Critical Review:
How effective are newborn infant hearing screening protocols for detecting Auditory Neuropathy Spectrum Disorder?

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This critical review investigates the effectiveness of current hearing screening protocols in detecting Auditory Neuropathy Spectrum Disorder (ANSD). This review examines populations from both the well baby population as well as populations from neonatal intensive care units (NICU). Study designs include: Single group, case reports and non randomized clinical trials. Overall, research suggests a combined protocol of automated OAE and an automated ABR on every baby can help to decrease ANSD misses. However, due to lack of follow-up, lack of research available on the well baby population, and the inability to generalize between the two populations, a definite answer to this question can not be found at the moment.

Introduction

Auditory Neuropathy Spectrum disorder (ANSD) is a hearing impairment in which the outer hair cells are functioning normally and the inner hair cells or the VIIIth nerve exhibit absent or abnormal function. (Berg et al, 2005). The clinical presentation of ANSD includes a normal cochlear microphonic or normal otoacoustic emissions (OAE) combined with an abnormal or absent auditory brainstem response (ABR). Other features of ANSD vary widely, with pure tone thresholds that range from normal hearing to a profound hearing impairment, absent acoustic reflexes, and poorer speech perception in noise than would be predicted by a pure tone audiogram alone. Hearing is usually significantly impaired in noisy environments. (Dowley et al, 2009)

It is important to detect all forms of hearing loss; sensorineural, conductive and ANSD early in life so that appropriate intervention strategies can be put into place. (JCIH, 2007) Ideally, newborn hearing screening methods should provide the ability to detect ANSD accurately and efficiently. The NICU population is considered to be an at risk population; Therefore, the screening methods used for NICU babies often include two different screening methods before discharge, in order to rule out hearing loss associated with several different pathologies, including ANSD. Conversely, the well baby population generally have no risk factors, and are usually screened with only one method before discharge. This poses a problem for the infants of the well baby nursery because healthy babies with no risk factors can still exhibit ANSD, and most well baby screening protocols are not designed to detect this disorder. In such cases, the ANSD form of hearing impairment would not be detected at birth.

According to the Joint Committee on Infant Screening, 2007, there are separate protocols for infants in the NICU nursery and those in the well baby nursery. Screening in the well baby nursery usually consists of an OAE screen, followed by an ABR screen only if an infant fails the initial OAE screen. If the infant subsequently passes the follow-up ABR screen, they are considered to have a final "pass" result. This two-stage (or two-tier) protocol is common. The OAE screen is generally used as the primary screening tool because they are time and cost efficient and also non-invasive. (Khairi et al, 2009). The OAE screening tool is accurate for detecting the most common hearing disorder, a sensorineural hearing loss. If an infant passes the OAE, they are then discharged. Consequently, an infant with ANSD can be missed because the initial OAE screen does not detect a retrocochlear lesion. (Khairi et al, 2009). In addition to not detecting ANSD, performing an OAE alone may miss a mild- moderate SNHL as well. As an alternative to the tier-stage protocol, some hospitals use a single technology screening protocol, repeating the screening test several times before discharge. The screening technologies used with this single technology protocol may be an OAE screener alone, or an ABR screener alone. (JCIH, 2007)

In the NICU population; however, the main screening protocol used is the automated ABR (Joint Committee on Infant Screening, 2007). If an infant does not pass the automated ABR, they are to be referred directly to an audiologist for a rescreening or complete diagnostic evaluation. (JCIH, 2007)

There is an abundance of literature on infants of the NICU; however, the literature is scarce on infants from the well population. In addition, the literature that do exist; do not follow up with these infants to examine which type of hearing impairment the infant presents with; therefore, it is hard to come up with a definite answer to this question.

Objectives

The primary objective of this paper is to critically evaluate how effective current newborn screening protocols are for detecting ANSD in both the well baby population and in the high risk intensive care unit populations. (NICU)

Methods

Search Strategy

Computerized search databases including SCOPUS, MEDLINE and CINAHL were searched using the following key words; (hearing) OR (cochlea) OR (auditory) AND (neuropathy) AND (dyssynchrony) AND (infant) AND (screening).

Search strategy was limited to articles written in English and also limited to human participants. Reference lists in selected journal articles were also examined to seek out additional reference sources.

Selection Criteria

Studies included in this critical review were required to investigate the different newborn hearing protocols at birth. The studies selected were required to perform both an OAE and an ABR screening on at least one population in the study (either the NICU or the well baby population).

No limitations were placed on the type of research design used.

Data Collection

Searches using the above mentioned search databases were used. Six studies were found for this critical review. Study designs include: Case series (1), single group design (2), single group with a case series (1) and non randomized clinical trials (2)

Results

Study 1: Hall, Smith, & Popelka (2004) performed a prospective, longitudinal study using a single group followed by a case report design. Hall et al, measured both an OAE screen and ABR screen concurrently in both ears of 300 infants 13 to 42 hours after birth. Results were analyzed for sensitivity, specificity and positive predictive value. Of the 300 neonates that were screened at birth, 294 received both an OAE and an ABR pass outcome. The remaining 6 infants subsequently received a diagnostic evaluation and were identified as hearing impaired. The sensitivity of the screening procedure was 100%, and the specificity was 99.7 %. The 6 hearing impaired children were followed up in a case series report with a full diagnostic evaluation. The follow up study revealed 1 case of auditory neuropathy. The results of this study indicated a prevalence of auditory neuropathy of 0.33 %(1/294) in the well baby population.

The level of evidence according to the Experimental Design Decision Tree is a 3. Overall, these results suggest that the use of a combined approach (OAE and ABR screen on every baby) to infant hearing screening improves the effectiveness compared to either measure alone. The combined approach is more effective at detecting auditory neuropathy as well as a hearing impairment in the well baby population. If an OAE screen had been used alone, then auditory neuropathy as well as a mild sensorineural hearing impairment might have been missed. This study provides good evidence for research in this area because an ABR and OAE were done on every baby in a well baby population. Furthermore, each baby that was considered to be hearing impaired were followed up with a full diagnostic evaluation to determine the type of hearing impairment.

Study 2:

Ngo, Tan, Balakrishnan, Lim & Lazaroo (2006) completed a prospective, case report design. They investigated the characteristics of nine infants suspected of presenting with ANSD from an infant hearing screening in a pediatric hospital. Fifty two cases of hearing impairment were detected from screening 14,807 consecutive cases. Of those cases of hearing impairment, nine infants had characteristics consistent with ANSD. All newborn infants were screened with an automated ABR test. Infants with an abnormal result were referred on to a Pediatric Otolaryngology Service. In this sample of infants, two of the infants with hearing loss were from a well baby population, while the remaining seven infants were from an at risk population. Although in this study, they did not compare back to an OAE screener, nor did they do an OAE screening, they state that the automatic ABR screener gives less false positives and less false negatives than the automatic OAE screener. They also state that the use of an OAE screener alone provides limitations in detecting infants with auditory neuropathy. The incidence of ANSD in the general population, in this study, is 0.6 per 1000 infants. The percentage of ANSD in infants with hearing loss is 17.3 % in this study.

The level of evidence of this study according to the Experimental Design Tree is a 3. This study provides evidence to the research in this area; however, the authors do not state how they performed any of their tests nor do they compare results to an OAE screener. Therefore, according to this study, we can not state

whether one method is better at detecting ANSD than others because there is no proof provided in this study.

Study #3:
Berg, Spitzer, Towers, Bartosiewicz, & Diamond, (2005) conducted a prospective, single group design. The purpose of this study was to evaluate a two tier screening protocol on infants admitted to the NICU. The study implemented a protocol of an automated ABR followed by an automated OAE if the infant had a refer result on the ABR. 477 infants met the inclusion criteria to participate in this study. 115/477 infants presented with absent ABR's in at least 1 ear and a present OAE response; which is consistent with ANSD.

This study did not follow up with the children who fit the ANSD profile; however, this study concludes that a automatic ABR followed by an automatic OAE for the infants that fail the ABR is an effective tool for detecting ANSD in an at risk population. However, this is a different population than the well baby population and the same procedures are not used in the well baby population; therefore, we can not generalize the results. In addition, since the study did not follow up or perform any diagnostic evaluations, we can not be sure of the prevalence of ANSD in this particular population. The level of evidence of this study is a 3, according to the Experimental Design Tree.

Study 4:
Suppiej et al, 2007, conducted a prospective, single group design. The purpose of the study was to evaluate hearing screening protocols on a cohort of infants admitted to the NICU. High risk infants (n=533) admitted to the Department of Pediatrics of Padua University between September 2003 and February 2005 were eligible for this study. The study compared the diagnostic reliability of automated OAE's, automated ABR's, and conventional ABR's (CABR). Neonates that were excluded from the study included; infants who were discharged before 48 hours, and the parents of 204 infants did not accept to participate in the study. Consequently, 206 infants participated in this study. The protocol included examination with conventional ABR, automated otoacoustic emissions (OAE) and automated ABR. Infants tested with all three methods totaled 151. All infants returned for a follow-up regardless of the screening results. Automated OAE screening was performed on all infants at follow-up. Automated ABR was repeated on those infants failing the automated ABR at birth while a conventional ABR was done on those infants failing the conventional ABR at birth. The screening identified 6/206 infants with a hearing loss. In this study, none of the infants showed the pattern of ANSD; absent conventional ABR/present automated OAE's. However, 13.8 % of ears showed the pattern of absent automated ABR/present automated OAE's during the neonatal period. This was a false suspicion of ANSD because these infants had subsequent recovery when a conventional ABR was performed at the follow-up. This could have been an example of delayed maturation in these newborn infants.
Sensitivity, specificity, positive and negative predictive values were performed for the three tests. The results show that the conventional ABR is the most reliable test because of its higher sensitivity and specificity. The automated ABR performed the worst out of the three tests. All three tests show a low positive predictive value. False positive results were observed in all three tests; 21.2% in automated OAEs, 28.5 % in automated ABR and 8.9 % in conventional ABR.
The level of evidence in this study was a 3 according to the Experimental Design Tree. This study suggests that conventional ABR provides the most accurate results; however most screening programs do not use this as a screening tool because it is time consuming and is costly. This study suggests that a conventional ABR can confirm or deny the suspicion of ANSD in the high risk infant population.

Study 5:
Gravel et al, 1999, conducted a prospective, non randomized clinical trial study design. The purpose of this study was to examine the differences among screening protocols for a well baby nursery and a neonatal intensive care unit (NICU) through a universal newborn hearing screening demonstration project at 8 different hospitals. The two technologies used were ABR and OAE screening. In the well baby nursery, OAE was the primary screening tool- followed by a conventional ABR(CABR) or screening ABR(SABR) if there was a refer result on the OAE. In 2 hospitals, OAE was the only screening protocol used. In the NICU, five different screening protocols were used. One hospital used OAE screening alone. The other combinations of screening procedures were: OAE/SABR, OAE/CABR, SABR/OAE, and BOTH(infants needed to pass both in order to be considered a pass). Overall, the fail rate at discharge from the hospital was significantly lower when a two tier screening protocol was used in the well baby nursery. In the NICU, the same results were found. When a two technology screener was used, the fail rate at discharge was lower than when just using one screening technology alone (OAE). It was also found that conventional ABR as opposed to SABR was more beneficial as the second screener when the OAE failed. Results of this study show that it is better to use a two tier screening protocol to detect hearing losses. However, in the case of detecting auditory neuropathy, it is better to screen with some form of ABR first followed by an OAE in both populations. In the well

baby nursery, auditory neuropathy would most likely be missed all the time because they performed OAE first followed by the ABR if the OAE had a fail result.

This study did not provide the reader with any numbers of how many infants passed and how many failed the OAE and ABR screening. With the lack of results, we cannot hypothesize about the prevalence of infants with ANSD. This study does not help to answer the research question because a two tier technology is usually done in most well baby populations for the most part. This study also did not perform both an OAE and ABR on each baby; therefore, these results do not give us insight into the infants with ANSD that are missed.

Study 6:

Spivak et al, 1999, conducted a prospective, non randomized clinical trial to examine the feasibility of a newborn hearing screening protocols in a well baby population and a NICU population. In the well baby nursery (WBN) the screening protocol of choice was the OAE in all hospitals. Six out of the eight hospitals adopted the two technology screening protocol- OAE followed by CABR or SABR if a refer result on the OAE. Two hospitals used a CABR after an OAE fail and four hospitals used the SABR after an OAE fail. Two hospitals adopted the OAE screening procedure alone. In the NICU, two hospitals used SABR followed by TEOAE for infants who did not pass the SABR. Two hospitals used OAE followed by CABR for infants failing the OAE. Two hospitals used OAE followed by SABR for infants failing the OAE. On hospitals required a pass on both TEOAE/ABR. One hospital used OAE as a screener with no second method.

This study is very similar to the study conducted by Gravel et al, 1999. Based on this study, in the well baby nursery, auditory neuropathy will likely be missed in this population because of the two tier screening system. If they pass the OAE, they will be discharged but might still present with ANSD; however, they are not followed up with or have any diagnostic data; which is a major limitation of the study. This study does not provide evidence of what is the best screener to use for detecting ANSD. This study, as mentioned in the above study, does not perform an OAE and ABR screener on every baby in the well baby population; therefore, it is difficult to infer on the percentage of infants with ANSD that were missed. The level of evidence was a 2a according to the experimental decision design tree.

The results of all of these studies show that auditory neuropathy is more likely to be missed in the well baby population than the NICU population. In most of these studies, the NICU infants are tested with an ABR first; while in the well baby populations they are tested with OAE first, followed by an ABR if a refer result on the OAE. In the well baby population for Auditory Neuropathy, infants usually present with normal OAE's; therefore ANSD will likely be missed in the well baby population without a two screener method on every baby.

Discussion and Conclusions:

Some of the studies used different screening methods; therefore, it is difficult to make comparisons across the studies. For example, one study performed both OAE and ABR screening on every baby, while another performed an A-ABR followed by an A-OAE if the infant failed the ABR. Another study simply performed A-ABR alone.

Furthermore, some studies in this critical review failed to bring the infants back for a diagnostic evaluation or a follow- up; therefore, we can not conclude if ANSD or a hearing impairment was missed.

A major limitation in some of these studies was the sampling criteria. In most of the studies, they did not have selection criteria. It was simply stated that infants were chosen but doesn't state how this was accomplished.

Hall et al, (2004) provide useful evidence for an answer to this research question. They performed A-ABR and A-OAE on every baby and also followed up with the babies that failed the screening. They found one infant on the follow up with ANSD and a prevalence of ANSD as 0.33 %. Therefore, if the researchers had not used both methods of screening on every infant and had not followed up with the infants who failed, this infant may have been missed.

Another critical issue involves the prevalence of ANSD in the infant population. Based on research reviewed in this paper, we can not say what the prevalence of ANSD is in any population because nobody really knows. In most of the research reviewed in this paper, the studies did not provide a follow-up for the infants that failed the screening; therefore, nobody knows how many infants with ANSD were missed. In some of these critical reviews, a prevalence of ANSD is given. However, no follow-up with the infants who failed is done and we can not know for sure if this number is accurate. For example, in the study done by Berg et al, 2005, they state the incidence of ANSD in that particular study to be 24.1 %; however, they did not do any follow up or do any diagnostic testing; therefore, we do not know if this number is accurate. Conversely, there is not enough

literature on the well baby population to be sure of the prevalence of ANSD in that population.

In the final two studies done on the New York State Universal Hearing Screening Program (Gravel et al,2000 & Spivak et al, 1999), they both do not state how many infants were tested over the three years, therefore, we can not state an appropriate prevalence of ANSD for either population. These studies also do not provide any follow up or diagnostic evaluations; therefore, we do not know if any infants with ANSD were missed.

Furthermore, most of the studies that exist are done on the NICU population rather than the well baby population. Therefore, it is hard to generalize the results because the NICU infants are a higher risk population and therefore, need more medical attention and additional testing to rule out other pathologies and impairments. This means that most NICU nurseries already have a two method screener in place before the infants can be discharged; thus, not missing ANSD in this population.

Based on these studies, it is evident that further research is needed on this subject. There are not enough studies that perform a two method screener on every baby in the well baby population. This would entail screening an infant with both an OAE and an ABR regardless of the outcome of the OAE before discharge.

Although we cannot fully answer the research question due to lack of research, one trend seemed to emerge throughout the research. A two method screening protocol would be beneficial in detecting ANSD. Using simply an OAE screen might miss a mild sensorineural hearing loss or ANSD.

Clinical Implications and Recommendations

The evidence regarding the effectiveness of hearing screening protocols in detecting ANSD still needs further research. The benefits and costs need to be weighed to determine where to go in clinical practice. Since the NICU population generally receives two screening methods as opposed to the well baby population generally receiving one, ANSD is more likely to be missed in the well baby population. On one hand it is easy to say that we should do a two screening method on every baby to rule out ANSD. However, this method is also more costly and more time consuming than the current protocols. There needs to be more research on the well baby population in order to make an informed decision.

Future research should focus more on the ABR screening method. We need to have an ABR screen for the well baby population because the OAE is only telling us how the outer hair cells are functioning. It is possible that an infant with ANSD can have normal hearing; therefore, the OAE results are normal and the infant is discharged. Future research should focus more on the well baby population and implementing a two method screen on every baby. An OAE screen followed by an ABR screen regardless of the outcome of the OAE screen should be done. Also, the infants who fail the ABR screen should be followed up with a diagnostic evaluation in order to determine the appropriate cause of the hearing impairment. The diagnostic ABR should be done with both condensation and rarefaction clicks in order to distinguish a cochlear microphonic from the true ABR waveform.

Further research should also include larger sample sizes so that we can get more information on the prevalence of ANSD.

In conclusion, there is not enough evidence right now to change clinical practice. Further research needs to be done in order to answer this research question.

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