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Original Research Article

Could tympanometric volume be a useful tool to predict the success of type I tympanoplasty in simple chronic otitis media

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ABSTRACT

Background: Middle ear aeration level is an important precursor of chronic otitis media (COM) and one predictive factor for tympanoplasty success. Tympanometry measures the volume of the external ear canal, middle ear cavity, aditus, and mastoid air cells in patients with tympanic membrane (TM) perforation. The aim of the study was to determine whether the pre-operative tympanometric volume and the interaural tympanometric volume differences in unilateral simple COM can predict the success of type I tympanoplasty.
Methods: Retrospective analysis of type I tympanoplasties performed in adults between January 2017 and December 2020 in a tertiary hospital. Bilateral COM, revision surgery and tympanoplasty using cartilage grafts or associated with other procedures were excluded. Success was defined as no evidence of TM perforation on otoscopic examination and tympanogram, at least six months after surgery.
Results: Sixty-one patients were evaluated. The mean age was 43 years old, and there was a female predominance (55.7%). The overall success rate was 77%. Location or size of perforation weren't different among patients with and without surgical success. We found a statistically significant result (p=0.009) regarding interaural tympanometric volume differences, with a median of 2.7 ml (IQR 3.6) in the surgical success group and a median of 1.3 ml (IQR 1.26) in the recurrence group. 90.6% of patients with interaural tympanometric volume difference greater than 2 ml had successful surgery.
Conclusions: A good aeration of middle ear, demonstrated by higher interaural tympanometric volume differences, can predict success of type I tympanoplasty.

Keywords: Chronic otitis media, Tympanoplasty, Ear canal volume, Tympanometry

INTRODUCTION

Tympanoplasty is a surgical procedure used to access and treat pathology of the tympanic membrane and the middle ear. The main goal of the surgery is to reestablish middle ear function by restoring the integrity of a perforated tympanic membrane and to access and treat pathology in the middle ear (chronic infection, cholesteatoma or ossicular chain alterations).[1,2] Eustachian tube dysfunction and altered ventilation of the middle ear is recognized as the most important precursor of chronic ear disease.[1,3]

Additionally, adequate aeration of the middle ear is one of the main predictive factors for the success of tympanoplasty.[1,4] There are some indicators of good ventilation that may be seen as good prognostic factors for the success of tympanoplasty: aeration of the opposite ear, increased age in children, fewer episodes of otorrhea, normal middle ear mucosa, among others.[1,5] It is therefore clinically relevant to assess the ventilation of the middle ear and mastoid air cells in patients with chronic ear disease when considering surgery.

Tympanometry is a noninvasive exam that measures the impedance and static compliance of the tympanic membrane and tympano-ossicular system. This result reflects the state of middle ear ventilation and eustachian tube function.[3,6] A typical tympanometry report of a normal ear comprises the external ear canal volume and the compliance of the tympanic membrane.[3,6] Mathematically, the tympanometry curve is derived from the acoustic admittance which measures how easily the sound from the tympanometry probe is transmitted through the sound conducting system.[7]

Tympanometry also measures the volume of the sound conducting system, which in a normal ear measures the volume of the ear canal while in patients with simple chronic otitis media (COM) it measures the ear canal volume plus middle ear and possibly mastoid cells. So, in a patient with unilateral simple COM, if we subtract the volume of the good ear to the total volume of the affected ear, we obtain the volume of the middle ear plus the mastoid cells, and it is usually greater than 2 ml.[6,7] This means, in theory, that a higher ear volume in tympanometry measure reflects a greater aerated middle ear in patients with COM without cholesteatoma. This theory was demonstrated in a work by Epprecht et al. who studied the correlation between tympanometry volumes and the volume of mastoid air cells measured on CT scans and concluded that there is a high correlation between those two measures in patients with dry tympanic membrane perforations.[4] It has been demonstrated by Merenda et al that the tympanometric volume of the middle ear, as measured by tympanometry, is an important factor when considering timing of tympanoplasty in the pediatric patient: larger volumes correlate with higher success rates.[5]

The aim of the study was to determine whether, in adult patients with unilateral simple COM, the pre-operative tympanometric volume and the interaural tympanometric volume differences, which evaluates only the volume of the middle ear, can predict the success rate of type I tympanoplasty.

METHODS

We performed a retrospective analysis of all patients who underwent type I tympanoplasty procedure in Hospital de Braga with temporalis fascia graft for chronic otitis media without cholesteatoma and without otorrhea for at least six months between January 2017 and December 2020. The data was collected from the patients' electronic clinical processes in the Glintt® platform. Approval of the study by the ethical guidelines committee was obtained. The following data were registered: age, gender, localization and size of perforation, tympanoplasty technique and pre-operative tympanometric volumes of both ears. With these data, and assuming that both healthy and pathologic ear have identical ear canal volumes, we calculated the interaural tympanometric volume differences by subtracting the volume of the healthy ear to the total volume of the pathologic one, which gives us de volume of the middle ear and mastoid cells. We also used a cut-off of 2 cm^3 for the interaural tympanometric volume differences and divided the patients in two groups according to that cut-off.

The exclusion criteria were patients younger than 18 years-old, patients with bilateral COM, tympanoplasty using cartilage grafts, revision surgery, lack of clinical information, and when tympanoplasty was associated with other procedures (for example mastoidectomy, ossicular reconstruction, or balloon Eustachian tuboplasty).

We considered the surgery successful when the patient had no evidence of TM perforation in otomicroscopy associated with a normal tympanogram (volume inferior to 2 cm^3 and type A curve), for at least six months of follow-up. Sampling method was a census and included all patients who fulfilled the inclusion criteria and didn't present any exclusion criteria.

The statistical analysis was performed with IBM Corp. Released 2020. IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp®. Categorical variables results are described in frequencies and percentages. Continuous variables measures are presented as means and standard deviations or medians and interquartile ranges if the variables didn't present a normal distribution which was evaluated using skewness and kurtosis or Shapiro-Wilk test. The two-sample t test or the Mann Whitney test were used to compare two independent samples while ANOVA or Kruskal-Wallis test were applied to compare more than two independent samples according to the distribution of the variables. The chi-square test was used to evaluate the association between two or more categorical variables. A multivariate analysis was performed with logistic regression to evaluate if the ear canal volume or the ear canal volume difference can predict a successful surgery. We considered a result statistically significant when de p value was <0.05.

RESULTS

Sixty-one patients who fulfilled the inclusion criteria and had no exclusion criteria were included in our study. The age of our patients ranged from 19 to 68 years with a mean age of 43 (±14.4) years, and there was a slight female predominance (55.7%).

The tympanometric ear canal volume of the whole group varied between 1.7 and 9.8 cm^3 and the median volume was 3.7 cm^3 (IQR 3.22). The majority (59%) of perforations were small (<25%), 29.5% were marginal and around half of them were posterior (50.8%), 29.5% anterior and the remaining 19.7% were inferior. The tympanometric volume was not influenced by the size (<25%; 25-75%; >75%) or location (anterior, posterior, or inferior) of the perforation but it tended to be statistically significantly higher (p=0.006) in patients with marginal perforations (Mdn=5.2; IQR 4.2) when compared with

patients with central perforations (Mdn= 2.92; IQR 2.7) (Table 1). The overall success rate for type I tympanoplasty performed during the study period was 77%. We didn't find any statistically significant differences regarding the age, gender, location, size and marginal or not perforations between patients of which surgery was successful and those with recurrence of the TM perforation (Table 2). Also, we found no statistically significant difference between those groups regarding the tympanic ear canal volume measure. However, we verified a statistically significant result (p=0.009) when comparing the interaural tympanometric volume differences. The patients whose surgery was successful, the interaural tympanometric volume differences median was 2.7 ml (IQR 3.6) whereas in the recurrence group the median was 1.3 ml (IQR 1.26) (Table 3). Additionally, both the interaural differences and the tympanometric volume of the perforated ear, had an impact on surgical outcome of tympanoplasty in the multivariate analysis (Table 4). In fact, an increase in 1 cm^3 in the interaural tympanometric volume difference increases de odds of having a successful surgery by 2.6% (p=0.003). However, we also verified that a higher volume of the pathologic ear canal in tympanometry increases the chance of having a reperforation (p=0.008). Since a higher interaural tympanometric volume difference seemed to increase the odds of a successful surgery, we applied a 2 cm^3 cut-off and found a statistically significant relation between having a difference bigger than 2 cm^3 and a successful surgery (p=0.008), 90.6% of patients with interaural volume difference ≥2 cm^3 had a successful surgery while the same was only verified in 62.1% of the patients with a difference ≤2 cm^3 (Table 2).

Table 1: Association between the characteristics of perforation and pathologic ear canal tympanometry volume.

Variables	Test	P value
Localization of perforation	H(2)=5.56	0.062
Size of perforation	H(2)=2.891	0.236
Marginal perforation	U= 214.5	0.006

Note: H(2)=Kruskal-Wallis H; U= Mann-Whitney U

Table 2: Comparison between successful surgery and re-perforation groups- categorical variables.

Variables	Successful surgery (n)	Re-perforation of tympanic membrane (n)	Statistics (X^2)	P value
Gender			0.538	0.463
Female	25	9		
Male	22	5		
Site of perforation			1.592	0.451
Anterior	12	6		
Posterior	25	6		
Inferior	10	2		
Size of perforation			3.536	0.171
<25%	28	8		
25-75%	18	4		
>75%	1	2		
Marginal perforation			1.557	0.212
Yes	12	6		
No	35	8		
Interaural tympanometric volume difference ≥2 cm^3			7.015	0.008
Yes	29	3		
No	18	11		

Note: X^2 = chi-square of Pearson.

Table 3: Comparison between successful surgery and re-perforation groups- continous variables.

Variables	Successful surgery (n=47)	Re-perforation of tympanic membrane (n=14)	Statistics	P value
Age (years)	M= 42.70±14.171	M= 53.87±15.625	t=-0.262	0.795
Tympanic pathologic ear canal volume	Mdn= 3.88 AIQ 3.53	Mdn= 2.73 AIQ 1.85	U=219.5	0.060
Tympanic healthy ear canal volume	Mdn= 1.1 AIQ 0.40	Mdn= 1.49 AIQ 0.62	U=154.5	0.003

Continued.

Variables	Successful surgery (n=47)	Re-perforation of tympanic membrane (n=14)	Statistics	P value
Interaural tympanometric volume difference	Mdn= 2.7 AIQ 3.6	Mdn= 1.31 AIQ 1.26	U=176	0.009

Note: t= t student; U= Mann Whitney U; M= media; σ=standard-deviation; Mdn= median; IQR= interquartile range.

Table 4: Comparison between successful surgery and re-perforation groups- continous variables.

Variables	B	Wald	P value	OR (95% CI)
Tympanic ear canal volume measure	3.225	6.986	0.008	25.152 (2.301-274.875)
Interaural tympanometric volume differences	-3.650	8.686	0.003	0.026 (0.002-0.294)

Note: OR= odds ratio; CI= confidence interval.

DISCUSSION

A good aeration of the middle ear and mastoid cells is known to be a good predictive factor for tympanoplasty success.[1,4,8] Traditionally, this aeration could be evaluated through some measurements in a three-dimensional volume reconstruction CT scan.[6,9] Recent studies by Kim et al and Epprecht et al demonstrated that, when the mastoid antrum is patent, there is a good correlation between middle ear and mastoid cells volume measurements done with three-dimensional volume reconstructions CT scan or calculated with the interaural volume differences with tympanometry.[6,9]

Since a good aeration of the middle ear is an important predictive factor for a successful tympanoplasty and tympanometry is a good tool to evaluate that, it was expected that a higher ear canal volume measurement in tympanometry would increase the chance of having a successful surgery. However, our multivariate analysis revealed exactly the opposite and we believe this was a coincidence. The volume of the tympanometry in the pathologic ear comprises not only the middle ear and mastoid cells, but also the external ear canal and we didn't find significant differences between successful surgery and re-perforation groups. However, if we look to the healthy ear, the tympanometric volume, which comprises only the external ear, is significantly higher in patients with re-perforation.

Assuming both external ear canals are similar, the re-perforation group probably had higher pathologic ear canal volume due to the external ear component not necessarily because of better aerated mastoid cells. This means that when we are interested in evaluating the aeration of the middle ear, we shouldn't look for the total tympanometric volume of the pathologic ear, but instead we should calculate the interaural tympanometric volume difference which gives us only the volume of the middle ear. This is evident in our results: the interaural volume difference is significantly higher in the successful surgery group, reflecting a higher aerated level and for each cm^3 increase, the chance of a good outcome improves 2.5%. Kim et al demonstrated that a tympanometry volume higher than 2 cm^3 has a positive predictive value of good middle ear and mastoid cells aeration on CT scans of 89 per cent.[9] With this reference value, we applied it as a cut-off measure and divided our population in 2 groups, one with interaural ear volume difference above and the other below 2 cm^3.

The group above 2 cm^3 had significantly higher success rate with 90.6% of the surgeries successful while the group below had only 62.1%. Once again, this result supports that a higher aerated middle ear has potentially better results. This was also concluded in a study by Merenda et al about type I tympanoplasty with underlay autograft temporalis fascia in the pediatric population where tympanometry volume greater than 3 cm^3 had an 89 percent success rate compared with 34 percent for those who had a volume of less than 3 cm^3.[6] On the other hand, Yegin et al concluded in their work with type 1 tympanoplasties with cartilage that mastoid pneumatization did not affect the success rate of surgery, which may be explained by the greater resistance that cartilage offers to pressure changes.[4]

Performing mastoidectomy with tympanoplasty for tympanic membrane perforations in the absence of cholesteatoma remains controversial and not all results show that it improves the success of tympanoplasty. Eliades et al in a review of literature concluded that mastoidectomy doesn't seem to add significant benefit for uncomplicated tympanic membrane perforations, however, it may have a role in patients with complicated disease but, due to lack of evidence, there isn't a formal recommendation for this population.[11] Later, Trinidade et al in a review of literature also concluded about the lack of evidence to support routinely therapeutic mastoidectomy in simple OMC, but hey mentioned that it could be considered in cases where prior tympanoplasty has failed, antimicrobial resistance has been found, or in patients with sclerotic mastoids.[11]

Limitations

We acknowledge some limitations in our work, firstly it is a retrospective study with a relatively small population and the follow-up period of 6 months was small. Also, we only studied type I tympanoplasties with fascia. Prospective studies with large population number and with different

techniques are needed in order to assess the possible advantages of mastoidectomy and in which population it should be recommended.

CONCLUSION

The interaural difference in tympanometric volumes in simple unilateral COM reflets the aeration of the middle ear and can give us additional information about the function of the middle ear and the mastoid. As supported by our results, good ventilation of the middle ear, demonstrated by a higher interaural tympanometric volume difference, can be a predictive factor for success in type I tympanoplasty and should always be considered in the preoperative evaluation. When interaural tympanometric ear-canal volume difference is higher than 2 ml, the chance of having a successful surgery increases.

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Carla A. Ribeiro and Cátia C. Azevedo contributed equally to the work.

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