Project Number: MQP-BC-DSA-4248

ANALYSIS OF HEARING SCREENING RESULTS AND FREQUENCY OF RISK FACTORS FOR HEARING LOSS IN NEWBORN INFANTS FROM INSULIN-DEPENDENT DIABETIC MOTHERS

A Major Qualifying Project Report

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

in

Biology/Biotechnology

by

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October 23, 2006

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ABSTRACT

The main objective of this study was to determine whether infants of diabetic mothers are at risk for hearing impairments. This was a retrospective analysis of the hearing screening results of newborn infants at UMMHC (Worcester) from January 1, 2004 – January 1, 2006. Although several interesting trends were observed that matched published risk factors for hearing loss, our results indicated that there was no statistical significance regarding the frequency of risk factors for hearing loss between the diabetic and control groups studied, nor was there any statistical significance regarding the newborn hearing screening referral rates between the two groups. Future studies may reveal a significant difference for offspring hearing loss between Type-1and Type-2 maternal diabetic conditions, or gestational versus pre-gestational diabetics. The data should help to more closely define the metabolic disturbances associated with each diabetic condition and their subsequent effects on the development of the neonatal auditory system.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

PREFACE

Diabetes is known to modify the maternal levels of glucose, lipids and amino acids therefore making the intrauterine environment challenging to the developing fetus. As a result, it would be expected that these maternal metabolic disturbances would have the potential to adversely affect the overall health of the newborn, and specifically for this study the development of the auditory system. This study could be used as a resource for obstetricians, pediatricians, neonatologists, and audiologists who are researching factors that have the ability to cause hearing loss in newborn infants. Although this report utilized a small sample size, it provides a foundation for future studies within the realm of hearing loss and its risk factors. UMMHC (Worcester) provided the use of their facilities, databases and medical record patient charts that were necessary for this study. Dr. Francis Bednarek, M.D. (Director, Neonatal Intensive Care Unit) was the UMMHC project investigator for this study and helped to outline the risk factors that would be of interest regarding hearing loss of the newborn infants. Betty Lapoint, R.N. (Obstetric Nurse) and Beth Powers (NICU Research Nurse) assisted with the data retrieval from the UMMHC patient databases. Beth Allen (Medical Records) assisted with gathering the medical charts that were utilized in this study.

BACKGROUND

This MQP investigated the incidence of hearing loss in the neonates of pre-gestational diabetic and non-diabetic mothers at the University of Massachusetts Memorial Health Center (UMMHC) (Worcester, MA). The incidence of hearing loss will be based on the hearing screening results for a sample of newborns of diabetic and non-diabetic mothers.

Diabetes and Maternal Health

There are two types of pre-gestational diabetes, Type 1 and Type 2. Type 1 diabetes (also referred to as insulin-dependent diabetes mellitus, or IDDM) is caused by an insufficient amount of insulin secreted into the blood from the pancreas. Type 2 diabetes results from an insulin resistance, as well as an inability to secrete more insulin to overcome this resistance. It is well documented that diabetes in pregnancy places the mother as well as the infant at a great health risk. Some examples of well known birth complications due to diabetes in the mother are: difficulty breathing, low blood sugar, jaundice, low calcium levels, and heart problems. These risks have been extensively studied, but the risk correlation between a diabetic mother and the hearing of her infant has been understudied. Due to the above complications, there is potential for the infant to develop physical disruption in the formation of their ear, resulting in hearing loss (Kalkhoff, 1991).

Auditory Function

The ear is divided into three separate sections: the outer ear, the middle ear, and the inner ear (Figure-1). The outer portion of the ear (red in the figure) contains the pinna and the external auditory canal. The cartilaginous folds of the pinna provide amplification of sounds in the frequency ranges that make up speech (1.5 to 7 kilohertz, kHz) with an amplification of 5 to 20 decibels (dB). The amplification of the sound is related to the resonance of the concha (the bowl-like area in the external ear) specifically in the frequency range of 5 kHz. The ear canal provides resonance in the frequency range of 2.5 kHz (Plewes, 2006). The ear canal also provides protection due to its structure. The canal is long in length, and has a very rigid wall, both of which provide protection from injury to the sensitive inner ear.

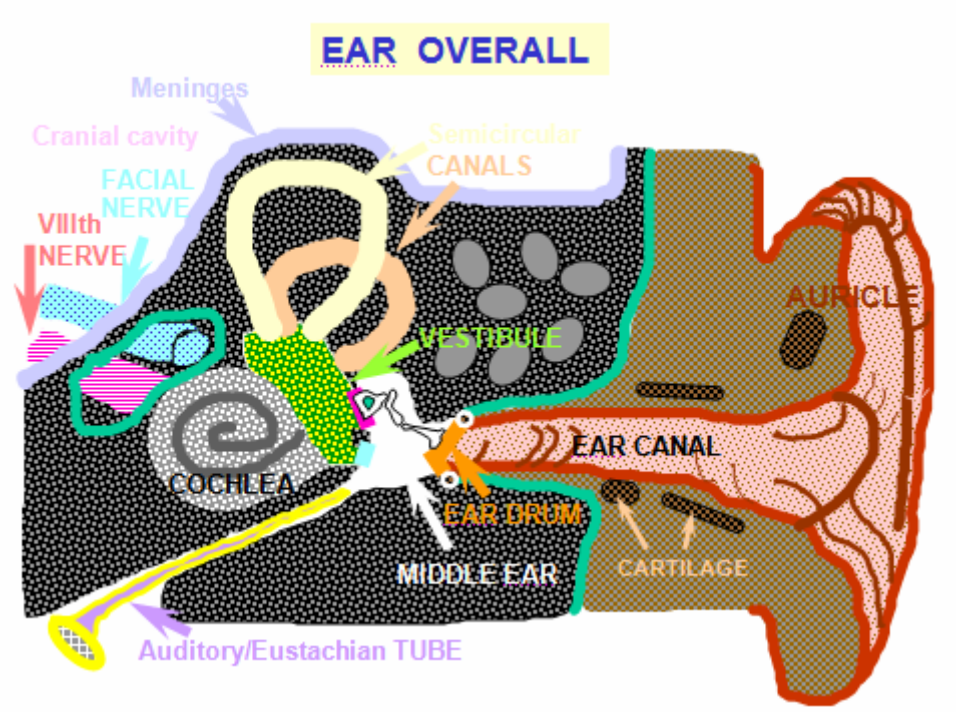

Figure 1. Ear Structures. An overview of human ear structures (Beresford, 2006).

The tympanic membrane separates the external ear canal from the tympanic cavity (middle ear) (white in the figure). The tympanic membrane bows in and out with the waves of the frequency of the incoming sound (Alberti, 2006). The middle ear also contains three specific bones: malleus, incus, and stapes. As the vibrations from the external ear enter the middle ear, the vibrations activate the lever system of the three bones and eventually reach the inner ear (black in the figure). The vibrations then allow for the movement of the fluid in the inner ear which is essential for sound conduction. The middle ear's main purpose is to help amplify sound. The middle ear is essential for hearing because if sound comes in contact with the fluid of the inner ear directly, there would be a loss of sound of about 30 dB. The middle ear prevents this loss from occurring (Porth, 2005).

The inner ear is a very complex structure within the temporal bone that has two functions: hearing and balance. The two main distinctions within the inner ear are the cochlear which is responsible for the auditory portion, and the vestibular structures which are responsible for balance (Johnson, 2003). The Organ of Corti is located within the structure of the cochlea and is considered to be the main organ for hearing. Within the Organ of Corti, there are 16,000 hair cells which are the receptors of sound. Humans have approximately 4,000 inner hair cell and 12,000 outer hair cells. These receptor cells are modified epithelial cells. They are cylindrical or flask-shaped and have a bundle of sensory hairs called stereocilia (hairs) at their apical end. The hair cells are held in position by a system of supporting cells (Figure 2). Each hair cell is innervated at its base by afferent endings of sensory nerve fibers (red in the figure) and by one or several endings of efferent centrifugal nerve fibers (Alford, 2006). The primary auditory cortex

is the portion of the brain that is responsible for recognizing and organizing the signals received from the ear. The afferent fibers of the auditory nerve leave the cochlea and enter the brain at the brain stem and medial geniculate nucleus (located in the thalamus). The brain stem is used for alertness, and the thalamus is used to sort out the information given to it and it sends information to other higher portions of the brain where the sounds are organized into meaningful groupings. Auditory signals are sent to both temporal lobes therefore a disturbance in one side of the auditory pathway will not affect the hearing to any great extent (Alford, 2006).

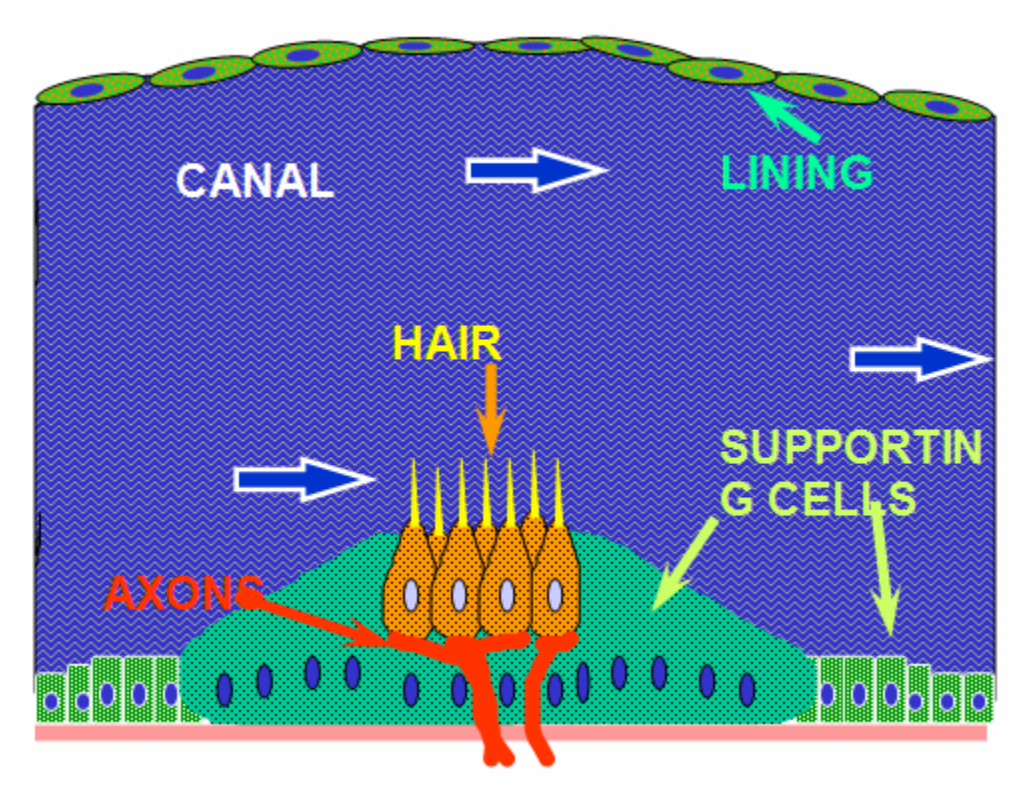

Figure 2: Hair cell location within the Organ of Corti (Beresford, 2006).

Hearing Loss Risk Factors

Reduced hearing acuity during infancy and early childhood interferes with the development of speech and language skills. The known risk factors for hearing loss are: peri-natal infection, trisomy syndrome, hyperbilirubinemia, prolonged ventilation, low birth weight, ototoxic medications, low Apgar scores, prolonged stay in the neonatal intensive care unit (NICU), and a family history of permanent hearing loss (Plews, 2006). These known risk factors will be examined in this MQP to determine if the likelihood of obtaining these risk factors is higher in a pre-gestational diabetic mother compared to a non-diabetic mother.

Congenital disorders can also cause a severe hearing loss and are present at birth. One prime example is dysplasias. Dysplasias are poor development of the bony and/or membranous labyrinth (interconnecting fluid cavities of the inner ear). This can affect the structure and function of the receptor organs and supporting cells which ultimately leads to severe hearing loss. Maternal rubella (German measles) has the ability to cause severe hearing loss by causing damage to the developing cochlea (Plewes, 2006). When hearing loss occurs as a result of maternal Rubella, 50% of the offspring have bilateral severe to profound hearing loss. The hearing loss may also be progressive ("The Joint Committee on Infant Hearing", 2000).

Cytomegalovirus (CMV) is a severe viral infection which can cause damage to the cochlear duct therefore causing severe hearing damage. CMV is estimated to be present in 0.5 to 2.4% of all live births (Chu et al., 2003). “It is estimated that 10% of CMV-infected newborns are at risk for serious consequences such as hearing loss” (Schildroth, 1994). CMV is often asymptomatic in mothers, thus it is often overlooked.

This oversight can cause hearing losses to go undetected even at birth. The initial hearing screening for the infant is often normal, and the hearing loss may not be evident until the child is slightly older, and the loss is often progressive in nature. If hearing tests were done periodically for infants born to CMV-positive mothers throughout their early childhood there would be a much better prognosis for avoiding any developmental delay.

Trisomy (an extra chromosome present within the cells), depending on which chromosome, can cause malformations in the ossicles, and the organ of Corti, leading to hearing loss (Taylor et al, 1963).

Hyperbilirubinemia is another risk factor that can lead to hearing loss. Bilirubin is the final product of heme degradation, and is largely produced by the breakdown of red blood cells. In the fetus, the placenta eliminates most of the lipid-soluble bilirubin, but in the newborn, bilirubin must be conjugated, or chemically changed, in the liver to a water-soluble form before it can be excreted in the bile (Stevenson et al., 2001). In the adult, bilirubin passes into the small bowel where bacteria reduces or converts it to urobilinogen. Urobilinogen is excreted in the stool and essentially no bilirubin is absorbed from the gastrointestinal tract (Stevenson et al., 2001). The fetal gut is sterile and therefore not able to reduce bilirubin to urobilinogen. Conjugated bilirubin cannot pass through the intestinal mucosa, but because it is not reduced to urobilinogen and remains in the bowel, it is deconjugated and becomes available for reabsorption (Stevenson et al., 2001). Bilirubin appears to be poisonous to cells. Toxic levels of unconjugated bilirubin may cause infants to develop kernicterus which results from the complications that occur once bilirubin has entered the brain. These complications can include: encephalopathy, hearing loss, and in some cases even death. There does not

appear to be any direct damage to the structures of the inner ear, rather the problem results with deficient auditory nuclei in the brainstem, and deficient neurons in the cochlea.

Newborns produce bilirubin at a rate of approximately 6 to 8 mg per kg per day. This is more than twice the production rate in adults, primarily because of increased red blood cell turnover in neonates. Bilirubin production typically declines to the adult level within 10 to 14 days after birth. Jaundice refers to the yellow color of the skin, sclera, mucous membranes, and body fluids when bile pigment (bilirubin) is present as a result of excess bilirubin in the blood. Jaundice is considered pathologic (neonatal hyperbilirubinemia) if it is presents within the first 24 hours after birth, the total serum bilirubin level rises by more than 5 mg per dL per day, or is higher than 17 mg per dL, or an infant has signs and symptoms suggestive of serious illness (Taylor et al., 1963).

Infant hearing loss can also be caused by problems during delivery. During delivery, the baby could experience a lack of oxygen which could cause hearing loss. This condition would require prolonged ventilation. Hypoxia and anoxia may produce lesions of the central nervous system and may also produce cochlear damage (University of Pittsburg, 2006).

Another risk factor in hearing loss is low birth weight. Low birth weight is categorized as lower than 3 lbs 5 oz (Kokitsu-Nakata et al., 2004). The likelihood of neurological and developmental or sensory conditions occurring in a low birth weight infant is significantly increased when compared to a normal birth weight baby. Low birth weight has been associated with the development of a hearing loss most likely due to neurological and sensory developmental impairments.

Ototoxic drugs (drugs that can cause hearing loss) can cause hearing damage at any age. Ototoxicity is a trait shared by aminoglycoside and macrolide antibiotics, loop diuretics, platinum-based chemotherapeutic agents, some NSAIDs (non-steroidal anti-inflammatory drugs) and anti-malarial medications. Because their benefits in treating certain life-threatening diseases often outweighs the risk, the use of these ototoxic drugs can often not be avoided. The clinical symptoms often seen as a result of taking an ototoxic medication are: hearing loss, tinnitus, and dizziness (Kaufman, 2006). Examples of aminoglycoside antibiotics are gentamicin and tobramycin. The main mechanism of action that causes hearing loss due to aminoglycosides are:

1) The medication penetrates into the middle ear entering the labyrinthine fluid through the bloodstream.
2) The presence of the medication in the fluid damages the hair cells and the auditory nerve fibers.
3) The damage causes the sensory hairs to swell due to increased plasma membrane permeability. There is also evidence that mitochondria and ribosomes are damaged. Ionic channels may also be blocked (Mencher et al., 2001).

The second group of ototoxic medications is diuretics. Two examples of diuretic ototoxic medications are ethacrynic acid and furosemide. Rapid infusion of these drugs can cause a sensorineural hearing loss that is rapid in onset, and vertigo may be present. These symptoms can last up to hours and days and in some cases hearing loss has been permanent (Kaufman, 2006).

The third main group of ototoxic medications is quinine derivates. These drugs are capable of causing irreversible sensorineural hearing loss, and tinnitus is the major symptom. There could be a total absence of hair cells throughout the Organ of Corti if this class of medication is used during the first trimester of pregnancy (Mayo Clinic, 2006).

The final group of ototoxic medications is salicylates such as aspirin. High doses of salicylates can cause reversible hearing loss and tinnitus that will resolve within 24-72 hours after the medication is discontinued (Kaufman, 2006).

Low Apgar scores could also be a risk factor for hearing loss. An Apgar in the 1st minute of less than 4, and an Apgar in the 5th minute that is less than 6 are considered significant for hearing loss.

The longer that an infant needs to stay in the neonatal intensive care unit, the stronger the likelihood of the child developing a hearing impairment (Ghorayeb, 2006).

Finally, if there is a family member with a permanent childhood hearing loss, this will increase the chances of that infant being hearing impaired as well (Jurkovicova et al., 2002).

Importance of Hearing Screening

"Because hearing deficits of cochlear or neural origin are not obvious in the neonate even when these deficits are severe, hearing impaired neonates, including diabetic mothers, were not identified at birth" (Stanton et al., 2005). Screening is one of the most important methods of early diagnosis of treatable diseases in children, and hearing loss is an important treatable disease of childhood. Everyday in the United

States, 33 babies are born with permanent hearing loss. Thus, approximately 1 in 1,000 newborns is born profoundly deaf, with another 2-3 out of 1,000 babies born with partial hearing loss, making hearing loss the number one birth defect in America ("National Center on Hearing Assessment and Management", 2006). Of the 12,000 babies in the United States born annually with some form of hearing loss, only half exhibit a risk factor, meaning that if only high-risk infants are screened, half of the infants with some form of hearing loss will not be tested and identified (Harrisou and Roush, 1996).

The diagnosis of congenital hearing loss is often delayed. In one survey conducted before hearing screening was common, the median age at diagnosis was 13 months for infants with severe to profound bilateral sensor-neural hearing loss, and 17 months for those with mild-to-moderate hearing loss (Harrisou, and Roush, 1996). Children with hearing loss experience delayed development in language, learning and speech. When hearing loss is detected after the first few months of life, the most critical time for stimulating the auditory pathways to hearing centers in the brain is lost, significantly delaying speech and language development (Elssmann et al., 1987). The Joint Committee on Infant Hearing (2000) and the U.S. Public Health Services Healthy People 2010 (2006) health objectives recommend that all newborns be screened for hearing loss by 1 month of age, having diagnostic follow-up by 3 months, and receive appropriate intervention services by 6 months of age. Recent research has concluded that children born with a hearing loss who are identified and given appropriate intervention before 6 months of age demonstrated significantly better speech and reading comprehension than children identified after 6 months of age (Yoshinaga-Itano et al., 1998).

Therefore the guidelines for universal newborn hearing screening were implemented. Hearing testing in the past was only done when one or more of the previously discussed risk factors were present. However, as stated in the Colorado and New York State study, 50% of infants with hearing loss did not present with one of the well studied risk factors (Rose, 1992). Therefore, the need for a universal testing program was apparent. The Joint Committee on Infant Hearing (JCIH) 2000 determined and implemented the guidelines that all neonates, regardless of the presence or absence of risk factors, be tested for hearing loss ("The Joint Committee on Infant Hearing.", 2000). Language delays and communication impairments begin to develop when hearing loss is not detected very early on in a child's life. Therefore, newborn hearing screening will help to reduce the language and communication impairments that otherwise would have developed. Currently, 45 states (plus the District of Columbia) have Early Hearing Detection and Intervention laws or voluntary compliance programs that screen the hearing of 95% or more of newborns (forty states have laws and five states have voluntary programs) ("EHDI Publications.", 2006). In 1998, Massachusetts legislation required that a hearing screening test be performed on all newborns in a birthing hospital or birthing center. Parents may refuse the test for religious reasons. Hearing screening tests are required to be a covered benefit of most health insurance policies. In the absence of a third-party payer, costs of newborn hearing screening and any subsequent diagnostic evaluation will be paid by the state ("EHDI Publications", 2006).

In order to be compliant with the JCIH and the Massachusetts Department of Public Health, the UMMHC protocol for newborn hearing screening provides all newborns with an automated auditory brainstem response screening (A-ABR) prior to

discharge from the hospital. The A-ABR screening is used to determine any early hearing loss in the infant. The A-ABR screening test works by recording electrophysiological responses from the brain stem in response to sound. The A-ABR test presents a series of clicking sounds through headphones that cover the baby's ears. Three small sensors that detect the electrical physiological responses are placed on the babies head and connected to the computer equipment. Filtered responses from the brain stem and the hearing nerve are observed in the form of waves by the equipment. The wave forms recorded from the infant are compared by the computer with a template for a normal hearing response. If the hearing system is working normally, then the computer will report strong responses. If there is no strong response then the computer will report that a referral should be made.

PROJECT PURPOSE

The goal of this MQP was to compare hearing screening results in newborns from insulin-dependent pre-gestational diabetic mothers versus non-diabetic controls. Many of the factors previously established in the literature as related to hearing loss were screened as variables for the two groups.

METHODS

Participants

The study protocol was approved by the UMMHC Human Research Subject Institutional Review Board. This is a retrospective study of 55 maternal insulin-dependent diabetes mellitus (IDDM) mothers and their newborns, and 55 non-diabetic controls and their newborns. The subjects for this study were all derived from the newborns who received newborn hearing screening at the University Of Massachusetts Memorial Health Center (UMMHC) in Worcester (MA) between the dates of January 1, 2004 – January 1, 2006. Infants of non-diabetic mothers (which served as the control group) were randomly selected from the hospital population within the outlined time period. There were 55 pre-gestational IDDM mothers within the outlined time period.

Screening Protocols and Methods

All newborns at UMMHC were screened for hearing loss according to the established hospital protocol. A screening protocol using Automated Auditory Brain Stem Response (A-ABR) screening techniques was used for all newborns (NICU and well babies).

The ALGO2 Newborn Hearing Screener by Natus Medical, was used to perform the automated ABR hearing screening using the manufactures disposable earphone couplers and disposable electrodes. Both ears were tested simultaneously with 35dBnHL with 100ml clicks presented at repetition rates of 37/s for the right ear and 34/s for the left ear. The number of stimulus presentations varied from a minimum of 1000 to a

maximum of 15,000 until a result was obtained for each ear. The ALGO2 screening result of “pass” or “refer” was based on the likelihood ratio of 160 calculated from responses obtained for blocks of 500 sweeps, and compared with an internal “normal hearing” template. If the criterion likelihood ratio was not reached within 15,000 stimulus presentations, then the screening result was a “refer”. A screening result of “pass or “refer” was obtained for each ear.

Universal newborn hearing screening was required by the state of Massachusetts during the period of study. The parents or guardians of newborns who did not pass the UMMHC screening were counseled to schedule a diagnostic ABR test at a facility approved by the Massachusetts Department of Public Health. A list of facilities that could perform this follow-up service was provided to the parent or guardian as required by state law.

Statistics

Statistical significance was calculated for each parameter using the chi-square method for each group (control and the diabetic). The protocol for calculating the statistics for this paper can be found at the following reference ("Chi Square", 2006). Once a p value was calculated, whether it was significant was determined by using the following table.

Chi-Square Distribution Table of Significance

Degrees of Freedom *(df)*	**Probability** (p)										
	0.95	0.90	0.80	0.70	0.50	0.30	0.20	0.10	0.05	0.01	0.001
1	0.004	0.02	0.06	0.15	0.46	1.07	1.64	2.71	3.84	6.64	10.83
2	0.10	0.21	0.45	0.71	1.39	2.41	3.22	4.60	5.99	9.21	13.82
3	0.35	0.58	1.01	1.42	2.37	3.66	4.64	6.25	7.82	11.34	16.27
4	0.71	1.06	1.65	2.20	3.36	4.88	5.99	7.78	9.49	13.28	18.47
5	1.14	1.61	2.34	3.00	4.35	6.06	7.29	9.24	11.07	15.09	20.52
6	1.63	2.20	3.07	3.83	5.35	7.23	8.56	10.64	12.59	16.81	22.46
7	2.17	2.83	3.82	4.67	6.35	8.38	9.80	12.02	14.07	18.48	24.32
8	2.73	3.49	4.59	5.53	7.34	9.52	11.03	13.36	15.51	20.09	26.12
9	3.32	4.17	5.38	6.39	8.34	10.66	12.24	14.68	16.92	21.67	27.88
10	3.94	4.86	6.18	7.27	9.34	11.78	13.44	15.99	18.31	23.21	29.59
	Nonsignificant								Significant		

("Chi Square", 2006)

RESULTS

As shown in Table 1, the A-ABR screening referral rate for newborns in my randomly-selected non-diabetic control group was 9.09% (5/55). The A-ABR screening referral rate for the newborns of the maternal IDDM mothers was slightly greater at 10.9% (6/55). This is not statistically significant based upon the p value of 0.167. Refer to Table #1.

Table #1: Summary Chart

Variable	Control Frequency%	Diabetic Frequency%	P value	Control Referral%	Diabetic Referral%	P Value
Overall Failure	NA	NA	NA	9.09%	10.9%	0.167
Well Baby	90.91%	80.0%	0.38	10.0%	13.6%	0.366
NICU	9.09%	20.0%	2.25	0%	0%	0
<37 weeks gestational age	14.5%	25.5%	1.64	0%	0%	0
<2,500 grams	18.18%	18.18%	0	0%	10%	1.0
>4,000 Grams	7.27%	18.18%	2.57	0%	10.0%	0.399
Apgar	9.09%	1.82%	2.63	0%	0%	0
Hyperbilirubinemia	25.4%	32.7%	0.5	7.14%	11.11%	0
Ototoxic Medication	10.9%	16.36%	0.625	0%	0%	0
Gentamicin Total Dose	10.9%	16.36%	0.625	0%	11.11%	0.534
Ventilation	7.27%	14.5%	1.34	0%	0%	0
Perinatal Infection	14.55%	23.6%	1.18	0%	0%	0

Based on the screening protocol, newborns of both the well baby nursery and the neonatal intensive care unit (NICU) who failed the A-ARB, received a diagnostic ABR. All babies passed the follow-up diagnostic ABR testing. In the sample of maternal IDDM mother's infants, 20% (11/55) were cared for in the (NICU) compared with the

9.09% (5/55) of infants in the control group. There was a 2.25 p value for these results, thus the difference between the admission into the NICU between the two groups is not statistically significant. All remaining newborns were cared for in the well baby nursery.

In the well baby nursery there was a 13.6% (6/44) referral rate for the maternal IDDM mothers and a 10% (5/10) referral rate for the control group. There was a 0.366 p value comparing the two groups, thus there is no statistical significance between the groups regarding referral rate. For the NICU, the two groups also showed no statistically different referral rate (p value = 0.00) (Table #2). There were no referred babies in either group for the second test.

Table #2: Referral Rates Based on Nursery (First Test)

	Control	**Diabetic**	**P Value**
Well Baby	5/50	6/44	0.366
NICU	0/5	0/11	0
Total	5/55	6/55	0.167

All NICU babies at the UMMHC, even those who pass the A-ABR screening test, are considered to be at higher risk for hearing loss, and thus receive an annual diagnostic ABR exam. The results of these tests were not considered part of this MQP study and were therefore were not analyzed.

Infants that were born before 37 weeks of gestational age are considered premature. In the control group, 14.5% (8/55) were premature. In the maternal IDDM group, 25.5% (14/55) were premature. The p value was determined to be 1.64 thus the

difference between the two groups regarding gestational age (GA) was not statistically significant (Table #3).

Table #3: Frequency of Prematurity

	Control	Diabetic	P Value
<37 weeks GA	8/55	14/55	1.64

No baby was referred in either group for the gestational age of < 33 weeks. Between the ages of 33-36 weeks, there was a 28% (2/7) referral rate for the maternal IDDM group compared to 0% for the control group. A p value of 2 was obtained regarding the refer rate for this age range between the two groups and was therefore not statistically significant. There was a 10.9% (4/41) referral rate for the maternal IDDM group compared to 10.6% (5/47) in the control group for the gestational age category of greater than 36 weeks. A p value of 0 was determined, thus there is no statistical significance between the two groups regarding the referral rates for ages greater than 36 weeks (Table #4).

Table #4: Referral Rate Based on Gestational Age

Gestational Age	Control	Diabetic	P Value
<33 weeks	0/2	0/7	0
33-36 weeks	0/6	2/7	2
>36 weeks	5/47	4/41	0
Total	5/55	6/55	0.167

The low birth weight infants (<2,500grams) showed no difference between the two groups. Both groups had 18.18% (10/55) abnormally low birth weight. Thus there was no statistical difference between groups regarding the number of babies below 2,500 grams. Abnormally high birth weights (>4,000grams) were found for infants born to IDDM mothers, 18.18% (10/55) compared to the 7.27% (4/55) of the control group. The frequency of abnormally high birth weight between the two groups was not statistically significant based upon the low p value of 2.57 (Table #5).

Table #5: Frequency of Abnormal Birth Weight

	Control	**Diabetic**	**P Value**
<2,500 grams	10/55	10/55	0
>4,000 grams	4/55	10/55	2.57

No babies were recorded in the database below the weight of <1,500 grams in either group, thus no conclusions can be drawn for that category. There was a 25% (1/4) referral rate for IDDM mothers in the birth weight range of 1,000-2,499 grams and a 0% for the control group. The p value that was determined was 2.32 thus not statistically significant. For infants between the weights of 2,500 and 3,999 grams, there was a 11.4% (4/35) referral rate for the maternal IDDM group compared to the 12.1% (5/41) of the control group. The p values were determined to be 0, thus there was no statistical significance. There was 10% (1/10) referral rate for the maternal IDDM group, and a 0% referral rate for the control group for babies >4,000 grams. Thus, a p value of 0.399 was calculated

indicating no statistical significance between the two groups regarding referral rate for babies greater than 4,000 grams (Table #6).

Table #6: Referral Rate For Abnormal Birth Weight

	Control	**Diabetic**	**P Value**
<1,500 grams	0/1	0/6	0
1,500-2,499 grams	0/9	1/4	2.32
2,500 -3,999 grams	5/41	4/35	0
>4,000 grams	0/4	1/10	0.399
Total	5/55	6/55	0.167

During an Apgar exam, a baby is examined in the first minute post-birth, and given a score that represents his/her overall health. The score ranges from 0-10, with 10 being the best. The baby is then given a score at 5 minutes using the same criteria used during the first minute. If the baby receives a score in the first minute of 0-4, and a score in the fifth minute of 0-6, the baby is considered at risk for hearing loss. My data considered either the first Apgar, second Apgar, or both scores, within the outlined risk range. There was a higher percentage of babies with low Apgar scores in the control group 9.09% (5/55) compared with the maternal IDDM group (1.82% (1/55). The difference between the two groups regarding the Apgar scores is not statistically significant based on the low p value of 2.63. All of the babies in both groups received "pass" results on the A-ARB testing (Table #7).

Table #7: Frequency of Low Apgar Score

Control	Diabetic	P Value
5/55	1/55	2.63

The condition of hyperbilirubinemia was present for 32.7 % (18/55) in the maternal IDDM group, compared with 25.45% (14/55) for the control group. The baby was considered to have hyperbilirubinemia if it was specifically notated on the medical record chart. The p value was determined to be 0.5, thus the difference between the two groups in regards to hyperbilirubinemia was not statistically significant (Table #8).

Table #8: Frequency of Hyperbilirubinemia

Control	Diabetic	P Value
14/55	18/55	0.5

Also, of the infants who had hyperbilirubinemia in the maternal IDDM group, 11.11% (2/18) were referred, while 7.14% (1/14) were referred in the control group. The p value was determined to be 0 thus there was no statistical significance between the referral rate for either group (Table #9).

Table #9: Referral Rate of Hyperbilirubinemia

Control	Diabetic	P Value
1/14	2/18	0

The prevalence of the administration of ototoxic medications was slightly higher in the maternal IDDM group: 16.36% (9/55) compared with the control group of 10.9% (6/55). The p value was determined to be 0.625 thus the difference between the ototoxic medication administration for both groups is not statistically significant. None of the babies in either group were referred (Table #10).

Table #10: Frequency of Ototoxic Medication

Control	Diabetic	P Value
6/55	9/55	0.625

A highly proven, more specific risk factor (gentamicin total dose) was also considered. Recent studies suggest that gentamicin ototoxicity is more closely related to total daily dose, than to pill dose. Conventionally, gentamicin is given three times per day, with a total dose per day ranging from 3 mg/kg to 5mg/kg. These doses may need to be modified for special situations such as when kidney function is impaired. For three times per day dosing, ordinarily a peak of 5 to 10 mg/kg, and a trough of less than 2, is aimed for (Kaufman, 2006). My data regarding frequency of gentamicin total dose administration was identical to the ototoxic medication data: 16.36% (9/55) for the maternal IDDM group and 10.9% (6/55) for the control group, therefore we did not find a correlation between total dose and ototoxicity. A p value of 0.625 was calculated thus there was no statistical significance for the presence of gentamicin total dose for either group (Table #11).

Table #11: Frequency of Gentamicin Total Dose

Control	Diabetic	P Value
6/55	9/55	0.625

Considering all of the results from the gentamycin cases, only one infant failed the hearing screening and that infant was within the maternal IDDM group. Therefore we did not find a correlation between total dose and ototoxicity. There was an 11.11% (1/9) for the maternal IDDM group and a 0% for the control group. A p value of 0.534 was calculated thus there was no statistical significance for the referral rate for either group (Table #12).

Table #12: Referral Rate for Gentamicin Total Dose

Control	Diabetic	P Value
0/6	1/9	0.534

The risk factor of prolonged ventilation showed no significant prevalence in the maternal IDDM group14.5% (8/55) compared to the 7.27% (4/55) of the control group. The p value was determined to be 1.34 thus not statistically significant for the amount of ventilation applied to either group. All babies in both groups were cared for in the NICU and all of these babies passed the hearing screening, thus there was no statistical significance between the two groups for hearing screening results (Table #13).

Table #13: Frequency of Ventilation

Control	Diabetic	P Value
4/55	8/55	1.34

The presence of a perinatal infection was higher in the maternal IDDM group 23.6% (13/55) compared with the control group 14.55% (8/55). But the p value was determined to be 1.18 which shows no statistical significance of the difference. None of the newborns in either group failed the hearing screening thus there is no statistical significance between the groups regarding hearing results (Table #14).

Table #14: Frequency of Perinatal Infection

Diabetic	Control	P Value
13/55	8/55	1.18

Of all the babies in the entire study, only one had a renal abnormality and therefore statistical analyses were not performed. Also this infant did pass the hearing screening.

DISCUSSION

The main objective of this study was to determine whether infants of diabetic mothers are at risk for hearing impairments that would eventually lead to communication impairments. The main focus of this study was to examine the results of the UMMHC hearing screening results for infants born to mothers that were IDDM. I found that 10.9% of infants of maternal IDDM mothers were referred by the A-ABR screening test compared with the 9.1% of the non-diabetic control infants. Therefore these results show no trend of statistical significance between the two groups.

Based on previous studies, the infant of the diabetic mother is prone to develop several problems in the neonatal period, such as difficultly breathing, low blood sugar (less than 40mg/dl), jaundice, too many red blood cells (polycythemia), low calcium level, and heart problems. The risk of respiratory distress is highest when maternal blood sugars have been poorly controlled ("Diabetes Mellitus in Pregnancy", 2004).

The newborn of a diabetic mother is exposed to difficult conditions because the presence of diabetes disrupts the intrauterine environment (Stanton et al., 2005). A study done by Macintosh et al (2006) found a three-fold increase in the congenital anomaly rate in women with diabetes compared with the general maternity population. Diabetes alters the maternal levels of glucose, lipids and amino acids and therefore has a direct effect on the developing fetus.

A retrospective study done by Stanton, et al. (2005), determined the hearing screening outcomes in infants of pregestational diabetic mothers. Results of that study showed a higher hearing screening failure rate for the IDDM mothers (11% for IDDM

compared with 5.5% for the non-diabetic control group) however this difference was not statistically significant.

Diabetes is the most common medical complication of pregnancy. A nationwide population-based survey revealed that nearly 4% of pregnant women in the United States have diabetes: 88 percent had gestational diabetes mellitus, defined as glucose intolerance that appeared during pregnancy, whereas 12% were known to have diabetes. Of those with pregestational diabetes, 35 percent had type 1, and 65 percent type 2 diabetes ("American Diabetes Association", 2006).

Diabetes control prior to, as well as throughout pregnancy, is essential for positive health outcomes for the mother with diabetes and her infant. Serious malformations can occur early in pregnancy even before the woman knows she is pregnant. Congenital anomalies are more likely in infants of women with diabetes. The increased risk for anomalies ranges from 6 to 12%, a two to five-fold increase over the 2-3% incidence noted in the general population. This increased incidence of congenital anomalies accounts for about 40% of the deaths of infants of women with diabetes. There is a growing body of assessment indicating an increased risk of preterm low birth-weight delivery for mothers with diabetes. With proper counseling, management, and specialty care, the outcome of most diabetic pregnancies can approach that of non-diabetic pregnancies (Lindsay et al., 2000).

Perinatal complications of the diabetic pregnancy include: birth defects (anomalies in the hearing and spinal cord are the most common, followed by skeletal, renal, genitourinary, and gastrointestinal anomalies), macrosomia (infants weighing in the top 10 percent of their gestational age-generally a birth weight over nine pounds or 4000

grams and neonatal problems (difficulty breathing, low blood sugar, jaundice, polycythemia, low calcium levels and heart problems) ("American Diabetes Association", 2006).

In the Stanton study, they found a significant difference in the birth-weight distribution between the diabetic and non-diabetic groups. The diabetic group had more abnormal birth-weight babies. They also found a significant difference in premature births, with the diabetic group having more premature births (less than 37 weeks gestational age). My study found a greater frequency of premature births in the maternal IDDM group however the difference was not statistically significant. In the Stanton study, they found the number of macrosomic (>4,000g) babies was significantly greater in the maternal diabetic mother group. My study showed a greater frequency of macrosomic babies in the maternal IDDM group compared with the control group however it was also not statistically significant.

The other high risk factors for hearing loss that showed a greater frequency of prevalence within the maternal IDDM group included; hyperbilirubineima, ototoxic medication, gentamicin total dose, prolonged ventilation and perinatal infection. Although the frequency was higher in the maternal IDDM group, none of the data was statistically significant. A low Apgar score was actually more prevalent in the control group of my study, however it was also not statistically significant.

The frequency and percentage of referral hearing testing in the study showed no significant difference between the maternal IDDM group and the control group, even though many of the hearing loss risk factors were more prevalent (not statistically significant) in the IDDM group. Also, the follow-up diagnostic ABR testing done on all

of the referred newborns, yielded normal hearing results for all the infants. Therefore, my study findings indicate that a history of maternal IDDM does not significantly increase the neonatal hearing screening referral rate.

Thus the results from my study suggest that the condition of diabetes does not statistically correlate with the development of hearing loss specific risk factors for the 55 member sample group analyzed here, although several interesting trends were observed in agreement with the literature regarding risk factors for hearing loss which suggests that the presence of maternal IDDM may compromise the development of the neonatal auditory system.

Future studies may reveal a significant difference between type1- and type 2 maternal diabetic conditions. Also comparisons should be performed for gestational and pre-gestational diabetics in order to more closely define the metabolic disturbances associated with each diabetic condition and their subsequent effects on the development of the neonatal auditory system.

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