

Advancing Precision in Functional Endoscopic Sinus Surgery: The Role of Navigation Technology

Ravi Ramalingam¹, Aswathi Paleri², K K Ramalingam³, Sanjay Udipi⁴, Wasim Khan⁵, Ramu Harirajan⁶

¹⁻⁶Department of Otorhinolaryngology, KKR ENT Hospital and Research Institute, Chennai, Tamil Nadu, India

Correspondence to: Ravi Ramalingam, Department of Otorhinolaryngology, Chennai, Tamil Nadu, India, Email : Kkrenthospital@gmail.com

Received date: November 06, 2024; **Accepted date:** November 17, 2024; **Published date:** November 30, 2024

Citation: Paleri A, Ramalingam R, Ramalingam KK, et al. Advancing Precision in Functional Endoscopic Sinus Surgery: The Role of Navigation Technology. *Int J Med Res Surg.* 2024, 1(2):15-22. doi: [10.70275/ijmrs200236](https://doi.org/10.70275/ijmrs200236)

Copyright: ©2024 Ravi Ramalingam, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution and reproduction in any medium, provided the original author and source are credited.

ABSTRACT

Objectives: Navigation technology is a useful tool for surgeons performing complex rhinologic procedures, such as extensive sinonasal polyposis (SNP), revision surgeries, anatomical variations, and cerebrospinal fluid leaks. This study aimed to evaluate the role of navigation systems in functional endoscopic sinus surgery (FESS).

Materials and Methods: Sixty patients from KKR ENT Hospital, Chennai, were divided into Group A (FESS with navigation) and Group B (FESS without navigation). Patients with chronic rhinosinusitis (CRS) with SNP, revision surgeries for SNP or sinonasal tumors (SNT), and frontal sinus disease (FSD) were included. Pre- and postoperative Lund-Mackay scores, Sino-Nasal Outcome Test-22 (SNOT-22) scores, and CT scans were analyzed. Navigation assistance using the Fusion Compact Medtronic System was employed based on surgical evaluation. Postoperative nasal endoscopy and follow-ups assessed outcomes.

Results: No significant differences in SNOT-22 and endoscopic scores were observed between groups. However, intraoperative complications and recurrence were higher in Group B, indicating better outcomes in Group A. Navigation significantly improved precision and reduced complications ($p < 0.05$).

Conclusion: Navigation technology enhances surgical accuracy and reduces complications, offering significant benefits in complex FESS cases.

Keywords:

Chronic rhinosinusitis, Endoscopic sinus surgery, Sinonasal polyposis, Navigation system, Surgical precision.

Introduction

Chronic rhinosinusitis (CRS) is the inflammation of nasal cavity and paranasal sinuses that lasts for more than 12 weeks, with or without acute exacerbations.¹ CRS is considered the most common problem in the field of otorhinolaryngology and it is a highly prevalent inflammatory disease in several countries,² representing a,

substantial burden of disease on healthcare, productivity, and the quality of life.³⁻⁵ In India, the incidence of CRS is gradually increasing and has significant socioeconomic implications.⁶⁻⁸ Nasal obstruction is the most common symptom in CRS, with nasal discharge, facial congestion, facial pain and hyposmia being the other symptoms.⁹ Chronic rhinosinusitis is confirmed by nasal endoscopy to assess the extent of sinonasal mucosal inflammation and presence of polyps.¹⁰ Topical and systemic steroids are widely used for the treatment of CRS; however, surgery is reserved for patients if the medical treatment fails or is inadequate.¹¹

Chronic rhinosinusitis with nasal polyps is a subset of CRS, where benign outgrowths of sinonasal mucosa, known as nasal polyps, are typically found bilaterally. It is clinically diagnosed based on the presence of objective and subjective evidence of chronic sinonasal inflammation.¹² Carcinomas of the nasal cavity and paranasal sinuses account for 3% in head and neck and 0.2–0.8% of all the malignant neoplasms in the body. The tumors originating in the sinonasal cavity may arise either from the lining epithelium or from the underlying bone and cartilage.¹³ The frontal sinus disease (FSD) is the most common inadequate¹¹ source of intracranial complication in sinusitis, that occurs by hematogenous spread through a communicating venous system.¹⁴

Despite the advantages of endoscopic visualization, FESS is associated with inherent risks, including trauma to surrounding structures, intraoperative bleeding, and rare but severe complications such as death. Major complications occur in approximately 0.5–1% of cases. The complexity of FESS, particularly in cases involving prior surgeries, distorted anatomical landmarks, or invasive diseases, presents challenges due to the proximity of critical vascular and neural structures.

Navigation technology has emerged as a transformative tool in endoscopic sinus and anterior skull base surgeries, aiding surgeons in identifying critical structures and navigating altered anatomical landscapes. This technology improves visualization, reduces surgical time, and enhances surgeon confidence, particularly in challenging cases such as extensive polyposis, tumors, or revision surgeries. However, its impact on reducing intraoperative complications and improving patient outcomes remains a topic of debate.

This study aimed to evaluate the utility of navigation technology in FESS by comparing surgical outcomes, complications, and effectiveness between surgeries performed with and without image guidance. FESS and various anterior skull base surgeries are extremely challenging due to the variety of vascular and neural structures in a very confined space. Moreover, with previous surgical procedures, scarring, and the destructive nature of some diseases, surgical landmarks are distorted,

Materials and Methods

A total of 60 patients were recruited from June 2017 to June 2019 at KKR ENT Hospital and Research Institute, Chennai. Patients with extensive sinonasal polyposis (SNP), CRS with recurrent nasal polyps after surgery, sinonasal tumors (SNT), and FSD or anatomical variants of the paranasal sinuses were included in this study. Patients with an antrochoanal polyp, mucocoele, mycetoma, or dentigerous cyst diagnosed by computed tomography (CT) scan and those under the age of 18 were excluded. All the patients were divided into two groups— group A comprised of 30 patients (14 with SNP, 7 with SNTs, 7 undergoing revision FESS, and 2 with FSD) who were operated on with the aid of navigation. The remaining 30 patients (16 with SNP, 4 with SNTs, 9 undergoing revision FESS, and 1 with FSD) without the assistance of image guidance were classified as group B. Patients who could not afford the expenditure of navigation-aided surgery and those who did not follow-up after the surgery were excluded. A detailed explanation of the availability, cost, and advantage of navigation technology in the current scenario as far as their disease pathology is concerned was given to all the patients. Upon ethical approval from the KKR Institutional Ethics Committee, written consent was obtained from all the subjects.

Sino-Nasal Outcome Test-22 Score

Sino-Nasal Outcome Test-22 (SNOT-22) score is a validated questionnaire for CRS-specific outcome measure consisting of 22 items that capture sinus-specific and general health-related impact of the disease process.²⁵ Factor analysis of the SNOT-22 has revealed that the instrument measures five distinct health domains. The rhinological domain consists of the questions addressing all of the cardinal symptoms of CRS except for facial pain/pressure.

Modified Lund-Mackay Postoperative Endoscopic Score

The Modified Lund-Mackay postoperative endoscopic score (MLMES) is a sinus cavity staging system that scores the endoscopic appearance of the sinus cavities by incorporating polyp, edema, discharge, crusting, and scarring.²⁶

The endoscopic appearance of sinonasal mucosa is graded from zero to six as: 0—normal mucosa, 1—mild edematous mucosa with a patent cavity, 2—severe edematous mucosa with a compromised cavity, 3—mild polypoid mucosa with a patent cavity, 4—severe polypoid mucosa with a compromised cavity, 5—polyp confined within the cavity, and 6—polyp extending beyond the cavity.

Preoperative Assessment

The SNOT-22 questionnaire was provided to all the subjects, and the scores were calculated. All patients underwent clinical examination, radiological, and laboratory investigations. A CT scan of the nose and paranasal sinuses was conducted for all patients in group A according to the navigation protocol specified by the Medtronic Fusion Navigation System. In contrast, patients in group B underwent a regular CT scan of the paranasal sinuses. Pre-intervention nasal endoscopy was performed on both sets of patients, and scores were calculated using the Lund-Mackay endoscopic scoring system. The CT images were then loaded into the computer. The headband, monitor, and emitter were arranged in the Fusion Compact. The setup time for the same was calculated and recorded.

Workflow and Setting Up of Navigation System

Up till the salivary stone's surface could be easily recognized, the laser was focused on it. Using forceps, the salivary stone was extracted while being careful not to break it. After the stone was removed (figure 5), the submandibular gland was pressed, resulting in the production of saliva. There was no unusual bleeding after the satisfactory completion of the surgical treatment. For thirty days, the patient was monitored to ensure healing and saliva production.

Surgery

Prior to surgery, the surgeon conducted an endoscopic examination to verify the preoperative endoscopic values. In most cases, the FESS procedure included middle meatal antrostomy, fronto-ethmo-sphenoidotomy, and medial maxillectomy with tumor clearance for patients with sinonasal tumors (SNT) in both groups. During the procedure, the preoperative setup time (specific to Group A) and intraoperati

Postoperative Outcome

Post-surgical reviews were conducted at 4 and 12 weeks. Participants underwent nasal endoscopy, and the SNOT-22 questionnaire was recorded during both visits. Patients post-FESS were advised longterm alkaline and steroid nasal douching along with antihistamines.

Statistical Analysis

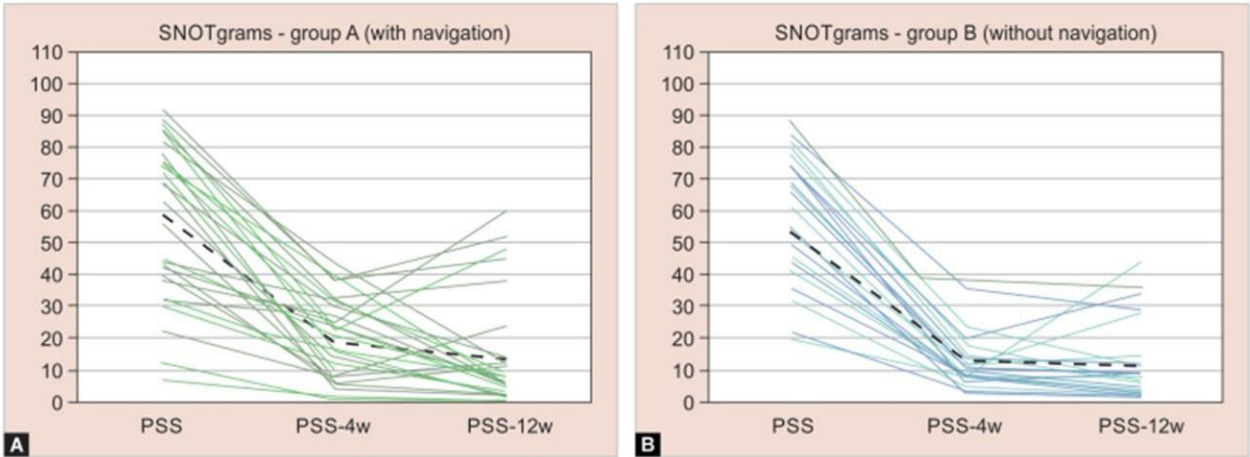
Descriptive statistics such as frequency, percentage, mean, and standard deviation were utilized. Pearson's correlation was employed to establish the relationship between endoscopic score and SNOT-22 score. The Chi-squared test of proportions was used to test for significant differences in baseline demographic variables.

Results

In group A, a total of 20 males and 10 females were recruited, while in group B, there were 19 males and 11 females, resulting in 65% males and 35% females among the subjects. The majority of the subjects were aged above 40 years old (68.33%), with 31.67% being <40 years old. Common symptoms included nasal blockage, the need to blow nose, sneezing, difficulty falling asleep, facial pain, runny nose, and post-nasal drip. Nasal blockage was identified as the predominant problematic symptom encountered in both sets of patients. The SNOT-22 scores were plotted against time to create SNOTgrams. In Figure 1, patients in group A were to have a higher SNOT-22 score before (Fig. 1A) and after 12 weeks (Fig. 1B). Almost 50% in both the groups who were subjected to surgery were diagnosed with chronic rhinosinusitis with polyposis. Additionally, 23% and 30% revision cases in both group A and group B respectively, had recurrent polyposis. Disease extent was measured endoscopically, preoperatively with LMES and postoperatively with MLMES, shown in Table 1. Group A had a mean endoscopic score of 7.90 ± 0.54 preoperatively, marginally higher compared to group B (7.43 ± 0.41). The postoperative 4th-week endoscopic score was notably higher in group A (7.37 ± 1.24), indicating a more extensive FESS

with more sinuses opened and thus higher mucosal edema and discharge compared to group B (4.83 ± 0.90). By the end of 3 months, both group A (3.30 ± 1.09) and group B (3.52 ± 1.09) had almost identical mean endoscopic values. There was no statistically significant difference in the endoscopic score and SNOT-22 scores preoperatively and postoperatively at 4 weeks and 12 weeks between the two groups ($p > 0.05$). There was also no statistically significant improvement in patient outcomes following FESS with navigation assistance compared to nonimage-guided surgery at the end of 12 weeks in both endoscopic and SNOT-22 scores ($p > 0.05$). However, SNOT-22 scores and endoscopic score over the follow-up period of 12 weeks showed a significant improvement ($p < 0.05$) in both groups.

By using Pearson correlation coefficient, a significant correlation was established between the preoperative endoscopic score (Fig. 2A) and SNOT-22 score ($r=0.363$, $p=0.004$), for postoperative endoscopic (Fig. 2B) at the end of 4 weeks ($r=0.758$, $p=0.0001$), 12 weeks ($r=0.722$, $p=0.0001$) within the two groups (Fig. 2C). The mean preoperative SNOT-22 score was higher in group A (Fig. 3A) specifically in revision FESS and FSD than group B (Fig. 3B). After the surgical intervention, group A had managed to attain similar mean SNOT-22 score like in group B suggesting greater clearance of disease with the aid of image-guidance. There were no intraoperative complications in group A is an advantage of over



Figs 1A and B: PSS: Preoperative SNOT-22 Score, PSS 4w: Postoperative SNOT-22 Score at 4 weeks, PSS 12W: Postoperative SNOT-22 Score at 12 weeks in group A (A) in green and group B (B) in blue

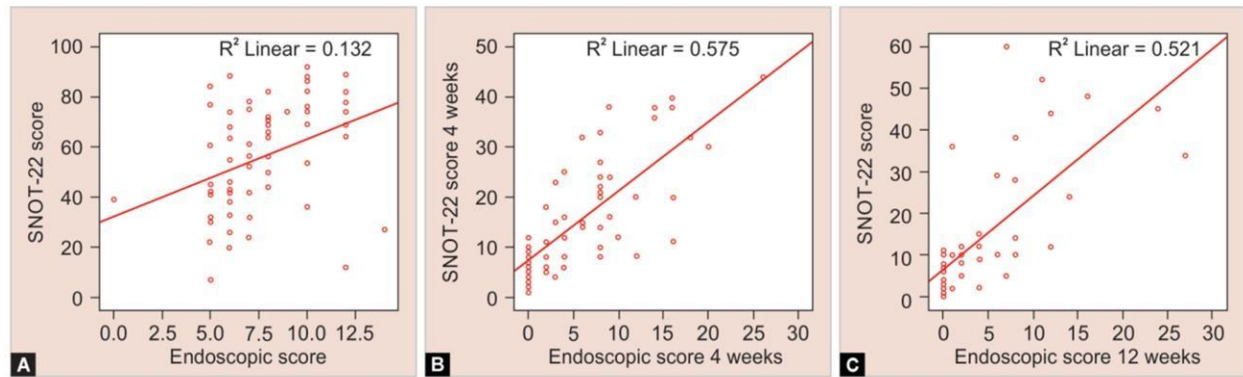
Table 1: Comparison of endoscopic, SNOT-22, LMES, and MLMES scores among groups A and B

	Endoscopic score*	p-value	SNOT-22 score†	p-value	Lund-Mackay preoperative endoscopic score	p-value	MLMES	p-value
Preoperative								
Group A	7.90 ± 0.54	0.432	58.23 ± 4.40	0.325	7.90 ± 0.54	0.432	–	
Group B	7.43 ± 0.41		53.80 ± 3.64		7.43 ± 0.41			
Postoperative 4th week								
Group A	7.37 ± 1.24	0.175	18.80 ± 2.36	0.137	–		7.37 ± 1.24	0.175
Group B	4.83 ± 0.90		12.90 ± 1.50				4.83 ± 0.90	
Postoperative 12th week								
Group A	3.30 ± 1.09	0.634	13.13 ± 3.14	0.667	–		3.30 ± 1.09	0.634
Group B	3.52 ± 1.09		11.03 ± 2.07				3.52 ± 1.09	

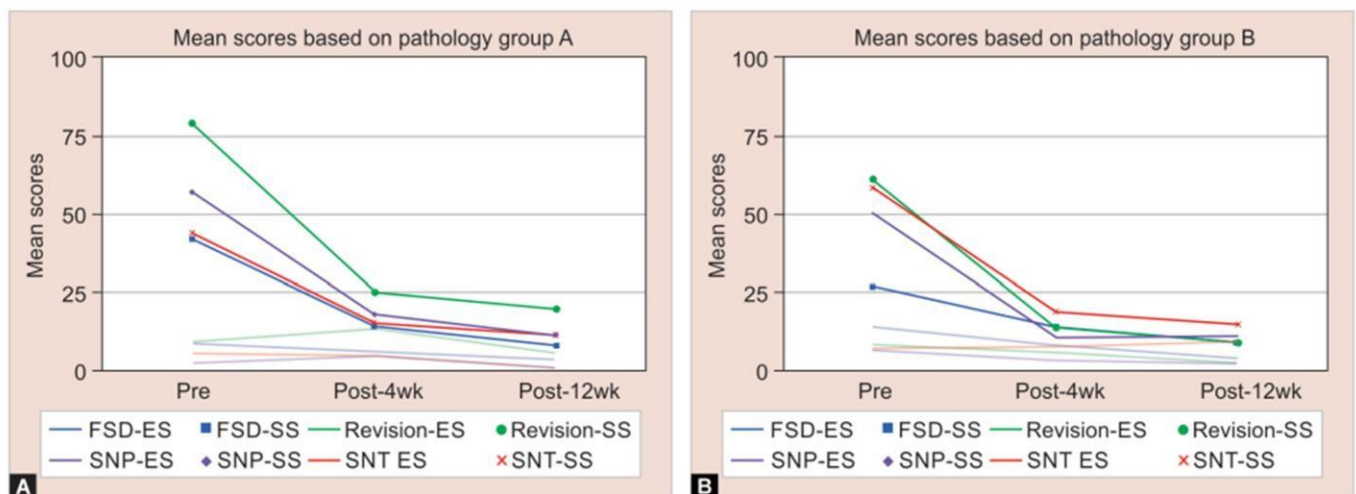
MLMES, Modified Lund-Mackay postoperative endoscopic score; comparison between mean endoscopic score* and SNOT-22 score† in groups A and B, respectively

group B. The intraoperative time consumption for group A (Fig. 4A) had progressively reduced with a mean of 85 minutes for surgery compared to 101 minutes for group B (Fig. 4B). When comparing the ease of surgery score as per the operating surgeon, significant difference ($p < 0.01$) was observed between the groups.

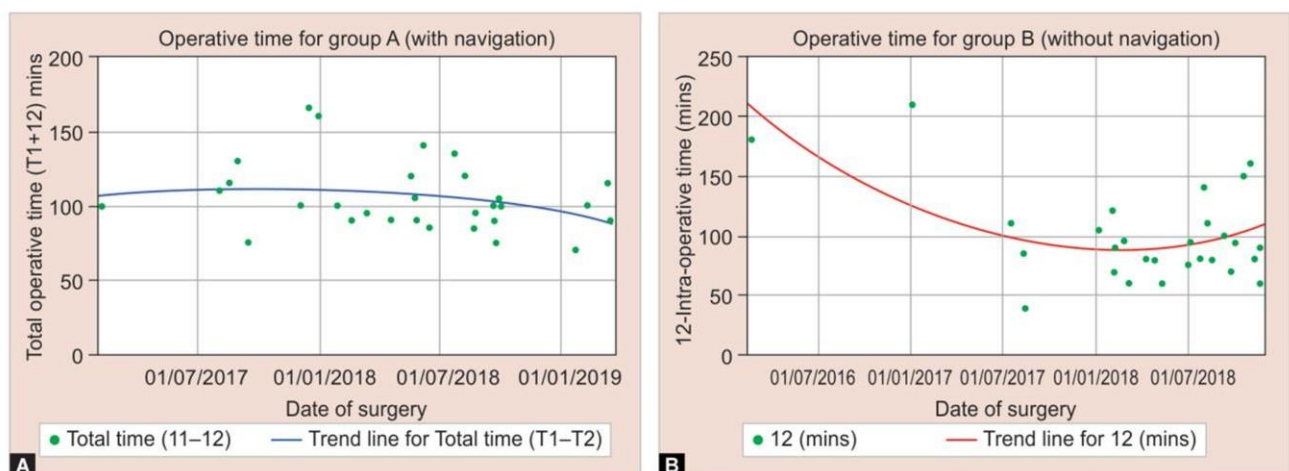
After the postoperative period, patients were followed up for 12 months. Recurrences of pathology included one left SNT (25%), one revision (25%), and two SNP (50%) in group A, compared to two SNP (40%), one revision (20%), and two SNT (40%) in group B.



Figs 2A to C: Correlation between preoperative (A), postoperative endoscopic score and SNOT-22 score at 4 (B) and 12 (C) weeks in both groups



Figs 3A and B: Graphical representation and comparison between endoscopic scores and SNOT-22 scores, in group A and group B; ES, endoscopic score; FSD, frontal sinus disease; SNP, sinonasal polypsis; SNT, sinonasal tumor; SS, SNOT-22 score



Figs 4A and B: Operative time of FESS using the navigation in group A (A) and without navigation in group B (B)

CRS with nasal polyps were managed medically with a short course of oral steroids and long-term steroid nasal douching. Additional surgery was considered for patients with a history of revision FESS and a diagnosis of a rare SNT, which was performed 1 year after the initial surgery. In group B, among the recurrences encountered in patients with SNT, one had an undifferentiated squamous cell carcinoma (SCC) originating in the sphenoid sinus, and the other patient had a neuroendocrine tumor. The patient with undifferentiated SCC underwent surgery approximately 8 months after the first surgery, while the other patient was lost to follow-up after 3 months. The recurrences in cases of SNP and revision FESS were managed medically. Therefore, 2 patients (6.67%) from both groups underwent revision surgery.

Discussion

Patients with labyrinthine paranasal sinus orientation, compounded by extensive disease, bone erosion in cases of SNT, or difficult access as in FSD, benefit significantly from image guidance in ESS.²⁷ In our study, the Medtronic Fusion navigation system was used for FESS, offering advantages over nonimage-guided procedures in terms of time efficiency, less invasiveness, accuracy, precision, real-time 3D visualization, increased surgeon confidence during deeper sinus and skull base exploration, and minimal patient discomfort. In this study, 39 (65%) were males and 21 (35%) were females, consistent with findings from a study by Bagul,²⁸ which indicated that paranasal pathologies are more common in males (62%) compared to females (33%). The outcomes of the patients were measured between and within groups using the SNOT-22 questionnaire and MLMES scores. The SNOT-22 is a reliable and validated tool for assessing quality of life in patients with sinus diseases during both preoperative and postoperative periods.^{29,30}

The comparison of SNOT-22 scores can be presented graphically as SNOTgrams, which display patient symptoms through scores both preoperatively and postoperatively, as well as any exacerbations over time. In this study, the mean SNOT-22 scores between the two groups did not show notable differences over 3 months. However, a significant reduction in

After the postoperative period, patients were followed up for 12 months. Recurrences of pathology included one left SNT (25%), one revision (25%), and two SNP (50%) in group A, compared to two SNP (40%), one revision (20%), and two SNT (40%) in group B. overall SNOT-22 scores was observed in both groups following FESS. This is consistent with several studies demonstrating a statistically significant improvement in quality of life, as measured by SNOT-22, following ESS, irrespective of whether navigation was used or not.^{25,31,32} The MLMES is a sinus cavity scoring system that scores the inflammatory burden of sinus cavities post ESS has great inter- and intraobserver variability.³³ In the present study, MLMES scores correlated well with the subjective SNOT-22 scores, but using the image-guidance did not change the patient's outcome both subjectively as well as objectively ($p > 0.05$) as seen in the other studies too.²⁶

The present study gathered enough evidence that, over time, as the familiarity between the system and the operating surgeon increases, the preoperative setup time reduces. The setup time over 2 years improved from 15–35 to 10–15 minutes, which is strikingly similar to the study conducted by Al-Swaiahb and Al-Dousary, with a Landmark X system.³⁴ In another study, similar outcomes were deduced, where the preoperative setup time typically reduced to 5–15 minutes.³⁵ The surgeon's questionnaire scores provided light on the fact that in the hands of an experienced surgeon image guidance helps identifying altered anatomy due to extensive disease or previous surgery.

However, this can lead to overconfidence and the surgeon over-estimating the surgical skills. Similarly, accuracy and technical errors in image generation can also lead to an unforeseen complications. There were two intraoperative complications, an anterior ethmoidal artery bleed in revision surgery and the other, a cerebrospinal fluid leak with a right-sided SNT; however, later it was confirmed as undifferentiated SCC by biopsy report in group B and none in group A.

The results of the intraoperative incidence of complications was very similar to a retrospective comparative study conducted³⁴ and further supported by studies conducted by Olson and Citardi³⁶ and Fried et al.³⁷ A regular follow-up of the patients at timely intervals for early detection of recurrence is strongly recommended.

In this study, group A had only one major complication (orbital entry) and group B had seven major complications. This suggests that navigation helps minimize the complications associated with ESS, even though the number of patients were not proportionately enough to demonstrate the outcomes, and hence, it's statistically insignificant ($p > 0.05$). Mostly, the patients with CRS who had complications associated with ESS also experienced these issues in other populations.²⁶ In our study, there were four cases (13.33%) of recurrence in group A compared to five (16.67%) in group B. Additional surgery was advised for a patient each in both groups. The present study showed there was no statistically significant benefit of navigation over image-guidance assisted group. A similar result was put forward in a few other populations as well, in terms of revision surgeries.^{38,39} Even though there was no difference in patient outcomes, the surgeon's confidence in approaching the difficult cases were markedly above when accompanied with image-guidance²³ Especially in the hands of a trained surgeon well-versed in anatomical aspects, the likelihood of significant intraoperative complications was markedly reduced.^{37,40} The present study must be interpreted within the context of its limitations. The small study population constrained various statistical outcomes. However, in summary, navigation technology has enabled surgeons to approach surgically challenging cases with minimal perioperative morbidity. Effective use of navigation systems requires proper training in setup and extensive surgical experience. Despite the benefits of navigation systems, surgeons also need advanced surgical proficiency and a deeper understanding of anatomical nuances in the surgical field. Nevertheless, imageguided surgery should be offered as an option to patients, dealing

with intricate cases of paranasal pathology.

Conclusion

Navigation technology tends to increase the surgeon's confidence in operating on challenging cases and reduces surgical morbidity. Thus, the image-guided navigation system has proven valuable in enhancing and complementing the knowledge and skill of surgeons.

Author Contribution

AP conducted the experiment and drafted the manuscript. RR served as the surgeon. KKR, SU, WK, and RH critically revised the manuscript. VR supported in writing and formatting the draft. All authors reviewed and contributed to the manuscript.

Ethical Approval

Ethical clearance was given by ethical committee of the Institutional.

Informed Consent

Informed consent was obtained from all individual participants included in the study.

References

1. Rosenfeld RM, Piccirillo JF, Chandrasekhar SS, et al. Clinical practice guidelines on adult sinusitis. *Otolaryngol Head Neck Surg* 2007;137:375–377. DOI: [10.1177/0194599815572097](https://doi.org/10.1177/0194599815572097)
2. Halawi AM, Smith SS, Chandra RK. Chronic rhinosinusitis: epidemiology and cost. *Allergy Asthma Proc* 2013;34:328–334. DOI: [10.2500/aap.2013.34.3675](https://doi.org/10.2500/aap.2013.34.3675)
3. Soler ZM, Wittenberg E, Schlosser RJ, et al. Health state utility values in patients undergoing endoscopic sinus surgery. *Laryngoscope* 2011;121:2672–2678. DOI: [10.1002/lary.21847](https://doi.org/10.1002/lary.21847)
4. Rudmik L, Smith TL, Schlosser RJ, et al. Productivity costs in patients with refractory chronic rhinosinusitis. *Laryngoscope* 2014;124:2007–2012. DOI: [10.1002/lary.24630](https://doi.org/10.1002/lary.24630)
5. Bhattacharyya N. Incremental health care utilization and expenditures for chronic rhinosinusitis in the United States. *Ann Otol Rhinol Laryngol* 2011;120:423. DOI: [10.1177/00034894112000701](https://doi.org/10.1177/00034894112000701)
6. Surapaneni H, Sisodia SS. Aetiology, diagnosis and treatment of chronic rhinosinusitis: a study in a teaching hospital in Telangana. *Int J Otorhinolaryngol Head Neck Surg* 2016;2:14–17. DOI: [10.18203/](https://doi.org/10.18203/)

7. Karuthedath S, Singh I, Chadha S. Impact of functional endoscopic sinus surgery on the pulmonary function of patients with chronic rhinosinusitis: a prospective study. *Indian J Otolaryngol Head Neck Surg* 2014;66:44–48. DOI: 10.1007/s12070-014-0758-7
8. Regi K, Elizabeth S, Vedantam R. Impact of functional endoscopic sinus surgery on patients with chronic rhinosinusitis: a prospective, cohort study among Indian patients. *Clin Rhinol Int J* 2018;11:1–6. DOI: 10.5005/jp-journals-10013-1333
9. Meltzer EO, Hamilos DL, Hadley JA, et al. Rhinosinusitis: establishing definitions for clinical research and patient care. *Otolaryngol Head Neck Surg* 2004;114:155–212. DOI: 10.1016/j.jaci.2004.09.029
10. Kaszuba SM, Steward MG. Medical management and diagnosis of chronic rhinosinusitis: a survey of treatment patterns by United States otolaryngologists. *Am J Rhinol* 2006;20:186–190. PMID: 16686386.
11. Bhattacharyya N. Clinical outcomes after endoscopic sinus surgery. *Curr Opin Allergy Clin Immunol* 2006;6:167–171. DOI: 10.1097/01.all.0000225154.45027.a4
12. Stevens WW, Schleimer RP, Kern RC. Chronic rhinosinusitis with nasal polyps. *J Allergy Clin Immunol Pract* 2016;4:565–572. DOI: 10.1016/j.jaip.2016.04.012
13. Das S, Kirsch CFE. Imaging of lumps and bumps in the nose: a review of sinonasal tumours. *Cancer Imaging* 2005;5:167–177. DOI: 10.1102/1470-7330.2005.0111
14. Lang EE, Curran AJ, Patil N, et al. Intracranial complications of acute frontal sinusitis. *Clin Otolaryngol* 2001;26:452–157. DOI: 10.1046/j.1365-2273.2001.00499.x
15. Lund V J, Rowe-Jones J. Surgical management of rhinosinusitis. Scott Brown, 7th edition. Great Britain: Hodder Arnold; 2008. pp. 1481–1482.
16. Marple BF, Stankiewicz JA, Baroody FM, et al. Diagnosis and management of chronic rhinosinusitis in adults. *Postgrad Med* 2009;121:121–139. DOI: 10.3810/pgm.2009.11.2081
17. Soteriou E, Grauvogel J, Laszig R, et al. Prospects and limitations of different registration modalities in electromagnetic ENT navigation. *Eur Arch Otorhinolaryngol* 2016;273:3979–3986. DOI: 10.1007/s00405-016-4063-9
18. Kennedy DW, Shaman P, Han W, et al. Complications of ethmoidectomy: a survey of fellows of the American Academy of Otolaryngology-Head and Neck Surgery. *Otolaryng Head Neck Surg* 1994;111:589–599. DOI: 10.1177/019459989411100509
19. Irugu DV, Stammberger HR. A note on the technical aspects and evaluation of the role of navigation system in endoscopic endonasal surgeries. *Indian J Otolaryngol Head Neck Surg* 2012;66:307–313. DOI: 10.1007/s12070-011-0380-x
20. Leonard S, Reiter A, Sinha A, et al. Image-based navigation for functional endoscopic sinus surgery using structure from motion. *Proc SPIE Int Soc Opt Eng* 2016;9784:97840. DOI: 10.1117/12.2217279
21. Strauss G, Limpert E, Strauss M, et al. Evaluation of a daily used navigation system for FESS. *Laryngorhinootologie* 2009;88:776781. DOI: 10.1055/s-0029-1237352
22. Fried MP, Parkh SR, Sodougui B. Image-guidance for endoscopic sinus surgery. *Laryngoscope* 2008;118:1287–1292. DOI: 10.1097/MLG.0b013e31816bce76
23. Metson RB, Cosenza MJ, Cunningham MJ, et al. Physician experience with an optical image guidance system for sinus surgery. *Laryngoscope* 2000;110:972–976. DOI: 10.1097/00005537-200006000-00017
24. Tschopp KP, Thomaser EG. Outcome of functional endonasal sinus surgery with and without CT-navigation. *Rhinology* 2008;46:116–120. DOI: 10.1055/s-2007-966090
25. Kennedy JL, Hubbard MA, Huyett P, et al. Sino-nasal outcome test (SNOT-22): a predictor of postsurgical improvement in patients with chronic sinusitis. *Ann Allergy Asthma Immunol* 2013;111:246–251. DOI: 10.1016/j.anai.2013.06.033
26. Snidvongs K, Dalgorf D, Kalish L, et al. Modified Lund Mackay Postoperative Endoscopy Score for defining inflammatory burden in chronic rhinosinusitis. *Rhinology* 2014;52:53–59. DOI: 10.4193/Rhino13.056
27. Samarakkody ZM, Abdullah B. The use of image guided navigational tracking systems for endoscopic sinus surgery and skull base surgery: a review. *Egypt J Ear Nose Throat Allied Sci* 2016;17:133–137. DOI: 10.1016/j.ejenta.2016.07.005
28. Bagul M. CT study of paranasal sinus pathologies. *Indian J Sci Res* 2016;4:13. DOI: 10.17354/ijss/2016/364
29. Hopkins C, Gillett S, Slack R, et al. Psychometric validity of the 22-item Sinonasal Outcome Test. *Clin Otolaryngol* 2009;34(5):447–454. DOI: 10.1111/j.1749-4486.2009.01995.x
30. Fokkens W, Lund V, Hopkins C, et al. European Position Paper on Rhinosinusitis and Nasal Polyps 2020. *Rhinology* 2020;20:1–464. DOI: 10.4193/Rhin20.600
31. Lind H, Joergensen G, Lange B, et al. Efficacy of ESS in chronic rhinosinusitis with and without nasal polyposis: a Danish cohort study. *Eur Arch Oto-Rhino-Laryngol* 2016;273:911–919. DOI: 10.1007/s00405-015-3667-9
32. Soler ZM, Jones R, Le P, et al. Sino-nasal outcome test-22 outcomes after sinus surgery: a systematic review and meta-analysis. *Laryngoscope* 2018;128:581–592. DOI: 10.1002/lary.27008
33. Lund VJ, Mackay IS. Staging in rhinosinusitis. *Rhinology* 1993;31:183–184. DOI: 10.1016/S0194-5998(97)70005-6
34. Al-Swaiahb JN, Al-Dousary SH. Computer-aided endoscopic sinus surgery: a retrospective comparative study. *Ann Saudi Med* 2010;30:149–152. DOI: 10.4103/0256-4947.60522
35. Metson R, Gray ST. Image-guided sinus surgery: practical considerations. *Otolaryngol Clin North Am* 2005;38:527–534. DOI: 10.1016/j.otc.2004.11.002
36. Olson G, Citardi MJ. Image-guided functional endoscopic sinus surgery. *Otolaryngol Head Neck Surg* 2000;123:188–194.