

Critical Review: Do children with bilateral cochlear implants have better sound localization abilities than those children implanted unilaterally?

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The aim of this critical review was to examine the literature regarding the effects of bilateral versus unilateral cochlear implantation on sound localization abilities in children aged 2 to 16 years. Overall, the findings suggest that bilateral cochlear implants offer some benefits for sound localization that are not achievable with unilateral implantations. Further research, using well-designed studies with a sufficient sample size is still needed to further quantify the benefits of bilateral cochlear implants for sound localization in this population.

Introduction

The advent of cochlear implants has drastically improved the management of severe to profound hearing loss in children. Recently, there has been an increasing interest in providing children with maximum hearing benefit through bilateral implantations (Litovsky, 2006a). This interest stems, in part, from studies on adults with bilateral cochlear implants that have demonstrated the benefits of binaural hearing (Van Hoesel, 2004).

To date, the majority of studies on bilateral cochlear implants have been performed on adults so very little is known about the benefits and/or risks of implanting a child with a second device (Litovsky, 2006a). The disparities between these populations make it difficult to generalize the benefits of bilateral implantations in adults to a pediatric population. For many adults, hearing loss is acquired later in life so prior acoustic stimulation has provided their auditory system with the stimulation required to develop binaural listening skills. Children on the other hand, have congenital or early onset hearing loss and often have little to no sound stimulation prior to implantation. This auditory deprivation can have compromising effects on the auditory system, affecting the child's ability to derive benefit from a cochlear implant. These differences, among others, make it necessary to directly assess the benefits provided to children from bilateral implantations.

Bilateral implantations can improve an individual's ability to hear in difficult listening situations by enhancing speech recognition and improving sound localization ability. When the same sound is heard from both ears, the listener becomes aware of speech and other sounds at a softer level, making communication easier. In noise, binaural hearing allows the auditory system to compare the signals being received by each ear in order to suppress the unwanted noise, making speech easier to understand.

Hearing with two ears also improves sound localization acuity, giving a listener the ability to locate speech and other important sounds in their environment.

The goal of this paper was to review the current literature on a pediatric population to determine whether bilateral cochlear implants provide improved localization acuity compared to unilateral cochlear implants.

Objective

The primary purpose of this paper was to critically evaluate the existing literature regarding the effects of bilateral versus unilateral cochlear implantation on sound localization abilities in children. Outcomes of the studies in this paper will allow for evidence-based recommendations to be made for future cochlear implant candidates.

Methods

Search Strategy:

Computerized databases including MEDLINE, EMBASE, CINAHL, SCOPUS and PubMed were searched using the following search strategy:

((cochlear implant) AND (children) AND (sound localization)) AND ((bilateral) AND/OR (unilateral)).

Those studies not in the English language were excluded from the search.

Selection Criteria:

Studies selected for inclusion in this critical review were required to investigate the effects of bilateral and unilateral cochlear implantation on sound localization abilities in a pediatric population.

Data Collection:

Results of the literature search yielded case series and cohort studies congruent with the aforementioned selection criteria.

Results

Litovsky et al (2004) investigated directional hearing abilities in three children with bilateral cochlear implants. Each of the participants (8-12 years) was sequentially implanted with a period of several years between the first and second implant. Testing commenced two to three months following the activation of the second implant.

Sound localization measurements were made using fifteen loudspeakers positioned in a semicircular array at 10 degree intervals, ranging from -70 to 70 degrees. Each speaker was positioned at ear level at a distance of 1.5 m from the center of the participants head. Stimuli consisted of 10 bursts of 25-millisecond pink noise at an average level of 60 dB SPL. Following the stimulus presentation, the child reported the speaker corresponding to the perceived location of the sound using an interactive computerized pointing game.

This study concluded that there was no significant difference between the monaural and binaural localization tasks, although the children did perform slightly better in the binaural conditions. The improvement in sound localization with binaural hearing suggests that there may be some benefit to binaural hearing two to three months after the activation of the second implant however, the study did not find the improvement to be significant. It is possible that the number of participants in this study was insufficient to show a significant effect for binaural benefit. Another possibility is that the two to three month period following the second implant may have been insufficient to allow the child to acquire the spatial awareness and regularity needed to process directional cues. Allowing the children to gain further experience with the second cochlear implant and including more participants in the study may result in more noticeable improvements in sound localization tasks in the binaural condition.

A study performed by Litovsky et al (2006a) evaluated sound localization acuity in a group of nine bilaterally implanted children aged 3 to 16 years. Each child was sequentially implanted with a one to eight year period between the first and second implant. The cause of deafness varied for each of the participants. Testing procedures commenced two to fourteen months after the activation of the second cochlear implant.

Measurements using the minimum audible angle (MAA) were obtained using the same fifteen speaker arrangement as that described in the Litovsky et al (2004) study. Stimuli were spondaic words presented at an average of 60 dB SPL. Following the presentation of stimuli, the children indicated their response using computerized interactive software.

Of the nine children who participated in the task, seven showed a bilateral benefit for sound localization acuity. Although these children performed better in the binaural mode, the amount of benefit depended on the individual children's experience from both pre- & post- implantation. Two of the children showed no improvement in the binaural condition, but highlighted the importance of previous auditory stimulation and the effects of experience following implantation. Further work in this area should attempt to control for prior acoustic stimulation pre-implantation as well as length of experience post-implantation.

The research of Litovsky et al. (2006b) evaluated the potential benefits of bilateral cochlear implants by comparing localization acuity using measures of MAA. The participants were 10 children aged 3 to 14 years, sequentially implanted with a one to seven year period between the first and the second implant. Testing commenced after a period of three to twenty-six months after the activation of the second implant.

Sound localization measurements were again obtained using the same fifteen loudspeaker arrangement discussed in the Litovsky (2004) study. Stimuli were a set of spondaic words presented at an average level of 60 dB SPL. Once the stimuli were presented, the child used the computer mouse to select icons on the screen indicating left or right positions.

For all of the children, the binaural mode indicated MAAs that were significantly smaller than in the monaural mode, suggesting a bilateral benefit for localization acuity. The effect sizes, however, varied significantly between the children. This inconsistency is likely a result of individual differences in age, experience and cognition and may simply represent the true variability among different individuals. Future attempts could be made to control for some of these experimental confounds in order to improve the validity of the outcomes.

Beijen et al (2007) performed a study to compare a group of bilaterally implanted children with a group of unilaterally implanted children to evaluate the

improvement in sound localization abilities. The participants were five bilaterally implanted children ranging from 2 to 6 years of age. Four of the five children were implanted simultaneously, while the other child received a second implant six months following the first. Each of the children had eleven months to four years of experience with their second implant. The control group included five unilaterally implanted children (4 to 6 years) that matched the bilaterally implanted children as closely as possible with regard to age, cause of deafness and minimum experience with their cochlear implant. In all the children, meningitis was cause of deafness. The control group had a minimum of one year experience with their cochlear implant.

The localization test used was based on a double visual reinforcement audiometry setup. The child was placed on a chair in the middle of a virtual arc with a radius of one meter, with one visual reinforcement audiometry system on each side. A simple game was presented by an experienced assistant who sat directly opposite the child to keep the child occupied and focused within the center of the setup. Stimuli were prerecorded melody bands limited to between 5 and 4kHz presented at a fixed level of 60 dB SPL.

To get more information on various aspects of daily living with a cochlear implant, two questionnaires were chosen and administered to the children's parents. Using the Speech, Spatial and Qualities of Hearing Scale (SSQ) and Peds QL questionnaire on hearing and health-related quality of life, parents' subjective perception of their child's performance was evaluated.

This study concluded that those children with bilateral cochlear implants had significantly better scores on the localization test than the children with unilateral cochlear implants. Scores were also significantly higher on the spatial domain of the SSQ or the Peds QL between the two groups. Although there are inherent reliability and validity limitations in using parent ratings of performance, valuable information can be obtained when used in conjunction with measures of sound localization.

Conclusion

In all of the studies, similar conclusions regarding sound localization benefits with bilateral implantations were found. Although limitations were apparent, they were not so great as to deem the findings to be inconclusive. The combined evidence in this review was strong enough to conclude that bilateral implantations provide some sound

localization benefits that may not be attainable with unilateral implantations.

Recommendations for Clinical Practice

Although most of the children demonstrated localization benefit in the binaural mode, these findings should be used with caution when making a decision to fit a child with bilateral cochlear implants. Sound localization ability is only one of many factors to consider when making this decision. Each child should be assessed and treated on an individual basis as it is difficult to pre-determine who will derive sound localization benefit from a second cochlear implant. It is also important to consider the inherent risks that are taken for sequential bilateral implantations and the substantially increased cost for two devices (Papsin and Gordon, 2007).

Recommendations for Future Research

Obtaining reliable behavioral measures or subjective feedback from children is a challenge, making the benefits of bilateral implantations difficult to assess. Those studies that are available are confounded by variables such as age, age of implantation, habilitation programs, motivation, experience, length of time between implants, quality of the device and test procedures. All of these variables contribute to the outcomes of bilateral implantation and should be controlled for in order to improve the validity of the findings. Most of the findings discussed in this review are in agreement, but individual differences make it difficult to determine the exact degree of improvement in sound localization ability. Further research using well-designed studies, with larger sample sizes and controlled inter-subject variability will help to further quantify the benefits of binaural hearing in this population.

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