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Original Article

Improved nasal function and reduced recurrence after endoscopic sinus surgery combined with vidian neurectomy in allergic rhinitis with chronic rhinosinusitis

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Abstract: Objective: To compare the clinical outcomes of endoscopic sinus surgery (ESS) combined with vidian neurectomy versus ESS alone in patients with allergic rhinitis and chronic rhinosinusitis, and to identify factors associated with postoperative recurrence. Methods: A total of 375 patients with allergic rhinitis and chronic rhinosinusitis treated between 2019 and 2024 were included in this study. Patients were grouped into either the ESS alone (conventional treatment group; n=194) or the ESS with vidian neurectomy (combined treatment group; n=181) groups based on their treatment protocols. Propensity score matching (PSM; 1:1) was applied to balance baseline characteristics. Perioperative metrics, including nasal function, inflammatory and immune markers, as well as symptom and quality-of-life scores were compared between the two groups. Recurrence within 12 months postoperatively was recorded. Multivariate logistic regression analysis was performed to identify independent risk factors for disease recurrence. Results: After PSM, baseline characteristics were comparable between the two groups. Compared with the conventional treatment group, the combined treatment group showed a shorter operative time (median 34 vs 45 min, P<0.001) and lower postoperative nasal resistance (0.16 vs 0.21 Pa/(cm^3·s), P<0.001). Additionally, the combined treatment group demonstrated significantly lower IL-6 levels (11.16±3.68 vs 12.61±3.62 ng/L, P<0.001), accompanied by a greater reduction in C-reactive protein (CRP) and a more pronounced increase in IFN-γ. Endoscopic and patient-reported scores improved more, including Lund-Kennedy and SNOT-22. The overall recurrence rate was 19.2% (72/375), with the combined treatment group reporting significantly lower recurrence rates. Multivariate analysis identified ESS alone (OR=6.017, P=0.003), smoking (OR=3.82, P=0.022), higher preoperative IL-4 (OR=1.46, P<0.001), higher eosinophil percentage (OR=5.932, P<0.001), and higher SNOT-22 scores (OR=1.442, P<0.001) as independent predictors of recurrence. Conclusion: The addition of vidian neurectomy to ESS was associated with superior improvements in symptoms and nasal function, modulation of inflammatory responses, and a reduced 12-month recurrence rate. Preoperative IL-4, eosinophils, SNOT-22 score, and smoking status are closely associated with disease recurrence.

Keywords: Allergic rhinitis, chronic rhinosinusitis, endoscopic sinus surgery, vidian neurectomy, propensity score matching, recurrence analysis

Introduction

Allergic rhinitis (AR) and chronic rhinosinusitis (CRS) frequently coexist. Shared epithelial barrier defects, type-2 inflammation, and neural reflex pathways mechanistically link the two conditions, making the combined phenotype more prevalent in clinic settings [1]. In routine care, many patients cycle through topical sprays and irrigations, short systemic courses, and intermittent allergy control, yet overall control remains suboptimal.

Surgery can improve outcomes but is not universally curative. In a multicenter randomized trial of chronic rhinosinusitis with nasal polyps (CRSwNP), endoscopic sinus surgery (ESS) improved disease-specific quality of life at 12 months; however, the mean SNOT-22 advantage over optimized medical therapy was modest (-4.9 points) and fell short to reach the commonly accepted minimal clinically important difference, underscoring residual symptoms in a substantial proportion of patients after ESS [4]. Long-term follow-up studies also demonstrate relapse rates, with a 5-year cohort study reporting polyp recurrence in 35.4% of patients and revision surgery in 17.7% [5].

Adjunctive medical strategies may modify outcomes. High-volume steroid irrigations improve drug delivery to the sinus cavities and achieve greater improvements in sinonasal scores compared with low-volume delivery in both CRS and AR populations [2]. Following ESS for CRS with concomitant AR, the addition of allergen immunotherapy to saline irrigation was reported to reduce one-year recurrence rates and enhance epithelial recovery compared with conventional medication alone, accompanied by better inflammatory marker profiles [3]. Disease laterality also influences prognosis: bilateral CRSwNP tends to carry greater symptom burden and poorer prognostic outcomes than unilateral disease, which affects both trial interpretation and real-world expectations [6].

These gaps motivate interventions targeting neural mechanisms underlying rhinorrhea and nasal congestion. Vidian neurectomy (VN) interrupts parasympathetic input to the nasal mucosa, thereby reducing secretory tone. Observational studies in AR patients with CRSwNP have reported significant improvements in nasal symptoms and endoscopic findings after unilateral VN [7] and selective VN combined with ESS, with higher overall therapeutic efficacy compared with ESS alone and acceptable safety profiles [8]. In patients with coexisting asthma, endoscopic VN has also been associated with better asthma control and decreased exacerbation triggered by nasal symptoms [11], and similar benefits have been reported in Chinese cohorts with AR combined with asthma [9]. Techniques vary among centers: comparison of trunk versus branch resection report durable symptom control with both approaches, with more sustained effects of trunk neurectomy in refractory AR cohorts [10]. More recently, inferior turbinate submucosal surgery combined with extended neural modulation has demonstrated reductions in symptoms and medication use in difficult-to-treat rhinitis, suggesting that broader autonomic targeting may add value in selected patients [12].

Risk stratification strategies are also evolving. A clinicopathologic nomogram incorporating comorbidities such as asthma and gastroesophageal reflux, polyp subtype, eosinophils, and global sinus involvement has shown good discrimination and calibration for predicting postoperative CRSwNP recurrence, with both internal and external validation [13]. Imaging-based tools have also advanced: a deep-learning radiomics nomogram integrating CT features with clinical factors showed strong predictive performance for preoperative recurrence risk in CRS surgical candidates and serve as a complementary tool for selecting patients for combined neural interventions [14].

Against this background, this study investigated whether adding vidian neurectomy to ESS improves nasal function, relieves symptom burden and inflammation, and reduces one-year recurrence rates in patients with AR and CRS. Additionally, factors associated with disease recurrence were also explored in this study.

Methods and materials

Sample size calculation

Sample size estimation was performed based on Visual Analog Scale (VAS) data reported by Qi et al. [ref], employing the formula for mean differences between two independent samples. In their study comparing endoscopic selective vidian neurectomy combined with functional endoscopic sinus surgery (FESS) versus FESS alone in patients with allergic rhinitis combined with chronic rhinosinusitis with nasal polyps, both groups showed comparable baseline symptom severity. The experimental group (n=69) received FESS plus selective vidian neurectomy, while the control group (n=61) underwent conventional FESS with conservative treatment for allergic rhinitis. With a two-sided significance level of $\alpha=0.05$ and a statistical power of 80%, sample size estimation was performed using the formula for comparing two independent means: $n = 2(Z_{\alpha/2} + Z_{\beta})^2\sigma^2/\delta^2$, where $Z_{\alpha/2} = 1.96$ (for $\alpha=0.05$, two-sided), $Z_{\beta} = 0.84$ (for $\beta=0.20$, i.e., 80% power).

Based on VAS outcomes reported in the reference study and the minimal clinically important difference (MCID) for VAS scores (typically ranging from 1.0 to 2.0 points), sample size calculations were performed. Using a pooled standard deviation of 2.5 points and detecting a mean difference of 1.5 points (MCID), the required sample size was calculated as approximately 44 per group. Considering a more conservative mean difference of 1.0 point, approximately 98 patients per group would be required. Given clinical practicality and statistical power balance, a minimum of 50 patients per group was deemed appropriate. After accounting for an anticipated 15% dropout rate, the final required sample size was 59 patients per group, totaling 118 patients. The present study enrolled 375 patients (194 in the conventional treatment group and 181 in the combined treatment group), substantially exceeding the minimum required sample size, thereby ensuring adequate statistical power for detecting clinically meaningful differences.

Sample source

This retrospective study was conducted on 375 patients who underwent surgical treatment at our center between January 2019 and February 2024. Patients were divided into the conventional treatment group (n=194) and the combined treatment group (n=181) based on their surgical approach. This study was approved by the Ethics Committee of Baoji High-tech Hospital.

Inclusion and exclusion criteria

Inclusion criteria: Adult patients ≥18 years; physician-diagnosed allergic rhinitis, defined by a positive skin-prick test or serum specific IgE ≥0.35 kU/L; diagnosis of chronic rhinosinusitis, defined by symptoms lasting for ≥12 weeks together with objective evidence on nasal endoscopy and/or CT (Lund-Mackay ≥4); Chronic rhinosinusitis without nasal polyps (CRSsNP) phenotype only; receipt of ESS or ESS combined with vidian neurectomy under general anesthesia; availability of complete preoperative and 6-month postoperative assessments, including nasal resistance and mucociliary transport, inflammatory and immune markers, and symptoms or quality-of-life scores; and a minimum follow-up period of 12 months with documented recurrence status; No systemic corticosteroids, immunosuppressants, or biologic therapies within 3 months before surgery (maintenance intranasal steroids/antihistamines were permitted if the treatment regimen had been stable for at least 4 weeks).

Exclusion criteria: CRSwNP, fungal sinusitis, sinonasal malignancy, septal perforation, or a history of prior ESS or vidian/posterior nasal neurectomy; major contraindications to general anesthesia (e.g., ASA ≥IV); coagulopathy (platelets $<100\times10^9$/L or INR >1.5); uncontrolled diabetes (e.g., HbA1c >9%); active tuberculosis or other severe systemic illness; acute bacterial exacerbation at enrollment, primary ciliary dyskinesia, cystic fibrosis, granulomatous disease, aspirin-exacerbated respiratory disease (AERD); pregnancy or lactation; incomplete follow-up data or missing key clinical data.

Surgical protocol

All patients underwent inferior turbinate submucosal dissection under general anesthesia with endoscopic guidance. Preoperative infiltration anesthesia was achieved using 1% lidocaine with minimal epinephrine solution in the upper and anterior nasal mucosa. Longitudinal incision was made along the superior and anterior inferior turbinate, followed by meticulous inferior turbinate mucosal dissection to completely expose the inferior turbinate bone. For inferior turbinate hypertrophy, partial bone res ection was performed before mucosal repositioning. Bilateral nasal cavity sponge packing was applied for hemostasis.

The combined group additionally underwent vidian neurectomy: After infiltration anesthesia with 1% lidocaine containing a low concentration of epinephrine in the sphenopalatine fossa region, the sphenopalatine ganglion and posterior inferior turbinate were exposed. A longitudinal incision of approximately 5 mm was made lateral to the attachment of the middle turbinate to identify the vidian foramen. The vidian nerve was bluntly dissected using a long probe, confirmed, and then transected, followed by hemostasis. Both groups received nasal cavity saline sponge packing for 3 days postoperatively and oral antibiotics for 1 week. All patients were evaluated on postoperative day 1 (**Figure 1**).

Clinical data collection

Clinical data were obtained from hospital electronic medical records and postoperative outpatient follow-up records. Collected information included general demographic data (age, sex, and body mass index [BMI]), disease dura-

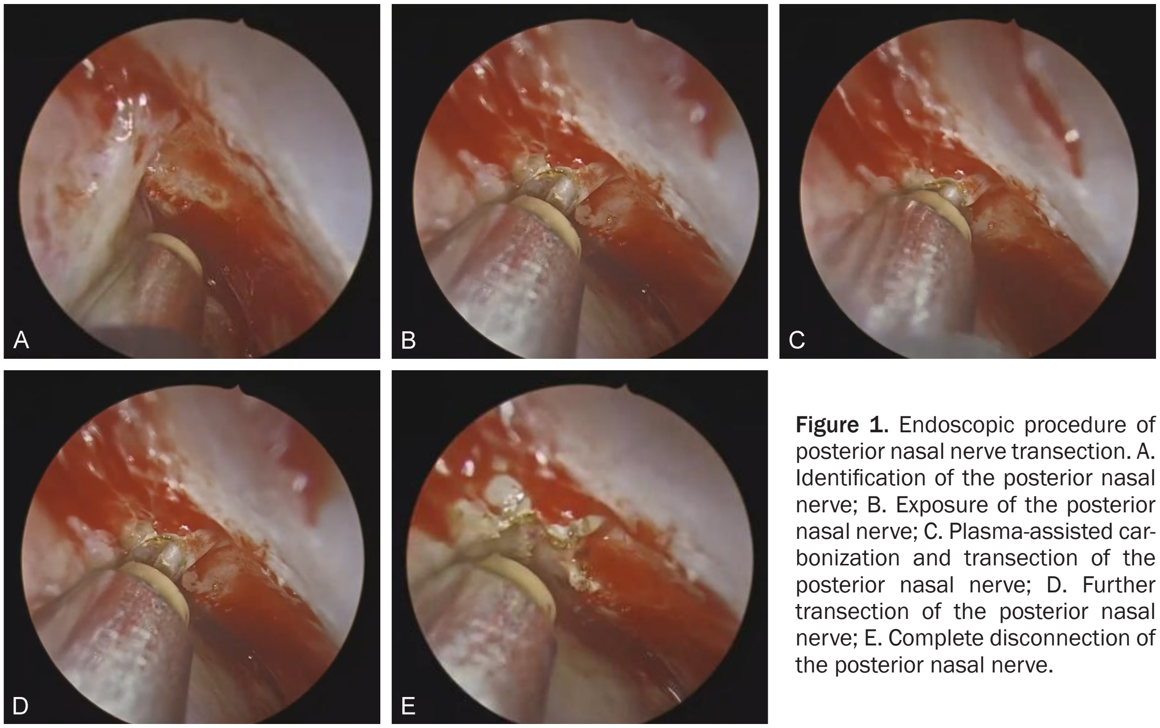

Figure 1. Endoscopic procedure of posterior nasal nerve transection. A. Identification of the posterior nasal nerve; B. Exposure of the posterior nasal nerve; C. Plasma-assisted carbonization and transection of the posterior nasal nerve; D. Further transection of the posterior nasal nerve; E. Complete disconnection of the posterior nasal nerve.

tion, smoking history, alcohol consumption history, primary symptoms (nasal congestion, rhinorrhea, and excessive sneezing), and comorbidities (hypertension, diabetes, and asthma). Perioperative indicators included operative time, intraoperative blood loss, and hospital stay duration. Nasal function assessments included nasal resistance, nasal mucociliary transport time, and transport rate, evaluated preoperatively and at 6-months postoperatively. Inflammatory and immune markers included interleukin-6 (IL-6), C-reactive protein (CRP), interferon-γ (IFN-γ), IL-4, and eosinophil percentage (EOS%). Symptom severity was assessed using the VAS and Lund-Kennedy scores (LK scores), whilst quality of life assessment utilized the Rhinoconjunctivitis Quality of Life Questionnaire (RQLQ) and the 22-Item Sino-Nasal Outcome Test (SNOT-22). All patients underwent postoperative follow-up for a minimum of 12 months, with disease recurrence recorded. Data extraction was independently performed by two investigators, with cross-verification to assure accuracy and completeness.

Functional scoring

Nasal symptom severity and health-related quality of life were assessed preoperatively and at 6 months postoperatively using validated subjective and objective instruments. Symptom intensity was evaluated using a 10-cm Visual Analog Scale (VAS), in which patients rated the overall severity of nasal symptoms (including nasal obstruction, rhinorrhea, sneezing, and nasal itching) from 0 (no symptoms) to 10 (worst imaginable symptoms) as previously described [19].

Endoscopic findings were assessed using the Lund-Kennedy (LK) scoring system [20]. Each nasal cavity was graded for three components - mucosal edema, secretions, and crusting/scarring/granulation - on a 0-2 scale (0= none, 1= mild/moderate, 2= severe), yielding a unilateral score of 0-6 and a total bilateral score of 0-12. Higher LK scores indicate more pronounced mucosal inflammation and postoperative healing abnormalities.

Health-related quality of life was measured using the Rhinoconjunctivitis Quality of Life Questionnaire (RQLQ) and the 22-item Sino-Nasal Outcome Test (SNOT-22). The RQLQ evaluates the impact of rhinoconjunctivitis on daily functioning across seven domains (activities, sleep, non-nose/eye symptoms, practical problems, nasal symptoms, eye symptoms, and emotional function). Each item is rated on a 7-point scale (0= not troubled, 6= extremely troubled), and the overall RQLQ score is calculated as the mean of item scores; higher values reflect poorer quality of life. The SNOT-22 assesses sinonasal symptom burden and its effect on daily life over the preceding period, with each item scored from 0 (no problem) to 5 (problem as bad as it can be), produces a total score range of 0-110. Higher SNOT-22 scores denote worse sinonasal-related quality of life. For interpretability, changes in SNOT-22 were also considered clinically meaningful when exceeding the commonly accepted minimal clinically important difference (MCID) threshold (approximately 9 points) [24].

All questionnaires were completed by patients independently at each assessment point, and higher scores on VAS, LK, RQLQ, and SNOT-22 were interpreted as indicating greater disease severity or poorer quality of life.

Laboratory testing

Inflammatory and immune markers measured included IL-6, CRP, IFN-γ, IL-4, and EOS%. Fasting peripheral venous blood was collected in the morning within seven days before surgery and again at six months postoperatively. Samples were processed promptly in the hospital laboratory. Serum IL-6, IFN-γ, and IL-4 levels were quantified using enzyme-linked immunosorbent assay kits (ELISA; Shanghai Enzyme-linked Biotechnology) according to the manufacturer's instructions. CRP was measured using immunoturbidimetry on an automated biochemical analyzer (Mindray, China). EOS% was determined using a five-part differential count on a hematology analyzer (XN-9000, Sysmex, Japan).

Observation metrics

The primary observation measures included recurrence of chronic rhinosinusitis 12 months after surgery (occurrence/non-occurrence), postoperative recovery of nasal function (nasal resistance and ciliary function), improvement in subjective symptoms (VAS and LK scores), changes in quality-of-life scores (RQLQ and SNOT-22 scores), and alterations in inflammatory/immune markers (IL-6, CRP, IFN-γ, IL-4, and EOS%). Recurrence was defined as postoperative reappearance of classic CRS symptoms, accompanied by endoscopic or imaging evidence of inflammation necessitating further medical or surgical intervention. Secondary outcome measures encompassed operation duration, intraoperative blood loss, length of hospital stay, and perioperative safety metrics.

Statistical methods

All data analysis was performed using R 4.3.3 (R Foundation for Statistical Computing, Vienna, Austria), primarily using packages of *tidyverse* (data cleaning and processing), *tableone* (baseline characteristic comparison), *MatchIt* (propensity score matching), *cobalt* (matching balance assessment), *rstatix* and *stats* (paired testing and conventional statistics), *glm* (logistic regression analysis).

Continuous variables were presented as mean ± standard deviation ($\bar{x}\pm s$) or median [interquartile range] based on normality testing results. Between-group comparisons for normally distributed data were performed using independent samples t-tests, while non-normally distributed variables employed Mann-Whitney U tests. For pre- and post-treatment comparisons, paired t-tests were applied to normally distributed variables, and Wilcoxon signed-rank tests for non-normally distributed variables. Categorical variables were presented as frequencies and percentages, with between-group comparisons using χ^2 tests or Fisher's exact test, as appropriate.

Propensity score matching (PSM) employed 1:1 nearest neighbor matching based on age and disease duration, with a caliper width of 0.02. Matching quality was assessed using standardized mean differences (SMD), with an SMD <0.1 indicating adequate balance between groups. Factors associated with chronic rhinosinusitis recurrence were identified using univariate and multivariate logistic regression analyses. Results were reported as odds ratios (OR) with corresponding 95% confidence intervals (CI). All tests were two-sided, with P<0.05 considered statistically significant.

Results

Comparison of baseline characteristics of study population (before and after PSM)

Before PSM, significant differences were observed in age and disease duration (both P<0.001) between the conventional treatment

Table 1. Comparison of baseline characteristics of the study population before and after PSM

Factor	Before PSM	After PSM	Statistic/*P* value (Before PSM)	Statistic/*P* value (After PSM)
Age (years)	Conventional: 48.00 [46.00, 50.00] Combined: 46.00 [45.00, 48.00]	Conventional: 47.00 [45.00, 48.00] Combined: 47.00 [45.00, 48.00]	7.327/<0.001	0.335/0.738
Sex (male/female)	Conventional: 142/52 Combined: 127/54	Conventional: 80/29 Combined: 75/34	0.424/0.515	0.558/0.455
BMI (kg/m²)	Conventional: 24.08±1.98 Combined: 23.97±1.82	Conventional: 24.26±1.91 Combined: 23.92±1.88	-0.905405405	-6.973544974
Disease duration (years)	Conventional: 5.00 [4.00, 6.75] Combined: 4.00 [2.00, 5.00]	Conventional: 4.00 [3.00, 6.00] Combined: 4.00 [3.00, 6.00]	5.329/<0.001	0.747/0.455
Smoking history (yes/no)	Conventional: 126/68 Combined: 123/58	Conventional: 69/40 Combined: 74/35	0.380/0.538	0.508/0.476
Alcohol history (yes/no)	Conventional: 62/132 Combined: 69/112	Conventional: 34/75 Combined: 43/66	1.565/0.211	1.626/0.202
Nasal obstruction (yes/no)	Conventional: 163/31 Combined: 143/38	Conventional: 93/16 Combined: 88/21	1.569/0.210	0.814/0.367
Rhinorrhea (yes/no)	Conventional: 147/47 Combined: 147/34	Conventional: 78/31 Combined: 89/20	1.638/0.201	3.097/0.078
Excessive sneezing (yes/no)	Conventional: 132/62 Combined: 130/51	Conventional: 77/32 Combined: 76/33	0.636/0.425	0.022/0.882
Hypertension (yes/no)	Conventional: 19/175 Combined: 22/159	Conventional: 9/100 Combined: 13/96	0.536/0.464	0.809/0.368
Diabetes (yes/no)	Conventional: 16/178 Combined: 18/163	Conventional: 8/101 Combined: 11/98	0.327/0.567	0.519/0.471
Asthma (yes/no)	Conventional: 74/120 Combined: 58/123	Conventional: 43/66 Combined: 31/78	1.528/0.216	2.946/0.086

Note: Before PSM n=194 (conventional group)/181 (combined group), after PSM n=109/group. BMI, Body Mass Index.

group (n=194) and combined treatment group (n=181). However, other variables (sex, BMI, smoking history, alcohol consumption history, main symptoms, and comorbidities) showed no significant differences between the two groups (P>0.05).

After PSM (n=109/group), no significant differences were observed in baseline characteristics between the two groups (P>0.05), indicating effective balance of inter-group differences (**Table 1**). Propensity score distributions before and after PSM showed high overlap between groups after PSM, with SMDs approaching 0, validating matching effectiveness (**Figure 2**).

Comparison of perioperative indicators (before and after PSM)

Before PSM, significant differences existed between the two groups in operative time (P<0.001) and hospital stay (P<0.001), with more favorable outcomes in the combined group, whereas intraoperative blood loss showed no significant difference (P=0.509). After PSM, differences in operative time (P<0.001) and hospital stay (P<0.001) remained significant, with the combined group continuing to show better outcomes, while intraoperative blood loss remained non-significant (P=0.511) (**Table 2**).

Comparison of nasal function indicators (before and after PSM)

Before treatment, no significant between-group differences were observed in nasal resistance, nasal mucociliary transport time, or transport rate both before and after PSM (all P>0.05).

At 6 months postoperatively, before PSM, the combined group demonstrated significantly greater improvements than the conventional group in nasal resistance, nasal mucociliary transport time, and transport rate (all P<0.001). These differences remained significant after PSM (all P<0.001). Within-group comparisons before and after treatment showed significant improvement in all three indicators for both groups (P<0.001) (**Table 3**).

Comparison of inflammatory and immune markers (before and after PSM)

Before treatment, both before and after PSM, no significant differences were observed between the two groups in IL-6, CRP, IFN-γ, IL-4,

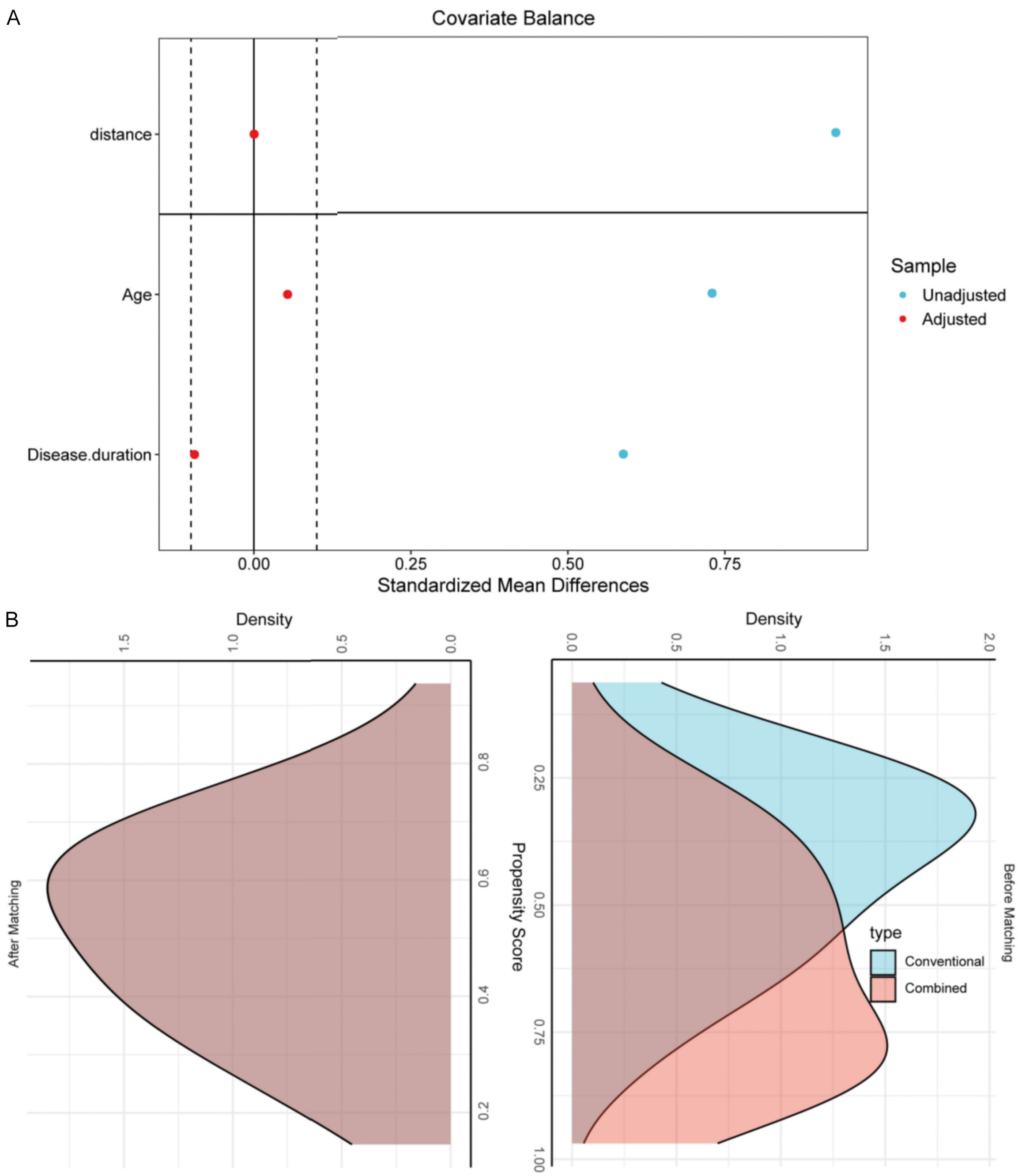

Figure 2. Balance of baseline variables and distribution of propensity scores before and after PSM. A. SMD comparison of age and disease duration before and after matching. Red dots represent post-matching data; blue dots represent pre-matching data. Dashed lines indicate SMD thresholds of 0.1 and 0.25. B. Left panel: distribution of propensity scores in the two groups before matching; right panel: distribution of propensity scores after matching. Blue indicates the conventional group, red indicates the combined group. Note: PSM, Propensity Score Matching; SMD, Standardized Mean Differences.

and EOS% (P>0.05). After treatment, prior to PSM, the combined group showed significantly greater improvements in IL-6 (P<0.001), CRP (P<0.001), IFN-γ (P<0.001), IL-4 (P<0.001), and EOS% (P=0.046) compared to the conventional group; results remained statistically significant after PSM, with the combined group performing better in IL-6 (P=0.004), CRP (P<0.001), IFN-γ (P<0.001), IL-4 (P<0.001), and EOS% (P=0.038). Within-group comparisons before and after tre-

Table 2. Comparison of perioperative indicators before and after PSM

Variable	Before PSM	After PSM	Statistic/*P* value (Before PSM)	Statistic/*P* value (After PSM)
Operative time (min)	Conventional: 44.00 [35.00, 54.00] Combined: 35.00 [27.00, 43.00]	Conventional: 45.00 [35.00, 54.00] Combined: 34.00 [27.00, 43.00]	5.910/<0.001	4.618/<0.001
Intraoperative blood loss (mL)	Conventional: 105.50 [82.00, 140.00] Combined: 85.00 [74.00, 96.00]	Conventional: 108.00 [82.00, 140.00] Combined: 85.00 [76.00, 95.00]	0.660/0.509	0.657/0.511
Hospital stay (d)	Conventional: 4.00 [3.00, 5.00] Combined: 4.00 [3.00, 5.00]	Conventional: 4.00 [3.00, 5.00] Combined: 4.00 [3.00, 5.00]	5.817/<0.001	4.246/<0.001

Note: Before PSM n=194 (conventional group)/181 (combined group), after PSM n=109/group.

atment showed significant improvement in all five markers for both groups (P<0.001) (**Tables 4**, **5**).

Comparison of symptoms and quality of life scores (before and after PSM)

Before treatment, no significant differences were observed between the two groups in VAS, LK, RQLQ, and SNOT-22 scores either before and after PSM (all P>0.05). After treatment, before PSM, the combined group was superior to the conventional group in VAS (P=0.040), LK (P<0.001), RQLQ (P<0.001), and SNOT-22 (P<0.001) scores. After PSM, the combined group was superior to the conventional group in LK (P<0.001), RQLQ (P=0.002), and SNOT-22 (P<0.001) scores. However, differences in VAS score between the two groups were no longer statistically significant (P=0.407). Within-group comparisons before and after treatment showed significant improvement in all four scores for both groups (P<0.001) (**Tables 6**, **7**).

Comparison of baseline characteristics between recurrence and non-recurrence groups (before and after PSM)

Before PSM, postoperative recurrence occurred in 72 patients, with a recurrence rate of 19.2%. Significant differences were observed between the recurrence group (n=72) and non-recurrence group (n=303) in treatment approach (P<0.001), smoking history (P=0.005), asthma (P<0.001), intraoperative blood loss (P=0.018), preoperative IL-6 (P<0.001), IL-4 (P<0.001), EOS% (P<0.001), and SNOT-22 scores (P<0.001), while other variables showed no significant differences (P>0.05). After PSM (42 patients in the recurrence group, and 176 patients in the non-recurrence group; total recurrence rate 19.27%), significant differences existed between the recurrence and non-recurrence groups in treatment approach (P=0.002), smoking history (P=0.020), diabetes (P<0.001), asthma (P=0.020), intraoperative blood loss (P=0.012), preoperative IL-6 (P<0.001), CRP (P=0.015), IL-4 (P<0.001), EOS% (P<0.001), and SNOT-22 scores (P<0.001), while other variables showed no significant differences (P>0.05) (**Table 8**).

Multicollinearity and logistic regression analysis of recurrence-related factors (before and after PSM)

Before and after PSM, variance inflation factors (VIF) for all variables indicated negligible multicollinearity (VIF<2.3). Continuous variables were dichotomized according to optimal cutoff values.

Before PSM, univariate logistic regression analysis identified treatment approach (P=0.001), smoking history (P=0.006), asthma (P<0.001), intraoperative blood loss (P=0.009), preoperative IL-6 (P<0.001), IL-4 (P<0.001), EOS% (P<0.001), and SNOT-22 scores (P<0.001) as factors significantly associated with postoperative recurrence. Multivariate logistic regression analysis revealed that compared with the combined group, conventional treatment approach was an independent risk factor for postoperative recurrence (OR=6.017, P=0.003, 95%CI: 2.003-21.099), smoking history (OR=3.82, P=0.022), elevated preoperative IL-4 (OR=1.46, P<0.001), elevated EOS% (OR=5.932, P<0.001), and elevated SNOT-22 scores (OR=1.442, P<0.001) were also identified as independent risk factors. Asthma, intraoperative blood loss, and preoperative IL-6 were not statistically significant in multivariate analysis (P>0.05).

After PSM, univariate logistic regression analysis showed that treatment approach (P=0.003),

Table 3. Comparison of nasal function indicators before and after PSM

Indicator	Before PSM		After PSM		P
	Conventional	Combined	Conventional	Combined	
Nasal Resistance (Pa/(cm³·s))					
Pre-treatment	0.48 [0.44, 0.50]	0.48 [0.44, 0.50]	0.47±0.05	0.47±0.05	0.808/0.281
Post-treatment	0.20 [0.16, 0.25][c]	0.16 [0.14, 0.19][c]	0.21 [0.17, 0.25][c]	0.16 [0.14, 0.19][c]	<0.001/<0.001
Mucociliary Transport Time (min)					
Pre-treatment	26.00 [25.00, 27.00]	26.00 [26.00, 27.00]	26.00 [25.00, 28.00]	26.00 [26.00, 27.00]	0.896/0.742
Post-treatment	17.00 [15.00, 18.00][c]	14.00 [13.00, 16.00][c]	17.00 [15.00, 18.00][c]	14.00 [13.00, 16.00][c]	<0.001/<0.001
Mucociliary Transport Rate (mm/min)					
Pre-treatment	6.21 [5.34, 6.92]	6.36 [5.64, 7.01]	6.08±1.34	6.29±1.23	0.119/0.238
Post-treatment	7.52 [7.12, 8.15][c]	8.25 [7.49, 8.66][c]	7.50 [7.08, 8.15][c]	8.25 [7.44, 8.68][c]	<0.001/<0.001

Note: Before PSM n=194 (conventional)/181 (combined), after PSM n=109/group. *P* values shown as Before PSM/After PSM for between-group comparison. [c]P<0.001 vs pre-treatment (within-group).

Table 4. Comparison of inflammatory markers before and after PSM

Indicator	Before PSM		After PSM		P
	Conventional	Combined	Conventional	Combined	
IL-6 (ng/L)					
Pre-treatment	20.77±4.80	20.90±5.03	21.30±4.80	20.63±4.83	0.802/0.305
Post-treatment	12.61±3.62[c]	11.16±3.68[c]	12.54±3.60[c]	11.17±3.34[c]	<0.001/0.004
CRP (mg/L)					
Pre-treatment	21.01±3.14	20.76±2.97	20.78±2.96	20.79±2.95	0.421/0.982
Post-treatment	13.30 [10.53, 15.57][c]	9.40 [7.00, 13.60][c]	13.20 [10.50, 15.50][c]	9.20 [7.20, 13.70][c]	<0.001/<0.001

Note: Before PSM n=194 (conventional group)/181 (combined group), after PSM n=109/group. Pre-treatment = preoperative data, post-treatment = data at 6 months after surgery. Within-group comparison *P* value markings: [c]P<0.001. IL-6, Interleukin-6; CRP, C-Reactive Protein.

Table 5. Comparison of immune markers before and after PSM

Indicator	Before PSM		After PSM		P
	Conventional	Combined	Conventional	Combined	
IFN-γ (ng/L)					
Pre-treatment	26.73±3.67	26.85±4.03	26.55±3.77	27.08±4.05	0.764/0.323
Post-treatment	35.35 [31.92, 39.60][c]	41.80 [37.10, 45.80][c]	35.70 [32.60, 40.00][c]	42.50 [38.20, 46.20][c]	<0.001/<0.001
IL-4 (ng/L)					
Pre-treatment	53.23±4.68	52.83±4.89	52.96±4.54	52.67±5.00	0.416/0.662
Post-treatment	42.90 [36.92, 46.13][c]	33.10 [28.90, 40.30][c]	43.10 [38.50, 45.50][c]	32.50 [28.40, 40.20][c]	<0.001/<0.001
EOS%					
Pre-treatment	8.14±1.19	8.16±1.09	8.13±1.12	8.05±1.16	0.884/0.593
Post-treatment	5.61 [3.36, 7.83][c]	4.81 [3.70, 6.26][c]	5.97 [3.30, 7.93][c]	4.72 [3.70, 5.89][c]	0.015/0.004

Note: Before PSM n=194 (conventional group)/181 (combined group), after PSM n=109/group. Pre-treatment = preoperative data, post-treatment = data for 6 months after surgery. Within-group comparison *P* value markings: [c]P<0.001. IFN-γ, Interferon-gamma; IL-4, Interleukin-4; EOS%, Eosinophil Percentage.

Table 6. Comparison of symptom scores before and after PSM

Indicator	Before PSM		After PSM		P
	Conventional	Combined	Conventional	Combined	
VAS Score					
Pre-treatment	7.00 [4.25, 8.00]	7.00 [4.00, 8.00]	7.00 [4.00, 8.00]	7.00 [4.00, 8.00]	0.735/0.709
Post-treatment	3.00 [2.00, 4.00][c]	3.00 [2.00, 4.00][c]	3.00 [2.00, 4.00][c]	3.00 [2.00, 4.00][c]	0.040/0.407
LK Score					
Pre-treatment	8.00 [7.00, 8.00]	8.00 [7.00, 9.00]	8.00 [7.00, 8.00]	8.00 [7.00, 8.00]	0.708/0.612
Post-treatment	3.00 [2.00, 4.00][c]	2.00 [1.00, 3.00][c]	4.00 [3.00, 4.00][c]	2.00 [1.00, 3.00][c]	<0.001/<0.001

Note: Before PSM n=194 (conventional group)/181 (combined group), after PSM n=109/group. Pre-treatment = preoperative data, post-treatment = data for 6 months after surgery. Within-group comparison *P* value markings: [c]P<0.001. VAS, Visual Analog Scale; LK, Lund-Kennedy score. Statistical significance markers for within-group comparison (vs pre-treatment): [c]P<0.001.

Table 7. Comparison of quality of life scores before and after PSM

Indicator	Before PSM		After PSM		P
	Conventional	Combined	Conventional	Combined	
RQLQ Score					
Pre-treatment	82.59±9.97	82.76±10.12	82.75±9.48	82.68±9.95	0.870/0.957
Post-treatment	34.00 [29.25, 37.00][c]	30.00 [26.00, 34.00][c]	34.00 [30.00, 38.00][c]	31.00 [26.00, 35.00][c]	<0.001/0.002
SNOT-22 Score					
Pre-treatment	42.32±5.68	41.38±5.63	42.59±6.14	41.30±5.80	0.107/0.114
Post-treatment	20.00 [18.00, 23.00][c]	14.00 [11.00, 15.00][c]	21.00 [18.00, 23.00][c]	13.00 [11.00, 15.00][c]	<0.001/<0.001

Note: Before PSM n=194 (conventional group)/181 (combined group), after PSM n=109/group. Pre-treatment = preoperative data, post-treatment = data for 6 months after surgery. Within-group comparison *P* value markings: [c]P<0.001. RQLQ, Rhinoconjunctivitis Quality of Life Questionnaire; SNOT-22, 22-Item Sino-Nasal Outcome Test.

smoking history (P=0.023), asthma (P<0.001), intraoperative blood loss (P=0.002), preoperative IL-6 (P<0.001), CRP (P=0.043), IL-4 (P< 0.001), EOS% (P<0.001), and SNOT-22 scores (P<0.001) were significantly associated with postoperative recurrence. Multivariate logistic regression analysis identified conventional treatment approach (OR=12.899, P=0.014, 95% CI: 2.11-138.617), higher intraoperative blood loss (OR=1.033, P=0.019), elevated preoperative EOS% (OR=10.121, P<0.001), and elevated SNOT-22 scores (OR=1.667, P<0.001) as independent risk factors; while lower preoperative CRP (OR=0.6, P=0.011) was associated with increased recurrence risk, suggesting a potential protective effect. Smoking history, asthma, preoperative IL-6, and IL-4 showed no statistical significance in multivariate analysis (P>0.05) (**Figure 3**).

Discussion

Adding vidian neurectomy to endoscopic sinus surgery brought broader clinical benefits than

Table 8. Comparison of baseline characteristics between recurrence groups before and after PSM

Factor	Before PSM (Recurrence/ Non-recurrence)	After PSM (Recurrence/ Non-recurrence)	Statistic/*P* value (Before PSM)	Statistic/*P* value (After PSM)
Treatment approach (Conventional/Combined)	50/22 vs 144/159	30/12 vs 79/97	11.194/<0.001	9.555/0.002
Smoking history (yes/no)	58/14 vs 191/112	34/8 vs 109/67	8.003/0.005	5.436/0.020
Asthma (yes/no)	41/31 vs 91/212	34/8 vs 109/67	18.471/<0.001	5.436/0.020
Intraoperative blood loss (mL)	99.50 [84.00, 140.00] vs 90.00 [77.00, 120.00]	106.00 [84.00, 142.50] vs 90.00 [78.00, 120.00]	2.356/0.018	2.500/0.012
Pre-op IL-6 (ng/L)	22.58±5.69 vs 20.41±4.62	23.65±5.09 vs 20.32±4.53	-3.418/<0.001	-4.174/<0.001
Pre-op CRP (mg/L)	20.80±2.77 vs 20.91±3.12	20.40 [18.65, 21.00] vs 21.40 [19.20, 23.13]	0.282/0.778	2.422/0.015
Pre-op IL-4 (ng/L)	57.20 [53.92, 61.20] vs 51.90 [49.10, 55.40]	57.17±4.06 vs 51.78±4.32	8.395/<0.001	-7.347/<0.001
Pre-op EOS%	9.24 [8.54, 9.96] vs 7.91 [7.27, 8.64]	9.48 [8.47, 9.97] vs 7.85 [7.14, 8.59]	8.667/<0.001	6.822/<0.001
Pre-op SNOT-22 score	48.00 [44.00, 51.00] vs 41.00 [37.00, 45.00]	49.50 [45.00, 52.00] vs 40.00 [36.75, 45.00]	9.111/<0.001	7.818/<0.001

Note: Before PSM n=72 (recurrence group)/303 (non-recurrence group), after PSM n=42 (recurrence group)/176 (non-recurrence group). IL-6, Interleukin-6; CRP, C-Reactive Protein; IL-4, Interleukin-4; EOS%, Eosinophil Percentage; SNOT-22, 22-Item Sino-Nasal Outcome Test.

surgery alone in patients with allergic rhinitis complicated with chronic rhinosinusitis. Patients in the combined group experienced shorter operative times, more effective recovery of nasal airflow, and greater improvements in both endoscopic and patient-reported outcomes. Although the shorter operative time appears counterintuitive given an extra procedural step, similar patterns appear when selective neural procedures simplify dissection and reduce time spent on edematous tissue management [15]. Surgical technique may partly explain this observation. An intrasphenoidal approach provides a direct pathway to the vidian canal, ensuring improved visualization and controlled hemostasis, hence facilitating effective instrument manipulation and potentially reducing surgical time [16]. Studies on posterior nasal neurectomy and vidian neurectomy in refractory rhinitis and chronic rhinosinusitis demonstrated sustained postoperative improvements of nasal obstruction and rhinorrhea post-surgery [17, 18]. Evidence syntheses indicate that the equilibrium between efficacy and safety depends on the extent of neural interruption: trunk resection is associated with a higher risk of dry eye, whereas selective procedures provide symptom alleviation with a diminished risk of lacrimation-related complications [10, 11]. Our cohort adhered to this selective mindset, which likely contributed to favorable symptom control without increasing the risk of ocular problems. Long-term studies of polyp-predominant groups with both allergic rhinitis and asthma have shown that selective vidian procedures combined with sinus surgery results in nasal symptoms relief and reduced medication requirements, which align with our findings [15].

The observed immunological pattern helps explain the clinical benefits of the combined procedure. The combination surgery significantly reduced the levels of IL-4, IL-6, CRP, and EOS% and increased the levels of INF-γ. Vidian neurectomy dampens parasympathetic input to the nasal mucosa, lowering cholinergic tone, reducing glandular secretion, and suppressing neurogenic inflammation; collectively, these effects may lessen upstream triggers and weaken type-2 inflammatory bias. Human data support this mechanistic sequence: in house dust mite-sensitive AR, endoscopic vidian neurectomy has been associated with reductions in total and specific IgE levels and decreased pro-inflammatory cytokines, alongside better quality of life at 1 year postoperatively [19]. Studies on T-helper balance further suggest that small regulatory switches can redirect cytokine output; modulation of the microRNA-150-5p/EGR2 axis in allergic rhinitis represents one such mechanism and provides a plausible framework for the IL-4 and IFN-γ changes observed in our study [20]. Eosinophil biology adds another layer. In polyp disease, inflammatory eosinophils contribute to tissue injury and remodeling, while other subpopulations serve homeostatic roles; a greater inflammatory burden has been linked to disease activity and postoperative relapse [21]. Against that backdrop, it is expect-

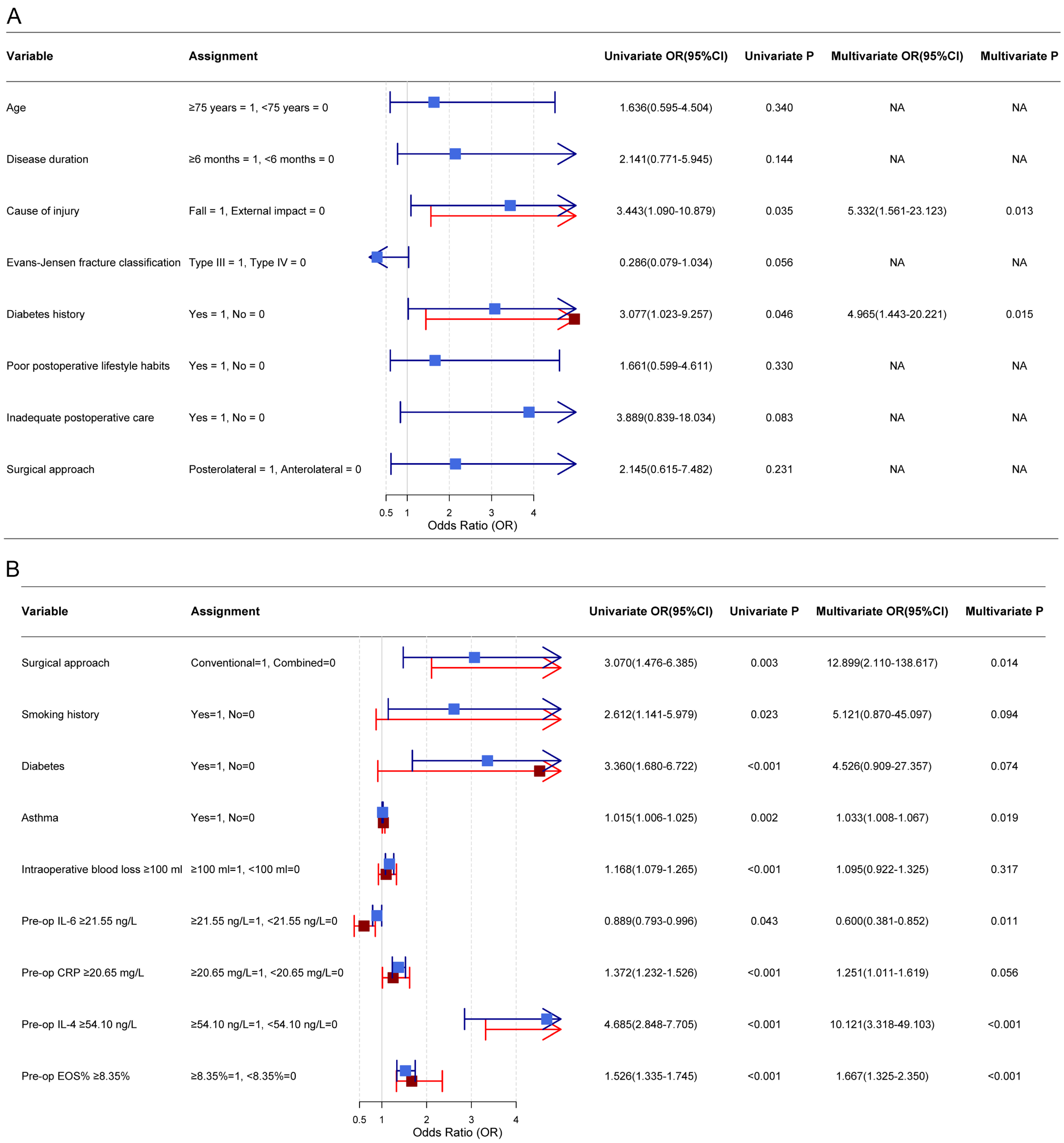

Figure 3. Logistic regression analysis of postoperative recurrence factors before and after propensity score matching (PSM). A. Forest plot of univariate/multivariate analysis of patient recurrence before PSM. B. Forest plot of univariate/multivariate analysis of patient recurrence after PSM. Note: IL-6, Interleukin-6; CRP, C-Reactive Protein; IL-4, Interleukin-4; EOS%, Eosinophil Percentage; SNOT-22, 22-Item Sino-Nasal Outcome Test.

ed that higher preoperative EOS% and elevated IL-4 levels were associated with recurrence in our multivariate models, and that their postoperative reduction paralleled symptomatic improvement. External models in eosinophilic CRSwNP identify eosinophils and IL-5 as meaningful predictors of postoperative recurrence [22], which echoes our findings. Broader prognostic analyses consistently highlight tissue eosinophils, radiographic disease burden, and type-2 inflammation as recurrent risk themes [23]. Baseline symptom severity also carried prognostic weight. Higher preoperative SNOT-22 scores predicted postoperative recurrence, a pattern that aligns with the summarized prognostic utility of SNOT-22 across CRS studies and clinical experience that high-burden patients are more susceptible to relapse when upstream drivers remain insufficiently controlled [24]. Comorbid asthma usually associated with poorer outcomes in CRSwNP compared with isolated AR and reflects a more pronounced type-2 milieu, which helps contextualize risk in patients who carry both diagnoses [25].

Both before and after PSM, the conventional strategy was associated with substantially higher odds of relapse, and smoking emerged as an independent risk factor. Observational cohorts show that recurrence accumulates over time and is more common in patients with heavier baseline disease burden on imaging or with eosinophilic inflammation; higher Lund-Mackay scores and eosinophilia have been identified as independent predictors, and a considerable proportion of recurrent cases ultimately require revision surgery [26, 27]. Olfactory status also warrants consideration. Presurgical olfactory function informs postoperative improvement in CRSwNP, where anosmic patients demonstrate the greatest gains whereas normosmics patients tend to benefit less; olfaction correlates with endoscopic and radiographic inflammation [28]. In this study, the greater reduction in endoscopic scores after ESS plus vidian neurectomy likely contributed to the improvement in quality of life, although olfactory testing was not a primary endpoint. Safety must be weighed alongside efficacy when recommending adjunctive neural procedures. Because conventional nerve trunk interruption carries the risk of dry eye, selective vidian techniques are preferred when the therapeutic goal is to alleviate rhinorrhea and congestion without jeopardizing lacrimal function [18]. The current results were generated under guideline-consistent definitions of AR and chronic rhinosinusitis and with standard instruments for symptom assessment and quality-of-life evaluation [24, 29-31]. Nevertheless, the results should be interpreted with the inherent limitations of a single-center, retrospective design and a 12-month horizon. Although PSM balanced age and disease duration and the benefit persisted after matching, residual confounding from unmeasured variables cannot be excluded. Phenotype differences across the literature also merits caution. Much of the external evidence referenced derives from cohorts enriched for nasal polyps, sometimes with concomitant asthma, while our inclusion focused on allergic rhinitis with chronic rhinosinusitis without nasal polyps. Extrapolation across phenotypes should therefore be undertaken judiciously, even when inflammatory pathways overlap. Clinically, the implications are pragmatic. For patients with type-2 inflammatory features or heavy symptom burden, adding a selective vidian procedure to sinus surgery represents a reasonable therapeutic choice. This strategy improves nasal airflow and endoscopic inflammation, shifts the immune milieu away from Th2 dominance, and in our data, reduces early recurrence. Future studies with longer follow-up are needed to assess durability and capture late events; selective procedures with proven long-term reductions in symptoms and medication use will serve as a benchmark [15]. Patient selection can be refined by incorporating routine biomarkers, such as EOS% and IL-4, into the decision-making process, together with validated patient-reported outcome measures for baseline risk stratification [22, 23]. Surgical technique improvements that protect exposure and reduce collateral damage should continue to be preferred [16].

The therapeutic value of ESS paired with vidian neurectomy is primarily reflected in various aspects. First, this combined strategy expands treatment options for patients with complex AR with CRS, especially those who respond poorly to standard treatments. A systematic review by Niu et al. [11] reported that vidian neurectomy combined with FESS was more effective than conventional FESS alone in patients with AR and CRSwNP. Through simultaneously addressing anatomical abnormalities and neural regulation dysfunction, the combined procedure enables a “one-stop” treatment, potentially avoiding staged operations and cumulative surgical trauma. Second, based on recurrence predictors identified in this study, individualized risk assessment can be established. Existing literature, including network meta-analysis, suggests that FESS combined with posterior nasal neurectomy is more effective than FESS alone for patients with AR and CRSwNP [32]. For patients with elevated preoperative IL-4 levels, increased EOS%, high SNOT-22 scores, and smoking history, combined surgical approaches should be prioritized with strengthened postoperative follow-up management.

This study has several limitations. As a single-center retrospective study, external validity is inherently limited, and confirmation in multicenter prospective studies is warranted. Moreover, 12-month follow-up duration remains insufficient for evaluating long-term efficacy and safety; therefore, longer follow-up periods should be pursued in future work. Additionally, while PSM methodology effectively controlled measured confounding factors, unmeasured factor influences cannot be excluded.

Future research directions should encompass: executing multi-center randomized controlled trials to yield superior evidence-based medicine; thoroughly investigating the molecular mechanisms of neuro-immune regulation networks; and formulating personalized therapy strategies grounded in biomarkers.

Conclusion

This study verifies that the combination of ESS and vidian neurectomy exhibits enhanced efficacy relative to ESS alone in the management of AR with CRS, indicating substantial benefits in enhancing nasal function, regulating immune-inflammatory responses, and mitigating symptoms. Preoperative IL-4 levels, EOS%, SNOT-22 scores, and smoking history are reliable indicators of recurrence.

Disclosure of conflict of interest

None.

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