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Intelligence development of pre-lingual deaf children with unilateral cochlear implantation

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ABSTRACT

Objective: The present study aims to test whether deaf children with unilateral cochlear implantation (CI) have higher intelligence quotients (IQ). We also try to find out the predictive factors of intelligence development in deaf children with CI.

Methods: Totally, 186 children were enrolled into this study. They were divided into 3 groups: CI group (N = 66), hearing loss group (N = 54) and normal hearing group (N = 66). All children took the Hiskey-Nebraska Test of Learning Aptitude to assess the IQ. After that, we used Deafness gene chip, Categories of Auditory Performance (CAP) and Speech Intelligibility Rating (SIR) methods to evaluate the genotype, auditory and speech performance, respectively.

Results: At baseline, the average IQ of hearing loss group (HL), CI group, normal hearing (NH) group were 98.3 ± 9.23, 100.03 ± 12.13 and 109.89 ± 10.56, while NH group scored higher significantly than HL and CI groups ($p < 0.05$). After 12 months, the average IQ of HL group, CI group, NH group were99.54 ± 9.38,111.85 ± 15.38, and 112.08 ± 8.51, respectively. No significant difference between the IQ of the CI and NH groups was found ($p > 0.05$). The growth of SIR was positive correlated with the growth of IQ ($r = 0.247$, $p = 0.046$), while no significant correlation were found between IQ growth and other possible factors, i.e. gender, age of CI, use of hearing aid, genotype, implant device type, inner ear malformation and CAP growth ($p > 0.05$).

Conclusions: Our study suggests that CI potentially improves the intelligence development in deaf children. Speech performance growth is significantly correlated with IQ growth of CI children. Deaf children accepted CI before 6 years can achieve a satisfying and undifferentiated short-term (12 months) development of intelligence.

1. Introductions

The development of multichannel cochlear implant (CI) and the improvement in surgical skills have made cochlear implantation an accepted and standard treatment for severe to profound sensorineural hearing loss in children and adults. The primary effect of CI is to enable speech perception [1], and improvements in speech perception are often accompanied by gains in oral language development [2].

The outcome of CI varies over a wide range among pediatric patients. Some prelingually deafened children show outstanding behavioral performance, such as the rapid acquisition of spoken language and the production of intelligible speech after years of CI-assisted rehabilitative effort, while other children develop awareness of environmental or speech sounds but never catch up with normal age-appropriate auditory language [3]. Previous studies have provided the evidence that the younger age at implantation, the better outcomes of spoken language and speech perception [4,5]. Some studies indicated that children with CI who had GJB2-related deafness displayed better auditory and speech performance [6,7]. A great deal of researches have been devoted to understanding hearing and spoken language development in deaf children with CI, very little has been performed to investigate general intelligence development after CI.

As we known, children with even mild or unilateral hearing loss tend to score lower on intelligence tests than normal hearing peers [8,9]. Studies of some aspects of cognitive capabilities in children with and without normal hearing have revealed that the latter

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experience difficulties at the cognitive level [10,11]. We wonder that, as long as deaf children provided with sufficient language and communication access by CI, could they obtain a better outcome of intelligence development? And what are the predictive factors of their intelligence development? A few studies stated that children with CI display distinctive developmental patterns in cognitive function, compared with normal hearing children and deafness children [12,13], and implant age was a predictive factor of intelligent development of children with CI [14]. There is still a need for a greater understanding of CI users' intelligence development and the predictive factors.

Thus, this study aims to evaluate the intelligence quotients diversity among CI children, deaf children and normal-hearing children. We also try to find out the related factors that influence the outcomes of intelligence development in deaf children with CI.

2. Methods

2.1. Subjects

We recruited 66 children (cochlear implantation group, CI group) with profound hearing loss who received unilateral CI at the Department of Otolaryngology Head and Neck Surgery, the Second Xiangya Hospital, Central South University in China. The inclusion criteria were: bilateral pre-verbal profound sensorineural hearing loss, and age between 3 and 6 years. Exclusion criteria included a history of a seizure disorder, learning disability, progressive neurological problem or traumatic brain injury, additional significant disabilities (e.g., blindness, autism), not using mandarin as the primary mode of communication or any other serious medical condition.

The CI group consist of 32 girls and 34 boys, mean age 4.35 ± 0.98 (range 3–6 years). All children were implanted with unilateral CI at a mean age of 3.35 ± 0.98 months (range 2–5 years). Thirty four (51.5%) children used hearing aid while thirty two (48.5%) children did not. CI children were implanted with unilateral CI of CI24R (Cochlear Corperation, Australia) (n = 27), Combi40+ (MED-EL Corperation, Austria) (n = 30) or Hires90k (AB Corperation, America) (n = 41). Eight (12.1%) children were found Large Vestibular Aqueduct Syndrome (LVAS), while fifty eight (87.9%) were not.

We also recruited 66 healthy children with normal hearing (normal-hearing group, NH group) and 54 deaf children without CI (hearing loss group, HL group) who were matched with children with CI in CI group by their chronological ages, hearing loss degree, hearing aid experiences, genders and family incomes. The same exclusion criteria used in the CI group were used to select the control group.

The HL group consisted of 25girls and 29 boys, with mean age 3.94 ± 0.89 (range 3–6 years). The NH group consisted of 66 healthy children, 32 girls and 34 boys, with mean age 4.09 ± 1.02 (range 3–6 years). No statistically significant difference among three groups on gender (p = 0.125), age (p = 0.964) and family incomes (p = 0.461) were found (Table 1).

Informed consent was obtained in all cases, and protocols were approved by scientific ethical committee of the Second Xiangya Hospital.

2.2. Research procedures and content

Table 2 shows the research procedures and content of this study. All patients took the IQ test in the first and 12th month, respectively. Children in CI group had the auditory and speech tests in the first and 12th month. Besides, CI group had underwent Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) of ears, deaf related gene test and cochlear implantation in the first month.

2.3. Assessments

2.3.1. The Hiskey-Nebraska Test of Learning Aptitude

For the evaluation of intelligence, all the children in 3 groups were assessed the first time in the first month after recruited into this study and the second time 12 months later at the Deaf Children Rehabilitation Center of Hunan Province. The Hiskey-Nebraska Test of Learning Aptitude (H-NTLA) is among the most widely used measures of non-verbal intellectual ability with hearing impaired youngster, and has been described as one of the best individual tests for this population [15]. It is widely used all over the world [16].

The H-NTLA consists of measure aspects of visual memory, visual organization, visual discrimination, and visual association. Administration is through pantomimed directions, and responses are given nonverbally. It includes 12 subtests which are sort from easy to difficult: (1) beads stringing; (2) color remembering; (3) figure identification; (4) picture association; (5) paper folding; (6) short-term visual memory; (7) building blocks; (8) picture finishing; (9) number remembering; (10) building mazy blocks; (11) picture analogy; (12) spatial reasoning. Subjects age 3–8 take the former 8 subtests while age 9–17 take the later 7 subtests. Subjects in this study range from 3 to 6 years old, thus, we used the former 8 subtests. Two experienced psychologists conducted all subtests separately. Each subtest score is converted to learning age. From 8 subtests, we got 8 learning ages, and the median learning age is used to determine each participant's ratio intelligence quotient (RIQ). RIQ = (median age/chronological age) × 100. According to two psychologists, we got 2 RIQ scores for every subject. We used

Table 1
General information about the participants.

		CI (n = 66)	HL (n = 54)	NH (n = 66)	χ^2	*p*
Gender					0.074	0.964
	Male	34	29	34		
	Female	32	25	32		
Age					9.990	0.125
	3 years	16	19	16		
	4 years	19	23	19		
	5 years	23	8	23		
	6 years	8	4	8		
Family incomes (RMB/year)					1.548	0.461
	<30,000	9	9	10		
	30,000–80,000	35	29	36		
	>80,000	22	16	20		

CI = cochlear implant; HL = hearing loss; NH = normal hearing.