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A survey of infant hearing screening programs in Santa Clara County hospitals

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A SURVEY OF INFANT HEARING SCREENING PROGRAMS IN SANTA CLARA COUNTY HOSPITALS

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Abstract

A Survey of Infant Hearing Screening Programs

in Santa Clara County Hospitals

by Kirstin Elizabeth Beach

Recent reports recommend that universal hearing screening be used in the United States to facilitate early identification of children with hearing loss. This report reviews the screening protocols currently used in hospitals in Santa Clara County. Seven hospitals participated in structured interview sessions designed to document the infant hearing screening protocol of each hospital. Factors influencing the current screening policies were identified.

The results revealed that four of the seven hospitals have in-house infant hearing screening programs. Of the four programs, three utilize automated auditory brainstem responses and the fourth hospital uses the 1990 Joint Committee on Infant Hearing High Risk Register. The results also indicated a need for further research on the effects of early intervention, the effectiveness of different infant hearing screening protocols, and ways for hearing professionals to work together to provide the most effective identification and intervention services for hearing impaired children.

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DEDICATION

This thesis is dedicated to my parents for teaching me the value of education, to all the educators who have helped me along the way, to S. Gerber Ph. D. for introducing me to the controversies surrounding infant hearing screening, and to my friends and family for keeping me going throughout my academic career.

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Chapter I

Introduction

Hearing impaired children experience a variety of problems. Many authors agree that hearing impaired children do not receive appropriate auditory, linguistic, and social stimulation (Coplan, 1987; NIH, 1993; Ruben, 1987). The lack of auditory stimulation results in delayed speech, language, and cognitive development. Poor speech, language, and cognitive skills often lead to reduced academic achievement and consequently restricted job opportunities (Gottlieb, Zinkus, & Thompson, 1979; NIH, 1993; Ruben, 1987).

Advances in technology have made it possible to diagnose hearing loss at any age. Early diagnosis, in combination with early aural habilitation, has been shown to improve speech, language, cognitive, academic, and social skills (Chamberlain, 1987; Feinmesser, Tell, & Levi, 1982; Mace, Wallace, Whan, & Stelmachowicz, 1991; Pappas & McDowell, 1983; Ruben, 1987). The critical period for language learning is approximately birth to thirty six months (Coplan, 1987). Subsequently, aptitude and flexibility for language acquisition decreases with age (Ruben, 1987). Early auditory stimulation, therefore, is necessary to counteract the potential effects of the auditory deprivation induced by

early childhood hearing impairment (Pappas et al., 1983; Ruben, 1987).

Despite the widely acknowledged need for early intervention, the average age of hearing loss identification in the United States is two and one half years (Coplan, 1983; NIH, 1993). Specifically, in 1983, Coplan found that the average age of identification for deaf children was 24 months and 48 months was the average age of identification for children with lesser degrees of hearing loss. Looking at a population with a low socioeconomic background, Ruben and colleagues (1982) found that these populations had an average age of identification of hearing loss of 5.3 years.

Due to the late age of hearing loss identification within the United States, there has been a recent move to promote the early identification of hearing loss in children. In 1991, the Joint Committee on Infant Hearing targeted six months as the maximum age for identification of hearing loss and for beginning intervention services. Healthy People 2000, a report generated by the Surgeon General's office in 1990, proposed 12 months of age as the maximum age for identification of childhood hearing impairments.

Meeting these and other goals for the early identification of hearing loss is a formative task. Approximately five million babies are born each year in the United States. Approximately one in 1000 will have a profound hearing loss, and as many as four to ten times that number

will have a lesser degree of hearing loss (Mauk et al., 1993). Performing diagnostic audiology on every child born in the United States would be extremely costly and time-consuming. The National Institutes of Health (1993) recently proposed universal hearing screenings to reduce the cost and time of identifying children with hearing loss and to increase the number of children identified at an early age.

The Rhode Island Hearing Assessment Project (1993) was designed to investigate whether or not universal infant hearing screening was easy to administer as well as cost effective. The study found that given 5000 live births per year, a hospital could screen for hearing loss in each baby for a cost of approximately $19.53. Based on these results, it was concluded that universal screening for infant hearing impairment can be both easy to administer and cost effective.

Turner, Frazer, and Shepard (1984) suggested that to evaluate the true cost of a screening program, the cost per true positive, cost per false positive, and the cost per false negative need to be calculated. These calculations should provide a more complete picture of the actual total cost of an individual infant hearing screening program (Bess, 1993; Turner & Cone-Wesson, 1992).

The controversy regarding universal hearing screening, the true cost and actual statistical effectiveness, support the need for more research. More studies are needed to carefully analyze the cost effectiveness of current infant

hearing screening programs, and that information then needs to be shared among hearing health care professionals so that more effective and cost efficient hearing screening programs can be created (Blake & Hall, 1990).

The purpose of this study was to describe the methods currently being used by hospitals within Santa Clara County to screen infants for the risk of hearing impairment and to find out if the hearing health care professionals working for hospitals within Santa Clara County are in favor of universal infant hearing screenings. It was hoped that this information would become available to those individuals wishing to update their infant hearing screening protocols and to those individuals interested in knowing more about the infant hearing screening services currently being provided throughout Santa Clara County. With this information, the ability of health professionals to identify infants with hearing loss may be facilitated.

Chapter II

Literature Review

Introduction

It is well known that hearing loss in early childhood puts a child at risk for delayed speech, language, and cognition and reduces academic success (Cox & Horn, 1983; Horton, 1975; McConnell & Liff, 1975; Parving, 1992; Rapin, 1978; Schum, 1991; Skinner, 1978; & Tyler, Tye-Murray, Gantz 1991). It is possible to reduce the delays in speech, language, and cognition and increase the chance of academic success through early identification of hearing impairment and early remediation (Feinmesser, Tell, & Levi, 1982; Mace, Wallace, Whan, & Stelmachowicz, 1991; Ruben, 1987; Pappas & McDowell, 1983). The National Institutes of Health (NIH) recommends that every child born in the United States of America be screened for hearing impairment as a neonate. NIH recommends the use of otoacoustic emissions in combination with auditory brainstem responses to carry out the universal screening (NIH, 1993). The Joint Committee on Infant Hearing recommends the screening of only at "risk" infants. JCIH recommends the use of a high risk register in conjunction with otoacoustic emissions and auditory brainstem responses (JCIH, 1993). The goal for infant hearing screening is to find children with hearing impairment at an earlier age and

to start aural rehabilitation for those children before they pass through the critical period for language (Hall, Kripal, & Hepp, 1988).

The state of California is one of 14 states with mandated infant hearing screenings (Blake & Hall, 1990). California state assembly bill number 1022 mandated that all neonatal intensive care unit graduates born in hospitals that participate in California Children's Services programs be screened for hearing impairment. The state suggested the High Risk Register (Joint Committee on Infant Hearing, 1982), the Crib-O-Gram, behavioral testing and the auditory brainstem response test as possible methods for screening infants at risk for hearing loss. Assembly Bill 1022 has not been updated since 1983. Between 1983 and 1993, new technologies and developments were introduced to infant hearing screening protocols. The Joint Committee on Infant Hearing updated and expanded their High Risk Register since otoacoustic emissions became available clinically. Blake and Hall (1990) noted that hearing health professionals and other health care workers needing to create or change infant hearing screening programs or protocols, must become aware of successes and failures within and between states.

The purpose of this study was to describe the methods being used by hospitals within Santa Clara County to screen infants for the risk of hearing impairment and to find out if the hearing health care professionals working for hospitals

within Santa Clara County are in favor of universal hearing screenings. It was hoped that this information would become available to those individuals wishing to update their infant hearing screening protocols, and to those individuals interested in knowing more about the infant hearing screening services being provided throughout Santa Clara County.

Early Intervention

Early intervention allows for language learning during the natural language learning period of zero to three years. The greater the delay between hearing loss onset and intervention, the greater the chance for permanently depressed language skills (McConnell, 1975). The acquisition of speech and language is an innate trait. Auditory input is necessary for a child to reach speech and language maturity (McConnell, 1975; Shah, 1978). The ability to understand speech is based on the ability to classify speech sounds, understanding the rules for combining speech sounds into words, attaching meaning to combined words, and attaching meaning to rhythmic patterns of speech (Cox et al., 1983; Skinner, 1978). By three and one half years of age a child will have acquired most of the structures underlying adult speech and language (Horton, 1975). Hearing loss of any degree is known to have some impact on the acquisition of speech and language and consequently cognition, academic success, and career opportunities (Cox et al., 1983; Horton,

1975; McConnell et al., 1975; Parving, 1992; Rapin, 1978; Schum, 1991; Skinner, 1978). McConnell and Liff (1975) studied two groups of children with the purpose of showing the difference in expressive language abilities among hearing impaired children who had received early intervention and those who hadn't received early intervention. They concluded that the early intervention program was very important for language development to be stimulated at approximately the same time the hearing child is naturally learning language.

In summary, early identification of hearing loss and early aural rehabilitation are necessary for the hearing impaired child to achieve normal development of speech, language, and cognition, which in turn may provide the child with a better chance at academic and also economic success.

Methods of Screening for Hearing Loss

Since early intervention is critical, many methods have been proposed and investigated for early identification of hearing loss. This section will review the methodologies that have been developed over the last three decades.

Behavioral Observation Audiometry

Screening for infant hearing loss began in the early 1960's. Marion Downs used behavioral observation audiometry (BOA) to identify hearing impaired children in Colorado (Hall, 1993). BOA employs a 90 dB HL narrow band noise with a

30 dB per octave attenuation below 750 Hz. The noise is presented while the baby is in a state of light sleep. The baby must make no body or eye movements for at least 15 seconds before the stimulus is presented. The stimulus is presented and the presence or absence of a whole body movement response is recorded. A maximum of eight trials are given with at least 15 seconds between stimulus presentations. Each stimulus presentation is one half to two seconds long. Two positive responses are required for an infant to pass the screening. (Downs & Gerkin, 1989; Mencher, 1977). Two independent scorers, unaware of the stimulus presentation, are used to avoid observer bias (Mencher, 1977).

The arousal screener and Crib-O-Gram are two types of BOA. The Auditory Response Cradle (ARC), another BOA screener, is not available in the United States and will not be covered in this report.

Arousal screeners utilize a 90 to 100 dB narrow band noise or white noise stimulus. The stimulus is presented for two seconds while an observer records a whole body movement as a response to the sound (Urban, 1975). An advantage of the arousal screening test is that it can be administered in as much as 60 dB of ambient noise. It is also inexpensive and requires little administration time. The disadvantages include subjective response observation and the inability to

identify mild to moderate hearing losses due to the level of stimulus presentation (Northern & Gerkin, 1989).

The Crib-O-Gram is an automated BOA screener. A 2000 to 4000 Hz narrow band of noise is presented 20 times at 92 dB HL. Motor movements and respiration are recorded 15 seconds prior to the stimulus presentation and six seconds after the presentation. The 20 stimulus trials are given over a period of seven to 24 hours.

The State of Mississippi was given Crib-O-Gram equipment by the Lion's Club in 1981. Malphus (1989) reported a total test time of 30 minutes with only five minutes needed of staff attention. He also found that there were three false alarms for every true positive. That means that for one hearing impaired child to be identified, four had to fail the Crib-o-Gram hearing screening protocol of Mississippi.

The advantages of using the Crib-O-Gram include ease of use, minimal personnel requirements, and screening directly in the nursery. The disadvantages include mechanical failure, high initial costs, extended test time, a high false positive rate and a high intensity stimulus that will not detect mild to moderate hearing losses (Malphus, 1989; Northern et al., 1989).

High Risk Register

In the early 1970's, the American Speech and Hearing Association convened the first Joint Committee on Infant

Hearing (Hall, 1993). In 1972 the Joint Committee on Infant Hearing published five risk factors for sensorineural hearing loss creating the first High Risk Register (HRR). The original High Risk Register included: 1) Familial history of childhood hearing loss, 2) Congenital infections (e.g. TORCH), 3) Hyperbilirubinemia of levels requiring transfusions, 4) Craniofacial anomalies, and 5) Birth weight of less than 1500 grams (3.3 pounds). In 1982, the Joint Committee on Infant Hearing expanded the HRR with two additional factors, bacterial meningitis and asphyxia with an Apgar score of less than or equal to three at five minutes. In 1990, the HRR was revised to include ototoxic medications, mechanical ventilation for equal to or greater than ten days, and stigmata or findings associated with syndromes known to include hearing loss (Turner et al. 1992). The draft of the 1993 Joint Committee on Infant Hearing proposes changing "risk factors" to "indicators" and leaving the 1990 list of factors unchanged.

In 1991, Mauk, White, Mortensen, and Behrens published a study on the effectiveness of a HRR based screening program in Utah. The program was based on the 1982 High Risk Register. The authors set out to find the patterns of identification for children ages six to nine with educationally significant sensorineural hearing losses. The children were born in the state of Utah during the High Risk Register birth certificate screening program and were

attending the Utah School for the Deaf at the time of the study. A total of 70 subjects were located. A structured telephone interview was conducted with the parents or guardians of each subject. Questions were asked about whether the child fell under a risk factor on the High Risk Register, whether certain auditory behaviors were observed and at what age, how the first health professionals responded when parents approached them concerns about their child's hearing, the age at which the hearing loss was suspected, the age hearing loss was confirmed, and the age habilitative intervention began. Trained paraprofessionals conducted structured telephone interviews over a period of four weeks.

Only half of the subjects in the study had one or more of the 1982 High Risk Register risk factors. Placement in the neonatal intensive care unit immediately after birth was reported by 57% of the subject's parents. If neonatal intensive care admission had been included as a risk factor nine of the children missed by the 1982 High Risk Register would have been identified. This would have increased the percent of subjects with sensorineural hearing loss exhibiting one or more risk factors to 63%.

The results indicated that only 33% of the parents with children found to be at risk for hearing loss and who were later identified as having a sensorineural hearing loss made appointments for hearing evaluations when contacted by the State Bureau of Communicative Disorders. Only one third of

the parents who made hearing evaluation appointments kept them.

Approximately 40% of parents with children who had moderate to profound hearing losses noticed behaviors that might indicate hearing loss when their child was birth to three months old. Of the parents of mild to moderately hearing impaired children, 21-36% noted their child was not responding to environmental sounds and was not comprehending age appropriate words between the ages of six to sixteen months. Parents who noticed abnormal auditory awareness in their child between the age of birth to three months suspected hearing loss at the mean age of five and one half months. If the parents noticed abnormal auditory awareness between the ages of six to twelve months, the mean age of suspected hearing loss was 13.7 months. Furthermore, the results indicated that parents of high-risk children suspected hearing loss five months earlier, obtained hearing evaluations seven months earlier, had confirmation of hearing loss eight months earlier, and had their child fitted with hearing aids and in habilitative services five months earlier than the parents of children who did not exhibit one or more risk factors for hearing loss.

Based on the study results, the authors concluded that the Utah HRR based infant hearing screening program was an effective means to identify educationally significant sensorineural hearing loss. The authors noted that because

information about a neonatal intensive care unit stay is easier to obtain than many of the official risk factors, it would be appropriate to add neonatal intensive care nursery stays to the High Risk Register. Furthermore, it was concluded that to expect all of the children who fell at risk for hearing impairment under the High Risk Registry to return for diagnostic follow-up testing was not practical. The number of children lost to follow-up was concluded to be supportive of the need for aggressive follow up administration. Consistent with other studies, Mauk et al. (1991) found that parents did notice behavioral indications of hearing loss. However, many of those parents were reported not to realize that the behaviors were indications of an existing hearing loss. Children who failed the High Risk Register and whose parents did not respond to follow-up mailings by making hearing assessment appointments or parents who had no concerns regarding their child's hearing were reported as indications of the need to provide more education about hearing loss to both parents and the primary physicians. The authors concluded that the High Risk Register aided in the identification of children with educationally significant hearing loss.

The Joint Committee on Infant Hearing 1993 draft position statement is clear that children who exhibit one or more HRR factors should receive follow-up screening and that the HRR alone is not a sufficient screen for hearing loss in

neonates. The advantage of the High Risk Register as an initial screen is the relative ease of administration and the relatively low cost. The disadvantages are the number of both false positives and false negatives leading to poor specificity and sensitivity (Hall, 1993; Turner, 1990).

Auditory Brainstem Response (ABR)

In the 1960's, the advent of the fast-averaging computer made recording auditory evoked potentials possible. In 1971, Jewett and Wilson published a study on Auditory Brainstem Response (ABR) that changed the direction of pediatric audiology (Warren, 1989). In the 1970's and 80's the ABR test was refined and became an infant hearing loss screening tool (Hall, 1993; Warren, 1989). The ABR is now a commonly used neonatal hearing screening tool (McCall & Ferraro, 1991). Warren described the Auditory Brainstem Response as a series of vertex positive waves reflecting electroencephalic changes that are generated from the auditory nerve (VIII cranial nerve) to the midbrain occurring in the first 10 milliseconds after the onset of a calibrated square wave broad band click stimuli with a 100 millisecond duration. The response is recorded by surface electrodes attached to the scalp (Warren, 1989).

Klein, Alvarez, and Cowburn published a study in 1992 investigating the stimulus rate parameters for ABR testing in infants. The study included 84 neonates and infants ranging

in postconceptional age from 30-78 weeks. The subjects ranged in gestational age from 29-42 weeks. A majority of the infants were at risk for hearing loss according to the 1982 Joint Committee on Infant Hearing High Risk Register. Tests were performed in the well-baby nursery (WBN) or the neonatal intensive care nursery (NICU). A one tenth of a millisecond alternating polarity pulse stimulus was presented monaurally through TDH-39 earphones. A 20 millisecond window of neuroelectric activity was analysed for preterm infants. Full term or post term infants tested in the audiology outpatient clinic were tested with a 12 msec analysis window. Based on the normative data for the test sited, a stimulus rate of 90 clicks/sec was chosen. Only infants who had a detectable ABR with a 40 clicks per second stimulus presentation rate at 30 dB nHL were given the 90 clicks/sec protocol. The latency of wave V was measured only after a clear and repeatable peak was visible. Wave V amplitude was measured as the peak of wave V to the bottom of the following negative voltage trough.

Results showed that the wave V latencies for all post conceptional age groups were consistently longer for the faster stimulus repetition rates. The percent of relative change in wave V latency at the 40/sec stimulus repetition rate was more constant across age than the change for the 90/sec stimulus repetition rate. For the 40/sec stimulus repetition rate, the amplitude of wave V doubled. This

occurred across the entire range of ages studied. Decreases of 20% in wave V amplitudes were found only in the 37 and 51 weeks age groups.

For the 30 weeks post conceptual age (PCA) group waves I, III, and V were present at 20 and 40/sec stimulus presentation rates. However, only wave I was present for the 90/sec stimulus presentation rate. The 36 weeks PCA group had no waves present at the 90/sec stimulus presentation rate. The 37 weeks PCA group had robust waves I, III, and V with slightly increased latencies for the 90/sec stimulus presentation rate. Additionally, the probability of detecting wave V's at a 90/sec stimulus presentation rate was found to be as follows: post term babies had a 92% probability of clearly present wave V's, preterm babies had a 50% probability of clearly present wave V's, and full-term babies had a 71% probability of clearly present wave V's.

The authors concluded that because stimulus rate is chosen based on latency and amplitude of wave V, based on their results, the 90 clicks/sec presentation rate was not appropriate for either preterm infants or for full-term infants. However, the 90 clicks/sec presentation rate may be appropriate for post-term infants. Furthermore, based on their findings of latencies up to 10.25 msec in preterm babies, the authors recommended an analysis window of at least 13 msec for preterm ABR testing. The results of this study indicated infant maturity as being more important to

the response detectability than minor manipulations of stimulus parameters. Additional information is needed, however, on other stimulus rates, stimulus intensities, and numbers of sweeps averaged before the most effective stimulus and recording parameters can be determined (Klein, Alvarez, & Cowburn, 1992).

Other studies of infant ABR recordings have consistently found normal wave V latencies to be as much as eight point five milliseconds and that neonates with an impaired ear may evidence wave V latencies of greater than 10 milliseconds. As a result, it had been recommended that the analysis window be at least 15 milliseconds (Hall et al., 1988; Warren, 1989). The intensity of the stimulus is set according to the individual program's pass/fail criterion. If the intensity level is 30 dB nHL or below, the number of false positives may be increased, but if the intensity level is 40 dB nHL or higher the number of false negatives may rise. As a result, intensity levels are recommended to be 30 and 40 dB nHL (Hall et al., 1988). The stimulus signal is delivered to the ear through headphones or insert earphones. Because neonatal external ear canals are prone to collapse, insert earphones are recommended (Hall et al., 1988; Warren, 1989). The neonates' ear canals may be so small that insert earphones are not feasible. In such cases circumaural "jelly" headphones are recommended (Hall et al., 1988). ABR testing requires a quiet patient. Neonates may either be sleep

deprived and in a state of slight starvation so that feeding will induce natural sleep or anesthetized (Hall et al., 1988; Warren, 1989).

In 1991, McCall and Ferraro published a study that considered the effects of the infants' state of awakeness on ABR recordings. The authors were concerned about myogenic activity interfering with ABR recordings for the awake but quiet neonate. Subjects included 52 medically stable neonates from the Kansas Medical Center Neonatal Intensive Care Unit. All subjects were considered at risk for hearing loss by the 1982 Joint Committee on Infant Hearing High Risk Register. Mean postgestational age was 47.8 weeks with a range of 37-65 weeks.

ABR testing was done in an examining room. Ambient noise levels did not exceed those recommended by Richmond et al. (1986). Responses were recorded by a Nicolet "Audit V" system. The stimulus was a broad band 100 millisecond electric pulse click. Clicks were presented using alternating polarity at a rate of 33.3 clicks/second. Filter cut offs were set to 100 and 3000 Hz with a rolloff rate of 12 dB/octave. A 15 millisecond window was used to average the 1534 samples of electrophysiologic activity. Artifact rejection was set to reject trials with amplitudes exceeding 90% full scale deflection.

Subjects were placed into one of three categories based on their state of awakeness during test administration. If

the subject exhibited sucking behavior and mild movements of their extremities, they were classified as "awake-active." "Awake-calm" neonates were very quiet with relatively no motion. The final category was "asleep." Placement into a category was based on consensus between the examiner, a graduate student assistant, and the child's caregiver. The electrophysiologic activity also was monitored for gross differences in awake and asleep states during the test. Asleep neonates had to remain asleep throughout the test to be classified as an asleep subject. Classifications of "awake-active" versus "awake-calm" were subjective and could be changed during the ABR. If, however, a baby's state of awakeness changed during the test and did not stabilize the test was rejected from the study. If the test computer rejected 30% or more of the responses, the trial was excluded from the study.

The screening protocol required measurements in both ears at intensity levels of 60 dB nHL and 30 dB nHL. A neonate passed the screening if a reliable and repeatable wave V was recorded at the 30 dB nHL intensity level with symmetrical latencies in both ears. Final pass/fail judgments were made from a hard copy of the waveforms by an examiner who was unaware of the state of awakeness during the test.

Of the total number of subject tested, 17% were excluded due to fluctuations in their state of awakeness during test administration which precluded classification into one

category of wakefulness. The group of "awake clam" babies had observable waves but the morphologies of the waves were poorly defined. When those same babies were asleep, the waveforms were well defined and repeatable. The "awake-active" babies had distorted waveforms for the 30 dB nHL level which resulted in "failed" tests. When those babies were tested asleep, their recordings were normal and they "passed" the test.

Of the 52 neonates, 28 were "asleep" during screening and 24 were "awake." Of the "awake" babies, eight passed the screening and 16 failed. Of the 14 "awake active" babies, four "passed" the screening and ten "failed." Of the "awake calm" babies, four "passed" the screening and six "failed." Chi-square analysis indicated a significant difference in pass-fail rates for babies "asleep" versus babies "awake," but no significant differences were found in pass-fail rates between the "awake active" versus "awake calm" babies. Based on the results, the authors concluded that due to myogenic activity in "awake" subjects leading to contaminated ABR tracings and resulting in a large false-positive rate, the "awake" baby failure rate became unacceptably high. The authors recommended screening neonates while asleep to reduce false-positive rates. They also noted that when natural sleep is not possible, steps should be taken to facilitate sleep for the duration of the test.

ABR machines vary according to their capabilities. Some machines, such as the ALGO-1, are designed only to screen for hearing loss. These machines do not require a skilled user nor do they require interpretation of wave forms. A conventional ABR machine is capable of both screening functions and threshold searches. These machines, such as the Biologic, require a skilled examiner to interpret the results. The advantage to the conventional machine is the examiners' option to change parameters during the test. Additionally, diagnostic testing can be administered immediately after the neonate fails the screening. An advantage of the automated screening ABR is the ability to have paraprofessionals administer the test, thereby reducing the cost of the screening protocol (Hall, 1993; Hall et al., 1988).

Hall et al. (1988) listed some common problems and solutions for ABR screening protocols. It was suggested that testing wait until 40 weeks post conceptual age to overcome problems associated with prematurity and ABR test responses. For transient conductive losses that are common in the NICU, it was recommended that the neonate have otologic management and immitance audiometry. Problems with collapsing ear canals and poor earphone placement may be solved by using insert earphones. It was suggested that the tester choose a stimulus rate for which their particular test site has normative data. Ambient noise can be reduced by testing in a test suite and

problems with movement artifacts can be solved by increasing the repetitions or by pausing the test and waiting for the neonate to settle down.

Hyde, Riko, and Malizia (1990) described some of the disadvantages of screening with ABRs. False positives may come from poor recording conditions, poor recording techniques, and inadequate neural synchrony. Despite the shortcomings of the ABR, it is an easily administered and highly reliable screening tool for neonatal hearing impairment.

Otoacoustic Emissions (OAE)

A relatively new screening tool is the measure of otoacoustic emission. An otoacoustic emission is sound the normally functioning cochlea delivers back through the middle ear and outer ear canal in response to an acoustic stimulus. A spontaneous otoacoustic emission is a sound generated by the cochlea that occurs in the absence of a sound stimulus as a result of normally present spontaneous neural activity. The otoacoustic emission is in and of itself nonessential to hearing; however, the function producing the emissions is essential to normal hearing sensitivity (Johns & Niparko, 1993). There are two otoacoustic emission (OAE) classifications, spontaneous OAE's and evoked OAE's. The spontaneous OAE is present in approximately 70% of all normal

hearing ears. The absence of spontaneous OAE's does not indicate hearing loss (Hall, 1993).

The evoked emission comes in two forms, the transient evoked otoacoustic emission (TEOAE) and the distortion product otoacoustic emission (DPOEA). Both evoked OAE's have been found to be clinically useful (Kemp & Ryan, 1991; Kemp et al., 1993; Hall et al., 1993). The TEOAE is a frequency response to acoustic stimulation occurring four to fifteen msec after the stimulus presentation (Kemp et al. 1993). Because of the stimulus onset to response latency, the TEOAE is also known as the delayed otoacoustic emission. The DPOAE is a tonal response to two simultaneously presented pure tones whose frequencies, F_1 and F_2, occur at various distortion product frequencies, for example $2F_1-F_2$ (Kemp et al., 1993; Hall, 1993).

The evoked otoacoustic emission can be measured noninvasively in a relatively short amount of time (Zwicker, 1990; Johns et al., 1993; Bonfils, Avan, Grancois, Marie, Trotoux & Narcy, 1990). Recording the evoked otoacoustic emission is dependent on a bi-directional propagation into and out of the external meatus, the middle ear, and the cochlea (Hall, 1993). The otoacoustic emission is recorded in the frequency range of 500 to 4000 Hz (Zwicker, 1990; Bonfils et al., 1990). To record evoked OAEs, a probe is placed into the external meatus. The probe delivers the stimulus and picks up the resulting emissions. A computer then analyzes

the emissions and provides the examiner with a visual read out of the emissions (Zwicker, 1990). The evoked OAE has been correlated to normally functioning cochleas with hearing thresholds of 35 dB HL or better (Bonifils et al., 1988). The evoked OAE is not usually present in an ear with cochlear hearing losses of 35 dB HL or greater (Kemp et al., 1991; Kemp et al., 1993; Bonfils, Piron, Uziel, & Pujol, 1988; Bonfils et al., 1990).

Stevens et al. studied the use of click evoked otoacoustic emissions in neonatal screening (1990). This prospective study investigated the possibility of using evoked otoacoustic emissions to identify hearing impaired neonates. Subjects were babies admitted to the North Trent Neonatal Intensive Care Unit at the Jessop Hospital for Women. Most subjects were tested prior to hospital discharge. The mean birth weight was 2220 grams with a range of 540-4890 grams. Gestational age ranged from 24-42 weeks with a mean of 34 weeks. Testing age ranged from 32-49 weeks post conception with a mean age of 37.5 weeks. Each baby received ABR testing and EOAE testing in both ears. Any baby who did not have a normal ABR response at or below 43 dB nHL in one ear and 53 dB nHL in the other ear was recalled for further ABR testing. Whenever possible, the retest was done prior to discharge, otherwise, it was carried out four to six weeks post due date on an outpatient basis. ABR's were scored using the criterion of presence or absence of a waveform. Scoring was done by the

tester and two other experienced ABR administrators who acted independently of one another. Acceptance of the presence or absence of a waveform was based on agreement between two or more scorers.

Otoacoustic emissions were evoked using a click stimulus delivered by a Knowles Electronics ED2950 miniature earphone. A Knowles Electronics type BT1751 miniature microphone was used to detect the emissions. A piece of silicone rubber tubing was place over the probe containing the microphone and earphone. The probe was then sealed into the neonates external ear canal. The stimuli were 100 microseconds unipolar rarefaction square waves presented at a rate of 32.5 clicks/second. Sweeps with data outside ±3 mPa were rejected. Testing was carried out in a sound treated room with a maximum ambient noise level of 28 dBA, with the equipment running, and 27 dBA from the microphone. The tester was able to end the test earlier than the preset 1000 sweeps if he or she was certain that emissions were present. The initial stimulus level was *31/41 dB nHL. (The * was used to differentiate EOAE stimulus levels from ABR stimulus levels.) The limits of the equipment were reached at *41/51 dB nHL. Scoring was done by the tester and two other clinicians experienced with EOAE all acting independently of one another.

All of the infants tested by both the EOAE and the ABR were between the ages of birth to six weeks post due date.

Additionally, 92.3% were tested at seven to twelve weeks after birth and 71.4% were tested at over twelve weeks after birth. The EOAE and ABR recording times were similar. The ABR total test time was longer due to the time required for electrode applications. The mean test time for EOAE's was 12.1 minutes. The mean test time for ABRs was 21.0 minutes.

Results were reported by: 1) how well the EOAE predicted the ABR screening outcome for ages birth to three months, 2) how well the EOAE plus ABR screening protocol predicted ABR follow-up failure at three months, 3) how well the EOAE screen predicted follow-up findings at 2 years, 4) how well the ABR screen predicted follow-up findings at 2 years, and 5) how well the three month follow-up ABR predicted follow-up findings at 2 years.

The EOAE screen was found to predict 51 of 67 ABR screen failures in the birth to three months of age group. The EOAE in combination with ABR screening protocol was found to predict 27 of 29 three months of age follow-up ABR failures. These conditions had sensitivities of 76% and 93%, respectively. Their corresponding selectivities were 86% and 84% respectively.

The results of the EOAE screen, ABR screen, and ABR at the three months follow-up were compared to the findings of follow-up hearing evaluations at two years of age. The EOAE screen failed 19 of 32 hearing impaired children found at the two year follow-up appointment. The ABR screen failed 17 of

32 hearing impaired children found at the two year follow-up appointment. The three months follow-up ABR failed 10 of 32 hearing impaired children found at the two year follow-up appointment. These results did not include four aural atrisas, 13 non-survivors, and 10 missed follow-up appointments.

Despite low sensitivities, the EOAE screen, ABR screen, and ABR at three months follow-up had high selectivity when compared to the follow-up hearing evaluations at two years. The selectivities were as follow: 1) EOAE screen, 82%, 2) ABR screen, 91%, and 3) ABR at three months follow-up, 95%.

The authors concluded that the difference in specificity and sensitivity for the EOAE and ABR screen at the three month follow-up appointment and the two year follow-up appointment could have been a result of hearing impairments developing after three months and before two years of age. They concluded that the sensitivity of the EOAE to predict the ABR screen outcome was an indication of EOAE as an appropriate initial screening tool. Because the EOAE is faster to administer, the authors concluded that EOAE screening reduced the cost of the screening protocol when compared to similar ABR screening protocols. They cautioned that a full cost-benefit analysis of EOAE testing as a predictor of long term hearing loss was needed.

Norton and Widen (1990) studied age-related changes in EOAE's in normal ears to provide a normative data base for

the study of clinical populations. Click-evoked emissions were measured with an IL088. Stimuli were presented for 80 msec. The stimuli were rectangular pulses presented 50/second at 80 dB peSPL. The pulses were delivered through a probe that fit into the subjects' external ear canal. Subjects older than three years were seated in reclining chairs with their heads well supported. Younger children and infants were seated in their parents' lap. Subjects were in a separate room away from the computer, printer, monitor, and interface box during test administration. The tester was seated in the room with the subject and had control of the test via a keyboard.

A small probe containing the microphone and transducer was placed into the external meatus and sealed with a shortened immitance probe tip. The probe fit was important for blocking external noise to create a better signal-to-noise (S/N) ratio. Because small ear canal volumes can vary the overall sound pressure level of the stimulus, the tester adjusted the gain and attenuation attempting to keep the stimulus as close to 80 dB peSPL as possible. The noise rejection rate was set for each subject by the examiner. If the noise level exceeded the rejection level, the sample was not added to the running average. Testing time ranged from 58 seconds to three and a half minutes per subject.

Subjects were 17 days to 30 years old. They were divided into three age group categories. Group one was birth to nine

point nine years old. Group two was ten to nineteen point nine years old. Group three was twenty to twenty-nine point nine years old. Every subject who was over three years old had normal pure-tone audiograms and normal middle ear function. Younger subjects had varied amounts of audiological data, but all data were within normal limits. All subjects had negative otologic and medical histories.

The amplitude and temporal characteristics of the EOAE testing was variable across six ears. The greatest difference was seen between the one and one half month old and the 20.5 year old. As age increased it was discovered that EOAE amplitude decreased by a statistically significant amount.

In all of the ears tested, the EOAEs were judged present by two independent observers. In all of the age groups, as the amplitude decreased, reproducibility also decreased, indicating that as EOAEs became smaller, noise increasingly affected the recording.

The authors concluded that click-evoked otoacoustic emissions were present and robust in normal neonates, infants, and young children. The change in amplitude as a function of age was reported to reflect changes in the external and middle ear acoustics and cochlear dynamics. They also concluded that EOAE's could be used as a screening tool for cochlear dysfunction and to monitor changes in cochlea function over time and that more research was needed

including cross-sectional longitudinal clinical studies of EOAE's in infants and children.

Vohr and colleagues (1993) reported on factors contributing to the interpretation of TEOAE's. They recommended the neonate be sleeping or in a quiet state of wakefulness during test administration to increase the possibility of a shorter test time. Test time may also be significantly shorter if the examiner is good with neonates, understands how to soothe a fussing baby, knows when the baby is likely to be quiet, and know when to abort testing and to try again at another time. Another factor is the probe seal. A poor fit can be the result of the wrong probe size, movement on the part of the baby, or the probe being up against the canal wall. Poorly fitting probes may lead to a large noise component and inadequate or absent emissions. It is recommended that the stimulus level be chosen before testing begins. Low stimulus amplitude during the test is usually due to blockage of the probe or an inadequate probe fit. The external canal volume can also affect stimulus amplitude. Additionally, emissions can not be present without a normally functioning cochlea. If emissions are weak or absent it may be due to cochlear dysfunction or poor test conditions.

The authors summarized eight problems with TEOAE's including the number of samples, stimulus, reproducibility, probe stability, infant state of awareness, debris in the

external ear canal, and the timing of test procedures. An emission obscured by noise may be brought above the noise floor by running more samples. A stimulus below 71 dB peSPL may result in inadequate responses. To assess cochlear function, an appropriate stimulus must be used. Low reproducibility may be due to noise or some other form of interference. The strength of the emission varies as a function of probe stability. The screen is likely to take the least amount of time if the infant is in a state of sleep. Crying may reduce the pass rate from 79% to 58%. Interference with the mechanical transmission of sound through the external ear canal and middle ear will effect sound toward the cochlea and the emission from the cochlea. Vernix caseosa, partial obstruction, and canal collapse all may reduce the TEOAE pass rate. Timing is especially important now that many babies are being discharged between 24 and 48 hours after birth. In the first 24 hours of life the infant is likely to have debris in the external ear canal that will interfere with TEOAE testing (Vohr et al., 1993).

Based on current research, otoacoustic emissions may become an effective screening tool in the future. More research is needed regarding clinical application, testing procedures, normative data for neonatal populations (Hall, 1993), and longitudinal studies analyzing specificity and sensitivity (Norton et al., 1990).

Goals and Objectives for Future Infant Hearing Screenings

In 1993, the National Institutes of Health (NIH) developed a consensus statement regarding the early identification of hearing impairment in infants and children. The NIH consensus recommends that every child born it the United States be screened for hearing loss. Ideally, the initial screening should occur prior to discharge from the hospital. If an infant can not be screened before being discharged from the hospital, it is recommended that initial screening occur before three months of age. If the initial screen is failed, it is recommended that follow-up audiometry be administered before the infant is sixth month old (NIH Consensus Development Conference, 1993).

Both the American Speech-Language Hearing Association (1993) and the Joint Committee on Infant Hearing (1993) recommend that initial infant hearing screening be administered in the first three months of life and that follow-up diagnostic audiometry be administered by six months of age. The Joint Committee on Infant Hearing and the American Speech-Language Hearing Association recommend screening only those children at risk for hearing loss.

The question of universal infant hearing screenings versus selective infant hearing screenings has been approached through six questions of clinical epidemiology. Those questions are: Is the disorder serious?, is there a

high prevalence of the disease?, can a diagnosis be made?, do resources for treatment exist?, does the disease respond to treatment?, and is there an advantage to early identification and intervention? (Bess, 1993; Hall et al., 1988). The questions were answered with regard to universal infant hearing screenings by Hall, Kripal, and Hepp (1988). They suggested that hearing impairment is a serious disease. If intervention is not provided the child's speech and language development will be delayed. The prevalence of hearing impairment is approximately 4-5% of all at risk infants. Hearing impairment can be diagnosed clinically at any age. Medical, surgical, and audiological intervention does exist and treatments and therapies have been shown to improve communication skills.

Bess (1993) provided reasons why hearing impairment should not be considered a candidate for universal screening. He states that while safe and effective screening tools exist, they have not been shown to be good enough in a statistical sense for use as universal screeners. For example, the ABR is not an acceptable screener since it is not a direct measure of hearing, it will not identify a low frequency hearing loss, and the false positive rate is too high. Bess reported that to identify one hearing impaired neonate with ABR testing, 100 must fail the screen and be referred for further diagnostic testing. Moreover, the EOAE has a greater false positive rate than the ABR and current

EOAE data is out of laboratory experiments, not clinical application, there is no consensus on pass/fail criterion, and there is no data on the follow-up of infants who have passed EOAE screenings. Furthermore, currently no sensitivity and specificity statistical analysis of the EOAE + ABR protocol suggested by NIH is available.

Bess noted that information regarding treatment efficacy is limited. There exists little research beyond the studies in the 1970's that show a benefit of early intervention. More research, therefore, is needed to show the effects of early versus late intervention. Regarding the question of accessible treatment, Bess noted that 25% of live births in the United States are in rural and remote areas. These babies are the least accessible and yet may be some of the most "at risk" for hearing impairment.

Given four million live births a year in the United States, a conservative cost estimate for universal hearing screening is three million dollars per year. This means that to identify 4000 neonates we must spend $7500.00 per baby born. On top of the initial screening cost must be added the cost of false positives and parental anxiety (Bess, 1993).

Another factor that must be considered with regard to universal hearing screening is the amount of compliance with professional recommendations. If the parents of a child do not comply with the medical and audiological recommendations, the screening can not be effective. Current estimations of

non-compliance are from 25-80%. Given that a parent complies with the professional recommendations, the ultimate goal of a screening program is to facilitate early identification and intervention. Despite screening programs, there is still a six to nine month lag between identification of hearing impairment risk and intervention (Bess, 1993; Clayton, 1993).

Kemp and Ryan (1991) note that applying screening to a wider population increases the number of retest and follow-up services needed. They suggest that efficiency can not be determined without considering the cost in staff time to detect and confirm hearing impairment in those children who fail the initial hearing screening. Beyond the actual monetary cost of universal hearing screening, the emotional cost of parental anxiety should also be figured into the efficacy equation. The purpose of hearing screening is to identify a subpopulation whose prevalence of hearing loss is greater than the general population so that diagnosis and intervention is more manageable (Kemp & Ryan, 1991; Turner, 1990). The question of whether a universal screening policy will make the diagnosis and treatment of hearing loss more manageable needs further investigation (Bess, 1993; Hall, 1993).

In 1990, Blake and Hall studied the different policies for infant hearing screening across the United States. A questionnaire was sent to all 50 states and the District of Columbia requesting information on state mandated and or

recommended infant hearing screening protocols. Written responses were received from 39 states. The remaining 12 states provided information during follow-up telephone interviews. When incomplete written information was received, a follow-up telephone call was made. The purpose of the survey was to identify the status of mandated neonatal screening programs. The results of the survey were current as of November, 1988. The authors noted that because screening policies develop over time, some changes may have been made between the time the surveys were received and the date the study was published.

It was found that neonatal hearing screening legislation varied from state to state. Programs ranged from comprehensive state-wide coverage for screening, to screening for only those infants admitted to neonatal intensive care nurseries. It was also found that 64% of the states with mandated screenings had or were planning to have a comprehensive program that would follow the babies from identification of a hearing risk through intervention for a confirmed hearing impairment. Of the states without mandated programs, only 11% had or were considering a comprehensive identification through intervention program.

State representatives were asked to site reasons for not mandating infant hearing screening. The reasons sited included: 1) screening techniques were too expensive, 2) state demographics precluded one statewide program, 3)

hearing professionals had not come to a consensus for the best way to screen infants for hearing impairment, 4) no proven efficacy exists for the screening programs in use, 5) screening could be done without a mandate, 6) a lack of follow-up testing and intervention availability, and 7) a lack of personnel and equipment to administer screenings and follow-up services. Blake and Hall concluded that these legislative concerns indicated the need for further research in many areas of infant hearing screening.

The survey also revealed reasons for mandating hearing screening. They included: 1) to insure hospital compliance, 2) to create consistent follow-up, 3) to allow for earlier intervention services, 4) to coordinate existing programs, 5) the availability of instrumentation for screening, 6) the technological ability to diagnosis hearing loss at any age, 7) and mandating programs may allow for a central referring and informational agency.

The authors found that many professionals were in the process of establishing statewide infant hearing screening programs. They suggested that in order to help those professionals, more research is needed regarding current screening programs and their efficacy at finding hearing impaired children and decreasing the age at which habilitation begins. They also suggested that states with mandated or volunteer programs should publish data about their individual programs and that interstate cooperation

should be increased with regard to sharing screening program information.

The State of California mandated an infant hearing screening program in 1983 through Assembly Bill 1022. Hospitals participating in the California Children's Services programs are required to screen all neonatal intensive care nursery graduates using the 1982 Joint Committee on Infant Hearing High Risk Register. Infants who exhibit one or more high risk factors are to receive follow-up screening no later than six months of age. This second screening is to include either electrophysiological or behavioral response testing. Infants who fail the screening are to be referred to California Children's Services, the child's primary physician is to be notified, and referrals are to be made for audiological follow-up. Additionally, the state requires an effort be made to reduce the level of parental anxiety associated with a failed screening.

The purpose of this study was to discover the methods being used by hospitals within Santa Clara County to screen infants for the risk of hearing impairment and to find out if the hearing health care professionals working for hospitals within Santa Clara County are in favor of universal infant hearing screenings. It was hoped that this information would become available to those individuals wishing to update their infant hearing screening protocols, and to those individuals interested in knowing more about the infant hearing screening

services being provided throughout Santa Clara County. In this way, services to infants with suspected hearing loss can be facilitated.

Chapter III

Methods

Introduction

Congenital hearing loss is known to cause delays in language, speech, and cognitive development (Cox & Horn, 1983; Horton, 1975; McConnell & Liff, 1975; Parving, 1992; Rapin, 1978; Schum, 1991; Skinner, 1978; Tyler, Tye-Murray, & Gantz, 1991). As a result, there is a movement in the United States toward universal hearing screening, the screening of every newborn in order to identify children with hearing impairments at an earlier age and to facilitate early intervention (NIH, 1993). The State of California has mandated infant hearing screenings for intensive care nursery graduates of hospitals participating in California Children's Services programs. California does not mandate a particular method for infant hearing screening. The High Risk Register (Joint Committee on Infant Hearing, 1982), auditory brainstem response testing, and the Crib-O-Gram are all suggested as possible screening techniques. Since Assembly Bill 1022 mandated neonatal intensive care nursery hearing screenings, otoacoustic emissions have been introduced for clinical use and the Joint Committee on Infant Hearing has updated it's High Risk Register.

In a 1990 study that surveyed the 50 United States and the District of Columbia, Blake and Hall found California to be one of nine states mandating some form of infant hearing screening. The authors recommended that screening programs publish their protocols to help other hearing health professionals know what is going on outside of their own practice and to help with decisions on changing protocols and mandates. The purpose of this study was to describe the methods being used in hospitals within Santa Clara County to screen infants for the risk of hearing impairment and to find out if hearing health care professionals working for hospitals within Santa Clara County are in favor of universal infant hearing screenings. It was hoped that this information would become available to those individuals wishing to update their infant hearing screening protocols and to those individuals interested in knowing more about the infant hearing screening services being provided throughout Santa Clara County.

Instrument

A structured telephone interview was developed and pilot tested especially for this study to gather information about hospital infant screening methods and hearing health care provider opinions on the need for universal infant hearing screenings. The questions used in the survey were derived from a review of the literature regarding test procedures,

testing parameters, and published hospital screening protocols. The interview included questions about populations screened, personnel required to accomplish the screenings, test types and their parameters, pass/fail criterion and feelings about universal infant hearing screenings. The interview was piloted and revised with the help of hearing health care providers outside of Santa Clara County. The complete survey can be found in Appendix A.

Sample

Hospitals included in the study were chosen for their geographic location and their obstetric services. Ten hospitals, nine private and one public, provide regular birthing services in Santa Clara County. Each hospital was contacted and asked to participate in this study. Of the seven hospitals that agreed to participate, one was public and six were private.

Procedure

A carefully scripted request for participation, including the purpose of the study, the content of the survey, and the protection of the primary source and institution, was give over the telephone. An appointment was made with a hearing health care professional from each of the seven institutions that agreed to participate. The survey was administered over the telephone during the interview

appointments. The surveys required 10 to 30 minutes for administration. Answers were recorded on spreadsheets with randomly assigned numbers to protect the identity of the primary source and the institution. Four primary sources stated that due to time constraints they could not answer the survey questions during a telephone interview. Those four primary sources were mailed the standardized survey form, the same survey form used to administer the telephone interviews, and asked to return the form in the provided self addressed stamped envelope. The surveys were returned without marks indicating the name of the institution or primary source to protect their identities. The primary sources of all seven participating institutions answered the survey questions in the month of March, 1994.

Data Analysis

Each question on the survey was coded numerically. First, the percentage of hospitals with no infant hearing screening, intensive care only infant hearing screening, well baby only infant hearing screening, and universal hearing screening was calculated. The frequency of use for each individual test was calculated along with the populations screened with each test. Test parameters were charted and analyzed for frequency of use. Percentages regarding professionals in favor, opposed, and unsure of the need for universal infant hearing screenings were calculated. A

frequency analysis was calculated for the reasons given in favor of universal infant hearing screenings and reasons given in opposition to universal infant hearing screenings. This information then was utilized to provide information on the methods in use for infant hearing screenings in Santa Clara County hospitals, both public and private, and the current feelings of hearing professionals working at those institutions regarding the need for universal hearing screenings for infants.

Chapter IV

Analysis

The purpose of this study was to describe the methods currently being used by hospitals within Santa Clara County to screen infants for the risk of hearing impairment and to find out if the hearing healthcare professionals working for hospitals within Santa Clara County are in favor of universal infant hearing screenings. It was hoped that this information would become available to those individuals wishing to update their infant hearing screening protocols, and to those individuals interested in knowing more about the infant hearing screening services currently being provided throughout Santa Clara County. With this information, the ability of hearing health professionals to identify infants with hearing loss may be facilitated.

Responses to the survey were divided into two categories, those hospitals with infant hearing screening programs and those without infant hearing screening programs. (See Table 1) Three hospitals had no infant hearing screening programs and four had infant hearing screening programs. The hospitals with infant hearing screening programs were further broken into categories according to populations screened.

Table 1

Screening Institutions and Populations

	Institution						
	#1	#2	#3	#4	#5	#6	#7
Screening Performed	Yes	Yes	Yes	Yes	No	No	No
Population Screened	NICU only	NICU only	NICU only	NICU and selected WBN	None	None	None

NICU denotes a neonatal intensive care unit population

WBN denotes a well baby population

Current Screening Protocols

Hospitals were asked which populations they screened, both neonatal intensive care and well baby nursery babies, neonatal intensive care babies only, or well baby nursery babies only. They were then asked what type of screening tool was used for the population they screened and whether professionals and/or volunteers performed the screening. The results form the questions regarding the population of newborns screened in each facility are summarized in Table 2.

Table 2

Screening Methods and Staff

	Institution			
	#1	#2	#3	#4
Population	NICU	NICU	NICU	NICU and selected WBN
Method	aABR	HRR	aABR	aABR
Tester	Nurse	Nurse	Nurse	Nurse/NICU Volunteer/WBN
Interpreter	Nurse	Nurse	MD	Nurse/NICU MD/WBN

NICU denoted neonatal intensive care unit populations

WBN denotes well baby nursery populations

aABR denotes automated ABR testing

Three hospitals reported providing neonatal intensive care nursery only screening programs. Of those programs, two used automated ABR screenings and one used the 1990 Joint Committee on Infant Hearing High Risk Register (HRR). All of the NICU only programs were provided prior to discharge.

In each NICU only automated ABR screening program, a trained nurse provided the screening services. One automated ABR program had the same nurse interpret the screening as a

pass or fail. The other automated ABR program required a physician to interpret the screening results as a pass or fail.

The program with a nurse doing both the screening and the pass/fail interpretation notified the attending physician and resident of failures. If the baby was going to be a patient in the high risk development clinic, the clinic was notified of the failed infant hearing screen. If the child was not going to be a patient of the high risk development clinic, the primary care physician was notified of the failed infant hearing screen.

For the program that had nurses do the screenings and a doctor interpret the results, both the child's pediatrician and a neonatologist were informed of failed infant hearing screens. The infant was then referred for a follow-up ABR.

Institutions were asked to provide such statistics as how many babies were screened per year, how much it cost to fund the entire screening program per year, and what kind of follow-up records were kept. This information is in Table 3. The cost analysis data was not available for the automated ABR screening program that had a nurse provide services and interpret results. The program screened 290 babies per year. To fail the baby had to fail two automated ABR tests at the same stimulus presentation level. The reported degree of hearing loss targeted by this program was 35 dB nHL or greater bilaterally. Approximately 25 babies failed this

program per year. Follow-up data were not available so hit rate, false alarm, and correct rejection rate calculations could not be made.

Table 3

Cost Analysis of Individual Institutions

	Institution			
	#1	#2	#3	#4
Screened/yr NICU	290	NA	150	144
Failed/yr NICU	25	25	24	12
Cost/baby NICU	NA	NA	$20	$15
Screened/yr WBN				48
Failed/yr WBN				12
Cost/baby WBN				$15
Total program cost/yr	NA	NA	$3000	$2880

NA denotes information not available

The program with nurses providing screening and doctors interpreting results estimated the cost per baby screen was $20.00. They screened 150 babies a year for a total program cost of $3000.00. To fail this screening protocol a baby had to fail on automated ABR screen. The degree of hearing

impairment targeted by the program was not available for this program. The hospital reported 24 fails a year. Given a $20.00 per baby screened cost, the cost of finding an fail was $125.00. Actual hit rate, false alarm rate, and correct rejection rate statistics were not calculated because follow-up data also were not available.

The NICU only program providing HRR screenings was administered by a nurse. If the infant had one or more high risk factors, s(h)e failed the screen and the primary care physician and parents were notified. The infant was then referred to neurology for follow-up testing.

All three NICU only program employees reported that the hospital was reimbursed for screening services in part or in full by the baby's health insurance provider.

The fourth hospital providing infant hearing screenings used an automated ABR to screen all NICU graduates and selected well baby nursery (WBN) graduates. The NICU graduates were screened by trained nurses who also interpreted the screening results prior to discharge. To fail the screening, a baby had to fail one automated ABR. Failures were reported to a neonatologist or pediatrician and followed up with ABR testing.

Well baby nursery (WBN) graduates were screened by volunteers prior to discharge whenever possible. If a screen could not be performed prior to discharge, the baby returned for an automated ABR screening that was performed by

volunteers. The results for both pre and post discharge screenings were interpreted by physicians. To fail a screen the baby had to fail one automated ABR screen. Failures were reported to the primary care physician and followed up by the primary care physician.

The primary source reported screening 144 NICU graduates a year and 48 WBN graduates per year. They reported failure rates to be 12 babies from the NICU graduates and 3 babies from the WBN graduates.

The cost of screening one NICU baby was $15.00. The cost of NICU screenings per year was $2,160.00. The cost to find one infant hearing screening failure in the NICU was $180.00. The cost of screening one WBN baby was $15.00. The cost of WBN screenings per year was $720.00. The cost of finding one WBN infant hearing screening failure was $240.00.

The total cost per year for the infant hearing screening in both the NICU and the WBN was $2880.00. The hospital employee reported that the infants health insurance provider paid for all or part of the screening cost for both NICU and WBN infant hearing screens.

Automated ABR Parameters

Hospitals providing screening with such tools as ABR or EOAE's were asked to define their test parameters. These results are shown in Table 4 and Table 5. The parameters for the automated ABR screening programs were reported and varied

from institution to institution. All three programs administered tests to babies that were awake and calm or in a state of natural sleep. The screens were all performed in the nursery, except for the post discharge well baby nursery graduate screens for which no test site was reported. Each program source reported an alternating polarity click stimulus. The two programs with reported stimulus intensity levels used 35 dB nHL clicks. One program source reported using 37 clicks per second, one reported using 35 clicks per second and one program source did not provide the rate of stimulus repetitions. Of the three program's employees, only one reported the type of transducer used to deliver the stimulus to the infants ear. That program used "acoustic tubes." The number of sweeps per ear was reported by two of the programs. One used 1000-15000 sweeps per ear and the other used 15000 sweeps per ear. One program employee reported their high and low pass filter settings. The high pass filter was 50 Hz and the low pass filter setting was 1500 Hz. Two program primary sources reported electrode placement on the infants forehead, the nape of the neck, and a cheek. The third program primary source reported electrode placement as the nape of the neck, the vertex, and the ear. All three programs test both ears. One program primary source reported masking the non test ear.

Total test time varied from fifteen minutes to one hour. All three program's employees reported that the machine would

print out "pass" or "fail." The decision is based on statistical analysis of the evoked response and the resulting waveforms.

Table 4

Automated ABR Recording Parameters

	Institution		
	#1	#3	#4
Awareness	awake or asleep	awake or asleep	awake or asleep
Transducer	acoustic tubing	NA	NA
Sweeps/screen	1000-15000	1000	NA
High pass filter	NA	50 Hz	NA
Low pass filter	NA	1500 Hz	NA
Electrode montage	nape, vertex, ear	nape, cheek, forehead	nape, cheek, forehead
Masking	yes	No	No

NA denotes not available

Table 5

Automated ABR Stimulus Parameters

	Institution		
	#1	#3	#4
Stimulus	click	click	click
Intensity	35 dB nHL	35 dB nHL	NA
Stimulus per second	35	35	NA

Note: NA denotes not available

Hospitals without Infant Hearing Screening Programs

Three hospital primary sources indicated they had on in house infant hearing screening programs. These results are shown in Table 6. Two of those three hospital primary sources indicated that when the nursery staff or a parent had concerns about an infants hearing status, the infant was referred out of the hospital for a hearing screening. The third hospital's employee indicated that should the primary care physician have concerns about the infant's hearing during well baby visits, it was up to the primary care physician to decide when and how to assess the infants hearing.

Table 6

Non Screening Institution Protocols

	Institution		
	#5	#6	#7
Concerned party	Nursery Staff or parent	Nursery Staff or parent	Primary care MD
Referral	to separate institution	to separate institution	at the descretion of the Primary Care MD

Note: Concerned party is the person or persons who suspect a possible hearing impairment.

Future Screening Protocol Creation

Regarding the questions of who was on the screening protocol creation team, two primary sources reported the team that created their screening protocol included a doctor, nurse, and hospital administrator. All seven of the healthcare providers interviewed had read the Healthy People 2000 report (US Department of Health and Human Services, 1990), the NIH consensus paper on infant hearing screening (1993), and the 1990 Joint Committee on Infant Hearing (JCIH) position paper. The only institution considering changing

their current protocol reported basing the reason for changes in their protocol on the recommendations of Healthy People 2000, NIH consensus paper, and the JCIH 1990 position paper.

Each institution was asked which of the following factors would influence future changes in their protocol: 1) federal/state/county legislation, 2) research showing the need for early identification and remediation for the hearing impaired, 3) lack of consensus among hearing professionals for the best and most effective screening method, 4) budget constraints, 5) evaluations of cost effectiveness of infant hearing screening, 6) cost of screenings to the hospital, 7) health insurance reimbursements, 8) the availability of professionals to perform the screening, and 9) availability of follow-up services. The results are summarized in Table 7. Federal, state, and county legislation, research showing the need for early identification and intervention for the hearing impaired, the lack of consensus among hearing professionals as the best and most effective screening protocol, budget constraints, evaluation of cost effectiveness, costs to the hospital to provide screenings, and health insurance reimbursements were named as factors influencing possible future changes in infant hearing screening protocols.

Table 7

Factors Influencing Protocol Creation

Number	Factors Influencing
4	Federal/State/County Legislation
3	Research showing the need for early identification and intervention
3	Lack of consensus among hearing professionals for the best and most effective screening methods
3	Budget constraints
2	Evaluation of cost effectiveness of infant hearing screening
3	Cost of screenings to the hospital
3	Health insurance reimbursements

Note: Number refers to the number of responses for each factor.

With regard to future legislation and screening needs, one healthcare provider indicated that if any level of government were to create new legislation for infant hearing screening, the government should indicate who will pay for those services. One healthcare provider felt that universal hearing screenings were not indicated based on a recent New England Journal of Medicine article that discussed the cost-waste of universal screening protocols. Another healthcare

provider felt that mandated universal hearing screenings and legislated insurance reimbursements were appropriate based on research that indicates the selective screening protocols are not finding all of the children with congenital and early childhood hearing impairment. This professional stated that mandated universal hearing screenings would reduce the number of missed hearing impaired infants and reduce the number of hearing impaired children who go unidentified up to the age of three years.

Chapter V

Discussion

The purpose of this study was to describe the methods currently used by hospitals within Santa Clara County to screen infants for the risk of hearing impairment and to find out if the hearing health care professionals working for hospitals within Santa Clara County are in favor of universal hearing screenings. It was hoped that this information would become available to those individuals wishing to update their infant hearing screening protocols, and to those individuals interested in knowing more about the infant hearing screening services being provided throughout Santa Clara County.

Involvement of Audiologists in Screening Programs

The survey was field tested with an institution outside of Santa Clara County. It was assumed that the field test would be representative of the actual interview process for personnel in charge of hearing screenings in local hospitals. This did not prove to be the case, however, since the trial interviewee was an audiologist. None of the hospitals in Santa Clara County who agreed to participate in the study had an audiologist involved at any level with their hearing screening program. This made it difficult for the professionals interviewed to understand and answer some of

the questions. For example, most professionals required restatement of the question that asked "what type of transducer is used?" Had the survey been field tested with a non-audiologist professional, such language would have been found to be inappropriate and could have been changed prior to the administration of the survey.

Additionally, many of the questions regarding ABR test parameters were unanswered and the information was consequently unavailable. The parameters unavailable included high and low pass filter settings, transducer types, samples per screen, click rate, and stimulus levels. It may be that the technician or volunteer actually presenting the screening ABR's would have been able to answer such parameter questions.

Hall and Hepp (1988) found that false alarms from an automated ABR screening may be the result of prematurity, transient middle ear problems, imprecise earphone placement, collapsing ear canals, inappropriate stimulus rates, too much ambient noise, high movement artifact. Manipulating the automated ABR test parameters can help reduce the number of false positives by reducing or eliminating the potential problems. Without an understanding of the test parameters and their normal settings for the particular automated ABR at the individual institutions, manipulations would not be possible and false alarm rates may be unnecessarily high.

The lack of understanding of ABR test parameters indicates a need for more education. For testing to be effective and efficient, at least the professional in charge of overseeing the screening should have some knowledge of the different test parameters, what manipulations are available, and what the effects of those manipulations would be on the results of the screening. Relying on the automated ABR manufacturer to set parameters for the individual institutions needs may be artificially increasing the number of over referrals resulting from false positives.

None of the institution's employees reported an audiologist to be a part of the screening staff or a part of the screening protocol creation team. Interestingly, the NIH consensus paper (1993) indicated the need for research to show the difference, if one exists, between screening programs that carried out by audiologists versus those that were carried out by trained nonprofessionals or volunteers. Such research might help the hospitals in Santa Clara County decide if there is a need to have an audiologist on the infant hearing screening staff.

Screening protocols

Seven hospitals participated in a telephone survey designed to discover what infant hearing screening services the individual institutions were providing. Four hospital employees reported having infant hearing screening programs

for their neonatal intensive care nursery graduates. One of the four hospital primary sources reported selective screening services provided to well baby graduates. Of the reported infant hearing screening programs, three of the four (75%) used an automated auditory brainstem response (ABR) screen. The remaining program utilized the 1990 Joint Committee on Infant Hearing High Risk Register (HRR).

Automated ABR test parameters were reported by the three hospitals with an automated ABR screening program to the best of their ability. One hospital employee indicated using a high pass filter setting of 50 Hz and a low pass filter setting of 1500 Hz. Hall and Prentice (1992) recommended the low pass filter be set a 1500 Hz and the high pass filter be set a 30 Hz. The rationale for the low pass filter was that ABR energy tends to be from below 1500 Hz and high frequency electrical interference might be reduced. The rationale for the 30 Hz high pass filter was that it would allow for all the low frequency energy contributing to the neonatal ABR.

Salamy (1994) disagrees with the high pass filter recommendation of 30 Hz. He stated that lowering the high pass filter below 150 Hz will only degrade the waveform and increase the number of artifacts.

One program employee reported a 35 clicks per second stimulus repetition rate and another reported a 37 clicks per second stimulus repetition rate. In order to reduce 60 Hz interference with the waveform, Hall and Prentice (1992)

recommended that the repetition rate not be divisible by 60. They further recommended that the ideal repetition rate was 37.1 clicks per second.

Stimulus intensity rates were reported to be 35 dB nHL by two institution employees. Hall and Prentice (1992) recommended a 35 dB nHL stimulus intensity as being low enough to rule out serious hearing impairment and at the same time it was reported to be high enough to reduce the number of false positives.

Rarefaction was recommended as the best click polarity by Hall and Prentice (1992), however, condensation and alternating polarities were also noted as able to elicit neonatal ABR's. All three institutions with automated ABR infant hearing programs reported using alternating click polarities.

The number of sweeps per screening reported by the participating hospital employees varied from 1000 to 15,000. Hall and Prentice (1992) stated that the optimal number of sweeps varies according to the signal to noise ratio for each individual test.

In summary, the results from the survey indicated that the parameters used in the automated ABR screenings were inconsistent with the parameters recommended in the literature. This finding may be due to the fact that the testing was automated with the parameters pre-set by the manufacturers to conform to standard clinical practice.

However, as Hall and Prentice (1992) noted, the professional using automated ABR machines should know and understand the capabilities of the automated ABR machine for changing pre-set parameters and the use of those capabilities to set parameters for the individual site's needs.

Protocol Statistics

The automated ABR programs for neonatal intensive care nursery graduates screened between 290 and 144 babies a year. The number of infants reported to fail the automated ABR screenings varied between 12 and 25 per year. The reported cost per baby screened was $15.00 to $20.00. The cost of finding one baby that failed the screen in the neonatal intensive care nursery was between $125.00 and $180.00.

The automated ABR program for selected well baby nursery graduates screened 48 babies a year. The well baby nursery screening program employee reported 3 fails a year. The cost of the screening was reported to be $15.00. The cost per year was reported to be $720.00. The cost of finding one baby that failed the screen in the well baby nursery was $240.00.

The primary source of the fourth program which was based on the High Risk Register (JCIH, 1991) did not provide cost per baby or babies screened per year statistics. It was estimated that 25 neonatal intensive care babies failed the HRR screening program each year.

Turner, Frazer, and Shepard (1984) stated that a definitive screening test would be one with a 100% hit rate and a zero percent false alarm. In a later article, Turner (1990) reported that the hit rate of the HRR to be 95% within the intensive care nursery population. And the false alarm rate for the same population to be 60%. The ABR was also reported to have a hit rate of 95% in the neonatal intensive care nursery population. However, the false alarm rate was reportedly 15%, much lower than the HRR's 60% false alarm rate. Clearly neither the HRR nor the ABR is a definitive screening test. Because neither test is definitive, a comparison of protocol models is essential in deciding which of the protocols is most effective. Turner and Cone-Wesson (1992) suggested that comparison of screening protocols could be done by graphing the cost per hearing loss hit rate function for each individual program. This graph would visually depict the trade off between cost and performance. To calculate the cost per hearing loss hit rate function the cost per hearing loss and hit rate must first be calculated.

Hit rate was defined by Turner (1990) as the percentage of hearing impaired infants in the nursery who are identified by the protocol as hearing impaired. The false alarm rate was defined as the number of infants with normal hearing who were identified as hearing impaired by the screening protocol. To calculate hit rate and false alarm rate, all of the infants in a nursery would have to be followed until they were old

enough for diagnostic hearing procedures and their status as hearing impaired or normal hearing could be confirmed (Turner, 1990).

Bess (1993) stated that the true cost of an infant hearing screening protocol could not be determined simply by dividing the total yearly cost of providing the hearing screening by the number of infants found to be hearing impaired by diagnostic follow-up. The true cost was stated as including the cost of follow-up procedures for false positive screening results and the cost of identifying children who were missed by the infant hearing screen as hearing impaired but later found to have a hearing loss.

The institution employees in this study did not report the cost per infant with a confirmed hearing loss. The lack of hit rate information and cost per hearing loss information made calculating the cost/performance function as suggested by Turner and Cone-Wesson (1992) impossible. Additionally it is not possible to calculate the true cost of each hearing screening protocol as suggested by Bess (1993).

The NIH consensus paper (1993) emphasis the need for maintaining a data base that tracks the progress of children and their hearing status. The database was recommended as a means for monitoring the performance of screening programs. The ultimate goal of an infant hearing screening program is to facilitate early diagnosis and intervention for congenital hearing impairment. Without follow-up statistics, the

screening program can not be evaluated for it's ability to facilitate early diagnosis and intervention for congenitally hearing impaired infants.

In summary, the true cost of the programs in Santa Clara County are not calculable with the information and statistics provided by this survey. The Rhode Island Infant Hearing Project (1993) found similar per baby screened costs for their OAE+ABR screening protocol; however, the Rhode Island Infant Hearing Project did not publish per actual hearing loss costs. Long term studies are required to find and compare per hearing loss costs for infant hearing screening protocols.

Future Infant Hearing Screening Protocols

One participating institution's primary source reported concern that legislated infant hearing screening protocols would be an additional cost to the individual hospitals. The hearing health professional indicated that should infant hearing screening become federally legislated, the legislation needs to provide a means of funding the screenings.

One participating informant indicated that as a direct result of the NIH consensus for the early identification of hearing impairment in infants and young children (1993) and the Healthy People 2000 report (1990), they were considering changing their infant hearing screening protocol. This individual also reported that universal infant hearing

screenings were necessary to find all of the infants with congenital hearing impairments. This comment was based on the informant's opinion that children with severe to profound hearing losses are not being identified as hearing impaired until as late as three years of age.

Another informant disagreed with the use of universal infant hearing screenings. This opinion was stated to be based on studies that found the cost more money than could be justified for the number of hearing impaired children found.

A third informant was of the opinion that no matter what the program was, any legislation regarding infant hearing screenings would be needed to provide a method of funding the mandated program.

The comments indicate that the use of universal hearing screening is not agrees upon among health care providers in Santa Clara County. One health care provider was pro universal hearing screening based on the number of hearing impaired children who are missed by selective screening programs. Another health care provider was con universal hearing screenings based on published cost effectiveness articles. This disagreement reflects not only the current conflict among hearing professionals, but also the need for more research.

In summary, the results form this study indicate that the effects of early intervention need to be researched, the effectiveness of hearing screening protocols need to be

calculated based on follow-up hearing assessment findings, and the cost of services provided as a result of false negative hearing screening findings (Bess, 1993), and hearing professionals need to work together to find the most effective way to identify and provide intervention services to children with hearing impairments before they pass through the critical period for language development (Blake & Hall, 1988). The data from this study will be disseminated to all the hospitals in Santa Clara County. It is hoped that the information will be beneficial to those health care providers who are responsible for developing and/or refining programs leading to early identification of hearing loss.

Chapter VI

Summary

It is known that early childhood hearing impairment puts a child at risk for delayed speech, language, and cognition (Cox et al., 1993; Horton, 1975; McConnell et al., 1975; Parving, 1992; Rapin, 1978; Schum, 1991; Skinner, 1978; Tyler et al., 1991). Through early identification of hearing impairment and intervention, the effects of hearing impairment on speech, language, and cognition can be reduced and the chances of academic success can be increased (Feinmesser, et al., 1982; Mace et al., 1991; Ruben, 1978; Pappas et al., 1983). The ultimate goal of infant hearing screening is to find children with hearing impairments at an earlier age and to start aural habilitation for children with hearing impairments before they pass the critical period for language acquisition and development (Blake & Hall, 1988).

This study surveyed hospitals in Santa Clara County for an accurate description of the hearing screening protocols in current use. Seven hospitals participated in the survey. Four of the hospitals had infant hearing screening programs; three did not. Of the infant hearing screening programs; three used automated auditory brainstem response testing and one used the High Risk Register (JCIH, 1991).

The following conclusions were made based on the survey results. First, some of the terminology in the survey may have been unfamiliar to the non-audiology respondents. Second, more education is needed for the professionals in charge of hearing screening programs with regard to ABR parameters. This may indicate the need for more direct participation by audiologists in the infant hearing screening protocol. Third, more statistics are needed to accurately describe the sensitivity and specificity of the programs in current use in Santa Clara County. Finally, hearing professionals are not in agreement with regard to the most cost-effective and sensitive measures for early identification. Future research is indicated with regard to the benefits and limitations of all protocols, including universal screening.

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APPENDIX

Hospital interview

1. Does your hospital have an infant hearing screening program?

yes no

2. Do all new parents receive a packet on normal speech and hearing development?

yes no

3. Is the screening program Universal?

yes no

If yes skip to question 6.

4. Is the screening program for intensive care unit babies only?

yes no

5. Is the screening program for well baby nursery babies only?

yes no

6. What is the degree of hearing loss your screening program targets? (Please specify in dBHL)

Intensive care nursery_____

Well baby nursery_____

7. Is the screening program pre or post discharge from the hospital?

Intensive care nursery predischarge post discharge

Well baby nursery predischarge post discharge

8. At what age are the infants screened? Please specify in hours.

Intensive care nursery_____

_____

Well baby nursery_____

_____

9a. What screeners are included in the screening protocol? Please check all that apply.

Intensive care nursery		Well baby
_____	High Risk Register	____
_____	Noise Maker	_____
_____	Crib-o-Gram	_____

_____	ABR	_____
_____	ECoG	_____
_____	OAE	_____
_____	Other	_____

9b. If "other", please specify the test used.
Intensive care nursery_____
Well baby nursery_____

10. Is the screener performed by a medical doctor, nurse, audiologist, speech pathologist, medical technician, volunteer or other? Please specify for each screener used.

Intensive care nursery		Well baby
_____	High Risk Register	_____
_____	Noise Maker	_____
_____	Crib-o-Gram	_____
_____	ABR	_____
_____	ECoG	_____
_____	OAE	_____
_____	Other	_____

11. Is the screener performed in a sound booth, in the nursery, or other? Please specify for each screener used.

Intensive care nursery		Well baby
_____	High Risk Register	_____
_____	Noise Maker	_____
_____	Crib-o-Gram	_____
_____	ABR	_____
_____	ECoG	_____
_____	OAE	_____
_____	Other	_____

Answer number 12 only if multiple screeners are used

12. In what order are the screeners performed? Please number from first to last.

Intensive care nursery		Well baby
_____	High Risk Register	_____
_____	Noise maker	_____
_____	Crib-o-Gram	_____
_____	ABR	_____
_____	ECoG	_____
_____	OAE	_____
_____	Other	_____

13. What are the test parameters for the following tests? Answer only for those tests included in the current infant hearing screening protocol.

Noise makers

14. What is the state of awareness?

Intensive care nursery	awake	light sleep
Well baby nursery	awake	light sleep

15. What is the stimulus level? Please answer in decibels and state the referent (e.g. dBSPL, dBHL)

Intensive care nursery_____

well baby nursery_____

16a. What is the stimulus type?

Intensive care nursery	pure tone	noise
Well baby nursery	pure tone	noise

16b. What frequency pure tone is used?

Intensive care nursery_____

Well baby nursery_____

16c. What noise is used?

Intensive care nursery	narrow band	white	other
Well baby nursery	narrow band	white	other

17. How many trials are run for each baby?

Intensive care nursery_____

Well baby nursery_____

18. What is an accepted response to the stimulus?

Intensive care nursery_____

_____

Well baby nursery_____

_____

19. What is the pass/fail criterion?

Intensive care nursery_____

_____

Well baby nursery_____

_____

20. What is the duration of the test from start to finish? Please include preparation time.

Intensive care nursery_____

Well baby nursery_____

Crib-o-Gram

21. What is the state of awareness?

Intensive care nursery awake light sleep
natural sleep
Well baby nursery awake light sleep
natural sleep

22. What is the stimulus level? Please specify in decibels with the referent (e.g. dBSPL, dBHL).
Intensive care nursery_____
Well baby nursery_____

23a. What is the stimulus type?
Intensive care nursery pure tone noise
Well baby nursery pure tone noise

23b. What are the pure tones used?
Intensive care nursery_____
Well baby nursery_____

23c. What noises are used?
Intensive care nursery narrow band white other
Well baby nursery narrow band white other

24. How many trials are run per infant?
Intensive care nursery_____
Well baby nursery_____

25. What is the pass/fail criterion?

Intensive care nursery_____

_____

_____

_____

Well baby nursery_____

_____

_____

_____

26. What is the approximate duration of the test from start to finish? Please include preparation time.
Intensive care nursery_____
Well baby nursery_____

ABR/ECoG

27a. What is the state of awareness during the test?

ABR

Intensive care nursery awake asleep
Well baby nursery awake asleep

ECoG

Intensive care nursery awake asleep
Well baby nursery awake asleep

27b. What is the state of wakefulness?

ABR

Intensive care nursery awake-active awake-calm
Well baby nursery awake-active awake-calm

ECoG

Intensive care nursery awake-active awake-calm
Well baby nursery awake-active awake-calm

27c. What is the state of sleep?

ABR

Intensive care nursery natural sedated
sleep deprived
Well baby nursery natural sedated
sleep deprived

ECoG

Intensive care nursery natural sedated
sleep deprived
Well baby nursery natural sedated
sleep deprived

28. Is the machine automatic or manual?

ABR

Intensive care nursery_____
Well baby nursery_____

ECoG

Intensive care nursery_____
Well baby nursery_____

29. What is the stimulus polarity?

ABR

Intensive care nursery alternating condensation
rarefaction
Well baby nursery alternating condensation
rarefaction

ECoG

Intensive care nursery alternating condensation
rarefaction
Well baby nursery alternating condensation
rarefaction

30. Is the stimulus a click, tone burst, or other? If other please specify

ABR

Intensive care nursery_____

Well baby nursery_____

ECoG

Intensive care nursery_____

Well baby nursery_____

31. What is the stimulus level? Please specify in dBnHL

ABR

Intensive care nursery_____

_____

Well baby nursery_____

_____

ECoG

Intensive care nursery_____

_____

Well baby nursery_____

_____

32a. What type of transducer is used?

ABR

Intensive care nursery_____

Well baby nursery_____

ECoG

Intensive care nursery_____

Well baby nursery_____

33. What is the stimulus presentation rate?

ABR

Intensive care nursery_____

_____

Well baby nursery_____

_____

ECoG

Intensive care nursery_____

_____

Well baby nursery_____

_____

34. How many samples are taken?

ABR

Intensive care nursery_____

Well baby nursery_____

ECoG

Intensive care nursery_____

Well baby nursery_____

35. What are the high and low filter settings?

ABR

Intensive care nursery_____

_____

Well baby nursery_____

_____

ECoG

Intensive care nursery_____

_____

Well baby nursery_____

_____

36. What electrode placement is used?

ABR

Intensive care nursery_____

_____

_____

Well baby nursery_____

_____

_____

ECoG

Please specify transtympanic or extratympanic placement.

Intensive care nursery_____

Well baby nursery_____

37. Is testing done monaurally or binaurally?

ABR

Intensive care nursery_____

Well baby nursery_____

ECoG

Intensive care nursery_____

Well baby nursery_____

38. Is the nontest ear masked?

ABR

Intensive care nursery	yes	no
Well baby nursery	yes	no

ECoG

Intensive care nursery	yes	no
Well baby nursery	yes	no

39. What is the pass/fail criterion?

ABR

Intensive care nursery_____

_____

Well baby nursery_____

_____

ECoG

Intensive care nursery_____

_____

Well baby nursery_____

_____

40. What is the duration of the test? Please include preparation and clean up time.
ABR_____
ECoG_____

OAE
41. Which OAE is elicited?
Intensive care nursery spontaneous transient distortion product
Well baby nursery spontaneous transient distortion product

42. What is the state of awareness during testing?
Intensive care nursery asleep awake
Intensive care nursery asleep awake

43. What is the stimulus presentation level?
Intensive care nursery_____
_____
Well baby nursery_____
_____

44. What is the noise rejection rate?
Intensive care nursery_____
_____
Well baby nursery_____
_____

45. What is the reliability percentage excepted as a response?

Intensive care nursery_____

_____

Well baby nursery_____

_____

46. What type of probe tip is used?
Intensive care nursery_____

_____

Well baby nursery_____

_____

47. What is the pass/fail criterion?

Intensive care nursery_____

_____

_____

Well baby nursery_____

_____

_____

47. What is the duration of the test? Please include time required for preparation and clean up.

_____

48. Who interprets the screener used? Please specify for each screener used, doctor, nurse audiologist, speech pathologist, medical technician, other.

Intensive care nursery		Well baby
_____	High Risk Register	_____
_____	Noise Maker	_____
_____	Crib-o-Gram	_____
_____	ABR	_____
_____	ECoG	_____
_____	OAE	_____
_____	Other	_____

49. How does an infant fail the entire screening protocol?

Intensive care nursery_____

_____

_____

Well baby nursery_____

50. Who is notified of the screening results? Please be specific.

Intensive care nursery_____

Well baby nursery_____

51. What services are the infants who fail the screening referred to? Intensive care nursery_____

Well baby nursery_____

52. How many babies are screened per year?
Intensive care nursery_____
Well baby nursery_____
Total _____

53. How many infants fail the hearing screening per year?
Intensive care nursery_____
Well baby nursery_____
Total_____

54. What is the cost of the protocol per year?
Intensive care nursery_____
Well baby nursery_____
Total_____

55. What is the cost of the protocol per infant screened?
Intensive car nursery_____
Well baby nursery_____
Total_____

56. How is the hospital reimbursed for performing the infant hearing screening protocol?

Intensive care nursery_____

Well baby nursery_____

57. Does the hospital compile the following statistics? Please check all that apply.

Intensive care nursery		Well baby
_____	individual test hit rate	_____
_____	individual test miss rate	_____
_____	individual test false alarm	_____
_____	individual test correct rejection	_____
_____	protocol hit rate	_____
_____	protocol miss rate	_____
_____	protocol false alarm	_____

_____ protocol correct rejection _____

Policy creation

58. When was your current protocol created?
Intensive care nursery_____
Well baby nursery_____

59a. Which professionals were on the team that created the protocol?

Intensive care nursery		Well baby
_____	Doctor	_____
_____	Nurse	_____
_____	Audiologist	_____
_____	Speech pathologist	_____
_____	Administrator	_____
_____	Other	_____

59b. If "other" please specify_____

_____

60. Are you aware of the *Healthy People 2000* report generated by the US Department of Health and Human Services?
yes no

61. Are you aware of the National Institute of Health consensus on hearing screening (April, 1993)?
yes no

62. Are you aware of the Joint Committee on Infant Hearing position paper (1991)?
yes no

63a. Are you considering changing your screening protocol as a result of reading either *Healthy People 2000*, the National Institute of Health consensus on hearing screening, or the Joint Committee on Infant hearing position paper?
yes no

63b. If yes, which paper or papers influenced your decision to consider changing the infant hearing screening protocol?

_____

_____

64. In creating a policy on infant hearing screening, which of the following would be considered? Please mark all that apply.

_____Federal legislation
_____State legislation
_____County legislation
_____Research showing the need for early identification and remediation of the hearing impaired
_____Lack of consensus among hearing professionals for the best way to screen
_____Budget constraints
_____Evaluation of the cost effectiveness of infant hearing screening
_____Cost to the hospital to provide infant hearing screening
_____Health insurance reimbursements or lack there of
_____Availability of professionals to carry out the screening
_____Availability of follow up services for those infants who fail the screening

_____Other (please specify)_____

_____

_____

64. What are your feelings about possible Federal or State legislation that would mandate selective or universal hearing screening?

_____

_____

_____

_____

_____

_____

65. Do you feel that universal hearing screening is advisable, under what conditions, and what problems do you foresee with universal screening?_____

_____