Am J Transl Res 2025;17(7):5475-5484
www.ajtr.org /ISSN:1943-8141/AJTR0165342

Original Article

Effects of endoscopic minimally invasive surgery on olfactory function and quality of life in patients with chronic rhinosinusitis and nasal polyps

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Received April 15, 2025; Accepted June 17, 2025; Epub July 15, 2025; Published July 30, 2025

Abstract: Objective: To evaluate the efficacy of endoscopic minimally invasive surgery (EMIS) in improving olfactory function and quality of life among patients with chronic rhinosinusitis with nasal polyps (CRSwNP). Methods: A cohort of 117 patients diagnosed with CRSwNP between January 2020 and June 2024 were included in this retrospective study. Patients were assigned to either a control group (n=50, treated with conventional endoscopic sinus surgery [ESS]) or a research group (n=67, treated with EMIS). Comprehensive assessments were conducted, including treatment efficacy, safety profile, olfactory function, nasal ventilation (airway resistance), nasal status, stress biomarkers, and quality of life. Results: Compared to the control group, the research group showed significantly better outcomes in terms of: (1) overall therapeutic efficacy, (2) postoperative safety profile (lower postoperative complication rates), (3) olfactory function recovery, (4) nasal ventilation and functional status, (5) quality of life improvement, and (6) reduced surgical stress response (all P<0.05). Conclusion: EMIS significantly improves olfactory function and quality of life in patients with CRSwNP, offering clinical advantages over conventional ESS and supporting its broader clinical application.

Keywords: Endoscopic minimally invasive surgery, chronic rhinosinusitis, nasal polyps, olfactory function, quality of life

Introduction

Chronic rhinosinusitis (CRS) is a persistent inflammatory disorder of the nasal and sinus mucosa, lasting for ≥12 weeks. It is characterized by chronic inflammation of both the nasal cavity and paranasal sinuses, commonly presenting with facial pain and sinus pressure, and represents a significant clinical burden in otolaryngology [1, 2]. CRS is clinically classified into two phenotypes: CRS with nasal polyps (CRSwNP) and CRS without nasal polyps (CRSsNP). Epidemiological data indicate that CRSwNP accounts for approximately 75% of cases and typically demonstrates better treatment responsiveness compared to CRSsNP, which tends to present with more severe symptoms, including pronounced nasal obstruction and marked olfactory impairment, along with a higher postoperative recurrence rate [3]. Despite the availability of multiple treatment modalities, therapeutic outcomes in CRSwNP remain suboptimal. Surgical intervention provides symptomatic relief for 1.5-4.0 years, but the recurrence of nasal polyps often necessitates revision surgery, with an incidence ranging from 10% to 60% [4-7]. As emphasized by Niu et al. [8], both surgical and pharmacologic approaches currently yield suboptimal results, highlighting the urgent need for improved treatment strategies. These limitations significantly impair patients' quality of life (QoL) [9], thereby motivating our exploration of more effective surgical techniques to enhance clinical outcomes in CRSwNP.

Recent advances in surgical techniques have positioned endoscopic minimally invasive surgery (EMIS) as a promising therapeutic option for CRSwNP. Initially applied in pediatric populations, EMIS has demonstrated superior efficacy and safety profiles, particularly in reducing

https://doi.org/10.62347/PWLD5244

postoperative recurrence rates and minimizing pain [10]. Emerging evidence suggests its advantages over biological therapies (e.g., omalizumab, dupilumab, and mepolizumab) in achieving substantial reductions in nasal polyp size [11]. De Corso et al. [12] further substantiated these findings in an observational study, reporting sustained clinical benefits at 12-month follow-up in severe CRSwNP cases. Despite these promising outcomes, critical knowledge gaps persist regarding the effects of EMIS on two key clinical endpoints: olfactory function restoration and QoL enhancement. The current study therefore aims to systematically evaluate the therapeutic potential of EMIS in addressing these outcomes, with the ultimate goal of optimizing treatment strategies for CRSwNP. The innovation of this study lies in its comprehensive evaluation of EMIS, encompassing therapeutic efficacy, safety profiles, olfactory function, nasal ventilation, nasal cavity status, stress-related biomarkers, and health-related QoL. Through this comprehensive evaluation, the study offers an objective and holistic analysis of the clinical outcomes following EMIS, providing evidence to help optimize management of clinical CRSwNP treatment.

Materials and methods

Patient selection

This retrospective study enrolled 117 consecutive patients diagnosed with CRSwNP, who were admitted to Northern Jiangsu Peoples Hospital between January 2020 and June 2024. Based on the surgical approach, participants were allocated into either the control group (n=50), who underwent conventional endoscopic sinus surgery (ESS), or the research group (n=67), who received EMIS. The study protocol was approved by the Institutional Review Board of Northern Jiangsu People's Hospital prior to patient enrollment.

Based on power analysis, this study was designed to detect response rates of 65.0% in the control group and 85.0% fin the research group. Assuming a 90.0% confidence level and 70.0% statistical power, the minimum required total sample size was determined to be 84 participants. The final enrollment exceeded this threshold. The sample size was determined using the following formula:

$$n = \frac{2 \times \left(Z_{\alpha/2} + Z_{\beta}\right)^2 \times \left(p_1\left(1 - p_1\right) + p_2\left(1 - p_2\right)\right)}{\left(p_1 - p_2\right)^2}$$

Inclusion criteria: (1) a definitive diagnosis of CRSwNP according to established clinical guidelines [13]; (2) clear indications for surgical intervention; (3) persistent clinical symptoms lasting more than 12 weeks, accompanied by objectively confirmed olfactory dysfunction; (4) availability of complete medical records; and (5) normal cognitive function and communication ability.

Exclusion criteria: (1) pregnancy or lactation; (2) presence of acute or chronic infections, intracranial neoplasms, history of traumatic brain injury, endocrine or psychiatric disorders, or other medical conditions affecting olfactory function; (3) coexisting atrophic rhinitis or sinonasal fungal infections; (4) previous history of nasal surgical procedures; or (5) congenital anosmia or documented allergic-related olfactory loss.

Intervention methods

All enrolled patients underwent a standardized preoperative evaluation protocol, including complete blood count, urinalysis, biochemical profiling (with serum potassium assessment), electrocardiography, and computed tomography (CT) of the nasal cavity and paranasal sinuses.

Prophylactic antibiotic therapy was initiated one day prior to the scheduled surgical procedure. For patients with nasal obstruction on the morning of surgery, 10 mg of topical ephedrine nasal drops was administered, with the surgical procedure commenced 10 minutes after decongestion. A standardized nasal irrigation protocol was implemented: once in the morning of surgery, again 6 hours postoperatively, and continued regularly for the following 24 hours. All patients underwent nasal endoscopic examination on the first postoperative day to objectively assess patency of the nasal airway.

The control group underwent conventional ESS under general anesthesia in the supine position. A high-definition nasal endoscope was

inserted to visualize the nasal cavity. The procedure began with the complete excision of nasal polyps and meticulous exposure of the middle meatus. Vasoconstrictors were applied to facilitate clear identification of the polyps and surrounding anatomy. After polyp excision, sinus ostia were enlarged using specialized microdebriders to ensure complete evacuation of purulent secretions and residual polypoid tissue, thereby restoring adequate sinus drainage and ventilation. The nasal medial and lateral walls were fully exposed, followed by resection of the uncinate process, opening of the maxillary sinus and anterior ethmoid sinuses, and recanalization of the nasofrontal duct. Intraoperative bleeding caused by polyp involvement of adjacent tissues was managed with timely hemostasis. The procedure concluded with thorough irrigation of the surgical field using normal saline and placement of a gelatin sponge soaked with hemostatic agents which were removed on postoperative day 2. Postoperatively, all patients received standardized intravenous antibiotics: cefamandole nafate (Shanghai Aladdin Bio-Chem Technology Co., Ltd., C133440; 2.0 g diluted in 100 mL 0.9% sodium chloride solution administered (Beijing Yita Biotechnology Co., Ltd., SY5284) over 3-5 minutes) for 3 consecutive days.

The research group received advanced EMIS under intravenous combined general anesthesia. With patient positioned in a supine position, nasal endoscopy was performed to achieve optimal visualization of the nasal turbinates, agger nasi cells, and middle meatus. Under high-magnification endoscopic guidance, nasal polyps were precisely excised using microdebrider technology. The middle and terminal segments of the uncinate process were resected to adequately expose the ethmoid bulla while preserving adjacent structures. A systematic anterior-to-posterior ethmoidectomy was then performed, removing pathological tissue around the sinus ostia with healthy mucosa preserved to facilitate natural dilation of sinus openings. For patients presenting anatomical variations, targeted anatomical corrections were performed prior to functional sinus surgery to optimize the surgical field and improve postoperative outcomes. Following completion of the surgical procedure, respiratory secretions were cleared, and expandable hemostatic sponges were applied for nasal packing. Postoperative management included intravenous cefamandole nafate (same dosage and regimen as in the control group) for three days to prevent infection.

Nasal packing was removed within 1 to 2 days following the surgical procedure for all patients in both treatment groups. Following pack removal, patients were prescribed salmon calcitonin nasal spray, administered as one metered spray (200 IU) per affected nostril twice daily. All participants underwent mandatory follow-up nasal endoscopic examination on postoperative day 3 to assess surgical outcomes and healing progress. Both groups were given routine care, including preoperative preparation (nasal hair removal, nasal cavity cleaning, oral hygiene with mouthwash), clinical status monitoring, and preoperative education on disease awareness and surgical procedures.

Data collection and outcome measurement

(1) Therapeutic efficacy evaluation [14]: Treatment outcomes were categorized based on standardized endoscopic criteria. Cured: Endoscopic confirmation of patent sinus ostia and complete resolution of purulent secretions in the surgical cavity. Improved: Partial epithelialization of the surgical cavity accompanied by localized mucosal hypertrophy and edema; residual purulent secretions present, but with observable clinical symptom improvement. Ineffective: Evidence of sinus ostium obstruction on endoscopy, absence of symptomatic improvement, or presence of cavity adhesions.

(2) Safety assessment [15]: The safety profile was evaluated through systematic monitoring and documentation of the incidence of nasal adhesions, periorbital ecchymosis, and maxillary sinus ostium stenosis. All adverse events were recorded, and their frequencies were calculated for comparative analysis.

(3) Olfactory and nasal ventilatory function determination [16]: Olfactory function was quantitatively evaluated using the standardized T&T olfactometry at three timepoints: preoperative baseline (T0), 1 month postoperatively (T2), and 3 months postoperatively (T3). Scores ranged from 0 (normal olfactory function) to 8 (complete anosmia), with higher scores corresponding to more severe olfactory dysfunction. Ventilatory function was measured using ante-

Table 1. Comparison of baseline characteristics between the two groups

Indicator	Control group (n=50)	Research group (n=67)	χ^2/t	P
Gender			0.699	0.403
Male	30 (60.00)	35 (52.24)		
Female	20 (40.00)	32 (47.76)		
Age (years)	44.72±6.44	43.39±9.59	0.848	0.398
Disease duration (years)	3.94±1.50	3.78±1.80	0.510	0.611
Clinical staging			0.656	0.884
Type II, Stage 1	20 (40.00)	22 (32.84)		
Type II, Stage 2	15 (30.00)	22 (32.84)		
Type II, Stage 3	5 (10.00)	8 (11.94)		
Type III	10 (20.00)	15 (22.39)		
Family history			0.109	0.741
None	45 (90.00)	59 (88.06)		
Yes	5 (10.00)	8 (11.94)		

rior rhinomanometry to determine airway resistance, where elevated measurements indicated greater nasal obstruction and impaired ventilation.

(4) Nasal status analysis [17]: Acoustic rhinometry was employed to measure nasal cavity volume (NCV) and nasal minimum cross-sectional area (NMCA). These data were recorded at three evaluation time points (T0, T2, and T3) for longitudinal comparison.

(5) Stress biomarker measurement [18]: Fasting venous blood samples (5 mL) were collected in the early morning. Following centrifugation, serum concentrations were analyzed for cortisol (COR) and norepinephrine (NE) levels. Measurements were performed at baseline (T0) and immediately postoperatively (T1) using a portable automated biochemical analyzer (Shanghai Dibosi Biotechnology Co., Ltd., PUZS-300).

(6) QoL assessment: Patient-reported outcomes were measured with the validated 36-Item Short Form Health Survey (SF-36) [19], covering eight health domains, namely physical functioning (PF), role-physical (RP), bodily pain (BP), general health (GH), vitality (VT), social functioning (SF), role-emotional (RE), and mental health (MH). Each domain was scored on a 0-100 scale, with higher scores indicating better QoL.

Statistical analysis

Categorical variables were expressed as counts and percentages (n/%), and continuous variables as mean ± standard error of the mean (SEM). Comparative analysis of categorical data was performed using Pearson's chi-square test. For continuous variables, inter-group comparisons were conducted with independent samples t-tests, while intra-group longitudinal analyses employed paired samples t-tests. All statistical analyses were performed using SPSS Statistics version 24.0. Graphical representations were generated using GraphPad Prism version 7.0. A *P*-value <0.05 was considered significant.

Results

Baseline characteristics

The research and control groups demonstrated comparable baseline characteristics, with no significant differences in gender distribution, mean age, disease duration, clinical staging, or family history (all P>0.05), as detailed in **Table 1**.

Therapeutic outcomes

Comparative analysis revealed a superior overall treatment efficacy in the research group (89.55%) compared to the control group (76.00%) (P<0.05), as presented in **Table 2**.

Safety profiles

Safety assessment identified distinct adverse event patterns between groups. In the control group, nasal adhesions (4 cases) were predominant, followed by maxillary sinus ostium stenosis (3 cases) and periorbital ecchymosis (2

Table 2. Comparison of therapeutic outcomes between the two groups

Indicator	Control group (n=50)	Research group (n=67)	χ^2	P
Cured	20 (40.00)	35 (52.24)		
Improved	18 (36.00)	25 (37.31)		
Ineffective	12 (24.00)	7 (10.45)		
Total effective rate	38 (76.00)	60 (89.55)	3.866	0.049

Table 3. Comparison of safety profiles between the two groups

Adverse event	Control group (n=50)	Research group (n=67)	χ^2	P
Nasal adhesions	4 (8.00)	1 (1.49)		
Periorbital ecchymosis	2 (4.00)	1 (1.49)		
Maxillary sinus ostium stenosis	3 (6.00)	2 (2.99)		
Total	9 (18.00)	4 (5.97)	4.195	0.041

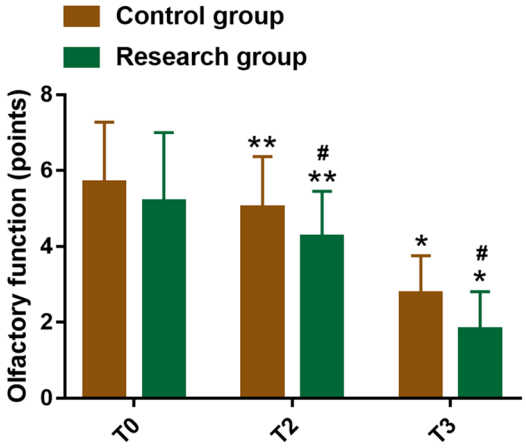

Figure 1. Comparison of olfactory function between the two groups. Note: *P<0.05, **P<0.01 vs. T0; #P<0.05 vs. control group.

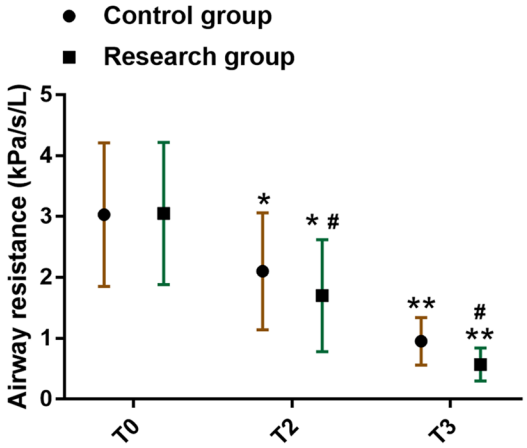

Figure 2. Comparison of nasal ventilatory function between the two groups. Note: *P<0.05, **P<0.01 vs. T0; #P<0.05 vs. control group.

cases). In contrast, maxillary sinus ostium stenosis (2 cases) was most frequent in the research group, with nasal adhesions and periorbital ecchymosis (1 case each) occurring less commonly. The research group demonstrated a significantly lower overall incidence of adverse events compared to the control group (P<0.05), as shown in **Table 3**.

Olfactory function

Olfactory function scores at T0 were comparable between groups (P>0.05). Both groups exhibited significant improvement at 1-month (T2) and 3-month (T3) follow-ups, indicated by decreased olfactory scores (P<0.05). Notably, the research group demonstrated superior olfactory recovery at both T2 and T3 compared to the control group (P<0.05). The details are represented in **Figure 1**.

Nasal ventilatory function

Nasal airway resistance measurements demonstrated comparable baseline values (P> 0.05) between groups. Both groups showed significant reductions at T2 and T3 (P<0.05). Importantly, the research group demonstrated more pronounced improvement at both time points (P<0.05), as shown in **Figure 2**.

Nasal status

No significant intergroup differences were observed in NCV or NMCA at T0 (P>0.05). Both groups exhibited a marked rise in NCV and

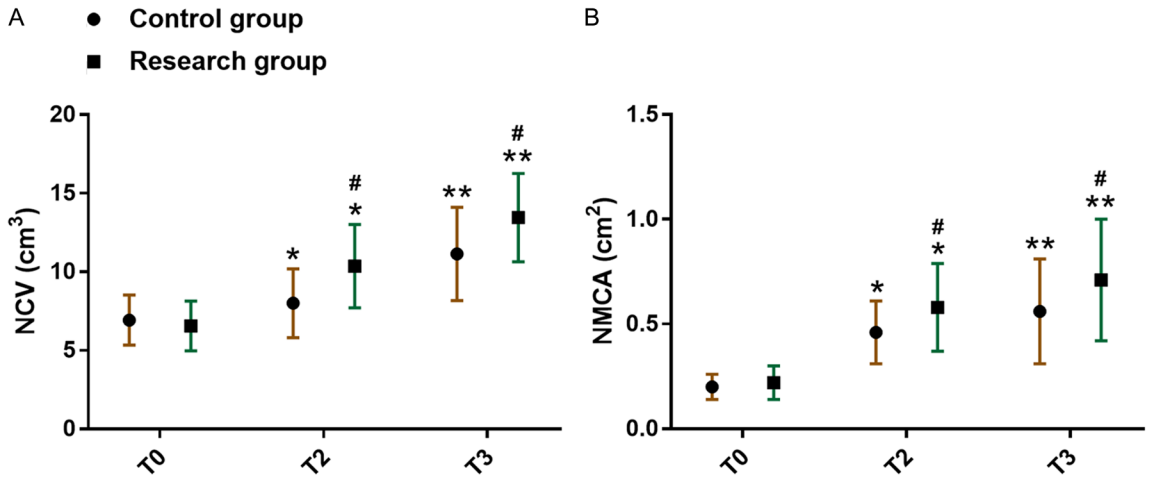

Figure 3. Comparison of nasal status between the two groups. A. Nasal cavity volume (NCV); B. Nasal minimum cross-sectional area (NMCA). Note: *P<0.05, **P<0.01 vs. T0; #P<0.05 vs. control group.

Table 4. Comparison of stress biomarker profiles between the two groups

Indicator	Control group (n=50)	Research group (n=67)	t	P
COR (ng/mL)				
T0	212.98±39.66	220.39±45.35	0.922	0.359
T1	267.56±48.84**	235.09±43.13	3.806	<0.001
NE (pg/mL)				
T0	228.98±50.32	226.87±40.58	0.251	0.802
T1	288.64±50.46**	236.94±42.76	5.988	<0.001

Note: COR, cortisol; NE, norepinephrine. **P<0.01 vs. T0.

NMCA at T2 and T3 (P<0.05), with the research group demonstrating greater improvement in nasal status (P<0.05). Changes in nasal status are depicted in **Figure 3**.

Stress biomarkers

The serum levels of COR and NE were similar at T0 (P>0.05). At T1, the levels of COR and NE in the control group significantly upregulated compared to both T0 and to the research group (both P<0.05). In contrast, these levels in the research group barely changed compared to baseline (P>0.05). The details are shown in **Table 4**.

Quality of life (QoL)

Baseline SF-36 scores across all measured domains were comparable between groups (P>0.05). Both groups showed significant improvements in all QoL domains at T3 compared to baseline (P<0.05). Notably, the research group achieved significantly higher scores than controls in every domain at T3 (P<0.05), as shown in **Table 5**.

Discussion

The pathophysiology of chronic rhinosinusitis with nasal polyps (CRSwNP) is a multifaceted process characterized by persistent inflammation of the nasal mucosa and subsequent tissue remodeling. These pathologic alterations compromise the nasal epithelial barrier integrity, thereby contributing to CRSwNP development [20]. Nasal polyp formation is driven by a combination of anatomical factors - particularly the close apposition of mucosal surfaces in narrow nasal passages - and sustained inflammatory cascades that synergistically promote polyp development [21]. While histologically benign, these polyps significantly impair olfactory function and reduce overall QoL [22], underscoring the importance of optimizing surgical interventions that specifically address these patient-centered outcomes.

Table 5. Comparison of quality of life outcomes between the two groups

Indicator	Control group (n=50)	Research group (n=67)	t	P
Physical functioning (points)				
T0	72.24±5.13	71.19±7.55	0.848	0.398
T3	81.16±6.62*	88.03±6.50**	5.611	<0.001
Role-physical (points)				
T0	67.50±6.48	69.03±6.90	1.218	0.226
T3	79.74±6.40*	85.16±6.40**	4.532	<0.001
Bodily pain (points)				
T0	70.54±6.06	71.54±6.94	0.813	0.418
T3	76.64±6.01*	83.48±6.51**	5.808	<0.001
General health (points)				
T0	71.12±6.48	68.45±8.14	1.911	0.059
T3	80.02±5.42*	85.13±6.66**	4.437	<0.001
Vitality (points)				
T0	71.84±7.78	73.87±8.16	1.358	0.177
T3	82.00±5.43*	87.31±5.69**	5.091	<0.001
Social functioning (points)				
T0	73.38±6.39	72.27±6.86	0.891	0.375
T3	85.62±6.48*	88.37±6.30**	2.307	0.023
Role-emotional (points)				
T0	70.82±7.23	69.96±8.63	0.571	0.569
T3	85.06±5.16*	90.64±5.54**	5.548	<0.001
Mental health (points)				
T0	71.52±7.84	70.51±9.40	0.616	0.539
T3	84.88±5.71*	88.42±6.48**	3.073	0.003

Note: *P<0.05, **P<0.01 vs. T0.

Our comparative analysis demonstrated superior therapeutic efficacy in the EMIS group compared to conventional ESS (89.55% vs. 76.00%). This enhanced efficacy profile likely stems from the technical advantages of EMIS, which overcome the limitations of conventional methods such as restricted visualization and incomplete lesion resection - factors known to worsen surgical outcomes [23]. The minimally invasive technique, employing the advanced Hopkins rod-lens system, offers superior image resolution and wider dynamic viewing angles, enabling precise polyp localization and complete excision while maximally preserving normal mucosal tissue in the sinonasal cavities [24, 25]. From a safety perspective, EMIS was associated with a significantly lower incidence of adverse events compared to conventional surgery, including reduced postoperative nasal adhesions, periorbital ecchymosis, and maxillary sinus ostium stenosis. These findings align with findings by Dalziel *et al.* [26], who reported complication rates ranging from 0.3-22.4% in CRSwNP patients undergoing similar minimally invasive procedures. Furthermore, Chen *et al.* [27] demonstrated comparable safety profiles between EMIS and biological therapies for CRSWNP treatment.

EMIS demonstrated significant improvements in olfactory function, nasal ventilation, and overall nasal status in patients with CRSwNP at both 1-month and 3-month follow-ups. These findings indicate that EMIS is superior to conventional techniques in preserving the physiological integrity and functional architecture of the nasal cavity. The observed benefits may stem from the ability of EMIS to maximize structural preservation while maintaining nasal function, thereby facilitating more efficient recovery of olfactory and ventilatory functions [28]. In contrast, conventional ESS is often associated with greater tissue trauma and more pronounced postoperative sinus dysfunction, which can adversely affect olfactory and ventilation outcomes [29]. Supporting our

results, Zhao *et al.* [30] reported similar improvements in olfactory function among CRS patients following EMIS. Furthermore, EMIS induces comparatively lower surgical stress in CRSwNP patients. Su *et al.* [31] found that EMIS not only enhanced olfactory function in refractory CRSwNP cases but also minimized perioperative stress responses, a conclusion consistent with our data. Notably, EMIS-treated patients exhibited significantly better QoL metrics at the 3-month postoperative assessment. The significant improvement in QoL is primarily attributed to the minimally invasive nature of EMIS, which reduced postoperative complications while effectively restoring olfactory function, improving nasal ventilation, and optimizing overall nasal physiology. Furthermore, EMIS significantly reduced surgical-induced stress responses compared to conventional approaches. Collectively, these advantages foster a more favorable recovery process, ultimately leading to enhanced QoL for patients. This aligns with findings from Tashman *et al.* [32], who documented sustained QoL benefits in CRS patients undergoing EMIS over a 5-year follow-up period.

This study has several limitations that should be acknowledged. First, we did not perform stratified analyses based on disease severity levels, which could have helped identify subgroups of patients who might benefit most from EMIS. Second, our evaluation did not include an economic cost analysis; incorporating such data would provide valuable insight into the practical applicability of EMIS in clinical settings. Third, the follow-up period was relatively short, lacking long-term data (e.g., 3-5 years post-intervention). Extended follow-up studies are necessary to comprehensively assess the sustained efficacy and durability of treatment outcomes with EMIS. Future research efforts should prioritize addressing these limitations to provide a more comprehensive understanding of the clinical value of this technique.

In conclusion, EMIS represents a clinically advantageous approach for CRSwNP management, offering high efficacy with an excellent safety profile. By optimizing olfactory and nasal ventilatory function while minimizing surgical trauma, EMIS not only accelerates recovery but also contributes to sustained improvement in patients' QoL. These compelling advantages support its broader adoption as a preferred surgical option in CRSwNP management.

Disclosure of conflict of interest

None.

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References

[1] Anastasi F, Canevari FRM, Gallo S, Gramellini G, Heffler E, La Mantia I, Monti G, Ragusa M and Macchi A. Olfactory impairment in Italian patients with chronic rhinosinusitis with nasal polyps: a patient-centered survey. Front Allergy 2025; 5: 1519069.

[2] Palacios-Garcia J, Porras-Gonzalez C, Moreno-Luna R, Maza-Solano J, Polo-Padillo J, Munoz-Bravo JL and Sanchez-Gomez S. Role of fibroblasts in chronic inflammatory signalling in chronic rhinosinusitis with nasal polyps-A systematic review. J Clin Med 2023; 12: 3280.

[3] Starry A, Hardtstock F, Wilke T, Weihing J, Ultsch B, Wernitz M, Renninger M, Maywald U and Pfaar O. Epidemiology and treatment of patients with chronic rhinosinusitis with nasal polyps in Germany-A claims data study. Allergy 2022; 77: 2725-2736.

[4] Bachert C, Sousa AR, Lund VJ, Scadding GK, Gevaert P, Nasser S, Durham SR, Cornet ME, Kariyawasam HH, Gilbert J, Austin D, Maxwell AC, Marshall RP and Fokkens WJ. Reduced need for surgery in severe nasal polyposis with mepolizumab: randomized trial. J Allergy Clin Immunol 2017; 140: 1024-1031, e1014.

[5] Bachert C, Bhattacharyya N, Desrosiers M and Khan AH. Burden of disease in chronic rhinosinusitis with nasal polyps. J Asthma Allergy 2021; 14: 127-134.

[6] Calus L, Van Bruaene N, Bosteels C, Dejonckheere S, Van Zele T, Holtappels G, Bachert C and Gevaert P. Twelve-year follow-up study after endoscopic sinus surgery in patients with chronic rhinosinusitis with nasal polyposis. Clin Transl Allergy 2019; 9: 30.

[7] Loftus CA, Soler ZM, Koochakzadeh S, Desiato VM, Yoo F, Nguyen SA and Schlosser RJ. Revision surgery rates in chronic rhinosinusitis with nasal polyps: meta-analysis of risk factors. Int Forum Allergy Rhinol 2020; 10: 199-207.

[8] Niu Z, Sha J, Zhu D and Meng C. Investigation and characterization of the RAS/RAF/MEK/ERK pathway and other signaling pathways in

chronic sinusitis with nasal polyps. Int Arch Allergy Immunol 2025; 186: 252-263.
[9] Fujieda S, Matsune S, Takeno S, Ohta N, Asako M, Bachert C, Inoue T, Takahashi Y, Fujita H, Deniz Y, Rowe P, Ortiz B, Li Y and Mannent LP. Dupilumab efficacy in chronic rhinosinusitis with nasal polyps from SINUS-52 is unaffected by eosinophilic status. Allergy 2022; 77: 186-196.
[10] Zheng J, Yu L, Hu W and Yu Y. Systematic review and meta-analysis of the curative effects and safety of endoscopic sinus surgery in children with chronic sinusitis with nasal polyps. Transl Pediatr 2022; 11: 1171-1181.
[11] Miglani A, Soler ZM, Smith TL, Mace JC and Schlosser RJ. A comparative analysis of endoscopic sinus surgery versus biologics for treatment of chronic rhinosinusitis with nasal polyposis. Int Forum Allergy Rhinol 2023; 13: 116-128.
[12] De Corso E, Porru DP, Corbo M, Montuori C, De Maio G, Mastrapasqua RF, Panfili M, Spanu C, Di Bella GA, D'Agostino G, Rizzuti A, Passali GC and Galli J. Comparative real-world outcomes of dupilumab versus endoscopic sinus surgery in the treatment of severe CRSwNP patients. Clin Otolaryngol 2024; 49: 481-489.
[13] Chin CJ, Scott JR and Lee JM. Diagnosis and management of chronic rhinosinusitis. CMAJ 2025; 197: E148-E154.
[14] Huang A, Li T, Li MS, Huang ZX, Wang DH, Cheng L, Zhou B, Wang H and Liu Z. Association of comorbid asthma and the efficacy of bioabsorbable steroid-eluting sinus stents implanted after endoscopic sinus surgery in patients with chronic rhinosinusitis with nasal polyps. Curr Med Sci 2023; 43: 1005-1012.
[15] Chen S, Lin C and Fang Z. Effectiveness and incidence of adverse reactions of nasal endoscopic surgery in the treatment of chronic rhinosinusitis with nasal polyps. BMC Surg 2025; 25: 165.
[16] Tajiri T, Suzuki M, Nishiyama H, Ozawa Y, Kurokawa R, Ito K, Fukumitsu K, Mori Y, Kanemitsu Y, Fukuda S, Uemura T, Ohkubo H, Takemura M, Maeno K, Ito Y, Oguri T, Iwasaki S and Niimi A. Efficacy of dupilumab for severe chronic rhinosinusitis with nasal polyps and asthma: a prospective study. Ann Allergy Asthma Immunol 2024; 133: 550-558, e2.
[17] Wu Y, Shi X, Ni S and Sun H. Efficacy of clarithromycin combined with fluticasone propionate on nasal function, nasal mucociliary transport function, and serum inflammatory markers in chronic rhinosinusitis patients after functional endoscopic sinus surgery. Ear Nose Throat J 2024; 1455613241294244.
[18] Xie X, Ji D, Chen F, Lin Z, Deng K, Song J and Wang J. Arthroscopic versus open fixation for medial malleolus fractures improves trauma response and bone healing. Sci Rep 2025; 15: 15050.
[19] Mullol J, Azar A, Buchheit KM, Hopkins C and Bernstein JA. Chronic rhinosinusitis with nasal polyps: quality of life in the biologics era. J Allergy Clin Immunol Pract 2022; 10: 1434-1453, e1439.
[20] Jiang X, Shu L, Liu Y, Shen Y, Ke X, Liu J and Yang Y. YES-associated protein-regulated Smad7 worsen epithelial barrier injury of chronic sinusitis with nasal polyps. Immun Inflamm Dis 2023; 11: e907.
[21] Goulioumis AK, Kourelis K, Gkorpa M and Danielides V. Pathogenesis of nasal polyposis: current trends. Indian J Otolaryngol Head Neck Surg 2023; 75 Suppl 1: 733-741.
[22] Merrill T and Kanaan A. Managing chronic rhinosinusitis with nasal polyps in the elderly: challenges and solutions. Clin Interv Aging 2022; 17: 685-698.
[23] Govindaraj S, Adappa ND and Kennedy DW. Endoscopic sinus surgery: evolution and technical innovations. J Laryngol Otol 2010; 124: 242-250.
[24] Hintschich CA, Fischer R, Seebauer C, Schebesch KM, Bohr C and Kuhnel T. A third hand to the surgeon: the use of an endoscope holding arm in endonasal sinus surgery and well beyond. Eur Arch Otorhinolaryngol 2022; 279: 1891-1898.
[25] Alsaleh S, Manji J and Javer A. Optimization of the surgical field in endoscopic sinus surgery: an evidence-based approach. Curr Allergy Asthma Rep 2019; 19: 8.
[26] Dalziel K, Stein K, Round A, Garside R and Royle P. Endoscopic sinus surgery for the excision of nasal polyps: a systematic review of safety and effectiveness. Am J Rhinol 2006; 20: 506-519.
[27] Chen J, Wang H, Zhang C, Shi L, Zhang Q, Song X, Wang D, Hu L, Yu H and Sun X. Comparative short-term efficacy of endoscopic sinus surgery and biological therapies in chronic rhinosinusitis with nasal polyps: a network meta-analysis. Clin Transl Allergy 2023; 13: e12269.
[28] Ramirez-Gil LS, Ley-Tomas JJ, Hernaiz-Leonardo JC, Alobid I, Mullol J and Ceballos-Cantu JC. Effects of endoscopic sinus surgery on olfactory function. Curr Allergy Asthma Rep 2023; 23: 715-731.
[29] Re M, Massegur H, Magliulo G, Ferrante L, Sciarretta V, Farneti G, Macri G, Mallardi V and Pasquini E. Traditional endonasal and microscopic sinus surgery complications versus endoscopic sinus surgery complications: a meta-analysis. Eur Arch Otorhinolaryngol 2012; 269: 721-729.

[30] Zhao R, Chen K and Tang Y. Olfactory changes after endoscopic sinus surgery for chronic rhinosinusitis: a meta-analysis. Clin Otolaryngol 2021; 46: 41-51.
[31] Su B, Han Q, Xi X and Zhou Z. Effect of modified endoscopic sinus surgery combined with middle turbinate resection on olfactory function and stress response in patients with refractory chronic rhinosinusitis with nasal polyps. Am J Transl Res 2022; 14: 1279-1287.
[32] Tashman K, Adams D, Vickery TW, Holbrook EH, Gray ST, Bleier BS, Scangas G and Metson R. Five-year EuroQol 5-dimension outcomes after endoscopic sinus surgery. Laryngoscope 2024; 134: 2592-2601.