Auditory and Vestibular Research

Post-meningitis cochlear implantation

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Highlights:

- Pediatric patients exhibit significantly better CI outcomes compared to adults
- Early CI (≤3 months) leads to improved speech outcomes following bacterial meningitis
- The severity of cochlear ossification limits the depth of electrode insertion

ABSTRACT

Background and aim: Bacterial meningitis, mainly Streptococcus pneumonia, is a primary cause of profound bilateral sensorineural hearing loss. Post-meningitic cochlear ossification, bony cochlear lumen obliteration, and often complicates cochlear implantation (CI) are happen post meningitis. The aim of this study is to evaluate the hearing outcomes and complications of CI in patients with hearing loss due to bacterial meningitis.
Methods: A 10-year retrospective review of 45 patients (pediatric and adult) underwent CI after bacterial meningitis at Martyr Gazi Alhariri Hospital, between 2012 and 2022. The outcomes were analyzed using speech perception scores, radiological imaging findings, and surgical reports for each patient.
Results: Early implantation (≤3 months post-meningitis) correlated with higher open-set speech recognition. Ossification severity inversely predicted electrode insertion depth (r= -0.67, p<0.01). In terms of audiological outcomes, open-set speech recognition was achieved in 62.2% of the patients (28/45), and pediatric showed significantly better performance than adults (75.0% vs. 35.3%). Similarly, early CI (≤3 months post-meningitis) was associated with higher rates of open-set speech recognition than was delayed implantation (>3 months) (72.7% vs. 43.5%; p = 0.003). The mean speech intelligibility rating (SIR) score for the entire cohort was 3.4±1.2, with pediatric patients scoring significantly higher than adults (4.1±0.8 vs. 2.7±1.1, respectively; p = 0.01).
Conclusion: Early CI and computed tomography (CT) imaging are critical for achieving better outcomes in post-meningitic deafness. Anticipatory CI within 3 months of post-meningitis enhances outcomes. Advanced imaging and adaptable surgical strategies can alleviate ossification-related challenges.
Keywords: Bacterial meningitis, cochlear implantation, drill-out procedure, partial electrode insertion

Introduction

Meningitis, especially the bacterial type, is a common cause of acquired sensorineural hearing loss (SNHL) in children and is considered one of the most debilitating complications of bacterial meningitis, occurring in approximately 10–35% of survivors (1). Deafness following meningitis is irreversible in 35% of cases and profound in 5% (2). SNHL is usually bilateral, symmetrical, and more common in males aged < 5 years, which can be start within a few days of the onset of meningitis, as many histopathological studies have demonstrated

that proliferation of fibroblasts (the initial step in ossification) can begin within 48 h of infection (3, 4), however, it can present up to 12 years after the onset of meningitis (3).
Following meningitis, bacteria spread mainly through the cochlear aqueduct, and less commonly, the internal auditory canal into the inner ear causes degeneration of the hair and ganglionic cells and obliteration of the scala of the cochlea by new bone formation (5).
New bone formation mainly affects the scala tympani of the basal turn of the cochlea, which is the site of electrode insertion during cochlear implantation, rendering Cochlea Implant (CI) technically difficult (6).
With the increase in surgical experience, availability of sophisticated computed tomography (CT) and magnatic resonance imaging (MRI) imaging techniques, and new electrode array models, it is worthwhile to proceed with implantation in these children (7-8). This study evaluated the importance of early surgical intervention and imaging in a cohort from Iraq, where the incidence of bacterial meningitis remains high due to insufficient meningitis vaccination coverage.
It has been recommended as a protocol to investigate all children with proven or suspected bacterial meningitis for deafness by pure-tone audiometry (PTA) and auditory brainstem response (ABR) before discharge from the Otology Center of Martyr Gazi Alhariri Hospital.

Methods

Participants and study design

This was a single-center, retrospective cohort study of patients who underwent CI for post-meningitic SNHL between 2012 and 2022 at Martyr Gazi Alhariri Hospital, Baghdad, Iraq.

Inclusion Criteria

- Bacterial meningitis was confirmed based on a positive cerebrospinal fluid (CSF) culture and Polymerase Chain Reaction (PCR).
- Profound bilateral SNHL (PTA >90 dB).

Exclusion Criteria

- Congenital hearing loss
- Incomplete follow-up (<12 months)
- Missing or lost data.

Work up

The collected data included history and examination notes focusing on the duration of hearing loss, drug history, noise exposure, and family history of hearing disabilities.Preoperative audiological information included free field, pure tone audiometry, otoacoustic emission, and auditory brainstem response measurements.

Radiological data

These included reports of thin-slice CT scan and MRI of the temporal bone, which were obtained from the records to assess scala tympani/vestibuli patency and the degree of ossification.
The intraoperative and postoperative notes were reviewed and recorded, beside, the follow-up data for the first year post-implantation were also evaluated.

Variables

Primary Outcome

- Speech Perception Scores: Assessed using the *Categories of Auditory Performance (CAP)* and *Speech Intelligibility Rating (SIR)* scales.

Secondary Outcomes

- Electrode Insertion Depth (mm): Measured intraoperatively or via postoperative imaging.
- Ossification Grade: Assessed using a CT-based 4-point scale:
    - *0 = Normal*
    - *1 = Partial ossification of the basal turn*
    - *2 = Advanced ossification with limited access*
    - *3 = Complete obstruction of the cochlea*

- Complications: Documented events including, but not limited to:
    - Facial nerve stimulation
    - Device failure
    - Other surgical or postoperative complications

Confounding Variables and Covariates

- Meningitis Severity: Evaluated based on:
    - *Cerebrospinal fluid (CSF) white blood cell (WBC) count*
    - *Glasgow Coma Scale (GCS)* at presentation
- Bacterial Etiology: Determined via:
    - CSF culture
    - Polymerase chain reaction (PCR) testing
- Socioeconomic Status (SES): Evaluated using:
    - *Parental education level* (for pediatric cases)
    - *Residential setting* (rural vs. urban)

These variables (meningitis severity, bacterial species, and socioeconomic status) were included as covariates in multivariate regression models to assess their potential influence on speech perception outcomes.

Surgical protocol

Cortical mastoidectomy with posterior tympanotomy and facial recess approach was followed by the drill-out technique for scala tympani ossification. Types of electrodes used: double-array or perimodiolar. Based on the ossification grade,

- Cochlear Nucleus (CI 522/622) for partial ossification cases.
- Med-El Flex 28 for complete ossification.

Statistical Analysis

Data were analyzed using SPSS version 24.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics are presented as mean ± SD for continuous variables and as frequencies and percentages for categorical variables. Group comparisons were performed using the independent samples t-test for continuous variables and chi-square test for categorical variables. The correlation between the ossification grade and electrode insertion depth was assessed using Pearson's correlation coefficient. Multivariate linear regression analysis was conducted to evaluate the potential influence of confounding variables, including meningitis severity (CSF, WBC count and Glasgow Coma Scale), bacterial etiology, and socioeconomic status, on speech perception outcomes (CAP and SIR scores). Statistical significance was set at $p < 0.05$.

Results

Patient Characteristics

A total of 45 patients were included in the study, comprising 28 pediatric patients (<15 years) and 17 adults. The overall mean age was 9.2±8.8 years, with pediatric patients averaging 3.1±2.9 years and adults 32.5±6.7 years. The male-to-female ratio was 24:21, with similar distributions in the pediatric (15:13) and adult (9:8) subgroups. Early cochlear implantation (defined as ≤3 months post-meningitis) was performed in 22 patients (48.9%), with a significantly higher proportion in the pediatric group (64.3%) than in the adult group (23.5%). Preoperative CT scans revealed grade 2–3 cochlear ossification in 26 cases (57.8%), occurring in 57.1% of pediatric and 58.8% of adult patients. Mild or no ossification (grade 0–1) was observed in the remaining 19 (42.2%) patients. (Table 1)

Radiological and Surgical Findings

On preoperative CT, Grade 2–3 cochlear ossification was observed in 57.8% of cases (26/45), which was significantly associated with reduced electrode insertion depth (18.2 ± 2.4 mm vs. 25.6 ± 1.9 mm, $p < 0.001$). (Table 1)

Audiological Outcomes

In terms of audiological outcomes, open-set speech recognition was achieved in 62.2% of the patients (28/45), and pediatric patients showed significantly better performance than adults (75.0% vs. 35.3%). Similarly, early cochlear implantation (≤3 months post-meningitis) was associated with higher rates of open-set speech recognition than was delayed implantation (>3 months) (72.7% vs. 43.5%; p = 0.003). The mean speech intelligibility rating (SIR) score for the entire cohort was 3.4±1.2, with pediatric patients scoring significantly higher than adults (4.1±0.8 vs. 2.7±1.1, respectively; p = 0.01). Patients who received early implantation also demonstrated higher SIR scores than those with delayed implantation (4.1 ± 0.7 vs. 2.7 ± 1.0). Full electrode insertion was achieved in 75.6% of patients (34/45), with higher rates observed in pediatric patients (82.1%) than in adults (64.7%) and in early implanted cases (90.9%) than in delayed cases (60.9%). (Table 2)

Surgical Complications

Surgical complications were observed in a subset of patients. Partial electrode insertion occurred in 24% of the cases (11/45), with a higher incidence in adults (35.3%) than in pediatric patients (17.9%). Facial nerve stimulation was reported in 18% of patients (8/45) and more frequently in adults (23.5%) than in children (14.3%). All patients were successfully managed with postoperative programming adjustments. Device failure was rare, occurring in two cases in the cohort (2/45), with one case each in the pediatric and adult groups. (Table 3)

Discussion

Our findings, particularly the 75% open-set speech recognition rate in early CI cases, underscore the critical importance of early intervention and application of advanced imaging techniques in managing post-meningitic deafness. These results align with those reported by Carlson et al.(9), who documented an 80% open-set recognition rate, and surpass those of Durisin et al.(1), potentially due to the use of a more detailed and stricter ossification grading system in our study. Our outcomes are also consistent with those of Young et al.(10), who reported 80% open-set recognition in children implanted within three months post-meningitis, emphasizing the necessity of timely CI to avoid labyrinthine ossification and fibrosis. The comparatively lower speech perception scores in adults may reflect delayed referral and implantation, highlighting the need for prompt diagnosis and intervention in all age groups.

We observed a significant inverse correlation between ossification grade and electrode insertion depth (r = -0.67, p < 0.01), in line with the findings of Balkany et al. (11), who noted insertion lengths often reduced to <15 mm in cases of Grade 3 ossification. Facial nerve stimulation occurred in 18% of the patients, possibly due to increased neural excitability following meningeal inflammation. This observation was comparable to the results reported by Hansen et al. (12). The type of bacterial pathogen did not significantly influence speech outcomes (p = 0.21), suggesting that microbiological etiology may not be an independent predictor of CI success, although studies with larger sample sizes are warranted to confirm this.

Electrode selection in our study was guided by preoperative imaging and ossification severity to optimize insertion depth. However, no significant difference in speech outcomes was observed between implant devices, likely because of adherence to standardized surgical protocols (13). Early cochlear implantation following meningitis is strongly associated with improved speech perception outcomes, particularly in pediatric patients. The use of high-resolution imaging, including CT and MRI, plays a crucial role in preoperative planning by identifying the severity of ossification and predicting surgical challenges.

This study is limited by its retrospective design and single-center setting, unlike the multicenter study by Van Loon et al.[13], which also emphasized the benefits of early CI in meningitis-associated deafness. Additionally, variability in post-implantation rehabilitation adherence may have influenced speech perception outcomes, an aspect that warrants further evaluation.

Conclusion

Anticipatory CI within 3 months of post-meningitis enhances outcomes. Advanced imaging and adaptable surgical strategies can alleviate ossification-related challenges. Our findings support the need for timely referral and intervention to maximize auditory outcomes and reduce complications, such as partial electrode insertion and facial nerve stimulation. While bacterial etiology did not significantly impact outcomes, the ossification grade was inversely correlated with insertion depth, underscoring the value of detailed imaging assessment. Standardized surgical techniques and individualized electrode selection contributed to consistent results across devices. Future prospective multicenter studies are recommended to validate these findings and further explore the role of rehabilitation compliance in post-CI outcomes.

Author Contributions:

AMA: Study design, acquisition of data, writing, and drafting the manuscript; HMHA: Study design and supervision, interpretation of the results, writing draft, and critical revision of the manuscript; MSM: Interpretation of the results, methodology, writing – original draft, and critical revision of the manuscript; SAS: Investigation, methodology, software, writing – original draft and statistical analysis.

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Ethical Considerations

This study was approved by the Ethics Committee of The Otorhinolaryngology Department, College of Medicine, University of Baghdad (Code: 180-2974 in 30/4/2020).

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Table 1: Demographic and clinical characteristics

Variable	Total (n=45)	Pediatric (n=28)	Adult (n=17)
Mean age (years)	9.2±8.8	3.1±2.9	32.5±5.6
Male: Female ratio	24: 21	15: 13	9: 8
Timing of CI(≤3 month)	22 (48.9%)	18 (64.3%)	4(23.5%)
Ossification grade (CT scan)			
Grade 0-1	19 (42.2%)	12 (42.9%)	7 (41.2%)
Grade 3	26 (57.8%)	16 (57.1%)	10 (58.8%)

Table 2: Audiological outcome by age group and timing

Outcome	Overall (n=45)	Pediatric (n=28)	Adult (n=17)	Early CI ≤3 m (n=22)	Delayed CI >3 m (n=23)
Open-set speech recognition	28 (62.2%)	21 (75.0%)	6 (35.3%)	16 (72.7%)	10 (43.5%)
Mean SIR score (±SD)	3.4 ± 1.2	4.1 ± 0.8	2.7 ± 1.1	4.1 ± 0.7	2.7 ± 1.0
Full electrode insertion	34 (75.6%)	23 (82.1%)	11 (64.7%)	20 (90.9%)	14 (60.9%)

SIR: Speech Intelligibility Rating; CI: Cochlear Implantation

Table 3: Complications recorded in the study.

Complication	Pediatric (n=28)	Adult (n=17)
Partial electrode insertion	5 (17.9%)	6 (35.3%)
Facial nerve stimulation	4 (14.3%)	4 (23.5%)
Device failure	1 (3.6%)	1 (5.9%)