Critical Review:
The Impact of Early Hearing Detection and Intervention Programs on language development of children with hearing loss.

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Hearing impairment at any age has a direct impact on communication capabilities. In particular, hearing loss in children can greatly affect language development. Therefore, it would stand to reason that early detection and intervention for children with hearing loss would be greatly beneficial. Early Hearing Detection and Intervention Programs (EHDI) have been implemented worldwide, and have been present in certain Canadian provinces like Ontario since 2002 as the Ontario Infant Hearing Program. However, there continue to be concerns in regards to the cost of these programs versus the benefit provided. This critical review examines the circulating literature in regards to EHDI programs and their influence on language development. Research suggests that EHDI programs are in fact of great importance and can significantly alter the establishment of language in children. More research is needed that provides a direct cost-benefit analysis, not only in terms of language development benefit, but that also includes dollars and cents as the bottom line.

Introduction

Hearing impairment is the most prevalent sensory deficit currently affecting our population. Although sources differ in exact estimates, the Canadian Working Group on Childhood Hearing (CWGCH) reports that permanent childhood hearing impairment in particular, affects between 1 and 6 babies per 1,000 live births. Without screening for hearing impairment, children routinely remain undetected until about 3 years of age, which is a critical period for language learning. Research has found that early identification hearing impairment and subsequent rapid intervention for these children can positively impact their language development (Yoshinaga-Itano, 2003). As language development is also associated with successful speech and socio-emotional variables, it is vital to have a comprehensive Early Hearing Detection and Intervention (EDHI) program in place.

Several studies have emphasized the significance of EDHI programs and the importance of implementation being carried out during critical periods of language learning, thus preventing the communication delays which often accompany children with a hearing impairment (Moeller, 2000). The Joint Committee on Infant Hearing recommends the following: all babies be screened prior to 1 month, diagnostics done by 3 months of age if referred, and intervention initiated before 6 months for those with confirmed hearing impairment. However, concerns continue to be raised about the cost effectiveness versus benefit of these programs, regardless of the former statement and the extensive worldwide support they have received.

Therefore, this critical review serves as an update to evaluate the literature concerning the current efficacy of EHDI programs and their implications for language development for children. Language development is the outcome of interest due to its educational and socio-emotional importance (Yoshinaga-Itano, 2003).

Objectives

The primary objective of this paper is to critically review the existing literature concerning EHDI programs, and thus evaluate the impact of Newborn Hearing Screening and subsequent early intervention programs on the language ability of children with hearing loss.

Methods

Search Strategy

The following databases were utilized in this literature search: PubMED, Medline, and Google Scholar. The following search terms were used:

- (Early Hearing Detection and Intervention Program)
- (Early Hearing Detection and Intervention Program) AND (language development)
- (Early Hearing Detection and Intervention Program) AND (educational outcomes)
- (Early Intervention) AND (outcomes)

No limitations were set for this search strategy.

Selection Criteria

Articles selected for review were those that discussed Early Hearing Detection and Intervention programs and their impact on language development. Certain

exclusion criteria were applied. Only articles written in 2005 to present day were included in the study in order to examine the most current literature and happenings in the field. Additionally, only those countries with similarities and relevance to the Canadian context were incorporated (i.e. Canadian, American, UK, Australian). Articles which discussed history and theoretical background, and may not have fallen within the aforementioned criteria were included in the introduction.

Data Collection

Results of this literature search generated four main articles consistent with the selection criteria. The designs were as follows: a retrospective mixed design study (between and within group), a prospective longitudinal matched cohort study, a longitudinal quasi-experimental (between groups) study, and a systematic review.

Results

Meinzen-Derr, Wiley, and Choo (2011)

This retrospective study is a mixed between and within group design. It examined the role of early intervention on expressive and receptive language development among young children with hearing loss. Specifically, it clarified the definition of "early intervention", stipulating that early intervention by 6 months of age is the critical point for maximizing language results. All participants were enrolled in Ohio's internationally renowned early intervention program, which is a comprehensive family-centered program for children with hearing loss providing services on a weekly or biweekly basis. The sample of children included those enrolled in program between 2004 and 2007, who were being longitudinally monitored, which totaled to 640 infants and toddlers. Those with complex medical issues or incomplete case data were excluded; therefore, only 328 subjects were included. However, there were characteristic differences between the children including contrasts in hearing loss configurations, severity of hearing impairment, and mode of communication.

The language measure was assessed using the SKI*HI Language Development Scale (LDS), which is a parent report observation scale for receptive and expressive vocabulary skills. The LDS is looked upon favorable as being a valid and reliable, and even greatly correlated with other language scales. For the purposes of this study, the groups were categorized as early entry (enrollment in early intervention program prior to 6 months) and late entry (enrollment age 6 months or later). The authors used statistical analyses on continuous and categorical variables appropriately. Language quotients (LQ) were calculated to determine the appropriateness of the vocabulary compared to age-matched norms, with those scores that approximated 100 being more age-appropriate.

Results indicated that children who had an early entry into the program, regardless of hearing aid severity for the most part, had statistically significant higher adjusted mean receptive and expressive language quotients (LQ). A particular strength of this study is that they also included children with unilateral hearing loss (a group which is currently under-studied), finding that those in the early group had appropriate skills and were able to maintain them. Meanwhile those in the late group did show significant increases, which the authors noted could be represent a "catch-up" period. The severe to profound group was complicated by the presence of children with cochlear implants. However, the authors recognized this, and further stratified the groups into those without cochlear implants and those with them. The study did outline the confounding variables that affected the cochlear implantation group, such as diminished sample size and difference in post implant acclimatization period.

It is often criticized that there is no consensus in the field on a critical age or cutoff of when children should be enrolled in early intervention. Thus, this study investigated this issue by further splitting the early enrollment group into those enrolled before 3 months and from 3 - 5.9 months. They found no significant change in language over time between these groups. The study additionally evaluates other published authors who argue for different cutoff ages, however, maintains that their present study has been the largest to date. It also demonstrates compelling evidence from their longitudinal analysis as to the importance of enrollment age, which they suggest as before 6 months, for optimal language learning.

The various methods of statistical analysis used, such as the Students *t* test, chi-square, and least mean squares, are tools regularly used in the field today and are appropriate for this study. They allow the significance between means to be evaluates, observed outcomes to be examined and to estimate unknown parameters, respectively. Furthermore, the study alludes to the effectiveness of the SKI*HI curriculum, as well as, mentions the advantages and limitations of using the LDS and LQs.

Overall, this was a well formulated study, presenting a legitimate research question, with a plausible rationale. The study had a large sample size and the methods were discussed in detail. The authors acknowledge limitations. Moreover, all the descriptive statistics were clearly expressed. It presented a 2a level of evidence. Thus, the validity is compelling and provides credible evidence for the clinical importance of early enrollment for children with hearing impairment.

Vohr et al (2011)

These authors put together a prospective longitudinal matched cohort study. It investigates the impact of early intervention for children with hearing loss on expressive vocabulary in the first 2 years of life. This is a follow up to a previous study done where the authors described the benefits of enrollment prior to 3 months on language development in children at 12 to 16 months. The present study had as a primary objective to assess the changes in vocabulary between 12 to 16 and 18 to 24 months in children with hearing loss compared to normally hearing children. They also sought to determine if those children enrolled at or before 3 months would have larger expressive vocabularies compared to those enrolled later. Additionally, they hypothesized that those who were enrolled in early intervention programs by 3 months would demonstrate a larger growth in vocabulary between 12 to 16 and 18 to 24 months, as opposed to those enrolled later.

All the participants of the study were identified in the Rhode Island newborn screening program and after giving consent, were referred to the Part C EI and the Family Guidance Program. Notably smaller than the aforementioned study, this study consisted of 31 children with hearing loss and 92 normally hearing children. The matching criteria for the cohorts were clearly outlined, and the authors elaborated on the boundaries that applied in situations where insufficient matches were found.

To evaluate language development, the MacArthur-Bates Communicative Development Inventory (MCDI) was completed by mothers at both time periods of interest. It is confirmed in the study that the MCDI has been normed, validated, and demonstrates high concurrent validity with other measures of early language. They further account for speakers of different languages and how they handled one family that used American Sign Language. Additionally, the maternal and child characteristics of the groups were presented in detail for comparison. The former statements allow some confidence in the legitimacy of the methods used and the subsequent results. The authors noted that some children were diagnosed with neuro-developmental co-morbidities by 18 to 24 months, whereas none were diagnosed in control participants. This was accounted for and data was reanalyzed, however, it contributed to a further decline in sample size.

As expected, results showed that at 12 to 16 and 18-24 months, children with hearing loss scored lower on most subtests of the MCDI, and produced fewer words as compared with their normally hearing counterparts. The study did find that those children with hearing loss who were enrolled by 3 months trended higher for words produced, and for words produced percentile was higher at 18 to 24 months. Comprehensively, the study also analyzed for effects of degree of hearing loss, finding significantly higher Words Produced percentile at both time periods for those children with hearing loss enrolled by 3 months. Somewhat ambiguous is the terminology used of 'trending higher' versus 'higher', which could be stated more explicitly or rendered with an explanation by the authors. Again in their discussion section, it is stated that their analyses indicate beneficial effects of enrollment by 3 months for all children with hearing loss, with trends for benefit for those with moderate to profound and mild hearing loss.

The authors further discuss results from other studies that have had similar findings, yet have used later cutoffs (i.e. 6 months and 11 months) for early intervention enrollment. They do however state that the lack of significance could be due to sample size and skewing of the data, but do not elaborate further. The study did find that all groups had an increase in vocabulary size between 12 to 16 and 18 to 24 months, but children with hearing loss enrolled after 3 months, and in particular those with moderate to profound losses, had the slowest growth. Although significant differences between the groups was not noted, the authors suggest that this could demonstrate that delayed enrollment in intervention has persistent detrimental effects on vocabulary. Moreover, the authors found that vocabulary growth between the 2 time periods in children with hearing loss did not continue at the same rate as the controls, which led them to suggest that rapid early vocabulary may be delayed or absent for them. There was no further elaboration, yet this certainly is an area for future research.

Overall, the study presented some valid clinical objectives with a justifiable rationale. Additionally, the longitudinal study had good follow-up, which can often be difficult to achieve. The tools used for the study were well founded, including standardized assessments. They further mentioned the performance of *t*-tests on continuous and X^2 on categorical variables, which are valid descriptive statistics for this study. It was important to use the t-tests to figure out if there was in fact a significant difference between the 2 means (before 3 months or after), and X^2 helped to summarize the discrepancies between the expected and observed outcome. The vocabulary however could have been more precise and direct. They authors also noted some limitations including the reduced sample size of children with hearing loss, and the fact that it was an observational study design does introduce some bias. The study provides a 2a level of evidence and comprehensively presents compelling evidence for the importance of early intervention. Nevertheless, although earlier intervention is always deemed better, there may need to be some additional research to see if 3 months is the most realistic proposed age cutoff for intervention.

Kennedy et al (2006)

This study was a quasi-experimental (between groups) design that examined the language ability of children after early detection of permanent childhood hearing impairment. The study was conducted in southern England, where screening for hearing loss is recommended before the age of 3 months, and appropriate follow-up intervention by 9 months. Although a larger number were initially identified, consent was obtained for 120 children with bilateral permanent hearing impairment. Reasons for this decline in number of participants were outlined in chart form. Those remaining were then divided in groups. Sixty-one children were born during periods of universal newborn screening, 57 had hearing impairment confirmed by 9 months, and there were 63 age matched children with normal hearing. Included in the aforementioned participants, were children enrolled in a similar previous trial. Speech and oral language skills were evaluated and compared to the age at which there was confirmed hearing impairment. In this study they specify their definition of early confirmation as that which occurs by 9 months of age. They further state that this was consistent with the U.S. Preventive Services Task Force benchmark at the time of 10 months.

For evaluation purposes, 2 unbiased researchers evaluated the child during a home visit. One interviewed the principal caregiver and completed the Children's Communication Checklist. Meanwhile, the child was separately assessed by another researcher using the Test for Reception of Grammar, The British Picture Vocabulary Scale (receptive language), the Renfrew Bus Story Test (expressive language), and the Ravens Progressive Matrices Test (nonverbal). These assessments were performed during mid-childhood at a mean of 7.9 years of age. A chart denoting additional characteristics of the child and family was provided.

Z-scores were derived in the study, and the methods for calculating the scores of the different language tests were outlined. Furthermore, the authors assessed associations between groups of ages of confirmed hearing and language and speech scores with two sample t-tests. Multiple linear regressions were also performed for stated potential confounders, along with examination of normality and homogeneity of residual variance. These methods contribute to improving the validity of the present study. Importantly, the authors noted that remedial therapy was provided to all participants, as it is a public service available in the United Kingdom for deaf preschool children. Details of hearing aid use and cochlear implantation were also given.

As may be expected, results indicated that confirmation of hearing impairment by 9 months was more significantly more common among those exposed to newborn hearing screening. Furthermore, those confirmed by 9 months had higher adjusted mean aggregate scores for receptive language than those children confirmed later, or who were not exposed to newborn screening at all. However, there were no significant differences in speech between those confirmed by 9 months and after 9 months, or between those exposed to newborn screening and those not. Thus, the scores were significantly higher for language, but not for speech. The authors do suggest that the stated potential benefit of screening and early confirmation (and subsequent intervention) of the sample may be conservative. They note this could be due to the delays between screening and confirmation (and intervention) that were present with the studied birth cohort, which have now been shortened.

The authors do provide a potential reason for the lack of significance of speech measures. They acknowledge the fact that speech was assessed by parent or professional report rather than a direct objective measurement. This introduces bias and reflects a lack of sensitivity. This also does lessen the strength of the methodology used, which in turn could put into question the defensibility of the results. However, the authors have noted this limitation, and indicate they are currently performing objective analyses. Moreover, the study did take into account severity of hearing impairment through regression models, without any change to results, which coincides with findings from other studies. This study further evaluates previously published studies on very similar topics, emphasizing their limitations, such as un-blinded assessments, leading to questionable reliability.

Overall, this study presents a warranted clinical question that relates both universal hearing screening and early confirmation to implications in language development. It is a quasi-experimental (between groups) design possessing a 2a level of evidence. The statistical methods used were sensible, however some more objective assessments are required for more conclusive results (particularly in speech development). The limitations of the study were mentioned, such as the necessity for a larger sample size and longer follow-up of the children's language skills. Yet, with all considered, this study does provide compelling evidence as to the benefit of screening, early confirmation of loss, and subsequent intervention on language development of children with hearing loss. Yet, like the other studies a definite critical age has not been determined.

Nelson, Bougatsos and Nygren (2008)

These authors conducted a systematic review to serve as an update for the 2001 US Preventive Services Task Force (USPSTF) Recommendation to detect moderate-to-severe, permanent, bilateral congenital hearing loss. At the time of the

recommendation, evidence was inconclusive regarding the beneficial effects of earlier screening and treatment on later language development mostly due to the design limitations of previous studies. However, since then, there have been several new studies published regarding this very subject.

The systematic review further delineates 3 key questions around which it organizes the studies: (1)Among infants identified by universal screening who would not be identified by targeted screening, does initiating treatment before 6 months of age improve language and communication outcomes? (2) Compared with targeted screening, does universal screening increase the chance that treatment will be initiated by 6 months of age for infants at average risk or for those at high risk? (3) What are the adverse effects of screening and early treatment? These questions are all pertinent to this critical review, and the last key question could serve to provide information for those apprehensive of the universal newborn screening and early intervention programs.

The rationale for universal newborn hearing screening was presented, providing its history and framework. In addition, the incidence, risk factors and potential adverse effects of a hearing impairment were all discussed. This was adequate in providing justifications for their present systematic review.

Methodology was discussed in detail, outlining analytic frameworks, key questions and specified applicable definitions. Furthermore, the search strategy was comprehensively and clearly described with main sources of literature obtained from Cochrane and Ovid Medline databases. Yet, other sources were also mentioned. Inclusion and exclusion characteristics, as well as ratings of study quality were accounted for with clear and adequate criteria.

The studies evaluated were separated by the specific key questions they pertained to. For Key Question 1, there was a good quality retrospective cohort study, a fair quality retrospective cohort study, and several equivocal observational studies. There was a consensus among all articles that better outcomes where achieved for children with hearing impairment that were identified and/or treated early versus late. Question 2 produced search results consisting of one good quality nonrandomized, controlled trial, some descriptive studies and a national survey of parents. Finally Question 3 studies included 2 fair quality cohort studies, 1 poor quality case-control study and 5 survey studies. All the aforementioned studies were rated independently according to stated criteria, incorporating sample size, as well as strengths and limitations of each.

This systematic review presented a very comprehensive overview of the studies published since the USPSTF recommendation. Together the studies concluded that children exposed to universal screening and earlier intervention had better language outcomes in mid-childhood. Additionally, it was found that infants at average and high risk who had universal newborn screening had earlier intervention. Due to current practice standards, the authors mentioned the difficult of evaluating both benefits and adverse effects of screening but confirmed that initial parent reactions to a screening non-pass to be worry, questioning and distress. However, for most these feelings resolved, and most reported on the benefits.

The authors concluded that universal newborn hearing screening does in fact seem to lead to earlier referral, diagnosis and treatment for infants with hearing loss with a beneficial effect on language and functional outcomes. However, they note that a more substantial amount of compelling evidence is necessary for the entire process which only begins with universal newborn hearing screening.

Overall, this systematic review thoroughly scrutinizes the most recent studies in terms of newborn screening in infants with hearing impairment. This provides a strong level 1 of evidence, which analyzes each study in good detail. However, it is not apparent if the studies were rated with blinding, or if a heterogeneity or moderator analysis was conducted. Nevertheless, the results were sufficiently relevant to clinical practice today, with important information concerning children with hearing impairment. It certainly delivers compelling evidence of the favorable impact of newborn screening and early intervention on the language outcomes of children.

Discussion

The studies reviewed present important findings relevant to children worldwide born with permanent childhood hearing impairment. The ramifications of childhood hearing impairment, a few of which include delayed language, learning, and school performance, are readily accepted worldwide. Upon investigation of the effects of newborn screening and subsequent early intervention on language outcomes for children, the results overwhelmingly indicate that early intervention for children with hearing loss is associated with later beneficial language outcomes. Most of the evaluated studies provide compelling evidence to support the latter. Thus, there is compelling evidence to suggest the necessity of newborn hearing screening and early intervention programs to improve outcomes and quality of life for children with hearing impairment. In addition, convincing arguments have been regarding the cost-benefit analysis. They assert that modern technology allows for efficient screening and early intervention program costs are more beneficial and reasonable than the higher cost to society further down the road. Yet, more studies are needed in this area to compile a larger

amount of compelling evidence for governments that are unconvinced of the cost effectiveness of EHDI.

The true uncertainty exists as to what the most appropriate age cutoff is for when intervention should occur to maximize the beneficial effects on functional, particularly on language, outcomes. All the examined studies vary on when this suggested age should be. For example, some studies propose intervention should be before 3 months, others before 6 months, and some before 9 months. Future research should focus on investigating the optimal age to maximize future outcomes for children with hearing impairment to receive intervention services. This way, resources can be directed in the appropriate manner, and children with hearing impairment are provided with the best advantage for ultimate language development.

Newborn hearing screening programs and particularly early intervention programs differ greatly throughout the world. More research is necessary when it comes to the actual setup and functioning of an early intervention program. Comparative studies are important to distinguish the highlights and limitations of each program and amalgamate them into one. This way early intervention programs can have a well-founded framework, and implementation can be more accessible and valid. Moreover, standard guidelines can help to resolve the follow-up issues that commonly occur between the screening and intervention stages.

Clinical Implications

There is widespread consensus that hearing impairment, particularly when unconfirmed or without proper intervention, is associated with difficulties in several function areas, including language development. This critical review has examined several current studies that provide compelling evidence as to the importance of newborn hearing screening and subsequent early intervention enrollment for children with hearing impairment when it comes to optimizing their language development throughout childhood. The studies clearly show advantages and better language outcomes for most of the children who did have early enrollment in intervention, often regardless of hearing severity. This has huge clinical implications in the field of clinical audiology.

In Canada, for those provinces that have newborn hearing screening, there needs to be better follow up to make sure that those infants with hearing loss detected through newborn screening are receiving the proper intervention they need at an early age. For those provinces that have yet to adopt a newborn screening and early intervention program, the reviewed studies certainly provide persuading evidence for one to be instituted as the benefits for the children outweigh the costs.

The critical review also draws attention to areas of future research which have been mentioned previously in the paper. However, most importantly is the need for consistency in the framework and administration of early intervention programs to ensure that globally children with hearing impairment are receiving the best opportunities to optimize their language development and quality of life.

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