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## Aditus ad antrum patency on CT as a predictor of tympanoplasty outcomes in chronic otitis media

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To evaluate the prognostic significance of aditus ad antrum patency, as determined by computed tomography (CT), on the surgical outcomes in patients with chronic suppurative otitis media (CSOM). This study analyzed CSOM patients who had tympanoplasty at a tertiary hospital from 2015 to 2019. Patient demographics, operative reports, preoperative CT scans and outcomes were reviewed. Aditus ad antrum patency was evaluated on CT images. Outcome measures included graft success and postoperative air-bone gap (ABG) at the last follow-up ( $\geq 6$  months). During the study, 138 patients with CSOM patients were included. Computed tomography (CT) scans revealed a blocked aditus in 37 patients (26.8%). Patients in the patent aditus group demonstrated a significantly better hearing prognosis compared to those in the obstructed aditus group ( $P = 0.002$ ). In the low- and intermediate-risk subgroups, patients with a blocked aditus exhibited significantly poorer postoperative hearing outcomes compared to those with a patent aditus ( $P < 0.001$ ). Multivariate logistic regression analysis identified obstructed aditus ad antrum (OR 1.83, 95% CI 1.10–3.04;  $P = 0.020$ ) and a Middle Ear Risk Index (MERI) score greater than 3 (OR 2.68, 95% CI 1.06–6.75;  $P = 0.037$ ) as independent adverse prognostic factors for hearing success in patients with CSOM. A patent aditus ad antrum correlates with preoperative dry ear, no middle ear granulation, a well-pneumatized mastoid, and a low MERI score. Preoperative CT showing aditus ad antrum patency may independently predict hearing outcomes and help stratify risk in CSOM patients.

**Keywords** Aditus ad antrum patency, Computed tomography, Ventilation, Mastoidectomy

Chronic suppurative otitis media (CSOM) is a prevalent condition that results in tympanic membrane perforation, hearing loss and otorrhea. Tympanoplasty is the surgical intervention employed to repair the tympanic membrane, restore ventilation and drainage of the tympanic cavity, and reconstruct the ossicular chain. Since its introduction by Zollner<sup>1</sup> and Wullstein<sup>2</sup> in 1956, tympanoplasty has been considered a safe and effective surgical procedure for the management of middle ear disease, with reported success rates ranging from 64 to 98%<sup>3–5</sup>. Previous studies have identified key predictors for successful surgical outcomes. Black et al.<sup>6</sup> introduced the (SPITE) factors (surgical, prosthetic, infection, tissue, and Eustachian tube). Becvarovski and Kartush developed the middle ear risk index (MERI), considering otorrhea, perforation, cholesteatoma, ossicular chain, middle ear granulation and previous surgery, with smoking added in 2001<sup>7</sup>. In essence, a favorable environment for ossicular chain reconstruction and a well-aerated tympanic cavity (supported by healthy middle ear mucosa and a functioning Eustachian tube) are essential.

The middle ear ventilation system comprises the Eustachian tube, the mastoid air cell system (MACS), middle ear mucosa and regional ventilation. The MACS fulfills at least two critical functions: serving as a buffer and facilitating transmucosal gas exchange. The aditus ad antrum acts as the gateway to the MACS. The aditus ad antrum is a narrow, triangular passage located in the posterior epitympanum, serving as a connection between the attic and the mastoid antrum. It is bordered superiorly by the tegmen, medially and inferiorly by the lateral semicircular canal (LSCC) and the second genu of the facial nerve, and laterally by the scutum<sup>8</sup>. If this entrance becomes obstructed, the mastoid loses its buffering capacity with respect to middle ear pressure, and the transmucosal gas exchange through the mastoid is compromised. Consequently, obstruction of the aditus can significantly impair both the ventilation and transmucosal gas exchange functions of the mastoid. Deregulation or dysventilation of middle ear pressure can result in various middle ear pathologies<sup>9</sup>, thereby impairing sound conduction within the middle ear. Surgical intervention is typically necessary for the excision of lesions and subsequent reconstruction. However, middle ear dysventilation increases surgical risk and may contribute to the likelihood of surgical failure. Recently, research have demonstrated that the utilization of a 30-degree endoscope

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facilitates the intraoperative evaluation of aditus patency. In cases where aditus obstruction is strongly suspected, procedures such as antrostomy or mastoidectomy are undertaken to assess and restore patency. Furthermore, a saline test may be employed to evaluate the patency of the aditus. However, these surgery interventions contribute to increased operative duration and elevated surgical costs.

The assessment of aditus patency prior to surgery is a primary concern. A preoperative temporal bone computed tomography (CT) is routinely conducted to evaluate the location, size, extent, and anatomical characteristics of lesions. The patency of aditus ad antrum can also be effectively assessed using axial CT images, which are an integral component of the routine preoperative evaluation. Previous studies have not comprehensively investigated the impact of aditus patency on CT in the context of procedural planning, patient risk stratification, and surgical prognosis. The study aims to elucidate the significance of aditus ad antrum patency on axial CT images concerning the risk stratification and prognosis of patients with CSOM.

## Results

In this study, a total of 138 patients (median age 44 y; 60.1% female) were included. The cohort was divided into two groups: 101 patients in the patent group and 37 in the obstruction group. Among these patients, 92 (66.7%) underwent tympanoplasty without mastoidectomy, 18 (13%) underwent tympanoplasty with canal wall up (CWU) mastoidectomy, and 28 (20.3%) underwent tympanoplasty with canal wall down (CWD) mastoidectomy. The median follow-up period was 11 months, with a range of 6 to 46 months.

Table 1 presents a comparative analysis of the demographics and clinical characteristics of the two groups under study. Statistical analysis revealed no significant differences between the patent and obstruction groups with respect to age, gender, smoking status, location of tympanic membrane perforation and the presence of myringosclerosis.

A significant difference in preoperative dry ear incidence was observed between the two groups ( $P=0.006$ ). Specifically, 77.2% of patients in the patent group exhibited preoperative dry ear compared to 52.8% in the obstructed group. This indicates that the patent group had a higher proportion of patients with preoperative dry ear ( $P=0.006$ ). The patent group also had more patients with well-pneumatized mastoids ( $P<0.001$ ), indicating that a blocked aditus correlated with poorly pneumatized mastoids.

Blocked aditus in patients with CSOM is associated with higher MERI scores ( $P<0.001$ ). The mean MERI score was  $3.62 \pm 2.20$  in the patent group and  $5.65 \pm 1.87$  in the obstruction group, respectively. The patent group had a significantly lower proportion of intermediate-risk or high-risk cases ( $\text{MERI} > 3$ ) in comparison to the obstruction group ( $P<0.001$ ). Additionally, the obstructed aditus was correlated with the occurrence of middle ear granulation. Middle ear granulation was linked to an obstructed aditus, occurring in 54% patients of the obstruction group, and 23.8% of the patent group ( $P=0.001$ ). Representative intraoperative microscopic images of patent and blocked aditus ad antrum are shown in Fig. 1.

The results of the univariate and multivariate logistic regression analysis are presented in Table 2. In univariate analysis, obstructed aditus ad antrum, MERI score  $> 3$ , mastoid type (sclerotic), and surgical technique (CWD mastoidectomy) were significant unfavorable predictors of the hearing success (PTA-ABG  $\leq 20$  dB). In multivariate analysis, obstructed aditus ad antrum and MERI score  $> 3$  were independent adverse predictors of successful hearing outcome.

There was no significant correlation between aditus patency and graft outcome. The overall graft success rate was 86.2% (119/138). Graft outcomes were successful in 84.2% (85/101) patients in the patent group, and 91.9% (34/37) of patients in the blocked group. The difference in graft success rate between the two groups was not statistically significantly ( $c^2=1.36$ ,  $P=0.243$ ).

However, our observations indicated a better hearing prognosis in the patent group compared with the obstruction group. The mean preoperative PTA-ABG was  $27.31 \pm 10.84$  dB in the patent group and  $34.83 \pm 10.76$  dB in the obstruction group. Postoperatively, the mean PTA-ABG was  $18.53 \pm 14.14$  dB in the patent group, and  $32.04 \pm 12.56$  dB in the obstruction group. The cohort was stratified into three subgroups based on the MERI risk category. Subsequent analyses were conducted within these distinct subgroups. The results of subgroup analyses are illustrated in Fig. 2. In the low- and intermediate-risk subgroup, patients with a blocked aditus had worse postoperative hearing outcomes compared to those with a patent aditus. However, no significant differences in postoperative hearing were observed between patients with a patent versus a blocked aditus in the high-risk subgroup.

## Discussion

Prior studies have noted the importance of predicting aditus patency in CSOM patients before tympanoplasty. Over the past decade, the predictive power of clinical features, Eustachian tube function test and radiological test has been scrutinized. Kurien et al.<sup>10</sup> identified the inflation-deflation test as a reliable predictor of aditus patency in CSOM patients. Additionally, Bahgat et al.<sup>11</sup> found that a blocked aditus was more prevalent in elderly patients, those with a long history of otorrhea, marginal perforations, or the presence of myringosclerosis. In contrast to earlier findings, Varma et al.<sup>12</sup> found that inflation-deflation test, tympanosclerosis, and duration of discharge were not significant predictors of aditus patency. Instead, their research identified HRCT of the temporal bone as a significant predictor of aditus patency.

In this study, we defined the patency of aditus ad antrum using HRCT. Our findings indicated that a patent aditus was associated with preoperative dry ear, absence of middle ear granulation, pneumatized mastoid and a low-risk MERI category or lower MERI score. Granulation tissue is a frequently observed in CSOM patients who exhibited otorrhea. The presence of middle ear granulation tissue may significantly contribute to postoperative graft failure and hearing loss.

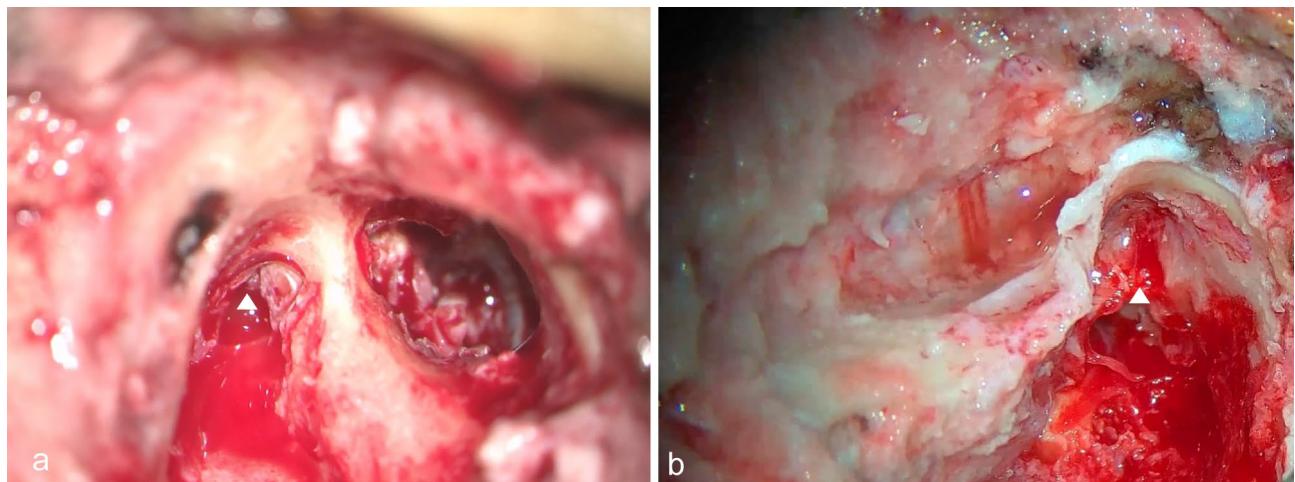
Variables	Aditus ad antrum patency		t, $\chi^2$	P value
	Patent (n = 101)	Blocked (n = 37)		
Age (y, mean $\pm$ SD)	44.21 $\pm$ 12.63	44.00 $\pm$ 15.66	0.080 <sup>b</sup>	0.936
Gender			8.106 <sup>a</sup>	0.004*
Male	33 (32.7)	22 (59.5)		
Female	68 (67.3)	15 (40.5)		
BMI (kg/m <sup>2</sup> )	24.14 $\pm$ 4.21	23.81 $\pm$ 3.67	0.430 <sup>b</sup>	0.668
Smoker	11 (10.9)	7 (18.9)	1.539 <sup>a</sup>	0.215
Preoperative dry ear	78 (77.2)	19 (52.8)	7.675 <sup>a</sup>	0.006*
Location of perforation			6.075 <sup>a</sup>	0.194
Central	65 (64.4)	19 (51.4)		
Anterior	17 (16.8)	10 (27.0)		
Posterior	1 (1.0)	2 (5.4)		
Marginal	8 (7.9)	1 (2.7)		
Subtotal	10 (9.9)	5 (13.5)		
Myringosclerosis	30 (29.7)	8 (21.6)	0.886 <sup>a</sup>	0.346
Graft material			10.656 <sup>a</sup>	0.00485*
Temporalis fascia	57	31		
Perichondrium	17	0		
Tragal cartilage with perichondrium	27	6		
Tympanoplasty			1.7443 <sup>a</sup>	0.1866
Type I tympanoplasty	29	15		
T + ossiculoplasty	72	22		
MERI score				
Mean $\pm$ SD	3.62 $\pm$ 2.20	5.65 $\pm$ 1.87	4.967 <sup>b</sup>	< 0.001*
$\leq 3$	55 (54.5)	4 (10.8)	21.08 <sup>a</sup>	< 0.001*
> 3	46 (45.5)	33 (89.2)		
Mastoid type			15.4 <sup>a</sup>	< 0.001*
Pneumatic	54 (53.5)	6 (16.2)		
Diploic	35 (34.7)	22 (59.5)		
Sclerotic	12 (11.9)	9 (24.3)		
Mastoidectomy			25.41 <sup>a</sup>	< 0.001*
No	77 (76.2)	15 (40.5)		
CWU	14 (13.9)	4 (10.8)		
CWD	10 (9.9)	18 (48.6)		
Middle ear granulation	24 (23.8)	20 (54.1)	11.44 <sup>a</sup>	0.001*

**Table 1.** Demographic characteristics and treatment data of patients (with patent aditus and blocked aditus). BMI, Body mass index; CWU, Canal wall up; CWD, Canal wall down; MERI, Middle ear risk index; SD, Standard deviation. Data are shown as mean  $\pm$  SD and number (percentage). Statistically significant findings are highlighted with (\*). <sup>a</sup>Chi-square test or Fisher's exact test. <sup>b</sup>Unpaired t test.

Mastoid pneumatization serves as a pivotal prognostic indicator in middle ear surgeries. The determinants influencing the process of mastoid pneumatization have been the subject of extensive debate. Several studies have supported the environmental theory, suggesting that acquired factors, such as middle ear infection, can impede mastoid pneumatization. The aditus, which connects the attic to mastoid antrum, plays a crucial role in this process. The patency of aditus is essential, as mucosa swelling or granulation tissue obstructing the aditus can significantly hinder mastoid aeration.

This study aims to elucidate the role of aditus patency, as assessed by preoperative HRCT in risk stratification. The findings indicate that, within the low- and intermediate-risk categories, patients with blocked aditus exhibited poorer hearing outcomes compared to those with patent aditus. These results underscore the significance of aditus patency as a pivotal factor in risk stratification for predicting postoperative hearing outcomes. Furthermore, the presence of an obstructed aditus ad antrum emerged as an independent adverse predictor of hearing success following tympanoplasty.

Preoperative HRCT serves as an invaluable and essential instrument for otologists, facilitating evaluation of precise anatomical structures, aditus patency, and surgical planning. Despite advancements in imaging technology, surgical decision making continues to depend significantly on the subjective judgement of individual surgeons, which can exhibit considerable variability. A pertinent example of this variability is the ongoing debate regarding the necessity of mastoidectomy in the surgical management of patients with CSOM. Many otologists advocate for the potential benefits of mastoidectomy in the management of infections and lesions, particularly



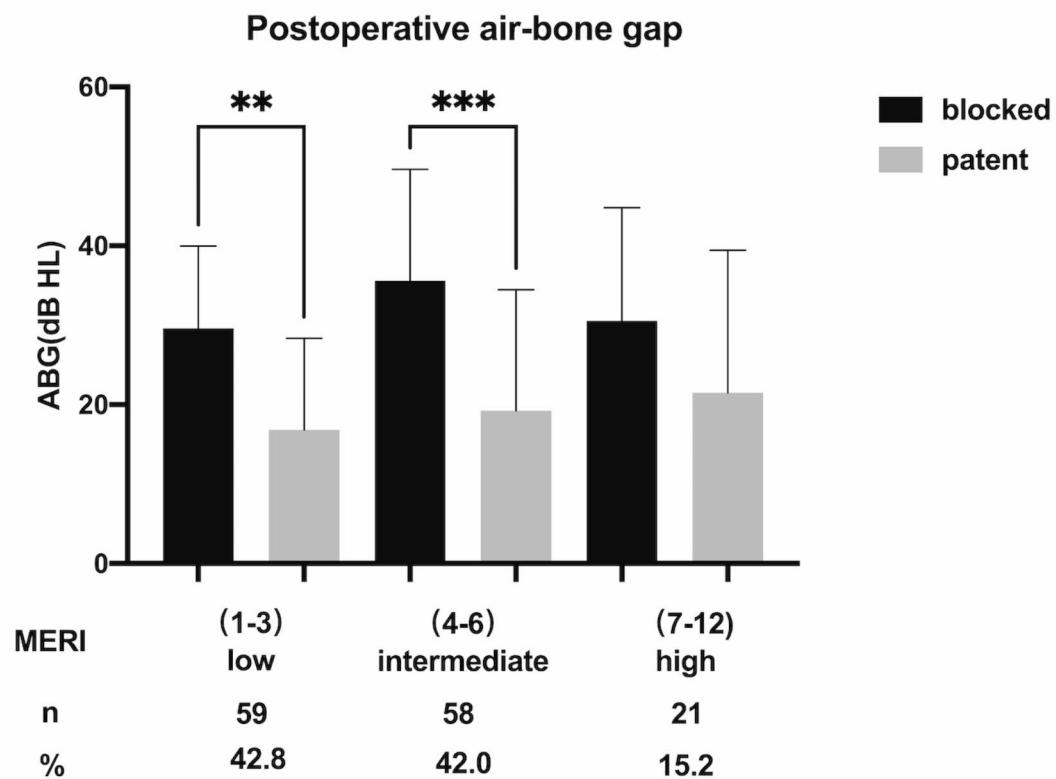
**Fig. 1.** Representative intraoperative microscopic images of the aditus ad antrum. **(a)** Right-sided patent aditus ad antrum (arrowhead). **(b)** Left-sided blocked aditus ad antrum (arrowhead).

Variables	Univariate		Multivariate	
	OR (95% CI)	P value	OR (95% CI)	P value
Obstructed aditus ad antrum	2.40 (1.52–3.79)	<0.001*	1.83 (1.10–3.04)	0.020*
MERI score > 3	3.98 (1.95–8.12)	<0.001*	2.68 (1.06–6.75)	0.037*
Mastoid type				
Pneumatic	1	0.026*	1	0.530
Diploic	2.00 (0.73–5.47)	0.177	0.96 (0.30–3.12)	0.946
Sclerotic	2.78 (1.31–5.88)	0.008*	1.54 (0.66–3.62)	0.317
Mastoidectomy				
No	1	0.014*	1	0.525
Canal wall up	1.19 (0.43–3.27)	0.735	1.08 (0.40–3.24)	0.893
Canal wall down	4.37 (1.62–11.77)	0.004*	2.04 (0.59–7.12)	0.261
Preoperative dry ear	0.79 (0.37–1.65)	0.526		
Middle ear granulation	1.91 (0.91–3.98)	0.086	0.58 (0.21–1.63)	0.301
Age	1.02 (0.99–1.04)	0.244		
Sex	0.79 (0.40–1.57)	0.507		
Smoker	1.93 (0.68–5.49)	0.215		

**Table 2.** Univariate and multivariate logistic regression analyses for estimating hearing success (n = 138). CWU, Canal wall up; CWD, Canal wall down; MERI, Middle ear risk index; OR, Odds ratio; CI, Confidence interval.

in cases involving discharging ears. Conversely, some practitioners contend that mastoidectomy may be superfluous. Trinidad et al.<sup>13</sup> reported that therapeutic mastoidectomy did not provide definitive benefits for patients with noncholesteatomatous chronic otitis media. Similar conclusions can be extended to cases involving ears with atelectasis or sclerotic mastoid. Identification of a blocked aditus ad antrum on HRCT should prompt surgeons to remove any granulation tissue or swollen polypoid mucosa obstructing the aditus. Performing additional antrotomy or mastoidectomy can enhance mastoid ventilation, thereby restoring a ventilated middle ear space and improving hearing.

The present study still has several limitations. Firstly, the inclusion criteria were restricted to patients who had undergone preoperative temporal bone CT and possessed complete follow-up data, potentially introducing selection bias. To mitigate this concern, a comparative analysis was conducted between patients with complete data and those with incomplete data (in Supplementary Table 1). The instances of missing data were thoroughly accounted for and deemed unlikely to introduce significant bias. Secondly, this study is a retrospective single-center study, necessitating further prospective studies from multiple centers to validate our findings. Additionally, while we assessed aditus ad antrum patency using HRCT, we did not differentiate the specific causes of obstruction. Future studies incorporating CT density measurements (Hounsfield units) or other imaging techniques may help further distinguish obstruction and their clinical implications. Furthermore, although aditus ad antrum patency was a key factor in surgical decision-making, the decision to perform mastoidectomy depended on multiple factors, including clinical history (e.g., persistent otorrhea, prior surgery),



**Fig. 2.** Comparison of the mean postoperative air–bone gap (ABG, dB HL) between the blocked aditus group and patent aditus group. \*  $P < 0.05$ ; \*\*  $P < 0.01$ ; \*\*\*  $P < 0.001$ ; MERI, middle ear risk index.

eustachian tube function, intraoperative findings, and surgeon preference. While this variability reflects real-world clinical decision-making it also introduces potential bias, which we acknowledge as a study limitation. Despite the limitations mentioned above, the present study underscores the importance of aditus ad antrum patency in risk stratification and predicting hearing outcomes in CSOM patients.

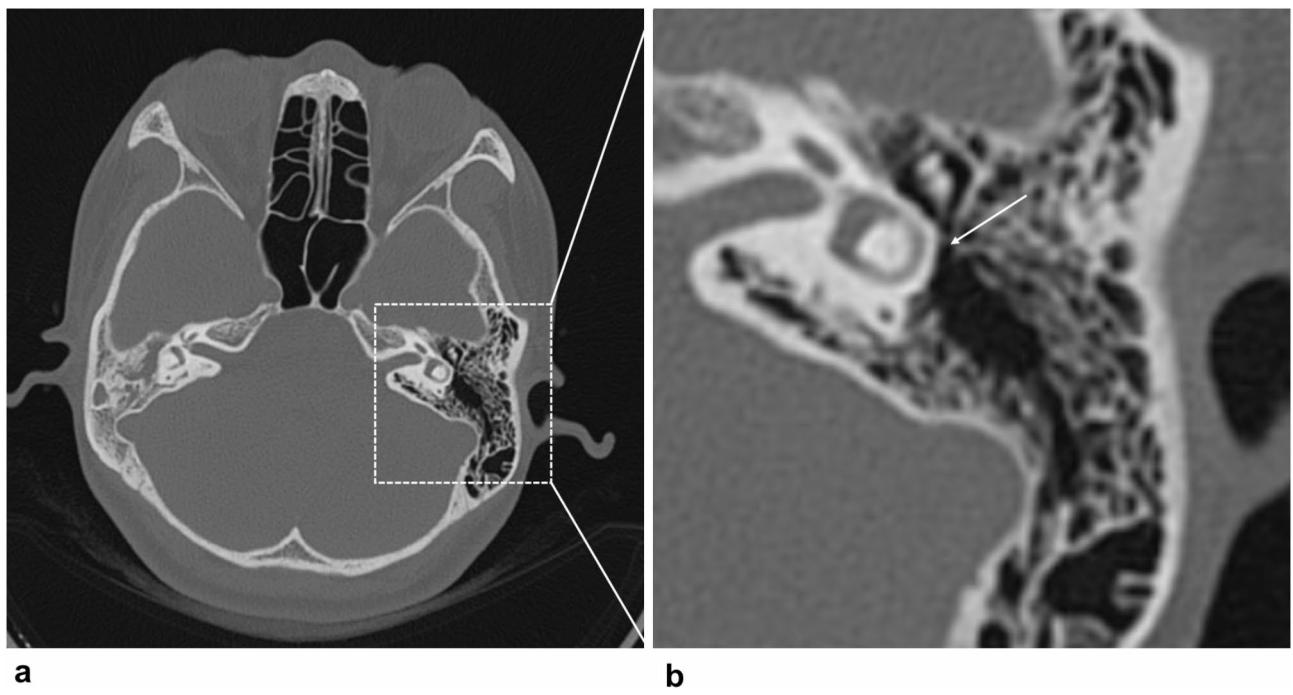
## Methods

### Study design and participants

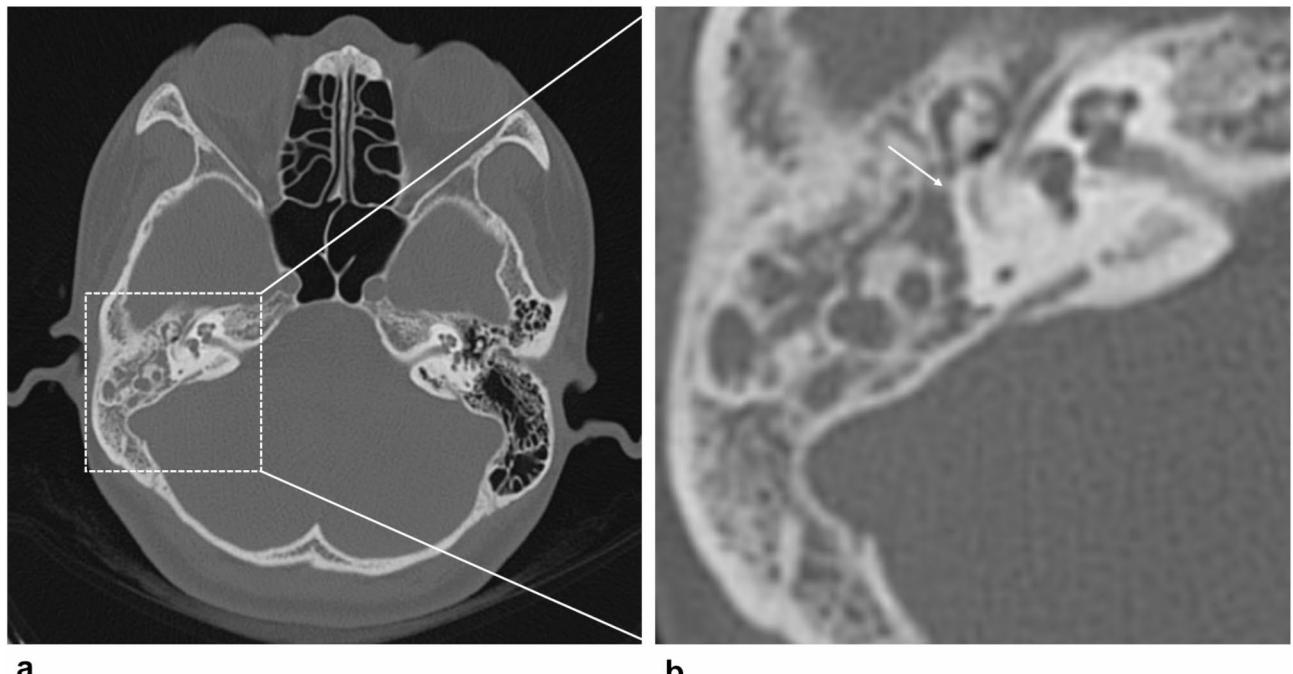
A retrospective analysis of medical records was conducted on patients diagnosed with chronic suppurative otitis media (CSOM) who underwent surgical intervention between January 1, 2015, and December 31, 2019, at Ningbo No.2 Hospital, Zhejiang, China. The study included all adult patients with CSOM who received tympanoplasty, with or without mastoidectomy, for the first time. Inclusion criteria encompassed the availability of preoperative temporal bone CT scans, and comprehensive clinical and follow-up data extending for a minimum of six months. Patients with cholesteatoma were excluded from this study. This study was conducted in accordance with the Declaration of Helsinki and adhered to relevant institutional and national guidelines and regulations. Ethical approval was obtained from the Ethics Committee for Human Research of Ningbo No.2 Hospital (Approval No.: SL-NBEY-KY2025-038-01). The requirement for informed consent was waived by the Ethics Committee for Human Research of Ningbo No.2 Hospital due to the retrospective nature of this study.

Demographics and clinical variables were retrospectively collected and extracted from electronic medical records. In all cases, the accuracy of the extracted data was confirmed by two independent investigators. The variables encompassed age, gender, smoking status, history of systemic diseases, preoperative dry ear status, location of tympanic membrane (TM) perforation, presence of myringosclerosis, mastoid type, middle ear granulation, surgical technique, etc. For each patient, the middle ear risk index (MERI) score was calculated using the MERI 2001 criteria<sup>8</sup>. Furthermore, the patency of the aditus ad antrum patency was assessed using a preoperative non-enhanced CT scan of the temporal bone, with a slice thickness of 0.6 mm. All CT images were independently evaluated by a skilled radiologist and an otolaryngologist, both of whom were blinded to the clinical data.

Based on the patency of the aditus ad antrum observed in axial CT images, patients were categorized into two groups: the aditus ad antrum group, indicating patency, and the aditus ad antrum group, indicating obstruction. Figure 3 presents axial CT images of the temporal bone demonstrating a patent aditus ad antrum. Conversely, Fig. 4 depicts preoperative CT imaging revealing complete obstruction of the aditus ad antrum.



**Fig. 3.** (a) Preoperative axial computed tomography (CT) scan of the temporal bone and (b) its local enlarged image shows patent aditus ad antrum (white arrow).



**Fig. 4.** (a) Preoperative axial computed tomography (CT) scan of the temporal bone and (b) its local enlarged image shows soft tissue density in the aditus ad antrum (white arrow) causing obstruction.

#### Surgical technique

All surgeries were performed under general anesthesia. Tympanoplasty techniques utilizing an inlay or underlay were employed, with either the postauricular or transcanal approach. Temporalis fascia served as graft material in myringoplasty. The decision to perform canal wall up (CWU) or canal wall down (CWD) mastoidectomy was based on both preoperative assessments and intraoperative findings. All surgeries were executed by senior surgeons.

## Outcome measures

The clinical status at the most recent follow-up was retrospectively extracted from outpatient clinic medical records. The follow-up duration was determined by calculating the interval from the date of operation to the date of the last follow-up. All patients had comprehensive follow-up records extending beyond 6 months. During the follow-up visits, each patient underwent a clinical examination, otoscopy, and pure tone audiometry (PTA) to evaluate the condition of the graft and postoperative hearing outcomes. In this study, graft success was defined as complete healing of the graft without the occurrence of atelectasis. The pre-operative and postoperative hearing thresholds were determined by the average thresholds at four frequencies: 0.5, 1, 2, and 3 kHz. In cases where the threshold at 3 kHz was unavailable, the average of the thresholds at 2 kHz and 4 kHz was utilized as a substitute. Hearing success was characterized by a PTA average air-bone gap (PTA-ABG) of 20 dB or less.

## Statistical analysis

Statistical analyses were conducted utilizing SPSS software 26.0 (IBM SPSS Statistics). Differences between quantitative variables across two groups were evaluated using either the t test or Mann-Whitney U test. For categorical variables, differences were analyzed employing the Chi-square test, Fisher's exact test, or the Wilcoxon rank-sum test.

Univariable logistic regression analysis was conducted on all potentially prognostic variables for preliminary screening. Variables demonstrating significance ( $P < 0.1$ ) were subsequently included in the multivariate logistic regression analysis. This approach was employed to investigate association between aditus patency and hearing success. A  $P$ -value of less than 0.05 was considered as statistically significant.

## Conclusion

The presence of a patent aditus ad antrum was correlated with a preoperative dry ear, well-pneumatized mastoid, absence of middle ear granulation, and a low MERI score. The patency of the aditus ad antrum, as observed on preoperative HRCT, may serve as a simple and assessable indicator for middle ear risk stratification and for predicting hearing outcome in CSOM patients.

## Data availability

Due to ethical concerns and participant privacy, the datasets supporting the findings of this study are not publicly available but can be obtained from the corresponding author upon reasonable request, subject to institutional review board approval.

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## Author contributions

Yuan Ren: Conceptualization, Methodology, Validation, Writing- Original draft preparation Xiaohui Zhu: Validation, Formal analysis, Data Curation, Writing- Reviewing and Editing Lu Zhang: Validation, Formal analysis, Writing—Review & Editing Cheng Kang: Investigation, Data Curation, Formal analysis Kai Wang: Methodology, Writing—Review & Editing, Funding acquisition, Supervision.

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## Declarations

### Competing interests

The authors declare no competing interests.

### Additional information

**Supplementary Information** The online version contains supplementary material available at <https://doi.org/10.1038/s41598-025-95378-z>.

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