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Prelingual auditory-perceptual skills as indicators of initial oral language development in deaf children with cochlear implants

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ABSTRACT

Objectives: To assess when prelingually deaf children with a cochlear implant (CI) achieve the First Milestone of Oral Language, to study the progression of their prelingual auditory skills in the first year after CI and to investigate a possible correlation between such skills and the timing of initial oral language development.

Methods: The sample included 44 prelingually deaf children (23 M and 21 F) from the same tertiary care institution, who received unilateral or bilateral cochlear implants. Achievement of the First Milestone of Oral Language (FMOL) was defined as speech comprehension of at least 50 words and speech production of a minimum of 10 words, as established by administration of a validated Italian test for the assessment of initial language competence in infants. Prelingual auditory-perceptual skills were assessed over time by means of a test battery consisting of: the Infant Toddler Meaningful Integration Scale (IT-MAIS); the Infant Listening Progress Profile (ILiP) and the Categories of Auditory Performance (CAP).

Results: On average, the 44 children received their CI at 24 ± 9 months and experienced FMOL after 8 ± 4 months of continuous CI use. The IT-MAIS, ILiP and CAP scores increased significantly over time, the greatest improvement occurring between baseline and six months of CI use. On multivariate regression analysis, age at diagnosis and age at CI did not appear to bear correlation with FMOL timing; instead, the only variables contributing to its variance were IT-MAIS and ILiP scores after six months of CI use, accounting for 43% and 55%, respectively.

Conclusion: Prelingual auditory skills of implanted children assessed via a test battery six months after CI treatment, can act as indicators of the timing of initial oral language development. Accordingly, the period from CI switch-on to six months can be considered as a window of opportunity for appropriate intervention in children failing to show the expected progression of their auditory skills and who would have higher risk of delayed oral language development.

1. Introduction

Currently, the standard of health care offers deaf children early access to optimal auditory perception thanks to the availability of universal newborn hearing screening programs and cochlear implants (CI), the latter providing exposure to language and, thus, the possibility to develop oral communication skills as close as possible to normal hearing (NH) peers [1–3].

However, clinical experience suggests that large variability exists for the development of prelingual auditory-perceptual skills for deaf children following CI, which constitutes one of the fundamental building blocks for initial development of oral language. That is, some children show rapid progress in oral communication, while others may lag behind and ultimately rely on using total communication or sign language, despite early diagnosis and timely treatment.

Known factors predicting oral language comprehension and production skills in implanted children include age at cochlear implantation [4], unilateral vs bilateral stimulation [4], socio-economic status of the family [1,5], degree of parental involvement in rehabilitation [6] and type of rehabilitation [7]. Some of these conditions are very difficult, or even impossible, to correct or

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modify in time; i.e. early enough to prevent their influence on prognosis. Further, the impact of such factors on language comprehension and production skills may only be seen in the long-term, not becoming evident until after several years of CI use [4,8].

Existing studies on preverbal perceptual skills of implanted children [9–12] rather focus on patient-related or environmental determinants of such skills, than on their potential to predict linguistic abilities.

It is of interest and important to investigate whether certain prelingual auditory skills may be predictive of an imminent beginning of *oral language development*; i.e. to determine when the deaf child's auditory-perceptual skills are sufficiently functional to allow the appropriate development of subsequent oral language and communication in the short term. This would be crucial information for the clinician or therapist to set up both adequate and timely intervention in cases who are at risk of poorer outcomes.

Therefore, the aims of this retrospective study on prelingually deaf Italian children are to investigate:

1. the time point after cochlear implantation at which initial oral language skills, defined as First Milestone of Oral Language (FMOL), are achieved;
2. the progress of prelingual auditory skills in the first year after CI;
3. whether clinical factors or prelingual auditory skills contribute to the timing of FMOL.

2. Material and methods

This retrospective study received approval by the Institutional Review Board and is in accordance with the Helsinki declaration. A written informed consent was obtained from parents of the enrolled children.

2.1. Selection criteria

Inclusion criteria were: bilateral, prelingual, severe-to-profound sensorineural hearing loss; age at CI between one and five years; all stimulation channels active; stable CI map after three months of CI use; CI-aided free-field auditory thresholds ≤ 30 dB HL; and Ling's Six-Sound Test [13] score ≥ 6 at three months' follow-up.

Exclusion criteria were the presence of deafness-associated disabilities associated with a significant cognitive delay; genetic syndromes; and postlingual onset of hearing loss.

2.2. Study population

A sample of 44 children (23 males and 21 females) who met the inclusion criteria were included into the retrospective study from a single, tertiary-care, pediatric audiology department receiving treatment between 2010 and 2013. All children were using a CI512 implant with either a CP810™ or a CP910™ speech processor (Cochlear®, Sydney, Australia). Fitting parameters (ACE strategy, 25 μs pulse width and 900 pps pulse rate) were the same for all subjects. Age at diagnosis was 14 ± 10 months (range = 4–45 months) and age at CI was 24 ± 9 months (range = 12–58 months).

2.3. Definition and assessment of FMOL

Currently, there is no shared definition for the achievement of baseline skills of oral language (i.e. the FMOL). In fact, the progression of such skills appears to occur as a continuum and shows considerable variability even among healthy children with no disabilities. Such variability becomes larger in deaf children, in whom a number of cumulative factors exist, ranging from socio-cultural aspects to specific clinical issues. Therefore, the criteria defining FMOL in the present study were established arbitrarily by means of the "Primo Vocabolario del Bambino" (English translation: "First Vocabulary of a Child") [14], a validated Italian version of the MacArthur-Bates Communicative Development Inventories – Words and Sentences [15] for the assessment of early receptive and expressive language skills, administered by a speech therapist once a month for a 24-month follow-up period. According to normative data from the Italian version, 12-month-old, normal-hearing children show an average comprehension of 53 ± 4 words and production of 8 ± 9 words. Therefore, in the present study, comprehension of at least 50 words and production of a minimum 10 words (including onomatopoeic sounds) were considered as indicators of the achievement of basal competences for the development of language, and thus as an equivalent of FMOL.

2.4. Prelingual auditory skills assessment

For the assessment of prelingual auditory skills a test battery was administered by a speech therapist at baseline (at CI switch on) and after 6 and 12 months of CI use. The battery consisted of the following evaluations:

- Infant-Toddler Meaningful Integration Scale (IT-MAIS) [16]: a structured questionnaire with an interview schedule designed to assess the child's spontaneous responses to sound in their everyday environment. The assessment is based upon information provided by the child's parents in response to 10 probes. These 10 probes assess three main areas: vocalization behavior, spontaneous alerting to sounds, and deriving meaning from sound. The questions are designed to elicit a dialogue between the examiner and the informant. This questionnaire also explores the duration of daily use of the processor and the child's adaptation to its use, and its score ranges from 0 to 36.
- Infant Listening Progress Profile (ILiP) [17]: this is an assessment tool of the child's listening responses, completed by the speech therapist via direct observations while engaging the child in play activities. This test investigates the first response to environmental sounds and to voices, sound recognition, and the child's identification of his/her name. The child's responses are scored from 0 (inconsistent) to 2 (always), with a total maximum score of 16.
- Categories of Auditory Performance (CAP) scale [18]: an auditory perception skill rating index consisting of eight performance categories. The rank achieved is scored from a hierarchy of auditory skills presented that increase in difficulty from no awareness of environmental sound (level 0) up to using the telephone with a familiar speaker (level 7).

2.5. Statistical analysis

It was performed using the Medcalc™ software (version 12.7, Marienkerke, Belgium). A Kolmogorov–Smirnov test confirmed the normal distribution of the continuous variables IT-MAIS and ILiP scores ($p > 0.05$). Therefore, Student's *t* test was used for between-group comparisons and ANOVA for the assessment of between- and within-subjects effects; instead, for ordinal variables (CAP) a Kruskal–Wallis test was used.

To evaluate the contribution of clinical factors (age at diagnosis and age at CI) and prelingual auditory skills (IT-MAIS, ILiP scores and CAP at baseline, 6 and 12 months of CI use) to the variance of FMOL timing, univariate and multivariate linear regression models were used. Multivariate regression followed a stepwise method: