Review Article

Minimal Hearing Loss: From a Failure-Based Approach to Evidence-Based Practice

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Purpose: A representative sample of the literature on minimal hearing loss (MHL) was reviewed to provide evidence of challenges faced by children with MHL and to establish the need for evidence-based options for early intervention.
Method: Research articles published from 1950 to 2013 were searched in the Medline database using the keywords *minimal hearing loss, unilateral hearing loss,* and *mild hearing loss*. References cited in retrieved articles were also reviewed.
Results: In total, 69 articles contained relevant information about pediatric outcomes and/or intervention for unilateral hearing loss, 50 for mild hearing loss, and 6 for high-frequency hearing loss. Six challenges associated with MHL emerged, and 6 interventions were indicated. Evidence indicates that although some individuals may appear to have no observable speech-language or academic difficulties, others experience considerable difficulties. It also indicates that even though children with MHL may appear to catch up in some areas, difficulties in select domains continue into adulthood.
Conclusions: Evidence indicates significant risks associated with untreated MHL. Evidence also demonstrates the need for early intervention and identifies several appropriate intervention strategies; however, no single protocol is appropriate for all children. Therefore, families should be educated about the impact of MHL and about available interventions so that informed decisions can be made.

Guidelines for the assessment and management of hearing loss in children have evolved over the years. The implementation of early hearing detection and intervention programs has been a driving force behind many of the changing protocols and updated guidelines for children with hearing loss. However, despite advances in identifying and providing appropriate care for children with hearing loss, children with minimal hearing loss (MHL) are still comparatively underrepresented in the literature and underserved in the community.

MHL has been defined in multiple ways throughout the literature. The most widely used definition includes three distinct configurations of sensorineural hearing loss: unilateral hearing loss (UHL), in which the air-conduction pure-tone average is ≥ 20 dB HL in the impaired ear; mild bilateral hearing loss (MBHL), in which the pure-tone average is between 20 and 40 dB HL in both ears; and high-frequency hearing loss (HFHL), in which the air-conduction thresholds are ≥ 25 dB HL at two or more frequencies above 2 kHz in both ears (Bess, Dodd-Murphy, & Parker, 1998).

Estimates of MHL prevalence vary depending on the age of the sample. Incidence rates at birth have been reported to be 0.35 per 1,000 births for UHL and 0.16 per 1,000 births for MBHL (R. Oyler & McKay, 2008; D. S. Ross et al., 2008). However, newborn screening and/or follow-up may miss additional children, and/or hearing loss may develop or progress after birth because prevalence rates in school-age children are reported to be as high as 56 per 1,000 for UHL; 15 per 1,000 for MBHL; and 12 to 13 per 1,000 for HFHL (Niskar et al., 1998). Bess et al. (1998) reported that the overall prevalence rate of MHL was 54 per 1,000 in their 1,218-student sample of children in Grades 3, 6, and 9. Of the three types of MHL, UHL had the highest prevalence rate (30 per 1,000); MBHL (10 per 1,000) and HFHL (14 per 1,000) had lower prevalence rates.

The etiology of MHL has not been the focus of much research, and, as with more severe degrees of hearing loss, the cause of MHL is often undetermined. A few studies have reported the known etiologies of hearing loss in their subject samples (e.g., Brookhouser, Worthington, & Kelly, 1991; English & Church, 1999). Tharpe and Sladen (2008) provided a review of the known causes of MHL, which include genetic causes, prematurity, enlarged vestibular aqueduct, congenital cytomegalovirus, mumps, meningitis, auditory neuropathy, and atresia. Other causes mentioned for MHL are sudden hearing loss, noise-induced hearing loss, and otitis media. Despite recommendations by the Joint Committee

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on Infant Hearing (JCIH; Muse et al., 2013), genetic evaluation and counseling are not yet performed routinely on children identified with hearing loss of any degree. These authors argued that screening for the most common genetic causes of hearing loss may help identify more children with MHL who may be missed by universal newborn hearing screening programs (Tharpe & Sladen, 2008).

Children with MHL typically were not identified until they entered school (Bess & Tharpe, 1986; English & Church, 1999; Lieu, Tye-Murray, & Fu, 2012). This trend was more pronounced before the implementation of early hearing detection and intervention programs because difficulty in school was usually the first indication of the hearing loss. Even after identification, the vast majority of these children receive little to no intervention. For example, a survey of 225 parents of children with MHL indicated that amplification was recommended to only 4% and assistive technology was recommended to 33% (Kochkin, Luxford, Northern, Mason, & Tharpe, 2007). The alternative to intervention traditionally has been preferential seating in the classroom, with a failure-based wait-and-see approach of monitoring for a significant change in hearing or decline in academic performance. With this approach, if the child fails in some area, intervention is then provided (Cozad, Marston, & Joseph, 1974; Holstrum, Gaffney, Gravel, Oyler, & Ross, 2008; Northern & Downs, 1978; R. Oyler & McKay, 2008; Tharpe, 1999, 2008). However, evidence suggests that children with MHL can benefit from early intervention, and the appropriateness of waiting for a measurable deficit before intervening has been called into question (Holstrum et al., 2008; Moeller, 2000; Yoshinaga-Itano, 1999; Yoshinaga-Itano, Sedley, Coulter, & Mehl, 1998). Despite this growing evidence, as indicated by Kochkin et al. (2007) and others (e.g., Holstrum et al., 2008; McKay, Gravel, & Tharpe, 2008), many children with MHL still experience a failure-based approach to intervention.

Perhaps one reason for the lack of consistent intervention for children with MHL is that there are no specific guidelines for the management of their hearing loss, thereby leaving many clinicians and health care providers with the impression that intervention is unnecessary. However, the lack of specific guidelines should not be mistaken for a lack of need or a lack of available intervention options. To the contrary, the Pediatric Amplification Protocol of the American Academy of Audiology (AAA; 2003) states that although children with MHL are candidates for various types of amplification and should make use of communication strategies, each child should be evaluated on a case-by-case basis. In 2005, the Centers for Disease Control and Prevention (CDC; 2005) sponsored the National Workshop on Mild and Unilateral Hearing Loss. The purpose of this workshop was to review and systematically analyze the available evidence concerning intervention for pediatric MBHL and UHL. Although the workshop provided a strong body of evidence supporting the need for intervention and presented different options available to these children, a universal protocol was not adopted. Instead, recommendations were built on the view that every child must be considered on an individual basis. Likewise, the JCIH recently released a supplement that addresses children with MHL (Muse et al., 2013). They recommended enrolling children with MHL in early intervention services if they qualify. However, because these children may not exhibit obvious or measurable delays in development, they may not qualify for state programs. Therefore, the JCIH also emphasized the need to carefully monitor children in a variety of domains, including hearing, language, and academics, if they are not receiving intervention services.

Although the general guidelines stated above are helpful, there is still no systematic protocol in terms of intervention for children with MHL other than diligent monitoring and parent education. Because intervention options are variable and because parents are active participants in clinical decision making, they need to be informed of the risks associated with MHL and to be made aware of different amplification and intervention options that may be appropriate for their child. Therefore, the purpose of this review article is not necessarily to provide a systematic or evidence-based review but rather to provide a review of a representative sample of the historical and current literature regarding (a) the impact of MHL in a variety of domains and (b) the treatment and management options available in order to assist clinicians and other health care providers with their decision-making process in managing children with MHL.

Method

An initial review of the literature was conducted using Medline database searches limited to the pediatric population (0–18 years) and to journal articles published from January 1, 1950, to April 1, 2013. The following key phrases were used: *minimal hearing loss, unilateral hearing loss,* and *mild hearing loss*. After reviewing the articles obtained from these searches, the references cited in all related studies were reviewed. Any applicable articles referenced in the previously obtained studies were also included for review. This process of collecting new articles via reference lists in published studies was repeated a total of three times. Articles were included if the topic of interest explicitly concerned the outcomes or intervention associated with one or more of the types of MHL. Select articles were included if they addressed all degrees of hearing loss but established significant findings pertaining to at least one type of MHL, as deemed noteworthy by CDC (2005). This process resulted in 102 articles that met the research criteria and were reviewed for the purpose of preparing this review article. Ten additional articles discussing intervention in audiologically similar adult populations were included. These articles were found during the process of going through references from the initial search and were included because, to the authors' knowledge, no comparable literature on these topics was available with pediatric populations (e.g., bone-anchored auditory implants [BAIs] in children with UHL).

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Results

The number of articles that met the inclusion criteria is shown in Figure 1 for each type of MHL by 5-year intervals. As can be seen from the figure, investigators have been reporting on children with MHL for more than 50 years, with periods of increased interest marking this history. An initial spike in research on UHL was seen in the late 1980s, and UHL has continued to be a topic of interest over the past three decades. Interest in MBHL has also been increasing over the past two decades; however, the literature addressing pediatric HFHL remains scarce.

Effects of MHL

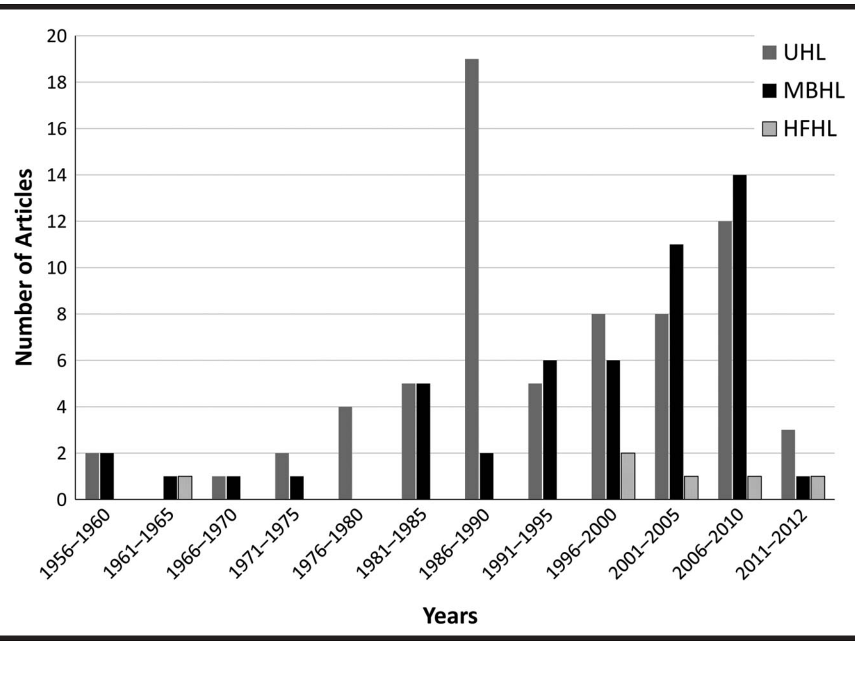
A wide range of effects have been documented for children with MHL, ranging from children who fail to keep up with age-matched peers in several domains to children who live their lives seemingly unaffected by their hearing loss. However, it is important to consider that children who appear unaffected and achieve normal scores on standardized measures may not be achieving their full potential and may have effects that have not been assessed or quantified. Research generally supports the idea that children with MHL do face more challenges than their peers with normal hearing (NH) and may need to use additional resources in order to compensate for their hearing loss. The challenges commonly associated with MHL fall in the domains of speech recognition, language development and competence, academic performance, psychosocial and emotional well-being, listening effort, and localization. Each of these domains is addressed in the sections that follow.

Speech Recognition

A large body of evidence indicates that children with UHL and MBHL demonstrate deficits in speech recognition, both in quiet and in adverse listening conditions with background noise and reverberation. Children with UHL and MBHL have been shown to have greater difficulty understanding speech compared with their peers with NH, even in ideal listening conditions (Bess & Tharpe, 1984; Jensen, Johansen, & Borre, 1989; M. Ross & Giolas, 1971). Both children with NH and children with hearing loss have been shown to have poorer speech recognition in noise than in quiet. However, numerous studies demonstrate that noise affects children with UHL and MBHL more negatively, especially as the noise level increases (Beattie, Barr, & Roup, 1997; Bess & Tharpe, 1984; Boney & Bess, 1984; Bovo et al., 1988; Crandell, 1993; Ruscetta, Arjmand, & Pratt, 2005; Welsh, Welsh, Rosen, & Dragonette, 2004). In addition to noise, the negative effects of reverberation are especially detrimental to children with UHL and MBHL (Boney & Bess, 1984; Jensen, Johansen, & Borre, 1989). Overall, the evidence is clear that children with UHL and MBHL are at a greater disadvantage than their peers with NH when trying to understand speech in listening environments that are less than ideal. No studies were found that assessed real-world outcomes for speech recognition in children with HFHL, although it is predicted that these children also may not understand others as well as children with NH, especially in the presence of noise and reverberation (Anderson, 2011).

For children with UHL, speech recognition is influenced by the direction of the signal in addition to noise level. Performance for these children has been shown to be

Figure 1. Number of articles examined for each type of minimal hearing loss from 1950 to 2012 in 5-year intervals. UHL = unilateral hearing loss; MBHL = mild bilateral hearing loss; HFHL = high-frequency hearing loss.



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comparable to that of peers with NH for some word recognition tasks when the signal is directed to the NH ear (Jensen, Johansen, & Borre, 1989; Ruscetta et al., 2005), although the majority of evidence demonstrates that these children achieve poorer scores compared with peers with NH even with this beneficial signal orientation (Bess & Tharpe, 1984; Bovo et al., 1988; Ruscetta et al., 2005). Due to the head shadow effect, speech recognition abilities of children with UHL are significantly worse when the signal is directed toward the impaired ear (Bess & Tharpe, 1984; Bovo et al., 1988; Feuerstein, 1992; Jensen, Johansen, & Borre, 1989; Ruscetta et al., 2005).

On the basis of subjective reports of difficulties in speech recognition, children with UHL are keenly aware of their deficits in speech understanding. Two thirds of children with UHL reported difficulty understanding speech in challenging listening environments, and about one third reported difficulty hearing their teacher at school (Bovo et al., 1988). Children with UHL also have higher reports of difficulty listening in noise compared with their peers with NH (Welsh et al., 2004). These difficulties with speech recognition appear to continue into adulthood, with 95% of adults with UHL reporting difficulties listening in noise compared with 6.7% of controls with NH (Colletti, Fiorino, Carner, & Rizzi, 1988). Overall, the data indicate that children with MHL perform poorer than their peers with NH on speech recognition tasks, particularly in adverse listening conditions such as a typical classroom environment.

Language Development and Competence

Considering the speech recognition deficits children with MHL demonstrate, it is not surprising that they also have deficits in speech production and overall language competence. Parental reports indicate that children with HFHL exhibit a delay in the onset of their first words (Goetzinger, 1962), and children with UHL have shown delayed onset of two-word phrases (Kiese-Himmel, 2002). Teachers have also reported poorer communication skills in school-age children with MHL (Bess et al., 1998; Norbury, Bishop, & Briscoe, 2001; F. Oyler, Oyler, & Matkin, 1988).

Results of standardized language measures on children with UHL have led to mixed conclusions, although each study's specific comparison criteria (national norms vs. peers with NH) may have been a limiting factor (Blair, Peterson, & Viehweg, 1985). The majority of evidence suggests that children with MHL have significant deficits on standardized language measures. These include lower performance scores compared with their peers with NH in a variety of areas, including vocabulary, reading, language mechanics, spelling, and overall phonological abilities (Bess et al., 1998; Briscoe, Bishop, & Norbury, 2001; Culbertson & Gilbert, 1986; Davis, Elfenbein, Schum, & Bentler, 1986; Halliday & Bishop, 2005; Lieu, Tye-Murray, Karzon, & Piccirillo, 2010; Lieu et al., 2012; Norbury et al., 2001; Peckham, Sheridan, & Butler, 1972; Wake, Hughes, Poulakis, Collins, & Rickards, 2004; Wake et al., 2006). Most studies found deficits in specific language areas rather than a universal deficit in all areas (Briscoe et al., 2001; Culbertson & Gilbert, 1986; Halliday & Bishop, 2005; Wake et al., 2006). These data seem to indicate that children with MHL are at greater risk for a variety of specific language deficits even if their overall language skill is not affected.

There are also reports that children with UHL and MBHL have no deficits in their overall language skills compared with national norms. In some cases, children had slightly poorer scores than their peers with NH, but overall group means did not reach significance levels (Gilbertson & Kamhi, 1995; Keller & Bundy, 1980; Klee & Davis-Dansky, 1986). In other studies, children with MBHL achieved standardized test scores that fell within normal ranges, although at times their scores were at the lower end of the normal range (Blair et al., 1985; Davis et al., 1986; Halliday & Bishop, 2005; Niedzielski, Humeniuk, Blaziak, & Gwizda, 2006). However, when the comparison group was peers with NH in their own class, scores were significantly lower (Blair et al., 1985; Halliday & Bishop, 2005), suggesting that group comparisons in the local educational system are an important consideration and should be taken into account when qualifying performance differences between the two populations.

Overall, the review of the literature indicates that children with MHL tend to have poorer language skills in specific areas compared with their peers. Language scores that fall at the low end of the normal range may also indicate that these children may not be achieving their full potential even though they are in the normal range.

Academic Performance

Many studies have reported that children with MHL fall behind academically on the basis of academic performance compared with their peers, grade retention, need for special education services, and standardized academic test scores. Children with MHL are 2.59 times more likely to have academic difficulties compared with children with NH (Bess et al., 1998). Moreover, children with MBHL ranging from 15 to 26 dB HL had a 1.1-year grade delay in their educational performance (Quigley & Thomure, 1969). More than two thirds of fifth graders with MBHL were among the lowest performers in their grade level, compared with only one third of children with NH (Daud, Noor, Rahman, & Sidek, 2010). Teacher reports also indicate that children with MHL tend to fall behind their classmates with NH in terms of academic achievement (Bess & Tharpe, 1984; Bess et al., 1998; Dancer, Burl, & Waters, 1995; Lieu et al., 2012).

Children with MHL are 10 times more likely to fail at least one grade compared with average schoolwide rates of grade retention (Bess & Tharpe, 1984; F. Oyler et al., 1988): 22% to 47% of children with MHL have repeated a grade—a significantly higher rate than their peers with NH (Bess & Tharpe, 1984; Bess et al., 1998; Bovo et al., 1988; Culbertson & Gilbert, 1986; Klee & Davis-Dansky, 1986; F. Oyler et al., 1988). Furthermore, rates of grade retention have been found to increase with age and with degree of hearing loss (Bess et al., 1998; F. Oyler et al., 1988).

Over the years, repeating a grade has given way to the use of special education services using individualized

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education programs (IEP) to supplement the education of children with academic difficulties. As the educational system has evolved, it is plausible to expect a reduction in grade retention rates but a growth in the number of children with MHL who have IEPs (English & Church, 1999). Children with MHL have been found to have high rates of special educational services in general (Bess & Tharpe, 1984; Brookhouser et al., 1991; English & Church, 1999; F. Oyler et al., 1988). Up to 54.0% of children with UHL have been reported to have IEPs (Lieu et al., 2012) compared with a national IEP rate of 12.3%. Children with UHL were also 4.4 times more likely to have an IEP than their siblings with NH (Lieu et al., 2010).

In an effort to incorporate more targeted evaluations of performance in particular areas, performance of children with MHL on standardized academic tests has been evaluated. Although children with MHL score lower than their peers with NH on some academic achievement subtests (Bess et al., 1998; Blair et al., 1985; Culbertson & Gilbert, 1986; Davis et al., 1986), many of these children also have scores within the normal range (Bess et al., 1998; Blair et al., 1985; Davis et al., 1986; Kiese-Himmel, 2002; Niedzielski et al., 2006), with no significant differences on academic tests compared with controls with NH (Bess & Tharpe, 1984; Bess et al., 1998; Culbertson & Gilbert, 1986; Peckham & Sheridan, 1976). However, it is important to note that not all reported studies compared scores with the scores of children with NH within the same school system. Age appears to be an important factor in studies of academic performance. In both academic and language domains, children with MHL appear to outgrow their difficulties and ultimately catch up to the performance levels of their peers with NH (Lieu et al., 2012; Peckham & Sheridan, 1976). By the time these children reach high school, significant differences between groups typically are not seen (Bess et al., 1998; Colletti et al., 1988; Reynolds, 1955). In addition, children with UHL have been shown to achieve equivalent levels of academic success and have similar posteducation employment rates compared with their peers with NH (Colletti et al., 1988; Ito, 1998). Overall, the literature regarding academic performance suggests that children with MHL are more likely to have academic difficulties, repeat a grade, and receive special education services, although over time they may outgrow these academic difficulties.

Psychosocial and Emotional Well-Being

Recent research on the effects of MHL on psychological, emotional, and social health has brought about a new awareness of the child's total well-being, highlighting that even children who seemingly exhibit no negative impact of their MHL may still be dealing with high levels of internal distress. Although some traditional research efforts on academic performance have shown that children with MHL are able to compensate for their loss (Lieu et al., 2012; Peckham & Sheridan, 1976) or are not negatively affected (Holstrum et al., 2008; Tharpe, 2008), research into the psychosocial and emotional effects of MHL seems to argue that just because a child is doing well in school and seems to adapt to challenging listening environments does not mean that MHL has not affected the child in some way.

One such indication that children with MHL experience greater levels of distress is the higher rates of behavior problems reported in these children. Higher rates of aggression, noncompliance, impatience, immaturity, hyperactivity, emotional inflexibility, impulsivity, and resistance to discipline have been reported in children with MHL (Bess & Tharpe, 1984, 1986; Bess et al., 1998; Brookhouser et al., 1991; Dancer et al., 1995; Davis et al., 1986; English & Church, 1999; Lieu et al., 2012; Peckham et al., 1972). These behavior problems may be a manifestation of the internal distress these children are experiencing. If this were true, it would be predicted that children who experienced greater challenges might have more internal distress and therefore more behavior problems. The finding that children with UHL who had failed a grade in school had a higher incidence of reported behavioral problems compared with children in the larger UHL subject group supports this notion (Bess & Tharpe, 1986).

Teacher reports have shown that children with MHL demonstrate reduced class participation (Bess & Tharpe, 1984; Dancer et al., 1995), poorer attention in class (Bess & Tharpe, 1984; Bess et al., 1998; Dancer et al., 1995; Lieu et al., 2012), poorer ability to work independently (Bess & Tharpe, 1986; Lieu et al., 2012), and poorer overall executive function (Lieu et al., 2012). They also have significantly lower energy levels and significantly higher reports of stress compared with their peers with NH (Bess et al., 1998).

Children with MHL have also been shown to have lower ratings of social support (Bess et al., 1998), and those with UHL have been reported to have poorer peer relations and to avoid large-group settings (Bess & Tharpe, 1984; Borton, Mauze, & Lieu, 2010). Children with MBHL have reported that they have difficulty making friends and being accepted by others (Davis et al., 1986). Middle school and high school students with MHL have lower self-esteem than those without hearing impairment (Bess et al., 1998), and almost one third of children with UHL were embarrassed by their hearing loss and felt inferior to their peers with NH (Bovo et al., 1988).

In addition to teacher reports, the Health-Related Quality of Life (HRQoL), a tool that quantifies how deeply a medical condition affects an individual's physical, emotional, psychological, and social well-being (Borton et al., 2010), has gained popularity in recent years. Children with UHL have been found to have lower scores than children with NH and children with bilateral hearing impairment on the PedsQL, a HRQoL measure specifically for evaluating children (Borton et al., 2010). Results have been mixed for children with MBHL. Children with MBHL had lower HRQoL scores than their peers with greater degrees of hearing loss and were more likely not to receive early intervention (Wake, Hughes, Collins, & Poulakis, 2004; Wake, Hughes, Poulakis, et al., 2004). However, no significant differences in HRQoL were reported between children with MBHL and children with NH (Wake et al., 2006).

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The psychosocial and emotional effects of MHL appear to continue into adulthood. A reduced quality of life has been associated with UHL for many years (Giolas & Wark, 1967). More recently it has been shown that adults with MBHL have high rates of irritability, feeling upset, and feeling left out, whereas adults with UHL have very high rates of feeling frustrated, upset, and left out (Newman, Jacobson, Hug, & Sandridge, 1997). Overall, the data indicate that children with MHL exhibit behavior problems in school more frequently than their peers with NH and may have social and emotional difficulties that continue into adulthood.

Listening Effort

Classrooms are known to be less than ideal listening environments (Bess, 1999; Bess, Sinclair, & Riggs, 1984; Crandell & Smaldino, 1995; M. Ross & Giolas, 1971). As noted previously, children with MHL have poor attention and deficits in speech recognition. Listening effort has been described as the increased use of cognitive and attentional resources in order to hear and understand speech (Hornsby, 2012). Listening effort has been measured using subjective reports of perceived ease of listening, physiologic markers of stress (e.g., cortisol levels and pupil dilation), and dual-task paradigms.

Subjective reports regarding listening effort in children with MHL are mixed. Significantly higher stress and fatigue levels have been reported (Bess et al., 1998), which may be the result of increased cognitive demands when listening in the classroom. The increased prevalence of psychosocial and emotional issues in children with MHL could also be related to increased listening effort. However, children with MBHL and HFHL have also been found to have no significant differences in stress and energy compared with children with NH (Hicks & Tharpe, 2002). Age may be a factor in these contradictory findings: Younger children (ages 5–11 years) appear to be no different from children with NH (Hicks & Tharpe, 2002), whereas older children (ages 12–18 years) appear to demonstrate the negative effects of increased listening effort (Bess et al., 1998). Young adults—even those with a simulated conductive hearing loss—reported significantly reduced ease of listening (Feuerstein, 1992), suggesting that reduced ease of listening might be a factor in older children and continue into adulthood.

The only report measuring listening effort using a physiologic marker in children with MHL used measurements of cortisol levels in children's saliva to monitor stress and fatigue. Stress leads to an increase in cortisol levels in preparation for the body to handle the stress (i.e., the fight-or-flight response), whereas lower cortisol levels have been noted in individuals with chronic and acute fatigue. Cortisol levels in children with MBHL and HFHL were compared with cortisol levels in their classmates with NH following class lectures and, consistent with their subjective reports, no significant differences were found (Hicks & Tharpe, 2002).

Another way to measure listening effort is to use a dual-task paradigm. These paradigms require children to perform two tasks: one auditory (e.g., word recognition) and one that does not involve listening (e.g., connecting the dots on a picture; Pittman, 2011). The rationale behind a dual-task paradigm is that as the child increases listening effort, performance on the secondary task decreases due to the need to reallocate cognitive resources toward the primary task of listening (McFadden & Pittman, 2008). Studies have demonstrated poorer secondary-task skills in adults with hearing loss compared with adults with NH (Downs & Crum, 1978; Kahneman, 1973). Children and young adults with MBHL have demonstrated poorer performance on dual-task paradigms (Feuerstein, 1992; Hicks & Tharpe, 2002; McFadden & Pittman, 2008). However, rather than a decrement in performance on the secondary task, children with MHL had significant decreases in performance on the primary auditory task (McFadden & Pittman, 2008), suggesting that children may have difficulty allocating cognitive resources away from a secondary task in order to accommodate increasing difficulty of the primary task. Overall, although more research is needed in this area, the data suggest that children with MHL may have to expend greater levels of cognitive resources for listening and that this difficulty may increase as they enter higher grades that are more demanding.

Localization

Sound localization is a particular difficulty for individuals with UHL. Horizontal localization skills are credited to two cues that rely on signal disparities between the two ears: interaural time differences serve as a localization cue for low-frequency sounds, whereas interaural level differences provide localization cues for high-frequency sounds (Mills, 1958; Nordlund, 1962; Stevens & Newman, 1936). Laboratory studies have demonstrated repeatedly that children with UHL have poorer localization skills than their peers with NH (Bess & Tharpe, 1984; Bess, Tharpe, & Gibler, 1986; Bovo et al., 1988; Humes, Allen, & Bess, 1980) and that the difficulty is greater with greater degrees of hearing loss (Bess & Tharpe, 1984; Bess, Tharpe, et al., 1986; Humes et al., 1980). The majority of children (Bovo et al., 1988) and adults (Colletti et al., 1988) with UHL also subjectively report difficulty localizing sounds. It is overwhelmingly apparent that children with UHL have a disadvantage in localization and that these deficits continue into adulthood. Overall, a large body of evidence exists suggesting that children with MHL are at risk for and may experience difficulties in a variety of domains, including speech recognition, language acquisition and skills, academic performance, psychosocial and behavioral issues, listening effort, and localization and that at least some of these difficulties continue into adulthood.

Individual Factors

Attempts have been made to determine whether certain characteristics may help predict whether a child with MHL will be more likely to demonstrate difficulties and need early intervention. However, results have been varied and sometimes conflicting regarding the effects of factors such as gender, race, ethnicity, socioeconomic status, age,

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maternal education, and treatment type (Dancer et al., 1995; Keller & Bundy, 1980; Lieu et al., 2010; Norbury et al., 2001).

One important factor is degree of hearing loss. In general, greater bilateral hearing impairment leads to poorer outcomes and performance on a variety of measures (Borg et al., 2002; Elfenbein, Hardin-Jones, & Davis, 1994; Peckham et al., 1972). However, findings in children with UHL have been mixed. Children with mild–moderate UHL have been found to have significantly better academic scores and better overall test scores on a language battery than their peers with greater degrees of UHL (Bess & Tharpe, 1984; Klee & Davis-Dansky, 1986). However, other studies have found no correlation between the degree of UHL and performance on a variety of standardized measures of academic and language abilities (Dancer et al., 1995; Keller & Bundy, 1980; Klee & Davis-Dansky, 1986). A larger proportion of children with UHL who had academic or behavioral problems in school had either minimal or profound UHL (Brookhouser et al., 1991). Children with UHL and MBHL have also been found to have poorer performance than those with greater degrees of bilateral hearing loss (Most, 2004, 2006), and it was suggested that this might be because they were not receiving rigorous intervention services.

Another factor discussed when examining the effects of UHL is the ear of impairment. Considering that the brain's language centers receive direct auditory input from the right ear, it has been proposed that children with right-ear impairment are more likely to have language and academic deficits. Several studies have supported this notion, finding significantly lower verbal test scores, poorer academic performance, higher rates of grade retention, and higher rates of speech and language delays in children with UHL in the right ear (Brookhouser et al., 1991; Jensen, Borre, & Johansen, 1989; Niedzielski et al., 2006; F. Oyler et al., 1988). However, a few studies have found no significant differences on the basis of the laterality of the hearing impairment (Dancer et al., 1995; Klee & Davis-Dansky, 1986). Overall, at this time there are no well-defined risk factors that indicate which children with MHL may be at greater risk for deficits in different domains (Holstrum et al., 2008; F. Oyler et al., 1988; Tharpe, 2008).

Intervention Options for Children With MHL

Despite the large body of evidence regarding the negative effects of MHL in different domains, there are no specific intervention protocols recommended for children with MHL. This may be due to the limited availability of research investigating the effectiveness of specific methods of intervention and mixed results for certain types of intervention. In addition, children with MHL are a diverse group, and a single approach may not best suit all individual children. Classroom modifications, frequency-modulated (FM) systems, hearing aids, contralateral routing of signal (CROS) hearing aids, BAIs, special education services, and monitoring are all management options that should be considered. However, any intervention plan must consider each child's unique needs and be implemented with the family's needs and expectations in mind (AAA, 2003; CDC, 2005; Muse et al., 2013).

Preferential Seating and Classroom Modifications

Preferential seating and classroom modifications are common recommendations for children with MBHL and UHL who have difficulties at school. Seating the child near the teacher and away from sources of noise is expected to decrease the detrimental effects of distance, noise, and reverberation, which in turn is expected to improve speech recognition (Bess, 1999; Bess, Klee, & Culbertson, 1986; Bess & Tharpe, 1984; Bess, Tharpe, et al., 1986; Brookhouser et al., 1991; Crandell & Smaldino, 1995; F. Oyler et al., 1988; Pakulski & Kaderavek, 2002). Even though preferential seating is widely recommended, there is a lack of evidence to demonstrate that it is sufficient. Classroom environments are less than ideal, and even optimal seating within the room may not provide adequate auditory and visual cues for children with hearing loss (Bess, 1999; Crandell & Smaldino, 1995; Nober & Nober, 1975; Ruscetta et al., 2005; Sanders, 1965). However, optimal classroom seating is an easy and cost-effective option that may be used in combination with other management strategies.

In addition to preferential seating, other classroom modifications may be beneficial. Acoustical treatment of the classroom with sound-dampening surfaces and changing the manner of classroom activities (e.g., avoiding walking around the class, which detracts from the potential benefits of preferential seating) have been shown to provide benefit (Bess, Tharpe, et al., 1986; Holstrum et al., 2008). Other helpful modifications recommended for teachers are to provide visual cues, use clear speech, state the topic of discussion, and stop frequently to check comprehension (F. Oyler et al., 1988; Pakulski & Kaderavek, 2002). Many teachers are unfamiliar with these methods of modifying the classroom and their own behavior and need guidance to adjust to teaching their student with MHL (Tharpe & Bess, 1991).

Although useful, optimal seating and classroom modification are most likely best treated as supplemental intervention approaches to be used with other intervention methods (Tharpe, 2008). Even if these modifications prove to be only marginally beneficial, they are not expected to be detrimental in any way (Holstrum et al., 2008). Therefore, these accommodations should be provided consistently in conjunction with other intervention methods when serving children with MHL.

FM Systems

FM systems transmit the signal of interest—typically the teacher's voice—via radio waves to a receiver worn by the child. In doing so the signal-to-noise ratio is improved, thus reducing the negative effects of noise, distance, and reverberation in the classroom. FM systems come in different configurations, ranging from personal FM systems worn by the child at ear level to sound field systems that use loudspeakers around the classroom. The specific type of

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FM system recommended should reflect the individual child's needs and classroom characteristics (McKay et al., 2008).

FM systems consistently have shown improvements in speech recognition in children with UHL and MBHL (Anderson & Goldstein, 2004; Hawkins, 1984; Kenworthy, Klee, & Tharpe, 1990; Tharpe, Ricketts, & Sladen, 2004; Updike, 1994) both in quiet and in noise (Updike, 1994). FM systems have also shown significantly better speech recognition than hearing aids and CROS hearing aids (Hawkins, 1984; Kenworthy et al., 1990; Updike, 1994). The greater the severity of UHL, the greater the benefit of FM (Updike, 1994). In order to ensure that children are able to hear their classmates as well as the teacher, FM systems should not have high attenuation (Lewis, Feigin, Karasek, & Stelmachowicz, 1991; Tharpe et al., 2004). For children with UHL it is important to keep the NH ear unoccluded. Tube fittings and lightweight headphones are the least-attenuating coupling options for personal FM systems and should be recommended for children with UHL (Kopun, Stelmachowicz, Carney, & Schulte, 1992). Children with HFHL achieved significantly better speech recognition when using a personal or desktop FM system compared with when using hearing aids alone or a sound field system with ceiling speakers (Anderson & Goldstein, 2004). In general, the use of FM systems is a beneficial intervention option that has been shown to lead to improvements in speech recognition in children with all three types of MHL.

Hearing Aids

Children with MHL should be considered candidates for hearing aids (AAA, 2003; Muse et al., 2013), although outcomes can be quite variable. Hearing aids can improve speech recognition and provide subjective benefit for children with UHL and MBHL (Blair et al., 1985; Briggs, Davidson, & Lieu, 2011; Davis et al., 1986; Hawkins, 1984; Johnstone, Nabelek, & Robertson, 2010; Kiese-Himmel, 2002; Updike, 1994). However, most of these same studies also found that certain children received no significant benefit from hearing aid use and that the hearing aids were detrimental at times (Blair et al., 1985; Briggs et al., 2011; Hawkins, 1984; Johnstone et al., 2010; Kiese-Himmel, 2002; Updike, 1994). It should be noted that many of these studies used analog hearing aids (Blair et al., 1985; Davis et al., 1986; Hawkins, 1984; Kiese-Himmel, 2002; Updike, 1994).

Several other factors have been reported to influence hearing aid outcomes. Children with severe to profound UHL are less likely to receive benefit from hearing aids (Kiese-Himmel, 2002; Updike, 1994). Another factor is background noise: hearing aids are less beneficial in noise than in quiet, although directional microphones may improve performance in noise (Ching et al., 2009; McCreery, Venediktov, Coleman, & Leech, 2012). Age at hearing aid fitting is another important factor, as hearing aids seem to be more beneficial if they are fit before the age of 5 to 6 years. This has been demonstrated for children with UHL (Johnstone et al., 2010) and MBHL (Blair et al., 1985), which documents the importance of early intervention for children with MHL.

No studies that focused on children with HFHL were found in the traditional hearing aid literature. However, adults with HFHL have demonstrated improved speech recognition and subjective benefit with hearing aids (Plyler & Fleck, 2006; Roup & Noe, 2009). Frequency-lowering hearing aids have recently been considered for individuals with HFHL to allow access to high-frequency information that would otherwise be unavailable (Glista et al., 2009). Although frequency-lowering hearing aids would not be appropriate for children with mild HFHL, they may be of benefit for children with precipitous HFHL that does not allow for adequate high-frequency amplification. Frequency-lowering hearing aids can significantly improve speech recognition, especially plural recognition (Glista et al., 2009), and subjective reports have indicated that the devices are beneficial (Glista, Scollie, & Sulkers, 2012). Overall, although more research is needed with digital hearing aids, the data suggest that early intervention with appropriate amplification should be considered for children with MHL except in cases of severe–profound UHL.

CROS Hearing Aids

CROS hearing aids are an option specifically suited for individuals with UHL. A CROS hearing aid has a microphone on the impaired ear that picks up signals and transmits the sounds to a receiver worn on the NH ear. The benefit of CROS is the improved ability to detect in the NH ear signals directed toward the impaired ear with the goal of improving speech understanding (Punch, 1988). Although CROS is an intervention option for adults with UHL (Hartford & Barry, 1965; Hartford & Dodds, 1966; Hartford & Musket, 1964), less favorable results have been seen in children. CROS systems have been reported to have no significant improvement in speech recognition or to have detrimental effects (Jensen, Johansen, & Borre, 1989; Kenworthy et al., 1990; Updike, 1994). In addition, comparisons between FM and CROS systems have demonstrated that FM systems lead to better speech understanding (Kenworthy, Klee, & Tharpe, 1990; Updike, 1994).

Although CROS hearing aids may be appropriate for adults, children may lack the skills needed for successful use of such a system. A CROS hearing aid can introduce greater noise levels to the child's good ear (McKay et al., 2008), and it may be impossible to seat a child in a classroom so that little to no noise is directed toward the microphone on the impaired ear. In addition, the successful use of a CROS hearing aid requires that the child be aware of potentially detrimental situations and capable of manipulating his or her location or environment to ensure the best outcomes. Some teenagers with UHL could potentially qualify as CROS candidates if their particular needs and lifestyle fit the limited benefits that CROS can provide. However, CROS is not an appropriate choice for young children who are not capable of actively adjusting their listening environment because failure to do so can decrease their overall speech discrimination ability (Punch, 1988).

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BAIs

Although commonly used for individuals with conductive or mixed hearing losses, BAIs have also been used by individuals with severe–profound UHL (also called *single-sided deafness* [SSD]). The premise behind the BAI in individuals with SSD is similar to CROS in that it sends to the NH ear signals detected at the impaired ear. However, a BAI transmits the signal to the NH cochlea via bone conduction. This approach has been suggested as a potential option for children with SSD, but there is no literature to support the use of BAIs in children at this time (McKay et al., 2008). In addition, the minimum age for implantation with a BAI is 5 years, although the option to use the device with a soft band is available for younger children. Despite the lack of evidence with children, there have been multiple studies showing the BAI to be a beneficial option for adults with SSD. Improved speech understanding in both quiet and noise and subjective reports of patient satisfaction and noticeable improvement have been reported, but improvement in localization has not (Bosman, Hol, Snik, Mylanus, & Cremers, 2003; Hol, Bosman, Snik, & Mylanus, 2004; Hol et al., 2010; Lin et al., 2006; Niparko, Cox, & Lustig, 2003; Wazen, Spitzer, Ghossaini, Kacker, & Zschommler, 2001). The BAI has been shown to be superior to unaided performance and to yield better speech recognition scores and subjective ratings compared with traditional CROS hearing aids (Bosman et al., 2003; Lin et al., 2006; Niparko et al., 2003). In addition, BAIs have been shown to improve self-rated quality of life and patient satisfaction when used with children who have conductive hearing losses (McDermott, Williams, Kuo, Reid, & Proops, 2009) and individuals with congenital unilateral atresia (Danhauer, Johnson, & Mixon, 2010).

Special Services

The JCIH supplement (Muse et al., 2013) calls for the provision of audiological, educational, and speech and language services for children with MHL. However, the literature regarding the benefits of special services is scarce, even though such services are widely used, and is available only for children with UHL (English & Church, 1999). Although limited, evidence suggests that intervention is beneficial: Children with UHL who had an IEP experienced a faster rate of increase in verbal test scores compared with those who did not have IEPs (Lieu et al., 2012). Flexer (1990) argued that audiological rehabilitation is necessary to supplement amplification provided to any child with hearing loss; this is true for the child with MHL.

Although related services required by any particular child with MHL may be outside the audiologist's scope of practice, an essential component of providing appropriate and comprehensive audiologic care is making appropriate referrals on the basis of clinician observations, teacher feedback, and parental reports. Referrals should not be limited to children who need medical attention or additional assistance at school but rather should include children with apparent psychosocial or emotional distress. Sometimes children with MHL may simply need the help of another related services professional (Bess, Klee, et al., 1986).

Monitoring

Monitoring children with MHL includes not only monitoring their hearing sensitivity on a regular basis but also monitoring them for the development or progression of any of the negative effects of MHL. This monitoring process is different from the failure-based wait-and-see approach, which delays provision of intervention services until the child exhibits difficulties and/or deficiencies in one or more areas. Monitoring should occur in conjunction with the provision of other intervention services. Audiological monitoring is recommended every 3 to 6 months for infants and toddlers and annually for school-age children with MHL (Matkin & Wilcox, 1999; Muse et al., 2013; R. Oyler & McKay, 2008). Monitoring should include parent education regarding the potential challenges of MHL so that parents can continually monitor their child at home. Parental education should also include information about noise-induced hearing loss and protecting their child's residual hearing (Bess & Tharpe, 1988; Brookhouser et al., 1991; Cozad et al., 1974; Henderson, Testa, & Hartnick, 2011).

In addition to audiologic monitoring, domains where deficits are commonly seen in children with MHL should be monitored regularly (McKay et al., 2008; Muse et al., 2013). These include speech and language, academic, psychosocial, and emotional well-being so that immediate referrals can be made when appropriate. Communicating with other professionals involved in the care of the child, including physicians and teachers, is essential to ensure that needs are being met (Tharpe, 1999).

Discussion

The purpose of this review article is to provide clinicians with the available evidence regarding the impact of intervention and intervention options available for children with MHL in order to assist with the clinical decision-making process. The results of this review indicate that, in general, children with UHL and MBHL have compromised speech recognition (particularly in adverse listening environments); may have poorer language skills and academic performance; and are more likely to have social, behavioral, and emotional problems. Children with UHL may also demonstrate difficulty localizing sounds. There is wide within-group variability in performance, with some children showing deficits and others seemingly demonstrating normal performance (Bess & Tharpe 1984, 1986; Borton et al., 2010; Briscoe et al., 2001; Crandell, 1993; Halliday & Bishop, 2005; Newman et al., 1997; Newton, 1983). However, at this time there are no clear risk factors that can predict which children will experience difficulties. The literature concerning children with HFHL is scarce. These children have been largely understudied, although they have significant and obvious difficulties (Cozad et al., 1974),

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and it is imperative that more research is conducted in this area.

Despite the variability in performance and apparent improvement in some areas (e.g., academic and language abilities) as children with MHL age, they may be developing compensatory strategies for dealing with their hearing loss—in particular, increased reliance on written information and tests. It is important to consider how learning and information change in upper grade levels, moving from oral to written materials. Although no specific risk factors have been identified, given the evidence base suggesting that right-ear impairment could be more detrimental to language and academic performance, it may be prudent to pay particular attention to language and overall academic performance if the child's right ear is affected.

A great amount of evidence suggests that children with MHL are more likely to experience difficulties in a variety of domains. However, in a survey of 225 families with dependents who did not use hearing aids, a majority of respondents indicated that their dependents had mild hearing losses that did not require amplification per the recommendation of a professional (Kochkin et al., 2007). The top three reasons given for not using hearing aids were (a) minimization of hearing loss, (b) recommendations from a professional, and (c) degree or unique nature of hearing loss. Overall, 25% of the families—including 21% of the families with a child with HFHL—reported that they were told that hearing aids would not help their child. Even though only 8% of the children with UHL had no residual hearing in the affected ear and therefore could not benefit from a hearing aid, 42% of the families of children with UHL reported that they were told that hearing aids would not help. Only one third of the families received recommendations for classroom assistance, and only three parents mentioned assistive technology in the classroom. Yet three fourths of the parents reported that their dependent who did not use amplification experienced quality-of-life problems. Among the 49 families with dependents who used amplification, almost one third reported grade improvements and about one half reported improvements in their dependent's social skills, classroom behavior, and self-esteem (Kochkin et al., 2007). These authors suggested that parents may be receiving misinformation from medical and hearing health professionals, especially regarding HFHL and UHL. Another factor that causes MHL to be minimized may be the terminology used, including the words *minimal* and *mild*. The use of the word *minimal* has been reported to be misleading to educators, who are unaware of the detrimental effects that can be associated with MHL (McCormick Richburg & Goldberg, 2005). Likewise, parents have expressed that the classifications used to describe degree of hearing loss do not accurately reflect the impact the loss has on a child's life (Haggard & Primus, 1999).

Due to the large individual variability in outcomes and performance, a universal protocol for intervention for children with MHL cannot be recommended. It is important to serve each child on an individual basis, monitor their progress closely, and provide appropriate individualized intervention. The following recommendations regarding intervention options for children with MHL ensue from the results of this review.

1. FM systems are the most suitable option to enhance speech recognition for children with UHL and MBHL and should be considered for all children with MHL.
2. Children with MHL should be considered candidates for hearing aids except in the case of severe–profound UHL. Technological advances in today's digital hearing aids should potentially lead to different outcomes than those reported previously. Additional research is needed to determine hearing aid benefits in children with MHL.
3. Although research is limited, BAIs should be considered as an option for children with UHL, whereas CROS hearing aids appear to not be a suitable option.
4. Preferential seating and classroom accommodations may be used as supplemental options together with other intervention strategies.
5. Children with MHL should be considered as candidates for an IEP before they begin to demonstrate deficits. Instead of the failure-based wait-and-see approach, providing these children with an IEP that is based on their hearing loss may help set the stage for close monitoring and prevention of deficits.
6. In addition to audiologic reassessments, monitoring should include determining whether the chosen intervention is beneficial to the child and whether appropriate outcomes are being achieved. Because evidence regarding intervention outcomes for children with MHL is relatively scarce, it is especially important to ensure that progress is being made as a result of the chosen intervention. If sufficient benefit is not measurable, it may be necessary to implement an alternative method of intervention.
7. Parents must be educated regarding all available options for their child with MHL so that they can make informed decisions and choices. Parent education must be ongoing because intervention options that were not suitable in infancy may need to be added as the child gets older and needs change.

With all the information available regarding the effects of MHL and the options available for intervention, it is time for professionals to stop minimizing MHL and holding children with MHL to a wait-and-see approach. All children with MHL should receive individualized and early intervention, including parent education and continual monitoring, with the goal of optimizing listening, ensuring success in the classroom environment, and helping each child meet his or her full potential. Early intervention needs to be provided in conjunction with close monitoring rather than intervening after the child demonstrates difficulties. As stated aptly by Bess (2004, as cited in Tharpe, Sladen, Dodd-Murphy & Boney, 2009, p. 81), "Minimal is not inconsequential."

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