Original Article

Evaluation of cochlear implantation effects on middle ear pressure

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ABSTRACT

Objectives: This study aims to investigate the effects of cochlear implantation on middle ear aeration, tympanometric values, and otitis media with effusion (OME) occurrence.

Patients and Methods: This prospective study conducted between February 2010 and May 2013 included 100 ears of 100 patients (57 males, 43 females; mean age 6.4±2.8 years; range, 1 to 18 years) who underwent cochlear implantation and had no prior history of ear surgery. Patients who had middle and/or external ear anomalies were excluded. During the preoperative evaluation, otoscopic, rhinoscopic and nasopharynx examinations, along with tympanometric investigations were performed. Postoperative tympanometric evaluations over 12-36 months' follow-up were performed and the values were compared, respectively.

Results: In the postoperative otoscopic examinations, tympanic membrane retraction was observed in 14 ears. The mean values of compliance and gradient were significantly lower in the postoperative evaluations. The peak pressure and external ear canal volume measurements were not significantly different after cochlear implantation surgery. The mean preoperative value of peak pressure of the male patients was significantly lower than that in the female patients. The mean preoperative value of external ear canal volume was lower in patients with adenoid hypertrophy. These differences were statistically significant ($p<0.05$).

Conclusion: The values of compliance and gradient were lower in postoperative tympanograms. Nevertheless, this does not mean that patients with low compliance and gradient values are more likely to develop OME or acute otitis media. Males and patients with adenoid hypertrophy also have a predisposition to OME.

Keywords: Cochlear implantation, middle ear, otitis media with effusion.

Otitis media with effusion (OME) is the most frequent disease of childhood after viral upper respiratory tract infections. Otitis media with effusion is an inflammatory response of the middle ear described as effusion in the middle ear with no acute infection symptoms.[1] The incidence of OME peaks at around one year of age and risk factors include male gender, daycare centers, bottle feeding, low socioeconomic status, crowded family environment, and winter season.[2]

The conventional technique of cochlear implantation, as described by Clark et al.,[3] includes mastoidectomy and posterior tympanotomy. During cochlear implant surgery, the mastoid air cells responsible for middle ear

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aeration are removed via cortical mastoidectomy and posterior tympanotomy. There is an assumption that mastoidectomy may contribute to an increase in the ventilation of the middle ear due to the enlargement of overall mastoid volume.[4] Sadé et al.[5] challenged this hypothesis and presented the theory that the amount and composition of middle ear gas depended primarily on the function of the middle ear and mastoid mucosa. In this study, we aimed to investigate the effects of cochlear implantation on middle ear aeration, tympanometric values, and OME occurrence.

PATIENTS AND METHODS

Clinical data of all patients undergoing unilateral cochlear implantation between February 2010 and May 2013 in Istanbul University, Istanbul Faculty of Medicine, Otorhinolaryngology Department were collected prospectively. We investigated all patients who were older than one year and younger than 18 years of age, without a history of prior ear surgery. Patients with middle and/or external ear anomalies were also excluded from the study. Finally, from 261 patients, 100 ears of 100 patients (57 males, 43 females; mean age 6.4±2.8 years; range, 1 to 18 years) were evaluated. The study protocol was approved by the Istanbul University, Istanbul Faculty of Medicine Ethics Committee (reference number: 2014/195). A written informed consent was obtained from the patients' parents. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Preoperative assessment included otoscopic examination, rhinoscopic and nasopharyngeal examinations with a flexible endoscope (Karl Storz 11101RP2, Tuttlingen, Germany), and tympanometric analysis using an audiometer (Interacoustics AZ 26 Impedance Audiometer, Assens, Denmark), all of which were performed in the audiology department. Any detected adenoid tissue that obstructed the airway between the nasopharynx and the choana by 50% or more was considered as adenoid hypertrophy.

Cochlear implantation was performed under general anesthesia using a postauricular modified minimal-incision. Cortical mastoidectomy was performed to reveal the sigmoid sinus, digastric ridge, lateral semicircular canal, and the body of the incus. The internal-receiver was placed on the temporal bone within a subperiosteal pocket behind the sinodural angle. The round window was visualized during the posterior tympanotomy. The implant was placed on the temporal bone and the electrode was inserted through the round window; the rest was in the mastoid cavity.

Twelve to thirty-six months after the cochlear implantation, the patients were called for follow-up. The otoscopic and tympanometric examinations were repeated.

A tympanometric study with a 226 Hz probe tone was performed in this study. The reason for the low frequency probe choice was to prevent microphone irregularities that may occur at high frequencies and to prevent acoustic reflexes during measurements. Values of the external ear canal volume, compliance, peak pressure, and gradient were recorded using a tympanogram. Preoperative tympanometric parameters were compared with postoperative values.

Statistical analysis

The IBM SPSS version 20.0 software (IBM Corp., Armonk, NY, USA) was used for all analyses. Student's t-test was used to compare two means to determine if there was any difference. Statistical significance was accepted for values with $p<0.05$.

RESULTS

Adenoid hypertrophy was detected in 20 patients. Tympanic membranes were intact in the otoscopic examination of all patients, but 14 patients had tympanic membrane retraction. On postoperative follow-ups, 20% of the patients visited pediatric clinics one-four (median: 2) times in the following year because of upper respiratory infections.

Volume, compliance, peak pressure, and gradient values of the pre- and postoperative tympanograms were compared. The mean values of compliance were 0.528±0.263 mL and 0.439±0.200 mL in the pre- and postoperative tympanograms, respectively ($t=-2.682$, $p=0.008$). The mean postoperative value of gradient

Table 1. T-test results for compliance, gradient, volume, and peak pressure measurements according to cochlear implant application

Parameter	n	$\bar{\chi}$	SS	SD	T value	*p*
Compliance (mL)						
Preoperative value	100	0.528	0.263	198	-2.682	0.008
Postoperative value	100	0.439	0.200			
Gradient (mL)						
Preoperative value	100	0.229	0.152	198	-2.408	0.017
Postoperative value	100	0.183	0.113			
Volume (mL)						
Preoperative value	100	0.676	0.158	198	1.191	0.235
Postoperative value	100	0.703	0.156			
Pressure (daPa)						
Preoperative value	100	-98.4	83.36	198	-0.983	0.327
Postoperative value	100	-111.32	100.63			

n: Sample size; SS: Sum of squares; SD: Standard deviation; daPa: Decapascal.

(0.183±0.113 mL) was also significantly lower than mean preoperative value (0.229±0.152 mL) (t=-2.408, p=0.017) (Table 1).

There was no significant difference between the mean values of pre- and postoperative peak pressure and external ear canal volume (Table 1).

It was determined that the mean preoperative value of peak pressure differed according to gender (t=-2.311, p=0.023). The mean value of peak pressure in males was (-131.09±106.76 decapascal [daPa]), which was significantly lower than that in females (-85.1±86.3 daPa) (Table 2).

The existence of adenoid hypertrophy affected the mean preoperative value of volume (t=-2.319, p=0.022). The mean volume in patients with adenoid hypertrophy (0.632±0.101 mL) was

Table 2. T-test results for preoperative peak pressure measurements according to gender

	n	$\bar{\chi}$	SS	SD	T value	*p*
Gender						
Male	57	-131.09	106.76	98	-2.311	0.023
Female	43	-85.12	86.25			

n: Sample size; SS: Sum of squares; SD: Standard deviation.

Table 3. T-test results for preoperative volume (mL) measurements according to the existence of adenoid hypertrophy

	n	$\bar{\chi}$	SS	SD	T value	*p*
Adenoid hypertrophy						
Yes	20	0.632	0.101	98	2.319	0.022
No	80	0.720	0.162			

n: Sample size; SS: Sum of squares; SD: Standard deviation.

significantly lower than in patients without adenoid hypertrophy (0.720±0.162 mL) (Table 3).

DISCUSSION

Middle ear pressure is regulated by mechanisms such as Eustachian tube (ET) function and the mastoid mucosa. Standard cochlear implantation surgery including mastoidectomy and posterior tympanoplasty, which was described by Clark[3] in 1979, causes alterations in mastoid volume and middle ear pressure. This conventional cochlear implantation technique was the method of choice for all patients in our study. It was reported that the mastoid volume was increased and aeration of the middle ear was higher in mastoidectomy in Newberg's study in 1981.[4] However, in 1995, Sadé et al.,[5] emphasized that the aeration of middle air was primarily related to middle ear function and mastoid mucosa. Migirov et al.[6] compared Clark's[3] conventional technique with the suprameatal approach without mastoidectomy and demonstrated that mastoidectomy did not affect the natural progress of OME in patients with cochlear implantation.[6]

It was found that cochlear implants may also increase the risk of infection as a result of foreign body reaction.[7] Another study reported the incidence of OME was lower in children with cochlear implants, and higher in ears without implants.[8] Conversely, Hoberg et al.[9] reported that acute otitis media (9%) and acute mastoiditis (1.9%) more frequently occurred postoperatively in patients who underwent cochlear implantation. According to this study, children under the age of two years had a higher risk of developing acute otitis media or acute mastoiditis, and the infection generally occurred three-four months following the operation.[9]

Raveh et al.[10] reported that acute mastoiditis occurred in 9% of patients after cochlear implantation. Googe and Carron[11] also demonstrated that acute otitis media occurred 30 days following implantation in 8.4% of patients. In our study, there was no increase in the incidence of OME after cochlear implantation. However, the mean postoperative value of compliance was significantly lower than the mean preoperative value.

Görür et al.[12] compared the values of compliance measured on first, seventh, and 30th days, postoperatively, after applying ventilation tubes to 15 children with chronic OME. The authors showed that the mean values of compliance were significantly increased over time.[12] Hassmann-Poznańska et al.[13] investigated 97 patients who had a history of ventilation tube application because of OME. They demonstrated that the mean values of compliance in patients who had normal otoscopic findings were higher than in patients of the same age in the control group. Yılmaz et al.[14] used 12 ears of six Vienna rabbits in their study. Although there was no difference between the values of compliance taken at rest and those taken after widening the middle ear by providing a gap in the tympanic bulla, they noticed that gradient values were significantly increased.[14]

Peak pressure is reliable because it can be considered as middle ear admittance. Peak pressure is not affected by swallowing or breathing.[15] Peak pressure ranges between -100 and +50 daPa in healthy ears. It shifts to negative values when there is ET dysfunction and OME.[15] Luo et al.[16] demonstrated that peak pressure values were very valuable in diagnosis in their study that included 207 ears with type-C curves in tympanograms. In our study, the mean preoperative peak pressure values of the males were significantly lower than those of the females. Tos and Strangerup[17] investigated mastoid bone pneumatization in 41 females and 38 males aged two-seven years, and reported that males had smaller mastoid cells and upper respiratory tract infections more often. As a result, it is seen that there is a predisposition to OME in male patients' ears with cochlear implants.

The relationship between adenoid hypertrophy (AH) and OME is controversial. In early studies about the pathophysiology of OME, physicians emphasized that obstruction of the ET disabled its functions and negative pressure appeared in the middle ear. Nowadays, in children with ET dysfunction, ET problems are more important than obstruction because of AH. Although AH is not large enough to cause an obstruction in the nasopharynx, it leads to colonization of pathogens and chronic

or recurrent inflammation.[18,19] Chen et al.[20] performed paracentesis and adenoidectomy to 26 of 46 patients with OME and reported that the volume of the external ear canal and mastoid cells reached the level seen in healthy children.[20]

In our study, 20% of all patients had AH. We demonstrated that the mean preoperative volume of the external ear canal in patients with AH was significantly lower than in patients without AH, which means that middle ear aeration also decreased.

Our study had a few limitations. A tympanometric study with wide band tympanometry would be better for obtaining detailed results, and a larger patient volume is needed to clarify this subject.

In conclusion, our study is the first to compare pre- and postoperative tympanometric immittance values after cochlear implantation. Male gender and adenoid hypertrophy are risk factors for OME. Due to the differences in compliance and gradient values, it can be said that there is a predisposition to OME in ears with cochlear implants. However, the peak pressure and external ear canal volume measurements were not significantly different after surgery. Although the values of compliance and gradient are low in OME, we cannot say that they are reliable enough. It is too early to say that the decrease in the mean value of compliance in patients with cochlear implants enables the occurrence of OME. Further research with larger patients groups is required.

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