOT-22 scores across any binary measure of frontal anatomy where appropriate. Significant associations were determined at a conventional 0.050 alpha level.

3. RESULTS

3.1. Preoperative Patient Characteristics and Disease Severity

A total of 63 enrolled patients who met all study inclusion criteria comprised the final study cohort. Mean postoperative follow-up time was 13.8(5.3) months. Study participant characteristics and extent of sinus surgery descriptors are noted in Table 1 while preoperative anatomic measurements are described in Table 2.

3.2. QOL Outcomes and Associations with Anatomy

Preoperative mean SNOT-22 scores were 58.7(19.7) with a postoperative mean score was 32.6(20.9). SNOT-22 scores were found to significantly improve over time ($p<0.001$) with a mean change of 26.1(21.6). A total of 54 (85.7%) of individual subjects undergoing frontal sinusotomy improved on SNOT-22 survey scores to a MCID (≥ 9).

There were no significant correlation coefficients between any of the continuous anatomic variable measurements and mean improvement in SNOT-22 scores over time ($r_p = 0.186$; $p = 0.163$) nor was there significant differences in mean improvement on SNOT-22 scores between subgroups with or without intersinus septal cells (26.5(22.4) vs. 28.8(20.4); $p=0.752$) or with or without an AEA on a mesentery (29.5(16.3) vs. 24.3(26.3); $p=0.372$). Likewise, there were no significant associations between patients achieving a MCID on SNOT-22 improvement and those who did not report that level of improvement for average widest A-P distance (8.9(2.7) vs. 9.9(2.4); $p=0.311$), Keros height (5.2(1.9) vs. 4.9(1.0); $p=0.704$), or narrowest ethmoid width (7.2(1.4) vs. 7.3(1.1); $p=0.746$). Similarly, there was no significant difference in the frequency of intersinus septal cells ($\chi^2=1.89$; $p=0.329$) or AEA on a mesentery ($\chi^2=2.16$; $p=0.142$) across patient groups who improved on SNOT-22 scores to at least one MCID value, compared to those subjects who did not improve.

3.3. Anatomic impact on operative time

Mean operative time was not significantly associated with the presence or severity of any anatomic variables ($p = 0.170$). Extent of frontal sinus surgery (Draf IIa vs. IIb) did significantly increase the operative time (105.3(33.5) vs. 130.1(46.7); $p=0.029$, respectively).

4. DISCUSSION

The frontal sinus is the most challenging of the paranasal sinuses to treat. Angled endoscopes, specialized instrumentation, and meticulous dissection techniques have facilitated making both Draf IIa dissections mucosal sparing and complete. However, the outflow tract is bordered by both the orbit and skull base, and is therefore often the narrowest of all of the postoperative sinus outflow tracts. The present study sought to investigate if these innate anatomic limits of frontal endoscopic sinus surgery impacted QOL outcomes and operative times in patients undergoing frontal sinus surgery. None of the anatomic variables measured herein were associated with a difference in QOL outcomes, as measure by the SNOT-22 instrument, or mean operative time. The extent of frontal sinus surgery was a significant predictor of increased operative with Draf IIb cases being associated with longer operative times than Draf IIa cases. These operative time findings may be intuitive but also help to validate the measurement since we expect more dissection to correlate with longer operative times. Our QOL findings are an important contribution to the literature as they validate that a wide range of anatomy is effectively treated with endoscopic sinus surgery. Interestingly, the reported prevalence of clinically meaningful improvement in this cohort subgroup undergoing frontal sinusotomy is also higher than that previously reported for all patients undergoing ESS.²

The goal of frontal sinusotomy is to achieve a lasting drainage pathway of the frontal sinus. Complete removal of all frontal recess cells prevents synechiae and cicatricial scarring of the frontal recess.¹⁷ Retained frontal cells and cicatricial scarring after instrumentation of narrow frontal recesses are both common causes of frontal sinus surgery failure and need for revision.¹⁸ Draf II surgery is an effective technique to maximally augment the frontal recess to the natural limits of a hand instrument: the lamina paparycea, the frontal beak and the

skull base. These fundamental limits lead to a range of cross-sectional areas of the frontal sinus outflow depending upon individual patient anatomy. It is conceivable that patients with inherently narrowed frontal sinus outflow tracts might not be well-served by ESS given the limits of instrumentation and the concern that narrowed anatomy would lead to increased rates of synechiae and failure.

The present study used surrogate measurements to evaluate the impact of a narrowed frontal outflow tract cross-sectional area and failed to find any connection with QOL outcomes. Prior study by Del Gaudio et al.¹⁹ examined the impact of the cross-sectional area of frontal sinus ostia, but with a radiographic outcome measure instead of a patient-centered measure of treatment outcomes. Retained cells and narrowed frontal sinus outflow tracts were not associated with increased evidence of sinus disease in that study. Although radiographic study is an important method to investigate disease for a clinician, it does not elucidate associations for improvement in QOL, the primary goal of endoscopic sinus surgery.¹¹

Prior study has also identified frontal beak configuration as a predictor of radiographic evidence of frontal sinus disease.¹⁶ The presence of an intersinus septal cell leads to a splitting of the frontal beak. Intersinus frontal cells tend to push the frontal outflow tracts laterally as well as increase the surface area of the frontal beak. The thick protrusions of the beak separating a frontal sinus and intersinus septal cell are typically beyond the strength of a hand instrument preventing maximal marsupialization. On the other hand, intersinus septal cells can also be used to extend a Draf IIa into a Draf IIb with a hand instrument if the increased pneumatization thins down the party wall and floor of the frontal sinus.²⁰ Although a surgically unaltered frontal outflow tract connected to an intersinus septal cell has been associated with radiographic disease,¹⁶ there may be certain cases where the presence of the intersinus septal cell facilitates a larger frontal sinusotomy with improved QOL.

The present study found that narrowed anatomy did not impact operative time; however, operative is increased by more extensive frontal dissections. Although there has been little study of ESS and operative time, there is an increasing interest in accurate operative time estimates as financial pressures increase on institutions to increase efficiency.²¹ These new financial challenges are in part the result of decreasing reimbursements coupled with the increasing costs of technology. This study is the first that seeks to characterize preoperative characteristics associated with increased operative times in ESS. Although this study is only a modest entry into formal study of operative times in ESS, there stands to be great gains in operative room efficiency if pre-operative characteristics could improve estimates even modestly. Accurate operative time forecasting would help minimize the direct costs of an idle operating room while minimizing the hidden costs of schedule overruns such as decrease in quality of care or strained staffing.²¹ Further study of operative times in rhinology is warranted based on the present study findings.

The failure to find a difference in QOL outcomes across this cohort may be for a variety of reasons. The inconsistent impact of anatomy on CRS found in the literature may reflect the heterogeneous nature of the disease where anatomic narrowing may contribute only a small part to a multifactorial process that is also a function of intrinsic mucosal inflammation

and/or dysbiosis.²² There may also be some minimum size threshold of the sinus outflow tracts that the present cohort didn't cross that may impact outcomes, or anatomic features that were not measured in the present study. Fortunately, there appears to be a wide range of anatomy that tolerates ESS. Further study investigating more extreme anatomy might conceivably identify a subset of patients where anatomy plays a more significant role in QOL outcomes. This study also did not examine the role of frontoethmoidal cells. Conceivably the pattern of frontoethmoidal cell pneumatization may factor more significantly into frontal ESS failure, although this was not the case in previous radiographic study.¹⁹ Finally, anatomic features may be associated with a true difference in QOL outcomes that the present study failed to detect. Although a larger sample size would facilitate achieving a statistical significance, the correlation coefficients between anatomic features and QOL outcomes were relatively weak. Further study with larger sample sizes might be cost prohibitive and add little clinical value.

5. CONCLUSIONS

Frontal sinus outflow dimensions, presence of a frontal intersinus septal cell and an anterior ethmoid artery on a mesentery did not impact QOL gains of frontal ESS or operative times. Failure to identify a difference in QOL outcomes may reflect the limited role of anatomy in CRS. Regardless, frontal ESS is an effective intervention to improve QOL across a broad range of frontal recess anatomy. This is the first study to investigate the impact of anatomy and surgical extent on operative time confirming that increased operative times are associated with more extensive frontal sinus surgery. Accurate preoperative forecasting of operative time will facilitate more efficient utilization of health care resources.

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Public clinical trial registration (<http://www.clinicaltrials.gov>) ID #NCT01332136 entitled "Determinants of Medical and Surgical Treatment Outcomes in Chronic Sinusitis"

REFERENCES

1. DeConde AS, Mace JC, Alt JA, Soler ZM, Orlandi RR, Smith TL. Investigation of change in cardinal symptoms of chronic rhinosinusitis after surgical or ongoing medical management. *Int Forum Allergy Rhinol*. 2014 (In press).
2. Smith TL, Litvack JR, Hwang PH, et al. Determinants of Outcomes of Sinus Surgery: A Multi-Institutional Prospective Cohort Study. *Otolaryngol Head Neck Surg*. 2010; 142(1):55–63. [PubMed: 20096224]

3. Kirihehene RKDRA, Rees G, Wormald P-J. The Influence of the Size of the Maxillary Sinus Ostium on the Nasal and Sinus Nitric Oxide Levels. *Am J Rhinol.* 2002; 16(5):261–264. [PubMed: 12422970]
4. Harvey RJ, Goddard JC, Wise SK, Schlosser RJ. Effects of endoscopic sinus surgery and delivery device on cadaver sinus irrigation. *Otolaryngol Head Neck Surg.* 2008; 139(1):137–142. [PubMed: 18585576]
5. Jang DW, Lachanas VA, Segel J, Kountakis SE. Budesonide nasal irrigations in the postoperative management of chronic rhinosinusitis. *Int Forum Allergy Rhinol.* 2013; 3(9):708–711. [PubMed: 23776108]
6. Soler ZM, Rudmik L, Hwang PH, Mace JC, Schlosser RJ, Smith TL. Patient-centered decision making in the treatment of chronic rhinosinusitis. *Laryngoscope.* 2013; 123(10):2341–2346. [PubMed: 23856802]
7. DeConde AS, Mace JC, Alt JA, Soler ZM, Orlandi RR, Smith TL. Investigation of change in cardinal symptoms of chronic rhinosinusitis after surgical or ongoing medical management. *Int Forum Allergy Rhinol.* 2014 (In press).
8. Alt JA, Mace JC, Buniel MCF, Soler ZM, Smith TL. Predictors of Olfactory Dysfunction in Rhinosinusitis Using the Brief Smell Identification Test. *Laryngoscope.* 2014; 147(7):E259–E266. [PubMed: 24402746]
9. Alt JA, Smith TL, Mace JC, Soler ZM. Sleep quality and disease severity in patients with chronic rhinosinusitis. *Laryngoscope.* 2013; 123(10):2364–2370. [PubMed: 23918740]
10. DeConde AS, Mace JC, Alt JA, Schlosser JR, Smith TL, Soler ZM. Comparative effectiveness of medical and surgical therapy on olfaction in chronic rhinosinusitis: a prospective, multi-institutional study. *Int Forum Allergy Rhinol.* 2014 (In press).
11. Rosenfeld RM, Andes D, Neil B, et al. Clinical practice guideline: Adult sinusitis. *Otolaryngol Head Neck Surg.* 2007; 137(3 suppl):S1–S31. [PubMed: 17761281]
12. Hopkins C, Gillett S, Slack R, Lund VJ, Browne JP. Psychometric validity of the 22-item Sinonasal Outcome Test. *Clin Otolaryngol.* 2009; 34(5):447–454. [PubMed: 19793277]
13. Lund VJ, Mackay IS. Staging in rhinosinusitis. *Rhinology.* 1993; 31(4):183–184. [PubMed: 8140385]
14. Lund VJ, Kennedy DW. Staging for rhinosinusitis. *Otolaryngol Head Neck Surg.* 1997; 117(3 Pt 2):S35–S40. [PubMed: 9334786]
15. Keros P. On the practical value of differences in the level of the lamina cribrosa of the ethmoid. *Z Laryngol Rhinol Otol.* 1962; 41:809–813. [PubMed: 14032071]
16. Goldsztein H, Pletcher SD, Reh DD, Metson R. The frontal wishbone: Anatomic and clinical implications. *Am J Rhinol.* 2007; 21(6):725–728. [PubMed: 18201455]
17. Kennedy DW, Senior BA. Endoscopic sinus surgery. A review. *Otolaryngol Clin North Am.* 1997; 30(3):313–330. [PubMed: 9162119]
18. Valdes CJ, Bogado M, Samaha M. Causes of failure in endoscopic frontal sinus surgery in chronic rhinosinusitis patients. *Int Forum Allergy Rhinol.* 2014; 4(6):502–506. [PubMed: 24616299]
19. DelGaudio JM, Hudgins PA, Venkatraman G, Benningfield A. Multiplanar computed tomographic analysis of frontal recess cells: Effect on frontal isthmus size and frontal sinusitis. *Arch Otolaryngol Head Neck Surg.* 2005; 131(3):230–235. [PubMed: 15781763]
20. Chiu AG, Vaughan WC. Using the Frontal Intersinus Septal Cell to Widen the Narrow Frontal Recess. *Laryngoscope.* 2004; 114(7):1315–1317. [PubMed: 15235368]
21. Cardoen B, Demeulemeester E, Beliën J. Operating room planning and scheduling: A literature review. *Eur J Oper Res.* 2010; 201(3):921–932.
22. Timperley D, Schlosser RJ, Harvey RJ. Chronic rhinosinusitis: An education and treatment model. *Otolaryngol Head Neck Surg.* 2010; 143 Supplement 3(5):S3–S8. [PubMed: 20970689]

Figure 1.
An example of the determination of A-P distance.

Figure 2.
An example of the determination of Keros height.

Figure 3.
An example of the determination of narrowest ethmoid width.

a

b

Figure 4.
An example of presence of an intersinus septal cell (**A**) and absence of an intersinus septal cell (**B**).

a

b

Figure 5.
An example of an anterior ethmoid artery on a mesentery (**A**) and absence of an anterior ethmoid artery mesentery (**B**).

Table 1

Baseline characteristics of subjects

Characteristics (n=63):	Mean(SD)	Range	N(%)
Age (years)	56.8 (14.0)	25.0 – 83.0	
Female			24 (38.1)
Asthma			26 (41.3)
Allergy (skin prick/RAST confirmed)			24 (38.1)
ASA sensitivity			10 (15.9)
Depression			11 (17.5)
Current tobacco use			1 (1.6)
COPD			1 (1.6)
Steroid dependency (asthma or sinusitis)			3 (4.8)
Prior sinus surgery			49 (77.8)
Nasal polyposis			44 (69.8)
Clinical disease severity measures:			
Baseline SNOT-22 score	58.7 (19.7)	18.0 – 99.0	
Baseline CT score	17.0 (5.0)	2.0 – 24.0	
Baseline Endoscopy score	10.5 (3.2)	4.0 – 18.0	
Extent of Surgery:			
Maxillary antrostomy			60 (95.2)
Sphenoidotomy			58 (92.1)
Partial ethmoidectomy			4 (6.3)
Total ethmoidectomy			59 (93.7)
Middle turbinate resection			27 (42.9)
Inferior turbinate resection			2 (3.2)
Septoplasty			17 (27.0)
Image guidance			57 (90.5)
OR time (minutes)		55.0 – 232.0	121.5 (44.0)
Frontal Draf IIa sinusotomy			22 (34.9)
Frontal Draf IIb sinusotomy			41 (65.1)

Extent of surgery variables include either unilateral or bilateral procedures. SD, standard deviation; RAST, radioallergosorbent test; ASA, acetylsalicylic acid; COPD, chronic obstructive pulmonary disease; SNOT-22, 22-item Sinonasal Outcome Test; CT, computed tomography; OR, operating room.

Table 2

Anatomic sinus parameters of study participants undergoing Draf IIa/b frontal sinusotomy procedures

Anatomic Measurements (n=63):	Mean(SD)	Range	N(%)
Widest A-P distance (mm.)	9.0 (2.7)	4.1 – 14.9	
Keros height (mm.)	5.1 (1.8)	1.8 – 11.5	
Narrowest ethmoid width (mm.)	7.2 (1.4)	5.0 – 11.9	
Presence of intersinus septal cell			49 (83.1) *
AEA on mesentery			30 (50.8) *

SD, standard deviation; A-P, anterior-posterior; AEA, anterior ethmoid artery.

* Due to missing data, percentages are reported as valid percentages