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OTOLOGY

Endoscopic tympanoplasty with limited tympanomeatal flap elevation in pediatric cases: comparison of anatomic and audiological results of grafts

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Abstract

Objectives The anatomical and functional success rates of tragal cartilage perichondrium and temporal muscle fascia, in pediatric patients who underwent endoscopic type 1 tympanoplasty with limited tympanomeatal flap elevation, were compared.

Methods In total, 35 pediatric patients (21 females, 14 males; mean age 11.0 ± 1.5 years; range 8–14 years) who underwent transcanal endoscopic type 1 tympanoplasty with limited elevation of the tympanomeatal flap were included in this study. Patients in group A received a tragal cartilage perichondrium graft and those in group B received a temporal muscle fascia graft. The groups were compared with respect to the pre- and postoperative air–bone gap (ABG) and tympanic membrane status.

Results The mean preoperative and postoperative ABG were 27.0 ± 9.2 and 9.0 ± 8.5 dB in group A, and 26.8 ± 8.8 and 11.6 ± 9.2 dB in group B, respectively. The group differences in pre- and postoperative ABG values were not significant ($p = 0.882$ and $p = 0.417$, respectively). However, in both groups, the postoperative ABG was significantly lower than the preoperative ABG (both $p = 0.0001$). The graft retention rate was 100% in group A and 88.2% in group B; the difference was not statistically significant ($p = 0.134$). There was also no statistically significant difference between the pre- and postoperative bone conduction values of the patients at 0.5, 1, 2, 3 or 4 kHz (all $p > 0.05$).

Conclusions Our study demonstrated that in pediatric patients undergoing endoscopic tympanoplasty, both the tragal cartilage perichondrium and the temporal muscle fascia can be used successfully and safely as grafts in endoscopic type 1 tympanoplasty performed by limited tympanomeatal flap elevation.

Keywords Endoscopic tympanoplasty · Pediatric · Tympanomeatal flap · Perichondrium · Fascia

Introduction

Tympanoplasty is one of the most common otologic surgeries in pediatric patients. The aim of this invasive procedure is to ensure anatomical and functional integrity of the tympanic membrane [1]. The first case of tympanic membrane perforation surgery was published by Berthold [2], in 1878, with modern tympanoplasty techniques later being introduced by Zöllner [3] and Wullstein [4]. Further development of tympanoplasty techniques, including minimally invasive endoscopic tympanoplasty, and their widespread use and refinement have resulted in a success rate for tympanoplasty of > 90% [5–7].

In endoscopic tympanoplasty, introduced in the 1990s, the anatomic structures in the middle ear, anterior and posterior epitympanic space, sinus tympani and facial recess can be well visualised endoscopically. Although tympanoplasty can be performed using different techniques and grafts, there is no consensus in the literature regarding the optimal tympanoplasty surgical technique, or regarding graft selection, for pediatric patients. In fact, very few studies have reported the results of endoscopic tympanoplasty for children. Thus, the experience and preferences of the surgeon currently

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determine the selection of the surgical technique and graft in pediatric tympanoplasty [1, 8–10].

Elevation of the tympanomeatal flap is one of the most fundamental steps in tympanoplasty [11]. Different types of incisions for tympanomeatal flap elevation have been described in the literature, but elevation of a superiorly based flap via a radial incision is the most commonly preferred option [11–13]. The amount of tympanomeatal flap to be elevated varies depending on the size of the perforation. Ayache [13] defined different types of tympanomeatal flap incisions according to perforation size and location. Satisfactory anatomic and functional success can be achieved via limited tympanomeatal flap elevation and use of various grafts. In endoscopic tympanoplasty, the tympanomeatal flap can be elevated through the transcanal route; however, flap elevation is not a strict requirement, especially when fat grafting is performed.

In this study, the anatomical and functional success rates of two types of grafts, tragal cartilage perichondrium and temporal muscle fascia, used in pediatric patients undergoing endoscopic type 1 tympanoplasty performed by limited tympanomeatal flap elevation, were compared.

Methods

This retrospective clinical study was conducted between January 2014 and January 2018 at the Ear Nose Throat, Head and Neck Surgery Clinic of our hospital. The study population consisted of 35 patients (21 females, 14 males; mean age 11. 0 ± 1.5 years; range 8–14 years) who underwent transcanal endoscopic type 1 tympanoplasty with limited elevation of the tympanomeatal flap. The Middle Ear Risk Index (MERI) scores of the patients ranged between 1 and 3. The study was approved by the Ethics Committee of our hospital (no: 05/11/2018-11-E.45058) and was carried out in accordance with the Principles of the Declaration of Helsinki and the Guideline for Good Clinical Practice. All the study patients were followed up in our clinic for at least 12 months.

The exclusion criteria were as follows: adult cases; tympanoplasty other than type 1; endoscopic tympanoplasties without elevation of the tympanomeatal flap; microscopic types of tympanoplasty; patients with mastoidectomy, defects of the ossicular chain, cholesteatoma or tympanosclerosis; patients who underwent prior tympanoplasty procedures; and patients who did not undergo regular follow-up examinations.

All patients underwent temporal computed tomography (CT) and audiologic examination prior to surgery. The temporal CT examination evaluated middle ear pathologies and potential neurovascular anomalies (high jugular bulb, fallopian canal defects, etc.). All the patients were operated on under general anaesthesia, performed according to the well-established principles of ear surgery.

Age, sex, operated ear, size of the tympanic membrane perforation, type of graft used, pathologies and status of the middle ear, preoperative and postoperative audiologic test results, graft status during postoperative follow-up, and the follow-up period were recorded. The data for this retrospective study were obtained from the patient files in the hospital records system. The middle ear status of the patients was assessed preoperatively using the MERI [14]; this was done to prevent bias, by matching the groups according to the MERI score. Patients with MERI scores > 3 were excluded from the study. The extent of tympanic membrane perforation was classified as 100% (total), $> 50\%$, or $< 50\%$.

The patients included in the study were divided into two groups according to the type of graft used: tragal cartilage perichondrium (group A) and temporal muscle fascia (group B). The graft type used in the tympanoplasty was assigned according to the experience and preference of the two surgeons (one surgeon used only tragal cartilage perichondrium for grafting, and the other used only temporal muscle fascia). All the operations were performed at our clinic in accordance with the well-established principles of ear surgery. Tympanic membrane perforation was assessed endoscopically in all patients before graft extraction, using a 3-mm 18-cm rigid endoscope (HOPKINS II; Karl Storz, Tuttlingen, Germany). The images were viewed on a 24-inch full HD monitor (Karl Storz). After the perforation margins were determined, the grafts were obtained. In all cases, the middle ear was entered after the tympanomeatal flap was elevated 5 mm lateral to the annulus of the tympanic membrane, which allowed safe positioning of the graft. If a wider exposure was needed, the degree of tympanomeatal flap elevation was adjusted under endoscopic guidance, with greater flap elevation applied for large and anterior perforations. In group A patients, the grafts were obtained by taking the anterior and posterior perichondrium of the tragal cartilage, while preserving the tragal cartilage itself. In group B, a 2- to 3-cm supra-auricular incision in the temporal muscle fascia was made. The grafts were placed over the malleus and under the anterior annulus with an over-underlay technique, after being shaped to fit the tympanic membrane perforation while also checking the ossicular chain. The tympanomeatal flap was then repositioned (Figs. 1a–e and 2a–e for groups A and B, respectively). The supra-auricular incision was then sutured in accordance with the anatomical plane. The grafts were supported medially and laterally using Gelfoam.

The status of the tympanic membrane at postoperative months 1, 3 and 6 and the pure-tone audiometry results at postoperative month 6 were recorded. We compared the pre- and postoperative air–bone gap (ABG) values and tympanic membrane status of the two groups, together with their preoperative and postoperative bone conduction values, to

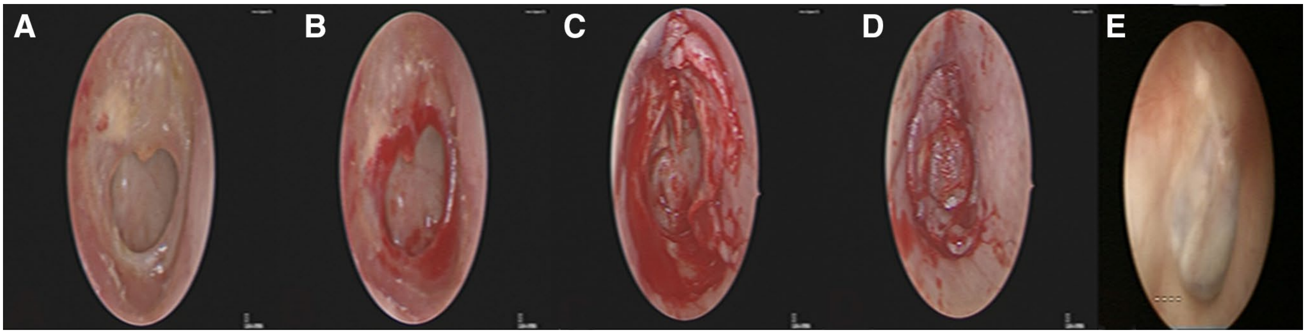

Fig. 1 Preoperative and postoperative surgical stages: group A. **a** Preoperative view of the tympanic membrane perforation. **b** View after determining the perforation edges. **c** Limited tympanomeatal flap elevation. **d** Graft placement using the over-underlay technique. **e** Postoperative view of the tympanic membrane at 12 months

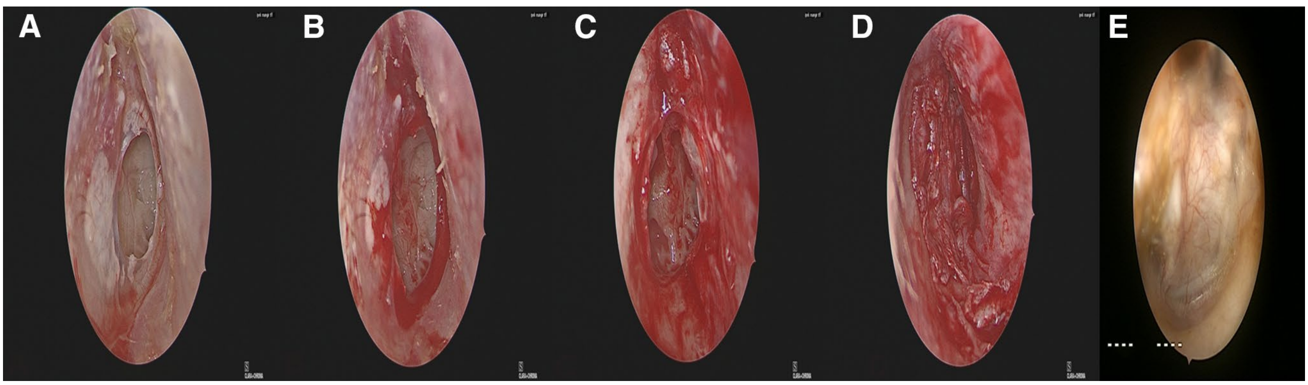

Fig. 2 Preoperative and postoperative surgical stages: group B. **a** Preoperative view of the tympanic membrane perforation. **b** View after determining the perforation edges. **c** Limited tympanomeatal flap elevation. **d** Graft placement using the over-underlay technique. **e** Postoperative view of the tympanic membrane at 12 months

evaluate the effect of the endoscopic procedure on cochlear function. The mean of four frequencies (0.5, 1, 2, and 4 kHz) was calculated to assess the ABG. An intact tympanic membrane, without signs of retraction or lateralisation, and a postoperative reduction in the ABG of <20 dB were considered indicative of surgical success.

Statistical analysis

The NCSS 2007 software (NCSS, Kaysville, UT, USA) was used for the statistical analyses. Descriptive statistics were initially generated (mean, standard deviation, median, frequency, rate, minimum, maximum). Student's t test was used to evaluate normally distributed quantitative patient data, and the Mann–Whitney U test was used to analyse data that did not show a normal distribution. Postoperative and preoperative evaluation results were compared using the paired-samples test. Pearson's chi-squared test and the Fisher Freeman Halton test were used to analyse qualitative data. Significance was defined as $p<0.05$.

Results

Group A consisted of 18 patients and group B of 17 patients; the mean operation time was 58.22 ± 10.06 and 54.14 ± 10.60 min, respectively. The two groups did not significantly differ in age, sex, length of follow-up, MERI score, operation time or perforation size (all $p>0.05$; Table 1).

The mean preoperative and postoperative ABG in group A were 27.0 ± 9.2 and 9.0 ± 8.5 dB, respectively; the corresponding values in group B were 26.8 ± 8.8 and 11.6 ± 9.2 dB. The group differences in pre- and postoperative ABG values were not significant ($p=0.882$ and $p=0.417$, respectively). However, in both group A and group B, the postoperative ABG was significantly lower than the preoperative ABG ($p=0.0001$ and $p=0.0001$, respectively). The degree of ABG improvement did not significantly differ between the groups ($p=0.328$; Table 2).

The graft retention rate was 100% in group A and 88.2% in group B; the difference was not significant ($p=0.134$).

Table 1 Comparison of subject data in each group

Variables	Group A (perichondrium) ($n = 18$)	Group B (fascia) ($n = 17$)	p
Age (years)	11.12 ± 1.3	10.8 ± 1.6	0.400[a]
Gender			
Females	10 (55.6%)	11 (64.7%)	0.581[c]
Males	8 (44.4%)	6 (35.3%)	
The side operated			
Right	7 (38.9%)	8 (47.1%)	0.625[c]
Left	11 (61.1%)	9 (52.9%)	
MERI score	2.08 ± 0.88	2.44 ± 1.22	0.578[b]
Graft intact			
Perfore	0 (0.0%)	2 (11.8%)	0.134[c]
Intact	18 (100.0%)	15 (88.2%)	
Perforation size			
Medium (25–50)	9 (50.0%)	6 (35.3%)	0.380[a]
Total (%100)	0 (0.0%)	1 (5.9%)	0.420[a]
Subtotal (> 50)	9 (50.0%)	10 (58.8%)	0.216[a]
Mean operating time (min)	58.22 ± 10.06	54.14 ± 10.60	0.318[d]
Mean follow-up time (month)	18.7 ± 3.44	19.9 ± 5.20	0.585[d]

[a]Independent samples test

[b]Yates continuity correction

[c]Fisher's exact test

[d]Mann–Whitney *U* test

Table 2 Comparison of air–bone gap and the hearing gains between the two groups pre- and postoperatively

Air bone gap	Preoperative ABG (dB)	Postoperative (dB)	p^a	Gain (median)
Group; mean ± SD				
Group A (*N*: 18)	27.0 ± 9.2	9.0 ± 8.5	0.001**	18.0 ± 7.20
Group B (*N*: 17)	26.8 ± 8.8	11.6 ± 9.2	0.001**	15.20 ± 6.70
p^b	*0.882*	0.417		*0.328*

[a]Paired samples test; comparison ABG between two groups pre- and postoperatively

[b]Mann–Whitney *U* test: comparison between two groups in terms of gain

**$p < 0.01$, *$p < 0.05$

Table 3 Comparison of the bone conduction values of patients pre- and postoperatively

	Preoperative BC	Postoperative BC	p*
0.5 kHz	7.00 ± 2.63	7.00 ± 2.34	0.643
1 kHz	7.00 ± 2.75	6.58 ± 2.29	0.160
2 kHz	7.17 ± 4.75	7.25 ± 3.37	0.510
3 kHz	7.47 ± 3.03	7.39 ± 2.98	0.436
4 kHz	7.28 ± 3.28	7.18 ± 2.24	0.602

BC bone conduction

*Mann–Whitney *U* test

The pre- and postoperative bone conduction values of all patients are listed in Table 3 and did not differ at 0.5, 1, 2, 3 or 4 kHz in either group (all $p > 0.05$).

Discussion

In this study, the anatomical and functional success rates of tragal cartilage perichondrium and temporal muscle fascia, in pediatric endoscopic type 1 tympanoplasty with limited tympanomeatal flap elevation, were compared. According to our literature review, this is the first study on this subject. Given the limited number of published studies focused on pediatric tympanoplasty and thus the limited amount of data, there is no consensus on many of the issues related to this procedure.

The majority of studies evaluating the results of endoscopic tympanoplasty were conducted in adults. Among the few pediatric studies, most compared endoscopic and microscopic (i.e. traditional) methods. For example, Awad and Hamid [15] reported similar anatomical and functional success rates between endoscopic type 1 tympanoplasty and other methods. Cohen et al. [16] compared the results of endoscopic and non-endoscopic tympanoplasties and also reported similar anatomical and functional success rates in pediatric cases. Lade et al. [17] noted that canaloplasty was needed to evaluate the ossicular chain in patients undergoing traditional, but not endoscopic, tympanoplasty. The authors reported similar success rates for the two tympanoplasty methods, but also superior cosmetic results for the endoscopic procedure. Recent literature data also support the use of endoscopic tympanoplasty as an effective and reliable method in pediatric patients [11].

The main factor affecting the success of tympanoplasty grafting is the blood supply and neovascularisation of the graft [11]. Disruption of the arterial blood supply of the graft will inevitably result in failure of the tympanoplasty. Applebaum and Deutsch [18] investigated the dynamic vascularisation of the tympanic membrane by fluorescein angiography and showed that the arterial blood supply of the tympanic membrane mainly originates from the malleolar artery in the posterior tympanic quadrant, the perfusion of which is richer than that of the anterior quadrant. The same authors found that blood flow to the anterior quadrant of the tympanic membrane is mainly from blood vessels branching from the annulus and that the rate of flow was consistently lower than that to the posterior quadrant. These studies suggest that in patients with limited tympanomeatal flap elevation, the blood supply will be less impaired, and the grafting success accordingly higher. An uninterrupted blood supply should allow for rapid wound healing and improved take of the graft. While limited incisions may reduce the continuity of the annulus and tympanomeatal flap, this remains controversial [19]. Limited tympanomeatal flap elevation may also prevent complications related to dissection of the annulus and reduce residual perforations, especially on the anterior side [11, 13].

Limited tympanomeatal flap elevation, while increasing the rate of graft success, affords surgeons less opportunity to evaluate middle ear structures and the ossicular chain. In addition, the steep learning curve associated with endoscopic tympanoplasty may result in a longer duration of surgery [9, 10]. However, given the flexibility of the graft and the flexible nature of the tympanomeatal flap, neither these restrictive factors nor the use of a limited incision are problematic, and with experience their potential drawbacks should be inconsequential.

In this study, the average preoperative ABG in group A was 27 dB and, in 50% of these patients, the perforation was of medium severity. The high preoperative ABG in this group might be explained by the location of the perforations, as a large number of group A patients had anterior perforations. Two patients in group B also had anterior perforations and the procedure was not successful in either of them. In addition, one of the patients had a total perforation and the other had a partial perforation. The graft success rate in our study was consistent with the results of previous reports of endoscopic and microscopic tympanoplasty [8, 11, 12]. In endoscopic tympanoplasty, either the tragal cartilage perichondrium or the temporal muscle fascia can be safely used as a graft. In addition, limited tympanomeatal flap elevation is not a limiting factor in any type of surgery using tympanic membrane perforations, including endoscopic tympanoplasty.

The greater sensitivity of the pediatric central nervous system to anaesthetic agents emphasises the importance of a short operation time. Furthermore, prolongation of the operation time and greater exposure to anaesthesia may affect the concentration of the surgeon and thus increase the risk of iatrogenic complications [20, 21]. Ideally, neither the surgical technique nor the graft used in the tympanoplasty should unnecessarily prolong the operation. In our patients, this was avoided by harvesting the graft from a site close to the surgical site. Thus, the mean operation time was 58.22 ± 10.06 and 54.14 ± 10.60 min in the perichondrial and fascia groups, respectively.

Among the strengths of this study was the relatively long-term follow-up period of 6 months postoperatively. Other strengths included the strict inclusion criteria and similar demographic characteristics and MERI scores of the two groups at baseline. Nonetheless, there were also several limitations to our study, such as its retrospective nature and the relatively small number of patients, which prevented statistically meaningful classification of the perforations as anterior, posterior, total or partial. However, the patients' medical files did indicate the extent of the tympanic membrane perforation [100% (total), > 50% or < 50%]. As noted above, the success rate of tympanoplasty was lower among patients with an anterior perforation. Also, the surgeries were performed by two different surgeons, although both had > 5 years of experience in ear surgery and all surgeries were performed in accordance with the current endoscopic otologic surgical guidelines. In the literature, there are few, if any, studies comparing the success of two different graft sources for pediatric endoscopic tympanoplasty with limited tympanomeatal flap elevation. Thus, further prospective randomised studies including larger numbers of patients are still required.

Conclusion

Our study compared the anatomic and functional success of perichondrial and fascia grafts for pediatric endoscopic tympanoplasty with limited tympanomeatal flap elevation. Both grafts were found to be suitable for use in endoscopic tympanoplasty. In addition, limited tympanomeatal flap elevation was shown to be effective, reliable and successful in our patients. We thus conclude that, in pediatric endoscopic tympanoplasty, both the tragal cartilage perichondrium and the temporal muscle fascia can be used in conjunction with limited tympanomeatal flap elevation for safe and successful endoscopic tympanoplasty.

Funding This study did not receive external funding.

Compliance with ethical standards

Conflict of interest The authors declare no conflicts of interest.

Ethical approval The study was approved by the ethics committee of the same hospital (Ethical committee no: 05/11/2018-11-E.45058). The study was carried out in accordance with the Principles of the Declaration of Helsinki and Guideline for Good Clinical Practices. All procedures performed in the 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.

Informed consent Informed consent was not obtained from the patients in this study due to its retrospective design and the implementation of anonymisation procedures.

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