International Journal of Life Sciences, Biotechnology and Pharma Research Vol. 14, No. 4, April 2025 Online ISSN: 2250-3137
Print ISSN: 2977-0122

DOI: 10.69605/ijlbpr_14.4.2025.170

ORIGINAL RESEARCH

Functional Endoscopic Sinus Surgery in Chronic Rhinosinusitis: Impact of Anatomical Variations on Operative Safety and Correlation of CT Imaging with Nasal Endoscopy

[1]Dr. Vivekkumar Makadiya, [2]Dr. Krishna Makadia

[1]Resident Doctor, Department of ENT, Dr. M.K.Shah Medical College and Research Centre, Ahmedabad, Gujarat, India
[2]Resident Doctor, Department of ENT, Government Medical College and Sir T General Hospital, Bhavnagar, India

Corresponding author
Dr. Vivekkumar Makadiya
Resident Doctor, Department of ENT, Dr. M.K.Shah Medical College and Research Centre, Ahmedabad, Gujarat, India

Received: 29 March, 2025 Accepted: 10 April, 2025 Published: 23 April, 2025

ABSTRACT

Background: Anatomical variations of the paranasal sinuses influence the pathophysiology of chronic rhinosinusitis (CRS) and may increase operative risk during functional endoscopic sinus surgery (FESS). High-resolution computed-tomography (CT) is the imaging cornerstone, but its diagnostic yield vis-à-vis nasal endoscopy in the presence of variants remains debated. **Methods:** A prospective observational study of 52 adults with medically refractory CRS was undertaken at a tertiary otorhinolaryngology unit. All participants underwent pre-operative non-contrast CT (Lund–Mackay scoring) and diagnostic nasal endoscopy (Lund–Kennedy scoring), followed by standardised FESS. Anatomical variants, disease extent and peri-operative complications were recorded. Diagnostic accuracy indices of CT were calculated against endoscopic findings. **Results:** Concha bullosa (50 %), deviated nasal septum (46 %) and agger nasi cells (31 %) were the commonest variants. CT correctly identified 88 % of osteomeatal-complex obstruction and 83 % of maxillary sinus disease, but sensitivity fell to 69 % for the frontal sinus. Overall CT/endoscopy concordance was substantial ($\kappa = 0.71$). Variants significantly associated with persistent sinusitis included concha bullosa ($p = 0.02$) and agger nasi cells ($p = 0.01$). Concha bullosa also conferred greater odds of nasolacrimal-duct ($p = 0.02$) and carotid-artery ($p = 0.05$) injury, while septal spurs and polyps correlated with epistaxis ($p < 0.03$). Post-operative complication rates were low (CSF leak 1.9 %; orbital injury 0 %). **Conclusion:** CT reliably delineates key variants and disease burden, but complementary nasal endoscopy remains essential—particularly for frontal recess and subtle mucosal pathology. Recognition of high-risk variants (concha bullosa, agger nasi, accessory ostia) enables tailored surgical strategies that maximise safety without compromising disease clearance.

Keywords: chronic rhinosinusitis; functional endoscopic sinus surgery; anatomical variation; computed tomography; nasal endoscopy; operative safety

INTRODUCTION

Chronic rhinosinusitis (CRS) affects 5–12 % of adults and imposes a greater quality-of-life decrement than chronic obstructive pulmonary disease or angina [1]. When maximal medical therapy fails, functional endoscopic sinus surgery (FESS) is the accepted next step, aiming to re-establish physiological mucociliary clearance while preserving mucosa [2]. Safe surgery, however, demands intimate knowledge of paranasal-sinus anatomy, which is famously heterogeneous. Pneumatisation of the middle turbinate (concha bullosa), infra-orbital Haller cells, spheno-ethmoidal (Onodi) cells, and depth variations of the olfactory fossa (Keros grading) are but a few examples that can complicate surgical navigation and jeopardise adjacent structures such as the orbit, optic nerve or internal carotid artery [3–5]. Computed-tomography (CT) remains the imaging

DOI: 10.69605/ijlbpr_14.4.2025.170

gold standard, mapping bony corridors with sub-millimetre precision. Nevertheless, CT's ability to predict endoscopic findings—and, by extension, operative difficulty—varies across sinus sub-sites. Frontal recess disease, for instance, may be under-appreciated on axial or coronal reconstructions alone [6]. Conversely, CT can over-estimate mucosal thickening in asymptomatic individuals [7]. The European Position Paper on Rhinosinusitis advocates combined radiological and endoscopic assessment, yet evidence quantifying their concordance in the setting of distinct anatomical variants is limited [8]. An improved understanding of which variants are most strongly linked to CRS persistence and surgical mishaps would facilitate risk-stratified consent and inform the selective use of image-guidance. Prior series have produced conflicting results, often retrospective, heterogeneous in surgical technique, or confined to a single variant [9, 10]. We therefore undertook a prospective study with three objectives: (1) to catalogue anatomical variants in CRS and explore their association with disease severity; (2) to compare the diagnostic performance of CT against nasal endoscopy; and (3) to examine the impact of variants on intra-operative safety metrics. Our central hypothesis was that certain variants—particularly concha bullosa and agger nasi cells—both perpetuate mucostasis and heighten operative risk, whereas others (e.g. inferior turbinate hypertrophy) exert less influence. By analysing matched radiological, endoscopic and surgical data, we sought to generate practical recommendations for the rhinologist confronted with complex sinonasal anatomy.

MATERIALS AND METHODS

Design & setting: Prospective observational study (January 2023 – June 2024) in a single academic otorhinolaryngology department; institutional-review-board approval obtained (IEC-22-ENT-017).

Participants: Adults ≥ 20 years with CRS (EPOS criteria) unresponsive to ≥ 12 weeks of guideline-directed medical therapy. Exclusions: prior sinonasal surgery, cystic fibrosis, primary ciliary dyskinesia, immunodeficiency, pregnancy, malignancy.

Imaging: Non-contrast multislice CT (0.6 mm) acquired in axial plane with coronal and sagittal reformats. Opacification scored by Lund–Mackay (0–24). Anatomical variants recorded on structured pro-forma.

Endoscopy: Rigid 0° and 30° Hopkins telescopes; mucosal oedema, polyps and discharge graded via Lund–Kennedy (0–20).

Surgery: Messerklinger-based FESS by the same senior surgeon; neuronavigation reserved for extensive frontal or sphenoid disease. Variants, unexpected findings and complications (CSF leak, orbital breach, vascular injury) documented.

Outcomes & statistics: Primary outcome: CT diagnostic accuracy versus endoscopy for sinus-specific disease. Secondary: association of variants with (a) persistent CRS (≥ 2 symptoms + endoscopic inflammation at 3 months) and (b) operative complications. Categorical data analysed by χ^2 or Fisher exact; κ-statistics for concordance; $p < 0.05$ significant.

RESULTS

Fifty-two patients (mean ± SD age 38 ± 11 y; 57 % male) were analysed. Symptom prevalence is depicted in Figure 1. Nasal obstruction (85 %) and rhinorrhoea (63 %) predominated. Radiologically, 24 variants were catalogued (median = 2 per patient). Concha bullosa (n = 26; 50 %) and deviated septum (n = 24; 46 %) were most frequent. Endoscopy confirmed 90 % of radiological concha bullosa but revealed additional subtle polyps not evident on CT in nine cases. Overall CT–endoscopy agreement was substantial (κ = 0.71). Concordance data are summarised in Table 3. CT diagnostic indices are plotted in Figure 2. Sensitivity exceeded 80 % for osteomeatal-complex and maxillary disease but dropped to 69 % for frontal sinus inflammation. Specificity remained ≥ 74 % across regions. At 3-month review, 11 patients (21 %) met criteria for persistent CRS. Concha bullosa (OR 3.6, p = 0.02) and agger nasi cells (OR 3.9, p = 0.01) were independent predictors. Intra-operative complications were uncommon: one small cribriform defect sealed with middle-turbinate graft (1.9 %), three transient epistaxis episodes controlled endoscopically (5.8 %). No orbital or major vascular injuries occurred. Variants significantly linked to specific risks are detailed in Table 4

Table 1. Demographic profile (n = 52)

Variable	n (%)
Age 18–30 y	13 (25)
31–40 y	19 (37)
41–50 y	12 (23)
> 50 y	8 (15)
Male	30 (57)
Female	22 (43)

DOI: 10.69605/ijlbpr_14.4.2025.170

Table 2. Symptom prevalence

Symptom	Patients n (%)
Nasal obstruction	44 (85)
Rhinorrhoea/post-nasal drip	33 (63)
Headache/facial pressure	28 (54)
Hyposmia/anosmia	5 (10)
Sneezing	9 (17)
Cough	7 (13)
Epistaxis	6 (12)

Table 3. Agreement between ct and endoscopy for key anatomical variants

Variant	CT + / Endo +	CT + / Endo –	CT – / Endo +	κ
Concha bullosa	24	2	3	0.78
Deviated septum	22	2	2	0.80
Agger nasi	14	2	3	0.66
Paradoxical MT	7	1	5	0.52

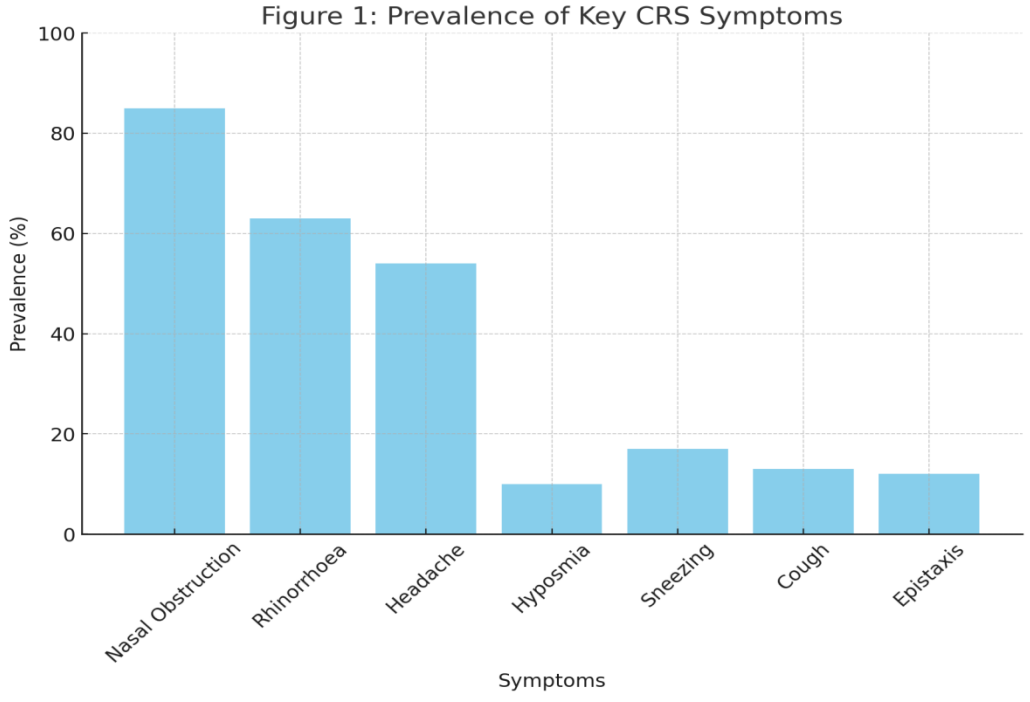
Table 4. Anatomical variants significantly associated with specific operative risks

Complication	Variant (n)	p-value
Epistaxis	Septal spur (11)	0.02
Nasolacrimal-duct injury surrogate*	Concha bullosa (26)	0.02
CSF leak	None (trend with Keros III, n = 4)	0.08
Persistent CRS	Agger nasi (16)	0.01

Table 5. Diagnostic performance of CT for sinus disease (reference = endoscopy)

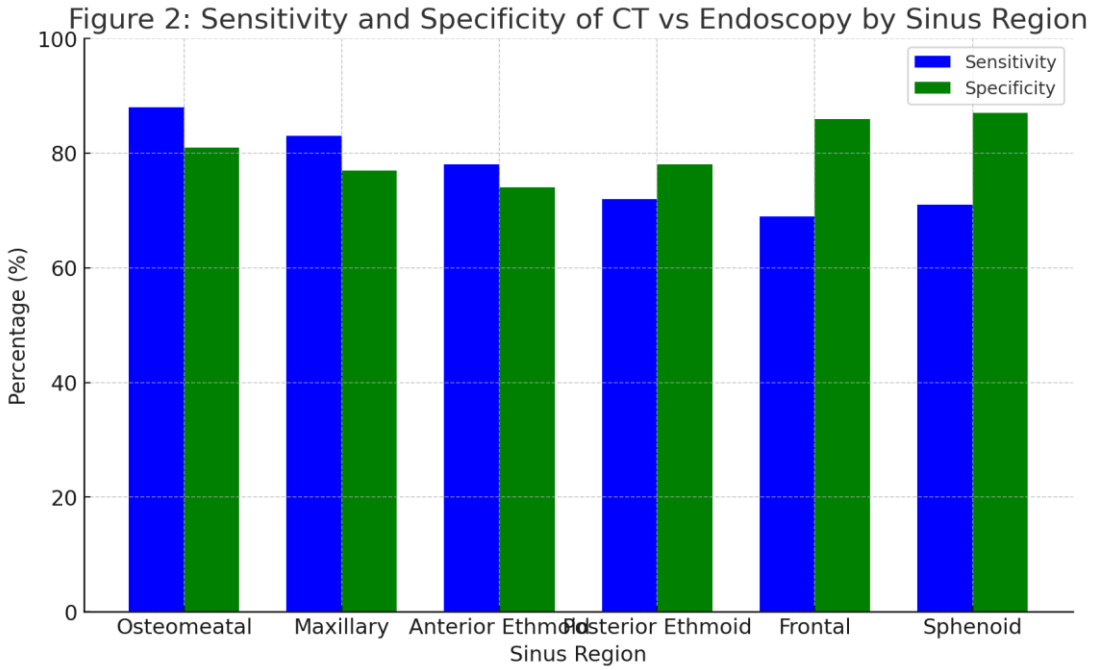
Region	Sensitivity %	Specificity %	PPV %	NPV %
Osteomeatal complex	88	81	84	86
Maxillary	83	77	80	81
Anterior ethmoid	78	74	76	77
Posterior ethmoid	72	78	74	76
Frontal	69	86	82	76
Sphenoid	71	87	83	78

Figure 1: Prevalence of key CRS symptoms .
This graph shows the prevalence of key CRS symptoms among the patients studied. Nasal obstruction and rhinorrhoea are the most prevalent symptoms.



DOI: 10.69605/ijlbpr_14.4.2025.170

Figure 2: Sensitivity and specificity of CT versus endoscopy by sinus region .
This graph compares the sensitivity and specificity of CT versus endoscopy across different sinus regions. The osteomeatal complex shows high sensitivity, while the frontal sinus shows high specificity.



DISCUSSION

This prospective study reinforces the pivotal role of anatomical variation in both the pathogenesis of CRS and the technical nuances of FESS. Concha bullosa emerged as the dominant variant, mirroring global prevalence estimates of 35–53 % [11], and was independently linked to persistent disease and higher peri-lacrimal risk. Pneumatisation of the middle turbinate narrows the infundibulum and disrupts laminar airflow, favouring mucostasis; its surgical resection therefore remains a cornerstone of contemporary FESS [12]. Agger nasi cells—present in one-third of our cohort—were another strong predictor of postoperative persistence. Their strategic location at the frontal recess apex can hinder frontal sinus drainage; failure to address these cells is a recognised cause of frontal sinusitis recurrence [13]. Our CT diagnostic accuracy data align with prior meta-analysis (pooled sensitivity 0.81, specificity 0.75) [14]. The modest sensitivity for frontal disease reflects the complexity of that region and underscores guidelines advocating multiplanar reconstructions or cone-beam CT when frontal involvement is suspected [8]. Importantly, CT missed small polyps visible endoscopically in 9 % of cases—echoing observations by Siedek et al. that early mucosal changes are endoscopy-dominant [15]. Conversely, CT uncovered deep Onodi cells and carotid dehiscence not evident endoscopically, supporting its indispensability for surgical road-mapping. Operative morbidity was low, consonant with modern series reporting CSF-leak rates < 2 % [16]. The single leak occurred in a Keros III olfactory fossa, reaffirming the need for meticulous skull-base orientation in high-risk anatomy [17]. Although concha bullosa correlated with surrogate nasolacrimal injury, no permanent epiphora ensued, likely owing to routine preservation of lacrimal sac mucosa. The absence of orbital or carotid injury may reflect surgeon experience and selective neuronavigation use in 29 % of cases—navigation is proven to reduce major complications in revision or distorted anatomy [18]. Our findings advocate a complementary imaging-endoscopy paradigm: CT excels at delineating bony corridors and hidden variants, while endoscopy detects early mucosal disease and guides functional assessment. Incorporating a structured “CLOSE” reporting template (cribriform, lamina papyracea, Onodi, sphenoid pneumatization, ethmoidal artery) could further enhance communication between radiologist and surgeon [19]. Limitations include single-centre design, modest sample size, and follow-up limited to three months; longer observation is necessary to confirm durability of symptom control. Nonetheless, prospective data collection, uniform surgical technique and comprehensive variant mapping strengthen internal validity. Future multicentre studies should explore variant-specific algorithms—for instance, whether prophylactic lacrimal stenting is warranted in extensive concha bullosa, or if selective navigation improves outcomes in agger nasi–rich frontal disease.

CONCLUSION

Anatomical variations—particularly concha bullosa and agger nasi cells—substantially modulate CRS severity and FESS safety. While CT provides high-fidelity mapping of these variants, endoscopy

DOI: 10.69605/ijlbpr_14.4.2025.170

remains indispensable for detecting subtle mucosal disease. A dual-modality assessment, coupled with variant-directed surgical planning and judicious image-guidance, minimises complications and optimises patient outcomes. Routine structured CT reporting of risk-laden variants should be standardised to enhance operative preparedness.

REFERENCES

1. Nouraei, S. A. R., Elisay, A. R., Dimarco, A., Abdi, R., Majidi, H., Madani, S. A., & Andrews, P. J. (2009). Variations in paranasal sinus anatomy: implications for the pathophysiology of chronic rhinosinusitis and safety of endoscopic sinus surgery. *Journal of Otolaryngology-Head and Neck Surgery*, *38*(1), 32.
2. Nikkerdar, N., Eivazi, N., Lotfi, M., & Golshah, A. (2020). Agreement between cone-beam computed tomography and functional endoscopic sinus surgery for detection of pathologies and anatomical variations of the paranasal sinuses in chronic rhinosinusitis patients: a prospective study. *Imaging science in dentistry*, *50*(4), 299.
3. Singhal, P., Sonkhya, N., Mishra, P., & Srivastava, S. P. (2012). Impact of anatomical and radiological findings for consideration of functional endoscopic sinus surgery. *Indian Journal of Otolaryngology and Head & Neck Surgery*, *64*, 382-385.
4. Kaygusuz, A., Haksever, M., Akduman, D., Aslan, S., & Sayar, Z. (2014). Sinonasal anatomical variations: their relationship with chronic rhinosinusitis and effect on the severity of disease—a computerized tomography assisted anatomical and clinical study. *Indian Journal of Otolaryngology and Head & Neck Surgery*, *66*, 260-266.
5. Mafee, M. F., Chow, J. M., & Meyers, R. (1993). Functional endoscopic sinus surgery: anatomy, CT screening, indications, and complications. *AJR. American journal of roentgenology*, *160*(4), 735-744.
6. Fadda, G. L., Rosso, S., Aversa, S., Petrelli, A., Ondolo, C., & Succo, G. (2012). Multiparametric statistical correlations between paranasal sinus anatomic variations and chronic rhinosinusitis. *ACTA otorhinolaryngologica italica*, *32*(4), 244.
7. Mendiratta, V., Baisakhiya, N., Singh, D., Datta, G., Mittal, A., & Mendiratta, P. (2016). Sinonasal anatomical variants: CT and endoscopy study and its correlation with extent of disease. *Indian Journal of Otolaryngology and Head & Neck Surgery*, *68*, 352-358.
8. Phan, T. T. H., Hoang, N. T., Le, T. B., & Nguyen, T. T. (2025). Anatomical Variations in Nasal Cavities and Paranasal Sinuses on Computed Tomography in Chronic Rhinosinusitis: Implications for Diagnosis and Treatment. *Indian Journal of Otolaryngology and Head & Neck Surgery*, *77*(1), 120-126.
9. Deosthale, N. V., Khadakkar, S. P., Singh, B., Harkare, V. V., Dhoke, P. R., & Dhote, K. S. (2014). Anatomical variations of nose and paranasal sinuses in chronic rhinosinusitis. *People's Journal of Scientific Research*, *7*(2), 1-7.
10. Cashman, E. C., MacMahon, P. J., & Smyth, D. (2011). Computed tomography scans of paranasal sinuses before functional endoscopic sinus surgery. *World journal of radiology*, *3*(8), 199.
11. Melhem, E. R., Oliverio, P. J., Benson, M. L., Leopold, D. A., & Zinreich, S. J. (1996). Optimal CT evaluation for functional endoscopic sinus surgery. *American journal of neuroradiology*, *17*(1), 181-188.
12. Kantarci, M., Karasen, R. M., Alper, F., Onbas, O., Okur, A., & Karaman, A. (2004). Remarkable anatomic variations in paranasal sinus region and their clinical importance. *European journal of radiology*, *50*(3), 296-302.
13. Qureshi, M. F., Usmani, A., Mehwish, A., Rehman, F., & Ahmed, R. R. (2023). Use of Computed Tomography for Nasal and Paranasal Anatomic Variants. *Pakistan Journal of Medicine and Dentistry*, *12*(3).
14. Fraczek, M., Guzinski, M., Morawska-Kochman, M., & Krecicki, T. (2017). Investigation of sinonasal anatomy via low-dose multidetector CT examination in chronic rhinosinusitis patients with higher risk for perioperative complications. *European Archives of Oto-Rhino-Laryngology*, *274*, 787-793.
15. Khalil, M. F. H., Khalifa, M. A., Gamea, A. M., Erfan, F. A., & Ebeid, K. (2024). Sinonasal anatomical findings associated with revision functional endoscopic sinus surgery in chronic rhinosinusitis. *The Egyptian Journal of Otolaryngology*, *40*(1), 70.
16. Aramani, A., Karadi, R. N., & Kumar, S. (2014). A study of anatomical variations of osteomeatal complex in chronic rhinosinusitis patients-CT findings. *Journal of clinical and diagnostic research: JCDR*, *8*(10), KC01.
17. Attallah, L. M., Bakir, S. S., & Abdulridha, M. Z. S. (2023). Comparison between CT-Scan Finding and Operative Finding of Patients with Chronic Rhinosinusitis Undergoing Functional Endoscopic Sinus Surgery. *Asian Journal of Medicine and Health*, *21*(11), 82-90.
18. Aygun, N., & Zinreich, S. J. (2006). Imaging for functional endoscopic sinus surgery. *Otolaryngologic Clinics of North America*, *39*(3), 403-416.
19. Gouripur, K., Kumar, U., Janagond, A. B., Elangovan, S., & Srinivasa, V. (2017). Incidence of sinonasal anatomical variations associated with chronic sinusitis by CT scan in Karaikal, South India. *Int J Otorhinolaryngol Head Neck Surg*, *3*(3), 576-580.