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Author

Hyde, M, Punch, R, Grimbeek, P

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Factors predicting outcomes of paediatric cochlear implantation

Factors predicting functional outcomes of cochlear implants in children

Authors: Merv Hyde, School of Education and Professional Studies, Griffith University, Queensland, Renée Punch, School of Education and Professional Studies, Griffith University, Queensland, Peter Grimbeek, Griffith Graduate Research School, Griffith University, Queensland

Corresponding author: Dr. Renée Punch, School of Education and Professional Studies, Griffith University, Gold Coast campus, Queensland, 4222, Australia.

Telephone: +61 7 5552 8453

Facsimile: +61 7 5552 8599

E-mail: r.punch@griffith.edu.au

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Keywords: cochlear implants, children, predictors, functional outcomes

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Abstract

This article reports the relationships between a large number of child and family related factors and children's functional outcomes, according to parental report, in the domains of spoken language communication, social skills and participation, academic achievement, and independence and identity, through a series of step-wise regression analyses. Parents of 247 children who had received cochlear implants in three eastern states of Australia completed a survey on their expectations and experiences of their children's outcomes with cochlear implants. A number of the independent variables were found to be associated, either positively or negatively, with children's outcomes. Implications for cochlear implant professionals, early intervention programs and educational authorities are discussed.

Introduction

Cochlear implantation is now the predominant response to profound and, increasingly, severe childhood deafness in most developed nations. Given the growing rate of early detection of congenital deafness due to the introduction of universal newborn hearing screening programs now common in many countries, the trend towards high rates of implantation in young children and infants is expected to continue. Accompanying the increasing incidence of paediatric cochlear implantation, myriad studies investigating children's outcomes have been reported in the literature. The majority of these have focused on spoken language development, whereas broader outcomes including educational and psychosocial outcomes, as well as family expectations and experiences, have received less attention in research studies (Spencer & Marschark, 2003; Thoutenhoofd et al., 2005). In their comprehensive review of paediatric cochlear implantation studies published between 1994 and mid-2001, Thoutenhoofd and his colleagues classified the findings from the studies as robust, but raised several pertinent issues, such as the limitations involved in the assessment of children's speech production and perception, and emphasized that it is important to assess how children are functioning and communicating "in their day-to-day lives, after implantation, rather than in clinical tests" (p. 243), and from parents' perspectives, which may more closely reflect the functional outcomes of children in everyday life situations than assessments made in clinical settings. Similarly, other researchers have suggested the importance of including broader outcome measures, particularly parental report, in the assessment of young children's outcomes (Knors et al., 2003; Lin et al., 2008).

Factors predicting outcomes of paediatric cochlear implantation

Given the variability in outcomes among children with cochlear implants, with not all children doing well (Hawker et al., 2008; Inscoe et al., 2009; Pisoni et al., 2008), it is important to increase understanding of the factors that influence outcomes. Many studies have reported on factors associated with positive outcomes, most commonly in the domains of speech perception and production, language development, and reading abilities. Independent variables most commonly included are child-related variables such as age at implant, communication mode or approach followed, type of educational setting, and IQ, and family-related variables such as socioeconomic status (SES).

A great deal of research has reported benefits from early age at implantation. For instance, Tait, Nikolopoulos, and Lutman (2007) found significant gains in vocal and auditory preverbal skills in children implanted between 1 and 2 years of age compared to children implanted between 2 and 4 years of age. Connor et al. (2006) reported benefits for speech and vocabulary outcomes for children implanted before 2.5 years over and above benefits attributable to longer use of the device. In a small group of children implanted in Australia between the ages of 14 and 27 months, Spencer (2004) found benefits of younger implantation on measures emphasising syntax knowledge and skills. A study of children who received implants between 11 and 40 months of age indicated positive effects of earlier implantation on expressive language (Tomblin et al., 2005). Nicholas and Geers (2007) found higher levels on measures of spoken language development in children who had received implants between 12 and 18 months of age compared to children implanted between 18 months and 3 years, even with the same duration of implant use. They concurred with Tomblin et al.'s conclusion that implantation in the first half of the second year of life produces an early burst of language

Factors predicting outcomes of paediatric cochlear implantation

growth that does not occur in children implanted after the age of 18 months. A recent study of 153 children implanted between 11 months and 5 years of age, with at least one year of implant use, attending educational settings using auditory-oral approaches, reported that age at implant had a significant, although small, effect on spoken language scores after gender, IQ, and parents' education level were held constant (Geers et al., 2009).

Research investigating reading outcomes also points to earlier implantation as a positive influence. In a study using structural equation modelling to examine factors affecting reading comprehension, Connor and Zwolan (2004) found that younger age at implantation had a direct positive effect on the reading skills of 91 children implanted at a wide range of ages. In the UK, Archbold et al. (2008) found a marked effect of age at implantation on reading outcomes; children implanted before 42 months of age achieved age-appropriate reading levels at both 5 and 7 years post-implant, whereas children implanted over that age did not.

However, age at implant has not proved a significant predictor of outcomes in all studies. In their study of children aged 8 and 9 years with 4 to 6 years of implant use, Geers and her colleagues found that age at implantation did not predict any of the speech perception, speech production, language skills or reading outcomes they assessed when other factors were held constant. They reported that nonverbal IQ scores and oral classroom communication mode (as compared to Total Communication) were significant predictors of positive outcomes. They also found some of the outcomes to be predicted by size of family (belonging to a smaller family predicted positive outcomes), gender (being female predicted positive outcomes), family SES, length of daily time using the

Factors predicting outcomes of paediatric cochlear implantation implant, and using an updated speech processor (Geers et al., 2003a; Geers et al., 2002; Geers et al., 2003b; Tobey et al., 2003). The authors suggested two possible reasons for the unexpected finding that age at implant did not have a significant effect on outcomes: all the children in the sample received their implant after 22 months of age and so may have missed the period of greatest added advantage from very early intervention; and any advantage that may have existed from early implantation may not have remained apparent at the test age of 8 or 9 years (Geers et al., 2003a).

Schorr, Roth, and Fox (2008) found that age at implant predicted positive outcomes on measures of receptive vocabulary and phonological memory, but not on other aspects of metalinguistics and morphology. Their sample included children with a wide range of ages and duration of implant use, and the authors suggested that the influence of age at implant on language performance may become less apparent in older children, past the stage of early language growth bursts more common in the early years of implant use.

A study conducted in Norway investigated the speech recognition and speech production of 79 children, the majority of whom were educated in settings where a bilingual approach (Norwegian Sign Language and spoken Norwegian) was used. The authors reported that amount of daily use of the implant, non-verbal IQ, an increased focus on oral communication in the educational setting, pre-operative hearing aid use and duration of implant use predicted better performance on most of the speech production and recognition outcomes, while age at implant was a predictor of speech recognition growth-rate only. The authors pointed out that the relatively high age of implantation among their sample, with only one child having been implanted before 2 years of age,

Factors predicting outcomes of paediatric cochlear implantation

could explain why age of implant was not a significant predictor of speech production and perception (Wie et al., 2007).

Research investigating the associations between speech and language outcomes and type of educational setting and communication mode has provided mixed results. Wie et al. (2007) and Geers and her colleagues (Geers et al., 2003a; Geers et al., 2002; Geers et al., 2003b; Tobey et al., 2003) found that educational settings emphasising oral communication rather than signed communication predicted better speech and language skills, and Geers (2003) reported that mainstream educational placement was associated with reading competence. However, Connor and Zwolan (2004) reported that communication mode (oral only or Total Communication) did not significantly predict reading comprehension skills. Connor et al. (2000) found a complex relationship among children's speech and language performance, educational approach/communication mode, and age at implantation, with no clear benefit from being educated with either an oral communication or a Total Communication approach.

Few studies have looked for predictors of broader outcomes than speech, language and reading skills in children with implants. In one study, Schorr, Roth, and Fox (2009) investigated factors associated with quality of life from the perspectives of 37 implanted children aged 5 to 14 years. The quality of life measure used was specifically related to the children's feelings about their cochlear implants and the benefits or problems their implants provided them. The authors reported that age at implantation did not predict scores on quality of life measures, although age at first amplification with hearing aids did. The children's perceived quality of life with their implants was not significantly associated with their speech perception scores. Schorr (2006) reported on

Factors predicting outcomes of paediatric cochlear implantation loneliness among the same 37 children, nearly all of whom were educated exclusively in general education classes. The findings indicated a significant relationship between age at implantation and loneliness, with higher age at implantation associated with higher loneliness scores. Speech perception and language skills were not found to be mediating factors in this relationship. Schorr suggested that an earlier age at implantation might enable children to feel a sense of belonging and to be more included in their school settings.

As part of Geers and colleagues' study of a range of outcomes among 8 and 9-year-old children, Nicholas and Geers (2003) reported on the children's personal and social adjustment, assessed with parents' ratings on the Meadow-Kendall Social-Emotional Assessment Inventory for Deaf and Hearing Impaired Students (Meadow-Orlans, 1983) and children's self-ratings on a pictorial assessment scale of self-image modified by the researchers for use with children with cochlear implants. No significant correlations were found between the parents' ratings of their children's social-emotional adjustment and outcome scores on speech, language and reading scales. Regression analysis found that older age (but not age at implantation or age at onset of deafness) was a significant predictor of children's self-image, and IQ and being female were significant predictors of parental perception of social-emotional adjustment. Variables related to hours of therapy, mainstream or special educational placement, and communication mode predicted neither child self-image nor parents' ratings of social outcomes.

Bilateral paediatric implantation is becoming more common and parents are increasingly being offered this option for their children. Studies to date have shown hearing benefits, including speech recognition in noise and improved ability to localise

Factors predicting outcomes of paediatric cochlear implantation sound, for some children (Ching et al., 2006; Galvin et al., 2007a; Galvin et al., 2007b; Litovsky et al., 2006; Scherf et al., 2007; Scherf et al., 2009). Little has been reported as yet about the long-term impact of bilateral paediatric cochlear implants, including social and educational outcomes, although some studies have reported parental perceptions of social and behavioural improvements following children's sequential bilateral implantation (Galvin et al., 2008; Scherf et al., 2009). There is currently insufficient evidence to determine the factors that influence outcomes of bilateral implants for children (Galvin et al., 2009).

The purpose of the current study was to establish the relationships between a large number of child and family related factors and children's functional outcomes, according to parental report, in the areas of spoken language communication, social skills and participation, academic achievement, and independence and identity, through a series of step-wise regression analyses. The study included a large sample across a range of locations in eastern Australia and included children with varying lengths of time since implantation, investigating the lived experience and functional outcomes for implanted children over time.

Method

Participants

Parents of children with cochlear implants in the Australian states of Queensland, New South Wales, and Victoria participated in the study. The number of surveys received from parents was 250. Three of these were excluded from the analysis due to missing data, resulting in 247 surveys in the analysis.

Factors predicting outcomes of paediatric cochlear implantation

Measures

A survey instrument for parents or guardians of children with cochlear implants contained three sections: 1) background information, 2) the process of making the decision about implantation; and 3) parents' expectations and experiences of their children's cochlear implantation.

Background information

The first section of the questionnaire for parents sought background information and contained 30 questions covering family demographics, including household structure, postcode, and language used in the home, as well as child-related information including age of hearing loss occurrence and identification, age of cochlear implantation, occurrence of bilateral implantation, use of hearing aids before the implant (and since, if used in the non-implanted ear), communication modes before and since the implant, educational setting and communication approach in the educational setting.

The decision-making process

In the second section of the survey, questions asked about the sources of information parents used while making the decision to have their child implanted and the length of time they considered a cochlear implant option before making their decision. A question asked respondents if they had been made aware of any possible negative outcomes associated with implantation in the areas of medical/health, auditory/audiological, social, psychological, and language-related outcomes.

Factors predicting outcomes of paediatric cochlear implantation

Parents' expectations and experiences of their children's outcomes

The questionnaire for the expectations and experiences section of the current study was adapted from a survey developed by Zaidman-Zait and Most (2005) for use with mothers of children with cochlear implants. Zaidman-Zait and Most's questionnaire contained 33 items divided into five sub-scales measuring mothers' expectations in the areas of Communication Abilities, Social Skills, Academic Achievements, Change in Future Life, and Rehabilitation Demands. The authors reported Cronbach's alpha coefficients for internal consistency for the subscales as follows: .86 for Communication abilities, .76 for Social Skills, .63 for Academic Achievements, .72 for Future Life, and .65 for Rehabilitation Demands.

For the current study, modification was made to some of the items to more closely reflect the Australian context, and a small number of items was added. A further subscale, Rehabilitation Stress, was added to gauge parent's perceptions of the decision-making and rehabilitation processes related to their children's cochlear implantation. Parents were asked to rate their level of agreement or disagreement with items with the stems "I expected that..." and "now I find that..." on the sub-scales named Communication Abilities, Social Skills and Participation, Academic Achievements, Future Life, Rehabilitation Efforts and Rehabilitation Stress. (This report focuses on children's outcomes, and the predictors of parents' rehabilitation efforts and stress will be reported elsewhere [authors, in preparation]. However, the parent expectation scores from the two rehabilitation subscales were included in this report's regression analysis as independent variables). Following exploratory and confirmatory analyses of parents'

Factors predicting outcomes of paediatric cochlear implantation

responses, some items in each subscale were excluded from the subsequent analyses if they did not cluster meaningfully and thus decreased the reliability of the subscale.

The items on the Communication Abilities subscale reflected abilities in spoken language communication in functional, everyday situations. The Social Skills and Participation items were concerned with the extent to which children made friends and were accepted by hearing peers, initiated and actively participated in play with children in general, and had improved social skills. The Academic Achievements subscale included children's ability to participate in a regular class, as well as items concerning levels of achievement in mathematics, reading and writing, and general age-related levels. The Future Life subscale was concerned with children's general functioning and independence as well as their identity as deaf or hearing persons. Sample items and alpha coefficients for the subscales used in the regression analysis are shown in Table 1.

Respondents were asked to rate their level of agreement with each item on a 5-point scale with responses *strongly disagree*, *disagree*, *neither agree nor disagree*, *agree* and *strongly agree*.

The survey instrument was pilot-tested with a number of parents of children with cochlear implants and was reviewed by teachers of the deaf and major stakeholders during ethics approval protocols.

Insert Table 1 about here

Procedure

Approval for the project was gained from the Human Research Ethics Committees of the universities, state government departments of education, early intervention centres, and hospitals with cochlear implant clinics involved in the study. Cochlear implant clinics,

Factors predicting outcomes of paediatric cochlear implantation

early intervention centres and education authorities facilitated distribution of the survey to the families of implanted children on their data-bases and organisations for parents of deaf children disseminated information about the project to their members. All parents who received an invitation to participate in the study were informed of the option of completing and submitting the survey online at the project's web-site.

Results

Characteristics of the parents and their children

Most of the 247 survey respondents were mothers (88.3%), while 10.1% were fathers, and 1.6% were "others"; of these, 2 were the child's grandmother, 1 was a foster parent to the child and 1 was the child's step-father. Most families had 1 child other than their deaf child (44.9%), 23.9% had 2 other children, 19.0% had 3 or more other children, and 12.1% had no other children. The large majority of parents were hearing (96.7%); 2.8% were hard of hearing, and 1 parent (0.4%) was Deaf. Although 9.7% of parents indicated that English was not their first language, only 4.0% reported that English was not the language they used most each day.

Of the 247 surveys in the analysis, 49.4% reported on a male child. Nearly all of the children (92.7%) had a profound hearing loss pre-implantation and 6.9% had a severe loss (0.4% unknown). For the majority of the children, parents reported that hearing loss was congenital (69.2%) or had occurred before the age of 2 years (11.1%), while 7.8% had lost their hearing over the age of 2, and 12.6% of parents reported that they did not know when their children's hearing loss had occurred. One quarter of the parents (25.3%) indicated that their children had additional difficulties or disabilities.

Insert Table 2 about here

Factors predicting outcomes of paediatric cochlear implantation

Table 2 reports further demographic details of the children. As the table indicates, there was a wide range of ages, ages at implantation, and duration of implant use in the group. The majority of children attended mainstream settings in which they spent most or all of their time in the regular classroom, usually with itinerant teacher of the deaf or co-teacher support. A further third of children attended special education settings including early intervention centres for deaf children and special education settings in regular schools or special schools. Parents reporting that their children were in “other” settings usually described these as being some kind of combination, for instance of day-care and early intervention, or said that their children were in higher education or in the workforce.

Families’ geographical locations were categorised by postcode and compared to Australian Bureau of Statistics information which classifies postcodes into an accessibility to services/remoteness index of regions termed Major Cities, Inner Regional, Outer Regional, Remote, and Very Remote (Australian Bureau of Statistics, 2006). The proportion of survey respondents living in each locality category closely reflected the 1996 Census population figures reporting percentages of people living in regions ranked on accessibility/remoteness (Australian Bureau of Statistics, 2001). For the purposes of our analysis, the Outer Regional, Remote, and Very Remote participants were grouped into one category, termed OR/Remote.

Families’ postcodes were also used to ascertain socioeconomic status (SES). Each postcode was assigned to one of ten decile positions according to the Index of Relative Socio-economic Advantage and Disadvantage which ranks areas on a continuum of social and economic advantage to disadvantage (Australian Bureau of Statistics, 2008).

Factors predicting outcomes of paediatric cochlear implantation

The majority of parents lived in areas ranked in the highest deciles: 75.1% lived in areas ranked in the top five deciles.

Sixty-five of the children (26.3%) had a sequential bilateral implant. The results reported here refer, unless otherwise stated, to the first implant.

Multiple regression analyses

Associations among the four outcome variables Communication Abilities, Social Skills and Participation, Academic Achievements, and Future Life (average subscale scores) and a select array of variables were examined via a series of step-wise regression analyses. Independent variables included in the analysis were family- and child-related demographic factors (major city or regional/remote location, SES, the state in which the family resided, number of other children in the family, and child's age), factors related to the child's deafness and implantation (age at onset of deafness, age at identification of hearing loss, age at implantation, length of time using hearing aids before implantation, implantation after the age of two years, and the presence of additional disabilities), factors related to the child's development post-implant (regular or special educational placement, communication modes used by the parent and in the educational setting, use of bilateral implants, and use of hearing aid in the non-implanted ear), and factors related to the parents' decision-making and expectations pre-implant (length of time considering the decision to implant, communication mode wanted for child, awareness of possible negative outcomes, and expectations in regard to communication, social, academic, future life, rehabilitation efforts, and rehabilitation stress outcomes). With the exception of quasi-interval variables such as age in years, these independent variables were transformed and entered into the stepwise regression analyses as dummy variables (0,1).

Factors predicting outcomes of paediatric cochlear implantation

Results from a large number of analyses are reported and for the sake of clarity of exposition these have been grouped in relation to the outcome domains of communication abilities, social skills and participation, academic achievements, and future life. Because the results represent a summary of many analyses, we have limited reporting to B, SE, beta values, and t, for statistically significant outcomes only (i.e., non-significant outcomes are not reported).

Insert Table 3 about here

Communication abilities

As indicated in Table 3, the family living in a major city location was predictive of positive communication outcomes. Post-implant variables associated with positive communication outcomes were having bilateral implants, being in a regular education setting, using spoken language communication approaches, and the parents using spoken English to communicate with the child. Pre-implant decision and expectation variables predicting positive communication outcomes were parents being aware of possible negative language-related outcomes and parents having expected positive communication outcomes for their child. Variables negatively associated with communication outcomes, that is, predicting less positive communication outcomes, were that the child had additional disabilities and had used hearing aids for more than two years before the implant.

Insert Table 4 about here

Factors predicting outcomes of paediatric cochlear implantation

Social skills and participation

As shown in Table 4, variables predicting positive social outcomes were having two other children in the family, parents currently using spoken English to communicate with their child, the child having spoken language communication approaches and the child having bilateral implants. Pre-implant variables predicting positive social outcomes were parents having expected positive social outcomes, parents having wanted speech as the child's only communication mode, and parents having been aware of possible negative language related outcomes. The child having additional disabilities and the child having been implanted at two or more years of age predicted less positive social outcomes.

Insert Table 5 about here

Academic achievement

As Table 5 indicates, the parent having expected positive academic outcomes and the child having bilateral implants and being in a regular education setting predicted positive academic outcomes. The child having additional disabilities and the parent having expected rehabilitation stress predicted less positive academic outcomes.

Insert Table 6 about here

Future life

As illustrated in Table 6, parents using spoken English with their child, parents having been aware of possible negative language-related outcomes, and parents having expected positive future life outcomes for their child predicted positive future life outcomes. In addition, the child using a spoken language communication approach predicted positive

future life outcomes. The parent having expected rehabilitation stress, and the child having additional disabilities predicted less positive future life outcomes.

Discussion

Among the large number of variables related to family and child characteristics, educational and communication factors, and the parents' pre-implant decision-making entered into the series of step-wise regressions, a small number were found to be consistently associated with children's outcomes in the areas of the four subscale domains, and others were predictors in one or two domains.

Several variables related to oral communication were shown to predict positive outcomes in many of the domains. The parent currently using spoken English with the child was predictive of positive communication, social, and future life outcomes. Most of the 10% of parents who were not mainly using spoken English with their child were using Auslan or some mix of spoken English and signed communication. The child following a spoken language communication approach in their educational setting or program also predicted positive outcomes in communication, social, and future life domains. Thus, it appears that the outcomes of children who were more "oral" were rated more highly by their parents on the everyday functioning areas of hearing and spoken language communication, social skills and participation, and general functioning and independence, but not in the area of academic achievements. In the area of communication abilities, these findings are consistent with others in the literature (e.g., Geers et al., 2003a; Geers et al., 2002; Geers et al., 2003b; Tobey et al., 2003; Wie et al., 2007).

Factors predicting outcomes of paediatric cochlear implantation

The child being in regular, mainstream educational settings was predictive of positive communication and academic outcomes. The majority of the children spending most of their time in a mainstream setting were receiving visiting teacher of the deaf support (and sometimes other supports, such as teacher aide time) and were unlikely to have any sign component in their instruction, although a small number were in co-taught classes where they received instruction in Auslan and English in a bilingual setting. Thus, it is unsurprising that being in mainstream classes predicted positive outcomes on the communication subscale, which assessed spoken language communication abilities. Of course, it is not possible to know whether being in a mainstream setting and following a spoken language communication approach was a cause or a consequence of good spoken language or academic abilities, as children may have been placed in special educational settings because their oral-aural communication abilities had not developed sufficiently to enable successful participation in regular classes.

We found associations between age at implant and outcomes. One of the predictor variables in the analysis was having been implanted at two or more years of age. This variable did not predict communication or academic outcomes, and so did not reflect studies that have found benefits of early implantation to the development of oral communication (e.g., Connor et al., 2006; Geers et al., 2009; Nicholas & Geers, 2007; Schorr et al., 2008; Tait et al., 2007; Tomblin et al., 2005) and reading skills (Archbold et al., 2008; Connor & Zwolan, 2004). However, in the present study, the child having used hearing aids for more than two years pre-implant was predictive of less positive communication outcomes. By definition, these children were over the age of two years

Factors predicting outcomes of paediatric cochlear implantation

when implanted, and so this finding indicates that later age at implant was associated with lower oral communication abilities.

Although not predicting communication, academic, or future life outcomes, the child having been implanted at over two years of age predicted low scores on the social skills and participation subscale. While little has been reported in the literature about the role of early implantation on social outcomes, Schorr (2006) found that higher age at implantation was significantly associated with higher loneliness scores for children educated mainly in mainstream settings. Although it could be expected that good oral communication abilities are likely to facilitate social relations with hearing children, and that children implanted early are likely to have better spoken language outcomes than those implanted later, Schorr reported that speech perception and language skills were not found to be mediating factors in the relationship between age at implantation and loneliness scores.

The finding that positive social outcomes were associated with having two other children in the family may indicate that the children benefited in their development of social skills by having more than one sibling, or that their social participation was facilitated by having siblings, and perhaps those siblings' friends, with whom to play and interact.

The child having additional disabilities was strongly predictive of less positive outcomes in all domains, indicating that the presence of additional difficulties or disabilities led to poorer communication, social, educational, and general functioning outcomes. We cannot know from the data whether additional disabilities limited the benefits children were able to gain from their implants, or whether disabilities affected

Factors predicting outcomes of paediatric cochlear implantation

the children's ability to achieve communication, social, academic, or independence outcomes, regardless of whether they used an implant or not. However, it is likely that these two factors interact to influence outcomes. Although studies show that the development of spoken language after implantation is not always achieved for children with additional disabilities, it has been found that cochlear implants have given children with significant disabilities important benefits that may lie outside the speech and language parameters generally considered the major goal of implantation, benefits that are more in the areas of quality of life and psychosocial wellbeing (Bacciu et al., 2009; Donaldson et al., 2004; Edwards, 2007; Edwards et al., 2006; Nikolopoulos et al., 2008).

One of the variables related to the decision-making process was found to influence the dependent variables of communication, social, and future life outcomes: the parent having been made aware, prior to their children's implantation, of potential negative language-related outcomes. This suggests that it is important that parents are comprehensively informed and have a realistic awareness that not all implanted children achieve optimal levels of spoken language communication. The findings also showed that parents' pre-implant expectations were associated with their perceptions of their children's outcomes. Having held high expectations of communication outcomes was found to predict positive communication outcomes; similarly, having held high expectations in the domains of social, academic, and future life outcomes predicted positive outcomes in those domains. As well, the parent having had high expectations that the rehabilitation process would be stressful predicted lower outcomes in the academic and future life domains. Overall, these findings could suggest that parents who are generally optimistic have high motivation to dedicate the time, work, and effort

Factors predicting outcomes of paediatric cochlear implantation needed for optimal outcomes from cochlear implantation for children. They could suggest that parents' high expectations constitute a driver of their efforts and their children's achievement. Qualitative findings from parent interviews in a separate phase of our study revealed an association between parents' expectations and their drive to ensure their children did well with the cochlear implant (authors, submitted). These findings suggest that implant programs should continue to advise with caution about the range of likely outcomes but also be aware that parents' expectations and hopes for their children's success with the implant can drive the determination and hard work that contribute to children's progress with their cochlear implants. Professionals in implant, therapy, and educational programs need to strike a difficult balance between encouraging parents' expectations and ensuring that parents have a comprehensive understanding of the range of outcomes that result for children from cochlear implantation.

Although Spencer (2004) reported an apparent association between parents spending a long time making the decision to implant and their children's progress with their implants, our analysis did not find any association between the length of time parents spent making the decision to have their children implanted and any of the outcomes domains. Nevertheless, it is important that such a major decision should not be rushed (Duncan, 2009).

Gender was not associated with any of the dependent variables in our study. This is in contrast to findings from Geers and colleagues who reported that being female was associated with higher spoken language (Geers et al., 2009; Geers et al., 2003b; Tobey et al., 2003) and reading skills (Geers, 2003). Other studies have also found effects for SES, with higher family SES predicting higher performance of measures of speech and

Factors predicting outcomes of paediatric cochlear implantation

language (Geers et al., 2003b; Schorr et al., 2008; Tobey et al., 2003) and reading skills (Geers, 2003), whereas our Australian study found no such effect of SES on any of the outcome variables.

The regression findings indicated that families' location in major city areas was associated with positive communication outcomes. In Australia, cochlear implantation is undertaken in hospitals in major cities only, and most of the providers of early intervention services for deaf children are based in the major cities, although some have centres or therapists in regional areas and some provide an outreach service for remote families, usually involving video or webcam conferencing to link parent and child with teachers or therapists. Families living some distance from major city centres face additional difficulties in accessing ongoing therapy, educational, and implant equipment maintenance services for their children. The current efforts of cochlear implant centres, early intervention programs and educational authorities to expand their services to more distant locations need to be continued, extended, and monitored.

The child having a bilateral implant was predictive of positive communication, social, and academic outcomes. (These children had all had their bilateral implant at a later surgery than their first; none had received simultaneous bilateral implantation.) This finding is of particular interest, given that increasing numbers of families have the option of having a bilateral implant for their child, and that studies have shown audiological benefits for some children (Ching et al., 2006; Galvin et al., 2007a; Galvin et al., 2007b; Litovsky et al., 2006; Scherf et al., 2007; Scherf et al., 2009). Evidence about the improvements a second, bilateral implant can make to children's quality of life compared to a single implant is sparse to date, making the decision about bilateral implants a

Factors predicting outcomes of paediatric cochlear implantation particularly difficult one for parents (Johnston et al., 2009). The current study's findings that having bilateral implants predicted positive outcomes in oral communication, social skills and participation, and academic achievements adds to the knowledge in this area. These findings may reflect the current situation in which children most likely to receive sequential bilateral implants are those children who are already achieving high levels of oral-aural communication with their first implant.

Strengths and Limitations of the Study

Our study investigated factors associated with children's functional outcomes in the areas of spoken language communication, social skills and participation, academic achievement, and independence and identity. Our instrument was designed to measure parents' perceptions of these functional outcomes in daily life for their children and so this study's findings cannot be compared directly with findings from clinical measures of speech production and perception or academic skills. Nevertheless, it is instructive to consider findings from parental reports in the context of the literature, which largely reports clinically measured outcomes, as parental report is a valuable and underutilised element of assessing the real-world, functional outcomes of paediatric implantation (Knoors et al., 2003; Lin et al., 2008; Thoutenhoofd et al., 2005).

The factors found to be associated with children's outcomes may have been mediated by factors to which we did not have access, such as the children's IQ and factors related to the implant device. Non-verbal IQ has been found to be a predictor of speech, language and reading abilities in several studies of children with cochlear implants (e.g., Geers et al., 2003a; Geers, 2003; Geers et al., 2003b; Wie et al., 2007). Implant factors such as use of updated speech processors, number of active electrodes,

Factors predicting outcomes of paediatric cochlear implantation and well-fitted maps have been found to predict positive speech development and reading outcomes (Geers et al., 2003a; Geers, 2003; Tobey et al., 2003).

The geographical dispersion of families among major city, regional and remote areas closely reflected the dispersion in the general Australian population, and so our findings are likely to be representative in this respect. However, the breakdown of socioeconomic level by respondents' postcodes indicated that three quarters of families lived in areas included in the five highest deciles ranking socio-economic advantage and disadvantage (Australian Bureau of Statistics, 2008), and the experiences of families from low socioeconomic backgrounds may not be fully represented in our findings. Our questionnaire was relatively long and detailed, and it may be that parents in the lowest SES categories are less likely to respond to surveys of this nature, not having the time or resources to do so (Fortnum et al., 2006). Despite the best attempts, this remains a challenge for future research.

Conclusion

This study of 247 children of varying ages with cochlear implants is one of the largest of its kind at present and, in addition to considering a number of important factors examined in other studies, it included a number of independent variables not normally included in regression analyses, such as parental expectations, length of time making the decision to implant, and families' geographic location. The study found that negative predictors of children's outcomes were children having additional disabilities and children being implanted over the age of 2 years. Positive predictors were found to be parental expectations of positive outcomes, parents' having been aware of possible negative language-related outcomes, the family living in a major city area, the child having a

Factors predicting outcomes of paediatric cochlear implantation

sequential bilateral implant, and several variables related to spoken language communication. Although there was a significant positive effect of parental use of spoken English with the child and of the child being in mainstream educational settings and following a spoken language communication approach, it is of interest that the study found no negative predictor values for parents' use of signed communication or the use of signed communication in the educational setting. Further research examining the impact of bimodal and bilingual communication with deaf students with cochlear implants would be beneficial.

In conclusion, the regression analyses reported here identified a number of predictors of children's outcomes across a range of developmental and academic domains, adding to empirical knowledge about the range of factors involved in successful outcomes of deaf children with cochlear implants. Each of these has to be considered in the specific contexts of educational practice and family situation to fully appreciate their influence and their implications for the medical, educational, and social services that support children and their families over time.

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Factors predicting outcomes of paediatric cochlear implantation

Table 1. Subscales of the parental expectations and experiences questionnaire

Subscale	Sample items (one each worded for expectations and for experiences)	Number of items	Alpha
Communication abilities	My child would be able to use the telephone My child is able to follow a conversation with a group of people	9	.89
Social skills and participation	My child would easily make friends with hearing children My child is accepted by his/her hearing peers	6	.90
Academic achievement	My child would achieve at least the expected level for his/her age My child participates easily in a regular class	4	.86
Future life	The cochlear implant would significantly improve my child's future life My child is as independent as other children his/her age	5	.74
Rehabilitation efforts	I would need to be heavily involved in communication teaching and practice activities with my child	5	.74

Factors predicting outcomes of paediatric cochlear implantation

	My child has needed a lot of family support		
Rehabilitation stress	The rehabilitation process would be extremely stressful for me	3	.62
	My level of stress is no greater than that for any other child of the same age		

Factors predicting outcomes of paediatric cochlear implantation

Table 2. Characteristics of children in parent surveys

	N	M	Range	SD
Age in years	247	9.42	.67-25.0	4.63
Time since implant in years	247	6.21	.25-18.0	3.79
Age at implantation in years	247	3.27	.38-16.42	3.16
Age at bilateral implantation	65	5.16	.63-18.42	4.09
Gender				
	Male	Female		
	49.8%	50.2%		
Educational setting	Main-stream	Special education	Other	
	58.6%	34.4%	6.1%	
Locality	MC	IR	OR/R	
	61.0%	29.3%	9.8%	

Note. MC = major city; IR – inner regional; OR/R = outer regional and remote

Factors predicting outcomes of paediatric cochlear implantation

Table 3. Summary of stepwise regressions predicting Communication Abilities

Variables	B	SE	Beta	t	Sig.
Urban location	.24	0.10	.15	2.37	*
Child used hearing aids >2 years before implant	-.26	0.12	-0.13	-2.14	*
Additional disabilities	-.62	0.11	-0.34	-5.59	***
Parent uses spoken English with child	.66	0.16	0.25	4.13	***
Spoken language communication approaches	.25	0.11	0.12	2.32	*
Regular educational settings	.20	.10	.13	2.08	*
Bilateral implants	.28	.10	.16	2.75	**
Parent expected positive communication outcomes	.26	0.07	0.18	2.90	**
Parent aware of negative language-related outcomes	.22	0.11	0.13	2.01	*

*p<0.05, **p<0.01, ***p<0.001

Factors predicting outcomes of paediatric cochlear implantation

Table 4. Summary of stepwise regressions predicting Social Skills and Participation

Variables	B	SE	Beta	t	Sig.
Two other children in family	.22	.11	.13	2.05	*
Additional disabilities	-.45	.10	-.26	-4.28	***
Parent uses spoken English with child	.36	.15	.15	2.46	*
Bilateral implants	.30	.09	.19	3.18	***
Implant at two or more years of age	-.20	.09	-.13	-2.15	*
Spoken language communication approaches	.34	.10	.22	3.51	***
Parent wanted child to use speech only	.26	.12	.13	2.09	*
Parent aware of negative language-related outcomes	.41	.10	.26	4.30	***
Parents expected positive social outcomes	.27	.07	.23	3.82	***

*p<0.05, **p<0.01, ***p<0.001

Factors predicting outcomes of paediatric cochlear implantation

Table 5. Summary of stepwise regressions predicting Academic Achievement

Variables	B	SE	Beta	t	Sig.
Additional disabilities	-.60	.13	-.29	-4.79	***
Regular educational settings	.47	.11	.26	4.32	***
Bilateral implants	.37	.11	.20	3.27	**
Parent expected positive academic outcomes	.26	.07	.23	3.69	***
Parent expected rehabilitation stress	-.14	.06	-.14	-2.20	*

*p<0.05, **p<0.01, ***p<0.001

Factors predicting outcomes of paediatric cochlear implantation

Table 6. Summary of stepwise regressions predicting Future Life

Variables	B	SE	Beta	t	Sig.
Additional disabilities	-0.44	0.11	-0.26	-4.24	***
Spoken language communication approaches	0.26	0.10	0.17	2.67	**
Parent uses spoken English with child	0.53	0.15	0.23	3.54	***
Parent aware of negative language-related outcomes	0.35	0.09	0.23	3.90	***
Parent expected positive future life outcomes	0.35	0.06	0.32	5.56	***
Parent expected rehabilitation stress	-0.16	0.05	-0.20	-3.42	***

*p<0.05, **p<0.01, ***p<0.001