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Technical Quality of Contemporary Endoscopic Sinus Surgery: An Assessment by Study of Anatomical Features Needing Attention at Revision Surgery

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Abstract: Although technical causes of endoscopic sinus surgery (ESS) failure have long been reported, we were curious about the quality of contemporary sinus surgery. The electronic health database of Mayo Clinic, Arizona was scrutinized to identify adult patients with diffuse chronic rhinosinusitis (CRS) who underwent revision ESS between January 2019 and September 2023 with a history of bilateral full-house ESS. Anatomical features on preoperative radiology and intraoperative endoscopy were cataloged: residual uncinate tissue, maxillary antrostomy with a non-incorporated natural os, residual ethmoidal septations (three septations > 3 mm), and inadequate sphenoid osteotomy (os size < 6 mm). Sixty-nine subjects were identified. A deviated nasal septum was present in 53.6%. Residual uncinate tissue was noted in 50.7% of patients associated with missed natural maxillary os in 39.13% of antrostomies. An inadequate os diameter was noted in 63.8% of sphenoidotomies. Significant residual septations were seen in posterior ethmoidal cells in 66.7% and anterior ethmoidal cells in 62.3% of patients. Residual frontoethmoidal cells were noted in 72.4% of patients. Although the extent of ESS must be individualized, a high prevalence of features reflecting suboptimal surgery that could limit the success of ESS was identified. These findings merit further consideration for focused training during residency and continuous professional development activities.

Keywords: chronic rhinosinusitis; endoscopic sinus surgery; revision surgery

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1. Introduction

Modern chronic rhinosinusitis (CRS) management relies on endoscopic sinus surgery and topical anti-inflammatory therapy [1,2]. Recognizing that diffuse CRS is not usually a disease of ostiomeatal obstruction [3], contemporary endoscopic sinus surgery (ESS) aims to re-establish mucociliary clearance by wide surgical ostia and clear ethmoidal corridors to facilitate topical drug delivery to the paranasal sinuses [4]. Hence, wide surgical openings incorporating natural ostia (maxillary, frontal, sphenoid sinuses), comprehensive ethmoid dissection, and complete clearance of the frontal outflow tract are the hallmarks of optimal ESS for pansinusitis [5,6].

Although many forms of CRS are biologically recalcitrant, in 1996, Stankiewicz, et al. [7] recognized that there was a subpopulation of failures attributed to anatomical findings, most of which (69–78%) could be revised successfully. Subsequent surgeons continued to identify suboptimal surgical dissection as a potential factor for recalcitrance in CRS [8]. Common features associated with suboptimal dissection identified over the years include incompletely dissected anterior and posterior ethmoidal cells, incomplete frontal outflow tract dissection, residual uncinate process with missed natural maxillary ostium, and inadequate sphenoidotomy [9–16]. Such studies have ensured targeted attention to these areas during primary surgery and training and have possibly played a crucial role in

improving the quality of ESS. In a recent meta-analysis, Loftus, et. al. [17], found significantly higher revision ESS rates for CRS with nasal polyps (CRSwNP) patients in studies published before 2008 (22.7% before vs. 18.6% after 2008).

In this study, we aim to investigate progress in the technical quality of ESS by studying residual anatomical features that needed to be further addressed during the revision ESS and could have contributed to CRS recalcitrance. This will be reflective of the impact of previous studies and the targeted surgical training and will further help us to direct our efforts to the identified areas during primary surgery and training for the optimization of ESS results.

2. Materials and Methods

This study was exempted by the institutional review board (IRB No. 23-010862). Records of adult CRS patients who underwent revision ESS for diffuse CRS at Mayo Clinic in Arizona between January 2019 and September 2023 were reviewed. Those with a history of "full-house" bilateral ESS (bilateral maxillary antrostomy, total ethmoidectomy, frontal sinusotomy, and sphenoid sinusotomy) were included for further study. Previous surgery was verified from the operative note. If the former was unavailable, documentation of the procedure in the progress notes, with radiographic and endoscopic evidence of bilateral pansinus surgery was used for verifying the performance of a full-house bilateral ESS.

Patients with sinonasal tumors and comorbidities affecting ciliary function like cystic fibrosis were excluded from the study.

The pre-revision ESS sinus computed tomography (CT) scan and the revision ESS operative notes of selected patients were scrutinized to identify the presence of:

- Residual uncinate process (Figure 1);
- Non-incorporated natural ostium/posteriorly placed maxillary antrostomy (Figure 2);
- Residual bony septae in anterior ethmoids, which were defined as >3 bony septae measuring 3 mm along lamina papyracea/skull base/middle turbinate on preoperative sinus CT (Figure 3) [residual agger nasi cells were excluded from this category and considered as residual frontoethmoidal cells];
- Residual bony septae in posterior ethmoids, which were defined as >3 bony septae measuring 3 mm along lamina papyracea/skull base/middle turbinate on preoperative sinus CT (Figure 3);
- Inadequate sphenoid osteotomy (ostium diameter < 6 mm) (Figure 4). This ostium size was chosen based on the study by Singhal, et al., who reported that a sphenoid ostium size of at least ~5 mm is required to ensure postoperative sinus irrigation [18];
- Presence of residual frontoethmoidal cells (anterior or posterior group) in the frontal sinus outflow tract (Figure 4).

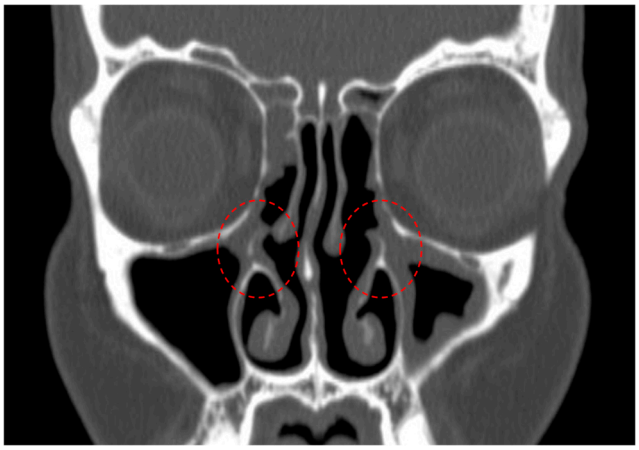


Figure 1. Coronal section of a preoperative non-contrasted sinus CT of a patient undergoing revision ESS showing residual uncinate process bilaterally (within red dotted circles).

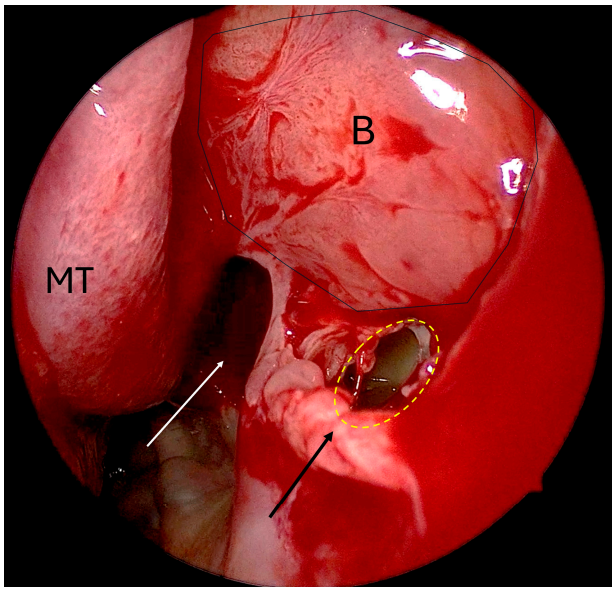


Figure 2. Endoscopic image of left nasal cavity showing missed natural maxillary ostium (yellow circle) visualized after removal of residual uncinate tissue (black solid arrow) with posteriorly placed maxillary antrostomy from previous ESS (white solid arrow); B—orbit, MT—middle turbinate.

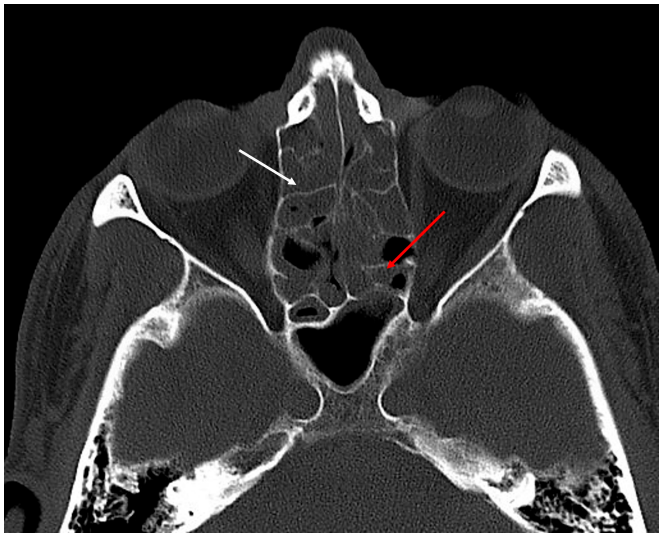


Figure 3. Axial section of non-contrasted sinus CT showing residual bony septae in anterior (white arrow) and posterior (red arrow) ethmoids bilaterally.

Other factors like the CRS phenotype, preoperative 22-item sinonasal outcome test (SNOT-22) score, histopathology examination (HPE) findings, and duration since previous sinus surgery were also noted.

Statistical analysis was performed using STATA/BE 18.0 software and Microsoft Excel. The median was used as the measure of central tendency for SNOT-22 scores and duration since the last sinus surgery. SNOT-22 scores were compared using the Mann–Whitney U test and the prevalence of each surgical factor was compared using a chi-square test between patients after grouping them based on the presence or absence of nasal polyposis. The least common bilaterally prevalent factors were compared for their directional preponderance using the chi-square test. Patients were divided into two groups: those who received previous surgery within 5 years and those whose surgery was more than 5 years ago. The prevalence of each anatomical feature was compared between these groups using the chi-square test. The interval from previous surgery was compared between patients of

CRSwNP and CRSsNP using the Wilcoxon rank-sum test. A p-value of <0.05 with a 95% confidence interval was chosen as the threshold for statistical significance.

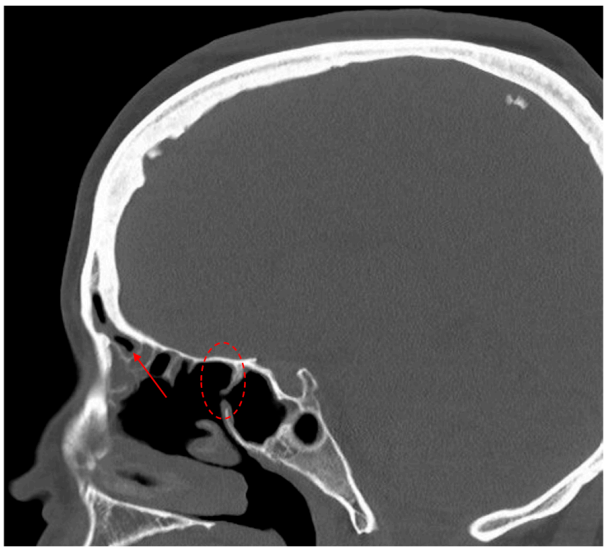


Figure 4. Parasagittal section of non-contrasted sinus CT showing inadequate sphenoid osteotomy (red dotted circle) with residual anterior and posterior frontoethmoidal cells in the frontal outflow tract (red arrow).

3. Results

Sixty-nine patients were identified. There were 29 patients (42.02%) with CRSsNP and 40 patients (57.97%) with CRSwNP. Duration since previous surgery ranged from 6 months to 26 years with a median value of 3.5 years (interquartile range: 8.5). A total of 42 out of 69 patients in this study underwent previous ESS within the last 5 years. Figure 5 demonstrates the distribution of patients according to the time interval from previous ESS. SNOT-22 scores were available for 62 patients. No significant difference in SNOT-22 scores was observed when comparing CRSwNP vs. CRSsNP groups. Clinical features and postoperative HPE findings of the study population are mentioned in Table 1.

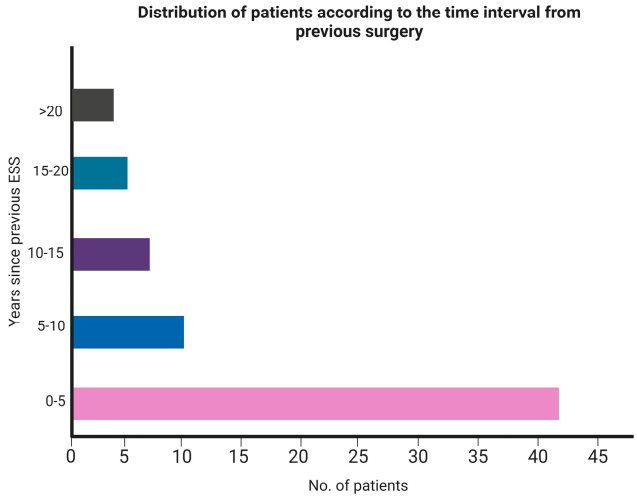


Figure 5. The graphical representation of patient distribution according to the time interval from previous surgery (in 5-year intervals) with no. of patients displayed on the x-axis and interval from primary ESS on the y-axis shows most patients in this study had primary surgery within 0–5 years of revision ESS.

Table 1. Clinical details of the study population with post revision ESS tissue eosinophil counts.

Total patients	69
CRSwNP/CRSsNP	40/29
Median time from last procedure (IQR) Range • <5 years • 5–10 years • 10–15 years • 15–20 years • >20 years	3.5 yrs. (8.5) 6 months-26 yrs. 42 10 8 5 4
Median pre-operative SNOT-22 (IQR): available for 62 patients	43 (30)
Histopathology findings: Eosinophil count/hpf (available for 66 patients) • <10 • 10–100 • >100	 38 (57.57%) 9 (13.63%) 19 (28.78%)

CRSwNP: chronic rhinosinusitis with nasal polyposis, CRSsNP: chronic rhinosinusitis without polyposis, SNOT-22: 22-item sinonasal outcome test, IQR: interquartile range, hpf: high power field.

Table 2 shows the prevalence of anatomical features identified in the study population possibly contributing to CRS recalcitrance. The most identified feature was residual frontoethmoidal cells—in 72.4% of patients (50/69). Other identified features, in descending order of frequency, were the residual bony septae in posterior and anterior ethmoid sinuses—66.7% (46/69) and 62.3% (43/69), respectively—inadequate sphenoid osteotomy—63.8% (44/69)—deviated nasal septum—53.6% (37/69)—residual uncinate tissue—50.7% (35/69)—and posteriorly placed maxillary antrostomy not incorporating the natural maxillary ostium—39.1% (27/69).

Table 2. Anatomical features potentially associated with CRS recalcitrance identified intraoperatively and during preoperative CT review addressed during revision ESS—their prevalence and bilateral occurrence.

Anatomical Features	**No. of Patients in Which Identified = *n* (Out of 69)**	**No. of Patients with Bilateral Presence of the Same Feature (Out of *n*)**
Deviated nasal septum	37 (53.6%)	-
Residual uncinate tissue	35 (50.7%)	15 (42.8%)
Missed natural maxillary ostium in maxillary antrostomy	27 (39.13%)	23 (85.18%)
Residual bony septae in anterior ethmoids	43 (62.3%)	40 (93.02%)
Residual bony septae in posterior ethmoids	46 (66.67%)	43 (93.47%)
Inadequate sphenoid dissection	44 (63.76%)	19 (43.18%)
Residual frontoethmoidal cells	50 (72.4%)	47 (94%)

The prevalence of each anatomical feature was compared between the CRSwNP and CRSsNP patients. Deviated nasal septum requiring septoplasty and posteriorly placed maxillary antrostomy not incorporating the natural maxillary ostium were observed with a higher prevalence in the CRSwNP group ($p < 0.05$); all other features had no significant difference in their prevalence between these groups ($p > 0.05$).

Duration from previous surgery was also compared between these two groups. CRSwNP patients had significantly longer intervals ($p < 0.001$); although, among 27 patients who had an interval of >5 years since previous surgery, only 4 were of CRSsNP. This could have skewed the results. Among 42 patients receiving previous surgery within 5 years,

24 had CRSsNP, and 18 had CRSwNP. On comparing these patients, no difference in the interval from previous surgery was found between CRSwNP and CRSsNP cases; $p = 0.35$.

Further analysis of identified features was performed after dividing patients into two groups based on intervals from previous surgery: those who received previous surgery within 5 years and those beyond 5 years. No difference in the prevalence of septoplasty ($p = 0.98$), residual frontoethmoidal cells ($p = 0.07$), residual uncinate tissue ($p = 0.23$), missed natural maxillary ostium ($p = 0.29$), residual anterior ($p = 0.21$) and posterior ethmoidal ($p = 0.056$) septations, and small sphenoidotomy ($p = 0.21$) were identified between these two groups.

These features were also assessed for their bilateral occurrence. Residual frontoethmoidal cells were most identified bilaterally—in 47/50 (94%) patients—followed by posterior ethmoids—in 43/46 (93.47%)—anterior ethmoids—in 40/43 (93.02%)—posteriorly placed maxillary antrostomy—in 23/27 (85.18%)—inadequate sphenoid osteotomy—19/44 (43.18%)—and residual uncinate tissue—15/35 (42.8%) patients. Features with the least bilateral occurrence (residual uncinate tissue and inadequate sphenoidotomy) were analyzed for differences in their prevalence on either the right or left side to assess their directional preponderance; no difference in the prevalence of either one was observed ($p > 0.05$).

4. Discussion

Since its introduction in the United States by Dr. David Kennedy in the late 1980s [19], ESS has undergone widespread adoption as the standard of care in the United States. The last 50 years have been remarkable for advancement with high-resolution endoscopes, preoperative high-resolution CT, instruments, microdebriders, and high-speed drills that allow for effective disease clearance with mucosal preservation, improved optical quality and intraoperative image guidance systems [20–22]. ESS is now a critical part of surgical training in residency and fellowships. These factors, along with advances in biotherapeutics have contributed significantly to improving patient outcomes by reducing disease recurrence and incidence of complications associated with ESS [23]. Even so, 4–19.1% of CRS patients still undergo revision ESS [24–26]. Although causes of recalcitrance may include biological severity, inadequate medical therapy, and poor patient compliance with medical therapy [8], suboptimal surgery is also a factor. As most of the patients underwent previous ESS within the last 5 years (Figure 5), our findings are representative of the current trends in the technical quality of ESS.

We investigated the technical quality of contemporary surgery by studying residual anatomical features that have possibly contributed to CRS recalcitrance and needed to be further addressed surgically at revision ESS. The prevalence was expectedly the highest for features related to incomplete frontal outflow dissection, where 72.4% of individuals had significant residual frontoethmoidal cells. Frontal surgery is recognized to be technically challenging, and exploration of the sinuses likely requires a surgeon skilled in safe mucosa-preserving surgery with complete dissection of the anterior and posterior fronto-ethmoidal cells in the narrow outflow tract. Incompletely dissected posterior ethmoidal cells and inadequate sphenoidotomies followed in frequency. Ethmoidectomy is under-recognized for its complexity because it requires dissection close to the lamina papyracea and skull base. Partial ethmoidectomy breeds surgical recalcitrance as partially dissected cells are more likely to scar, produce osteitis, and block the drainage pathway of the adjacent maxillary, sphenoid, and frontal sinuses [11]. A total of 63.8% of sphenoids lack a wide sinusotomy, affecting postoperative topical drug delivery to this sinus [18]. Sphenoid sinusotomy can be performed safely with proper training, knowledge of anatomical landmarks, CT review, and image guidance, if needed.

Our findings are somewhat in common with studies by Baban, et al. [15], where frontal recess (81.2%) followed by anterior (72.9%) and posterior ethmoids (70.8%) were the most common areas with suboptimal dissection, and Gore, et al. [10], where incomplete anterior and posterior ethmoidectomy were the most common findings in 75% of the study patients.

Posteriorly placed maxillary antrostomy (39.13%), residual uncinate process (50.7%), and deviated nasal septum (53.6%) were the least frequently identified features. Failed incorporation of the natural maxillary ostium into the surgically created antrostomy due to the widening of the accessory ostium, or the separation of the natural ostium by a scar band, leads to recirculation of the mucus into the maxillary sinus, precipitating recurrence of maxillary sinusitis [9]. There appears to have been significant progress in the technical quality of maxillary sinus surgery since the study by Parson, et al. [9], where a "missed ostium sequence" was reported in as many as 87% of patients undergoing revision ESS. Ongoing training might have contributed to this reduction in prevalence. However, maxillary antrostomy is widely considered a relatively straightforward procedure, and we were rather surprised that in approximately 40% of our patients, the natural ostium of the maxillary sinus appeared either not incorporated into the surgical antrostomy or separated from it by scar tissue. The prevalence of such features in surgery conducted after nearly four decades of ESS adoption point out the need for continued training in the technical execution of all sinus surgery. Although we observed a reduction in the prevalence of the above-mentioned factors compared to previously published literature, it is noteworthy that no significant difference was observed in the prevalence of these features when compared between patients who had previous surgery within the past 5 years and those who had surgery more than 5 years ago.

Septoplasty or revision septoplasty was necessary in 53.6% of patients. The presence of a deviated septum influences visualization, instrumentation, and the delivery of postoperative topical therapy [27]. It is important to consider the possible reasons for not performing a septoplasty. Certainly, prior insurance authorization for septoplasty versus sinus procedures required by certain insurance companies may cause barriers.

On assessment for directional preponderance, there was no favored prevalence of any of the listed features on a particular side, right or left ($p > 0.05$). The incidence of left-handedness is approximately 10% at a given time [28], which reflects that most endoscopic sinus surgeons are right-handed. Our findings differed from Gore, et al. [10], who reported a relative ease of operating on the left side for a right-handed endoscopic surgeon, resulting in a higher prevalence of residual bony septations along the skull base on the right side in their study.

A higher prevalence of posteriorly placed maxillary antrostomy and deviated nasal septum requiring septoplasty was found in CRSwNP patients ($p < 0.05$). This may be attributed to the relative difficulty in finding the natural maxillary ostium in the milieu of polypoid degeneration of ethmoids and the uncinate process. Regardless, other anatomical features were unaffected by the CRS phenotype. The CRS phenotype also does not seem to affect the duration of disease recalcitrance in our patients. This could reflect the possibility of an equivalent role of these anatomical features in disease recalcitrance irrespective of polyposis status.

Limitations of This Study

The retrospective nature of this study limits the derivation of a causal relationship from the available results. Although we could determine that each of these patients had undergone prior full-house ESS, we could not glean the philosophy of management that dictated the surgery and its extent. We could not obtain the details of the postoperative medical therapy employed after the previous surgery and associated patient compliance, which could have been the contributing factor in CRS recalcitrance along with the identified features. There is also a possibility of missing external follow-up records for additional medical or surgical CRS treatment between the known history and current patient presentation.

5. Conclusions

Although the extent of ESS must be individualized, a high prevalence of anatomical features that could limit the success of ESS was identified in patients with a history of prior full-house ESS in the contemporary era. This study does not intend to highlight the lack

of surgical skill or accuse our fellow surgeons of malpractice but aims to highlight the areas that merit further consideration for focused training during residency and continuous professional development activities. Surgical training focused on operative skills and the utilization of available supportive technology, emphasizing these areas with difficult surgical access and important surrounding structures, could improve the confidence of contemporary endoscopic sinus surgeons intraoperatively, and improve the technical quality of ESS. Addressing these areas in primary ESS for all CRS subtypes could help to reduce postsurgical recidivism.

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Informed Consent Statement: Patient consent was waived due to the study being a retrospective review of electronic health records and using de-identified patient data.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors on request.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

ESS	Endoscopic sinus surgery
CRS	Chronic rhinosinusitis
CRSwNP	Chronic rhinosinusitis with nasal polyposis
CRSsNP	Chronic rhinosinusitis without nasal polyposis
IRB	Institutional review board
CT	Computed tomography
SNOT-22	22-item sinonasal outcome test
HPE	Histopathology examination

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