



The significance of selected prognostic factors in pediatric tympanoplasty

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Abstract

Objectives The aim of this study was to determine the importance of selected prognostic factors on outcomes of tympanoplasty in children.

Materials and methods 241 children classified into three age groups (3–7, 8–12 and 13–18), had undergone tympanoplasty between 2001 and 2007 and were subsequently observed for at least 2 years. Prognostic factors were assessed with regard to their impact on the functional and anatomical outcome of the tympanoplasty defined, respectively, as postoperative air–bone gap and state of the middle ear.

Results In 85% of children, a tympanic membrane reconstruction was performed. An unchanged TM was achieved in 85% of the patients in early results and in 76% in later results. Air–bone gap closure was observed in 66% of cases. The earlier preventive retraction pocket tympanoplasty was performed, the better anatomical results were obtained—ranging from 91% in the 3–7 age group versus 75–70% in 8–12 and 13–18 age groups. The results of total or subtotal perforation reconstructions were worse than for small perforation with closure rates of 76.5% vs 94.5%, respectively.

Conclusion Age is not a factor determining the success rate in pediatric tympanoplasty. A better surgical outcome can be achieved in children with a dry ear, and better middle ear condition, because of previously performed surgeries. Preventive tympanoplasty is also advantageous. The hearing results in type 2 and 3 tympanoplasty are similar, but type 1 tympanoplasty has superior efficacy to the former two types.

Keywords Pediatric tympanoplasty · Prognostic factors · Functional results · Anatomic results · Retraction pocket

Introduction

Tympanoplasty is a surgical procedure performed to eradicate disease and reconstruct the middle ear mechanism. The outcomes of pediatric tympanoplasty reported by various authors vary significantly, with efficacy ranging from 35 to 93%. For this reason, this procedure still triggers controversy. Arguments supporting pediatric tympanoplasty consider different aspects of the expected results: improvement of hearing, communication skills, social, psychomotor and intellectual development, ability to participate in water

sports, restoration of middle ear anatomy, prevention of further middle ear damage, erosion of ossicles, tympanic membrane retraction, the formation of cholesteatoma, good chances of achieving a safe and dry ear. Arguments against are based on the above-mentioned frequent infections and ET function, but also stress that a percentage of perforation can close spontaneously, and that in children the perforation can play the role of tympanostomy tube. Attention is also drawn to technical difficulties associated with the narrow external auditory canal and the frequently observed difficult cooperation with children.

The aim of this study was to determine the importance of selected prognostic factors in anatomical and functional outcomes of reconstructive middle ear surgery in children with chronic middle ear disease. Additionally prognostic factors were analyzed for preventive tympanoplasty, a procedure rarely mentioned in the literature, nevertheless commonly performed.

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Methods

The authors have analyzed retrospectively 241 children aged 3.5–18.5 years operated in our institution between 2001 and 2007 (Table 1). The mean age was 11.7 ± 3.2 years. The surgical documentation and 2-years follow-up documentation was thoroughly studied.

All patients were subjected to a careful pre- and postoperative otomicroscopy and pneumatic otoscopy. Otoscopic findings were classified as: normal tympanic membrane, presence of middle ear fluid, retraction pocket type (1–3 according to Charachon classification), tympanic membrane perforation, otorrhea and cholesteatoma. We have assessed also the evidence of type 1, 2, 3 retraction pockets, middle ear fluid, reperforations and residual or recurrent cholesteatoma.

Pure tone audiometry was commonly performed on all patients before surgery and during follow-up period. The results were reported using pure tone average air–bone gap at four frequencies (500, 1000, 2000, 3000 Hz). The mean air–bone gap, standard deviation and air–bone gap change between pre- and postoperative tests were defined. An air–bone gap of less than 20 dB was regarded as a good, functional result.

The children were divided into the three age groups (Table 1). Two groups of patients were selected: children who received antibiotics more than five times per year because of upper respiratory tract infections (URTI) were classified as prone to URTI. The second group included children receiving antibiotics less frequently, without predisposition to infections. Depending on the type of otitis, media patients were divided into three groups: chronic suppurative otitis media, chronic otitis media with cholesteatoma, chronic atelectative otitis media. According to TM perforation size and location—6 groups of patients were identified: no evidence of TM perforation—also with the possibility of presence of TM retraction pockets, anterior perforation, involving anterior quadrants; posterior perforations, involving posterior quadrants; inferior perforations—involving inferior quadrants; central perforations (involving no more than 50% of TM as localized in the central part); subtotal perforations, involving 50–75% of TM; and total perforations, over 75% of TM perforation. These perforations, which cover over 50% of TM, were considered together within one group. According to the state of middle ear mucosa, patients were divided into three groups: (1) otorrhea and/or middle ear mucosa inflammation (polyps, oedema, granulation tissue), (2) no middle ear mucosa inflammation, otorrhea during 6 months before surgery, (3) no middle ear mucosa inflammation and no otorrhea for at least 6 months. We did not include measuring ET function in this study but

Table 1 Patient's characteristics

Data	n (%)
N	241
Gender	
F	89 (36.9)
M	152 (63.1)
Age group	
3–7	31 (12.9)
8–12	104 (43.2)
13–18	106 (44)
Upper respiratory tract infections	
Susceptible	112 (46.5)
Non-susceptible	129 (53.5)
Previously performed operations	
No	83 (34.4)
Yes	158 (65.6)
Type of chronic ear inflammation	
Chronic purulent middle ear inflammation	57 (23.7)
Chronic otitis media with cholesteatoma	105 (43.6)
Chronic atelectative middle ear inflammation	79 (32.8)
Tympanic membrane perforation	
No	57 (23.7)
Yes	184 (76.3)
State of tympanic cavity before operation	
No inflammation, dry ear	122 (50.6)
Other	119 (49.4)
State of ossicles	
Unchanged	104 (43.2)
Damaged	137 (56.8)
State of ossicles	
Destruction of malleus	5 (3.6)
Destruction of incus	85 (62.1)
Destruction of stapes suprastructure	47 (34.3)
Cholesteatoma	
No	133 (55.2)
Yes	108 (44.8)
Opposite ear state	
Unchanged	116 (48.1)
Changed	125 (51.9)
Air–bone gap before operation < 20 dB	
< 20	41 (17)
≥ 20	200 (83)
Type of tympanoplasty by Tos	
Type 1	141 (58.5)
Type 2.3 i 4	100 (41.5)
Tympanic membrane reconstruction	
No	35 (14.5)
Yes	206 (85.5)
Material used for TM reconstruction	
Fascia	114 (55.3)
Fascia and cartilage	76 (36.9)
Perichondrium and/or cartilage	16 (7.8)

Table 1 (continued)

Data	<i>n</i> (%)
Material used for TM reconstruction	
Fascia only	114 (55.3)
Other	92 (44.7)
Ossicles reconstruction	
No	157 (65.1)
Yes	84 (34.9)
Material for ossicles reconstruction	
Incus or head of malleus	42 (50)
Temporal bone	13 (15.5)
Cartilage	16 (19)
TORP	13 (15.5)
Unchanged tympanic membrane	
Early results	204 (84.6)
Late results ^a	133 (75.6)
Preserved tympanic membrane	
Early results	228 (94.6)
Late results ^a	158 (89.8)
Air–bone gap < 20 dB	
Early results	87 (36.1)
Late results ^a	114 (66.7)

^aLate results—*n* = 171 patients

analyzed the state of the contralateral (non-operated) middle ear, which indirectly indicates ET function. Patients with ossicular chain damage were divided as follows: the destruction of malleus handle, the destruction of the long process of incus with preserved stapes suprastructure, and stapes suprastructure missing. Cholesteatoma assessment included a division into three groups: with no evidence of cholesteatoma, congenital cholesteatoma, acquired cholesteatoma. We additionally divided patients into the following groups: into patients who underwent and those who did not undergo mastoidectomy, and into children who had an intact canal wall, and those who had canal-wall-down mastoidectomy.

We used the Tos classification of tympanoplasty. The material used for reconstruction of the tympanic membrane and ossiculoplasty was noted and taken into consideration. The evaluation of surgical results was based on anatomical and functional outcomes. Anatomical assessment included the following criteria, related to the postoperative state of TM: unchanged (intact) TM and preserved tympanic membrane. The postoperative air–bone gap covered functional outcome.

Demographic and clinical data underwent statistical analysis. Values were measured in a nominal scale and described in numerical values and percentages (%). To determine the relations between clinical factors and the surgical results, statistical analysis for quantitative variables was applied.

Variations in relevance were set down based on the chi-squared (χ^2) test, or Fisher's exact test, for the small-sized sample. For statistical analysis we used SPSS software version 20 for Windows. *p* values less than 0.05 ($p < 0.05$) were taken as statistically significant. Additionally, multivariate analysis was performed, using logistic regression models that included the variables determined to be significant in univariate analysis. For this analysis, the odds ratios (OR) and 95% CI were also calculated.

Results

In 158 cases, there was previously performed ENT operations including adenoidectomy, tympanostomy, tonsillotomy or tonsillectomy. The most prevalent type of chronic ear inflammation was cholesteatoma (43.6%), then atelectatic (32.8%), while purulent chronic ear inflammation was observed less frequently (23.7%). Tympanic membrane perforation before the operation was found in 184 children (76.3%). 56.8% of patients had ossicles destruction, most often involving the incus (62.1%). In 51.9% of operated children there were pathological changes observed in the other ear as well. 46.5% of patients were susceptible to upper respiratory tract infections. 200 patients had an air–bone gap of 20 dB or greater before the operation. Over 85% of patients had tympanic membrane (TM) perforation before the surgery, most frequently in posterior quadrants (29.5%). TM reconstruction was performed predominantly with use of temporalis muscle fascia enhanced with cartilage. Unchanged TM was achieved in 84.6% of the patients in early result and in 75.6% in late results. Preserved tympanic membrane was stated in 94.6% of children in early results and in 89.8% in late results. Air–bone gap closure was observed in 66.7% of cases (Table 1).

The study confirmed that there was no statistically significant difference between all age groups in early and late functional and anatomical results (Tables 2, 3). Children not susceptible for URTI presented in earlier checkups more often had an unchanged tympanic membrane than children susceptible to infections (Table 2). Previously performed operations such as: adenoidectomy, tonsillotomy, tympanostomy resulted in better anatomical outcomes after tympanoplasty in early results (Table 2). Additionally, tympanoplasty preceded by ENT operations increased the feasibility of TM preservation in early checkups 4 times (Table 4). Dry ear before tympanoplasty is positively related with good anatomical and functional results in early checkups as well as good anatomical results in late checkups (Tables 2, 3). Moreover, the probability of obtaining an unchanged TM in early results decreased five times in children susceptible to upper respiratory infection, and increased more than two times if the operated ear was dry (Table 4). Nearly the same benefit (three times) in the later

Table 2 Early results

Early results	Unchanged tympanic membrane		Preserved tympanic membrane		Air–bone gap < 20 dB	
	n/total n (%)	<i>p</i>	n/total n (%)	<i>p</i>	n/total n (%)	<i>p</i>
Gender						
F	73/89 (82.0)	0.387	84/89 (94.4)	0.906	31/89 (34.8)	0.754
M	131/152 (86.2)		144/152 (94.7)		56/152 (36.8)	
Age						
3–7	26/31 (83.9)	0.477	30/31 (96.8)	0.725	8/31 (25.8)	0.238
8–12	85/104 (81.7)		97/104 (93.3)		43/104 (41.3)	
13–18	93/106 (87.7)		101/106 (95.3)		36/106 (34.0)	
Upper respiratory tract infections						
Non-susceptible	84/112 (75.0)	< 0.001	104/112 (92.9)	0.263	39/112 (34.8)	0.700
Susceptible	120/129 (93.0)		124/129 (96.1)		48/129 (37.2)	
Earlier performed operations						
No	64/83 (77.1)	0.019	73/83 (88.0)	0.002	28/83 (33.7)	0.580
Yes	140/158 (88.6)		155/158 (98.1)		59/158 (37.3)	
Type of chronic ear inflammation						
Chronic purulent middle ear inflammation	47/57 (82.5)	0.702	51/57 (89.5)	0.144	23/57 (40.4)	< 0.001
Chronic otitis media with cholesteatoma	88/105 (83.8)		100/105 (95.2)		21/105 (20.0)	
Chronic atelectative middle ear inflammation	69/79 (87.3)		77/79 (97.5)		43/79 (54.4)	
Tympanic membrane perforation						
No	50/57 (87.7)	0.462	57/57 (100.0)	0.084	17/57 (29.8)	0.259
Yes	154/184 (83.7)		171/184 (92.9)		70/184 (38)	
Localization of the perforation						
Total, subtotal	12/17	0.161	13/17	0.021	3/17	0.069
Other	142/167		158/167		67/167	
State of tympanic cavity before operation						
No inflammation, dry ear	111/122 (91.0)	0.006	120/122 (98.4)	0.009	55/122 (45.1)	0.003
Other	93/119 (78.2)		108/119 (90.8)		32/119 (26.9)	
State of ossicles						
Unchanged	89/104 (85.6)	0.727	99/104 (95.2)	0.725	61/104 (58.7)	< 0.001
Damaged	115/137 (83.9)		129/137 (94.2)		26/137 (19.0)	
Type of ossicles damage						
Destruction of malleus	3/5 (60.0)	0.297	4/5 (80.0)	0.361	2/5 (40.0)	0.328
Destruction of incus	72/85 (84.7)		80/85 (94.1)		17/85 (20.0)	
Destruction of stapes suprastructure	40/47 (85.1)		45/47 (95.7)		7/47 (14.9)	
Cholesteatoma						
No	113/133 (85.0)	0.880	125/133 (94.0)	0.636	65/133 (48.9)	< 0.001
Yes	91/108 (84.3)		103/108 (95.4)		22/108 (20.4)	
Opposite ear state						
Unchanged	99/116 (85.3)	0.772	106/116 (91.4)	0.033	33/116 (28.4)	0.017
Changed	105/125 (84)		122/125 (97.6)		54/125 (43.2)	
Air–bone gap before operation						
< 20 dB	36/41 (87.8)	0.538	39/41 (95.1)	1.000	30/41 (73.2)	
≥ 20 dB	168/200 (84.0)		189/200 (94.5)		57/200 (28.5)	< 0.001
Type of tympanoplasty by Tos'a						
Type 1	117/141 (83.0)	0.394	132/141 (93.6)	0.420	62/141 (44.0)	0.003
Type 2,3 and 4	87/100 (87.0)		96/100 (96.0)		25/100 (25.0)	
Tympanic membrane reconstruction						
No	33/35 (94.3)	0.087	35/35 (100.0)	0.225	12/35 (34.3)	0.809
Yes	171/206 (83.0)		193/206 (93.7)		75/206 (36.4)	

Table 2 (continued)

Early results	Unchanged tympanic membrane		Preserved tympanic membrane		Air–bone gap < 20 dB	
	<i>n</i> /total <i>n</i> (%)	<i>p</i>	<i>n</i> /total <i>n</i> (%)	<i>p</i>	<i>n</i> /total <i>n</i> (%)	<i>p</i>
Material used for TM reconstruction						
Fascia	93/114 (81.6)	0.790	104/114 (91.2)	0.308	44/114 (38.6)	0.024
Fascia, cartilage	64/76 (84.2)		73/76 (96.1)		21/76 (27.6)	
Perichondrium, cartilage	14/16 (87.5)		16/16 (100.0)		10/16 (62.5)	
Ossicles reconstruction						
No	130/157 (82.8)	0.277	146/157 (93.0)	0.229	65/157 (41.4)	0.019
Yes	74/84 (88.1)		82/84 (97.6)		22/84 (26.2)	
Material used for ossicles reconstruction						
Incus or head of malleus	38/42 (90.5)	0.198	41/42 (97.6)	0.753	9/42 (21.4)	0.746
Temporal bone	13/13 (100.0)		13/13 (100.0)		4/13 (30.8)	
Cartilage	13/16 (81.2)		15/16 (93.8)		5/16 (31.2)	
TORP	10/13 (76.9)		13/13 (100.0)		4/13 (30.8)	

Statistical significant parameters are highlighted in bold

results of TM preservation was observed when operated ear was dry (Table 5). The statistics show that the type of middle ear inflammation can be a predictive factor for audiological results (Tables 2, 3). In early controls we observed the best audiological, results confirmed by air–bone gap closure in patients with chronic atelectative otitis media, than in children with purulent otitis media and the worst in the group with cholesteatoma (Table 2). Unchanged tympanic membrane in later results was achieved nearly three times more often in the chronic atelectative otitis media than in other groups (Table 5). Tympanoplasty in atelectative chronic ear inflammation gives 2.5 times more chances for air–bone gap closure (Table 5). The anatomical results for the reconstruction of total and subtotal perforations were worse than other types of perforations (Tables 2, 3). The functional results of tympanoplasty were the best in type 1, when there was no destruction of ossicles and no ossiculoplasty (Tables 2, 3). Furthermore, the ossicles destruction decreases the probability of air–bone gap closure in early results by more than 8.6 times (Table 4). A good audiological result can be reached 6.4 times more often in early results if the air–bone gap is less than 20 dB before the operation, and 4.7 times in later test results (Tables 4, 5). There were no differences in functional results when using various tympanoplasty material (Tables 2, 3). The air–bone gap closure was achieved four times more often in later results if the opposite ear was unchanged (Table 5).

Discussion

Age is the most often discussed tympanoplasty prognostic factor. According to Lancaster, the youngest operated child should be 3–4 years old [1]. There are strong suggestions

that the most important is the maturation of the ET, its muscle and cartilage growth, and in his opinion, the proper age of operation is 7 years [2]. Koch and Berger noticed that the results of operation in children above 8 years of age are worse than in younger groups [3, 4]. Tympanic membrane reconstruction success rate is from 20 to 50% worse in the group of children 8 years old and above [3, 5]. Raine and Singh found that 12 years is the appropriate age for operation, Goodman and Wallace suggest operating only adults [6, 7]. Another group of researchers (Smyth and Hassard) declare that they achieved the same results in all operated groups of patients [8]. Nevertheless, the earlier they perform the operation, the less pathology and damage to the middle ear is developed. The same view is shared by a number of other groups, including Lau and Tos [9], Chandrasekhar [10] Manning [11], Denoyelle [12], Te [13], Caylan [14]. Most of these authors describe only tympanic membrane reconstruction results, not postoperative audiological improvement. Kessler demonstrates higher late reperforation rate and fluid in the middle ear in the youngest group (0–6) [15].

Even though the opinion about an appropriate age for the surgery is so diverse, there are a few observable trends. Based on the available literature, we could group the currently held opinions into the following groups: (1) the opinion that the surgery in children should be postponed until 3–4 years of age [1]; (2) 7, 8, 9 years [2–4]; (3) 12 years or even later: after adolescence [6, 7]. However, it is clear that in most reports the critical age is 8 years [3, 5–7, 13, 16].

On the other hand, there is a group of authors who have reported an opposite result. They observed good results in approximately 80–90% of children [8, 10–15, 17] and noted no statistically significant difference among different age groups. In their opinion, tympanoplasty can be

Table 3 Later test results

Later test results	Unchanged tympanic membrane		Preserved tympanic membrane		Air–bone gap < 20 dB	
	<i>n</i> /total <i>n</i> (%)	<i>p</i>	<i>n</i> /total <i>n</i> (%)	<i>p</i>	<i>n</i> /total <i>n</i> (%)	<i>p</i>
Gender						
F	47/63 (74.6)	0.824	53/63 (84.1)	0.065	37/62 (59.7)	0.144
M	86/113 (76.1)		105/113 (92.9)		77/109 (70.6)	
Age						
3–7	17/21 (81.0)	0.821	20/21 (95.2)	0.161	15/20 (75.0)	0.612
8–12	58/78 (74.4)		66/78 (84.6)		52/77 (67.5)	
13–18	58/77 (75.3)		72/77 (93.5)		47/74 (63.5)	
Upper respiratory tract infections						
Non-susceptible	62/86 (72.1)	0.294	76/86 (88.4)	0.549	51/82 (62.2)	0.234
Susceptible	71/90 (78.9)		82/90 (91.1)		63/89 (70.8)	
Earlier performed operations						
No	31/46 (67.4)	0.133	38/46 (82.6)	0.087	25/44 (56.8)	0.108
Yes	102/130 (78.5)		120/130 (92.3)		89/127 (70.1)	
Type of chronic ear inflammation						
Chronic purulent/or cholesteatoma/middle ear inflammation	70/104 (67.3)	0.002	88/104 (84.6)	0.007	61/101 (56.8)	0.037
Chronic atelectative middle ear inflammation	63/72 (87.5)		70/72 (97.2)		53/70 (75.7)	
Tympanic membrane perforation						
No	37/48 (77.1)	0.775	45/48 (93.8)	0.405	29/47 (61.7)	0.397
Yes	96/128 (75)		113/128 (88.3)		85/124 (68.5)	
Localization of the perforation						
Total, subtotal	3/9	0.008	7/9	0.0284	5/9	0.461
Other	93/119		108/119		80/115	
State of the ear						
No inflammation, dry ear	87/107 (81.3)	0.027	102/107 (95.3)	0.002	74/105 (70.5)	0.183
Other	46/69 (66.7)		56/69 (81.2)		40/66 (60.6)	
State of ossicles						
Unchanged	76/96 (79.2)	0.224	84/96 (87.5)	0.276	72/93 (77.4)	0.001
Destruction	57/80 (71.2)		74/80 (92.5)		42/78 (53.8)	
Type of ossicles damage						
Destruction of malleus	3/4 (75.0)	0.913	4/4 (100.0)	0.529	1/4 (25.0)	0.333
Destruction of incus	36/50 (72.0)		45/50 (90.0)		29/49 (59.2)	
Destruction of stapes suprastructure	18/26 (69.2)		25/26 (96.2)		12/25 (48.0)	
Cholesteatoma						
No	90/116 (77.6)	0.386	106/116 (91.4)	0.328	78/113 (69.0)	0.361
Yes	43/60 (71.7)		52/60 (86.7)		36/58 (62.1)	
Opposite ear state						
Unchanged	58/75 (77.3)	0.639	68/75 (90.7)	0.736	58/74 (78.4)	0.005
Changed	75/101 (74.3)		90/101 (89.1)		56/97 (57.7)	
Air–bone gap before operation						
< 20 dB	28/34 (82.4)	0.305	33/34 (97.1)	0.204	27/31 (87.1)	0.008
≥ 20 dB	105/142 (73.9)		125/142 (88.0)		87/140 (62.1)	
Type of tympanoplasty by Tos						
Type 1	77/99 (77.8)	0.439	86/99 (86.9)	0.149	71/96 (74.0)	0.022
Type 2, 3 and 4	56/77 (72.7)		72/77 (93.5)		43/75 (57.3)	
Tympanic membrane reconstruction						
No	25/30 (83.3)	0.277	30/30 (100.0)	0.046	19/29 (65.5)	0.885
Yes	108/146 (74)		128/146 (87.7)		95/142 (66.9)	

Table 3 (continued)

Later test results	Unchanged tympanic membrane		Preserved tympanic membrane		Air–bone gap < 20 dB	
	<i>n</i> /total <i>n</i> (%)	<i>p</i>	<i>n</i> /total <i>n</i> (%)	<i>p</i>	<i>n</i> /total <i>n</i> (%)	<i>p</i>
Material used for TM reconstruction						
Fascia	51/79 (64.6)	0.019	67/79 (84.8)	0.342	50/78 (64.1)	0.666
Fascia, cartilage	45/53 (84.9)		47/53 (88.7)		35/51 (68.6)	
Perichondrium and/or cartilage	12/14 (85.7)		14/14 (100.0)		10/13 (76.9)	
Ossicles reconstruction						
No	85/109 (78.0)	0.342	95/109 (87.2)	0.144	76/106 (71.7)	0.075
Yes	48/67 (71.6)		63/67 (94.0)		38/65 (58.5)	
Material used for ossicles reconstruction						
Incus or head of malleus	22/33 (66.7)	0.617	30/33 (90.9)	0.818	20/32 (62.5)	0.690
Temporal bone	9/11 (81.8)		11/11 (100.0)		5/10 (50.0)	
Cartilage	10/12 (83.3)		11/12 (91.7)		8/12 (66.7)	
TORP	7/11 (63.6)		11/11 (100.0)		5/11 (45.5)	

Statistical significant parameters are highlighted in bold

Table 4 Multivariate analysis—early results

Early results				
Data	<i>p</i>	OR	95% CI	
Unchanged tympanic membrane				
Upper respiratory tract infection, yes	< 0.001	0.21	0.09–0.48	
State of tympanic cavity before operation, no inflammation, dry ear	0.053	2.29	0.99–5.29	
Earlier performed operations, yes	0.117	1.89	0.85–4.17	
Preserved tympanic membrane				
Earlier performed operations, yes	0.044	4.35	1.04–19.21	
State of tympanic cavity before operation, no inflammation, dry ear	0.202	2.95	0.56–15.61	
Opposite ear, unchanged	0.081	0.30	0.08–1.16	
Air–bone gap, < 20 dB				
Type of chronic ear inflammation, atelectative	0.474	1.40	0.56–3.48	
State of tympanic cavity before operation, no inflammation, dry ear	0.496	1.31	0.60–2.83	
Ossicles, preserved	< 0.001	8.65	2.81–26.67	
Cholesteatoma, no	0.760	1.15	0.46–2.88	
Type of Tos tympanoplasty, type 1	0.625	1.42	0.35–5.71	
Opposite ear, unchanged	0.149	0.61	0.32–1.19	
Air–bone gap before operation, < 20 dB	< 0.001	6.42	2.69–15.33	
Tympanic membrane reconstruction, yes	0.399	1.58	0.55–4.56	
Ossicles reconstruction, no	0.092	0.28	0.06–1.23	

Statistical significant parameters are highlighted in bold

performed at any age and an earlier procedure is advantageous due to the prevention of further disease progression and complications, and due to the restoration of middle ear anatomy and hearing. A comparison of reported outcomes is not simple because of different—and therefore not comparable—age groups: Tos [18] 2–7 and 8–14, Chandrasekhar [10] 0–6, 7–8, 9–12, 13–19, Kessler [15] 0–6, 7–12, 12–19, Koch [3] 0–8, 8–18, Caylan [14] 5–10 and 11–16. Yet another difficulty in comparing the outcomes

is the lack of assessment of hearing results. The key discussed issue is effectiveness of tympanoplasty in preschool children, where anatomical and physiological differences are the biggest.

In all analyzed age groups 0–7, 8–12, and 13–18, approximately 80% of patients had unchanged TM as early results and the same observation was made in the group of 0–7 also as a late result. In other age groups, the late results percentage lowered to 75%. A preserved TM was obtained in 95%

Table 5 Multivariate analysis—late results

Late results				
Data	<i>p</i>	OR	95% CI	
Unchanged tympanic membrane				
Type of chronic ear inflammation, atelectative	0.017	2.90	1.21–6.94	
State of tympanic cavity before operation, no inflammation, dry ear	0.337	1.45	0.68–3.12	
Preserved tympanic membrane				
Type of chronic ear inflammation, atelectative	0.094	3.91	0.79–19.20	
State of tympanic cavity before operation, no inflammation, dry ear	0.060	3.02	0.95–9.53	
Air–bone gap, < 20 dB				
Type of chronic ear inflammation, atelectative	0.023	2.54	1.14–5.69	
Ossicles, preserved	0.066	3.20	0.93–11.04	
Opposite ear, unchanged	<0.001	4.36	1.96–9.69	
Air–bone gap before operation, < 20 dB	0.012	4.68	1.40–15.67	
Type of Tos tympanoplasty, type 1	0.621	0.73	0.21–2.53	

Statistical significant parameters are highlighted in bold

as both the early and late result, excluding the median group with 85% later rate.

Air–bone gap less than 20 dB was observed early in 25% of the youngest patients, 34% of middle age group and in 41% of the third group. Late results were, respectively: 75%, 68%, and 64%. None of the differences was statistically significant, indicating that in the analyzed groups, age is not a good prognostic factor for the anatomical or functional outcome.

Outcomes of tympanoplasty can vary depending on disease etiology. Worse outcomes are reported in case of perforations due to a long-standing (and difficult to treat) inflammatory process, otorrhea, advanced tympanosclerosis. Outcomes in case of perforations caused by chronic otitis media and trauma were compared by Cohn [19] and Chandrasekhar [10] and were not statistically significant. In Carr's study, an additional cause—perforation after tympanostomy was considered and none out of 3 causes was significant [20].

The unchanged TM was observed three times more often in patients operated due to chronic adhesive otitis media. Preventive tympanoplasty in patients with progressive atelectative otitis media, which allowed the avoidance of cholesteatoma formation and disease progression, was performed in the type 2 retraction pocket with effusion in the middle ear cavity, and the type 3 retraction pocket. Tympanoplasty in this group seems to be acting as a preventive measure for further chronic otitis media and cholesteatoma formation. In comparison to tympanoplasty in chronic otitis media with cholesteatoma, the recurrence rate of cholesteatoma ranged from 10% in CWD procedures versus 30% in CWU procedures. In the early results in a group with CWU procedure we observed the worst functional results with an air–bone gap > 20 dB; in other groups outcomes were comparable. It is associated with the more extensive

damage caused by cholesteatoma and a two-staged surgery with a second-look procedure. Usually ossiculoplasty is performed in the second stage. Perforation size and location is another issue. Localization should be also kept in mind due to difficulties related to the narrow EAC in children. It is well known that the closure of a small perforation is easier and in theory associated with a better anatomical and functional result than expected in total and subtotal perforations. According to Halik [21], Postic [22] and Sade [23], anterior perforations present worse healing and higher reperforation rates due to a weaker revascularization process and a more complex surgery. Halik [21] and Koch [3] noted 50% of unsuccessful procedures with posterior–inferior perforations. Worse results were observed by Sheehy [24], Ophir [25], Sade [23] in total and subtotal perforations in children with special attention paid to the total perforations, which caused a worsening of patient's hearing. However, Chandrasekhar [11], Kessler [15], and Blanshard [26] all state that when a surgical technique is properly mentioned, these factors do not influence the success rate, although in the analyzed group the worse anatomical results were noted in children with total and subtotal perforations with occurring reperforations and retraction pockets. Furthermore, we observed that surgical intervention in the middle ear with no occurrence of perforation is not associated with a higher risk of perforation. It occurs in patients undergoing preventive tympanoplasty or second-look procedures. Additionally, in accordance with the available literature, a better hearing result was observed in children with posterior perforations in comparison to patients with total and subtotal perforations, or pars flaccida localization.

Classically, active middle ear inflammation was a contraindication for tympanoplasty because of the longer surgery, greater blood loss and worse operative conditions. The standard management, in case of active otorrhea, aims to

reduce infection. It is recommended by many authors [27, 28] to wait 6–12 months after obtaining a dry ear. The presence of granulation tissue in the middle ear according to Wiatr [27] was an unfavorable factor in hearing improvement following tympanoplasty. Denoyelle [12] also emphasized that otorrhea and middle ear inflammation are negative factors of tympanoplasty having an impact on middle ear effusion, reperforation rate and retractions. On the other hand, some authors, including Lau and Tos [17], Koch [3] and Ophir [25] observed good results in this group of patients, with up to 97% success rate. Caylan [14] made the most controversial report. He claimed that results in children with otorrhea are significantly better (100%) than in children with dry ear and should be operated at any age. In our department we observed better anatomical and functional results in early (2 times) and late evaluation (3 times) in the group with no middle ear mucosa inflammation and no otorrhea for at least 6 months.

Although we did not include measuring ET function in this study, its dysfunction is the main cause of middle ear pathology, and according to literature, it is an unfavorable factor of pediatric tympanoplasty. If we assume that the good state of opposite ear indicates good ET function, then we can conclude that hearing results are more than four times better when the other ear is unchanged and indirect ET function is good.

Various types of auditory ossicles destruction caused by inflammation and cholesteatoma encountered by the surgeon during reconstruction play an important role in the tympanoplasty procedure affecting both anatomical and functional results. Particular attention in the literature is paid to the malleus handle and stapes suprastructure. According to Austin [29], Fisch [30], Marquet [31] and De Vos [32], a preserved malleus handle is a favorable prognostic factor. Brackmann [33, 34] disagreed with this theory. Missing stapes suprastructure can be challenging for the surgeon. Tos [35], Fisch [30], and Charachon [36] concluded that it has a negative impact on tympanoplasty outcome, but their theory was not confirmed by any research and an anatomically and physiologically based analysis of the hearing mechanism. Furthermore, during reconstruction, the angle between TM, reconstructed ossicles and stapes suprastructure can significantly change sound transmission [37]. Placing TORP prosthesis on the stapes footplate did not disturb ear geometry as well as the sound transmission mechanism, and the best hearing result can be achieved with central placement of the prosthesis on the footplate. The difference in sound pressure transmitted by prosthesis placed in the anterior versus the posterior part of the footplate can have a level of 10–15 dB. Placing a piece of cartilage between the TM and the platform of the prosthesis to avoid extrusion worsens hearing and depends on cartilage size (5–10 dB for small pieces of cartilage, 17–18 dB for bigger) [38].

Better functional results were achieved in children when type 1 tympanoplasty was performed, as compared to other types of reconstruction. This observation is comparable to other reported studies [39]. The results shown indicate that any evidence of destruction of auditory ossicles causes eight times worse outcomes, independent of the involved ossicles, followed by a similar success rate in type 2 and 3 tympanoplasty.

Cholesteatoma in pediatric patients is considered to be more aggressive and to cause worse hearing outcomes when compared to adults [40]. A recurrence of the disease is an additional aspect particularly considered during the evaluation of tympanoplasty's final results. In the present study, if the cholesteatoma involved the attic, the results of the reconstruction were worse [41]. A similar outcome was when the extent of the disease was not limited to the tympanic cavity, with noted extensive middle ear involvement of EAC or scutum. In this group, the rate of relapse is higher due to the formation of retraction pockets close to the attic. Thus, while performing CWU tympanoplasties, attic obliteration with bony chips and conchal cartilage and scutum reconstruction seems reasonable [42]. Communication between mastoid and tympanic cavity is restored through posterior tympanotomy.

Conclusions

In this study we confirmed that age is not a factor in the improvement of tympanoplasty results. There was no statistically significant difference between all age groups in early and late functional and anatomical results.

Dry ear before tympanoplasty is very significant. Children susceptible for upper respiratory tract infection have more often aural effusion and five times less chance to have unchanged TM in early results. The probability of obtaining an unchanged TM increased more than two times if the operated ear was dry.

Tympanoplasty could be connected with other operations, which improves the middle ear conditions. Children that had previously performed operations, such as adenoidectomy, adenotonsilotomy or tympanostomy tube insertion achieve better postoperative tympanoplasty outcomes and a four times greater likelihood of a preserved TM.

In our outcomes we see also that the earlier preventive tympanoplasty in accordance with the adopted algorithm of retraction pockets treatment is performed, the better hearing and anatomical results are achieved.

Another conclusion is that tympanoplasty in atelective chronic ear inflammation gives 2.5 times greater chance for air–bone gap closure.

The audiological results depend on the type of tympanoplasty, they are similar–worse of type 2 and 3 than the results of type 1 tympanoplasty.

Other issue is the ossicles damage. It decreases the probability of air–bone gap closure in early results more than 8.6 times. If the air–bone gap is less than 20 dB before the operation, good early audiology results can be reached in early results 6.4 times more often, and 4.7 times in late results.

The state of the opposite ear is also a significant factor. It indicates the Eustachian's tube function, and if it is normal, the hearing results are four times more likely to be good, and air–bone gap closure is achieved.

In our study we notice that the use of cartilage or a perichondrium for myringoplasty implicates better stability of tympanic membrane than the use of the temporalis muscle fascia. Using different ossiculoplasty material, auto or allogenic for the ossicular chain reconstruction is not statistically significant.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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