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Cochlear implantation in children with meningitis related deafness: The influence of electrode impedance and implant charge on auditory performance – A case control study

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ABSTRACT

Objectives: Bacterial meningitis can cause a labyrinthitis. Consequences often are intracochlear soft tissue neoformation (cochlear obliteration) or intracochlear osteoneogenesis (cochlear ossification) and deafness. Cochlear implantation becomes challenging and hearing rehabilitation is complicated. This retrospective case-control-study aimed to find correlations between morphologic, electric and functional parameters.

Methods: The study group included children, who lost hearing due to a bacterial meningitis (n = 35 cases). Using preoperative computed tomography and intraoperative findings we grouped into 'unaltered cochleae', 'obliterated cochleae' and 'ossified cochleae'. Control group children suffered from deafness (n = 16) of other aetiology and presented with radiologically unchanged cochleae. Postoperative routine controls documented impedances, stimulation charge and hearing tests a various time points, which all were analysed.

Results: Control group patients showed a mean impedance of 6.3 kΩ and the mean charge applied was 19 nC. The study group averaged at 7.9 kΩ and 24.6 nC respectively. Patients with ossified cochleae had increased values of 8.6 kΩ and 29.7 nC. The control group reached a monosyllabic word understanding of 74% and the study group of 58%. Patients with ossified cochleae reached 36%.

Conclusions: Impedances and stimulation charge influence each other. Increased charge is necessary for higher cochlear implant output. Despite higher charges, patients with obliterated and patients with ossified cochleae significantly perform worse in hearing rehabilitation. Reduced audiological outcome in study group patients without morphologic cochlear changes furthermore hints at additional factors besides cochlear tissue neogenesis like postinflammational changes at the neural pathway.

1. Introduction

Bacterial meningitis is known to be the leading cause of postnatal deafness in children. It is supposed that inflammatory cells gain access to the cochlea along the cochlear, vestibular and facial nerves and via perilymphatic spaces [1]. Thus, inflammation is more pronounced in the scala tympani than in the scala vestibuli and is greatest in the basal turn of the cochlea [2–4]. Sequelae of inflammation are fibrosis and osteoneogenesis, which typically start within 4–8 weeks after the onset of the illness and is found in up to 34% of affected children [5]. It is characterized by an ongoing fibrous and bony cochlear obliteration, which may go on up to 30 years from the initial infection [6].

Cochlear implantation has been established as the treatment option of choice in patients with profound and severe sensorineural hearing loss. Cochlear implantation in post-meningitic patients is challenging due to the high incidence of cochlear bone formation. Whenever possible, implantations should be performed as soon as possible after deafness has been diagnosed as otherwise it might end unsuccessful [7–10].

One electrical parameter for evaluating the integrity of cochlear implants is electrode impedance. It is determined as the ratio between the electrical voltage, measured between two electrodes and current intensity. Impedance values are influenced by the tissue around the electrode, the position of the electrode contact on the electrode array and by the size of the electrode surface [11]. The other parameter is charge, which often increases with higher impedances. The actual

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reason for the increased charge is very often related to tissue formation, being reflected in higher impedance values.

Earlier studies found, that children with meningitis related deafness exhibit higher impedances in relation to a control group independent of the presence or the degree of fibrous cochlear obliteration or cochlear ossification. Therefore, yet unknown factors are presumed to influence impedance values. In contrast, charge consumption seems to depend on the degree of ossification and obliteration [12]. One has to be aware, that the dynamic process of obliteration and ossification will continuously influence the electrode nerve interaction.

The main aim of successful cochlear implantation is to achieve better speech and hearing performances. Here, little obliteration in early ossification seems to be of greater advantage as children implanted within 6 months after meningitis presented a significantly better audiological outcome than children being implanted later [13]. Further factors influencing postoperative hearing rehabilitation are the period of normal auditory input prior to being deafened, the duration of deafness prior to implantation and the age at implantation [14,15].

The aim of this study was to evaluate the functional outcomes of children with meningitis related deafness and to correlate these parameters to of fibrous obliteration and ossification of the cochlea on the one hand and also to the characterizing electrical parameters electrode impedance and stimulation charge. This knowledge shall help to better predict and manage a hearing rehabilitation outcome in the phase after successful cochlear implantation in meningitis related-deafness patients.

2. Patients and methods

2.1. Study design and demographic data

In our retrospective case-control study, we evaluated children treated with a cochlear implant at the Department of Otolaryngology of Hannover Medical School between 1996 and 2010. According to our Ethic's committee no particular patient's approval is necessary when initiating retrospective projects as patients or parents in general agree to a possible, retrospective data analysis when signing the treatment agreement at our university clinic.

For this study, inclusion criteria were uni- or bilateral deafness as a sequela of bacterial meningitis (study group; n = 35 implantations). The control group included children suffering from congenital deafness of unknown aetiology but without any history of meningitis (n = 16 implantations). Deafness in both groups was not part of any syndrome. Both groups had an even male to female ratio. Deafness was verified by brain stem evoked response audiometry (BERA) in all cases.

The aim was to find out, how electrode impedances and implant stimulation charge influence the auditory performance in respect to post-meningitic changes such as intracochlear soft tissue neoformation (cochlear obliteration) and intracochlear osteoneogenesis (cochlear ossification).

For better comparison, only patients with cochlear implants manufactured by Cochlear were analysed. Included implants were the CI24 M using the standard (‘straight’) electrode and the CI24R (CS) and CI24RE(CA), which were fitted with the modiolar-hugging (Contour) electrode. The peri-modiolar electrode array differs from the straight one by its positioning in the cochlea closer to the modiolus. In preliminary analyses, we compared impedance and charge consumption values of our patients with straight electrodes and of our patients with contour electrodes. Neither the control group nor the study group patients did show significant differences between these subgroups.

All patient charts had to be complete in the context of routine clinical controls including pre- and postoperative work-up with the entire audiological and electrical data according to our clinic standards. Patients with re-implantations, learning or motor disabilities, syndromic conditions and with bilateral sequential cochlear implantation were excluded. Sources for data extraction were the clinic's medical database, the engineer's database and the setting protocols for each patient employing the programming software *Custom sound 4.0* provided by the manufacturer Cochlear Inc.

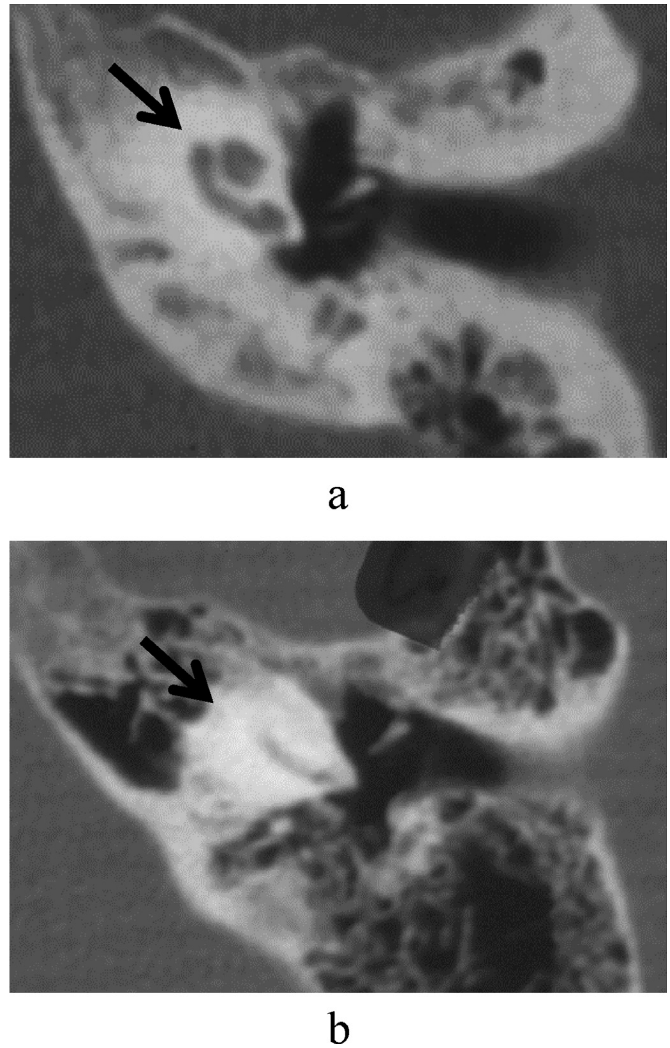

Fig. 1. HRCT-Scan of a left, unaltered cochlea (a). Each cochlear turn is clearly definable. In contrast, the ossified cochlea (b) of another patient is named ‘white cochlea’. The basal turn of the cochlea is hardly blurred while the second has completely disappeared.

2.2. Preoperative high-resolution computed tomography and assessment of the degree of cochlear ossification

The gold standard for evaluating bony structures in general and for evaluating the degree of cochlear ossification in particular is high-resolution computed tomography (HRCT). It is routinely performed in all of our cochlear implant candidates prior to implantation. During the years different protocols for scanning were used.

Scans were analysed by specialised neuro-radiologists of the Department of Neuroradiology at the Hannover Medical School. For this study ossification was assumed, when at least one cochlear turn was not distinguishable from the otic capsule (Fig. 1).

2.3. Cochlear implantation and intraoperative assessment of the degree of cochlear obliteration

According to our standard protocols, a routine mastoidectomy with a posterior tympanotomy was performed in all patients. Depending on the degree of ossification, different approaches to the cochlea were