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Unilateral Hearing Loss is Associated with Worse Speech-language Scores in Children: A Case-Control Study

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Abstract

Objective—To determine whether elementary school-aged children with unilateral hearing loss (UHL) demonstrate significantly worse language skills than their sibling controls with normal hearing, and whether they are more likely to receive extra assistance or resources at school.

Patients and Methods—Case-control study of age 6-12 year old children with UHL compared with sibling controls (74 matched pairs, total n=148), all with normal cognition by parental report. Scores on the oral portion of the Oral and Written Language Scales (OWLS) were the primary outcome measure. Potential confounders were evaluated for their effect on the OWLS scores. Multivariable analysis was used to determine whether UHL independently predicted OWLS scores.

Results—Children with UHL had significantly worse language comprehension (91 vs. 98, P = 0.003), oral expression (94 vs. 101, P = 0.007), and oral composite (90 vs. 99, P <0.001) scores than their siblings with normal hearing. Multivariable regression models demonstrated that UHL was an independent predictor of these OWLS scores, with moderate effect sizes of 0.3 to 0.7. Family income and maternal education level were also independent predictors of oral expression and oral composite scores. No differences were found between children with right or left UHL, nor with varying severity of hearing loss. Children with UHL were more likely to have an Individualized Education Plan (OR 4.4, 95% CI 2.0-9.5) and to have received speech-language therapy (OR 2.6, 95% CI 1.3-5.4).

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Conclusions—School-aged children with UHL demonstrated worse oral language scores compared with siblings with normal hearing. These findings suggest that the common practice of withholding hearing-related accommodations from children with UHL should be reconsidered and studied, and that parents, pediatricians, and educators be informed about the deleterious effects of UHL on oral language skills.

Keywords

unilateral hearing loss; children; speech or language delay; health status disparities

INTRODUCTION

Unilateral hearing loss (UHL) in children affects 0.4 to 34 per 1000 newborns, and 1 to 50 per 1000 school-aged children.[1-4] Although bilateral hearing loss (BHL) in children has been known to cause speech-language delays, delays in academic achievement, and lower rates of literacy and high school graduation, the effects of UHL on a child's speech-language development and academic achievement have not been well-documented. Small studies from the 1980s and 1990s suggested that compared with peers with normal hearing (NH), children with UHL experienced increased rates of grade failures (24-35% vs. 3% in the NH population), needed extra educational assistance (12-41%), and had increased behavioral problems.[5-8] However, these studies were often uncontrolled or poorly controlled (more cases than controls), or had significant selection biases (unclear reasons for inclusion or lack of data on all children). Although quality of life has not been directly assessed in children with UHL, adults with UHL have expressed negative psychosocial effects of UHL, such as decreased quality of life; feelings of frustrations, embarrassment and annoyance; and increased hearing handicap.[9, 10] Considerable biases may have affected the outcome of these studies, and little has been done to determine whether children with UHL were indeed at risk for problems in school, independent of potential confounding factors.[11] As a result, health and education professionals have often discounted the effect of UHL on a child's speech and language acquisition or academic achievement.

Limited information exists about the effect of UHL on acquisition of speech and language skills in infants and toddlers. Kiese-Himmel reported that the average age of the first word spoken was 12.7 months (range 10-33 months) and the average of the first two-word phrase was 23.5 months (range 18-48 months).[12] Although the age of the first word uttered was not delayed, the average age of the first two-word phrase was delayed an average of 5 months, based on a norm of 18 months. The Colorado Home Intervention Program reported results on 15 children with UHL followed since infancy.[13] Their speech and language skills were assessed when the children were at least 12 months of age. None had another known disability, but 4 (27%) had significant language delays, and 1 (7%) had a borderline language delay.

Three studies have looked at language skills in preschool or school-aged children. A longitudinal study evaluated 44 children with severe UHL at 7 and 11 years of age.[14] Although these children had a higher proportion of speech difficulties and "backwardness in oral ability and reading," only 4 children still had poor speech intelligibility at 11 years, and similar reading scores to NH peers. However, at least 13 of the 44 children had temporary hearing loss. Among 25 children age 6 to 13 years with UHL, there were few differences from NH controls on a battery of standardized language tests.[15] In contrast, a Swedish study found that 4 to 6 year old children with UHL had delayed language development compared to NH peers.[16]

Other risk factors for educational delay may be extrapolated from studies of children with BHL. For young children who are deaf or hard-of-hearing, the level of parental involvement and age at enrollment into a comprehensive intervention program were most strongly associated with speech and language outcomes at 5 years of age.[17] In children with cochlear implants, reading competence was associated with higher nonverbal intelligence, higher socioeconomic status, female gender, and later onset of deafness (after birth).[18] Additionally, speech production and language skills predicted the greatest amount of variance in the reading outcome, suggesting that avoiding speech and language delay is associated with improved prognosis for developing literacy. Thus, variables related to the child, family and socioeconomic status, may impact speech and language development, reading competence, and thereby educational achievement.

The purpose of this study was to determine whether a large sample of elementary school-aged children with UHL demonstrated significantly worse language skills than their sibling controls with NH. Using sibling controls minimized the confounding effects of family and environment on the development of language skills.

METHODS

Institutional Review Board approval through the Human Research Protection Office at Washington University School of Medicine was obtained prior to the onset of this study. All parent and child participants signed written informed consents and pediatric assents, respectively.

Design

Case-control study of children with UHL compared to sibling controls with NH.

Participants with Hearing Loss (Cases)

Children between the ages of 6 and 12 years were recruited from the pediatric otolaryngology clinics at St. Louis Children's Hospital/Washington University School of Medicine and several regional school districts: the St. Louis City Public Schools; Special School District of St. Louis County (Missouri); and the Belleville Area Special Services Cooperative (Illinois). Children from the school districts were identified through hearing screening programs or audiology testing associated with the school districts, and not as a result of receiving special services.

Inclusion criteria—Children were eligible if they had UHL, defined as an average threshold of any three consecutive frequencies of ≥30 dB hearing level (HL) in the affected ear. NH in the other ear was defined as a pure tone threshold average (PTA) of 500, 1000, and 2000 Hz of <20 dB HL, and threshold at 4000 Hz <30 dB. The hearing loss had to be sensorineural or mixed/conductive hearing loss considered 'permanent'.

Exclusion criteria—Children were excluded if they had temporary or fluctuating conductive hearing loss, or had a medical diagnosis associated with cognitive impairment (e.g., Down syndrome, congenital cytomegalovirus infection) or cognitive impairment per parental report.

Participants without Hearing Loss (Controls)

Controls subjects were eligible if they were siblings of participants with UHL, 6-12 years of age, had NH in both ears, and did not have any of the exclusion criteria listed above.

Demographic and baseline variables

Subject demographic information, parental socioeconomic data, subject current and past medical history, and subject educational history were obtained through parental questionnaire and interview. The percentage of federal poverty level (FPL) was calculated using family size and income[19]. Percentage of FPL was then categorized into three levels: <100% of FPL, 100-200% FPL, and >200% FPL.

Outcome variables

The oral portion of the Oral and Written Language Scales (OWLS) was the primary outcome for this analysis. The Listening Comprehension Scale (LC) measures the understanding of spoken language. The Oral Expression Scale (OE) measures the understanding and use of spoken language. The Oral Composite Scale (OC) combines the LC and OE scores into a single overall score. The scaled scores are normed to have a mean of 100 and a standard deviation of 15[20]. Cognitive ability was measured using the Wechsler Abbreviated Scale of Intelligence that provided the three traditional Verbal, Performance, and Full Scale IQ scores[21].

Hearing outcomes were measured in a sound-treated booth. PTAs were calculated as the average of 500, 1000, 2000, and 4000 Hz. Severity of hearing loss in the worse ear was categorized as mild if the PTA was <40 dB HL; moderate if the PTA was 40-69 dB HL; severe if the PTA was 70-89 dB HL; and profound if the PTA was ≥90 dB HL. Word recognition scores (WRS) were obtained monaurally in quiet using Central Institute for the Deaf (CID) W-22 word lists through headphones at 40 dB above the speech reception threshold, or the participant's most comfortable loudness level. WRS in noise using CID W-22 word lists were obtained through soundfield testing at +5 and 0 dB signal-to-noise ratios, with noise consisting of recorded 8-talker speech babble.

Secondary outcomes recorded included parent-report of speech-language delay or problems, receipt of speech-language therapy, and provision of individualized educational plans (IEPs) or section 504c accommodations for hearing disability at school.

Analysis

Descriptive statistics were obtained for each group, and included means and standard deviations, medians and interquartile ranges, and frequency counts. Bivariate analyses examined speech-language score outcomes associated with patient demographic, baseline clinical, and risk factor variables. Student's t test or one-way ANOVA were used for continuous variables. Chi-square or Fisher exact tests were used for categorical variables. Bivariate analysis of other outcomes involved calculating the odds ratio (OR) and 95% confidence interval (CI). A two-tailed alpha level of 0.05 was considered statistically significant.

Multivariable linear regression was used to control for the effect of multiple independent predictors of the OWLS scores. Variables with a bivariate P value <0.25 were candidates for selection into multivariable regression models to reduce Type II (or β) error.[22] Final multivariable models were developed to maximize the adjusted model R^2 and include predictor variables with partial R^2 ≥0.01. Models were checked for interactions and influence, and plots of residuals were examined. Statistical analysis was performed using SAS version 9.1.3 software (Cary, North Carolina).

RESULTS

Seventy-four pairs of case-control siblings (148 subjects) were included in this analysis. Characteristics of the children with UHL and their families are shown in Table 1. The majority had profound UHL, and the greatest proportion was identified via preschool or school screening. Other ways that UHL was identified included clinical suspicion of hearing loss, such as after head trauma or meningitis. Mean age of identification of UHL was 4.7 years (SD 2.6). Hearing loss was deemed "congenital" if it was identified through newborn hearing screening or attributed to temporal bone abnormalities found on computed tomography or magnetic resonance imaging. None had syndromic hearing loss. UHL had progressed in 15%. Fewer than half of cases had trialed amplification and/or assistive devices, and some had tried more than one option. Twelve percent of families had incomes below the 2005 FPL.

Other demographic and baseline characteristics of the subjects are shown in Table 2. No demographic or cognitive differences existed between cases and controls. Only one child, a control, had full scale IQ <70; none had performance IQ <70. More children with UHL suffered head trauma (OR 4.1, 95% CI 1.3-13.1), received speech therapy (OR 2.6, 95% CI 1.3-5.4), and had an IEP or section 504c accommodations (OR 4.4, 95% CI 2.0-9.5). No differences in neonatal risk factors for hearing loss[23] were identified, including history of jaundice or hyperbilirubinemia, NICU admission, ventilator or extracorporeal membrane oxygenation use, intravenous antibiotics, or persistent pulmonary hypertension of the newborn (data not shown). In addition, proportions with a history of recurrent otitis media and tympanostomy tubes, ADHD, and school-related behavioral problems (i.e., inattention, disruptive behavior, social isolation, or other teacher-identified problem) were not significantly different.

The bivariate effect of UHL and potential confounders on the OWLS scores are shown in Table 3. Children with UHL had lower scores on all three OWLS scores. Neither race/ethnicity, gender, nor income level had any significant effect on LC; however, all three affected OE scores, and race/ethnicity and income level affected OC scores significantly. No differences on the OWLS scores were found between children with right or left ear UHL, nor with severity of hearing loss. No differences in risk factors for speech or language delay[24] were identified, including birth order, very low birth weight, or history of tympanostomy tubes (data not shown).

Table 4 shows the persistent independent negative effect of UHL on the OWLS scores after adjustment for confounding using multivariable linear regression. UHL was associated with a 10.8 point decrement in LC, 4.1 point decrement in OE, and 5.7 point decrement in OC scores. The difference in scores translated to effect sizes of 0.3 to 0.7, or small-to-moderate effects. Severity of UHL accounted for more than 1% of the total variance for only LC scores. The multivariate models accounted for 34% to 61% of the total variance in scores.

In addition to UHL, the socioeconomic variables of income level and maternal education were significantly associated with OE and OC scores. Because FPL was a 3-level variable, being below the FPL was associated with a 7 point decrease in OE and an 8 point decrease in OC scores. Since maternal education was coded by yearly increments, children with mothers who are college-graduates would be predicted to have OE scores 3.2 points higher than children whose mothers graduated from high school only.

Multivariable models to predict OWLS scores in children with UHL only are shown in Table 5. Although the variables in the models are largely the same, additional variables added small increments to the overall adjusted R^2. For LC, the current use of any amplification (e.g., FM system, hearing aid or Baha® [Bone Anchored Hearing System])

was associated with a small increase. For both OE and OC scores, the age at which the UHL was identified added to the overall variance explained. In addition, WRS in noise added to the overall variance explained for the OC scores. For children who had received services through an IEP, age at which services began and duration of these services were not associated with the OWLS scores (data not shown).

DISCUSSION

In contrast to previous studies about children with UHL, we enrolled a large number of elementary school-aged children, carefully described their hearing, cognitive, and socioeconomic status, and included sibling controls. The results showed that UHL is associated with a significant negative effect on scores on standardized speech-language tests. Obtaining cases and controls within families controlled for a host of family, genetic, socioeconomic and environmental factors that could affect language development. Although speech-language scores do not translate directly into school performance, the secondary outcomes of speech therapy and IEPs suggest that the children with UHL had significant problems in school. The multivariable analysis suggested that use of amplification might be associated with a small increase in LC scores. We do not think selection bias influences these results because the participants with UHL were identified through hearing screening programs or diagnostic audiograms, not through special services programs at schools.

The etiology of UHL in children may encompass a different spectrum than BHL. Genetic mutations, such as connexin 26 mutations, rarely cause UHL, and syndromic hearing loss usually involves both ears.[25] The most common known etiologies in UHL are temporal bone anomalies such as enlarged vestibular aqueduct, cochlear dysplasias, and cochlear nerve aplasia.[26-28] Familial or hereditary UHL is rare and not well characterized.[29-31] Head trauma is a relatively common etiology of acquired UHL, but the frequencies of intrauterine infections, meningitis, otologic surgery, and ototoxic medications in UHL have not been well-tallied.[32] Children with microtia or auricular atresia may have syndromic hearing loss (e.g., Goldenhar syndrome), but usually have conductive or mixed hearing loss that are well-treated with Baha®.[33-35] Because neonatal risk factors for hearing loss have been identified in children with congenital BHL, it is not known if the same risk factors are important for children with UHL. Research is necessary to discover which risk factors and etiologies are associated with UHL.

No study of UHL has investigated whether severity of hearing loss affects speech or language outcomes. However, studies in children and adults with asymmetric BHL show that sound localization and speech discrimination are more difficult and outcomes are poorer than with symmetric BHL.[36-39] We speculate that when the difference in hearing between ears exceeds a threshold level, a person with UHL may experience difficulty with sound localization or speech discrimination in noise similar that experienced by those with asymmetric BHL. However, further research is necessary to determine whether a threshold effect might exist.

Unlike children with BHL, who are routinely fitted with hearing aids and receive accommodations for disability, children with UHL may not be considered to have a “significant hearing loss” because their hearing loss is not bilateral (e.g., Delaware) or not sufficient to interfere with speech or language development (e.g., Arkansas, Kentucky, Utah).[40] Each state has the right to define who is eligible for Part B and Part C of the Individual with Disabilities Education Improvement Act of 2004 (IDEA), and UHL is often not included.[41] Therefore, children with UHL are not automatically eligible for services in First Steps or Birth to Three programs (Part C of IDEA), pre-school or school IEPs (Part B of IDEA), or Section 504c of the Rehabilitation Act of 1973 accommodations for

disability.[42] Recommended interventions for children with UHL usually include preferential seating in class and an FM system that amplifies the teacher's voice relative to the background noise. Unless the child has another school-related issue (such as speech or behavior), or demonstrates significant developmental or educational delay, parents must often strongly advocate for their children with UHL to obtain FM systems in the classroom. Additionally, parents may be actively discouraged by school teachers and administrators from seeking Section 504c accommodations. Only 3 children with UHL in this study had Section 504c accommodations. Independent private or parochial schools may not have the resources or the mandate to provide these accommodations. The present results suggest that children with UHL should be eligible for the same accommodations as children with BHL.

Health disparities affected this study cohort significantly. Poverty was associated with decreases in speech-language scores similar in magnitude to UHL. Compared to those in the >200% FPL bracket, the OE and OC scores for children from families at 100-200% of FPL were lower by 4 points, and lower by 7-8 points in children from families <100% of FPL. Thus, a child with UHL who comes from a family with an income <100% FPL would be expected to have an OE score 11 points and OC score 14 points below a child with NH and family income >200% FPL. These large differences in oral language skills based on socioeconomic status are consistent with education and health disparities noted by others,[43] and have policy implications for health care and education. Although gaps in standardized achievement scores have not been measured directly in this cohort, speech and language development contributes to reading and literacy.[44-46] Interventions that reduce the negative impact of UHL on children should address both the functional problem of hearing with only one ear, and the problems poverty encompasses in affecting childhood language development.

Future research to determine when the onset of speech-language delays occurs, the mechanisms whereby UHL affects speech-language development, whether any interventions can mitigate the effects of UHL, and whether speech-language delays affect future educational performance and job acquisition are all necessary to allow children the opportunity to attain their potential.

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Abbreviations

UHL	unilateral hearing loss
BHL	bilateral hearing loss
NH	normal hearing
HL	hearing level
PTA	pure tone average
FPL	federal poverty level
OWLS	Oral and Written Language Scales
WRS	word recognition scores
CID	Central Institute for the Deaf
IEP	Individualized Educational Plan

LC	listening comprehension
OE	oral expression
OC	oral composite

REFERENCES

1. Everberg G. Etiology of unilateral total deafness. Ann Otol Rhinol Laryngol. 1960; 69:711–30. [PubMed: 13697635]
2. Mehl AL, Thomson V. Newborn hearing screening: the great omission. Pediatrics. Jan.1998 101(1):E4. [PubMed: 9417168]
3. Niskar AS, Kieszak SM, Holmes A, Esteban E, Rubin C, Brody DJ. Prevalence of hearing loss among children 6 to 19 years of age: the Third National Health and Nutrition Examination Survey. JAMA. Apr 8; 1998 279(14):1071–5. [PubMed: 9546565]
4. Widen JE, Folsom RC, Cone-Wesson B, et al. Identification of neonatal hearing impairment: hearing status at 8 to 12 months corrected age using a visual reinforcement audiometry protocol. Ear Hear. Oct 1; 2000 21(5):471–87. [PubMed: 11059705]
5. Bess FH, Tharpe AM. Unilateral hearing impairment in children. Pediatrics. Aug; 1984 74(2):206–16. [PubMed: 6462820]
6. Keller WD, Bundy RS. Effects of unilateral hearing loss upon educational achievement. Child Care Health Dev. Mar; 1980 6(2):93–100. [PubMed: 7357689]
7. Oyler RF, Oyler AL, Matkin ND. Unilateral hearing loss: Demographics and educational impact. Lang Speech Hear Serv Sch. Apr.1988 19:201–10.
8. Stein DM. Psychosocial characteristics of school-age children with unilateral hearing loss. JARA. 1983; 16:12–22.
9. Giolas TG, Wark DJ. Communication problems associated with unilateral hearing loss. J Speech Hear Disord. Nov; 1967 32(4):336–43. [PubMed: 6074893]
10. Newman CW, Jacobson GP, Hug GA, Sandridge SA. Perceived hearing handicap of patients with unilateral or mild hearing loss. Ann Otol Rhinol Laryngol. Mar; 1997 106(3):210–4. [PubMed: 9078932]
11. Lieu JE. Speech-language and educational consequences of unilateral hearing loss in children. Arch Otolaryngol Head Neck Surg. May; 2004 130(5):524–30. [PubMed: 15148171]
12. Kiese-Himmel C. Unilateral sensorineural hearing impairment in childhood: analysis of 31 consecutive cases. Int J Audiol. 2002; 41(1):57–63. [PubMed: 12467371]
13. Sedey, AL.; Carpenter, K.; Stredler-Brown, A. Unilateral Hearing Loss: What do we know, what should we do?. Presentation at the National Symposium on Hearing in Infants; Breckenridge, Colorado. 8-1-2002;
14. Peckham CS, Sheridan MD. Follow-up at 11 years of 46 children with severe unilateral hearing loss at 7 years. Child Care Health Dev. 1976; 2(2):107–111. [PubMed: 954156]
15. Klee TM, Davis-Dansky E. A comparison of unilaterally hearing-impaired children and normal-hearing children on a battery of standardized language tests. Ear Hear. 1986; 7(1):27–37. [PubMed: 3949098]
16. Borg E, Risberg A, McAllister B, Undemar BM, Edquist G, Reinholdson AC, et al. Language development in hearing-impaired children. Establishment of a reference material for a ‘Language test for hearing-impaired children’, LATHIC. Int J Pediatr Otorhinolaryngol. 2002; 65(1):15–26. [PubMed: 12127218]
17. Moeller MP. Early intervention and language development in children who are deaf and hard of hearing. Pediatrics. 2000; 106(3):E43. [PubMed: 10969127]
18. Geers AE. Predictors of reading skill development in children with early cochlear implantation. Ear Hear. 2003; 24(1 Suppl):59S–68S. [PubMed: 12612481]
19. Annual Update of the HHS Poverty Guidelines. Federal Register. Feb 18; 2005 70(33):8373–8375.

20. Carrow-Woolfolk, E. Oral and written language scales. Pearson Assessment; Bloomington, MN: 1995.
21. Wechsler Abbreviated Scale of Intelligence™ (WASI™). [accessed 5/15/09] http://pearsonassess.com/haiweb/cultures/en-us/productdetail.htm?pid=015-8981-502
22. Hosmer, DW.; Lemeshow, S. Applied Logistic Regression. 2nd ed. John Wiley & Sons, Inc.; New York: 2000.
23. Joint Committee on Infant Hearing 1994 Position Statement. American Academy of Pediatrics Joint Committee on Infant Hearing. Pediatrics. 1995; 95:152–156. [PubMed: 7770297]
24. Prathanee B, Thinkhamrop B, Dechongkit S. Factors associated with specific language impairment and later language development during early life: a literature review. Clin Pediatr. 2007; 46(1):22–29.
25. Morton CC, Nance WE. Newborn screening—A silent revolution. N Engl J Med. 2006; 354:2150–64.
26. Bamiou DE, Savy L, O'Mahoney C, Phelps P, Sirimanna T. Unilateral sensorineural hearing loss and its aetiology in childhood: the contribution of computerised tomography in aetiological diagnosis and management. Int J Pediatr Otorhinolaryngol. Dec 5; 1999 51(2):91–9. [PubMed: 10619622]
27. Neary W, Kent S, Yeong C, Coyne L. The role of audiological testing and computed tomography in the aetiological investigation of children with permanent unilateral hearing loss. Audiological Medicine. 2003; 1:215–23.
28. Simons JP, Mandell DL, Arjmand EM. Computed tomography and magnetic resonance imaging in pediatric unilateral and asymmetric sensorineural hearing loss. Arch Otolaryngol Head Neck Surg. Feb; 2006 132(2):186–92. [PubMed: 16490877]
29. Dikkers FG, Verheij JBCM, van Mechelen M. Hereditary congenital unilateral deafness: A new disorder? Ann Otol Rhinol Laryngol. 2005; 114(4):332–7. [PubMed: 15895791]
30. Dodson KM, Kamei T, Sismanis A, Nance WE. Familial unilateral deafness and delayed endolymphatic hydrops. Am J Med Genet A. Jul 15; 2007 143A(14):1661–5. [PubMed: 17497713]
31. Patel N, Oghalai JS. Familial unilateral cochlear nerve aplasia. Otol Neurotol. Apr; 2006 27(3): 443–4. [PubMed: 16639288]
32. Tharpe AM, Sladen DP. Causation of permanent unilateral and mild bilateral hearing loss in children. Trends Amplif. Mar; 2008 12(1):17–25. [PubMed: 18270175]
33. Priwin C, Jonsson R, Hultcrantz M, Granstrom G. BAHA in children and adolescents with unilateral or bilateral conductive hearing loss: A study of outcome. Int J Pediatr Otorhinolaryngol. Jan; 2007 71(1):135–45. [PubMed: 17092570]
34. McDermott AL, Williams J, Kuo M, Reid A, Proops D. Quality of Life in Children Fitted With a Bone-Anchored Hearing Aid. Otol Neurotol. 2009; 30(3):344–9. [PubMed: 19060775]
35. Kunst SJW, Leijendeckers JM, Mylanus EAM, Hol MKS, Snik AFM, Cremers CWRJ. Bone-Anchored Hearing Aid System Application for Unilateral Congenital Conductive Hearing Impairment: Audiometric Results. Otol Neurotol. 2008; 29(1):2–7. [PubMed: 18199951]
36. Arkbauer HJ, Mencher GT, McCall C. Modification of speech discrimination in patients with binaural asymmetrical hearing loss. J Speech Hear Disord. 1971; 36(2):208–12. [PubMed: 5087658]
37. Nabelek AK, Mason D. Effect of noise and reverberation on binaural and monaural word identification by subjects with various audiograms. J Speech Hear Res. 1981; 24:375–83. [PubMed: 7300279]
38. Noble W, Gatehouse S. Interaural asymmetry of hearing loss, Speech, Spatial and Qualities of Hearing Scale (SSQ) disabilities, and handicap. Int J Audiol. 2004; 43:100–114. [PubMed: 15035562]
39. Rothpletz AM, Tharpe AM, Grantham DW. The effect of asymmetrical signal degradation on binaural speech recognition in children and adults. J Speech Lang Hear Res. 2004; 47:269–80. [PubMed: 15157129]
40. [accessed 5/24/09] State EHDI/UNHS Mandates: Summary Table. http://www.infanthearing.org/legislative/summary/index.html

41. Part, C. [accessed 5/24/09] Early Intervention Eligibility for Infants and Toddlers with Hearing Loss. http://www.infanthearing.org/earlyintervention/eligibility.pdf

42. Holstrum WJ, Gaffney M, Gravel JS, Oyler RF, Ross DS. Early intervention for children with unilateral and mild bilateral degrees of hearing loss. Trends Amplif. Mar 1; 2008 12(1):35–41. [PubMed: 18270177]

43. Fiscella K, Kitzman H. Disparities in academic achievement and health: The intersection of child education and health policy. Pediatrics. 2009; 123(3):1073–1080. [PubMed: 19255042]

44. Swanson HL, Rosston K, Gerber M, Solari E. Influence of oral language and phonological awareness on children's bilingual reading. J Sch Psychol. 2008; 46:413–429. [PubMed: 19083366]

45. Hayiou-Thomas ME. Genetic and environmental influences on early speech, language, and literacy development. J Commun Disord. 2008; 41:397–408. [PubMed: 18538338]

46. Schuele CM. The impact of developmental speech and language impairments on the acquisition of literacy skills. Ment Retard Dev Disabil Res Rev. 2004; 10(3):176–183. [PubMed: 15611989]

Table 1

Characteristics of 74 children with unilateral hearing loss (cases) and their families in this study.

Characteristics	Number (%)
Children with unilateral hearing loss (n=74)	
Right sided hearing loss	44 (59%)
Severity of hearing loss	
Mild	4 (5%)
Moderate	15 (20%)
Severe	11 (15%)
Profound	44 (59%)
Identification of hearing loss	
Preschool or school screening	28 (38%)
Parental suspicion	12 (16%)
Screening by primary care provider	8 (11%)
Audiogram for ear infections	7 (9%)
Newborn hearing screening	5 (7%)
Other	14 (19%)
Etiology of hearing loss	
Congenital	28 (38%)
Trauma	5 (7%)
Meningitis	2 (3%)
Unknown	32 (43%)
Trial of amplification	
FM system	22 (30%)
Hearing aid	4 (6%)
CROS aid	3 (4%)
Baha®	3 (4%)
Participating families (n=74)	
Race/ethnicity	
White	59 (80%)
Black	9 (12%)
Hispanic	5 (6%)
Asian	3 (4%)
Estimated family income, $	
<40,000	23 (31%)
40,000-100,000	27 (36%)
>100,000	24 (32%)
Health insurance	
Public (Medicaid)	18 (24%)
Private	55 (75%)

Characteristics	Number (%)
Both public and private	1 (1%)
Maternal education	
Did not graduate high school	4 (6%)
High school graduate or GED	9 (12%)
Some college or associate's degree	28 (37%)
Bachelor's degree or higher	33 (45%)

Table 2

Demographic, educational, and medical history characteristics of 74 children with unilateral hearing loss (cases) compared with 74 siblings with normal hearing (controls).

	Cases	Controls	P value
Mean age (SD), years	8.8 (1.8)	9.1 (2.4)	0.33
Male sex, n (%)	38 (51%)	40 (54%)	0.87
Adopted, n (%)	6 (8%)	6 (8%)	1.0
First-born, n (%)	25 (34%)	30 (41%)	0.60
Repeated grade, n (%)	8 (11%)	4 (5%)	0.37
Mean age of 1st word (SD), in months	10.8 (4.2)	10.0 (4.4)	0.24
Mean age of 1st 2-word phrase (SD), in months	17.8 (8.8)	15.3 (8.3)	0.13
Received speech therapy, n (%)	31 (42%)	16 (22%)	0.01
IEP/504 plans, n (%)	34 (46%)	12 (16%)	<0.01
School-related behavioral problems, n (%)	23 (31%)	19 (26%)	0.58
Full scale IQ , mean (SD)	101.9 (17.2)	103.8 (17.3)	0.42
Verbal IQ, mean (SD)	102.6 (15.0)	104.3 (14.8)	0.50
Performance IQ, mean (SD)	100.8 (13.8)	102.5 (14.9)	0.46
Premature birth, n (%)	14 (19%)	10 (14%)	0.97
History of head trauma, n (%)	14 (19%)	4 (5%)	0.02
History of recurrent otitis media, n (%)	22 (30%)	18 (24%)	0.58
Received tympanostomy tubes, n (%)	24 (32%)	17 (23%)	0.27
Attention deficit hyperactivity disorder, n (%)	8 (11%)	6 (8%)	0.78

Table 3

Bivariate analysis of the effect of case (child with unilateral hearing loss) or control (sibling with normal hearing) status and other potential confounders on Oral and Written Language (OWLS) scores in 148 children aged 6-12 years.

	Listening comprehension Mean (SD)	Oral expression Mean (SD)	Oral composite Mean (SD)
Unilateral hearing loss	***	**	***
No (control)	97.2 (14.1)	99.8 (19.4)	98.2 (16.2)
Yes (case)	91.3 (10.8)	93.6 (16.0)	90.7 (13.2)
Race/ethnicity		****	***
White	95.3 (13.0)	99.8 (16.5)	96.6 (14.7)
Black	91.1 (10.5)	81.2 (17.8)	84.8 (13.1)
Other	88.8 (13.2)	89.8 (19.5)	88.3 (16.4)
Sex		*	
Male	94.1 (13.4)	93.8 (19.0)	92.6 (16.1)
Female	94.4 (12.3)	99.9 (16.3)	96.5 (14.0)
Percent of federal poverty level		***	***
<100%	93.3 (7.6)	88.6 (12.1)	87.0 (12.6)
100-200%	91.2 (13.7)	84.5 (20.0)	86.9 (16.2)
>200%	94.8 (13.4)	99.5 (17.6)	96.5 (14.9)
Hearing loss severity (worse ear)			
None	97.1 (14.2)	99.5 (19.4)	98.0 (16.2)
Mild	89.4 (6.1)	94.8 (12.3)	91.2 (8.2)
Moderate	89.9 (11.3)	100.0 (21.3)	90.9 (20.1)
Severe	93.3 (8.4)	92.8 (11.1)	91.5 (8.1)
Profound	91.8 (11.7)	92.2 (15.7)	90.9 (12.5)
Side of hearing loss			
Right	91.6 (11.4)	93.8 (14.3)	90.4 (13.0)
Left	90.9 (10.0)	93.4 (18.4)	91.1 (13.8)
History of recurrent otitis media			
No	93.7 (12.5)	95.7 (17.8)	93.4 (14.7)
Yes	95.9 (13.7)	99.5 (18.4)	97.2 (16.2)
History of head trauma			
No	94.0 (12.9)	96.5 (18.1)	94.6 (14.8)
Yes	95.8 (12.6)	98.0 (17.6)	93.3 (18.4)
Premature birth			
No	94.3 (13.4)	96.0 (18.5)	94.4 (15.2)
Yes	94.3 (8.8)	101.6 (13.8)	94.6 (15.8)

* P value <0.10

** P value <0.05

*** P value <0.01

**** P value < 0.001

Table 4

Multivariable linear regression models on speech-language (OWLS) scores in a sample of 148 children aged 6-12 years.

Outcome	Parameter estimate	Standard error	T value	P value	Adjusted R^2
Listening comprehension					0.34
Intercept	38.6	7.3	5.3	<0.001	
Unilateral hearing loss	−10.8	4.3	−2.5	0.01	
Full sum IQ	0.47	0.06	7.9	<0.001	
Age	1.0	0.4	2.7	0.009	
Severity of hearing loss	1.9	1.2	1.6	0.12	
Oral expression					0.61
Intercept	−20.0	9.3	−2.1	0.04	
Unilateral hearing loss	−4.1	1.9	−2.2	0.03	
Full sum IQ	0.79	0.07	11.7	<0.001	
Age	2.0	0.4	4.6	<0.001	
Female sex	5.3	1.9	2.8	0.005	
Poverty level	−3.7	1.5	−2.4	0.02	
Maternal education	0.8	0.4	2.2	0.03	
Oral composite					0.53
Intercept	13.7	7.7	1.8	0.08	
Unilateral hearing loss	−5.7	1.7	−3.3	0.001	
Full sum IQ	0.6	0.06	10.3	<0.001	
Age	1.7	0.4	4.3	<0.001	
Female sex	3.8	1.7	2.2	0.03	
Poverty level	−4.3	1.3	−3.4	0.001	

Table 5

Multivariable linear regression models on speech-language (OWLS) scores in a sample of 74 children aged 6-12 years with unilateral hearing loss.

Outcome	Parameter estimate	Standard error	T value	P value	Adjusted R^2
Listening comprehension					0.25
Intercept	41.3	11.4	3.6	<0.001	
Full sum IQ	0.4	0.08	5.0	<0.001	
Age	0.2	0.6	0.3	0.7	
Severity of hearing loss	2.2	1.1	1.9	0.06	
Current use of amplification	2.6	2.3	1.1	0.3	
Oral expression					0.61
Intercept	−10.4	12.8	−0.8	0.4	
Full sum IQ	0.7	0.09	7.3	<0.001	
Age	2.2	0.7	3.3	0.002	
Female sex	7.9	2.3	3.4	0.001	
Poverty level	−4.2	1.9	−2.2	0.04	
Age of hearing loss identification	−1.0	0.5	−2.1	0.04	
Maternal education	0.8	0.5	1.6	0.12	
Oral composite					0.40
Intercept	23.1	13.2	1.8	0.08	
Full sum IQ	0.4	0.09	4.5	<0.001	
Age	1.4	0.7	2.1	0.06	
Female sex	6.3	2.4	2.6	0.01	
Poverty level	−5.9	1.9	−3.2	0.002	
Word recognition score, 0 dB signal-to-noise ratio	0.2	0.1	1.6	0.12	
Age of hearing loss identification	−0.7	0.5	−1.4	0.17	