Blood Eosinophil Percentage and Improved Sinus CT Score as Diagnostic Tools for ECRS

Fengzhen Li, MM[1]*, Shenglei Wang, MM[1]*,
Xudong Cha, MM[1]*, Tengfei Li, MM[1]*, Yingqi Xie, MD[1],
Wenwen Wang, MM[2], Wenwen Ren, PhD[1] ,
Jianchun Liao, MM[1], and Huanhai Liu, MD[1]

Abstract

Objective. Differentiating 2 types of chronic rhinosinusitis with nasal polyps (CRSwNP) is important for the treatment. The current diagnostic methods using single indicators, including peripheral blood eosinophils and traditional sinus computed tomography (CT) scores, are not accurate. In this study, we aimed to investigate the diagnostic value of combining peripheral blood eosinophils and improved sinus CT scores for eosinophic chronic rhinosinusitis (ECRS).

Study Design. Retrospective cohort.

Setting. Tertiary medical center.

Methods. We conducted a study involving 81 patients with CRSwNP. Peripheral blood samples were collected from the non-ECRS and ECRS groups. Improved three-dimensional volume image analysis and Lund-Mackay scoring system were performed to quantify the thickening of sinus mucosa. Multivariate binary logistic regression analysis was carried out to detect the predictive value of the scoring indicators. For significant indexes, receiver operating characteristic (ROC) curve analysis was applied.

Results. The ECRS group had higher levels of blood eosinophil percentage and count, ethmoid sinus score, total sinus score, the ratio of ethmoid sinus score and maxillary sinus score, and the difference between ethmoid and maxillary score, compared to the non-ECRS group (P < 0.05). Binary logistic regression analysis demonstrated that both blood eosinophil percentage and the improved E − M score (subtraction of ethmoid and maxillary sinus scores) were significant predictors of ECRS diagnosis (*P* < .01). ROC curve analysis indicated that the combination of improved E − M score and blood eosinophil percentage had a higher diagnostic value compared to either factor alone (area under the curve = 0.874).

Conclusion. Our study suggested the combination of improved total ethmoid sinus-maxillary score and blood eosinophil percentage is more accurate in predicting the diagnosis of ECRS.

Chronic rhinosinusitis (CRS) is a widespread and frequently occurring disease in otolaryngology and head and neck surgery, characterized by inflammation of the nasal cavity and sinuses.[1,2] It affects approximately 8% of the Chinese population.[3] Patients with CRS typically experience symptoms such as rhinorrhea, nasal congestion, or nasal discharge lasting more than 12 weeks, can be combined with facial swelling pain and decreased sense of smell.[4] These symptoms can seriously affect patients' normal work or study and may result in a substantial economic burden on individuals and society.

According to whether it is accompanied by eosinophilic infiltration, chronic rhinosinusitis with nasal polyps (CRSwNP) is divided into eosinophic chronic rhinosinusitis (ECRS) and noneosinophilic chronic rhinosinusitis (non-ECRS). In Europe and America ECRS is prevalent among 80% of CRSwNP patients, while the incidence is lower in various regions of Asia.[5,6] However, the global incidence of ECRS has increased significantly over the last 20 years.[7] ECRS is mainly characterized as an inflammation with

[1]Department of Otolaryngology–Head and Neck Surgery, Changzheng Hospital, Naval Medical University, Shanghai, China
[2]Department of Neurology, Changzheng Hospital, Naval Medical University, Shanghai, China
*These authors contributed equally to this article and share first authorship

Corresponding author:
Wenwen Ren, PhD, Jianchun Liao, MM, and Huanhai Liu, MD, Department of Otolaryngology–Head And Neck Surgery, Changzheng Hospital, Naval Medical University, Shanghai, China.
Email: wenwenren@smmu.edu.cn, abliaojc@163.com, and liuhuanhaiok@smmu.edu.cn

eosinophil involved and raised T-helper cell type 2 cytokines.[8,9] With a high rate of recurrence of nasal polyps (NPs) after surgery, ECRS is also considered to be a refractory sinusitis.[5,10]

Accurate understanding and identification of ECRS are essential for clinical diagnosis and treatment. Currently, the classification of ECRS is primarily based on the degree of eosinophil infiltration in pathological tissue.[11] However, this invasive diagnosis method has limitations and latency, making it not conducive to clinical diagnosis and treatment. Consequently, there is a growing interest in developing noninvasive classification criteria that are simple and quick. Computed tomography (CT) is a critical diagnostic tool for CRS.[12] The Lund-Mackay (LM) CT score is a widely used scoring system for CRS, which provides a straightforward means of mapping the extent of thickened sinus mucosa in patients.[13,14] The higher the score, the more extensive and severe the sinus mucosal thickening. The scores vary from 0 to 24. However, the scoring system is not an effective tool for assessing disease severity as it does not accurately evaluate the extent of individual sinus mucosal thickness, and there is ambiguity in the definition of partial. Recent studies have employed three-dimensional (3D) analysis of axial CT images to calculate the ratio of diseased mucosa to the entire sinus cavity, enabling the measurement of mucosal inflammatory mucosal thickness on a continuous scale ranging from 0 to 1.[15] In the multicenter large-scale epidemiological study in Japan, the percentage of peripheral blood eosinophils exceeding 5% was identified as an important diagnostic criterion for ECRS.[7] Although objective and noninvasive indicators, such as sinus CT scores and peripheral blood eosinophil percentage, could be used as diagnostic criteria for ECRS, they are relatively singular and do not provide a comprehensive understanding and evaluation of disease severity. This study aims to investigate the combination of improved CT score and blood eosinophil percentage as diagnostic indicators for ECRS, with the goal of guiding the classification of CRSwNP and providing effective guidance value to the clinic.

Methods

Clinical Samples

A total of 81 patients with CRSwNP were recruited for this study. They all received treatment at the Department of Otorhinolaryngology Head and Neck Surgery, Changzheng Hospital (Shanghai, China) between October 2021 and December 2022. The identification of CRSwNP was on the basis of the criteria outlined in the European Position Paper on Rhinosinusitis and Nasal Polyps 2020. Inclusion criteria included persons aged 18 years or older who signed informed consent. Exclusion criteria encompassed patients with immunodeficiency, coagulation disorder, or cystic fibrosis. The amount of eosinophils in the peripheral blood were assessed by taking 3 cc of blood samples from per subject. NP tissues were acquired from subjects underwent endoscopic sinus surgery. Sample tissues were sectioned for hematoxylin-eosin (HE) staining, and the number of inflammatory cells were counted under high power (HP) magnification (×400). ECRS was diagnosed based on a percentage of eosinophils greater than 10% in the HP field.[16] This study was already approved by the Ethics Committee of Naval Medical University (Shanghai, China).

CT Imaging and LM Sinus Scores

CT imaging of the sinuses was completed using multi-detector CT scanner (Manufacturer: Philips). Patients were scanned in a uniform supine position, and images were reconstructed based on a standard algorithm with a thickness of 0.625 mm. Sinus LM scores were measured using the LM scoring system, which consisted of three grades: a score of 0 indicates no sinus cavity obstruction, 1 indicates partial sinus cavity obstruction and 2 indicates complete sinus cavity obstruction. The bilateral maxillary sinus, frontal sinus, posterior ethmoid (PE) sinus, anterior ethmoid (AE) sinus, sphenoid sinus, and ostiomeatal complex (OMC) were all measured. Meanwhile, the OMC is scored as 0 for not occluded or 2 for occluded.

3D Volumetric Image Analysis and Improved Sinus Score

Obtained axial and coronal CT images were manually analyzed by using Mimics software (version 17.0; Materialise). Air pixels were defined using the Hounsfield unit (HU) range of −1024 to −350 (noninclusive), while bone pixels were defined using the HU range of +240 to +2700 (noninclusive). After outlining the boundaries of the sinuses, the complete 3D sinus morphology and volume obtained. The cavity volume can be obtained directly using the HU threshold program after measuring the complete sinus cavity. The original sinus volume and remaining cavity volume were quantified, and the diseased mucosal volume was defined as the original sinus volume minus the remaining sinus volume. The artificial quantization process was carried out by 2 trained researchers who were not privy to all of the subjects' clinical data and only reviewed and scored the scans. Finally, the percentage of diseased mucosa in each sinus cavity (0-1) was obtained, with a total maximum score of 10 for the five group sinus cavities (excluding the OMC). Representative coronal CT images with the manual outlines and 3D sinus volume were shown in **Figure 1**.

Statistical Analysis

Statistical analyses were completed by using SPSS software (version 26.0, IBM Inc). Categorical variables were described as number (percentage) of the total population, which were analyzed with the χ^2 test. Continuous variables were showed as mean ± SD. The independent
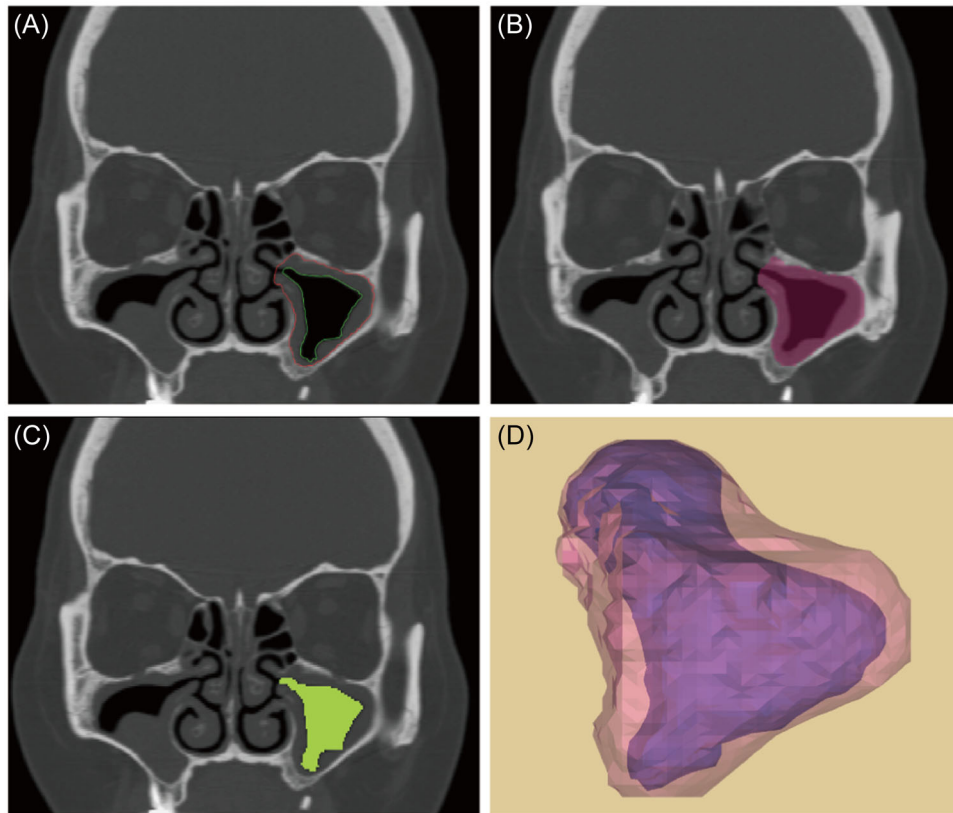
Figure 1. Representative coronal CT images with the manual outlines and maxillary sinus 3D model. (A) Coronal CT images of representative sinuses with the original maxillary sinus volume outlined with red lines and the maxillary remaining cavity volume indicated by green lines. (B) Original maxillary sinus volume constructed from single layer CT image contours. (C) Remaining maxillary sinus cavity volume constructed from single layer CT image contours. (D) 3D model of representative maxillary sinus constructed from multilayered CT images, purple indicates remaining cavity and red indicates original sinus volume. 3D, three dimensional; CT, computed tomography.

sample t test was executed to compare the mean values of normally distributed variables between the non-ECRS and ECRS groups. For non-normally distributed variables, the Mann-Whitney test was applied. Binary logistic regression analysis was conducted to establish an influencing factor model for predicting the diagnosis of CRSwNP. Receiver operating characteristic (ROC) curve was used to evaluate the predictive ability of clinical parameters. $P < .05$ was considered as a statistically significant difference.

Results

Eighty-one subjects (47 males and 34 females) met the study's inclusion criteria. Among the subjects, 37 cases (45.67%) were classified in the ECRS group, while 44 cases (54.32%) were in the non-ECRS group. **Figure 1** showed representative CT images of the sinuses, including outlines and 3D models of the original sinus volume and remaining cavity. The clinical and demographic characteristics of each subgroup are presented in **Table 1**, including measurements of the sinuses using both the LM scoring system and the improved CT sinus score method. There were no remarkable differences between the 2 groups in terms of gender, age, smoking, atopy, asthma,

or allergic rhinitis (false discovery rate > 0.05). For the difference in thickened sinus mucosa between the 2 groups, the improved scores provided a more sensitive detection than the LM scores.

Five additional scores were counted based on the LM scores and improved sinus score in **Table 2**. Total ethmoid sinus score (E score; the sum of AE and PE scores), the ratio of the E and M scores (E/M score), the difference between E and M scores (E − M score), the difference between PE and AE scores (PE − AE score), and the ratio of the PE and AE scores (PE/AE score) were described. Furthermore, the M score, F score, S score, PE/AE ratio, and PE − AE score showed no significant differences between 2 different groups. Notably, the peripheral blood eosinophil count and percentage, T score, E score, AE score, PE score, E/M score, and E − M score were remarkably higher in the ECRS group compared to the non-ECRS group, both in improved CT scores and LM CT scores ($P < .05$). Further details can be found in **Tables 1** and **2**.

Subsequently, a stepwise binary logistic regression was well applied, with ECRS or non-ECRS as dependent variables and indicators with statistically significant differences in univariate analysis (eosinophil ratio, improved total ethmoid sinus score [iE score], improved

Table 1. Clinical Characteristics of CRSwNP Patients

	ECRS (n = 37)	non-ECRS (n = 44)	t/F	Q		ECRS (n = 37)	Non-ECRS (n = 44)	t	Q
Male, No. (%)	29 (65.909)	18(48.649)	2.473	0.203					
Age, y	48.030 ± 15.016	48.640 ± 17.896	0.164	0.963					
Smoking, No. (%)	12(32.432)	15(34.091)	0.024	0.963					
Atopy, No. (%)	1(2.703)	1(2.273)	0.015	0.963					
Asthma, No. (%)	2(5.405)	1(2.273)	0.543	0.679					
AR, No. (%)	4(10.811)	5(11.364)	0.006	0.963					
Eosinophil count, mean (SD) (cells/μL)	484.1 (256.6)	166.6 (117.0)	−5.782*	<0.001					
Eosinophil ratio, mean (SD)	6.603 ± 4.312	2.893 ± 1.806	−4.651*	<0.001	LM M score	2.189 ± 0.701	2.114 ± 0.945	−0.402	0.798
iM score	1.247 ± 0.417	1.242 ± 0.464	0.047	0.963	LM F score	1.811 ± 1.198	1.523 ± 1.210	−1.167*	0.477
iF score	1.124 ± 0.554	0.907 ± 0.588	−1.755*	0.158	LM E score	4.459 ± 2.180	3.045 ± 1.952	−3.078*	0.006
iE score	2.477 ± 0.967	1.524 ± 0.886	−4.305*	<0.001	LM AE score	2.405 ± 1.189	1.659 ± 1.077	−3.611*	0.013
iAE score	1.314 ± 0.552	0.797 ± 0.484	−4.074*	<0.001	LM PE score	2.054 ± 1.290	1.318 ± 1.177	−2.446*	0.058
iPE score	1.164 ± 0.593	0.720 ± 0.518	−3.393*	0.003	LM S score	1.378 ± 1.187	1.250 ± 1.222	−0.477*	0.798
iS score	0.999 ± 0.615	0.780 ± 0.551	−1.669*	0.174	LM T score	9.838 ± 3.962	7.932 ± 3.812	−2.202	0.068
iT score	5.847 ± 1.871	4.453 ± 1.787	−3.669*	0.004					

Abbreviations: AE, anterior ethmoid; AR, allergic rhiniti; CRSwNP, chronic rhinosinusitis with nasal polyps; E, ethmoid; ECRS, eosinophic chronic rhinosinusitis; F, frontal; iAE score, improved anterior ethmoid sinus score; iE score, improved total ethmoid sinus score; iF score, improved frontal sinus score; iM score, improved maxillary sinus score; iPE score, improved posterior ethmoid sinus score; iS score, improved sphenoid sinus score; iT score, improved total sinus score; LM, Lund-Mackay; M, maxillary; PE, posterior ethmoid; S, sphenoid; T, total.

Table 2. Univariate Logistic Regression of Clinical Data Between the 2 Groups of CRSwNP Patients

	B	P	OR	95% CI		B	P	OR	95% CI
Sex	−0.713	.119	0.490	0.200-1.201					
Age	−0.002	.868	0.998	0.972-1.025					
Smoking	−0.075	.875	0.928	0.367-2.349					
Atopy	0.178	.901	1.194	0.072-19.779					
Asthma	0.899	.470	2.457	0.214-28.235					
AR	−0.056	.937	0.945	0.235-3.812					
Eosinophil count	0.009	<.001	1.009	1.005-1.014					
Eosinophil ratio	0.469	<.001	1.598	1.266-2.018					
iF score	0.666	.095	1.946	0.891-4.249	LM F score	0.203	.284	1.225	0.845-1.774
iM score	0.024	.962	1.024	0.377-2.782	LM M score	0.109	.685	1.115	0.659-1.886
iE score	1.072	<.001	2.921	1.675-5.093	LM E score	0.331	.005	1.393	1.106-1.755
iAE score	1.820	<.001	6.174	2.375-16.052	LM AE score	0.584	.006	1.793	1.178-2.729
iPE score	1.411	.001	4.099	1.731-9.707	LM PE score	0.447	.020	1.563	1.072-2.280
iS score	0.652	.096	1.920	0.890-4.142	LM S score	0.069	.714	1.071	0.741-1.549
iT score	0.422	.003	1.525	1.159-2.006	LM T score	0.130	.036	1.138	1.008-1.286
iE/M ratio	0.673	.007	1.945	1.193-3.172	LM E/M ratio	0.558	.011	1.747	1.138-2.683
iE-M score	1.219	<.001	3.378	1.862-6.128	LM E-M score	0.325	.007	1.385	1.095-1.751
iPE/AE ratio	−0.167	.539	0.867	0.550-1.367	LM PE/AE ratio	0.570	.098	1.768	0.900-3.472
iPE-AE score	−0.410	.380	0.675	0.281-1.623	LM PE-AE score	−0.062	.755	0.940	0.638-1.386

Abbreviations: AE, anterior ethmoid; AR, allergic rhiniti; CI, confidence interval; CRSwNP, chronic rhinosinusitis with nasal polyps; E, ethmoid; E/M ratio, the ratio of E and M scores; E − M score, difference between E and M scores; F, frontal; iAE score, improved anterior ethmoid sinus score; iE score, improved total ethmoid sinus score; iF score, improved frontal sinus score; iM score, improved maxillary sinus score; iPE score, improved posterior ethmoid sinus score; iS score, improved sphenoid sinus score; iT score, improved total sinus score; LM, Lund-Mackay; M, maxillary; OR, odds ratio; PE, posterior ethmoid; PE/AE ratio, ratio of the PE and AE scores; PE − AE score, difference between PE and AE scores; S, sphenoid; T, total.

Table 3. Stepwise Logistic Regression Model of Improved Sinus CT Score to Predict the Factors Influencing Diagnosis of CRSwNP

		B	P	OR	95% CI
Step 1	Eosinophil ratio	0.469	<.001	1.598	1.266-2.018
Step 2	Eosinophil ratio	0.474	.001	1.606	1.226-2.103
	iE-M score	1.141	.001	3.131	1.581-6.202

Abbreviations: CI, confidence interval; CRSwNP, chronic rhinosinusitis with nasal polyps; CT, computed tomography; iE-M, improved total ethmoid sinus score-maxillary; OR, odds ratio.

Table 4. Multivariate Logistic Regression Model of Lund-Mackay Scale to Predict the Factors Influencing Diagnosis of CRSwNP

	B	P	OR	95% CI
Eosinophil ratio	0.442	<.001	1.557	1.227-1.975
LM E − M score	0.196	.152	1.216	0.930-1.590

Abbreviations: CI, confidence interval; CRSwNP, chronic rhinosinusitis with nasal polyps; E − M score, difference between E and M scores; LM, Lund-Mackay; OR, odds ratio.

anterior ethmoid sinus score, improved posterior ethmoid sinus score, improved total sinus score [iT score], iE/M ratio, and iE-M score) as independent variables. The blood eosinophil percentage was chosen due to the extremely small odds ratio (OR) variation of eosinophil count. The results indicated that blood eosinophils percentage (P = .001, OR = 1.606, 95% confidence interval [CI]: 1.226-2.103) and iE-M score (P = .001, OR = 3.131, 95% CI: 1.581-6.202) were retained as predictive factors of diagnosing ECRS (**Table 3**). However, when the logistic regression model was constructed using LM CT score, the E − M scores were not statistically significant (**Table 4**). The test variables, including blood eosinophil percentage, and iE-M score, were analyzed using the ROC curve. **Figure 2** shows the ROC curve for the eosinophil percentage, iE-M score, and blood eosinophils percentage combined with iE-M score. The area under the curve (AUC) values and cut-off points for each parameter were shown in **Table 5**. When the eosinophil ratio was 5.250 or higher, the sensitivity was 0.568, and specificity was 0.886. On the other hand, an iE-M score of 0.690 or higher yielded a sensitivity of 0.757 and specificity of 0.750. Interestingly, the highest AUC value (AUC = 0.874, 95% CI: 0.782-0.937) was achieved when combining the blood eosinophil percentage with iE-M score.

Discussion

CRSwNP is a disease featured by chronic inflammatory changes and the formation of NPs in the nasal cavity and sinus mucosa. According to histopathological features, CRSwNP can be divided into 2 types: ECRS and non-ECRS.[7] NPs may be effectively studied using immunology and histology techniques. We used HE staining to count the absolute and relative number of eosinophils in
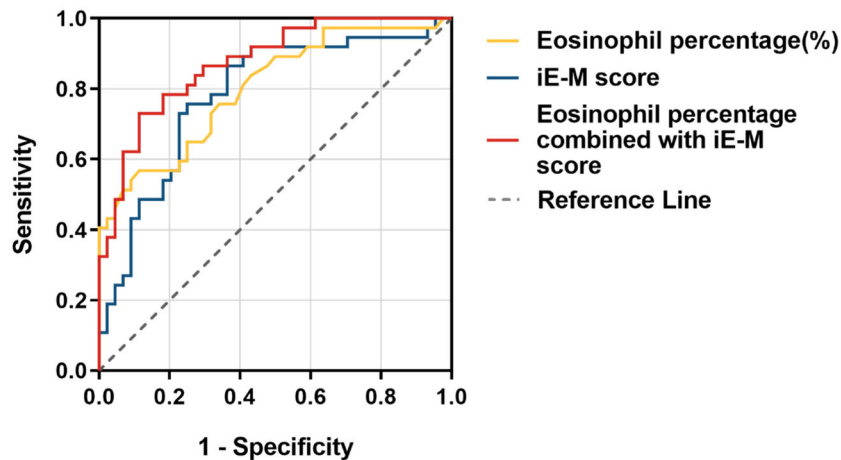
Figure 2. The receiver operating characteristic curve of peripheral blood eosinophil percentage, improved E − M sinus computed tomography score, and eosinophil percentage combined with iE-M score. E − M, subtraction of ethmoid and maxillary sinus scores; iE-M, improved total ethmoid sinus score-maxillary.

Table 5. Prognostic Evaluation of CRSwNP by Various Patient Indicators

	AUC	P	95% CI	Cut-off point	Sensitivity	Specificity
Blood eosinophil percentage (%)	0.801	<.001	0.698-0.882	5.250	0.568	0.886
iE-M score	0.783	<.001	0.678-0.867	0.690	0.757	0.750
Blood eosinophil percentage combined with iE-M score	0.874	<.001	0.782-0.937	0.483	0.730	0.886

Abbreviations: AUC, area under the curve; CI, confidence interval; CRSwNP, chronic rhinosinusitis with nasal polyps; iE-M, improved total ethmoid sinus score-maxillary.

the high-magnification visual field. The absolute count of eosinophils per HP field of view is now be used to diagnose ECRS. This diagnostic criterion running from 10 to 70 eosinophils per high-power field in different countries.[17]

Considering individual differences of the cell density in samples, the individual data became reliable, and the variation were reduced after using the ratio of the relative number of eosinophils to all inflammatory cells. However, the conventional practice of extracting NPs with forceps for histopathological evaluation before surgery can not only cause significant fear and psychological pressure for patients, but also increase the workload of medical staff and economic burden on them. As a consequence, evaluating NP through histopathology after surgery leads to delays in assessment, preventing patients from receiving timely and appropriate treatment. As a result, it is of great value to establish a noninvasive and convenient approach to distinguish between the 2 subtypes. CT scan has a crucial position in the diagnosis and management of CRS and has been demonstrated to be a valuable diagnostic indicator for predicting ECRS.[18] ECRS is primarily characterized by increased infiltration of tissue eosinophils, which secrete a variety of granular proteins and mediate local inflammatory responses, leading to nasal mucosal edema and the formation of NP.[19] According to CT imaging data, ECRS is manifested as abnormal thickening of the sinus mucosa and aggravated obstruction of the

sinus, oral and nasal passages complex. The sinuses CT LM score is a relatively objective indicator used to reflect the thickened mucosa of the nasal cavity and sinuses. However, it has certain limitations. According to the degree of sinus mucosal thickness, the score of completely absence of abnormal thickening in each sinus cavity is recorded as 0, partial thickening was scored as 1, and complete filling as 2. This system cannot accurately distinguish the degree of mucosal inflammation in each sinus cavity,[20,21] leading to subsequent inaccuracies in the assessment of the disease. Recent studies have utilized software-based tools to develop an objective scoring system that measures the thickened mucosa due to inflammation (ranging from 0 to 1).[15] This system focuses on assessing the ratio of diseased mucosa and sinuses volume, proving a more accurate reflection of sinus inflammation. However, it does not include the evaluation of OMC. As reported, Sooyoung Lim found that patients' sinus inflammation is closely related to clinical symptoms and disease-specific quality of life, unlike previous studies that showed no remarkable correlation between LM scores and disease severity or subjective feelings.[20,22] This indicated that the improved CT score can effectively reflect nasal and sinus mucosal thickening, which providing a new approach for objective diagnosis of ECRS.

In this study, we observed no obvious differences in the scores for improved maxillary, improved sphenoid, and improved frontal between the 2 groups. However, scores

of the iE and iT score were dramatically higher in the ECRS group. Previous studies indicated that ECRS patients tend to have more severe thickened mucosa in ethmoid sinus, while non-ECRS patients primarily exhibit mucosal thickening of the maxillary sinus.[20] Here, we indicated the abnormal thickening of the ethmoid sinus mucosa was more severe in ECRS patients, consistent with existing findings. Additionally, our results also suggested no significant difference in thickened mucosa of maxillary sinus between the 2 groups, which may be associated to the small sample size, systematic error, or other possible factors. Further studies with larger sample sizes are required to verify this observation. As the iE score showed the greatest differences between the 2 groups, we also calculated the difference and ratio of the total ethmoid sinus to the maxillary sinus, as well as the difference and ratio of the anterior and posterior ethmoid sinuses, in addition to the four fixed pairs of sinuses. We found that the iE/M ratio and iE-M score exhibited significant differences between the 2 groups. However, this method has limitations as it is semiautomatic and subject to observer bias. Therefore, there is necessary to develop a fully automated method to improve the accuracy and efficiency of the evaluation.

Eosinophils in peripheral blood interacted with vascular cell adhesion molecule 1 and intracellular adhesion molecule 1 before migrating to local tissues. This recruitment process also involved chemokines and their receptors, such as CC-chemokine ligand 11, CC-chemokine ligand 24, and CC-chemokine receptor 3.[23] The number of peripheral eosinophils can serve as an indicator for preoperative diagnosis of ECRS and the prediction of postoperative efficacy. Hu et al[24] established cutoff values of the blood eosinophil percentage $\geq 3.05\%$ or the blood eosinophil count $\geq 0.215 \times 10^9$/L to distinguish between ECRS and non-ECRS. Wang et al[25] reported that patients with CRS were preliminarily divided into ECRS and non-ECRS based on whether the percentage of peripheral blood eosinophils before surgery was greater than 5.65%. In our study, the percentage and number of peripheral blood eosinophils also showed significant statistical difference between the 2 groups, with a predictive threshold above 5.25% for the ECRS group. However, the level of peripheral blood eosinophilic granulocytes can be affected by other conditions, such as tumor, allergic reactions, diseases caused by parasites and hematology-related diseases. Therefore, it has certain limitations in the diagnosis of ECRS.

The previous studies had clarified a positive association between the peripheral blood eosinophil percentage and LM CT score among patients with CRS.[26] Although both indicators are valuable in diagnosing ECRS, there are still limitations. To address this, clinical indicators which showed significant differences in the univariate analysis were selectively entered into a binary logistics regression analysis. The small value of the absolute blood eosinophil amount resulting in statistically significant but without a valuable OR value, we excluded it from the binary logistic regression. Then, a stepwise logistic regression analysis of improved sinus scores and peripheral blood eosinophil percentage was performed. Meanwhile, LM sinus scores were also selected in another binary logistic regression based on a criterion of P less than .05. However, only the eosinophil ratio was retained in the model for predicting ECRS according to LM sinus scores. Based on the above analysis, we selected the percentage of peripheral blood eosinophils and iE-M score as predictors for the ROC curve analysis of ECRS. These results showed that combination of the 2 factors had higher diagnostic value than using 1 factor only.

Meanwhile, our method of obtaining 3D sinus morphology was semiautomatic. The contours of the sinus cavity were manually selected by clicking on the boundaries in axial and coronal positions by software. However, the stability of this method may be affected by operator variability. Additionally, the semiautomated method is time-consuming, which may hinder its large-scale application in the clinic. A recent study developed a convolutional neural network algorithm to automated 3D segmentation of sinuses, found that in patients with chronic sinusitis, the mean percentage opacification of the sinuses had a strong correlation with the LM score.[27] However, the study did not address the sinus opacification characteristics of eosinophilic sinusitis. Our work complements the sinus characteristics of patients with ECRS. Developing a similar fully automated program for this process will help establish a more effective and rapid clinical diagnostic standard for ECRS.

Overall, our findings suggest that combination of peripheral blood eosinophil percentage and iE-M score has diagnostic value for ECRS, and P value of AUC curve was .03 compared to iE-M and .05 compared to blood eosinophil percentage. However, the generalizability of these results remains unclear, which is a common challenge in many studies of this area. To further evaluate the diagnostic utility of improved CT scores combined with peripheral blood eosinophils in patients with ECRS, more sample size is needed for the next relevant study.

Conclusion

In short, our study demonstrated that the combination of iE-M score and peripheral blood eosinophil percentage had a superior diagnostic value in terms of ECRS predictions, which could assist physicians in accurately identifying ECRS and providing more precise treatment for patients.

Author Contributions

Fengzhen Li, manuscript drafting, data collection, data analysis; **Shenglei Wang**, data analysis, manuscript drafting; **Xudong Cha**, data collection, data analysis; **Tengfei Li**, data collection, data

analysis; **Yingqi Xie**, data collection; **Wenwen Wang**, data collection; **Wenwen Ren**, manuscript review; **Jianchun Liao**, study concept and design; **Huanhai Liu**, study concept and design, manuscript review. All authors approved the final manuscript.

Disclosures

ORCID iD

Wenwen Ren http://orcid.org/0009-0007-2865-8874

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