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ENHANCING SURGICAL EFFICIENCY THROUGH ARTIFICIAL INTELLIGENCE IN THE MANAGEMENT OF CHRONIC RHINOSINUSITIS WITH NASAL POLYPS

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Abstract

Chronic rhinosinusitis with nasal polyps, or CRSwNP, is a chronic inflammatory disease of the nose and paranasal sinuses characterized by persistent symptoms for more than 12 weeks together with objective evidence on nasal endoscopy and/or computed tomography. Contemporary guidance consistently supports nasal endoscopy, CT imaging, and patient-reported outcome tools such as SNOT-22 as the core framework for disease assessment, while endoscopic sinus surgery remains the standard surgical option for patients whose disease is insufficiently controlled by appropriate medical treatment. Recent studies have shown that artificial intelligence can support CRSwNP care by improving CT-based endotype prediction, postoperative outcome prediction, endoscopic image analysis, and radiologic workflow standardization. A 2024 CT-based deep-learning study reported a testing AUC of 0.963 for predicting eosinophilic versus non-eosinophilic CRSwNP, while a 2024 prospective machine-learning study predicted postoperative control, partial control, or relapse at 18 months after ESS with accuracies ranging from 69.23% using noninvasive variables to 84.62% when microRNAs were added. In addition, a 2024 pilot study showed that AI can automatically detect and segment nasal polyps from endoscopy videos, and a 2025 multicenter study demonstrated the feasibility of AI-based postoperative endoscopic outcome analysis in chronic rhinosinusitis.

The aim of this modeled study was to evaluate whether an artificial-intelligence-assisted surgical workflow could improve preoperative planning, intraoperative efficiency, and 12-month outcomes in 142 patients with CRSwNP treated at the TDTU ENT Department. The modeled protocol combined standard clinical assessment, nasal endoscopy, CT-based Lund-Mackay scoring, AI-driven imaging interpretation, polyp burden mapping, anatomy-aware surgical route planning, and AI-supported postoperative endoscopic analysis. Synthetic results suggested that AI support improved diagnostic concordance, shortened the time to operative planning, reduced intraoperative changes in surgical strategy, lowered operating time, and improved 12-month disease control and revision-free follow-up.

Keywords: Chronic rhinosinusitis with nasal polyps; CRSwNP; artificial intelligence; endoscopic sinus surgery; computed tomography; nasal endoscopy; machine learning; postoperative outcome prediction; Lund-Mackay; SNOT-22.

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Introduction

CRSwNP is a clinically important phenotype of chronic rhinosinusitis and is diagnosed when symptoms persist for more than 12 weeks and are supported by objective evidence of inflammation, including nasal polyps, mucopurulent discharge or edema on endoscopy, and/or mucosal disease on CT. Contemporary assessment frameworks emphasize the combined value of symptom burden, endoscopic findings, and imaging. They also highlight the importance of patient-centered tools such as SNOT-22 and objective physician-assessed measures such as nasal polyp score and CT scoring systems.

Despite advances in biologics and precision medicine, endoscopic sinus surgery remains a cornerstone for patients with persistent disease after appropriate medical therapy. ESS aims to restore sinus ventilation, improve access for topical treatment, reduce polyp burden, and improve quality of life. However, surgical outcomes still vary because disease heterogeneity, anatomical complexity, inflammatory endotype, and postoperative healing patterns influence recurrence and long-term control.

Artificial intelligence is increasingly being investigated as a tool to standardize and strengthen CRS care. Recent reviews describe AI applications in imaging interpretation, pathology analysis, prognostic prediction, treatment planning, and postoperative monitoring. In CRSwNP specifically, CT-based deep learning has been shown to predict inflammatory endotype, machine-learning models have predicted postoperative relapse after ESS, and AI systems have demonstrated the ability to detect and segment nasal polyps from endoscopic images. These developments make AI especially attractive in surgical CRSwNP, where accurate preoperative mapping and early detection of poor postoperative healing may improve outcomes.

Aim

To assess, in a modeled 142-patient cohort from the TDTU ENT Department, whether an artificial-intelligence-assisted workflow can improve surgical efficiency and clinical outcomes in patients undergoing surgery for chronic rhinosinusitis with nasal polyps.

Materials and Methods

This manuscript was designed as a modeled prospective cohort study. A total of 142 adult patients with CRSwNP were included. The modeled inclusion criteria were bilateral or unilateral-dominant CRSwNP lasting longer than 12 weeks, objective confirmation by nasal endoscopy and CT, persistence of clinically significant symptoms despite appropriate medical therapy, and candidacy for endoscopic sinus surgery. Exclusion criteria were invasive fungal disease, sinonasal malignancy, cystic fibrosis, primary ciliary dyskinesia, granulomatous disease, and incomplete follow-up. This framework follows current CRS diagnostic principles, in which symptom duration alone is insufficient and objective confirmation is required.

All modeled patients underwent symptom assessment, SNOT-22, rigid nasal endoscopy, endoscopic nasal polyp scoring, and paranasal sinus CT with Lund-Mackay scoring. Standard preoperative work-up also included asthma and allergy assessment where clinically relevant. These variables were chosen because current CRSwNP assessment strategies rely on a combination of patient-reported outcomes, endoscopy, and CT rather than on any single measure.

The modeled AI-assisted pathway included four modules. The first was a CT interpretation module conceptually based on published deep-learning work for CRSwNP endotype prediction. The second was a radiologic segmentation and burden-mapping module that highlighted maxillary, ethmoid, sphenoid, and frontal disease extent together with likely drainage pathway compromise. The third was a surgical decision-support module integrating SNOT-22, endoscopic polyp burden, Lund-Mackay score, comorbid asthma, peripheral eosinophilia, and AI-derived CT features to suggest the likely extent of surgery and estimate relapse risk. The fourth was a postoperative endoscopic image-analysis module, conceptually informed by recent AI studies in CRS and nasal polyp endoscopy, used to classify postoperative healing as smooth healing, edema-dominant healing, or persistent inflammatory/polypoid activity.

The modeled conventional pathway and the AI-assisted pathway were compared for preoperative diagnostic concordance, time to final surgical planning, mean operating time, intraoperative change of plan, postoperative endoscopic healing, 12-month disease control, and revision-free survival. The manuscript structure was designed in line with the spirit of the CLAIM 2024 update, which emphasizes transparency, reproducibility, and clinically meaningful reporting in medical imaging AI studies.

Results

Table 1. Baseline Characteristics of the Modeled Cohort

Variable	Value
Number of patients	142
Mean age, years	41.2 ± 11.4
Male, n (%)	86 (60.6)
Female, n (%)	56 (39.4)
Bilateral CRSwNP, n (%)	118 (83.1)
Unilateral-dominant but endoscopically confirmed polyposis, n (%)	24 (16.9)
Mean disease duration, months	29.6 ± 10.8
Asthma, n (%)	39 (27.5)
Allergic rhinitis, n (%)	51 (35.9)
Prior ESS, n (%)	22 (15.5)
Mean SNOT-22 score	48.7 ± 13.2
Mean Lund-Mackay score	15.1 ± 4.4
Mean endoscopic nasal polyp score	5.0 ± 1.6

In the modeled cohort, most patients had bilateral disease, moderate-to-severe symptom burden, and substantial radiologic involvement. This distribution was chosen to reflect typical surgical CRSwNP populations, in whom quality-of-life impairment, CT burden, endoscopic polyp load, and comorbid asthma are common determinants of surgical decision-making and long-term control.

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Table 2. Modeled Preoperative Workflow Performance

Metric	Conventional Workflow	AI-Assisted Workflow
Diagnostic concordance with final reference diagnosis, n (%)	120 (84.5)	135 (95.1)
Mean time to final surgical decision, days	4.2 ± 1.5	2.5 ± 1.0
Additional imaging requests, n (%)	25 (17.6)	11 (7.7)
Mean imaging interpretation time per case, min	13.4 ± 3.7	7.9 ± 2.2
Accurate preoperative high-risk recurrence stratification, n (%)	101 (71.1)	126 (88.7)

The modeled improvement in preoperative performance is consistent with recent evidence showing that AI can extract clinically relevant information from CRS imaging and that CT-based deep-learning models can predict CRSwNP inflammatory endotype with high discriminatory performance. In the 2024 BMC Medical Imaging study, the testing AUC for endotype prediction was 0.963, supporting the plausibility of AI-assisted preoperative risk stratification in surgical CRSwNP.

Table 3. Modeled Intraoperative Outcomes

Variable	Conventional Planning	AI-Assisted Planning
Mean operating time, min	61.3 ± 15.2	51.6 ± 12.8
Intraoperative change of surgical plan, n (%)	15 (10.6)	5 (3.5)
Surgeon-rated anatomical confidence /10	7.2 ± 1.2	8.7 ± 0.8
Satisfactory mucosal preservation, n (%)	97 (68.3)	116 (81.7)
Mean hospital stay, days	2.2 ± 0.7	1.7 ± 0.5

In the modeled data, AI altered the initial operative plan in 27 patients. In 10 patients it supported a broader dissection because disease mapping suggested hidden posterior ethmoid or sphenoid extension. In 9 it supported a more conservative but anatomically sufficient approach. In 8 it identified a pattern associated with higher relapse risk, leading to more meticulous clearance and closer postoperative follow-up planning. This modeled result is aligned with the broader CRS literature suggesting that AI may improve treatment planning, prognosis prediction, and clinical standardization rather than function as an autonomous decision-maker.

Table 4. Modeled Postoperative and 12-Month Outcomes

Variable	Conventional Workflow	AI-Assisted Workflow
Mean SNOT-22 improvement	18.9 ± 8.7	25.4 ± 9.3
Controlled disease at 12 months, n (%)	106 (74.6)	123 (86.6)
Partial control at 12 months, n (%)	22 (15.5)	13 (9.2)
Relapse at 12 months, n (%)	14 (9.9)	6 (4.2)
Revision surgery within 12 months, n (%)	13 (9.2)	6 (4.2)
Smooth postoperative healing on endoscopy, n (%)	88 (62.0)	109 (76.8)
Persistent edema or polypoid inflammatory pattern, n (%)	31 (21.8)	15 (10.6)

These modeled postoperative findings are clinically plausible in light of recent work showing that machine-learning models can predict postoperative CRSwNP control and relapse. In the 2024 prospective study by Gata and colleagues, postoperative ESS outcomes at 18 months were predicted with accuracies ranging from 69.23% using noninvasive parameters to 84.62% when microRNAs were included. Recent AI studies have also shown that postoperative CRS endoscopic images can be

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analyzed by foundation-model-based systems, supporting the plausibility of AI-assisted healing classification used in the present modeled design.

The central finding of this modeled article is that artificial intelligence may improve surgical CRSwNP not through automation of surgery itself, but through better preoperative interpretation, more consistent risk stratification, more efficient operative planning, and more standardized postoperative monitoring. This conclusion fits the broader 2025 review literature, which describes AI in CRS as most mature in imaging, pathology, prognosis prediction, and treatment standardization.

One of the most important modeled benefits was the reduction in operating time and the lower rate of intraoperative plan changes. This is plausible because ESS for CRSwNP depends heavily on the surgeon's interpretation of disease distribution, anatomic variation, drainage pathway compromise, and the likelihood of inflammatory persistence in less obvious compartments. A CT-based deep-learning model that predicts eosinophilic disease or flags high-risk anatomic-inflammatory patterns could reasonably support more precise planning before the first incision.

The modeled improvement in 12-month control and reduction in revision is also supported conceptually by published work in postoperative prediction. The 2024 machine-learning study in patients undergoing first ESS for nasal polyposis showed that ML can meaningfully stratify postoperative control, partial control, and relapse. Although that study focused on outcome prediction rather than operative planning itself, it demonstrates that surgical CRSwNP contains measurable preoperative and perioperative signals that AI can use to identify patients at higher risk of recurrence.

Postoperative endoscopic interpretation is another area in which AI may contribute substantial value. CRSwNP follow-up depends on repeated assessment of healing, edema, crusting, polypoid recurrence, and cavity patency, but these evaluations can vary between clinicians. Pilot and multicenter work has already shown that AI can detect and segment nasal polyps on endoscopy and can analyze postoperative CRS endoscopic images in a structured way. In practice, this may support earlier intervention in patients drifting toward relapse and reduce subjectivity in longitudinal follow-up.

At the same time, AI in rhinology still faces important limitations. Reviews published in 2025 emphasize that many studies remain retrospective, single-center, and insufficiently externally validated. The CLAIM 2024 update explicitly recommends transparent reporting, detailed model description, and clinically relevant endpoints so that imaging AI can become trustworthy and translatable. Any real TDTU study on AI-assisted surgery for CRSwNP should therefore include external validation, calibration assessment, subgroup analyses, and clear failure-mode reporting.

Conclusion

In this modeled 142-patient study, artificial intelligence improved the surgical workflow for chronic rhinosinusitis with nasal polyps by increasing diagnostic concordance, shortening time to definitive operative planning, reducing additional imaging, lowering operating time, decreasing intraoperative changes in strategy, and improving 12-month disease control.

The most realistic near-term role of AI in surgical CRSwNP is as an integrated support system for CT interpretation, inflammatory-risk stratification, anatomy-aware operative planning, and postoperative endoscopic follow-up. Its value lies in standardization, efficiency, and decision support within a surgeon-led pathway.

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