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**NEWBORN DIAGNOSTICS: EFFECTS OF HEARING SCREENING
FAILURES, APPOINTMENT ATTENDANCE & DISTANCE ON AGE OF
HEARING LOSS DIAGNOSIS**

By
Stephanie Claire Trippel

A thesis submitted to the faculty of The University of Mississippi in partial fulfillment of
the requirements of the Sally McDonnell Barksdale Honors College.

Oxford

February 2016

Approved by

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Reader: Dr. Anne Williams

Reader: Dr. Lennette Ivy

DEDICATION

I would like to dedicate this thesis to my Grandparents; I couldn't have done it without
their love and support

ACKNOWLEDGEMENTS

I would first like to thank my advisor, Dr. Tossi Ikuta for guiding me through this process and everything else he has done for me during my time at Ole Miss. I would also like to thank Dr. Anne Williams for being a reader for my thesis, helping me collect data, and facilitating my love for audiology. Also, thanks to Dr. Lennette Ivy, my third reader and the chair of the Department of Communication Sciences and Disorders. Finally, thanks to my parents and Jefferson for helping me with Excel.

ABSTRACT

This thesis investigates diagnostic outcomes of infants referred to the University of Mississippi Speech and Hearing Center between January 2010 and September 2014. Data were collected on the reason for referral, eventual diagnosis, appointment attendance, and distance traveled of the patients referred. A total of 177 patients were collected. It was determined that UMSHC reaches EDHI goals for most patients who receive a diagnosis. An overwhelming majority of patients referred were due to newborn hearing screening failure, and most patients received a diagnosis of within normal limits. Those patients who never received a diagnosis had poor attendance which seemed to be influenced by distance from the clinic. The results suggest a need for an additional screening or diagnostic center closer to those patients who seem to miss appointments more frequently.

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Introduction

The prevalence of hearing loss is at an all-time high, and is steadily increasing. According to a study conducted by the National Institute of Health, in the United States “nearly 1 in 8 individuals 12 and older has bilateral hearing loss, and nearly 1 in 5 has a unilateral or bilateral hearing loss” (Lin, Niparko, Ferrucci 2011). In the same study, Lin et al. acknowledge that although the overall risk of hearing loss may be decreasing, the prevalence of hearing loss is expected to rise because of the aging of the population (2011). The aging population greatly contributes to the prevalence of hearing loss; however there are many infants who are born with a congenital hearing loss or acquire a loss soon after birth. It can be difficult to detect hearing losses in infants, but with hearing screening and diagnostic technology more infants are being treated for hearing losses earlier.

Before Universal Newborn Hearing Screenings (UNHS), only “at risk populations” were screened for a hearing loss, these infants generally were in the intensive care unit or infants born with anomalies. However, since the 1990’s there has been a significant push to screen all newborns in the United States in an attempt to identify and treat hearing loss early. While there is no law at the federal level requiring infants to be screened, there are laws and legislation at the state level which mandate screenings. In addition to these laws, the Children’s Health Act of 2000 allows federal funding to be used in support of UNHS (Health Act). This federal money supports many UNHS advocacy programs, such as the Early Hearing Detection and Intervention (EHDI). The Joint Committee on Infant Hearing (JCHI) created EHDI in 1994. It sets goals and benchmarks for when children with hearing loss should be screened, diagnosed, and treated. EHDI has a “1-3-6 goal”

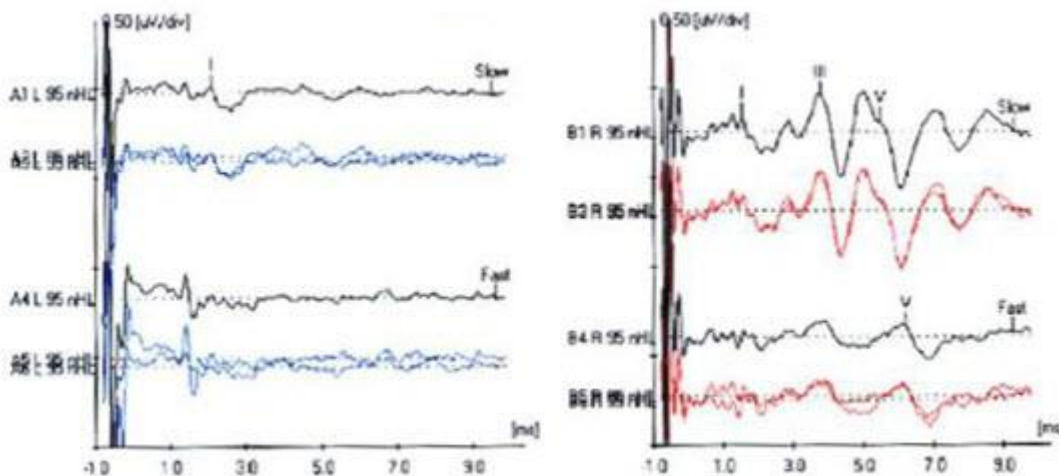
which states that newborns should receive a hearing screening by one month, should be diagnosed with a hearing loss by 3 months, and receive intervention for their hearing loss by 6 months (JCIH). The JCIH also provides a detailed procedure for audiologic evaluation based on age and benchmark quality indicators for each step.

An estimated 3 in 1,000 newborns have a hearing loss (White, 2007). For this reason, early screening, diagnosis, and intervention, as well as programs like EHDI are important in detection and advocacy for infants with hearing loss. Hearing loss can have extreme influence on a child's development if undetected. Studies have proven that an early diagnosis followed by intervention for hearing loss contributes to improved language, academic, and social-emotional development in children (Calderon & Naidu, 1999; Moeller, 2000; Nelson, Bougatsos, & Nygren, 2008). To identify hearing loss and prevent these developmental delays, infants are administered either Auditory Brainstem Response (ABR) or Otoacoustic Emissions (OAE) tests. Either test can be used for UNHS and which test is used varies by hospital and clinic. Mississippi law mandates that all infants born in Mississippi must be screened prior to discharge from the hospital. If the infant fails the screening three times in at least one ear, the infant must be referred to an audiologist for a full diagnostic session (MS State Department of Health, 2015).

Auditory brainstem response (ABR) is an auditory evoked potentials test that has multiple functions. ABR can be used as one of two tests for newborn hearing screenings, along with otoacoustic emissions (OAE) testing. However, at the University of Mississippi Speech and Hearing Clinic, as well as clinics and offices around the world, ABR is used for differential diagnostics and auditory threshold testing. ABR is useful in diagnosing auditory pathologies because the test is retrocochlear, whereas OAE tests do

not examine hearing past the structure of the cochlea. Because ABR works by sending a click stimulus through earphones, and examining function of the retrocochlear pathway, absent results could indicate a sensory or neural pathology. By using ABR patterns it is possible to make inferences about what pathologies could be causing disruptions in the procedure (Katz, 2015).

ABR works by measuring interwave latency responses. Waves I, III, and V are recorded along the auditory pathway at different thresholds played into the infant's ear. Each wave represents different parts along the auditory pathway. For example, Wave I represents function of the Eighth Cranial Nerve, Wave III the auditory pons, and Wave V is the most clinically significant, representing upper brainstem and colliculus activity (Katz, 2015). The image below represents a normal ABR with typical interwave latencies and peaks, in contrast to an abnormal ABR result indicating an acoustic neuroma (i.e. a benign growth along the auditory nerve), due to a diminished Wave I and an absence of Waves III and V.



The average length of stay after birth in a hospital is 1.6 days, which does not leave much time between screenings (Farhat & Rajab, 2011). Because Mississippi state

law mandates screenings must be performed before discharge, these screenings might be rushed and many infants are referred for a diagnostic session. Both OAE and ABR screenings require a clear ear canal and a sleeping infant to get clear results. Infants can have vernix (i.e. waxy coating on newborn skin) in the ear canal, fluid, or not stay still for the screenings; all of which could cause hearing screening failure not due to an actual hearing loss. This is why the recommended time for newborn hearing screening after birth is later than 24 hours to avoid the increased incidence of ear conditions affecting screening outcomes in the first hours post birth (Erenberg et al., 1999). The diagnostic follow up is an important part of the EHDI program and treating an infant with hearing loss, however many infants referred for this follow up diagnostic prove to have hearing within normal limits. This is poor utilization of time, money, and resources that might not have been necessary if hospital hearing screening protocol were different. Another potential issue in the process of diagnosis and intervention is the lack of follow up; families not bringing the infants for the diagnostic session.

The purpose of this paper is to 1) determine if the length of time passed after the final failed screening has an effect on eventual hearing loss diagnosis 2) evaluate the average number of diagnostic sessions needed to make an official diagnosis and 3) describe the effect of distance from the diagnostic center on diagnostic session attendance. Using data from the University of Mississippi Speech and Hearing Clinic in Oxford, MS, results of hearing screenings and diagnostic sessions of infants born in northern Mississippi were analyzed.

Methods

This retroactive study utilized the University of Mississippi Speech and Hearing Center's database. In the Hear Form system, data were collected on the 184 infants scheduled for an Auditory Brainstem Response diagnostic session at the UMSHC between January 2010 and September of 2014. Of the 184 patients, 7 were not included in analysis due to equipment failure. These seven patients were referred to a different diagnostic center and their final diagnosis was not in their file, as they never made another appointment at the UMSHC.

A total of 177 patient files were collected and analyzed. The data collected in each file included:

- Demographic information, including patient number, hometown, home county, and the referring source
- Medical history i.e. the reason for the patient's referral
- Scheduling history, including the number of diagnostic appointments scheduled, the number of diagnostic appointments attended, and reasons for any rescheduled appointments
- Age, in months, of the first diagnostic session and the final diagnostic session
- Diagnostic results

These data were collected from the clinic software based on time of first ABR appointment scheduled. All patients seen for an ABR diagnostic session were sorted based on date of appointment. From that chronological list, the patient numbers of the 184 participants starting in 2010 were collected. Those patient numbers were then entered

into the database and the hometown, referring source, reason for referral, scheduling history, ages, and results of ABRs were collected.

In some cases, the ABR results were not recorded in the database patient file. In such cases, the patient's paper file was pulled to ensure the correct final diagnosis and age of diagnosis were correctly recorded.

To find the travel distance and time for each patient, the start destination was entered into Google Maps based on the hometown listed in the patient file, and the ending destination was the University of Mississippi Speech and Hearing Center.

Results

Failed Hearing Screening & Diagnosis

Of the 177 infants referred to the University of Mississippi Speech and Hearing Center for a diagnostic session, 138 (78%) were referred due to failed hearing screenings after birth. Of these 138 infants, 75 eventually tested to be within normal limits of hearing, 23 proved to have a hearing loss or some type of inner ear disorder, and 40 infants never received a diagnosis. A majority of referred infants never received a diagnosis due to missed appointments, however one infant did not have a diagnosis in the system because the family went to another clinic to get the diagnostic session completed.

Infants who failed their hearing screening and got a diagnosis at UMSHC received that diagnosis at various ages, but were all diagnosed at age 6 months or younger. **Figure 1** shows the number of patients diagnosed at each age. This graph not only shows that a majority of infants who failed their hearing screening test have normal hearing, but at what ages they typically receive the diagnosis. Overall, the average age of infants with a result of normal hearing was 2.35 months, while the average for infants who proved to have some hearing loss or ear disorder was 3.17 months. Most patients who test within normal limits are diagnosed within one or two months, whereas as more infants who were diagnosed with hearing loss were diagnosed at age 3 months than any other age.

Figure 2 shows the cumulative percentage of infants diagnosed by age; this displays that infants who have normal hearing typically get diagnosed at a younger age than infants who have hearing loss. While over 90% of patients who were referred due to a hearing screening failure and had normal hearing were tested normal by four months

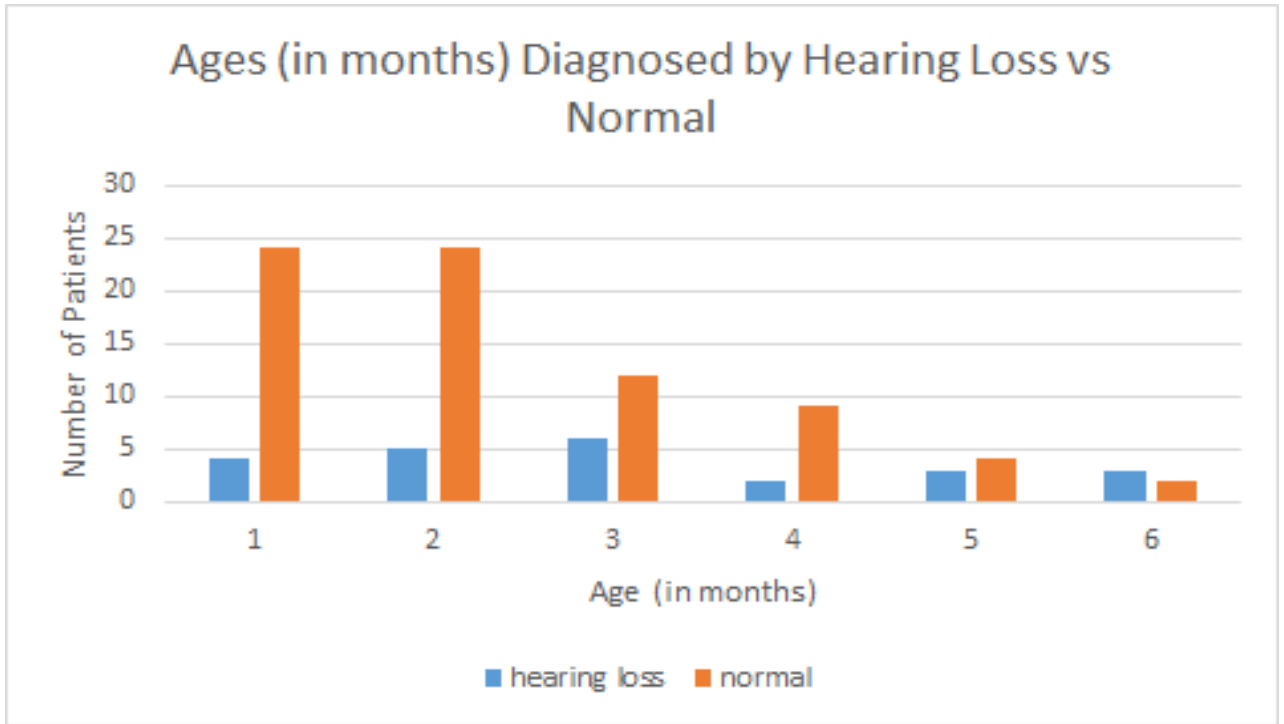


Figure 1. Infants referred for failed hearing screening and eventual diagnosis

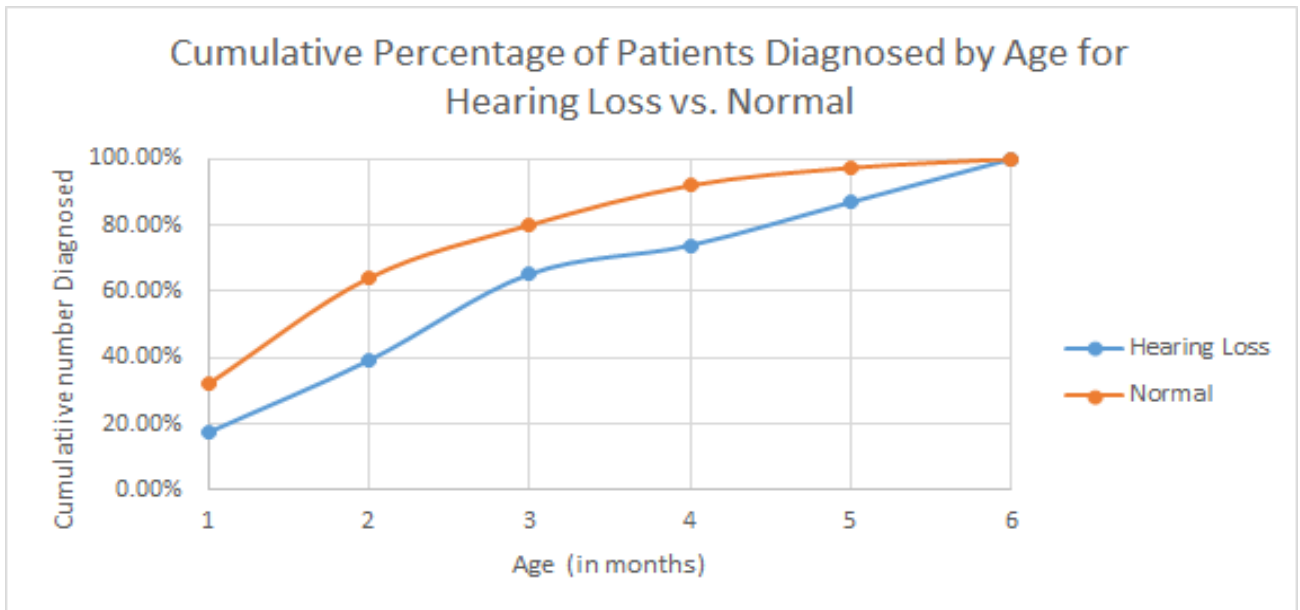


Figure 2. Infants referred for failed hearing screening and cumulative ages of diagnoses

old, only approximately 73% of patients with hearing loss were diagnosed by four months. While significantly more infant tested normal than with hearing loss, based on Figure 2, until 6 months of age, at least 10% more children with normal hearing were diagnosed each month than

children with hearing loss. **Table 1**

shows statistical analysis of age in months of diagnosis for all infants

	Diagnosis and Age (in months)				
	mean	median	mode	std dev	range
Hearing Loss	3.05	3	2	1.63	5
Normal	2.34	3	2	1.32	5

referred for failed hearing

Table 1. Diagnosis and Age based on results of diagnostic sessions

screenings based on the results of diagnostic sessions.

In addition to referrals for hearing screening failure, UMSHC received referrals for infants who were high risk. High risk reason for referrals included premature birth, ototoxic drugs or antibiotics administered, meningitis and genetic abnormalities. In two patient files, reasons for referral included both hearing screening failure and premature birth.

Other reasons infants were referred for a diagnostic screening included home births, head trauma, and broken screening equipment. In some cases, infants passed their original hearing screening but were referred for a diagnostic session because a family member or doctor suspected hearing loss. **Figure 3** shows all reasons for diagnostic appointments scheduled and the number of patients referred for each reason.

Appointment Attendance & Diagnosis

Regardless of the reason for referral, the goal of the diagnostic sessions is to determine if the infant has a hearing loss or pathology. Attendance at these diagnostic sessions are critical to get a timely diagnosis. At the UMSHC, of all infants referred for a

Reasons for Referral	Number of Patients
Hearing Screening Failure	138
High Risk	34
<i>Premature</i>	14
<i>Ototoxic Drugs</i>	8
<i>Antibiotics</i>	3
<i>NICU Follow Up</i>	3
<i>Family History</i>	4
<i>Down Syndrome</i>	1
<i>Meningitis</i>	1
Other	9
<i>Home birth- never screened</i>	3
<i>Head Trauma</i>	1
<i>Broken screening equipment</i>	1
<i>Suspected Hearing Loss</i>	4

Figure 3. Frequency for reasons of referral

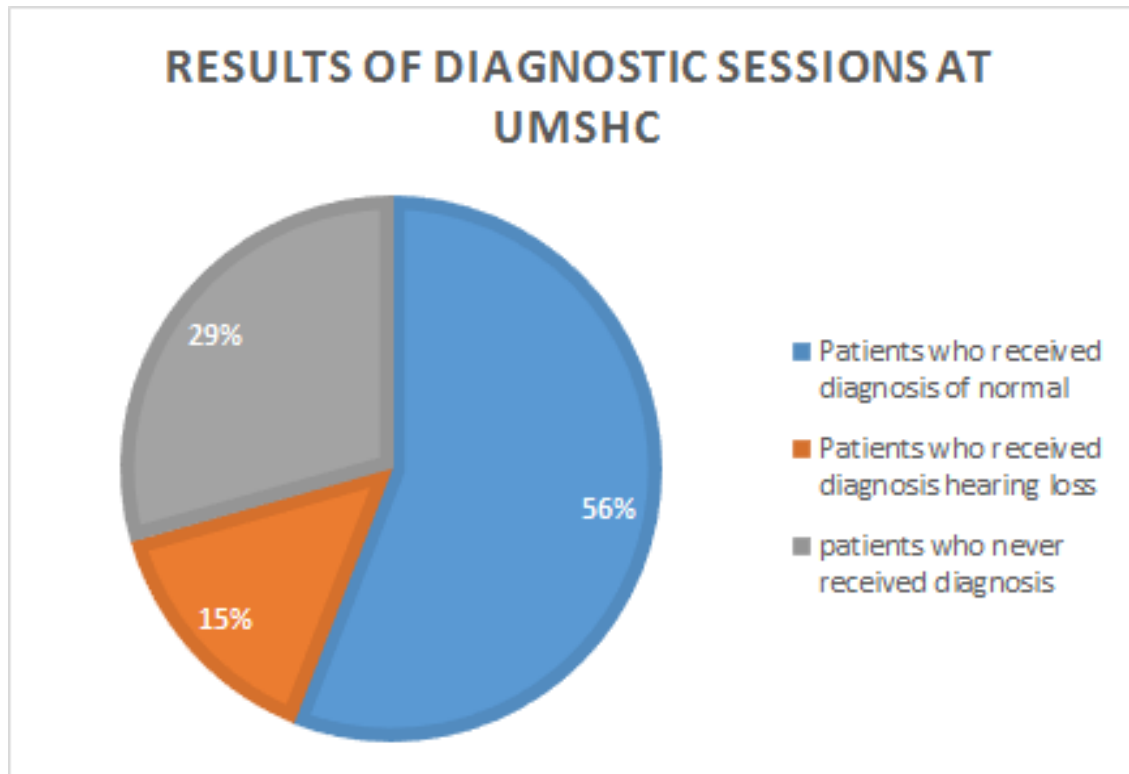


Figure 4 Results of all diagnostic sessions for newborns

diagnostic session, 71% received a diagnosis. **Figure 4** shows the breakdown of diagnostic session results of all infants referred to UMSHC. The 29% of patients who never received a diagnosis is due to a lack of appointment attendance. Of the 177 patients scheduled for a diagnostic session 96 never miss an appointment, regardless of how many appointments were scheduled. 57 patients missed one of their scheduled appointments, and 24 missed two or more. These data show that it is not unusual for more than one diagnostic appointment to be scheduled. Over 100 of the 177 patients scheduled more than one appointment. Half the time, appointments needed to be rescheduled because the patients never attended, and the other half, the audiologist needed the infant to come back another day for various reasons (fluid, awakened during testing, no clear results, etc). All infants seen for a diagnostic session are categorized as either within normal limits (WNL), having hearing loss (HL), or no diagnosis received. **Table 2** shows

Results of appointments	Appointments scheduled	Appointments attended	% Attendance
Avg # sessions for WNL	1.3	1.1	84.62%
Avg # sessions for HL	2.0	1.7	85.00%
Avg # session no diagnosis	1.5	0.1	6.67%

Table 2 Appointments scheduled and appointments attended based on results of session. WNL= within normal limits, HL= hearing loss

the average number of appointments scheduled versus appointments attended for each category of final diagnosis. Based on Table 2, infants who eventually tested with some degree of hearing loss scheduled and required more appointments. However, percentage of attendance for infants who tested within normal limits and infants who tested to have a hearing loss were similar. The number of appointments scheduled for infants who never received a diagnosis valued between those with a hearing loss and those within normal limits. However, the percentage of appointment attendance for those who never received a diagnosis was significantly lower at just 6.67%,

Most frequently, patients had multiple appointments scheduled because they missed previously scheduled appointments and never attended to get a final diagnosis. However, many patients who eventually received a diagnosis required and attended more than one appointment.

For those patients who required more than one appointment, there was an average of 1.88 months between their first and final diagnostic session. There was no significant difference in this average length of time based on actual diagnosis of within normal limits (1.9 month gap) or hearing loss (1.86 month gap).

Distance & Diagnosis

The referring sources for all the infants referred to UMSHC for a diagnostic evaluation span across northern Mississippi and even out of state. Because of the wide variety of referring source UMSHC received patients from all across the region. The

average distance of all infants referred to UMSHC for a diagnostic session was 49.1 miles and 55 minutes. The significance of distance from the site of a diagnostic session can be shown by average appointment attendance based on distance. **Figure 5** is a box plot that displays average, minimum, and maximum distances as well as upper and lower quartile ranges based on patients who missed zero, one, and two or more appointments. There is a clear trend showing that while the minimum distance from UMSHC is the same regardless of missed appointments, the average and maximum distance increases with number of missed appointments. **Figure 6** displays the distance of every town of all infants referred for a diagnostic session, with the 0 mark portraying the Speech and Hearing Center. Distance clearly has an impact on eventual diagnosis. The average distance of infants who never received a diagnosis was 60.3 miles, whereas the average distance for infants who received a diagnosis was only 44.5 miles.

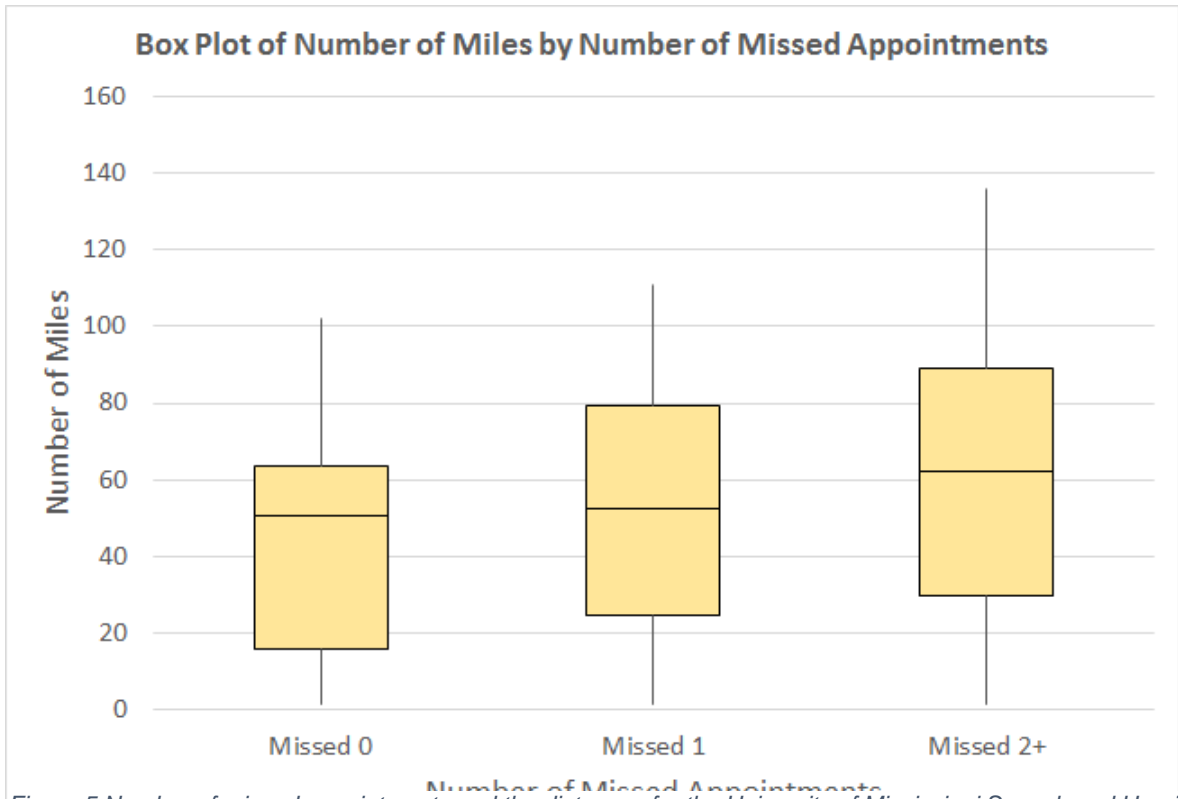


Figure 5 Number of missed appointments and the distances for the University of Mississippi Speech and Hearing Center

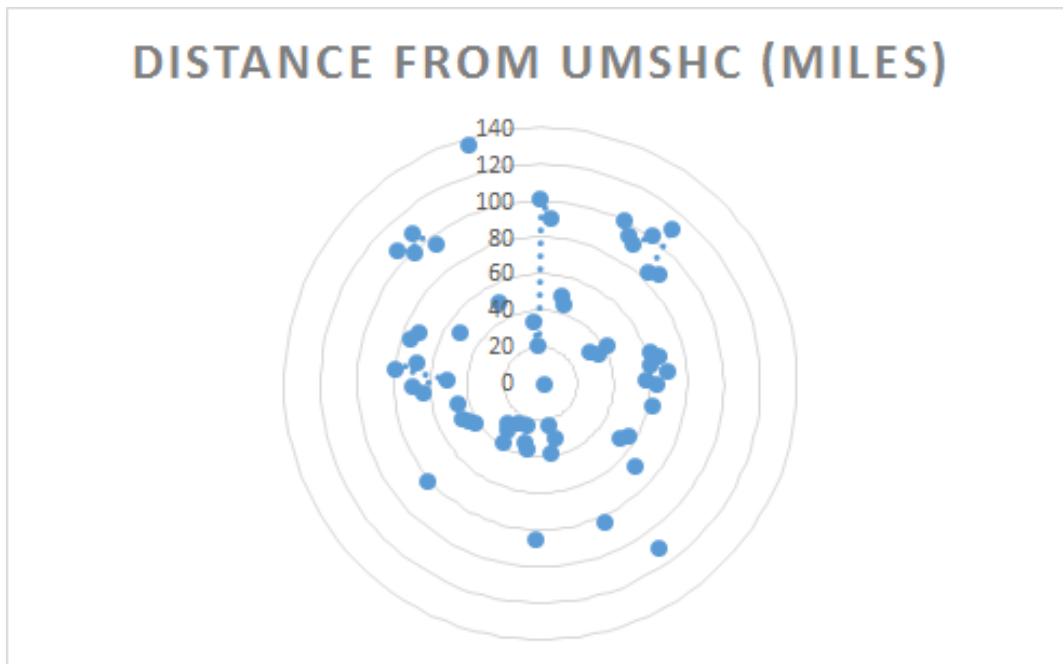


Figure 6 Distance from University of Mississippi Speech and Hearing Center in miles. Dots represent every town in which infants referred for a diagnostic session live.

Discussion

The University of Mississippi Speech and Hearing Center receives many patients and referrals every year. An overwhelming majority of infants referred to UMSHC come because of mandatory hearing screening failure or as a result of a high risk pregnancy. While diagnostic sessions are an invaluable part of the treatment process for hearing loss, many infants eventually test to be within normal limits and do not need any sort of treatment. Regardless of reason for referral, many patients at the Speech and Hearing Clinic do not attend all (if any) scheduled appointments, which interferes with achieving a diagnosis and potentially speech and language development. While official reasons for missing appointments were not typically noted in patient profiles, distance from the clinic proves to have a significant impact on appointment attendance.

Hearing Screenings

A majority of newborns referred to UMSHC come due to hearing screening failure. Most of these infants test to have no hearing loss and are not seen again after that diagnosis. Early Hearing Detection and Intervention (EHDI) aims to have all infants screened by one month, diagnosed by 3 months, and fit with a hearing device if necessary by six months. In most cases, infants who tested within normal limits or tested to have hearing loss were diagnosed by the EHDI timeframe. Those infants who were diagnosed later (age 4-6 months) or never received a diagnosis did not reach the EDHI diagnostic goal due to missed or rescheduled appointments. UMSHC schedules and tests infants who failed their newborn hearing screenings in a timely fashion in line with the EDHI program and does not see most of the failed hearing screening patients again because of normal results.

A limitation of this analysis is that age of diagnosis is dependent on factors other than the child's hearing on the day of appointment. These data do not take into account the scheduling conflicts of the infant's families and the UMSHC. For example, an infant could test within normal limits or prove to have a hearing loss at a younger age if scheduling would allow, but rescheduling caused a later date of diagnosis. There is also an increased average in age of diagnosis because many infants needed to have additional appointments due to the Auditory Brainstem Response test not being able to be successfully completed (e. g. fluid or unclear ABR results).

Appointment Attendance

While the timeframe of diagnosis at UMSHC is impressive, poor attendance rates for infant diagnostic sessions prevent the clinic from diagnosing many patients who are referred. Most patients regardless of diagnosis required more than one scheduled appointment. Patients who proved to have a hearing loss required more appointments on average, but attendance rates for these patients were good; similar to patients who received a final diagnosis of within normal limits. As can be expected, attendance rates for patients who never received a diagnosis were significantly poorer.

Some reasons for missed or rescheduled appointments were listed on file. Occasionally appointments had to be rescheduled due to conflicts at UMSHC. But most often family members called the clinic to say they would have to miss and reschedule. As stated before, most patients who received a diagnosis not in line with EHDI time frame goals missed or rescheduled appointments. Not reaching EHDI diagnostic goals could have a significant delay in age of treatment, which could delay speech and language development.

The calculations for appointment attendance included all total appointments made with the UMSHC and all appointments attended. Because the patient files did not typically include reasons for missing appointments, the missed appointment calculations did not take into account reasons for absences. All appointments that were missed were included in analysis, regardless of reason for being missed, (whether the family called ahead to cancel the previously scheduled appointment, if the infant was ill, etc., even if the missed appointment was due to issues at the clinic.)

Distance from Clinic

Because of insurance and Medicaid plans accepted, UMSHC accepts referrals for diagnostic sessions from all over northern Mississippi. An interesting finding from these data is how distance affects appointment attendance and consequently, age of diagnosis. There is a clear trend in greater distance from the clinic results in lower attendance rates. To be sure, many people from Oxford are referred and make appointments at the clinic, (the closest town included in this study to the clinic) yet attendance rates were not as stellar as expected. With an average number of missed appointments of 0.38 for Oxford residents, the average number of missed appointments for all other patients who are not Oxford residents was 0.7, showing only a slight improvement in number of missed appointments.

To find the distance from each patient to the clinic, the town center was used to calculate mileage, not the specific address of each patient. For this reason, distances and averages are an estimate and values would be different if the home address of each infant was used.

Suggestions and Further Research

The high frequency of referrals for failed hearing screenings and results of within normal limits suggests the timeframe for administering screenings should be adapted. The fact that a majority of patients who tested to have no hearing loss only needed one appointment to receive this diagnosis suggests that another screening should be scheduled at a closer location instead of a full diagnostic session. Because distance appears to have an impact on appointment attendance and age of diagnosis, it would benefit Mississippi to have another screening appointment done before a full diagnostic evaluation, or to have a diagnostic and screening center closer to those patients who missed appointments frequently.

Further research should be done to test the concept of a closer center for patients to receive an additional screening appointment, or a full diagnostic appointment if necessary. Data would suggest locations such as Tishomingo and Coahoma County. Another option could be for referring sources to make follow up screening appointments available. A quarter of patients included in this study were referred for a diagnostic session by Northwest Mississippi Regional Medical Center in Clarksdale and Magnolia Regional Health Center in Corinth; this could be a good location to offer follow up screenings or possible full diagnostic appointments. Perhaps a closer center for screenings or diagnostic appointments would make EHDI goals even more attainable and get infants cleared or diagnosed and fit for treatment at a younger age, which could have significant impacts on speech and language development.

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