# Lack of impact of radiologic septal measurements upon patient symptoms and performance of septoplasty during endoscopic sinus surgery*

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## Abstract

**Background**: Recent literature suggests that concurrent septoplasty during endoscopic sinus surgery (ESS) improves patient outcomes, however, the underlying indications for performing concurrent septoplasty are unknown. The objective of this study was to investigate the relationship between objective radiologic measures of nasal septal deviation with preoperative patient symptomatology and measures of CRS disease severity. We also sought to understand the association of objective radiologic measurements with surgeon performance of concurrent septoplasty during ESS.

**Methodology**: Seventy-four patients with CRS undergoing ESS were prospectively enrolled. Angles of septal deviation, intranasal areas and volumes were assessed on preoperative computed tomography (CT) scans and correlated with a robust battery of patient reported outcomes measures (PROMs), objective measures of CRS severity including olfaction scores, radiologic and endoscopic staging, and performance of septoplasty.

**Results**: Intranasal areas and volumes demonstrated only weak linear associations with patient-reported nasal congestion, however, angles of septal deviation alone did not correlate with congestion or any other PROM measure. Meanwhile, radiologic septal-related measurements did not correlate with objective measures of CRS disease severity or the performance of a concurrent septoplasty.

**Conclusions**: Though prior studies demonstrate improved patient outcomes in the setting of concurrent septoplasty during ESS, this study failed to establish an association between preoperative radiologic septal-related measurements and patient symptomatology or surgeon decision to perform septoplasty. Although objective factors to identify patients most likely to benefit from concurrent septoplasty remain unidentified, the potential improvement of surgical recommendations and patient outcomes makes this an important area of continued investigation.

**Key words**: chronic rhinosinusitis, septoplasty, sinus surgery, quality of life, olfaction disorders

## Introduction

Numerous studies have examined the effectiveness of rhinologic surgeries on patient outcomes, two of the most common being nasal septoplasty and endoscopic sinus surgery (ESS). Independently, both procedures have been shown to lead to improvements in disease-specific quality-of-life (QOL) metrics[1,2], however, the impacts of performing both surgeries concurrently on outcomes and the surgical indications for doing so are less clear.

In 2011, Rudmik et al. directly investigated this question by

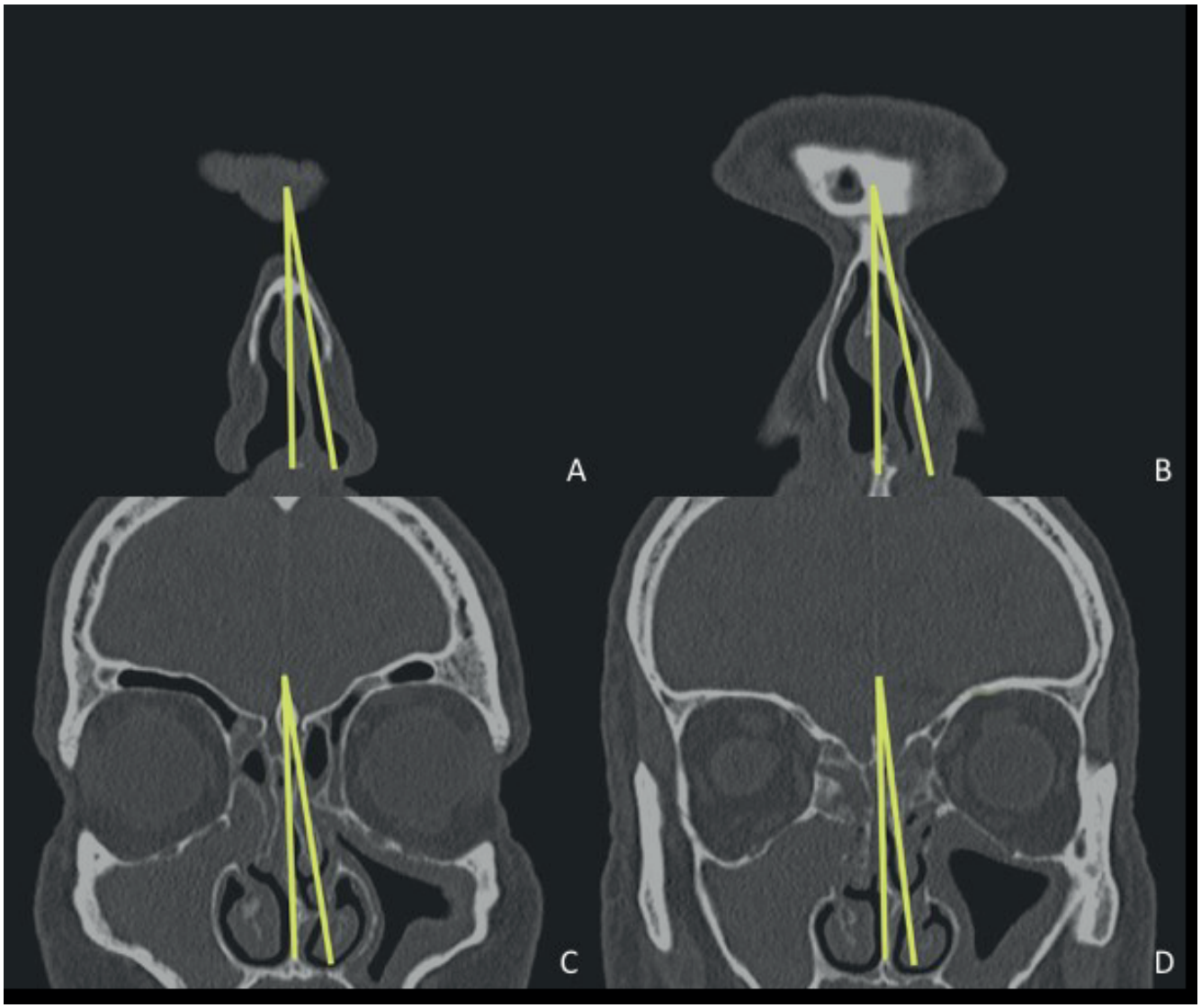


Figure 1. Example of measurement for nasal bone angle (A), inferior turbinate angle (B), crista galli angle (C), and the globe / optic nerve angle (D).

comparing a cohort of patients with chronic rhinosinusitis without nasal polyposis (CRSsNP) who underwent ESS alone to those who underwent ESS with a concurrent septoplasty, and concluded that septoplasty is not a confounding factor in QOL measures[3]. However, more recent investigations have reported that concurrent septoplasty is associated with improved patient-reported and surgical outcomes[4, 5]. In one study, 22-item Sinonasal Outcome Test (SNOT-22) survey scores averaged greater than 1 minimal clinically important difference (MCID) in patients who underwent a concurrent septoplasty. Interestingly, there was significant variation between practices for performing septoplasty, and patient improvements were largely driven by the ear/facial and psychological domains of the SNOT-22 instrument[5]. Meanwhile, another study demonstrated a lower relative risk of revision sinus surgery when a concurrent septoplasty was performed (OR=0.70)[4]. To this end, the most recent evidence suggests that concurrent septoplasty may improve patient outcomes, however the mechanism by which that is accomplished is unknown.

In light of these findings, our primary objective was to determine if specific objective criteria, such as radiologic measures of nasal septal deviation, are associated with chronic rhinosinusitis (CRS)-related symptomatology and CRS disease severity. Our secondary objective was to determine if any of these objective measures of septal deviation are associated with surgeon performance of concurrent septoplasty during ESS in patients with CRS. Identification of specific radiologic metrics associated with patient symptomatology and surgical outcomes could potentially guide and standardize surgeon performance of septoplasty during ESS.

## Material and methods

### Study population

Study participants were recruited within two academic, tertiary

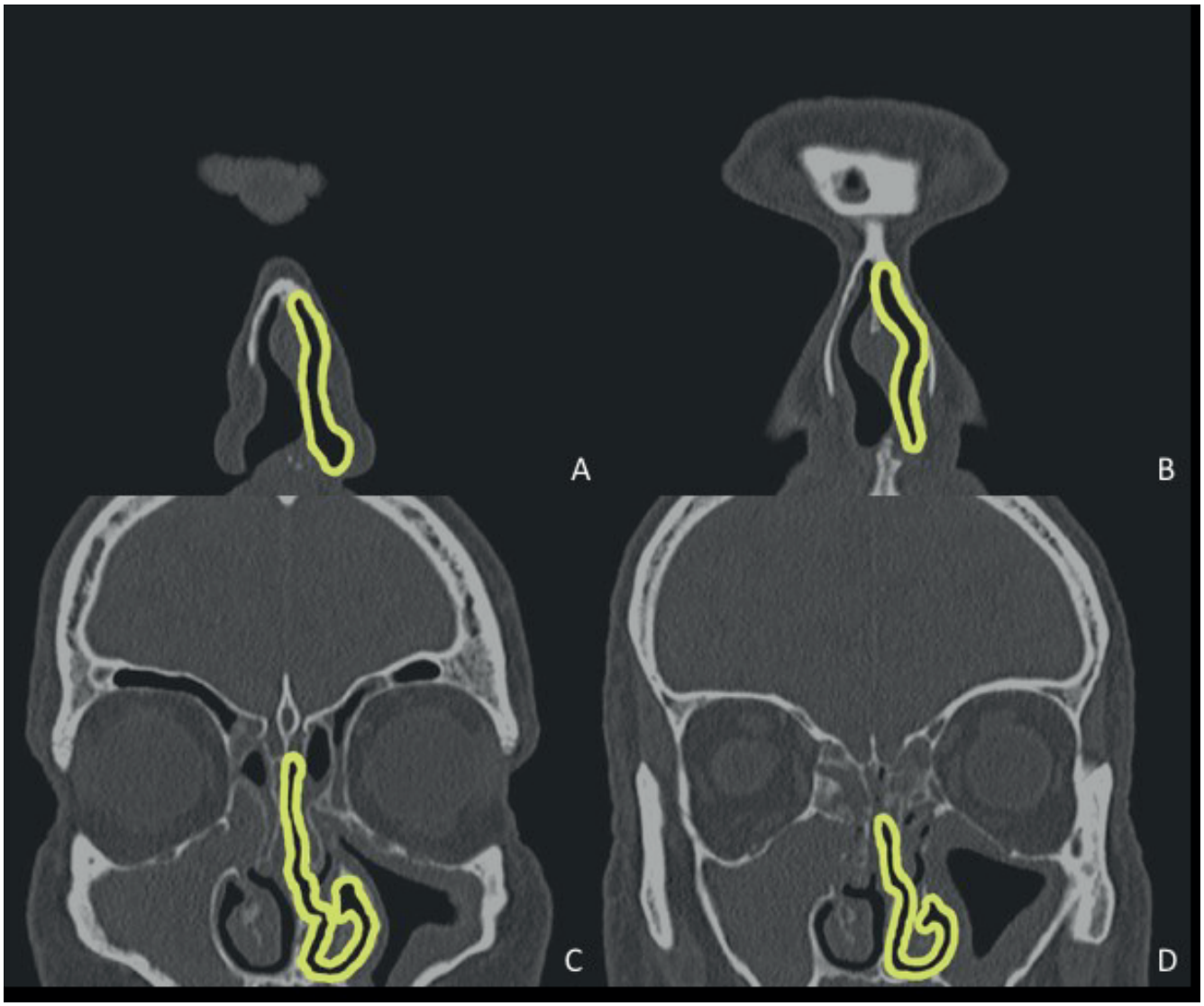


Figure 2. Example of determining the nasal bone area –cm$^2$- (A), inferior turbinate area (B), cristi galli area (C), and the posterior globe / optic nerve area (D).

referral clinics at the Oregon Health and Science University (OHSU; Portland, OR) and the Medical University of South Carolina (MUSC; Charleston, SC). CRS was confirmed using diagnostic criteria described in the Adult Sinusitis Guidelines established by the American Academy of Otolaryngology[6]. Study participants were enrolled in a prospective, observational cohort designed to evaluate patient-reported treatment outcomes surrounding ESS which has been previously described in the literature [5, 7-12]. Institutional Review Boards (IRB) at both OHSU (IRB#7198) and MUSC (IRB#12409) approved the study.
All study participants experienced continued symptoms of CRS after previously completing appropriate medical therapy and were considered surgical candidates per the standard of care, completed surgical counseling, and voluntarily elected ESS. The decision to perform septoplasty and extent of ESS was left to the discretion of the treating surgeon. Though extent of surgery was decided prior to surgery, if surgical access was limited intraoperatively secondary to a septal deviation, a septoplasty may have been performed to improve access and visualization. Patients requiring management of the nasal valve or caudal septum were excluded from this study, and therefore should be considered non-contributory to this analysis.

### Radiologic measurements

Septal deviations can occur in all 3 dimensions and vary from side to side, and as such, angles of septal deviation, nasal cross sectional areas, and nasal volumes were assessed using OsiriX Lite imaging software (Pixmeo; Bernex, Switzerland). Angles of deviation and cross-sectional areas (cm$^2$) were measured in the coronal plane. To ensure the standardization of these measurements, 2 reference coordinates (X,Y) of the most anterior maxillary crest and crista galli were marked, and a vertical reference line between these 2 points was used for each measurement. Next, 4 predetermined locations were identified, including the

most anterior aspect of the nasal bone, the head of the inferior turbinate, the crista galli, and the coronal cut just anterior to the optic nerve (Figure 1). At each anatomical site, a second tangential line was created to the most deviated portion of the nasal septum as shown in Figure 1 and completed bilaterally. Cross-sectional intranasal areas were outlined and calculated at each of the 4 predetermined locations (Figure 2). Total intranasal volumes ($cm^3$) were calculated between the most anterior point of interest (nasal bones) to the most posterior point of interest (optic nerve) using a preprogramed software algorithm. All images used to calculate volumes were reviewed so as to ensure no aberrancies that may have been introduced secondary to mucosal oedema or nasal polyps. Though rigorously performed, these measurements are not a validated measure of nasal geometry.

For data analysis of these metrics, further classification of these measurements was compiled into two independent categories. First, septal deviation on the "worst side" was defined as the side of the nasal airway with the greatest angle of deviation. Second, in an effort to depict the overall, bilateral, impact of deviation from midline, septal measurements were "combined" by summating corresponding values. The "combined" method would also account for differences in intranasal areas and volumes secondary to the nasal cycle. Though potential differences in intranasal areas and volumes secondary to the nasal cycle could have been overcome by applying topical nasal decongests prior to performing a CT scan, non-decongested nasal cavities may be more likely to provide an accurate reflection of active patient symptomatology.

### Sinonasal disease severity

Endoscopic examinations were quantified by each enrolling physician using the Lund-Kennedy staging system[13] and patients' bilateral olfactory function was evaluated using the Brief Smell Identification Test (BSIT; Sensonics International, Haddon Heights, NJ)[14]. Preoperative computed tomography (CT) of the sinuses was obtained without contrast, on all patients, prior to ESS and quantified using the Lund-Mackay staging system[15].

### Patient-Reported Outcome Measures

Participants were asked to complete a battery of patient-reported outcome measures (PROMs) to evaluate preoperative symptom severity across a range of health domains. The SNOT-22 and Rhinosinusitis Disability Index (RSDI) were used to describe sinonasal symptom severity and QOL[16-18]. Meanwhile, the SF-6D instrument was used to detail current health states using a normalized health utility value[19], the Patient Health Questionnaire-2 (PHQ-2) was used as a measure of depressive symptoms[20], and the Pittsburgh Sleep Quality Index (PSQI) assessed participant sleep quality[21].

Table 1. Preoperative demographics, patient characteristics, and comorbidities of the final study cohort (n=74).

| | Mean [SD] | N (%) |
|---|---|---|
| Age at enrollment (years) | 56.9 [13.8] | --- |
| Female* | ---- | 40 (54%) |
| Male* | ---- | 34 (46%) |
| **Medical history / comorbid diagnoses:** | | |
| Revision sinus surgery | ---- | 37 (50%) |
| Nasal polyposis | ---- | 29 (39%) |
| Asthma | ---- | 24 (32%) |
| ASA sensitivity | ---- | 7 (10%) |
| Allergy (positive mRAST/skin prick) | ---- | 29 (39%) |
| Depression* | ---- | 9 (12%) |
| Tobacco use/smoking | ---- | 1 (1%) |
| Alcohol use | ---- | 34 (47%) |
| Oral corticosteroid dependency | ---- | 9 (12%) |
| Diabetes mellitus (Type I / II) | ---- | 7 (5%) |
| **Patient Reported Outcome Measures:** | | |
| SNOT-22 total score | 54.6 [19.0] | ---- |
| RSDI total score | 48.0 [25.3] | ---- |
| SF-6D Health utility score | 0.68 [0.16] | ---- |
| PHQ-2 total score | 1.7 [1.7] | ---- |
| Positive depression screen (score > 3) | ---- | 22 (30%) |
| PSQI total score | 9.1 [4.7] | ---- |
| Poor sleep quality (score > 5) | ---- | 47 (67%) |
| **Measures of Disease Severity:** | | |
| Lund-Kennedy endoscopy score | 6.9 [3.6] | ---- |
| BSIT total score | 8.2 [3.4] | ---- |
| Abnormal olfaction (score < 8) | ---- | 30 (42%) |
| Lund-Mackay CT score | 13.5 [6.3] | ---- |

*self-reported; SD, standard deviation; ESS, endoscopic sinus surgery; ASA, acetylsalicylic acid; SNOT-22, 22-item SinoNasal Outcome Test survey; BSIT, Brief Smell Identification Test; mRAST, modified radioallergosorbent testing, CT, computed tomography; RSDI, Rhinosinusitis Disability Index; PHQ-2, 2-item Patient Health Questionnaire; PSQI, Pittsburgh Sleep Quality Index.

### Statistical analyses

Statistical analysis of data was completed using SPSS (version 24.0) statistical software (IBM Corp., Armonk, NY). Distributions of all scaled measures were assessed for normal distributions to direct appropriate statistical testing. Data normality and outlier identification was assessed using graphical analysis and the Shapiro-Wilk test for both preoperative septal deviation measurements and PROM scores. Descriptive statistics were completed for all study data. All two-tailed, bivariate correlations were completed using either Pearson's correlation coefficients or Spearman's rank coefficients (R), when appropriate.

Table 2. Summary of average septal deviation measurements for both the "worst side" and "combined bilateral" deviation for the total cohort (n=74).

| Angle (°): | Worst side deviation<br>Mean [SD] | Combined bilateral deviation<br>Mean [SD] |
|---|---|---|
| Nasal bone angle | 7.8 [2.8] | 13.2 [3.8] |
| Inferior turbinate angle | 10.9 [2.7] | 18.4 [4.4] |
| Crista galli angle | 8.2 [3.6] | 13.4 [4.7] |
| Posterior globe/optic nerve angle | 7.1 [3.8] | 11.5 [4.6] |
| **Intranasal Areas ($cm^2$):** | ---- | ---- |
| Nasal bone area | 1.6 [1.4] | 3.2 [2.0] |
| Inferior turbinate area | 1.4 [1.1] | 3.0 [1.9] |
| Crista galli area | 1.7 [1.4] | 3.5 [2.4] |
| Posterior globe/optic nerve area | 1.6 [1.2] | 3.3 [2.1] |
| **Total Intranasal Volume ($cm^3$):** | 3.8 [2.4] | 8.0 [4.5] |

SD, standard deviation; $cm^2$, square centimeters; $cm^3$, cubic centimeters

Mean differences in septal metrics were also compared between patients with and without septoplasty using independent samples t-testing. Comparisons in patient demographics and comorbidity, between patients with and without septoplasty, were completed using either independent samples t-testing or Pearson's chi-square tests. Type-I error probabilities (p-values) were reported for each comparison using a conventional alpha-level of 0.050 to identify significant differences. Because this study has a small sample size and was designed as an exploratory analysis, we elected to forgo correction for multiple comparisons which would reduce the false positive rate, but at the same time increase the false negative rate.

## Results

### Study population characteristics

A total of 74 study participants were included. Preoperative characteristics, PROMs, and measures of disease severity are further described in Table 1. The patient population was representative of tertiary care referral patterns, with 39% of patients carrying a diagnosis of CRSwNP, 50% of patients having previously undergone ESS, and patients presenting with a wide range of disease severity on both radiologic and endoscopic scoring systems (Table 1). A summary of mean septal deviation measurements for each described attribute are provided for the final cohort in Table 2, including deviation angles, areas, and volumes.

### Association of radiologic measurements with PROMs and CRS severity measures

When examining the single Likert scale item query of the SNOT-22 instrument which evaluates "Blockage / congestion of nose" there was weak correlation between the worst side septal deviation measures of the inferior turbinate area (R= -0.267; p=0.022), the crista galli area (R= -0.298; p=0.010), the posterior globe/optic nerve area (R= -0.370; p=0.001), and total intranasal volume (R= -0.352; p=0.002), whereas negative effect estimates reflect a worsening of nasal obstruction severity with decreasing areas and volumes (Table 3). Moreover, there was a weak correlation between SNOT-22 rhinologic domain scores and total worst side intranasal volume (R= -0.251; p=0.031; data not shown). Beyond these findings, no significant bivariate associations were found between any measurement of septal deviation and preoperative total SNOT-22 or total RSDI scores. Similarly, when examining non-rhinologic PROMs, no significant bivariate associations were found between any measurement of septal deviation and PHQ-2, SF-6D, or PSQI (R<0.200; p>0.050).

Additional correlation coefficients between septal deviation measurements for worst side and combined bilateral deviation with preoperative clinical measures of CRS disease severity are described in Table 4. The only statistically significant bivariate association was found between measure of combined bilateral deviation of the posterior globe/optic nerve area with Lund-Kennedy endoscopy scores (p=0.021) and BSIT total scores (p=0.017), however the magnitude of correlation was relatively weak (R<0.300).

### Radiologic measurements and decision to perform septoplasty

Twenty five of the 74 total patients (34%) underwent concurrent septoplasty during ESS. No significant differences were found in any septal deviation measurement between study participants undergoing ESS with septoplasty compared to ESS without septoplasty for either worst side measurements or combined bilateral measurements (Table 5) on average.

Patient characteristics and decision to perform septoplasty

Demographics between patients with and without concurrent septoplasty during ESS were statistically similar (Table 6). Patients not undergoing a septoplasty were more likely to have revision sinus surgery (p<0.001), nasal polyposis (p=0.016) and oral corticosteroid dependence (p=0.024). There were no differences in endoscopic or radiologic disease severity measures, or olfaction scores in patients undergoing concurrent septoplasty compared to those that did not. A separate analysis examining potential differences in the study population based on nasal polyp status was performed without change in the presented results.

## Discussion

Prior studies have demonstrated improvements in postoperative outcomes when a concurrent septoplasty is performed during endoscopic sinus surgery (ESS), however indications for

Table 3. Correlations between measurements of preoperative septal deviation and patient-reported outcome measures (n=74).

| Worst Side Measurements: | SNOT-22 "Blockage / congestion of nose" Item | SNOT-22 total score | RSDI total score | SF-6D Health utility score | PHQ-2 total score | PSQI total score |
|---|---|---|---|---|---|---|
| **Angle (°):** | **R** | **R** | **R** | **R** | **R** | **R** |
| Nasal bone angle | 0.177 | 0.120 | 0.021 | -0.039 | -0.070 | -0.003 |
| Inferior turbinate angle | 0.060 | 0.053 | -0.130 | 0.045 | -0.157 | 0.021 |
| Crista galli angle | 0.070 | 0.073 | -0.046 | 0.045 | -0.135 | 0.009 |
| Posterior globe/optic nerve angle | 0.111 | 0.153 | 0.103 | -0.192 | 0.064 | 0.089 |
| **Intranasal Areas ($cm^2$):** | ---- | ---- | ---- | ---- | ---- | ---- |
| Nasal bone area | -0.144 | -0.100 | -0.093 | 0.084 | -0.100 | -0.126 |
| Inferior turbinate area | **-0.267*** | -0.097 | -0.010 | 0.084 | 0.014 | -0.164 |
| Crista galli area | **-0.298*** | 0.017 | 0.075 | -0.057 | 0.158 | -0.016 |
| Posterior globe/optic nerve area | **-0.370*** | -0.085 | 0.028 | -0.024 | 0.123 | -0.086 |
| **Total Intranasal Volume ($cm^3$):** | **-0.352*** | -0.157 | -0.018 | 0.060 | 0.059 | -0.124 |
| **Combined Bilateral Measurements:** | | | | | | |
| **Angle (°):** | ---- | ---- | ---- | ---- | ---- | ---- |
| Nasal bone angle | 0.121 | 0.099 | -0.053 | -0.087 | -0.036 | 0.002 |
| Inferior turbinate angle | 0.016 | -0.002 | -0.170 | 0.034 | -0.156 | -0.024 |
| Crista galli angle | 0.018 | 0.049 | -0.141 | 0.113 | -0.182 | -0.029 |
| Posterior globe/optic nerve angle | 0.163 | 0.149 | 0.061 | -0.191 | 0.116 | 0.024 |
| **Intranasal Areas ($cm^2$):** | ---- | ---- | ---- | ---- | ---- | ---- |
| Nasal bone area | 0.012 | -0.108 | -0.133 | 0.140 | -0.185 | -0.113 |
| Inferior turbinate area | -0.161 | -0.046 | -0.022 | 0.082 | -0.019 | -0.153 |
| Crista galli area | **-0.287*** | 0.013 | 0.094 | -0.070 | 0.158 | -0.042 |
| Posterior globe/optic nerve area | **-0.355*** | -0.072 | 0.043 | -0.072 | 0.126 | -0.134 |
| **Total Intranasal Volume ($cm^3$):** | **-0.265*** | -0.104 | 0.009 | 0.031 | 0.073 | -0.138 |

$cm^2$, square centimeters; $cm^3$, cubic centimeters; R, either Pearson's correlation coefficient or Spearman's rank correlation coefficient for parametric or nonparametric distributions, respectively; SNOT-22, 22-item SinoNasal Outcome Test; RSDI, Rhinosinusitis Disability Index; PHQ-2, 2-item Patient Health Questionnaire; PSQI, Pittsburgh Sleep Quality Index. *Correlation is significant at the 0.050 level (two-tailed). **Correlation is significant below the 0.001 level (two-tailed).

performing septoplasty during ESS are not well defined [4, 5]. This study sought to identify factors associated with concurrent septoplasty during ESS, and to help guide surgical decision making. Despite rigorous objective characterization of a wide spectrum of septal angles, nasal areas and volumes, we could not identify a convincing correlation between radiologic measurements with a battery of validated patient-reported and objective measures of disease, or surgeon decision to perform septoplasty.

Using objective metrics to characterize nasal obstruction is not a novel concept. Many prior reports have attempted to correlate objective nasal measures with patient symptoms, but have had mixed success and generally fail to fully capture patient symptomatology. The most widely reported tools include acoustic rhinometry, rhinomanometry, and peak nasal inspiratory flow (PNIF) rates [22-25]. Meanwhile, imaging studies have been shown to correlate strongly with acoustic rhinometry, however, patient reports of nasal obstruction generally correlate poorly with CT findings and the use of imaging for the diagnosis of nasal obstruction is not recommended [26].

Nonetheless, to our knowledge, objective nasal-related measures have not been used to account for differences in preoperative patient symptomatology with CRS-related metrics, or describe the indications for performing a concurrent septoplasty during ESS in a CRS patient population. While intranasal areas and volumes in this study did demonstrate a weak linear association with the SNOT-22 item that evaluates "blockage / congestion of nose," angles of septal deviation alone did not correlate with nasal blockage. This suggests that broader metrics may be more useful or representative of patient symptoms than simple deviations from midline, which likely fail to account for dynamic changes in lateral nasal wall structures, such as the inferior turbinates. It is also possible that feelings of congestion

Table 4. Bivariate correlations between septal measurements for both "worst side" and "combined bilateral" deviation and preoperative clinical measures of disease severity (n=74).

| Worst Side Measurements: | Lund-Kennedy endoscopy score | BSIT total score | Lund-Mackay CT score |
|---|---|---|---|
| **Angle (°):** | **R** | **R** | **R** |
| Nasal bone angle | 0.017 | -0.070 | -0.187 |
| Inferior turbinate angle | -0.112 | -0.048 | -0.107 |
| Crista galli angle | 0.058 | -0.115 | -0.107 |
| Posterior globe/optic nerve angle | 0.174 | -0.146 | 0.019 |
| **Intranasal Areas ($cm^2$):** | ---- | ---- | ---- |
| Nasal bone area | -0.051 | 0.004 | 0.135 |
| Inferior turbinate area | -0.103 | 0.107 | 0.004 |
| Crista galli area | 0.007 | 0.111 | 0.047 |
| Posterior globe/optic nerve area | -0.003 | 0.128 | -0.020 |
| **Total Intranasal Volume (cm3):** | -0.053 | 0.147 | -0.091 |
| **Combined Bilateral Measurements:** | | | |
| **Angle (°):** | ---- | ---- | ---- |
| Nasal bone angle | 0.060 | -0.096 | -0.105 |
| Inferior turbinate angle | -0.064 | -0.014 | -0.095 |
| Crista galli angle | 0.103 | -0.089 | 0.030 |
| Posterior globe/optic nerve angle | **0.269*** | **-0.280*** | 0.106 |
| **Intranasal Areas ($cm^2$):** | ---- | ---- | ---- |
| Nasal bone area | -0.048 | 0.024 | 0.109 |
| Inferior turbinate area | -0.131 | 0.060 | -0.005 |
| Crista galli area | -0.043 | 0.074 | 0.037 |
| Posterior globe/optic nerve area | -0.036 | 0.111 | -0.060 |
| **Total Intranasal Volume ($cm^3$):** | -0.092 | 0.083 | -0.083 |

$cm^2$, square centimeters; $cm^3$, cubic centimeters; R, either Pearson's correlation coefficient or Spearman's rank correlation coefficient for parametric or nonparametric distributions, respectively; *Correlation is significant at the 0.050 level (two-tailed). **Correlation is significant below the 0.001 level (two-tailed).

could be secondary to sinonasal inflammation. As such, we are cautious to not overinterpret our findings as the overwhelming majority of preoperative nasal measurements in this study, both unilateral and combined, failed to demonstrate a correlation with the robust battery of CRS-related measures of disease. Beyond the association between the defined nasal-related measures and preoperative measures of disease, we attempted to identify characteristics that might influence surgeon decision to perform a concurrent septoplasty. There were however, no differences in septal metrics and the performance of septoplasty. Though demographics and medical comorbidities were similar between patients who underwent a concurrent septoplasty and those that did not, patients undergoing revision sinus surgery, patients with nasal polyposis, and patients with oral corticosteroid dependence were less likely to undergo a concurrent septoplasty. We suspect that concurrent septoplasty was less common in revision cases, because, if indicated, it likely would have been completed at the time of primary surgery. With the same reasoning in mind, along with the increased incidence of revision ESS in patients with nasal polyposis, it is not surprising that nasal polyposis and oral corticosteroid dependence were less likely with a concurrent septoplasty.

Unfortunately, this study fails to capture the surgeons' reasoning for performing a septoplasty, and this cannot be captured retrospectively. The data presented here suggests that objective nasal measurements fail to fully represent a surgeon's decision to perform a concurrent septoplasty during ESS. Future studies should aim to capture a more detailed preoperative nasal and endoscopic analysis, as well as, ask surgeons to describe their rationale to perform a septoplasty at the time of surgery to minimize the risk of bias.

Though septal metrics in this study did not correlate with patient-reported QOL, the investigation by Smith et al. suggests that concurrent septoplasty improves postoperative symptomatology, specifically the ear/facial and psychological domains of the SNOT-22[5]. It is possible that nasal obstruction plays a

Table 5. Comparisons between septal measurements during ESS with or without septoplasty (n=74).

| Angle (°): | ESS with septoplasty (n=25) Mean [SD] | ESS without septoplasty (n=49) Mean [SD] | p-value |
|---|---|---|---|
| Nasal bone angle | 7.9 [3.2] | 7.9 [2.5] | 0.984 |
| Inferior turbinate angle | 11.1 [2.6] | 10.7 [2.8] | 0.531 |
| Crista galli angle | 8.2 [2.7] | 8.2 [3.9] | 0.952 |
| Posterior globe/optic nerve angle | 7.8 [4.0] | 6.8 [3.7] | 0.292 |
| **Intranasal Areas ($cm^2$):** | ---- | ---- | ---- |
| Nasal bone area | 1.8 [1.7] | 1.6 [1.2] | 0.548 |
| Inferior turbinate area | 1.5 [1.2] | 1.4 [1.1] | 0.614 |
| Crista galli area | 1.9 [1.7] | 1.7 [1.3] | 0.609 |
| Posterior globe/optic nerve area | 1.7 [1.2] | 1.6 [1.2] | 0.829 |
| Total Intranasal Volume (cm3): | 3.5 [2.0] | 4.0 [2.6] | 0.443 |
| **Total Intranasal Volume (cm3):** | -0.053 | 0.147 | -0.091 |
| **Combined Bilateral Measurements:** | ---- | ---- | ---- |
| **Angle (°):** | 12.7 [3.7] | 13.4 [3.9] | 0.434 |
| Inferior turbinate angle | 18.0 [3.5] | 18.6 [4.8] | 0.592 |
| Crista galli angle | 12.8 [3.1] | 13.8 [5.4] | 0.374 |
| Posterior globe/optic nerve angle | 11.5 [3.9] | 11.6 [4.9] | 0.919 |
| **Intranasal Areas ($cm^2$):** | ---- | ---- | ---- |
| Nasal bone area | 3.5 [2.0] | 3.1 [2.1] | 0.485 |
| Inferior turbinate area | 3.4 [2.4] | 2.7 [1.5] | 0.123 |
| Crista galli area | 4.4 [3.0] | 3.1 [1.8] | 0.067 |
| Posterior globe/optic nerve area | 3.8 [2.5] | 3.0 [1.8] | 0.158 |
| **Total Intranasal Volume ($cm^3$):** | 8.1 [3.7] | 8.0 [4.9] | 0.933 |

ESS, endoscopic sinus surgery;°, degrees; $cm^2$, square centimeters; $cm^3$, cubic centimeters.

role in sleep quality and subsequently in mood, cognition and psychological aspects of QOL. Because of this, we investigated additional, non-CRS PROMs, but failed to identify additional associations. Further characterization of patient-reported nasal airway obstruction is possible with additional metrics, such as the Nasal Obstruction and Septoplasty Effectiveness (NOSE) Scale, however this instrument is not routinely captured in the CRS population.

This study highlights the difficulty in identifying correlations between patient symptomology and objective measures as they relate to concurrent septoplasty during ESS. Two recent reports highlight the controversy between objective and subjective measures of nasal obstruction outcomes[26, 27]. Nonetheless, beyond patient symptoms, it is intuitive that there is an underlying structural change in anatomy that accounts for postoperative symptom improvement. Alternative strategies of assessing nasal airflow, may have been be more useful in this current analysis, and we suspect that a portion of this answer might be better explained by computational fluid dynamics (CFD) technology, which is able to identify specific drivers of reduced airflow[28]. Overall, though this is a "negative" study, there are many strengths. The overarching scientific inquiry and study design is based in an important clinical question that attempts to identify metrics that could improve patient outcomes for a common condition. The prospective and multi-institutional nature of this study, along with a robust battery of validated subjective and objective CRS-related measures adds to its strengths. However, the relatively small sample size of this exploratory study limits statistical power. Furthermore, given the conceivable likelihood of a Type I statistical error, statistically significant results should be cautiously interpreted. Future studies should specifically examine other nasal characteristics, not assessed in this analysis, such as concomitant inferior turbinate hypertrophy, the presence of anatomical variants such as a concha bullosa, the extent of surgical access required, as well as alternative methods of intranasal evaluation, such as CFD. Additionally, forthcoming investigations should query surgeons at the time of surgery to delineate the reasoning for performing, or not performing, a

Table 6. Comparisons of preoperative demographics, patient characteristics, and comorbidity between study participants with and without concurrent septoplasty during endoscopic sinus surgery (n=74).

| | Septoplasty (n=25) | | No Septoplasty (n=49) | | |
|---|---|---|---|---|---|
| | Mean [SD] | N (%) | Mean [SD] | N (%) | p-value |
| Age at enrollment (years) | 53.6 [16.0] | ---- | 58.5 [12.4] | ---- | 0.149 |
| Female* | ---- | 12 (48%) | ---- | 28 (57%) | ---- |
| Male* | ---- | 13 (52%) | ---- | 21 (43%) | 0.455 |
| **Race:** | ---- | ---- | ---- | ---- | ---- |
| White/Caucasian | ---- | 25 (100%) | ---- | 44 (90%) | ---- |
| African American | ---- | 0 (0%) | ---- | 5 (10%) | 0.098 |
| **Ethnicity:** | ---- | ---- | ---- | ---- | ---- |
| Non-Hispanic/Latino | ---- | 25 (100%) | ---- | 48 (98%) | ---- |
| Hispanic/Latino | ---- | 0 (0%) | ---- | 1 (2%) | 0.472 |
| **Medical history / comorbid diagnoses:** | ---- | ---- | ---- | ---- | ---- |
| Revision sinus surgery | ---- | 5 (20%) | ---- | 32 (65%) | **<0.001** |
| Nasal polyposis | ---- | 5 (20%) | ---- | 24 (49%) | **0.016** |
| Asthma | ---- | 7 (28%) | ---- | 17 (35%) | 0.561 |
| ASA sensitivity | ---- | 1 (4%) | ---- | 6 (12%) | 0.411 |
| Allergy (positive mRAST/skin prick) | ---- | 11 (44%) | ---- | 18 (37%) | 0.545 |
| Depression* | ---- | 5 (20%) | ---- | 4 (8%) | 0.141 |
| Tobacco use/smoking | ---- | 0 (0%) | ---- | 1 (2%) | >0.999 |
| Alcohol use | ---- | 14 (56%) | ---- | 20 (42%) | 0.244 |
| Oral corticosteroid dependency | ---- | 0 (0%) | ---- | 9 (18%) | **0.024** |
| Diabetes mellitus (Type I / II) | ---- | 2 (8%) | ---- | 5 (10%) | >0.999 |
| **Measures of Disease Severity:** | ---- | ---- | | | |
| Lund-Kennedy endoscopy score | 6.2 [3.2] | ---- | 7.2 [3.8] | ---- | 0.301 |
| BSIT total score | 9.2 [2.8] | ---- | 7.7 [3.6] | ---- | 0.108 |
| Abnormal olfaction (score < 8) | ---- | 8 (32%) | ---- | 22 (47%) | 0.225 |
| Lund-Mackay CT score | 13.3 [6.8] | ---- | 13.6 [6.1] | ---- | 0.841 |

*self-reported; SD, standard deviation; ESS, endoscopic sinus surgery; ASA, acetylsalicylic acid; BSIT, Brief Smell Identification Test; mRAST, modified radioallergosorbent testing, CT, computed tomography.

concurrent septoplasty during ESS. An alternative consideration would be to perform a randomised trial of the performance of a concurrent septoplasty.

## Conclusion

Though prior studies have suggested improved patient outcomes in the setting of a concurrent septoplasty during ESS, this study failed to demonstrate an association between radiologic septal-related measurements with preoperative patient characteristics or symptomatology when patients undergo ESS with or without a concurrent septoplasty. Based on these results, static radiologic measures should not be used alone in a surgeon's decision-making algorithm to perform a concurrent septoplasty. Nonetheless, prior literature is compelling that septoplasty improves ESS-related outcomes and future studies should attempt to elucidate the underlying mechanism of improved outcomes.

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## Authorship contribution

NRR: data collection, data analysis, interpretation of results, and preparation of manuscript. ZMS: study design, patient enrollment, data analysis, interpretation of results, and revision of manuscript. JCM: data analysis, interpretation of results, and preparation of manuscript. MPC: data collection and analysis CP: data collection and analysis. RHJ: data collection and analysis. TLS: study design, patient enrollment, interpretation of results, and revision of manuscript. RJS: study design, patient enroll-

ment, data analysis, interpretation of results, and revision of manuscript.

## Conflict of interest

No financial disclosures of conflicts of interest exist for NRR, JCM, MPC, CP, RHJ or TLS. ZMS is a consultant for Olympus and 480 Biomedical as well as on the advisory board for Regeneron. RJS is consultant for Olympus and Stryker and has received grant support from Entellus and Intersect. There are no other financial disclosures or conflicts of interest for any other author.

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