The Rationale for Neonatal Hearing Screening
Raisons motivant le dépistage néonatal de la surdité

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Abstract

The object of this study was two-fold. First, the route to diagnosis of hearing loss and at-risk for hearing loss status was determined for 613 children with documented history of hearing aid use. The second objective was to document the age of diagnosis of hearing loss and of hearing aid fitting in these children. The results indicated that 9.8% (n=60) had been screened in infancy with auditory brainstem response subsequent to discharge from a neonatal intensive care nursery, while the remaining 90.2% (n=553) were referred by their physician. Fifty-seven percent of the infants had no risk factor for hearing loss in their history. The average age of diagnosis for children who were screened was 5.7 months and over 2.8 years for the children who were referred. Similar trends were found for the age of hearing aid fitting.

Abrégé

La présente étude vise deux objectifs. D'une part, elle retrace comment le diagnostic de surdité est survenu et l'état de risque chez 613 enfants porteurs de prothèses auditives. D'autre part, elle cherche à recenser l'âge auquel le diagnostic de surdité a été posé et l'âge auquel ces enfants ont commencé à porter un appareil auditif. Les résultats indiquent que 9,8 % (n=60) d'entre eux ont fait l'objet d'un test de dépistage en très bas âge avec la méthode des potentiels évoqués auditifs après être sortis d'une unité néonatale de soins intensifs, tandis que 90,2 % (n=553) ont été référés par leur médecin. Quelque 57 % des bébés n'avaient aucun facteur de risque de surdité. Les enfants qui ont reçu un test de dépistage avaient en moyenne 5,7 mois et ceux qui ont été référés avaient 2,8 ans. L'âge à l'appareillage reflète la même tendance.

Key words: hearing loss, children, newborn hearing screening, age of diagnosis

Permanent bilateral hearing loss is present in 1.6 to 6 per 1000 infants in the well baby nursery population (Parving, 1993; Watkin, Baldwin, & McEnery, 1991; Mauk & Behrens, 1993) and in 2 per 100 infants who graduate from a neonatal intensive care unit (NICU; Durieux-Smith, Picton, Edwards, MacMurray, & Goodman, 1987; Galambos, Hicks, & Wilson, 1984; Hyde, Riko, Corbin, Moroso, & Alberti, 1984). The consequences of an undetected hearing loss include significant delays in language, psycho-social development and academic achievement. These delays are apparent not only in children with severe to profound losses (Geers & Moog, 1989; Moeller, Osberger, & Eccarius, 1986) but also in those with mild and moderate hearing losses (Davis, Elfenbien, Schum, & Bentler, 1986).

In a recent study on the impact of the age of identification on language development, Yoshinaga-Itano, Sedey, Coulter, and Mehl, (1998) found that children whose hearing losses were identified by six months of age achieved near normal language development and demonstrated significantly better language scores than children identified after six months of age. These results suggest that early identification is critical for children with a hearing loss.

The average age of identification of a significant hearing loss, in children in the United States, has been reported as between 2½s and 3 years of age (Gustason, 1989; National Institutes of Health [NIH], 1993; Welsh & Slater, 1993). Lesser degrees of hearing loss can go undetected for much longer. In order to address this problem the American Joint Committee on Infant Hearing was formed and has published recommendations and position statements over the years (American Academy of Pediatrics, 1982, 1994; Joint Committee on Infant Hearing, 1990, 2000). These position statements have reflected the changes which have taken place in the technology to be used for newborn hearing screening and have also redefined the population to be screened.

The 1990 Joint Committee statement clearly recommended the use of the auditory brainstem response s(ABR) for hearing screening while discouraging the screening of newborns using behavioural methods. The 1994 statement affirmed the use of physiologic measures (i.e., ABR and otoacoustic emissions[OAEs]) and addressed the need to identify all infants with hearing loss. Because risk factor screening advocated in previous position statements (1982, 1990) had been shown to identify only 50% of infants with significant hearing loss (Elssmann, Matkin, & Sabo, 1987; Pappas, 1983; Mauk, White, Mortensen, & Behrens, 1991), the 1994 statement endorsed the recommendations of the NIH (1993) for the screening of all infants. The American Joint Committee (1994, 2000), the NIH (1993) and the American Academy of Pediatrics (1999) have recommended that infants with a hearing loss should have a confirmed diagnosis by three months of age and be enrolled in a family centered intervention program by six months of age.

In the US, more than twenty states have put in place, or are in the process of developing, universal hearing screening programs. The results of such programs indicate that early intervention, including amplification, can be made available to hearing-impaired newborns within 3 to 6 months of their birth (Mehl & Thompson, 1998).

In Canada, there has been no systematic approach to early diagnosis and management of hearing loss in infants. Screening activities have targeted high risk infants (Durieux-Smith & Picton, 1985; Hyde et al., 1984), and have been the result of local, rather than national initiatives.

The Children's Hospital of Eastern Ontario (CHEO) is a regional tertiary-care paediatric hospital serving children in a large geographical catchment area. Since 1981, graduates from the Neonatal Intensive Care Unit (NICU) at CHEO, have been systematically screened using ABR. The NICU graduates represent the only population in the area which is systematically screened for hearing loss. All other children suspected of having a hearing problem are referred to the Audiology department by their physician. Children who are referred to this center may or may not have risk factors (American Academy of Pediatrics, 1994) in their histories. The main objectives of this retrospective study were: to establish the route to identification of hearing loss and the risk status of a group of children wearing hearing aids, and to document the age of diagnosis of hearing loss and of hearing aid fitting in systematically screened children and in those referred by physicians.

Method

Study population

The data were gathered from a retrospective review of the medical and family histories of 855 children born between 1974 and 1995, who had been diagnosed with a hearing loss and fit with hearing aids at the Audiology Clinic of the Children's Hospital of Eastern Ontario (CHEO). All of the children had a diagnosis of a non-medically treatable hearing loss requiring amplification.

The review revealed that of the 855 children, 103 (12%) had an acquired hearing loss due to chronic middle ear disease (n = 59), meningitis (n = 30) or the administration of ototoxic medications (n = 14). These cases were excluded from the analysis since the focus of this study was to determine the age of diagnosis in congenital hearing losses. In addition, 139 of the 855 children had a unilateral hearing loss. Since the management of these cases is different than for children with a bilateral hearing loss, they were not included in the analysis. The total sample size for the study was therefore 613.

Route to Identification

CHEO's Audiology Clinic has been in operation since 1974. Referrals to the clinic are made through primary care community physicians or through other CHEO clinics and physicians. In addition, in 1981, CHEO established a screening program using click ABRs, for all newborns admitted to its NICU. This is a tertiary intensive care unit and all babies admitted to the unit have been transferred from the hospital of birth. The protocol and prognostic validity of the click ABR technique have been reported previously. Approximately 2% of CHEO NICU graduates have a hearing loss requiring amplification (Durieux-Smith et al., 1987).

The sample of children included in the study was divided into three groups. The first group included children (n = 60) who had been systematically screened in infancy with ABR because of admission to the CHEO NICU (*"screened"*). The second group included children (n = 203) referred by their physicians and who had risk factors in their histories (*"referred with high risk factors"*). The final group included children (n = 350) who were referred by their physicians with no apparent medical or genetic history (*"referred with no high risk factors"*) that would explain their hearing loss. Since the screening program was established in 1981, babies who had been admitted to the CHEO-NICU between 1974 and 1980 had not been systematically screened and fell into the second group.

Risk Status

The presence or absence of high risk factors for hearing loss in the histories of the 613 children was established by a comprehensive review of information from several sources including the medical charts at CHEO, a parental interview and the medical records of the birth hospital, where available. Individual risk factor categories were defined based on the 1994 Position Statement of the Joint Committee on Infant Hearing and are described in Table 1. Some children fell in more than one risk category. For example, some babies who were admitted to a NICU at birth may have had a syndrome or craniofacial anomalies. In order not to include these cases twice in different etiology categories, they were classified as NICU graduates.

Table 1. Definition of High Risk Factors for Hearing Loss for the Population of Hearing Aid Users.[1]

Category	Definition
Family History	- parent or sibling with a similar childhood hearing loss
Craniofacial anomalies	- morphological abnormalities of the pinna, ear canal or middle ear not associated with an identified syndrome
Syndromic Hearing Loss	- stigmata or other findings associated with a syndrome known to include hearing loss
In Utero Infections	- prenatal exposure to a TORCH infection (positive laboratory results or definitive opthamological evidence)
NICU graduates[2]	- admission to a NICU at birth: neonatal histories included at least one of the high risk indicators for use with neonates (birth weight less than 1500 g, hyperbilirubinemia, ototoxic medications, low Apgars or mechanical ventilation for more that 5 days)
Unknown	- no apparent medical or genetic history that would explain the hearing loss

1. Based on the Joint Committee on Infant Hearing 1994 Position Statement.
2. This category included children admitted to the CHEO NICU before and after the screening. program was established, and to NICUs in other hospitals.

Age of Diagnosis and of Hearing Aid Fitting

The ages of diagnosis and hearing aid fitting were documented from the medical charts. Diagnosis of hearing loss generally coincided with a recommendation for amplification. The age of hearing aid fitting represents the first fitting with a child's personal amplification device(s).

The ages of diagnosis and of hearing aid fitting were determined for children born between 1974 and 1995. The sample was divided into four birth year categories. The categories included children born between 1974 and 1980, 1981 and 1985, 1986 and 1990, and 1991 and 1995.

The ages of diagnosis and of hearing aid fitting were compared for children, in the different birth year categories, who had been systematically screened in infancy or who were referred. Since the screening program started in 1981, the comparison between the screened and the referred groups was made for the children born since that time. Additionally the ages of diagnosis and hearing aid fitting for referred children born since 1974 were examined over all four birth year categories to determine if there had been a change in the ages of diagnosis and hearing aid fitting over time.

The effect of the degree of hearing loss on the age of diagnosis was also examined. Degree of hearing loss was defined using the pure tone average of the better ear. The pure tone average was calculated as the average of the thresholds for 500, 1000 and 2000 Hz and classified as mild (25 to 40 dB), moderate (41-55 dB), moderate-severe (56-70 dB), severe (71-90 dB) and profound (91+ dB) (Goodman, 1967).

Results

Gender Distribution

The gender distribution for the sample of 613 children is shown in Table 2. There was no significant difference in the gender distribution of screened and referred children diagnosed with hearing loss $s(e^{ra2}(2, N = 613) = 0.37, p > .05)$.

Table 2. Gender distribution for the sample of 613 hearing aid users.

	Screened	Referred with high risk indicators	Referred with no high risk indicators
Males	30	99	173
Females	30	104	177

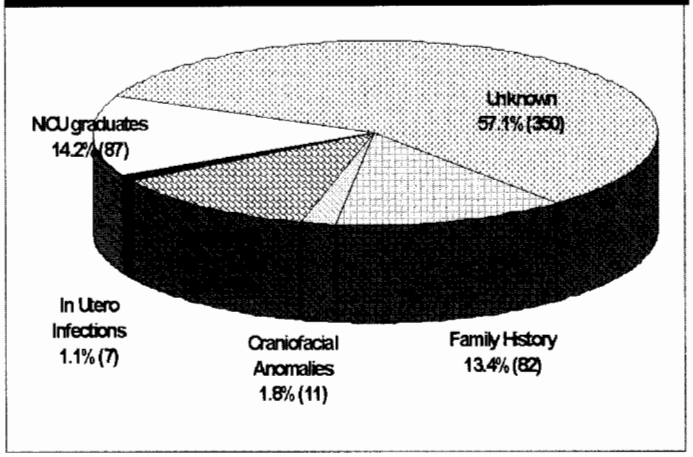
Route to Identification and Risk Status

Of the sample of 613 children wearing hearing aids, 60 (9.8%) had been systematically screened in infancy through the CHEO NICU program. The remaining 553 (90.2%) children were referred through their physicians.

The distribution of high risk factors for the sample of 613 children is shown in Figure 1. More than half of the children (*57.1%*) had no known risk factors in their histories. In the group of children with high risk factors in their histories, admission to a NICU , family history of hearing loss and diagnosis of a syndrome constituted the most frequent high risk factor categories.

Details of the route to identification for the 87 babies in the NICU category are seen in Table 3. Of the 87 babies with a hearing loss who had been admitted to a NICU, 60 had been identified with hearing loss through the CHEO NICU screen-

Figure 1. Risk Status for the 613 Children, Wearing Hearing Aids, Born Between 1974 and 1995.



ing program and 27 had been referred by a physician. Of the 27 referred babies, 6 had been admitted to the CHEO NICU when the screening program was in place. Four of these infants had passed the click ABR screen, while in two major medical concerns precluded testing.

Of the four children who had passed ABR and were eventually referred and found to have a permanent hearing loss requiring amplification, the time elapsed between ABR screen and diagnosis of the hearing loss ranged from one and a half years to four years. The stay in the NICU ranged from one month to five months. All of these children were very sick during their neonatal period and three of the four received ototoxic medication. Two of the children had losses in the 1K to 4K frequency range of moderate to severe and moderate to profound degree respectively. One child had an unusual configuration of hearing loss which was rising/falling with normal hearing sensitivity in each ear at one frequency between 1K and 4K. The fourth had Down's syndrome and was in the NICU for five months. This child was never tested with conventional behavioural audiometry and ABR results at 2.4 years showed a profound bilateral hearing loss.

Table 3. Route to Hearing Loss Identification of 87 Babies in the NICU Risk Category.

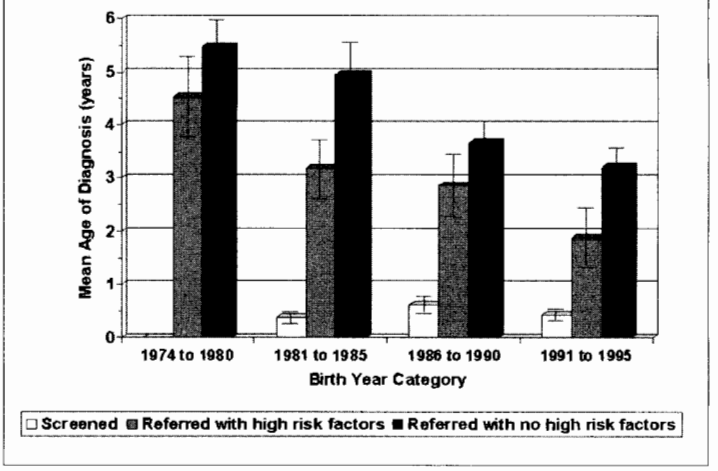
Route to Referral	Description	N
Screened	admission to the CHEO-NICU between 1981 and 1995	60
Referred	admission to the CHEO-NICU prior to 1981	9
	admission to a NICU at another hospital	12
	admission to the CHEO-NICU between 1981 and 1995 and passed ABR screen	4
	admission to the CHEO-NICU between 1981 and 1995 and were too sick to be screened	2

Of the children who were too ill to be tested, one had Down's syndrome and was in the NICU for two months. This child was tested with conventional audiometry between two and three years of age and found to have normal hearing sensitivity. He was diagnosed with a moderate hearing loss in the right ear and a profound hearing loss in the left at 3.6 years of age and fit with amplification. The other child was in the NICU for four months and then transferred to the long term care ward to be finally discharged at six years of age. This child has a profound bilateral sensorineural loss.

Age of Diagnosis

Figure 2 shows the mean ages of diagnosis for each birth year category for the screened and the referred groups. The referred group was divided into children with and without high risk factors in their histories. A 2 X 4 factorial analysis of variance (ANOVA) was undertaken to investigate if differences in the age of diagnosis existed as a function of referral group (i.e., children referred with risk factors in their histories and children referred with no risk factors) and birth year category (i.e., 1974 to 1980 up to and including 1991 to 1995). The analysis indicated that for the referred groups there had been a significant decrease in the age of diagnosis over time (F (3, 545) = 16.8, $p < .001$, $eta^2 = .084$) from a

Figure 2. Age of Diagnosis of Hearing Loss (Bars Represent 95 % Confidence Intervals).



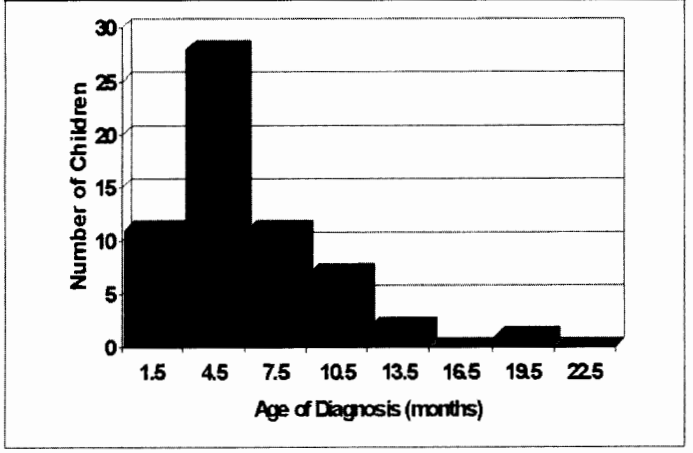
mean of 5.2 years (*95% CI*, 4.7 to 5.7 years) in the time period of 1974 to 1980 to a mean of 2.8 years (*95% CI*, 2.4 to 3.1 years) in the time period of 1991 to 1995. In addition, referred children with risk factors in their histories (M = 3.3, *95% CI*, 2.9 to 3.7 years) were diagnosed significantly sooner than those with no known etiology (M = 4.6, *95% CI*, 4.2 to 4.9 years) for their hearing loss (F (1, 545) = 21.4, $p<.001$, eta^2 = .038).

Systematic screening was initiated at CHEO in 1981. A oneway ANOVA was performed to determine if differences in the age of diagnosis of hearing loss existed as a function of group (i.e., screened vs referred). The analysis indicated that systematically screened children were diagnosed significantly sooner (M = 0.48 years, *95% CI*, 0.40 to 0.56) than referred children with risk factors (M = 2.76 years, *95% CI*, 2.36 to 3.16) and referred children with no risk factors (M=4.01, *95% CI*, 3.66 to 4.35) who were born during the same time periods (F (2,415) = 57.3, $p<.001$, eta^2 = .216).

Figure 3 shows the distribution of the age of diagnosis for the screened group. The average age of diagnosis for the screened group was 0.48 years (5.7 months, *95% CI*, 4.8 to 6.7). Only 11/60 (18%) were diagnosed by 3 months of age, 40/60 (*67%*) by 6 months of age and 57/60 (*95%*) by one year. Three cases (*5%*) were diagnosed at over one year of age, two of these children were very ill and for the other, the reason for the delay was not clear from the chart.

Figure 4 shows the relationships between the age of diagnosis and the degree of hearing loss for the three referral groups. Separate one-way ANOVAs were undertaken to determine if age of diagnosis varied as a function of degree of hearing loss. For the screened group there was no significant relationship between the age of diagnosis and the degree of hearing loss (F(4, 45) = 1.06, $p>.05$, eta^2 =.085). For the referred group with high risk indicators, there was a significant inverse relationship between the degree of hearing loss and the age of diagnosis (F(4,180) = 6.3, $p<.01$, eta^2 = .123). The relationship was the strongest for the referred group with no risk factors (F(4, 332) = 50.9, $p<.001$, eta^2=.380).

Figure 3. Distribution of Age of Diagnosis for Screened Children.



Age of Hearing Aid Fitting

Figure 4. Degree of Hearing Loss and Age of Diagnosis (Bars Represent 95 % Confidence Intervals).

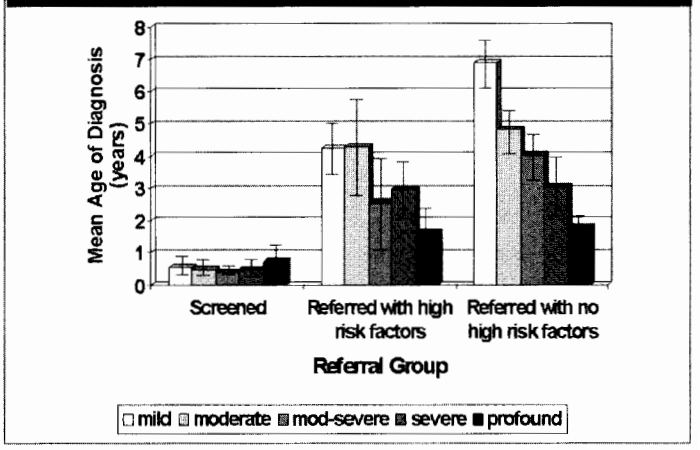
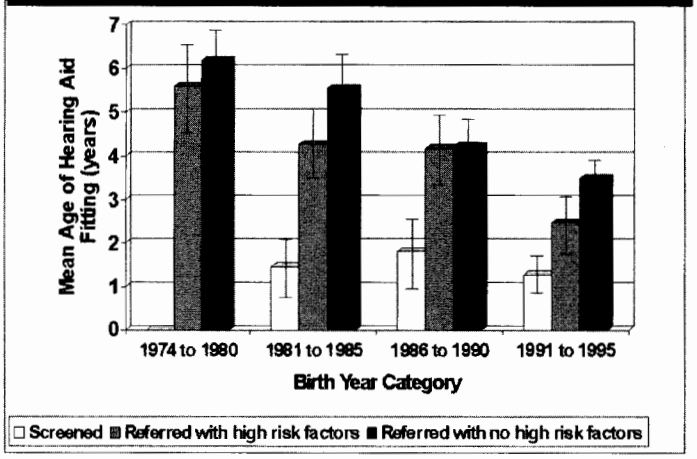


Figure 5 shows the distribution of the age of hearing aid fitting for each birth year category for the screened and referred groups. A 2 X 4 factorial analysis of variance was undertaken to investigate if differences in the age of hearing aid fitting existed as a function of referral group (i.e., children referred with risk factors in their histories and children referred with no risk factors) and birth year category (i.e., 1974 to 1980 up to and including 1991 to 1995). The analysis indicated that for the referred groups there had been a significant decrease in the age of hearing aid fitting over time (F (3, 540) = 16.7, $p < .001$, eta^2 = .085) from a mean of 6.0 years (*95% CI*, 5.4 to 6.6 years) in the time period of 1974 to 1980 to a mean of 3.1 years (*95% CI*, 2.7 to 3.5 years) in the time period of 1991 to 1995. In addition, referred children with risk factors in their histories (M = 4.3, *95% CI*, 3.9 to 4.8 years) were fit with hearing aids significantly sooner than those with no known etiology (M = 5.1, *95% CI*, 4.7 to 5.5 years) for their hearing loss (F (1, 540) = 6.05, $p<.001$, eta^2 = .011).

A one-way ANOVA was undertaken to investigate if differences in the age of hearing aid fitting existed as a function of group (i.e., screened vs. referred). The analysis indicated

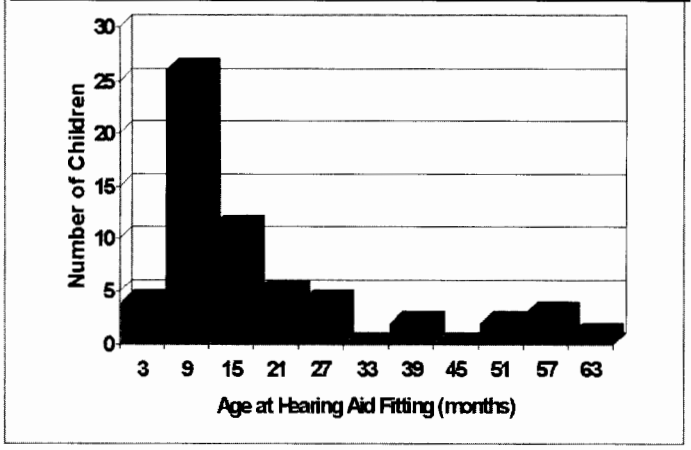
Figure 5. Age of Hearing Aid Fitting (Bars Represent 95 % Confidence Intervals).



that systematically screened children were fit with hearing aids significantly sooner (M = 1.5 years, *95% CI*, 1.1 to 1.8) than both groups of referred children who were born during the same time periods (F (2, 411) = 29.0, p <. 001, eta^2 = .126).

For the screened group the average age of first hearing aid fitting was 1.5 years (M=17.7 months, *95% CI*, 13.7 to 21.7 months). Only 5/60 (*8%*) children were fit with hearing aids by 6 months of age and 31/60 (*52%*) by 12 months. The majority of the screened group were fit by 24 months (*78%*) and *83%* were fit with hearing aids by 36 months. Eight children were fit with hearing aids after their third birthday. Figure 6 shows the distribution of the age of hearing aid fitting for the screened group. There are 16 cases where, despite the early diagnosis of hearing loss, the delay to the fitting of hearing aids was more than one year. These children either had multiple health problems, middle ear problems that delayed the fitting of hearing aids, social problems that resulted in poor follow-up or had fluctuating thresholds.

Figure 6. Distribution of Age of Hearing Aid Fitting for Screened Children.



Discussion

Of the 613 hearing aid users reviewed for this study only 60 (9.7%) had been identified through systematic hearing screening during the neonatal period. These children had been graduates of the CHEO tertiary neonatal intensive care unit. The CHEO NICU is a one of three neonatal intensive care units in the local area and although the admission to a NICU warrants hearing screening (Galambos et al., 1984; National Institutes of Health [NIH], 1993), the graduates of the other two NICUs were not systematically screened. The screening program at CHEO only targeted the neonates from the CHEO NICU because this population was easily accessible. This type of inconsistent screening activity is representative of the patchwork approach to screening which has taken place in Canada and which has been the result of local rather that provincial or national initiatives.

The determination of risk status in the population of hearing aid users in the study indicated that 57% had no known risk factors in their histories. This is somewhat higher than the 50% unknown etiology reported in other studies (Elssman et al., 1987; Jacobson & Jacobson, 1990; Mauk et al., 1991; National Institutes of Health [NIH], 1993; Watkin et al., 1991). This slightly higher percentage could be due to the fact that children with acquired hearing loss due to known risk factors (e.g. meningitis) had not been included in the sample.

The high percentage of unknown etiology in this Canadian population, lends support to the argument for the universal screening of infants. More that half of the children who wore hearing aids had no risk factors in their histories and would not have been screened if a program based on the high risk register had been in place.

Four children from the CHEO-NICU initially passed the ABR screen, however were later found to have a hearing loss requiring amplification. Three of these children most likely developed the hearing loss after the screen. Children who have had relatively long stays in a neonatal intensive care unit may develop a hearing loss after discharge (Nield, Schrier, Ramos, & Platzker, 1986). The stay in the NICU for the three children ranged from 4 weeks to 5 months and all had been treated with gentamicin. The fourth child had an unusual hearing loss with a rising configuration with normal thresholds at 2000 and 4000 Hz in the right ear and a rising-falling configuration with a normal threshold at 1000 Hz in the left ear. When used as a threshold measure, the click-evoked ABR is highly correlated with hearing sensitivity in the frequency

range from 1 to 8 kHz (Durieux-Smith, Picton, Bernard, & MacMurray, 1991; Hyde, Riko, & Malizia, 1990). Some infants with hearing loss but with normal hearing sensitivity at one frequency between 1 and 8 kHz can pass the newborn hearing screening. These cases clearly illustrate the need to include, in universal screening programs, surveillance throughout infancy and early childhood for those children at risk of developing a hearing loss subsequent to the neonatal period.

Two children with hearing loss who were NICU graduates had never been screened. Although generally the aim of neonatal screening programs such as the CHEO program is to test all infants discharged from the NICU, this mays not always be possible. Galambos, Wilson, and Silva, (1994) reported that only 58.3% of their NICU babies were, in fact, screened between 1984 and 1991. Reasons for not screening included transfer to other facilities, babies who were never scheduled for screening and attending physicians who did not see the need for hearing screening. In the CHEO study, the two babies who were not screened were too sick to be tested and were eventually lost to follow-up until they were referred for audiological evaluation because of a concern for their hearing. This clearly indicates the need for a tracking system which will ensure that babies who are not initially screened are referred for testing at a later date.

The ages of diagnosis and of hearing aid fitting were determined for the sample of 613 hearing aid users of which 60 had been systematically screened. It is assumed that the hearing losses in the referred groups were congenital. It is possible, however, that some of these children could have developed a hearing loss in their early years. It has been estimated that 20-30% of children who subsequently have a hearing loss will develop it during early childhood (National Institutes of Health [NIH], 1993). The retrospective nature of the study makes it impossible to determine which children in the referred category could have developed a hearing loss later in life but it is unlikely that all children in the referred group fell in this category. The sample may have included some children with late diagnosis secondary to a progressive genetic hearing loss although they would represent a very small portion of the study population. In addition, children with known risk factors associated with acquired hearing loss (e.g. meningitis) were not included in the sample.

The ages of diagnosis of screened children were significantly lower than for referred children. Of the systematically screened children, only 13/60 (22%) were diagnosed by three months and therefore fell within the recommendation of the NIH (1993) and the American Academy of Pediatrics (1994). Three children (5%) in this group were diagnosed after one year of age. Children graduating from a NICU are often plagued with serious medical problems which take priority over the diagnosis of hearing loss and meeting the goal of diagnosis by 3 months of age poses a real challenge.

The ages of diagnosis for the referred children were significantly higher than for screened children and were seen to improve over time. An improvement in the age of diagnosis over time has been noted by others (Elssman et al., 1987; Parving, 1993; Mauk et al., 1991) and may reflect a better awareness by physicians. Delay in diagnosis of referred children has been attributed to a lack of awareness on the part of health providers of the signs of hearing loss in children, the availability of diagnostic technology that allows for early diagnosis and of the value of early intervention (Ruben, 1991; Shah, Chandler, & Dale, 1978). Another contributing factor to the improvement in the age of diagnosis over time is the availability of better diagnostic methods such as the ABR, which have contributed to the accuracy of audiological diagnosis, particularly in very young children.

The mean age of diagnosis of 2.8 years for referred children born between 1991 and 1995 is clearly unacceptable. This compares to the age of diagnosis reported for populations with no systematic infant screening programs (Gustason, 1989; Harrison & Roush, 1996; Mace, Wallace, Whan, & Stelmachowicz, 1991; Mauk et al., 1991; Mehl & Thompson, 1998; Welsh & Slater, 1993). The somewhat lower age of diagnosis for referred children, who had risk factors for hearing loss in their histories, may indicate an increased awareness of primary care physicians of risk factors associated with a hearing loss and/or parents who are very attentive to their child's behaviour because of the presence of medical conditions in their histories. Similar findings have been reported by others (Harrison & Roush, 1996; Mace et al, 1991; Mauk et al, 1991; Stein, Jabaley, Spitz, Stoakley, & McGee, 1990; Vartiainen & Karjalainen, 1997).

The degree of hearing loss had a significant effect on the age of diagnosis for referred children but not for those who had been systematically screened. The more apparent symptoms in children with severe and profound hearing losses most likely prompted parents to seek an audiological evaluation sooner. The inverse relationship between age of diagnosis and degree of hearing loss is well documented in the literature (Elssman et al., 1987; Harrison & Roush, 1996; Kittrell & Arjmand, 1991; Vartiainen & Karjalainen, 1997).

The ultimate test of the effectiveness of a neonatal hearing screening program is the age at which children diagnosed

with a hearing impairment are fit with amplification and habilitation initiated. In this study, children who had been systematically screened in infancy were fit with hearing aids sooner than children who were referred. For the referred children , the pattern of hearing aid fitting reflected the age of diagnosis and over time the age of hearing aid fitting improved.

For the children who had been systematically screened in infancy, 52% were fit with amplification by one year of age. Only 8% of the children were fit by the recommended age of six months. A total of 83% of the children were fit by three years of age. These findings are similar to those reported by Galambos et al. (1994) who collected data on NICU graduates over an 8 year period. Only 15% of 47 graduates were fit with hearing aids by 6 months of age and by the third birthday, 20% had still not been fit with amplification. The reasons for these delays are similar for both studies. Delays can be traced to lengthy diagnostic procedures which can go on for months in difficult cases and also to the fact that fitting of hearing aids can have relatively low priority in the treatment of children with complex medical conditions.

In this study, the screening activity took place in an audiology department which provided diagnostic and habilitation services. The delay between diagnosis and intervention can not be attributed to a lack of continuity between screening, diagnostic and management activities as reported in other studies (Stein et al., 1990).

Summary and Conclusions

The results of this study illustrate the patchwork approach to neonatal hearing screening which has taken place in Canada. Only 10% of the hearing aid users had been identified through a systematic hearing screening program. The results also indicate that systematic screening significantly lowers the age of diagnosis and of hearing aid fitting for children with all degrees of hearing loss. The population screened in the study included only the graduates of one of the local neonatal intensive care units (NICU), most of whom were not diagnosed or fit with hearing aids within the recommended time frame of the NIH (1993) and the American Joint Committee on Infant Hearing (1994). Infants graduating from a tertiary intensive care unit represent a special challenge and the proposed guidelines may need to be modified for this population. Screening may miss infants who develop a hearing loss after the neonatal period or who are discharged prior to screening. Screening programs need to include tracking and surveillance as an integral part of the system. Finally, more that half of the children wearing hearing aids had no risk factors in their histories lending support to universal screening rather that screening based on risk factors.

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