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Outcomes of Conventional Amplification for Pediatric Unilateral Hearing Loss

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Abstract

Objectives—Although children with unilateral hearing loss (UHL) are at-risk for educational difficulties and behavioral problems, research in treatment outcomes is limited. Previous studies suggested that children with UHL would benefit from frequency-modulated (FM) assistive devices only. The objective of this study was to examine whether children with UHL would benefit from using a conventional hearing aid in the poorer-hearing ear.

Methods—Eight children, ages 7 to 12 years, with mild to moderately severe UHL, their parents and teachers participated in this study. Participants were fit with digital hearing aids using pediatric prescriptive targets. Primary outcome measures were speech perception tests in quiet and noise and subjective assessments from participants, parents and teachers, administered prior to and after three months of hearing aid use.

Results—Group average speech perception scores showed no significant aided benefit or detriment in any of the conditions tested. However, subjective assessments showed large significant aided benefits at home and school according to the children and their parents, and in quality of life as reported by the children with UHL.

Conclusion—Overall, the results suggest a hearing aid trial should be considered for children with mild to moderately severe UHL with individual monitoring for benefit.

Keywords

Unilateral Hearing Loss; Hearing Aid; Children; Speech Perception; Quality of life

INTRODUCTION

The implementation of universal newborn hearing screening programs has resulted in unilateral hearing loss (UHL) being identified at infancy, rather than remaining undetected until a school screening (1). However, it remains unclear how these children should be managed audiologically. Traditionally, many professionals believed that children born with UHL would not experience any handicap because they have one normal hearing ear, stating that children with UHL “will be able to go through school and learn like any other child”

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(2). They were not typically fit with amplification, and preferential classroom seating was the only educational recommendation. Early research, however, showed that this population is at risk for educational and behavioral problems, with 22-35% of children with UHL failing at least one grade and 20% being identified with behavioral problems by teachers (1, 3-4). Furthermore, 12-41% of children with UHL received additional educational services (1, 3-5). More recently, children with UHL reported lower total quality of life and psychosocial functioning than their normal hearing peers (6).

Although some children with UHL are at-risk for educational and behavioral problems, research in treatment outcomes for pediatric UHL is limited. The assistive listening options that have been evaluated in children with UHL include conventional hearing aids, CROS (contralateral routing of signal) hearing aids, and frequency-modulated (FM) systems. To date, FM systems have been the only assistive technology that has improved word recognition in quiet and in noise for children with UHL (7, 8). Research on the use of conventional amplification in children with UHL is based largely on results from subjective parental reports and questionnaires. These studies suggest that children with mild to moderately severe UHL tend to accept hearing aids, while children with severe to profound UHL do not (9, 10). Parents reported varying amounts of hearing aid use among children with UHL, with higher usage in school than outside of school (11, 12). Furthermore, parents perceived improvements in various listening situations (11, 13) and have been highly satisfied with amplification for their child (13).

Only one study has examined speech perception measures with a conventional hearing aid in children with UHL. Updike (8) examined the effects of FM systems, CROS aids, and conventional hearing aids on speech perception scores in 6 children, ages 5 to 12 years, with UHL ranging from mild to profound. The author concluded that conventional hearing aids and CROS aids did not enhance speech understanding but instead may be detrimental in noise, and that FM systems improved speech understanding in quiet and noise for all degrees of UHL. However, that study was limited by small sample size, use of analog hearing aids, unspecified fitting formula and verification, and no acclimatization period.

The objective of this study was to examine the potential benefits of a conventional hearing aid in children with mild to moderately severe UHL, using current hearing aid technology, speech perception measures, and subjective assessments from the child, parent, and teacher to analyze the whole child.

MATERIALS AND METHODS

Institutional review board approval was obtained from the Washington University Medical Center Human Research Protection office prior to commencing this study. Parent provided written informed consent, and child participants provided written pediatric assent.

Subjects

Eight children, 6 males and 2 females, ages 7 to 12 years old, with a permanent mild to moderately severe UHL and no significant cognitive impairment participated in this study. All participants underwent a complete audiometric evaluation. The participants had thresholds ≤ 20 dB at 250-8000 Hz in the normal hearing ear, with the exception of one subject who only met these criteria at 250-3000Hz. All participants had hearing thresholds > 20 dB, but < 70 dB, at four or more consecutive frequencies in the poorer hearing ear. Participants had unaided word recognition scores of 80% or higher, with the exception of Subject 2. Table 1 displays the demographic and audiologic profile of the participants.

Three of the participants had previous hearing aid experience, and one of the three currently wore a hearing aid. This participant discontinued hearing aid use for one month prior to participating. Additionally, one participant was home-schooled, and education data was examined separately due to the different learning environment.

Hearing Instrument

Each child was fit with an Oticon Epoq XW behind-the-ear (BTE) hearing aid with a standard earhook and custom earmold on the poorer ear. The hearing aids were provided by the Oticon Pediatrics Research Initiative (OPRI). All children were allowed to keep the hearing instrument at the end of the study, regardless of amount of benefit reported. The hearing instrument was set to each participant's hearing loss using Desired Sensation Level (DSL) 5.0a fitting targets. Each child had one program in the omnidirectional microphone mode with the volume control disabled. The fitting was verified using the Audioscan Verfit system and validated using aided soundfield thresholds and word recognition testing with masking in the better ear. The aided pure tone average (500, 1000, and 2000 Hz) and word recognition scores are listed in Table 1.

Outcome Measures

Speech perception measures included the Bamford-Kowal-Bench Speech-in-Noise-Test (BKB-SIN) (14) and the Nonsense Syllable Test (NST) (15). The BKB-SIN was chosen to represent perceptual scores with contextual cues and the NST to represent scores without contextual cues. The BKB-SIN uses BKB sentences and a four-talker babble presented at different signal to noise ratios (SNR) to determine the SNR corresponding to 50% correct key word identification (SNR-50). The NST is a 25-item speech recognition test that uses an open set of CVCV (consonant vowel consonant vowel) bi-syllables that do not have semantic content in English.

Subjective assessments of the child's hearing were obtained from the participants, their parents, and their teachers. Subjective measures, completed by the child, included the CHILD Child (Children's Home Inventory of Listening Difficulties) (16), LIFE Student (Learning Inventory for Education) (17), and the HEAR-QL (Hearing Environments And Reflection on Quality of Life Measurement for Children) (18). The CHILD Child measures the child's communication needs and listening skills in the home. The LIFE Student identifies classroom listening situations and additional school listening situations that are challenging. The HEAR-QL is a hearing-related quality-of-life (QOL) questionnaire that measures how hearing loss affects the child's QOL in three areas: environment, activities, and feelings.

Teacher subjective measures included the LIFE Teacher (17) and the SIFTER (19) (Screening Instrument for Targeting Educational Risk). The LIFE Teacher identifies changes in listening and learning behaviors in the classroom after a hearing aid trial to determine hearing aid benefit. The SIFTER identifies children at risk for educational failure in five areas: academics, attention, communication, class participation, and school behavior.

The parent subjective measure used was the CHILD Parent (16). The CHILD Parent measures the child's communication needs and listening skills in the home. The situations presented in each question are the same as the CHILD Child.

In addition to these questionnaires, a combination of open- and closed-ended questions regarding hearing aid use, satisfaction, and personal experiences were developed for this study.

Test Conditions

All speech perception measures were performed in the soundfield in a double-wall sound-treated booth using a GSI-61 audiometer. Two speakers were located 45 degrees from the midline, one meter to the left and one meter to the right of the subject.

Speech In Quiet—For the NST, CVCV stimuli were delivered through the speaker on the side of the normal-hearing ear (monaural direct, MD) and then through the speaker on the side of the ear with hearing loss (monaural indirect, MI) at 65 dB SPL. The subjects repeated each nonsense syllable. One list (100 phonemes) was used in each condition and was scored by percent of correct phonemes.

Speech In Noise—The BKB-SIN was administered in noise in the MD condition (speech to the normal-hearing ear and noise to the ear with hearing loss) and MI condition (speech to the ear with hearing loss and noise to the normal-hearing ear). The split track one version of the BKB-SIN was used to enable the signal to be presented from separate speakers to test in the MD and MI conditions. The overall level for the sentences was set at 65 dB SPL with four-talker babble decreasing in 3 dB SNR changes, from +21 dB to -6 dB. The subjects repeated each sentence presented. Two list pairs were used in each condition and averaged. The NST was also administered in the presence of four-talker babble background noise in the MD and MI conditions at a +6 dB SNR (signal at 65 dB SPL and noise at 59 dB SPL).

Procedures

Speech perception measures and subjective assessments were evaluated at the onset of the study and with amplification after at least three months of hearing aid use. The list of questions developed for this study regarding hearing aid use, satisfaction, and experiences were administered to each participant by telephone at 2, 4, 8, and 12-weeks after the hearing aid fitting.

Data Analysis

SPSS for Windows, Version 17.0 (SPSS, Inc., Chicago, IL) was used for analysis. Paired t-tests were used to compare pre- and post-measures. Two-sided P values less than .05 were considered statistically significant. Additional qualitative analysis of subjective data was also performed.

RESULTS

Speech Perception Results

Pre- and Post-hearing aid average scores for the NST in the MD Quiet, MI Quiet, MD Noise, and MI Noise conditions are shown in Figure 1. There was no change in the average scores in any condition.

Pre- and Post-hearing aid average SNR-50 scores for the BKB-SIN MD and MI conditions are shown in Figure 2. There was no significant change in the average score in any condition. Inspection of individual cases revealed that six of the eight children showed an improvement in scores (i.e. lower SNR-50) on both the BKB-SIN MD and MI conditions that ranged from 0.75 to 2.3 dB and 0.5 to 4.5 dB, respectively.

Subjective Assessment Results

Average post-hearing aid scores were significantly improved on the Child CHILD, Parent CHILD, Student LIFE Classroom Listening, Student LIFE Additional Situations, and HEAR-QL, as shown in Table 2.

The LIFE Teacher, a post intervention only test, revealed that half of the subjects' teachers found hearing aid use to be beneficial or highly beneficial. Three of the subjects' teachers reported no change, none reported a negative change, and one subject's questionnaire was not returned. The SIFTER results showed no significant change in average scores with the hearing aid.

Analysis of the hearing aid use, satisfaction, and experience questions revealed consistent hearing aid use in 75% of subjects at school, 50% at home, 50% while playing with friends outside of school, and 25% on the weekend. More than half of the subjects consistently wore their hearing aid during sports, gym, and/or recess. All participants reported benefit with the hearing aid in more than one situation. The most common situations included improvements in hearing their teacher (88%), their classmates (88%), in noise (75%), and from a distance (63%). Whereas six subjects reported no situations in which they heard worse with the hearing aid, one subject reported hearing worse in the cafeteria, and one subject reported it was harder to hear his younger sisters. Questions about hearing aid experiences revealed that 25% of subjects did not like the hearing aid, 25% reported being made fun of for wearing the hearing aid, and one subject was embarrassed to wear the hearing aid.

Data logging

Data logging was retrieved from the hearing aids of seven subjects. One subject's hearing aid broke and data logging could not be recovered. Over a 3-4 month trial period the average daily use was 5.1 hours per day with a range of 0.7 to 9.4 hours per day.

DISCUSSION

This pilot study of conventional hearing aid use in eight children with mild to moderately-severe UHL showed no significant changes, especially no decrease, on speech perception as measured by the BKB-SIN and NST. Thus, conventional hearing aid use did not cause any detriment for children with UHL. These results contrast with those from Updike (8) who concluded that the use of a conventional hearing aid was detrimental, particularly in a noisy environment. Instead, a majority of the children demonstrated improved scores on all the BKB-SIN conditions, supporting an overall trend towards better performance in noise on a test that may be considered more representative of real world listening conditions than the NST. These results may also differ from Updike (8) because the current study utilized digital hearing aids verified with electroacoustic measures using a prescriptive formula that has been validated on children. Furthermore, the present study ensured that subjects were audiologically appropriate hearing aid candidates with mild to moderately severe UHL and usable speech recognition, and provided an acclimatization period with the device.

Although there were no significant changes on speech perception results, there were large (>1 standard deviation) improvements on all child and parent subjective assessments for a variety of listening environments. There were clinically important improvements in the average post-hearing aid scores on both the Child CHILD and the Parent CHILD. These improvements agree with previous parent report findings (11, 13) and suggest that benefits of hearing aid use at home were apparent to both the child and the parent.

Significant improvements on the Student LIFE demonstrate that students noticed benefit from a conventional hearing aid in the classroom and in other difficult listening situations at school. The teachers' assessments were more mixed, with half reporting benefit on the LIFE Teacher, but no significant change on the SIFTER scores. Fitting of a hearing aid alone was not enough to produce major academic changes during the 3-4 month period, such as shifting a child from the "at risk for educational failure" category to "not at risk." Overall, the findings from the student and teacher questionnaires imply that children with UHL may

benefit from the use of a conventional hearing aid in the classroom, and benefits apparent to the student may or may not be recognized by the teacher.

Quality of life, as measured by the HEAR-QL, increased significantly with hearing aid use. Recent studies have shown children with UHL reported lower total QOL and psychosocial functioning than their normal hearing peers (6). Thus the fitting of a hearing aid may improve the QOL for some children with UHL, and further supports the perception of benefit.

Data logging from the hearing aids of seven subjects showed hearing aid use varied widely, with differing levels of hearing aid acceptance for each child. Most subjects reported greater hearing aid use on the subjective questions than recorded from data logging, indicating that objective recordings are important for obtaining accurate estimates of hearing aid use.

Subjective reports on hearing aid usage for this study are lower than those reported by parents in the McKay (12) study, which found 100% of UHL users wore their hearing aid in school and 59% wore their hearing aid outside of school. This difference may be due to child versus parent reports and a larger sample size in the McKay study. Despite less hearing aid use at home and on the weekends than at school, significant improvements observed with the hearing aid on the Child CHILD, Parent CHILD, and the HEAR-QL demonstrate benefit outside of school.

Each child reported more than one situation in which they found the hearing aid beneficial, though specific benefits varied by individual. Importantly, only two subjects reported a situation where they heard worse with the hearing aid, suggesting few detrimental effects from conventional amplification on children with UHL.

The main limitations of this study were a small sample size and no control subjects. Future research using a larger sample size with varied types, degrees, and configurations of hearing loss are needed to confirm the results of this study. In addition, speech perception measures that reflect real world listening environments, including sound localization abilities, should be evaluated.

CONCLUSION

In this study of conventional hearing aids on children with mild to moderately severe UHL, we found no significant benefit or detriment on speech perception scores in any condition. However, individual data from sentence testing in noise revealed that the majority of the children trended toward improved scores. The child, parent, and teacher questionnaires showed that children with UHL experienced significant benefits from a hearing aid at home, at school, and in their QOL. Based on the significant subjective benefits, combined with no detrimental effects, we conclude that a hearing aid trial should be considered for children with mild to moderately severe UHL, monitoring for benefit during the hearing aid trial.

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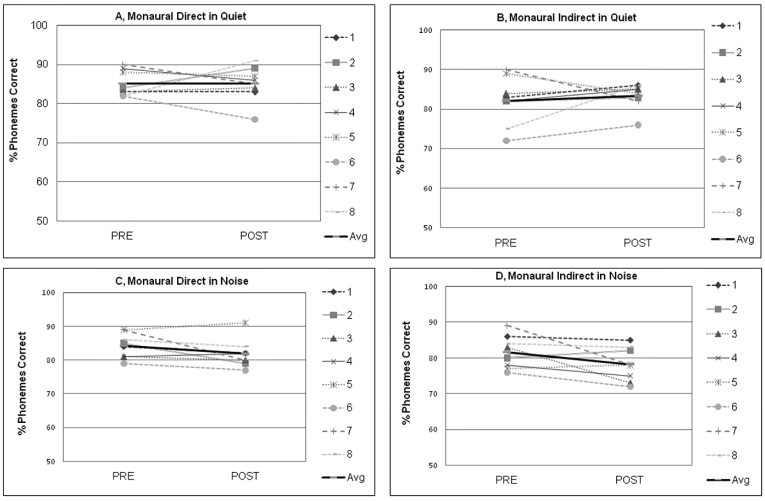

Figure 1.

Pre- and Post-scores on the Nonsense Syllable Test (NST) in a) the monaural direct quiet condition, b) monaural indirect quiet condition, c) monoaural direct in noise condition, and d) monaural indirect in noise condition. Each light gray line refers to an individual subject and the bold black line refers to the average across subjects. Scores are shown in percent of phonemes correct, with 100% as the highest possible score. No significant increase in decrease in group average score was seen on the NST in any condition.

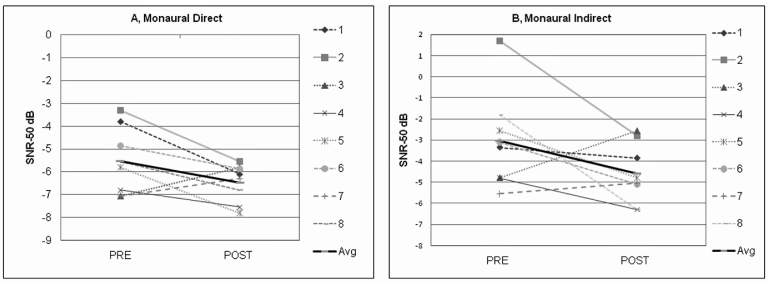

Figure 2.

Pre- and Post-scores on the Bamford-Kowal-Bench Speech-in-Noise-Test (BKB-SIN) in a) monaural direct condition, and b) monaural indirect condition. Each light gray line refers to an individual subject and the bold black line refers to the average across subjects. Scores are shown as SNR-50, corresponding to the signal-to-noise ratio in dB at which there is 50% correct key word identification. A better result is a more negative score, indicating an ability to recognize a signal in louder background noise. No statistically significant increase or decrease in the group average score was seen on the BKB-SIN in any condition, but trends for improved aided scores in noise was seen in the majority of subjects.

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Table 1

Demographic and audiologic profile of participants

	Gender	Age (years)	IQ	UHL Ear	UHL Type	UHL Shape	Unaided WRS	Aided PTA	Aided WRS
1	Male	11	78	Left	Conductive	Flat	88%	18 dB	92%
2	Male	10	80	Right	Sensorineural	Flat	24%	25 dB	24%
3	Male	10	109	Right	Sensorineural	Sloping	80%	20 dB	88%
4	Male	9	106	Left	Sensorineural	Mid to High Frequency Notch	96%	18 dB	92%
5	Female	10	129	Right	Sensorineural	Flat	92%	18 dB	80%
6	Male	12	113	Left	Sensorineural	Mid-Frequency Loss	92%	22 dB	88%
7	Female	9	98	Right	Mixed	Flat to Sloping	92%	20 dB	92%
8	Male	7	112	Right	Mixed	Rising	98%	20 dB	88%

* Aided testing performed with masking in the better ear

IQ, intelligence quotient

UHL, unilateral hearing loss

WRS, word recognition score

PTA, pure tone average (500, 1000, and 2000 Hz)

Table 2

Summary of subjective assessments.

	n	Max Score	Mean Pre	Mean Post	Difference	SD	Paired T value	df	*p* value
CHILD Child	8	8	5.74	6.99	1.25	.667	5.30	7	.001
CHILD Parent	8	8	5.38	6.56	1.18	.868	3.83	7	.006
LIFE Student Classroom Listening	7	100	65.1	81.3	16.1	12.9	3.32	6	.016
LIFE Student Additional Situations	7	100	57.9	78.6	20.7	8.86	6.18	6	.001
HEAR-QL	7	100	66.6	86.7	20.1	10.5	5.06	6	.002

LIFE, Learning Inventory for Education

CHILD, Children's Home Inventory of Listening Difficulties

HEAR-QL, Hearing Environments And Reflections on Quality of Life

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