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Original article

AHL, SSD and bimodal CI results in children

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A R T I C L E I N F O

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A B S T R A C T

Objective: This article aims to demonstrate that children with asymmetric hearing loss (AHL), specifically those with single side deafness (SSD condition) and pure SSD, with substantial hearing (> 70% normal speech discrimination) in the ear with hearing aid (HA), obtain clinically relevant speech perception benefit after cochlear implantation in the contralateral side.
Results: Retrospective study of two groups: (1) 36 AHL children with bimodal hearing and (2) SSD children with SSD. They had follow-ups of 24 and 12 months duration, respectively. The AHL children where implanted on one ear and depending on the contralateral ear condition, they were divided into two groups: children who reach a disyllabic speech test score lower than 50% in quiet at 65 dB-SPL without lip reading (27) and children with test score higher than 70% (9). The second group consisted on 2 children implanted to obtain SSD condition, as preliminary data, with 1 year of follow-up. They showed benefits of binaural stimulation.
Conclusion: Children in a bimodal situation, with substantial hearing (> 70% speech discrimination) in the ear with HA, obtain clinically relevant speech perception benefit after cochlear implantation in the contralateral side.

1. Introduction

Binaural hearing is the normal-hearing process used to localize sounds and may also serve to aid in segregation of speech from background noise in adverse listening conditions. The beneficial effects of binaural hearing are determined by a combination of physical phenomena and neurological processes which are fundamentally of central origin and related to integration of the signal perceived at each ear [1–4]. The improvements are based upon three mechanisms: the first two mechanisms, binaural loudness summation and binaural release from masking (or 'squelch'), reflect central processing; whereas the third, the head shadow effect, is explained by listening through the two ears separately. These mechanisms rely on two acoustic cues: the interaural time difference and the interaural level difference. The advantages of binaural hearing over monaural hearing have been well described over the past years [5,6].

The neurological component of binaural hearing is due to the capacity of the central auditory system to process and improve upon the auditory percept received at either ear individually, by combining the information arriving at both ears [1]. It is attributed to two processes: the "binaural squelch effect", i.e. the capacity to select the ear with the better SNR when speech and noise sources are spatially separated; and the process of "binaural summation", i.e. the capacity to centrally integrate the sound received at each ear to improve the auditory percept when speech and noise sources are coincident in space.

Over the last several years, evidence has emerged, showing a significant benefit of cochlear implant (CI) surgery in patients with single-sided deafness (SSD), asymmetric hearing loss (AHL) and also with bimodal stimulation.

SSD is defined as a condition where an individual has non-functional hearing in one ear and receives no clinical benefit from amplification in that ear, but the contralateral ear has a normal audiometric function. The key factor is that the poor or "bad" ear has not or will not receive benefit when traditional acoustic amplification is applied and the "good" ear must have a pure-tone average that is 20 dB or better across the pure-tone average (PTA) (0.5, 1, 2 and 4 kHz). SSD has been estimated to affect between 12–27 individuals in every 100,000 of the general population with the majority of losses being sudden and idiopathic; that is, a cause has not or cannot be determined [7].

AHL is defined as an interaural, PTA difference of more than 15 dB HL [8] that induces reduced abilities to localise sound in the horizontal plane and discriminate speech in noise [9]. Also [10] showed that children with AHL encounter significant social

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functioning disabilities (i.e. ability of a person to interact normally in society). These children also present higher rates of school failure compared to their normal-hearing peers and often have cognitive deficits [11,12].

The use of bimodal stimulation, an alternative method of providing binaural hearing, has arisen as a result of the extension of the candidacy indications for CIs to include patients with severe degrees of deafness [13–18]. Bimodal stimulation involves a combination of two different modes of stimulation: electrical stimulation via a CI in one ear and acoustic stimulation via a conventional hearing aid (HA) in the contralateral ear.

The standard of care for SSD and AHL is a contralateral routing of signals (CROS) hearing aid system. A CROS system picks up sounds arriving at the impaired ear using a remote microphone and presents those sounds to the non-impaired ear through a wired or wireless link [19]. The primary function of the system is therefore to overcome the acoustic shadow cast by the head and, in doing so, to improve access to sounds on the impaired side. The use of a CROS system has been found to improve the perception of speech in noise compared to the unaided condition when the most favourable signal-to-noise ratio is available at the impaired ear; i.e. with speech on the impaired side and the noise from the front [20–22] or speech from the front and noise on the non-impaired side [23–25]. The use of a CROS has also been found to have no effect on localization accuracy [20–22], which is compatible with the fact that the device is not designed to restore access to the binaural cues which underpin the ability to locate sounds in space.

Alternatives to a CROS include a bone-anchored hearing device (BAHD), which also transmits sounds arriving on the impaired side to the non-impaired ear, but achieves this by conduction through the cranial bones. Like the CROS, a BAHD does not restore binaural hearing in individuals with SSD for whom the sensorineural component of the hearing loss is severe-to-profound. Poor localisation ability has been cited by patients as a factor that contributes to their decision not to receive a BAHD, as have cosmetic concerns about the placement of a permanent bone-anchored abutment through the skin [26].

CI were used to treat intractable tinnitus in patients with SSD, which is the most extreme case of AHL where the poorer ear has with total deafness while the contralateral ear exhibits normal hearing. Apart from the suppression of tinnitus, many of the tinnitus patients treated with a CI achieve significantly better hearing results than with the BAHD, CROS-HA or the unaided situation, due to the benefit from binaural hearing [27,28].

This article aims to demonstrate that children with AHL, with substantial hearing (> 70% to normal speech discrimination) in the ear with HA (SSD condition) and pure SSD, obtain clinically relevant speech perception benefit after cochlear implantation in the contralateral side.

2. Material and methods

This is a retrospective study of two groups. The first consists of 36 AHL children with bimodal hearing and the second, of 2 SSD children. The groups underwent a follow-up of 24 and 12 months, respectively. The mean age was 3.2 years (range 2–11 years) in the first group, and 6.3 years (range 6–6.6) in the second. All children received a unilateral CI (nucleus cochlear AG) between 2004–2011 with conventional inclusion criteria.

In all cases, there were no implanted children with any of the following conditions:

- ossification or any other cochlear anomaly that might prevent complete insertion of the electrode array;
- severe-to-profound hearing loss related to meningitis, multiple sclerosis, posterior fossa tumours or central hearing related disorders;
- signs of retro-cochlear or central origin of hearing impairment;
- medical conditions that would contraindicate undergoing CI surgery (e.g. active middle ear infections, tympanic membrane perforation);
- psychological, neural or mental disorders that would contraindicate undergoing CI surgery as verified by a psychologist;
- any other additional handicaps that would prevent participation in evaluations.

Radiological examinations using CT and MRI were used. In all cases, the surgical anatomy was normal and complete insertion of the electrode was possible. X-ray imaging using Stenver's view was used to verify electrode position [29].

Fitting of the speech processor was performed in order to improve CI and HA performance. During the first month after the activation of the CI, or once the subject's speech processor map was considered stable, the HA and CI were further adjusted to additionally optimise the combined stimulation by balancing the loudness percept from each device. All patients routinely used the HA and CI simultaneously each day for the duration of the study.

The following tests were performed in all available configurations:

- pure-tone audiometry/free field (0.5–1–2 Kz);
- disyllabic speech test score in quiet at 65 dB-SPL in the best-aided condition without lip reading (S0);
- sentence test score in quiet at 65 dB-SPL in the best-aided condition without lip reading (S0).

Moreover, for the SSD group, disyllabic and sentences in noise tests with masking of the good ear were done, always using a plug in the auditory ear canal plus an earpiece.

The tests used are a standard protocol in our centre and are taken from the "Protocol for the assessment of hearing in Spanish Language adapted to infant population" by Huarte et al. The noise was at SNR +5 [30].

Data analysis was done using SPSS (version 20.0). Statistically significance was established for *P*-values < 0.05. The Student *t*-test was used in the statistical comparison for independent 100 samples. The study obtained the approval of the Ethical Committee of our Hospital in accordance with the Declaration of Helsinki.

3. Results

3.1. Descriptive analysis of AHL children

All children where implanted on one ear and according to the contralateral ear condition, they could be split into two subgroups. In the first one, the ear with the HA had Disyllabic Speech Test Scores lower than 50% in quiet at 65 dB-SPL without lip reading in the best-aided condition. This group had 27 children; mean age was 7.11 years (range 2–11 years). The second group reached Disyllabic Speech Test Scores higher than 70%. It was made up of 9 children, mean age was 4.1 years (range 2–7 years).

3.1.1. Analysis of AHL children, Disyllabic Speech Test Score lower than 50%

On the first group, 27 children with a Disyllabic Speech Test Score lower than 50% were studied. Twenty-five children where sequentially implanted 3–18 month after the first implantation. Fig. 1 shows the obtained results. The rest of children, 2, remained