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Investigation and literature review of unilateral hearing loss

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INVESTIGATION AND LITERATURE REVIEW OF UNILATERAL HEARING LOSS

by

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Abstract: ***Literature and research were gathered and analyzed to determine the impact UHL has on a child's education, speech and language development. The effects of early intervention and amplification were also analyzed.***

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Introduction

Binaural hearing (ability to hear with two ears) provides enhanced listening ability to an individual in four specific ways. One is localization, both in quite and in noise (Lieu, 2004; McKay, Gravel, Tharpe, 2008). Having two ears work together and having the signal sent to the brain, we can locate where the sound is coming from depending on when each ear receives the signal as well as how loud the stimulus is at each ear. A second benefit of binaural hearing is the elimination of the head shadow effect (Lieu, 2004; McKay et al, 2008). When a noise is presented on one side of the head, the ear closest to the noise is stimulated first. The sound then wraps around the head and the opposite ear receives the signal. Low frequency sounds wrap around the head more efficiently than high frequency sounds. High frequencies are reflected off the same side of the head that received the original signal, and therefore the opposite ear does not receive the stimulation. With binaural hearing the individual is able to detect the low frequency sounds in both ears no matter which side the signal is originally presented on, making the head shadow effect less detrimental to the listener. A third benefit of binaural hearing is the ability to pick out a signal in noise; also known as binaural squelch (Lieu, 2004; McKay et al, 2008). This differs from localization in that it concerns the ability to focus on a stimulus while in noise. This improvement in the ability to detect a signal or speech in the presence of background noise is also known as the "cocktail party effect". The fourth advantage of binaural hearing is the fact that an individual's overall thresholds are lowered, meaning that they are able to detect softer sounds. This is known as binaural summation. Binaural summation typically gives a 3-8 dB advantage for binaural listeners over those with unilateral hearing (Lieu, 2004).

When an individual has unilateral hearing (one normal hearing ear), localization becomes more difficult, and the head-shadow effect prevents some acoustic signals from being heard when the sound is presented on the side with the hearing loss. Picking out a signal in noise is extremely difficult, and thresholds are elevated when listening with only one ear.

A plethora of research was conducted during the 1980's to assess the potential consequences that unilateral hearing loss (UHL) has on children's education. It is noted that children have more difficulty hearing speech in noise than adults, and this can have a more detrimental effect on their language development than adults (Lieu, 2004). Additionally, children with UHL generally require a greater signal to noise ratio to understand speech which can put a child with this type of loss at a disadvantage in a school setting (Lieu, 2004). Due more current research, and the acknowledgement of the difficulties students may face when in an educational setting, how to manage unilateral hearing loss (UHL) is something that is currently being debated by audiologists, early interventionists, speech pathologists, and many others. There is not a standard audiologic definition for unilateral hearing loss, but the general definition has been stated as: average air conduction thresholds of 20 dB HL or greater in the affected ear with normal hearing in the other ear being considered less than or equal to 15 dB HL (Ross, Holsturm, Gaffney, Green, Oyler, &Gravel, 2008; McKay et al, 2008).

While reviewing literature for this study, it was noted that UHL and mild bilateral hearing loss (MBHL) are often researched and reported together. Although this study is not looking at the affects of MBHL, it is mentioned occasionally due to its close association to UHL in many other reports. In essence, the intent of this study is to provide a commentary on the research available regarding the impact that UHL can have on children.

Literature Review

More than 90% of newborns are screened for a hearing loss before they leave the hospital (Ross et al, 2008). Universal newborn hearing screening (UNHS) has identified many babies that are born with a hearing loss, but not all children with unilateral hearing loss are being identified. It is estimated that 0.19 children out of every 1000 screened have a UHL (Ross et al, 2008). Now with UNHS and early hearing detection, many children are being identified with a hearing loss within the first few weeks of life (Oyler & McKay, 2008).

Early identification and intervention for children with a UHL is important as it can impact the ability to listen, have an effect on communication, and result in a delay in language and speech development (Brown, Holstrum, Ringwalt, 2008; Holsturm, Gaffney, Gravel, & Oyler, 2008). Early intervention provides parents with knowledge about the potential impact that UHL may have on their child's development (Brown et al, 2008). This service also helps parents monitor developmental progress. Brown, et al., studied a group of 30 children, birth to age three, who were diagnosed with UHL. The study indicated that an estimated 30% of the children exhibited a language or communication delay (Brown et al., 2008). This study supports the fact that early intervention is important for children with this type of loss.

Along with informing the parents about the possible effects of UHL and monitoring the child's development for possible developmental delays, parent educators work with parents to provide ongoing assessments and offer information to the parents regarding accommodations to help their child learn in different environments (Brown et al., 2008). The early interventionist also helps the parent learn how to use the child's amplification devices (if they have any). Together the parent and the early interventionist can note differences in the child's language and

hearing and monitor possible progression of the loss. The early interventionist can help the parent understand why having otitis media with effusion, an ear infection with fluid in the middle ear space, should be treated as soon as possible. Otitis media with effusion can cause a slight conductive hearing loss, and can make it more difficult for the child to hear, especially if it is present in the better ear.

Early interventionists, audiologists, and other professionals are unclear as to which children with UHL are more at risk and would benefit from early intervention. Children with UHL are at risk for a progressive hearing loss that can lead to a higher severity of loss, and even a bilateral hearing loss (Brown et al., 2008). Therefore, current research suggests that early intervention services should be offered to a family as soon as a hearing loss is diagnosed. Early interventionists help the family and the child through this difficult time, and these services can affect the child's educational and social progress in a positive way (Brown et al., 2008).

Discussion of Educational Factors Past and Present Prospective

Prior to the 1980s and 1990s unilateral hearing loss (UHL) was thought to have little effect on children's language development and minor consequences, if any, on a child's education (Lieu, 2004). During the 1980s and 1990s studies began to reveal that there was a significantly increased number of students with UHL that had educational and behavioral problems when compared to their peers with normal hearing (Lieu, 2004). Before universal newborn hearing screening children with UHL were not identified until they were school aged and in most states 5 ½ years was the average age of identification (Lieu, 2004; Oyler & McKay, 2008). Children were often referred for further evaluation after a hearing screening that was performed at school, unless they had medical problems that lead to an early hearing screening

(Lieu, 2004). Due to the fact that many audiologists, physicians, and special educators did not believe that UHL had an impact on students' learning or development, children with UHL did not receive any special services. Their hearing loss was not considered to be a hindrance to their educational performance (Tharpe, 2008).

Bess and Tharpe (1986) found that in a pool of 60 children with UHL, ranging in age from 1-12, with the majority being between 5-6 years of age, about half of the students were performing at a satisfactory level in school. However, 35% had failed at least one grade and an additional 13.3% received support services. One child in the study was reported to have failed two grades. Out of the 60 students, 20% of them were described by the teachers as having some behavioral problems in the classroom. The graph below shows the percentage distribution of grades failed by children with a UHL.

Academic Progress	***60 children with UHL Percent***	***25 children with UHL Percent***
Satisfactory	51.7	68
Resource help required	13.3	8
Grade Failure	35	32
Behavior problems reported in classroom	20	12

Bess and Tharpe conducted an additional study of 25 children with UHL in order to support their original research to ensure that the results were illustrative of all students who had a UHL. When obtaining data on these 25 children, ranging between the ages of 6-13, Bess and Tharpe questioned the parents about the reasons for bringing their child to the speech and hearing center. The most common answer was that their child had been referred on a hearing

screening at school or the physician's office (36%). Twelve percent of parents listed that there were noticeable hearing problems and/or concerns about a possible speech or language problem, and 8% had difficulty in school. Out of this group of children, 32% had failed at least one grade, and 8% in this group were in need of school resource support. It was also noted that all of these students received preferential seating in the classroom. When comparing the numbers from this study to the previous study, the results are in good correlation with the larger group of 60 students.

It has been noted that having a right sided UHL seems to have more of an educational effect on students. In a study of 25 students with UHL, 62.5% of the students that failed a grade had the loss on their right side (Bess & Tharpe, 1986). In another study, conducted in 1989, 30 children with UHL were compared to 30 children in a control group that had normal hearing. This study looked at the difference between right and left sided UHL. Students who had a left sided UHL performed similarly to their normal-hearing peers on multiple verbal assessments, as opposed to the students that had a right sided hearing loss. The children with a right sided loss had a lower performance level on the verbal tests than the control group and those with a left sided UHL (Hartving Jenson, Borre, Johansen, 1989). Another study reported that children with right UHL were five times more at risk for failing a grade than children with left UHL (Oyler R., Oyler A., Matkin, 1988). This correlates with other research suggesting that, "…a right UHL may have a greater impact on central perception and processing of sound than a left UHL." (Lieu, 2004). The author concludes that this phenomenon exists due to the fact that the left cerebral hemisphere is known to be dominant for language development and language learning for the majority of individuals (Lieu, 2004).

Studies from the past and present that have analyzed the educational impact of UHL have come to the same conclusion; UHL can place a child at risk for academic failure (Bess, 1985; Oyler et al, 1988; Ross et al, 2008). The previous chart shows that grade failure and the need for resources required to help students with UHL is close to 50% in the larger study and 32% in the smaller study. This is a significant increase over students with normal hearing. Identifying the students that have a higher risk of academic difficulties or failures is difficult. There is no definitive way to predict which students will have difficulties in school. However, children who have a more severe loss, and those with a right UHL are at a higher risk of academic failure (Lieu, 2004).

When UHL is left undetected it is believed that it can have an impact on speech, language, behavior, and academic achievement for some students (Brown et al, 2008; Holstrum et al, 2008). The exact reason for these difficulties is still unknown, but it is reasonable to assume that part of the reason is a result of listening problems that the child encountered throughout the development of their language (Holsturm, Gaffney, Gravel, & Oyler, 2008, 2008; McKay et al, 2008). A possible component could be missing incidental language due to trouble hearing when there is background noise.

Research in this area is difficult to investigate because professionals have received a limited number of referrals to early intervention programs for children with UHL (Brown et al, 2008). This is due to the common belief that one normal hearing ear is good enough for a child with UHL. Since there is little evidence of effective remediation strategies, many professionals opt to do nothing (Holsturm et al, 2008). Children with UHL could benefit from having a speaker get their attention before talking, using amplification or assistive technology in

communication situations that are in less-than-optimal acoustic environments, and using visual cues and gestures when speaking (Brown et al, 2008; McKay et al, 2008).

Receiving appropriate educational services can become more difficult for children with UHL after their third birthday. Many children with UHL that received services under Part C of IDEA lose their services when they enter preschool because they no longer meet the strict eligibility criteria for Part B of IDEA. This is due to the fact that under Part C of IDEA, children from ages 0-3 can qualify for services if they have or are at risk for a developmental delay (Holstrum et al, 2008). The criterion differs from state to state for eligibility for Part C. In some states the child can be at risk for a delay, where as other states mention that a "significant" delay and/or hearing loss must be present to receive early intervention services (Holstrum et al, 2008). While a small number of states do not mention hearing loss in association with early intervention services, it is a goal to have each state ensure that all infants and children with a documented hearing loss, of any severity and type, will receive appropriate early intervention services (Holstrum et al, 2008). This would include children that have UHL. Although it is an important goal, and some children that have UHL receive early intervention services, it is still difficult for these children to continue services after their third birthday. This is due to the fact that children are no longer covered under Part C of IDEA after their third birthday; they transition to Part B. When transitioning from Part C to Part B services are difficult to maintain because Part B has much more restrictive requirements than Part C (Brown et al, 2008; Holstrum et al, 2008).

In most states Part B of the IDEA typically requires that a child exhibits a delay on a norm-referenced developmental test in order to receive services (Holstrum et al, 2008). This differs from the criteria in Part C, where children can qualify if they are at risk for a delay

(Holstrum et al, 2008). For example, a child that is enrolled in an early intervention program receiving services under Part C may be functioning within normal limits or have a slight delay. However, when the child becomes eligible for Part B programs it is required that the child has a disability or a developmental delay of 1.5 or 2 standard deviations below the norm (Holstrum et al, 2008). This means that the child will not be eligible for services under Part B if they only have a slight delay or no delay at all. This is disturbing because children with UHL are generally in quiet listening environments until they are preschool aged. They receive a lot of one-on-one instruction while covered under Part C, and most children ages 0-3 are not expected to perform in a noisy environment. The current literature suggests that children with UHL have deficits in their performance when they are placed in a group educational setting where they are confronted by the listening environments that are noisier than before (Holstrum et al, 2008). An example of this could be a preschool setting, where there are multiple activities occurring at once and a child is expected to hear a teacher amidst the noise.

There is an increase in the number of students within the school age that are identified with unilateral hearing loss. Currently children are tested using NBHS and again when they enter formal schooling. It is thought that at a child's 30-month visit to the doctor a hearing screening should be administered to help identify and provide intervention to the children that have a late-onset hearing loss (Ross et al, 2008). This may also help students keep up with their peers and provide them with support that could prevent them from falling behind.

Although research has been presented showing that UHL can have an educational impact on children, especially if the hearing loss is present in the right ear, the debate is continuing. Judith Lieu asks the question " should these children be treated as normal-hearing children, with

no special concerns for speech and language, or should these infants be fitted with hearing aids, or is there a middle ground between these two approaches" (2004)?

Assistive Technology

There are many different types of assistive technology devices available for those who are deaf and hard of hearing, but the decision of whether or not to fit children that have UHL with amplification is not standardized (Lieu, 2004; McKay et al, 2008). Different types of assistive technology have been assessed to see what is best for children with UHL. Audiologists do not have a standardized procedure for evaluating or aiding children with this type of loss. The current debate is how to manage or effectively improve hearing for children with UHL (McKay et al, 2008). The following research studies can help teachers, parents, and audiologists alike see a summarization of what types of assistive devices have the most benefit for children with UHL.

A FM (frequency modulated system) works on radio waves that are casted in the air. A receiver, also called a boot, can be coupled to the hearing aid, which will provide an increased signal to noise ratio for the child. The child wears a special receiver that connects to his/her hearing aid and the receiver receives the signal from the microphone that the teacher is wearing. The teacher wears a microphone approximately 6 inches away from her mouth, typically on her shirt. The receiver that the child is wearing receives the signal from the microphone and provides the child with a better signal to noise ratio than he/she would have without the FM system. This helps the child hear the teacher's voice as if he/she was standing in front of the teacher, while the teacher moves freely about the classroom setting. Another type of FM system is called a soundfield system. For this type of FM system the teacher still wears a microphone

on her clothes, and there is still a receiver that the child uses. Instead of the child having a receiver that is coupled to his hearing aid, the child has a speaker that sits on his/her desk. The speaker receives the signal from the teacher's microphone which increases the signal to noise ratio, which provides the child with a better sound quality than they would have otherwise received (Oyler & McKay, 2008). The child can set the volume of the speaker to provide the most effective signal to noise ration.

Although an ear-level FM system increases the signal to noise ratio more than a sound field FM system, the ear-level FM system is not always available. Studies have shown that a soundfield FM system is not only beneficial for the child with UHL, but it is beneficial for all students (McKay et al, 2008).

Another type of assistive technology that has been researched for children with UHL is the CROS aid (contralateral routing of signal). CROS aids are fitted by having an in-the-canal (ITE) hearing aid or a behind-the-ear hearing aid (BTE) placed at the impaired side. The signal that is received by the microphone is then transmitted to another hearing device on the ear with the normal hearing. This means that the better ear is not only being stimulated by the signals presented on that side, but it is also receiving the signal received on the impaired side. It is thought, through research, that a CROS system could have unfavorable results in a classroom setting due to the fact that the signals presented to the impaired ear are filtered through the microphone into the good ear. This means that the signals from both ears are being filtered into one ear (Oyler & McKay, 2008). Updike (1994) examined the use of conventional hearing aids, CROS aids, and the FM systems in 6 children with UHL. The study compared speech recognition scores in both quiet and in noise. Speech recognition was decreased when using both

the CROS aid and the conventional hearing aid in noise. It was found that only the FM systems provided improved speech recognition scores in both the quiet and noise. Little research has been conducted examining any possible benefits of the CROS aids on the pediatric population (McKay et al, 2008).

The BAHA (bone anchored hearing aid) is another type of assistive device used by children with UHL and conductive hearing loss. The BAHA is placed on the mastoid bone of the side with the hearing loss. For babies it can be placed on their forehead. The BAHA sends the signal from the impaired side to the normal hearing side, with the normal cochlea. The signal is sent transcranially via bone conduction (Oyler & McKay, 2008). The acoustic signal on the impaired side of the head is received by the BAHA and converts the signal into vibrations which bypass the middle ear system and are sent directly to the bones of the skull. Each cochlea is embedded in the temporal bones of the skull on both sides of the head; the transmission from the BAHA would stimulate both cochleas if they were both healthy. In this case, the use of the BAHA allows the cochlea on the side with normal hearing to be stimulated with the signal that is present on the impaired side of the head (McKay et al, 2008).

In one research study, that only had 9 subjects, the BAHA seemed to provide the patients with improved speech perception ability while using the device. In the study, the patients' BAHA-aided responses were improved from their pre-aided speech perception sensitivity. However, in this same study, the spondee threshold dropped significantly from the pre-aided scores. Although this study states that there was an improvement in hearing while using the BAHA with UHL patients, the numbers represented from this study were gathered in a sound booth through both air conduction and microphones (Wazen et al, 2001). This setting is not

representational of a real-life situation. The booth that the study was conducted in was perfectly sound, and there was not a presence of background noise or reverberations in the room. Although this device is used with children who have UHL, there is not a lot of research to state how effective the BAHA is for children (McKay et al, 2008; Oyler & McKay, 2008).

Lieu mentioned in her 2004 article that studies she reviewed found that the FM system was the only assistive hearing device that produced a high speech recognition score in monaural direct, monaural indirect, and omini directional listening situations. The FM system seemed to be the most popular amplification device for children with UHL. Also, the ear-level FM system, coupled to the hearing aid, provides the most optimal signal-to-noise ratio and should always be considered (McKay et al, 2008; Oyler & McKay, 2008).

From the research reviewed it is established that FM systems provide the most benefit to children with UHL. Although it is easy to use an FM system in a school setting, it is more difficult to use them at home, during play, and in other "real world" settings (Lieu, 2004). This is thought to be because the school systems do not always allow children to take devices home, the extra expense of purchasing the system, and also due to the reality that children do not always wear their hearing devices outside of the school setting. More research is needed to know which assistive technology devices are the most efficient and helpful, inside and outside of a school setting, for children with UHL.

Speech and Language

Limited information exists about the effect UHL has on the acquisition of speech and language. Parents of children with UHL were asked to reflect on the ages when their child spoke their first word and first 2-word phrase. The first word utterance was not delayed, occurring at

the average of 12.7 months (range 1-33 months). However, the average age of the child's first 2-word phrase was 23.5 months (range, 18-48 months). "The 2-word phrase was delayed an average of five months, based on a norm of 18 months" (Kiese-Himmel, 2002; Lieu, 2004; Oyler & McKay, 2008).

In Judith Lieu's 2004 article, *Speech-Language and Educational Consequences of Unilateral Hearing Loss in Children*, she stated that there were four studies that looked at language skills of school-aged students, including preschoolers. A longitudinal study was conducted and looked at 44 children who had a severe UHL. The children were first assessed when they were 7 years of age, and a follow up assessment was conducted when they were 11 years of age. Overall, the group of children with UHL had speech difficulties that were more prevalent than their peers with normal hearing. It was reported that in the follow-up assessment only 4 children had reduced speech intelligibility, but overall the reading scores were comparable to those of their peers with normal hearing. One factor that may have skewed the study was that 13 of the original children with UHL had normal audiograms during the follow-up assessment that was conducted when they were 11 years of age. It is assumed that they had a temporary severe UHL that could have been caused by otitis media with effusion. This is an ear infection that causes fluid build-up behind the ear drum in the middle ear space.

To further evaluate the effects UHL have on speech and hearing, another subgroup of 25 children with UHL were chosen from Bess and Tharpe's original study to be compared with a control group of their normal hearing peers. Results indicated that the children with UHL had significantly lower verbal academic test scores than their peers with normal hearing. It was also recognized through this study that the subgroup with a more severe hearing loss had significantly

lower IQ scores. Children with a mild to moderate UHL had significantly higher IQ scores when being compared to their peers who had a severe to profound UHL. Due to the scores, it is assumed that the IQ tests had a verbal component. When children have a language delay they should be assessed with a nonverbal IQ test, and if they are assessed with an IQ test that has a verbal component, the final quotient should not include the verbal score. The nonverbal section of the IQ test shows the child's learning potential. A child may score low on the verbal subtest, not due to their intelligence, but as a result of their language deficit.

Personal Stories of Living with UHL

In order to fully understand what it is like to have a unilateral hearing loss, and how it affects daily living, three personal stories of living with UHL were collected. Individuals were questioned about how their UHL affected their schooling and social lives. They were asked to share their stories and feelings about how UHL made them feel in different situations. One of the participants had a progressive UHL on her right side. She was diagnosed with a profound sensorineural loss when she was eight years of age. The other individual was thought to be born with a UHL, but the etiology of both of the participants is unknown. The third individual could not recall exactly when his UHL occurred, but remembers it was during his young teen years. A nail perforating the tympanic membrane, ear drum, and damaging the middle ear space was the etiology of his UHL. The extent of the damage is not known, but he has a severe conductive loss at best.

These individuals found school to be more challenging, although not all of them reported having difficulties in a learning environment. It was stated that learning in the classroom was difficult, and the only extra service they received was preferential seating. The teacher did allow

them move around the classroom depending on where the lesson was taking place. Classroom discussions were often difficult, as it was frustrating to know who was talking and what questions were being asked.

Overall it seemed as though the lunch room was especially difficult for these individuals. Trying to have conversations in this noisy environment resulted in misperceptions of being ignored to frustration at having to repeat. Some felt as though their friends thought they were lying about their hearing loss, but as they got older it seemed as though their friends began to accept their UHL. Friends would ask if they were on their "good side", and former frustrations became more of a joke.

All of the individuals that shared their stores stated that they continue to have difficulty localizing in quiet and in noise. One individual said that her children have to help her find the phone when it rings. Another individual stated that she likes her phone to light up when it rings so she can find where she put it. Each person interviewed seemed to accept their UHL and now finds humor in situations that were once frustrating. The individuals did say that having UHL as a child did make things more difficult. They feel that they did miss out on some things in school but they managed by asking lots of questions after class.

Some individuals reported that having a UHL can be quite frightening at times. It was stated that being in a crowded place with children can be scary if one of them is separated. Not being able to localize where your name is coming from can be terrifying, as well as not being able to always hear where an emergency vehicle is coming from.

The individuals that were interviewed all had intelligible speech, even to unfamiliar listeners. One individual does speak loudly, which could also be in part due to presbycusis

along with the UHL. None of these individuals received any special accommodations while in school, except for preferential seating, and they agreed that they would have benefited from some type of assistive hearing technology while in the classroom. Two of the three individuals graduated from high school and have some college education. The third individual began working after the eighth grade.

Future Research

There is still much to learn about unilateral hearing loss and its effect on educational performance (Brown et al, 2008). Research on the likelihood of a child with UHL developing a delay is just starting to emerge in literature. Although studies show that UHL can have an effect on an individual's learning, it is unknown which students are at risk for having these difficulties. Future research studies can focus on many aspects of UHL. Which students are at risk for speech and language delays along with educational difficulties? What type of assistive hearing devices and systems work best for children with UHL when in a classroom setting as well as in "real world" settings? Another area of research should focus on the types of services children with UHL are receiving, and of these services which seem to be the most effective. Future research regarding difficulties in social situations would also be beneficial. More research is also needed to study the differences between right and left UHL.

Conclusion

The literature and research on UHL support its educational impact on students. It is believed that early intervention, along with appropriate amplification, can help children with UHL develop speech and language. Research also supports the benefits of assistive technology, mainly the FM system, to help students feel more apart of the classroom community. There is

agreement that children should receive intervention as soon as they are diagnosed with a UHL and monitored for a progressive, bilateral loss, or signs of any developmental delays. Research seems to reveal that a right UHL can have a more detrimental educational effect than a left UHL, but more research is needed before confirming this conclusion.

It was also noted and concluded through this literature review that a standard is needed for declaring a child with UHL. There is not a standard definition or degree of hearing loss specified for an individual with UHL, nor is there a standard way to assess how to mange the hearing loss. Due to the lack of clarity and knowledge on this topic, further research is needed to help children with this type of loss receive proper intervention services. Further research is needed to determine how to manage UHL including protocol for testing, diagnosis, and amplification.

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