International Journal of Pediatric Otorhinolaryngology 78 (2014) 1000–1009

Contents lists available at ScienceDirect

International Journal of Pediatric Otorhinolaryngology

journal homepage: www.elsevier.com/locate/ijporl

Development of Mandarin spoken language after pediatric cochlear implantation

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ARTICLE INFO

Article history:
Received 15 October 2013
Received in revised form 10 March 2014
Accepted 17 March 2014
Available online 28 March 2014

Keywords:
Early language development
Mandarin Communicative Development Inventory
Receptive vocabulary
Expressive vocabulary
Cochlear implant
Early intervention

ABSTRACT

Objective: The purpose of this study was to evaluate early spoken language development in young Mandarin-speaking children during the first 24 months after cochlear implantation, as measured by receptive and expressive vocabulary growth rates. Growth rates were compared with those of normally hearing children and with growth rates for English-speaking children with cochlear implants.
Method: Receptive and expressive vocabularies were measured with the simplified short form (SSF) version of the Mandarin Communicative Development Inventory (MCDI) in a sample of 112 pediatric implant recipients at baseline, 3, 6, 12, and 24 months after implantation. Implant ages ranged from 1 to 5 years. Scores were expressed in terms of normal equivalent ages, allowing normalized vocabulary growth rates to be determined. Scores for English-speaking children were re-expressed in these terms, allowing direct comparisons of Mandarin and English early spoken language development.
Results: Vocabulary growth rates during the first 12 months after implantation were similar to those for normally hearing children less than 16 months of age. Comparisons with growth rates for normally hearing children 16–30 months of age showed that the youngest implant age group (1–2 years) had an average growth rate of 0.68 that of normally hearing children; while the middle implant age group (2–3 years) had an average growth rate of 0.65; and the oldest implant age group (>3 years) had an average growth rate of 0.56, significantly less than the other two rates. Growth rates for English-speaking children with cochlear implants were 0.68 in the youngest group, 0.54 in the middle group, and 0.57 in the oldest group. Growth rates in the middle implant age groups for the two languages differed significantly.
Conclusions: The SSF version of the MCDI is suitable for assessment of Mandarin language development during the first 24 months after cochlear implantation. Effects of implant age and duration of implantation can be compared directly across languages using normalized vocabulary growth rates. These comparisons for Mandarin and English reveal comparable results, despite the diversity of these languages, underscoring the universal role of plasticity in the developing auditory system.

1. Introduction

Cochlear implantation of very young children with profound bilateral sensorineural hear loss (SNHL) is widely recognized as a treatment that can enable children to develop and use spoken language. Longitudinal studies of children implanted before the age of 4 years have found that the rate of language development, as determined by growth of the child's receptive and expressive vocabulary during the first several years after implantation, often parallels that of normally hearing children, especially when children are implanted under the age of 2 years [1–6]. Other investigators have found that the language outcomes 7 years or more after pediatric implantation are often within the normative range of children with normal hearing [7,8], especially if the child has had even limited acoustic hearing prior to implantation [9,10].

The success of pediatric cochlear implant (CI) programs in the habilitation of children with bilateral profound SNHL has fostered many efforts throughout the world focused on providing hearing aids and/or CIs to hearing impaired children within the first

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http://dx.doi.org/10.1016/j.ijporl.2014.03.020
0165-5876/

months after hearing loss is identified through infant screening [11]. Perhaps the largest of these programs is in China. With the world's largest population, the number of childbirths per year in China is estimated at over 16.5 million [12]. Assuming an incidence of pediatric hearing impairment in normal childbirths of 0.2%, over 33,000 hearing impaired infants are born every year, resulting in approximately 137,000 hearing impaired children under the age of 6 years at a given time [13]. Some portion of these hearing impaired children will require cochlear implantation to develop and use spoken language. These considerations underscore the importance of understanding the various factors that can affect Chinese speech and language development after cochlear implantation. The foregoing results have all been obtained with English-speaking children, raising the question of whether the same is true for other diverse languages, cultures, and approaches to (re)habilitation throughout the world. This question can only be addressed with objective evaluations of early language development throughout the months and years following early implantation using measures that allow direct comparisons of English and Chinese language development.

Ideally, factors affecting spoken language development in non-tonal languages, such as English, are similar to those affecting tonal languages such as Mandarin, the primary language spoken in China. However, direct comparisons of spoken language development in English and Mandarin using comparable measures for both languages have not previously been possible because of the many differences in the phonology, structure, grammatical rules, and the vocabulary of the two languages. The current research describes a method based on comparisons of vocabulary growth rates that can bridge these numerous differences to allow direct comparisons of spoken language development in English and Mandarin. This research is part of a larger four-year longitudinal outcome study of profoundly deaf children implanted under the age of 6 years at West China Hospital of Sichuan University. The model for the design of this study and the selection of outcome measures is the childhood development after cochlear implantation (CDaCI) study which has been ongoing in the US since 2002 [1,2,14].

The CDaCI study employed a hierarchical battery of pediatric assessment tools to evaluate early prelingual auditory development, speech perception, and language development [14]. This battery consisted of the infant and toddler version of the Meaningful Auditory Integration Scale (ITMAIS) and the preschool version (MAIS), the early speech perception (ESP) test, the pediatric speech intelligibility (PSI) test, and the pediatric version of the hearing in noise test (HINT) [15–20]. Mandarin versions of each of these assessment tools have also been developed, normed, and used in clinical studies [21–30].

English spoken language development was evaluated with the Reynell Developmental Language Scales (RDLS) in the CDaCI study [31,32]. The RDLS utilizes direct interaction with and observation of the child to evaluate language comprehension and expression abilities, which are expressed as comprehension scores, analogous to measures of receptive vocabulary, and Expression scores, analogous to measures of expressive vocabulary. These scores are used to determine vocabulary growth rates as a measure of language development that can be compared with norm-referenced rates. The version of the RDLS used in the CDaCI study is appropriate for evaluation of developmentally normal children up to 6 years of age.

Ideally, Mandarin spoken language development should also be evaluated with the RDLS; however, these scales are not available in Mandarin. Studies of Mandarin language development in pediatric CI recipients have used measures of language development other than vocabulary growth rates [33,34] that do not enable direct comparisons of English and Mandarin language development. The current study utilized measures of vocabulary growth rates obtained with the Mandarin version of the MacArthur-Bates Communicative Development Inventory (CDI) [35], the Mandarin CDI or MCDI, developed by Tardif and Fletcher [36]. The MCDI has been used in a number of studies of early language development in Chinese children with normal hearing [37–42]; however, the MCDI has not previously been used in studies of pediatric CI recipients.

Unlike the RDLS, the CDI and MCDI utilize parent reports of the items in their child's receptive and expressive vocabularies and their use of age-appropriate grammatical structures. There are two vocabulary inventories in the MCDI relevant to the current study: the Words and Gestures (W&G) inventory, which assesses receptive and expressive vocabulary in developmentally normal children between 8 and 16 months of age, and the Words and Sentences (W&S) inventory, which assesses expressive vocabulary in children between 16 and 30 months of age [35,36]. The large sizes of these MCDI inventories, 411 words for W&G and 799 words for W&S, make it possible to evaluate both the size and linguistic structure of a child's vocabulary; however, the time required to administer these MCDI inventories in their entirety preclude may their use in a busy clinic setting. Soli et al. [43] have developed simplified short form (SSF) versions of these inventories with 50 items each that evaluate vocabulary growth, rather than the size and linguistic structure of the vocabulary. Developmental trajectories characterizing the rate of receptive and expressive vocabulary growth in developmentally normal children obtained with the SSF inventories are comparable to those measured with the full-length MCDI inventories.

The RDLS is intended for use with developmentally normal children up to 6 years of age, while the MCDI inventories are intended for use with developmentally normal children up to 30 months of age. Thus, the chronological age of CI recipients in the current study exceeds the age range for which the MCDI norms were developed. Thal et al. [6] have addressed this issue by administering both the RDLS and the CDI to a sample of pediatric CI recipients ranging in age from 32 to 86 months of age. They found the validity of the CDI as a predictor of the RDLS measures to be "excellent" as long as the language ability of the subjects was within the range measured by the CDI. Other investigators have also successfully used the CDI to predict RDLS measures for pediatric CI recipients [4,5]. These considerations suggest that comparisons of English language development obtained with the RDLS and Mandarin language development obtained with the MCDI are appropriate.

1.1. Direct comparison of Mandarin and English spoken language development

Given that different measures of English and Mandarin early language development must be used, a rationale that allows direct comparison of English spoken language development, as measured with the RDLS, and Mandarin spoken language development, as measured with the MCDI, is required. This rationale is based on the assumption that the rate of vocabulary growth provides a valid measure of spoken language development. Both the RDLS and the MCDI can be used to characterize receptive and expressive vocabulary growth rates by comparing estimates of vocabulary size obtained at multiple evaluation intervals. However, these measures of growth rates for different languages must be expressed in the same units to allow direct comparisons across languages.

Niparko et al. [2] express RDLS scores in terms of "language age," the chronological age at which the average developmentally normal child would achieve that score. Thus, increases in language age with increasing chronological age provide evidence of spoken language development. Scores obtained with the SSF inventories of the MCDI can also be expressed in terms of language age. Soli et al.