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ORIGINAL ARTICLE

Efficacy of various surgical methods in the treatment of allergic rhinitis: A network meta-analysis

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Abstract

Objective: We often use surgery to treat allergic rhinitis (AR) patients who have failed drug treatment, but there is currently no clear gold standard for the treatment of allergic rhinitis. Using network meta-analysis, we evaluated the efficacy of different surgical methods in the treatment of AR.

Methods: PubMed, Embase, The Cochrane Library, Web of Science, CBM, Wan Fang Data, and CNKI databases were searched to collect clinical randomized controlled trials of AR with different surgical methods that met the inclusion criteria. After two investigators independently screened literature, extracted data, and assessed the risk of bias of included studies, R software was used to evaluate inconsistency using the node splitting method, and Stata15.1 was used to estimate the ranking probability of treatment.

Results: A total of 47 randomized control studies involving 17 surgical schemes and 4144 participants were included. The results showed that after excluding surgical methods that did not form a closed loop, in AR patients without chronic rhinosinusitis and nasal polyps, surgical efficiency and symptom score ranked the same, which were posterior nasal neurectomy (PNN), Vidian neurectomy (VN), anterior ethmoid neurectomy (AEN), nasal septal reconstruction (NSR), and bilateral inferior turbinoplasty (BIT). In AR patients with chronic rhinosinusitis with nasal polyps, the effective rate (OR = 5.06; 95% CI = 2.75–9.32) and symptom and sign scores (MD = –3.80; 95% CI = –6.50-1.09) of PNN + FESS (functional endoscopic sinusitis surgery) were higher than FESS, and there was a significant difference.

Conclusion: Our findings suggest that PNN is the best single operation for patients with AR and without chronic rhinosinusitis and nasal polyps, and the combination of multiple procedures may be better than a single operation. FESS + PNN is more effectual in AR patients with chronic rhinosinusitis with nasal polyps.

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Introduction

Allergic rhinitis (AR) affects more than 25% of the global population.[1] The treatment of AR includes avoiding allergen, drug therapy,[2,3] immunotherapy,[4] and surgery. In the face of patients with AR who are ineffective to drug treatment, we may need surgical intervention. At first, we could not treat AR by neurotomy, but it was after 1970s and 1980s that Vidian neurectomy (VN) was used to treat AR.[5] Later, posterior nasal neurectomy (PNN) and anterior ethmoid neurectomy (AEN) were developed. At present, there are two main types of surgery for AR according to its mechanism[6]: (1) one is the surgery to improve nasal ventilation, such as nasal septal reconstruction (NSR), bilateral inferior turbinoplasty (BIT), and functional endoscopic sinusitis surgery (FESS). Inferior turbinate hypertrophy is a major factor affecting nasal ventilation. Many techniques and methods for reducing inferior turbinate volume have been reported, including submucosal resection, partial turbinectomy, radiofrequency ablation or cryoablation, microdeburring, and laser turbineplasty.[7] NSR can be used in patients with severe nasal septum deviation, while FESS is mainly used in patients with nasal polyps. (2) The other is to treat AR by removing the parasympathetic and sensory nerves, such as VN, PNN, and AEN.[6] During the operation of VN, the Vidian nerve trunk needs to be cut off nonselectively.[8] Therefore, while improving the symptoms of AR, it often leads to obvious symptoms such as dry eye and upper palate numbness. In severe cases, complications such as eye movement disorder and sphenopalatine artery hemorrhage may occur. PNN selectively cuts off the nerve branches distributed in the nasal cavity, so the postoperative pain response is smaller and the surgical complications are less.[9] At present, a large number of experiments have shown that the above surgical methods can improve AR,[10] but there is no gold standard procedure for the treatment of allergic rhinitis.[11] In this study, network meta-analysis was used to study the differences in the efficacy of different surgical methods and to evaluate them, so as to provide a reference for clinicians in the choice of surgical methods for allergic rhinitis.

Material and Methods

Search methods

This study has been registered with PROSPERO (CRD 42022328991).

We searched the databases of PubMed, Embase, The Cochrane Library, Web of Science, Wan Fang Data and CNKI and collected the randomized controlled trials that met the inclusion criteria up to February 2022. At the same time, the references included in the study were searched to supplement and obtain the relevant data. Keywords and subject terms included "allergic rhinitis," "posterior nasal neurectomy," "Vidian neurectomy," "anterior ethmoid neurectomy," "nasal septal reconstruction," "functional endoscopic sinusitis surgery," and "bilateral inferior turbinoplasty."

Inclusion and exclusion criteria

The studies included should comply with the following inclusion criteria: (1) Regardless of age, gender, etiology, and ethnic group; (2) The diagnosis of allergic rhinitis is in line with the "Guidelines for the diagnosis and treatment of allergic rhinitis"[10]; (3) With or without nasal septum deviation, sinusitis, nasal polyps, or other nasal structure problems;(4) All patients can tolerate surgical treatment; (5) No abnormal coagulation function and bleeding tendency; (6) No mental illness.

The exclusion criteria were: (1) Only abstract without full text and contact author did not reply; (2) Incomplete reporting of important data and no postoperative follow-up data; (3) Multiple studies from the same center, with data duplication, or literature with insufficient data; (4) Only discuss the literature of a single treatment modality.

Data extraction and methodological quality of included studies

Two researchers independently screened literature, extracted data, and cross-checked. If case of any disagreement, it was resolved through discussion or consultation with a third party. In literature screening, the title of the article was read first, and after excluding obviously irrelevant literature, the abstract and full text were further read to determine whether to include or not. If necessary, the original study authors were contacted by email or through telephone for undetermined but important information. Data extraction included research title, first author, publication year, age, gender, course of the disease, follow-up time, intervention measures, and outcome indicators.

The quality of the literature was assessed by two reviewers who independently analyzed the included literature according to the Cochrane risk of bias assessment criteria, and disagreements were reached through discussion. Evaluation contents included: (1) The generation of random allocation plan; (2) The concealment of the allocation plan; (3) The implementation of the blinding method; (4) The integrity of the result data; (5) The nonselective reporting of the results; (6) Other biases. "Low risk" indicated low risk of bias, "High risk" indicated high risk of bias, and "Unclear risk" indicated that the literature does not provide sufficient or uncertain information for bias assessment.

Statistical Analysis

Using Stata 15.1, a network meta-analysis was performed through a frequentist framework, analyzing indirect and direct evidences from a large amount of data. Corresponding network diagrams were drawn with different interventions after each pairwise comparison. The size of the circle indicated the number of specific interventions, and the thickness of the arm indicated the number of studies included. Results for these dichotomous variables were presented as odds ratios (ORs), and corresponding 95% confidence intervals (CrIs) for continuous variables results were presented as means difference (MD) with 95% confidence intervals. In addition, R software performed node-splitting tests to analyze the degree of inconsistency between indirect and direct evidence. The rank probability of efficacy and safety of the 17 surgical modalities was assessed using the cumulative ranking area under the curve (SUCRA). The methodological quality of studies was evaluated using Cochrane.

Results

Studies included in the network meta-analysis

A total of 6569 relevant literature were obtained from the literature screening process and preliminary examination of the results, of which 1331 were duplicate publications, and 4852 articles were excluded due to unrelated titles and abstracts. After layer-by-layer screening, the remaining 386 articles were selected for full-text review, 332 articles that were assessed as unqualified were excluded, and 47 articles, including 4144 patients, were finally included.[12-58] The search and selection steps are illustrated in Figure 1. The risk of bias of included studies was assessed according to the Cochrane Handbook. The results showed that the quality of all studies included in the RCT was high, and the risk bias was mainly due to the withdrawal of some subjects from the study. The bias risk assessment results of the included studies are shown in ss 2 and 3.

Effective rate of AR patients without chronic rhinosinusitis and nasal polyps

From Figure 4A, we found that PNN + AEN, VN + BIT, AEN + BIT, and PNN + BIT did not form a closed loop with other surgical methods, and the accuracy of the results is open to question. In Figures 5A and 6A, we found that VN + BIT (92.2%) had the highest ranking of the effective rate, PNN (88.5%) had the highest ranking of the effective rate in the single surgical modality and was comparable to NSR (OR = 5.71; 95% CI = 1.21-26.96), and BIT (OR = 6.19; 95% CI = 1.49-25.64) was significantly different. Surgical methods related to neurotomy, such as PNN (71.3%), VN (32.4%), and AEN (28.6%), were higher than those of NSR (8.6%) and BIT (5.6%). BIT (5.6%) was the lowest ranked surgical method, and was significantly worse than VN + BIT (OR = 37.85; 95%

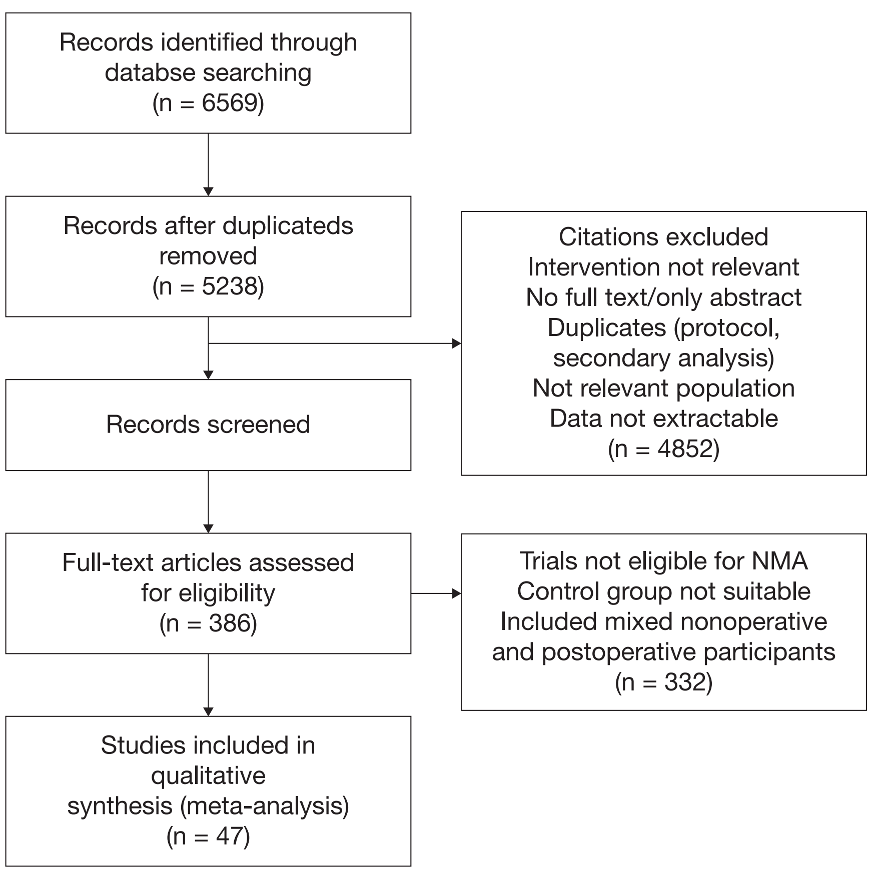

Figure 1 Flow diagram of study inclusion.

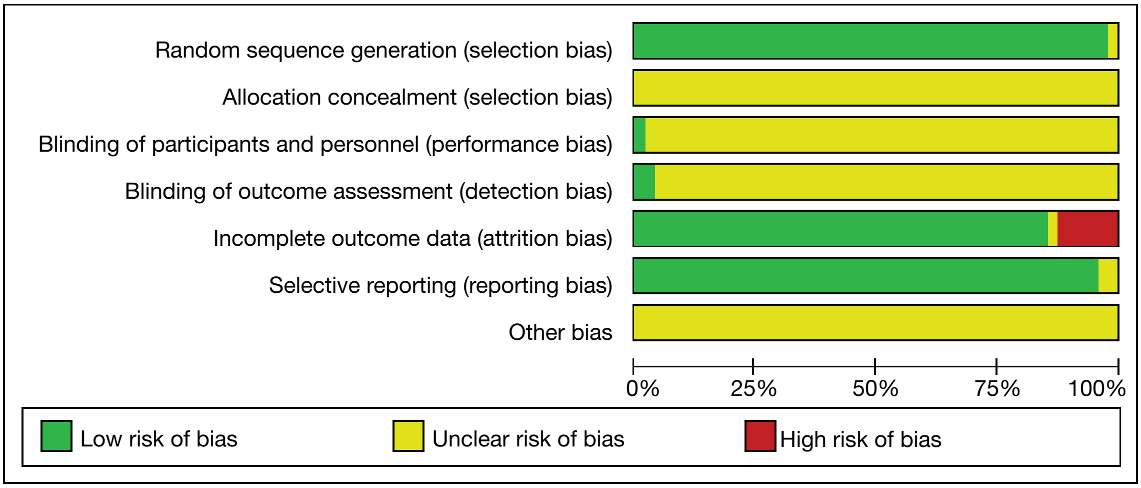

Figure 2 Risk of bias graph.

CI = 1.73-830.14), PNN + AEN (OR = 7.16; 95% CI = 1.83-28.05), PNN (OR = 6.19; 95% CI = 1.49, 25.64), AEN + BIT (OR = 5.49; 95% CI = 1.76-17.11), PNN + BIT (OR = 4.33; 95% CI = 1.20-15.61), AEN + NSR (OR = 3.58; 95% CI = 1.32-9.68), and NSR + BIT (OR = 3.52; 95% CI = 2.02-6.16). There were also significant differences.

Symptoms and signs scores of AR patients without chronic rhinosinusitis and nasal polyps

In Figure 4B, VN + NSR, PNN + BIT, AEN + BIT, and PNN + NSR also did not form a closed loop with other surgical modalities. Figures 5B and 6B suggest that PNN (88.5%) had the highest ranking of symptom and sign scores, compared with NSR + BIT (MD = –1.68; 95% CI = –3.07-–0.28), AEN (MD = –2.02; 95% CI = –3.82-–0.23), NSR (MD = –2.38; 95% CI = –3.88-–0.87), PNN + BIT (MD = –4.37; 95% CI = –6.38-–2.36), and AEN + BIT (MD = –4.63; 95% CI = –7.08-–2.15), and BIT (MD = –4.86; 95% CI = –6.55-–3.16), and had a large difference. Similar to the efficiency ranking, BIT (6.1%) was the lowest ranked surgical modality, compared with PNN (MD = –4.86; 95% CI = –6.55-–3.16), VN + NSR (MD = –4.81; 95% CI = –7.22-–2.40), AEN + NSR (MD = –4.21; 95% CI = –5.88-–2.54), PNN + NSR (MD = –4.18; 95% CI = –6.57-–1.79), VN (MD = –4.06; 95% CI = –5.58-–2.54), NSR + BIT (MD = –3.18; 95% CI = –4.45-–1.90), AEN (MD = –2.83; 95% CI = –4.21-–1.45), and NSR (MD = –2.48; 95% CI = –3.81-–1.15), and there was a significant difference. At the same time, the ranking results of the two evaluation methods at the time of a single operation were the same: PNN, VN, AEN, NSR, BIT.

Response rate in allergic rhinitis combined with chronic rhinosinusitis with nasal polyps (ARwCRSwNP) patients

Figures 4C, 5C, and 6C suggested that none of the surgical approaches formed a closed loop. PNN + FESS is significantly different from FESS (OR = 5.0; 95% CI = 2.75-9.32). Their efficiency rankings are PNN + FESS¤76.2%), AEN + FESS (72.3%), and FESS (1.5%).

Symptoms and signs scores of ARwCRSwNP patients

The network evidence map suggested that none of the surgical approaches formed a closed loop. PNN + FESS was significantly different from FESS (MD = –3.80; 95% CI = –6.50-–1.09). Their efficiency rankings were PNN + FESS (79.0%), AEN + FESS (53.9%), PNN + BIT (49.4%), FESS (17.6%).

Node-splitting forest graph results

The results of Figure 7 showed that there was no significant difference between the direct and indirect comparison results of the effective rate and symptom scores of different surgical methods in the treatment of AR patients without sinusitis and nasal polyps ($P > 0.05$).

Discussion

The surgical treatment of allergic rhinitis has a wide range of clinical applications. Types of operations include PNN, VN, AEN, NSR, FESS, and BIT. According to the patient's specific conditions, the combination of different surgical methods may also be adopted by clinicians. In order to evaluate the efficacy of different surgical methods in the treatment of AR, we conducted a network meta-analysis and divided AR patients into two groups: (1) AR patients without chronic rhinosinusitis and nasal polyps and (2) AR patients with chronic rhinosinusitis and nasal polyps. The effective rates and clinical symptoms and signs score of different surgical options were compared in each group of patients.

We found that the effective rate of AR patients without chronic rhinosinusitis and nasal polyps were ranked as VN + BIT, PNN, PNN + AEN, AEN + BIT, PNN + BIT, AEN + NSR, NSR + BIT, VN, AEN, NSR, BIT; symptom and sign score ranking PNN, VN + NSR, AEN + NSR, PNN + NSR, VN, NSR + BIT, AEN, NSR, PNN + BIT, AEN + BIT, BIT. However, PNN + AEN, AEN + BIT, VN + BIT, PNN + BIT, VN + NSR, and PNN + NSR did not form a closed loop with other surgical

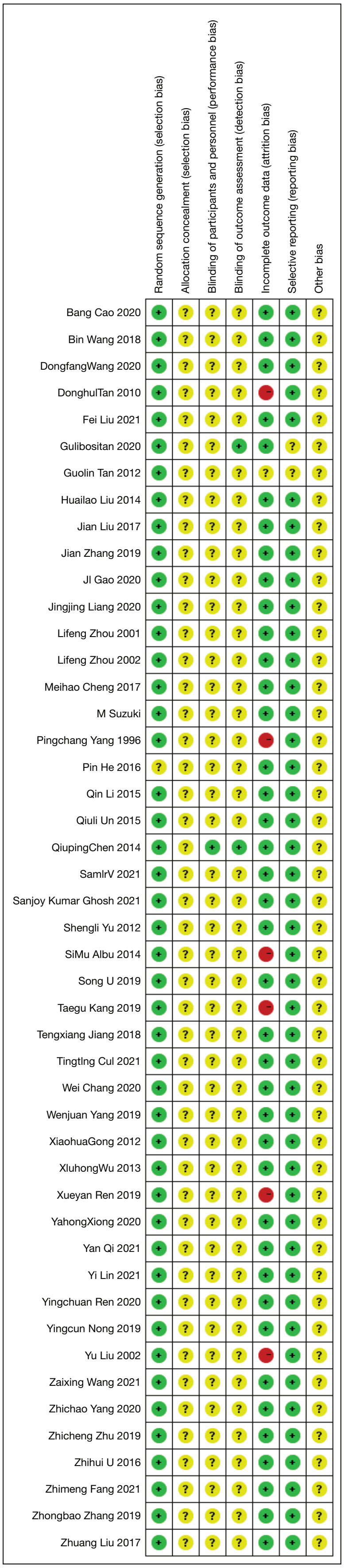

Figure 3 Risk of bias summary.

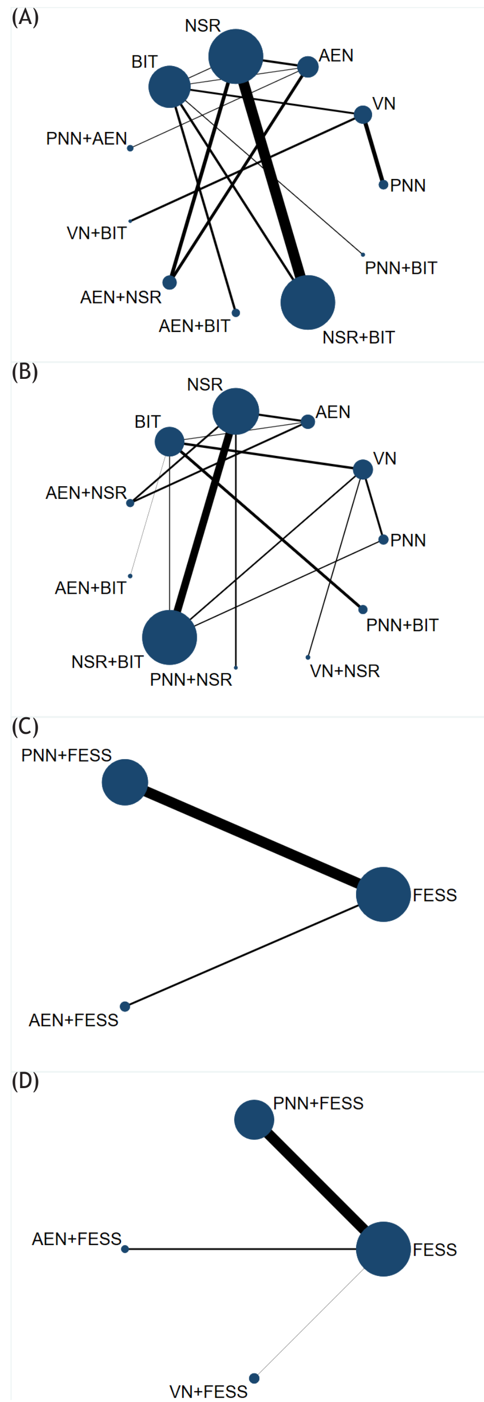

Figure 4 The evidence network for trials enrolled in this network meta-analysis.

methods, and the number of included literatures was one. The accuracy is greatly affected by the included literature, and we believe that the results can only be used as a reference. After excluding the influence of the above several surgical methods, the ranking results of the effective rate and symptom and sign score were similar, all of which were PNN, AEN + NSR, VN, AEN, NSR, and BIT. It can be observed that PNN is the best surgical method for the treatment of AR patients without chronic rhinosinusitis and nasal polyps.

(A)

VN+BIT	0.19 (0.01,5.54)	0.16 (0.01,3.77)	0.15 (0.01,3.90)	0.11 (0.00,3.24)	0.09 (0.00,2.42)	0.09 (0.00,2.15)	0.06 (0.00,1.07)	0.05 (0.00,1.23)	0.03 (0.00,0.67)	0.03 (0.00,0.58)
5.29 (0.18,154.74)	**PNN+AEN**	0.86 (0.12,6.21)	0.77 (0.13,4.54)	0.61 (0.09,3.94)	0.50 (0.11,2.28)	0.49 (0.12,1.96)	0.30 (0.06,1.55)	0.27 (0.09,0.82)	0.15 (0.04,0.59)	0.14 (0.04,0.55)
6.12 (0.27,140.87)	1.16 (0.16,8.31)	**PNN**	0.89 (0.14,5.48)	0.70 (0.10,4.75)	0.58 (0.10,3.28)	0.57 (0.12,2.62)	0.35 (0.12,1.01)	0.31 (0.06,1.58)	0.18 (0.04,0.83)	0.16 (0.04,0.67)
6.89 (0.26,184.97)	1.30 (0.22,7.70)	1.13 (0.18,6.95)	**AEN+BIT**	0.79 (0.14,4.37)	0.65 (0.14,2.95)	0.64 (0.18,2.27)	0.39 (0.09,1.68)	0.35 (0.09,1.40)	0.20 (0.05,0.72)	0.18 (0.06,0.57)
8.73 (0.31,247.28)	1.65 (0.25,10.75)	1.43 (0.21,9.68)	1.27 (0.23,7.03)	**PNN+BIT**	0.83 (0.16,4.18)	0.81 (0.20,3.29)	0.49 (0.10,2.39)	0.44 (0.10,2.00)	0.25 (0.06,1.04)	0.23 (0.06,0.83)
10.59 (0.41,271.55)	2.00 (0.44,9.16)	1.73 (0.31,9.82)	1.54 (0.34,6.96)	1.21 (0.24,6.14)	**AEN+NSR**	0.99 (0.40,2.43)	0.60 (0.15,2.33)	0.54 (0.19,1.51)	0.30 (0.13,0.69)	0.28 (0.10,0.76)
10.74 (0.47,247.65)	2.03 (0.51,8.08)	1.76 (0.38,8.09)	1.56 (0.44,5.53)	1.23 (0.30,4.97)	1.01 (0.41,2.50)	**NSR+BIT**	0.61 (0.21,1.79)	0.55 (0.24,1.23)	0.31 (0.21,0.46)	0.28 (0.16,0.50)
17.73 (0.93,337.26)	3.35 (0.64,17.47)	2.90 (0.99,8.52)	2.57 (0.59,11.15)	2.03 (0.42,9.87)	1.67 (0.43,6.53)	1.65 (0.56,4.87)	**VN**	0.90 (0.27,3.04)	0.51 (0.17,1.55)	0.47 (0.19,1.18)
19.70 (0.81,477.23)	3.73 (1.22,11.35)	3.22 (0.63,16.38)	2.86 (0.72,11.41)	2.26 (0.50,10.16)	1.86 (0.66,5.24)	1.83 (0.81,4.15)	1.11 (0.33,3.76)	**AEN**	0.56 (0.26,1.24)	0.52 (0.24,1.15)
34.93 (1.50,815.26)	6.61 (1.69,25.85)	5.71 (1.21,26.96)	5.07 (1.39,18.52)	4.00 (0.96,16.62)	3.30 (1.45,7.49)	3.25 (2.17,4.87)	1.97 (0.65,6.02)	1.77 (0.81,3.90)	**NSR**	0.92 (0.50,1.72)
37.85 (1.73,830.14)	7.16 (1.83,28.05)	6.19 (1.49,25.64)	5.49 (1.76,17.11)	4.33 (1.20,15.61)	3.58 (1.32,9.68)	3.52 (2.02,6.16)	2.13 (0.85,5.39)	1.92 (0.87,4.23)	1.08 (0.58,2.02)	**BIT**

(B)

PNN	0.05 (-2.16,2.26)	0.65 (-1.27,2.56)	0.68 (-1.81,3.16)	0.80 (-0.37,1.97)	1.68 (0.28,3.07)	2.02 (0.23,3.82)	2.38 (0.87,3.88)	4.37 (2.36,6.38)	4.62 (2.15,7.08)	4.86 (3.16,6.55)
-0.05 (-2.26,2.16)	**VN+NSR**	0.60 (-2.02,3.22)	0.63 (-2.44,3.70)	0.75 (-1.13,2.63)	1.63 (-0.65,3.91)	1.98 (-0.55,4.50)	2.33 (-0.02,4.68)	4.33 (1.68,6.97)	4.57 (1.57,7.57)	4.81 (2.40,7.22)
-0.65 (-2.56,1.27)	-0.60 (-3.22,2.02)	**AEN+NSR**	0.03 (-2.33,2.38)	0.15 (-1.68,1.98)	1.03 (-0.35,2.41)	1.38 (0.10,2.65)	1.73 (0.46,3.00)	3.73 (1.74,5.71)	3.97 (1.53,6.41)	4.21 (2.54,5.88)
-0.68 (-3.16,1.81)	-0.63 (-3.70,2.44)	-0.03 (-2.38,2.33)	**PNN+NSR**	0.12 (-2.31,2.56)	1.00 (-1.07,3.07)	1.35 (-0.95,3.65)	1.70 (-0.28,3.68)	3.70 (1.08,6.31)	3.94 (0.96,6.92)	4.18 (1.79,6.57)
-0.80 (-1.97,0.37)	-0.75 (-2.63,1.13)	-0.15 (-1.98,1.68)	-0.12 (-2.56,2.31)	**VN**	0.88 (-0.42,2.18)	1.23 (-0.46,2.91)	1.58 (0.17,2.99)	3.58 (1.72,5.43)	3.82 (1.48,6.16)	4.06 (2.54,5.58)
-1.68 (-3.07,-0.28)	-1.63 (-3.91,0.65)	-1.03 (-2.41,0.35)	-1.00 (-3.07,1.07)	-0.88 (-2.18,0.42)	**NSR+BIT**	0.35 (-0.90,1.59)	0.70 (0.09,1.31)	2.70 (1.03,4.36)	2.94 (0.75,5.13)	3.18 (1.90,4.45)
-2.02 (-3.82,-0.23)	-1.98 (-4.50,0.55)	-1.38 (-2.65,-0.10)	-1.35 (-3.65,0.95)	-1.23 (-2.91,0.46)	-0.35 (-1.59,0.90)	**AEN**	0.35 (-0.81,1.52)	2.35 (0.60,4.10)	2.59 (0.34,4.85)	2.83 (1.45,4.21)
-2.38 (-3.88,-0.87)	-2.33 (-4.68,0.02)	-1.73 (-3.00,-0.46)	-1.70 (-3.68,0.28)	-1.58 (-2.99,-0.17)	-0.70 (-1.31,-0.09)	-0.35 (-1.52,0.81)	**NSR**	2.00 (0.29,3.71)	2.24 (0.01,4.47)	2.48 (1.15,3.81)
-4.37 (-6.38,-2.36)	-4.33 (-6.97,-1.68)	-3.73 (-5.71,-1.74)	-3.70 (-6.31,-1.08)	-3.58 (-5.43,-1.72)	-2.70 (-4.36,-1.03)	-2.35 (-4.10,-0.60)	-2.00 (-3.71,-0.29)	**PNN+BIT**	0.24 (-1.84,2.32)	0.48 (-0.59,1.56)
-4.62 (-7.08,-2.15)	-4.57 (-7.57,-1.57)	-3.97 (-6.41,-1.53)	-3.94 (-6.92,-0.96)	-3.82 (-6.16,-1.48)	-2.94 (-5.13,-0.75)	-2.59 (-4.85,-0.34)	-2.24 (-4.47,-0.01)	-0.24 (-2.32,1.84)	**AEN+BIT**	0.24 (-1.54,2.02)
-4.86 (-6.55,-3.16)	-4.81 (-7.22,-2.40)	-4.21 (-5.88,-2.54)	-4.18 (-6.57,-1.79)	-4.06 (-5.58,-2.54)	-3.18 (-4.45,-1.90)	-2.83 (-4.21,-1.45)	-2.48 (-3.81,-1.15)	-0.48 (-1.56,0.59)	-0.24 (-2.02,1.54)	**BIT**

(C)

PNN+FESS	0.94 (0.17,5.33)	0.20 (0.11,0.36)
1.06 (0.19,6.00)	**AEN+FESS**	0.21 (0.04,1.06)
5.06 (2.75,9.32)	4.77 (0.94,24.16)	**FESS**

(D)

PNN+FESS	1.52 (-5.50,8.53)	1.90 (-4.99,8.78)	3.80 (1.09,6.50)
-1.52 (-8.53,5.50)	**AEN+FESS**	0.38 (-8.68,9.44)	2.28 (-4.19,8.75)
-1.90 (-8.78,4.99)	-0.38 (-9.44,8.68)	**VN+FESS**	1.90 (-4.43,8.23)
-3.80 (-6.50,-1.09)	-2.28 (-8.75,4.19)	-1.90 (-8.23,4.43)	**FESS**

Figure 5 Odds ratio estimates with 95% credible intervals of Effective rate and means difference with 95% credible intervals of Symptoms and Signs Scores.

PNN requires us to find and separate the posterior nasal neurovascular bundle at the posterior end of the middle turbinate, and then use bipolar electrocoagulation or plasma knife to coagulate and cut off the posterior nasal nerve.[9] The posterior nasal nerve is mainly composed of sensory fibers of the maxillary nerve and post-pterygonomic fibers of the sphenopalatine ganglion, which contain sympathetic and parasympathetic components. PNN simultaneously cuts off the branches of the sympathetic, parasympathetic, and sensory nerves of the nasal cavity[59]: The cutting of parasympathetic nerve fibers can reduce glandular secretion and inhibit vasodilation. Sensory nerve fibers are severed, which can greatly reduce the hypersensitivity of the nasal mucosa. Therefore, PNN can inhibit the secretion of glands caused by parasympathetic nerve excitation, reduce the sensory reflex in the nasal cavity, and simultaneously relieve symptoms such as nasal discharge, nasal itching, sneezing, and nasal congestion.[60,61] Studies, such as that

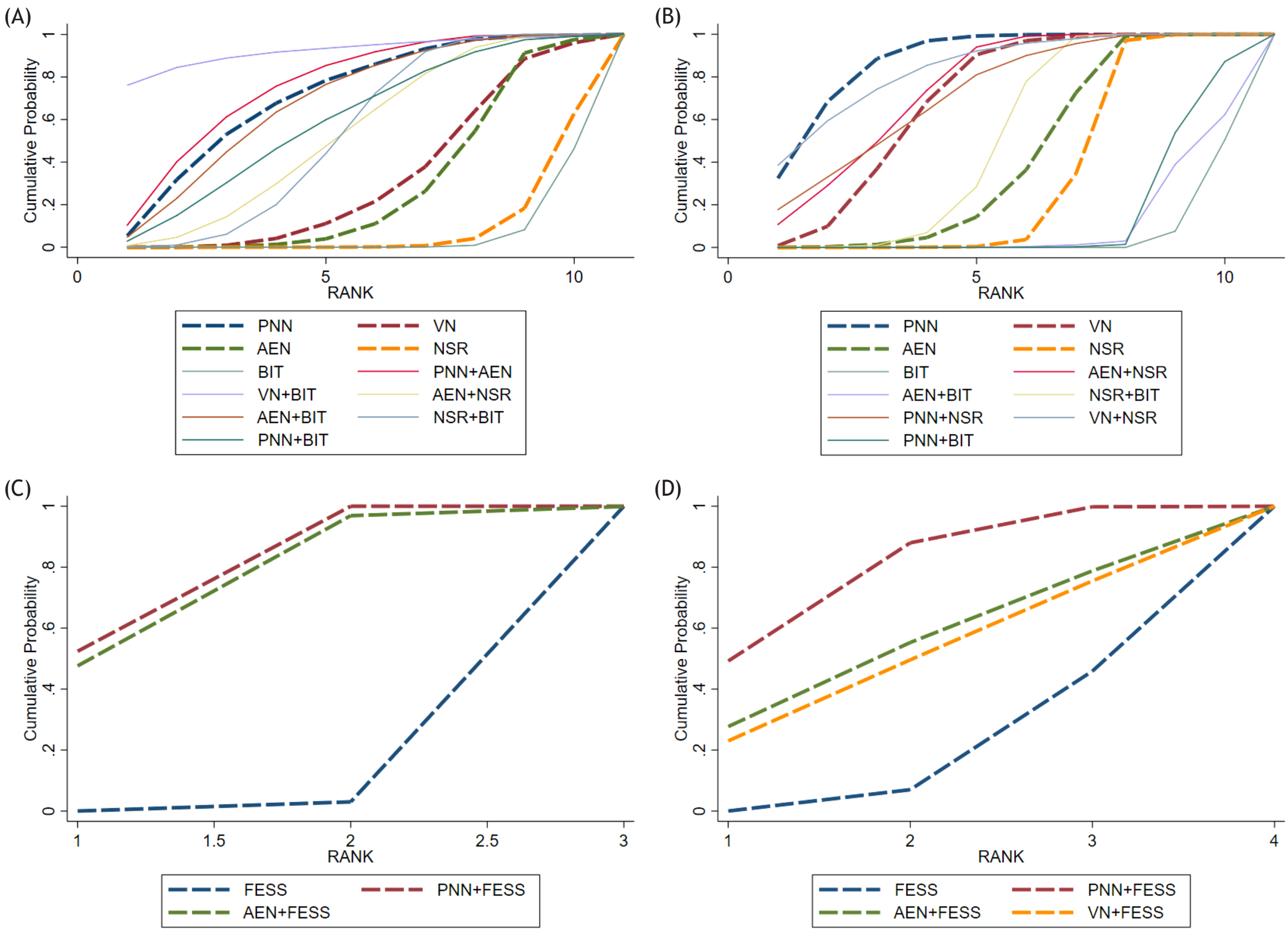

Figure 6 Cumulative sucra value, the larger the area under the curve, the higher the ranking.

of Ahilasamy and Rajendran,[59] also supported this view. They also found that the improvement of PNN was mainly reflected in nasal discharge, followed by nasal itching and sneezing.

The VN needs to separate the mucosa until the posterior border of the sphenopalatine foramen, then expose the pterygoid canal, and cut off the pterygoid nerve at the anterior border of the pterygoid canal.[8] In our study, although VN treatment of AR patients without chronic rhinosinusitis and nasal polyps had lower symptom and sign score than 9 + PNN, there was no statistical differences. This was in consistent with the research results of Lin and Huang[31] ($P = 0.218$) and Zhang Jian[33] ($P = 0.662$). The main difference between VN and PNN is that VN does not interfere with the sensory nerves in the nasal cavity,[59] and is often accompanied by cutting off the sphenopalatine artery, lacrimal gland nerve, and greater palatine nerve, intersecting the PNN, and the possibility of complications of VN was higher. Marshak et al.[8] found that the incidences of dry eyes was 23.96%, upper body paresthesia was 8.2%, infection was 5.34%, palatal fistula was 4.85%, and that of epistaxis was 1.75%.Complications of PNN were much lower than that of VN.[31] Therefore, compared with VN, PNN had fewer complications under the same curative effect, so it is the preferred surgical method for AR patients without chronic rhinosinusitis and nasal polyps.

The anterior ethmoid nerve is derived from the ophthalmic nerve,[62] which is a mixed nerve of sensory and parasympathetic nerve, and its main branches innervate the anterior nasal cavity and sinus mucosa. The therapeutic mechanism of AEN is similar to that of PNN and VN.[63] It achieves its goal by blocking the sensation of abnormal stimulation and inhibiting the secretion of inflammatory mediators.[64] Our study found that the efficacy and symptom and sign scores of AEN in the treatment of AR patients without chronic rhinosinusitis and nasal polyps were lower than those of PNN and VN, which may be related to the fact that its innervation of the mucosa is smaller than that of the posterior nasal nerve. It is worth noting that when comparing AEN and PNN, Zhang et al.[65] found that the scores of nasal itching and sneezing of AEN were significantly better than those of PNN ($P < 0.01$), and the scores of nasal discharge and nasal congestion after PNN were significantly better than those of AEN ($P < 0.01$). However, we did not find similar phenomena in other literature, and more high-quality literature is needed for verification.

The efficacy ranking of BIT was the lowest, and it was statistically different from the multiple surgical methods. The efficacy of BIT in the treatment of AR is worth recognition, and its mechanism is similar to that of NS, mainly through the following aspects[66]: (1) Reduce nasal airway resistance and relieve the symptoms of nasal congestion

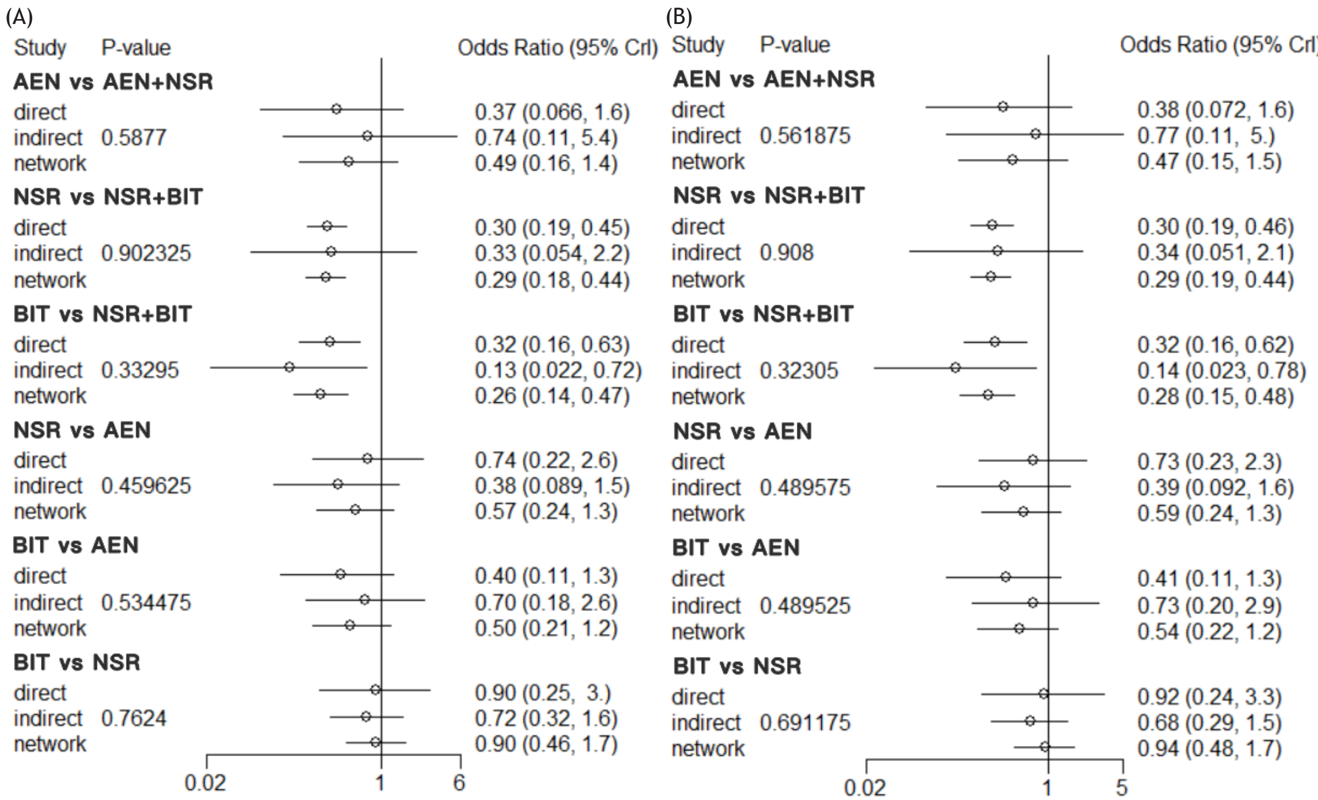

Figure 7 The node-splitting results, P > 0.05 indicates that there is no statistical difference between direct and indirect comparisons.

caused by it; (2) Reduce the contact area between the nasal mucosa and allergens, and reduce the concentration of allergens in the nasal cavity; (3) Remove some submucosal glands, sensory nerves, and parasympathetic nerves to a certain extent and reduce glandular secretion, and sensory and parasympathetic reflexes. Its efficacy in allergic rhinitis is worthy recognition,[67] and its efficacy is mainly reflected in the improvement of nasal congestion.[68] Its efficacy is not as good as other surgical methods, mainly because its influence is mainly on the nerve endings distributed on the inferior turbinate mucosa, so it is not as good as PNN, AEN, VN, etc. in improving symptoms such as sneezing and nasal itching.

Recent studies[50,69] have shown that NSR + BIT and NSR have no statistical difference in the improvement of non-obstructive allergic symptoms, which was consistent with our results. But after a network meta-analysis, we found that its ranking was higher than NSR. At the same time, this study found that the combined use of the two surgical methods was higher than the single surgery in terms of the efficacy rate and the ranking of symptoms and signs, including PNN + AEN, AEN + BIT, VN + BIT, PNN + BIT, VN + NSR, and PNN + NSR . Taking PNN + BIT as an example, the efficacy of PNN + BIT[70] in the treatment of AR is worth recognition, but there is only one literature in this study that directly compares it with BIT, which makes it inaccurate in the final ranking. However, we speculate that the efficacy of PNN + BIT may be higher than that of PNN, because PNN mainly improves nasal discharge, nasal itching, and sneezing, while BIT improves nasal congestion, which can form a certain complementarity. And the study concluded that the combined use of PNN and BIT did not significantly increase the complications.[70] But how exactly is it sorted? Is there a statistical difference? More relevant research is needed.

FESS is the surgical modality of choice in AR patients with chronic rhinosinusitis and nasal polyps. Therefore, in this study, we discuss them separately. This study found that all the combined operation efficiency and symptom and sign score ranking were higher than those of FESS alone, and there was a statistical difference between PNN + FESS[71] and FESS. Therefore, when using FESS to treat patients with chronic rhinosinusitis and nasal polyps, the combination of PNN and VN[13] would be a better choice. Because the included literature is few and no closed loop is formed, more literature support and further discussion are needed as to which surgical method is better. But according to our above findings, FESS + PNN may be a better choice.

The main limitations of this network meta-analysis are as follows: (1) The indicators included in this study are limited. New indicators such as intraoperative bleeding, dry eyes, and paresthesia of the upper palate need to be included. Improve the credibility of the article; (2) Due to limited literature reports, we are temporarily unable to conduct a network meta-analysis on the safety of different surgical methods for AR treatment; (3) Due to the limited quality of literature and research included in this study, and the limited reliability of the final results of a certain indicator, the interpretation of the results should be cautious, and the conclusions drawn still need to be demonstrated by higher-quality randomized controlled trials in future.

Conflict of Interest

The authors declare no potential conflicts of interest with respect to research, authorship, and/or publication of this article.

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