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Influence of the wet-ear state on the outcomes of tympanic membrane repair under ear endoscopy: a prospective case-control study

Jun Zhang¹, Qinglin Bai², Na Zhao¹, Cong Li¹ and Jia Yang^{1*}

Abstract

Background To prospectively determine whether tympanoplasty for tympanic membrane perforation (TMP) in wet ears impacts recovery.

Methods We prospectively enrolled 32 TMP patients (2021–2023) and divided them into the wet-ear (14 patients) and dry-ear groups (18 patients), according to the presence of middle-ear secretions/edema. All patients underwent high-resolution thin-slice computed tomography, ear endoscopy, and pure tone audiometry.

Results Perforation healing was similar in the dry-ear (94.44%) and wet-ear groups (85.7%, $P=0.5685$). At 3 months, dry ears were achieved in 94.44% and 92.86% of patients in the dry- and wet-ear groups, respectively ($P>0.05$). The air-bone gap (ABG) at 3 months was similar in the dry-ear (9.4047 ± 4.3415 dB) and wet-ear groups (6.5278 ± 5.4552 dB, $P=0.1171$). In both groups, the mean air-conduction threshold, bone-conduction threshold, and ABG significantly decreased postoperatively ($P<0.05$).

Conclusion Tympanoplasty for TMP in wet ears does not adversely affect healing.

Keywords Otoscopy, Tympanoplasty, Healing rate, Dry ear, Wet ear

Introduction

Tympanic membrane perforation (TMP) is a commonly encountered injury in otorhinolaryngology departments. TMP can be caused by various conditions such as ear gouging, surgery, foreign body in the external auditory canal, bone fracture, pressure injury, middle ear infection, and middle ear or inner ear tumor [1, 2]. Tympanoplasty

is generally necessary in such patients to close the middle ear cavity, and reduce the risk of middle-ear infection and improve hearing. In patients with chronic TMP, surgery is additionally required to remove the middle ear lesion [3].

Tympanoplasty with an autograft to repair the perforation is currently the gold standard for the clinical treatment of TMP, and is associated with a high rate of perforation healing [4, 5]. Usually, the operation is scheduled 1 month after the ear infection and/or inflammation has resolved, or in the other words, after the ear has become “dry” [6]. Operations on “wet” ears may easily aggravate the infection, which is not conducive to healing. In clinical practice, however, some patients are

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unable to achieve a dry-ear state because the presence of the perforation leads to recurrent middle-ear infections and inflammatory exudation. In such patients, surgery is often performed to achieve the desired dry-ear condition and avoid long-term, repeated antibiotic therapy, which results in microbial flora disorders, drug resistance, and other adverse consequences. Therefore, some authors have explored the feasibility of performing tympanoplasty in the wet-ear state.

Webb and Chang [7] analyzed the data of 150 patients with TMP, and found that although the preoperative air-bone gap (ABG) was significantly higher in patients with wet ears than in those with dry ears, the postoperative ABG did not significantly differ between the dry- and wet-ear groups [7]. In a large-scale prospective study ($n=268$), Mills et al. [8]. reported that at 6 months after tympanoplasty, the perforation-healing rate did not differ between TMP patients who had undergone surgery in the dry- or wet-ear phase (83% vs. 82%, respectively; $P=0.9$). Some authors have pointed out that the inflammatory-cell infiltration and tympanic capillary dilation during the wet-ear phase are more conducive to tympanic membrane healing postoperatively [9]. Yu et al. [10]., Yingran et al. [11]., Mandal et al. [12]., and Wen et al. [13]. have all confirmed that tympanoplasty performed in the wet ear condition can result in tympanic membrane healing and significantly improve the hearing of patients with TMP, regardless of the presence of effusion, swelling, or granulation in the mucosa of the tympanic chamber.

Therefore, we designed a prospective case-control study with strict inclusion and exclusion criteria to investigate the perforation-healing rate and hearing improvement after dry- vs. wet-ear tympanic membrane repair. We focused on determining whether the state of the middle-ear cavity (dry vs. wet ears) at the time of surgery influenced the postoperative outcomes, especially the rate of tympanic-membrane healing. All patients were followed up at 1 and 3 months after the operation to evaluate their hearing recovery and check for postoperative complications like tinnitus. We focused on tympanic membrane healing and hearing recovery, as these factors have a meaningful impact on clinical work. If we can prove that tympanoplasty under the wet ear condition has no adverse effect on the rate of tympanic membrane healing, we will be able to reduce the intensity and duration of antibiotic use in clinical practice, thereby avoiding the overuse of antibiotics, and shortening the hospitalization time and expenses of patients, which are very clinically meaningful results.

Materials and methods

Ethical statement

The ethics committee of Zhangqiu People's Hospital approved the study protocol (approval number:

2022018). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. All participants signed informed consent forms for undergoing surgery and for the publication of this research, after they had been thoroughly informed of the potential risks and contingency plans.

Patient selection

For this prospective case-control study, we enrolled 32 patients with TMP who presented to our hospital between March 2021 and March 2023. The inclusion criteria were as follows: (a) Patients with chronic suppurative otitis media in the quiescent stage without ossicular chain lesions, as confirmed on computed tomography (CT), or patients with old TMP caused by trauma. (b) All patients had TMP involving the pars tensa. (c) Hearing test results showed that the ossicular chain was intact, and acoustic immittance screening ruled out abnormal eustachian tube function. (d) CT showed no irreversible inflammatory lesion in the upper tympanum and mastoid. (e) Good eustachian tube function was detected according to acoustic immittance. (f) Endoscopic examination of the ear confirmed TMP requiring type I tympanoplasty [14]. (g) Patients undergoing tympanoplasty for the first time who were judged to be able to tolerate the operation, and patients without any systemic disease. (h) Patients with repeated infections who were unable to reach a completely dry-ear state provided informed consent to undergo the procedure in the wet-ear condition. (i) All the patients included in the study had relaxation perforations, and the area of the tympanic membrane perforation accounted for 1/4th to 1/3rd of the tympanic membrane area. (g) None of the patients had a history of smoking, as reflected in their admission records.

Patients with the following were excluded from this study: (a) Ossicular chain lesion detected on CT, which also plays an important role in differentiating between the dry and wet state of the middle ear in chronic suppurative otitis media [15], (b) a history of middle ear or inner ear operation, (c) perforation of the pars flaccida, otitis media with cholesteatoma, or other middle ear diseases, (d) concomitant fungal external otitis, (e) requirement of ossicular surgery or other middle-ear surgery at the same time, (f) refusal to sign the informed consent form, and (g) inability to tolerate the operation due to systemic diseases such as diabetes and hypertension.

The enrolled patients were divided into a wet-ear group and a dry-ear group, according to the findings of microscopy and CT examinations. All patients provided informed consent prior to the surgery. The ethics

committee of Zhangqiu People's Hospital approved the study protocol (approval number: 2022018).

Definitions of dry ear and wet ear

Dry ear: No fluid exudation for at least 4 weeks in patients in the quiescent stage of chronic suppurative otitis media and patients with old traumatic TMP; no abnormal secretion in the ear canal and the presence of dryness in the tympanic chamber on endoscopy (Fig. 1a); and no soft-tissue shadow in the middle ear on CT examination.

Wet ear: Chronic suppurative otitis media with fluid exudation; clear secretions in the ear canal, moist tympanum, or mucosal swelling without purulent secretion on endoscopy (Fig. 1b); and a soft-tissue shadow in the middle ear on CT examination.

Surgical method

All subjects underwent the same procedure: tympanic membrane repair under ear endoscopic guidance, and all procedures were performed by the same surgeon, who has 16 years of experience in ENT surgery (Fig. 2). After the induction of general anesthesia, the patient was placed in a supine position, and the head was adjusted so that the affected ear faced upward. We used a perichondrium-cartilage compound graft to repair the tympanic membrane [16] during ear endoscopy-guided surgery (endoscopic view angle, 25°). For marginal perforations at a distance of 0.5–1.0 cm from the tympanic ring, the skin and tympanic membrane were turned up through an arc incision in the external auditory canal, and the perichondrium-cartilage graft was made under the skin

and the membrane. For middle perforations, the perichondrium-cartilage graft was placed internally without reversal. After exploring the tympanum and ossicular chain, and flushing the tympanum with dexamethasone solution, we placed the chondroperichondrial graft with the flap reversed to restore the external auditory meatus flap, and the repair of the tympanic membrane was completed. The external auditory meatus was filled with a gelatin sponge and iodoform gauze (Fig. 3). Patients were discharged on the third postoperative day, and instructed to take antibiotics orally for 1 week after discharge. After 10 days, the iodoform gauze was removed, and chloramphenicol eye drops and ear drops were used locally for 1–2 weeks.

Postoperative follow-up

The patients were followed up for the first time at 10 days after the operation. The iodoform gauze strips and residual gelfoam were removed from the external auditory canal, and ear endoscopy was performed. At 1 month and 3 months after the operation, the patients were followed up again, with complete otoscopy and pure tone audiometry tests (including air-conduction and bone-conduction thresholds at 250, 500, 1000, 2000, and 4000 Hz). We judged the healing of the tympanic membrane, the dryness of the operation cavity, and the hearing improvement according to the examination results.

The final tympanic membrane healing and hearing improvement were determined at 3 months, according to the ear endoscopy results. ABG gain, which was defined as the difference between the pre- and postoperative

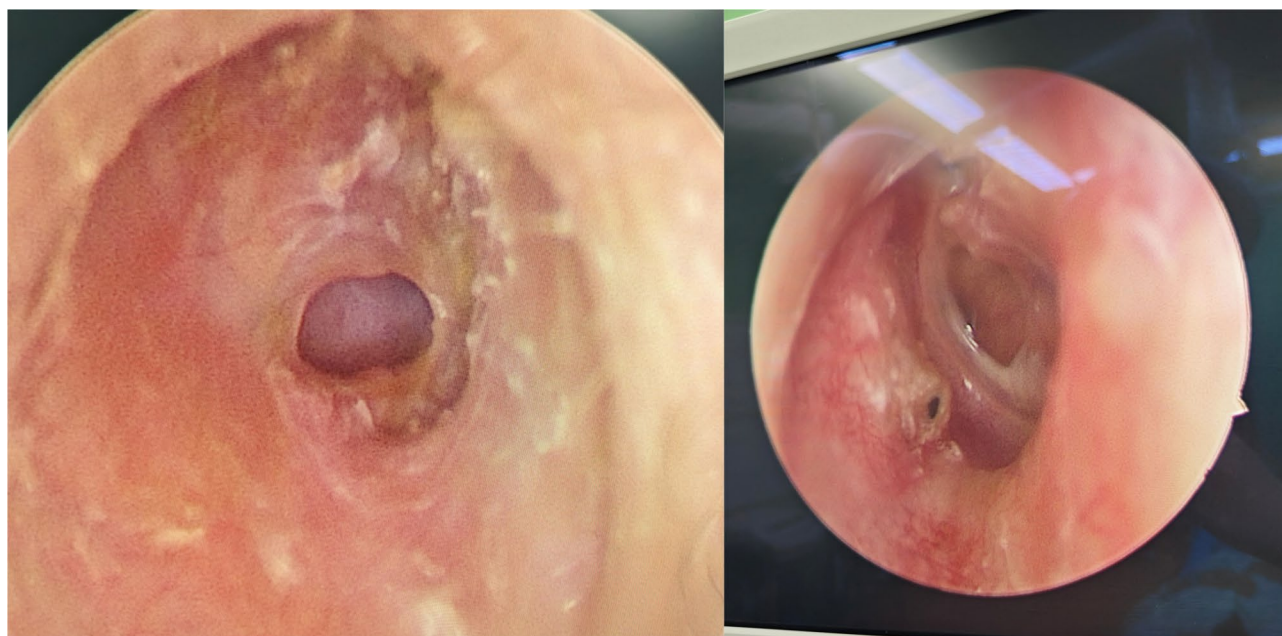


Fig. 1 Ear endoscopic images showing tympanic membrane perforation (TMP) in the dry- and wet-ear conditions. **(a)** Photograph of TMP in a dry ear, with no mucosal edema or watery exudation. **(b)** TMP in a wet ear, with mild mucosal edema and slight watery exudation



Fig. 2 Photographs of the tympanic membrane repair procedure performed by the same physician in all patients, was is also the author of this paper

ABG, was calculated to reflect the improvement in hearing after the operation. A mean postoperative ABG < 20 dB indicated successful hearing recovery. Tympanic membrane healing was defined as no residual TMP, and complete epithelialization and good shape of the tympanic membrane.

Statistical analysis

SPSS (version 19.0) statistical software was used for analysis. The datasets generated and analyzed during the present study are available from the corresponding author on reasonable request. The rate of tympanic membrane healing, pure tone audiometry results, ABG gain, and rate of tinnitus were compared between the dry ear group and the wet ear group before and 3 months after

the operation. Measurement data were analyzed using the *t*-test, while enumeration data were evaluated using the *t*-test, chi-square test, or Fisher exact test. $P < 0.05$ indicated a statistically significant difference.

Results

General information

A total of 32 patients were enrolled in this study, 18 in the dry-ear group and 14 in the wet-ear group. Age, sex, and affected side (left vs. right) did not significantly differ between the 2 groups (all $P > 0.05$, Fisher exact test; Table 1), indicating that the 2 groups were comparable.

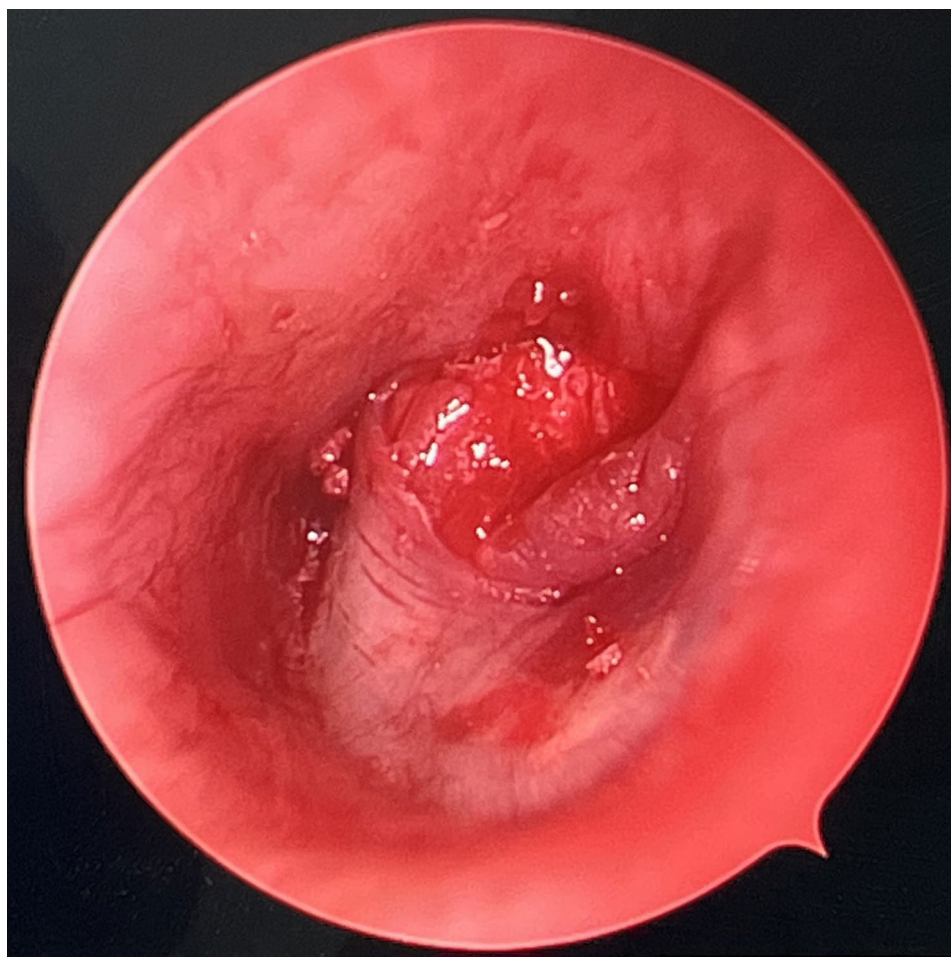


Fig. 3 Photographs of the freshly repaired tympanic membrane

Table 1 Comparison of age, sex distribution, and affected side between the 2 study groups

Parameter	Dry-ear group	Wet-ear group	Degrees of freedom	t value	P value*
Mean age (yrs)	44.588 ± 15.581	45.357 ± 15.579	29	0.1367	0.892
Sex (male/female)	8/10	4/10	1	0.1088	2.571
Affected ear (right/left)	8/10	5/9	1	0.8084	0.0588

*Chi square test

Main clinical outcomes

The perforation-healing rate at 3 months was comparable between the dry-ear and wet-ear groups ($P > 0.05$), indicating that surgery in the wet-ear phase did not decrease the rate of tympanic membrane healing. The dry-ear rate at 3 months was also similar in both groups ($P > 0.05$), indicating that surgery in the wet-ear phase did not affect the postoperative likelihood of achieving the dry-ear state (Table 2).

Postoperative hearing improvement

The mean air-conduction threshold, mean bone-conduction threshold, and mean ABG significantly differed between the dry-ear and wet-ear groups before and after the operation (all $P < 0.05$, t -test). In both the dry-ear and

wet-ear groups, hearing was significantly better after the operation than before the operation, indicating that the operation improved the patients' hearing (Table 3). The preoperative ABG was comparable between the dry-ear and wet-ear groups ($P = 0.0787$, $t = -1.8203$). The postoperative ABG was also similar in the 2 groups ($P > 0.05$, $t = 0.1171$). The above results show that tympanic membrane repair reduced the ABG and improved hearing, and that the hearing recovery was not adversely affected by surgery in the wet-ear state. This implies that operation can be performed under the wet-ear condition.

Postoperative complications

The incidence of tinnitus and hypoesthesia was significantly higher in the dry-ear group than in the wet-ear

Table 2 Comparison of clinical outcomes in the 2 study groups at 3 months after tympanoplasty

Parameter	Dry-ear group	Wet-ear group	P value	OR (95% CI)
Tympanic membrane healing			0.5681 (2-tailed) 0.2036 (1-tailed)	0.3529 (0.0286–4.3502)
Yes	17	12		
No	1	2		
Healing rate	94.44%	85.71%		
Dry ear			1 (2-tailed) 0.6915 (1-tailed)	0.7647 (0.0436–13.4116)
Yes	17	13		
No	1	1		
Dry-ear rate	94.44%	92.86%		

OR, odds ratio; CI, confidence interval

Table 3 Comparison of hearing recovery after tympanoplasty in the 2 study groups

Parameter	Dry-ear group	Wet-ear group
Mean airway conductance		
Preoperative	24.7037 ± 6.3736	64.1667 ± 11.331
Postoperative	13.5185 ± 7.0685	12.3214 ± 9.4234
P value	0	0.0001
t value	6.769	4.6546
Mean bone conductance		
Preoperative	11.1944 ± 5.7018	20.8333 ± 13.3813
Postoperative	5.9722 ± 3.3971	12.3214 ± 9.4234
P value	0.0021	0.0625
t value	3.3382	1.9436
Mean ABG		
Preoperative	21.25 ± 6.8387	17.6018 ± 4.4784
Postoperative	9.4047 ± 4.3415	6.5278 ± 5.4552
P value	0	0
t value	5.4714	6.6568

ABG, air-bone gap

group ($P > 0.05$, Table 4). Through the comparative analysis of the data in all groups, we concluded that operation under the wet ear condition has no effect on the rate of tympanic membrane healing.

Discussion

The results of this prospective study showed that tympanoplasty for the repair of TMP was feasible in patients with wet ears. Surgery in patients with wet ears resulted in tympanic perforation healing, reduced ABG, and hearing recovery at rates that were similar to the dry-ear group, without increasing the incidence of complications. When conservative treatment for TMP is ineffective, timely surgical intervention to repair the perforated

tympanic membrane and complete hearing reconstruction are particularly important. The present results show that surgery can be safely performed even for patients who are unable to achieve a dry-ear state preoperatively.

Tympanoplasty is classified into 5 types according to the Wullstein method: type I, tympanoplasty; type II, ossicular chain reconstruction; type III, columella-type tympanoplasty; type IV, small tympanoplasty; and type V, semicircular canal fenestration [17]. In this study, to minimize the influence of other external factors on the surgical results, we only selected patients who required type I tympanoplasty for tympanic membrane repair under ear endoscopy.

The repair of tympanic membrane defects is accomplished by implanting transplantation materials, which provide a scaffold for the regeneration and repair of the tympanic membrane epithelium and mucosa, thereby restoring the anatomical and functional characteristics of the tympanic membrane and improving hearing. The purpose of surgical treatment is to improve the ventilation and drainage system of the middle ear, reconstruct the sound transmission structure, and avoid the damage caused to the middle-ear structures by repeated infections, so as to improve hearing [18, 19]. Our analysis showed no significant difference in the rate of TMP healing nor the time required to achieve a dry-ear state between the dry- and wet-ear groups. Patients in both groups underwent hearing examinations before the operation, and at 1 month and 3 months after the operation. The results showed no significant between-group differences in the ABG. Therefore, for tympanic membrane repair surgery, the “wet” condition of the tympanic mucosa, for example, mild edema and slight watery exudation, does not affect the postoperative rate of TMP

Table 4 Comparison of postoperative complications in the 2 study groups

Parameter	Dry-ear group (n = 18)	Wet-ear group (n = 14)	P value (2-tailed)	P value (1-tailed)	OR	95% CI
Tinnitus	1	2	1	0.5964	1.625	0.1321–19.9872
Hypoesthesia	1	1	1	0.6915	0.7647	0.0436–13.4116

OR, odds ratio; CI, confidence interval

healing nor the hearing improvement. Most patients achieved a dry-ear state within 3 months after the operation. In this study, the rate of tympanic membrane healing was slightly lower in the wet-ear group than in the dry-ear group, though the difference was not statistically significant. This may be related to the small sample size. Larger samples will be needed in future works to verify this conclusion.

In the present study, eustachian tube function was routinely assessed during the operation. The acoustic immitance was examined preoperatively, and the eustachian tube orifice was examined for inflammatory exudation and tenderness by using intraoperative endoscopy. In addition, the eustachian tube was flushed with normal saline during the surgery to avoid eustachian tube occlusion, which can lead to poor postoperative healing. Caylan et al. [20]. believe that the increased mucosal blood vessels on the tympanic membrane in the wet-ear state may increase the rate of tympanic membrane healing. Chai Wei et al. [21]. conducted a pathological study of the tympanic membrane remnant after TMP, and found that capillary dilation and inflammatory-cell infiltration in the tympanic membrane remnant were more obvious in the wet-ear condition than in the dry-ear condition. Whether the increase in capillaries in the tympanic membrane plays a positive role in perforation healing needs to be determined in further research work.

Some studies have shown that epithelial stem cells are mainly distributed in the tympanic ring and malleus stem area of the tympanic membrane [22, 23]. The epithelial repair and closure of TMP is mainly completed by the differentiation and proliferation of stem cells in the germinal center of the epithelium on the malleus stem, which is away from the perforated tympanic ring, and cell migration to the perforation; it is not the result of epithelial hyperplasia at the margins of the perforation. Tympanoplasty can have good results as long as it provides a scaffold for epithelial cell migration. A flat-surface graft facilitates the migration of the proliferating epithelial cells to the center of the perforation for healing [24]. This also suggests that the success of the operation depends not only on a healthy internal environment but also adequate preparation of the implantation bed during the operation, which is key to the migration of cells from the germinal center, and increases the rate of tympanic membrane healing and improves the rate of surgical success. Qu Juan et al. [25]. consider that the rate of tympanic membrane healing is adversely affected by the following: (i) small anterior tympanic membrane remnant and poor blood supply, (ii) neovascularization proceeding from the posterior to the anterior direction, so that the anterior remnant is the last to develop neovascularization, and (iii) graft contracture and collapse in the anterior part, resulting in the graft becoming detached

from the remaining tympanic membrane, which may be related to insufficient tamponade in the tympanum or premature drainage of the eustachian orifice. Some studies have reported that the occurrence of tympanic membrane fissure after tympanic membrane repair is related to the treatment of the tympanic ring, the treatment of the external auditory canal flap, and the method of graft implantation [26, 27].

Although our data showed that surgery in the wet-ear state did not affect the rate of TMP healing, our sample size was small, and surgery in the wet-ear state should be undertaken with caution. It is ideal to achieve a dry-ear state before the operation; however, if this is not possible because of the existence of TMP and repeated infections, the patient should be informed of this condition and the possibility of unsatisfactory healing after the operation. After receiving the patient's consent, prophylactic antibiotic treatment should be given and the operation performed. Antibiotic treatment is recommended for another 3 days after the operation. In the present study, bleeding and exudation were observed after the operation. However, as the tympanic membrane was repaired under otoscopy and the wound surface was small, the exudation disappeared after 3 days. If there is no improvement or gradual reduction in exudation, the iodoform gauze used to pack the ear canal can be withdrawn, and the secretions collected for bacterial culture and drug-sensitivity tests to adjust the antibiotic treatment as required. In our study, 1 patient who underwent wet-ear surgery had increased exudation during the healing period; the tympanic membrane healed normally in this patient after administration of the above treatment. In another patient from the wet-ear group, the tympanic membrane did not heal probably because the perforation was large. A small residual lacunar perforation was observed at the interface of the tympanic membrane with the external auditory canal when this patient was reexamined at 3 months after the surgery; however, this patient's subjective hearing improvement was acceptable.

The limitations of this study should be acknowledged. The biggest deficiency of our study is that the amount of data is too small. This is because in order to reduce the factors that may affect the healing of the tympanic membrane, we applied strict inclusion and exclusion criteria, which were designed to minimize their potential impact on the results. Nevertheless, the rigorous screening of the patients, though restrictive, provides a degree of credibility to the results. This provides us with confidence to carry out more operations in our clinical practice in the future. Additionally, these results will serve as a base for collecting further data to demonstrate the feasibility of our study.

Conclusion

We concluded that type I tympanoplasty for TMP can be safely performed in the wet-ear state, without adversely affecting the surgical outcomes. Mucoïd ear discharge at the time of surgery is not a contraindication for tympanoplasty, as it has no adverse effects on the outcomes of the surgery with respect to graft uptake and hearing improvement. This study concluded that there is no added advantage of drying the ear; rather, the delay in treatment with this approach tends to increase morbidity and dropouts.

Abbreviations

ABG Air-bone gap
TMP Tympanic membrane perforation

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Author contributions

Conceptualization: Jia Yang
Data curation: Qinglin Bai
Formal analysis: Jun Zhang
Funding acquisition: Jia Yang
Investigation: Na Zhao
Methodology: Qinglin Bai
Project administration: Yang Jia
Resources: Qinglin Bai
Software: Cong Li
Supervision: Jun Zhang
Validation: Qinglin Bai
Visualization: Na Zhao
Writing – original draft: Jia Yang
Writing – review & editing: Jun Zhang
All of the authors have read and approved the manuscript.

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Data availability

The datasets generated and analyzed during the present study are available from the corresponding author on reasonable request. With regard to the publication and utilization of data and materials, all contributing authors to this article have executed consent declarations.

Declarations

Ethics approval and consent to participate

The ethics committee of Zhangqiu People's Hospital approved the study protocol (approval number: 2022018). All participants signed informed consent forms for undergoing surgery and for the publication of this research, after they had been thoroughly informed of the potential risks and contingency plans. All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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