

**DEVELOPMENT OF ORAL COMMUNICATION IN
INFANTS WITH A PROFOUND HEARING LOSS: PRE-
AND POST-COCHLEAR IMPLANTATION**

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ABSTRACT

An in-depth, longitudinal study of the speech and oral language development of eight infants with a profound hearing loss who receive early interventions focused on developing their auditory, speech and oral language capacity is presented in this thesis. Infants were tracked for two years, during the period when they are changed from a hearing aid to a cochlear implant. All infants in this study had their hearing loss identified early and were fitted with hearing aids between 1 and 7 months of age and received their cochlear implant between 8 and 16 months of age. They attended a number of different auditory-verbal early intervention programs (depending on where they lived) all of which focused on developing speech and language skills through listening. Attendance at their particular early intervention program at least once a week was in addition to weekly attendance the Sydney Cochlear Implant Centre for therapy and audiological services. A broad range of measures has been used to track the infants' acquisition of oral language skills, including measures of communicative intention, pre-speech and speech development, and oral language development. Despite a wide range of individual differences across the group of infants, the results suggest some general trends. In the area of communicative intent most infants followed typical development patterns in terms of both the types (e.g. requesting, answering etc) and forms (gestural, vocal, verbal) used, but they showed delays in their frequency of usage of these types and forms. For speech development the infants demonstrated typical speech skills by 18-months post-cochlear implantation in the areas of consonant inventories, severity of phonological involvement (speech intelligibility) and phonological process development, but they showed delays in vowel and consonant acquisition. Finally, for language development the infants were delayed relative to typical development at 18 months post-implantation.

The findings support and extend previous studies which have demonstrated the benefits of early intervention for communication development in infants with hearing loss (Calderon & Naidu, 2000; Mayne, Yoshinaga-Itano & Sedey, 2000; Moeller, 2000; Yoshinaga-Itano & Apuzzo, 1998). However, the delays in the oral communication skills of the infants in the current study suggest that more intensive long-term intervention is required if the infants are to attain typical oral speech and language development. The findings capture the complexity of early oral language development, which has been lacking in previous studies of infants with significant hearing loss, receiving a cochlear implant (Dettman, Briggs, & Dowell, 2005; Houston, Ying, Pisoni, & Iler Kirk, 2003; Schauwers, Gillis, Daemers, De Beukelaer, & Govaerts, 2004).

The present data also provide some limited support for earlier implantation, that is, before 12 months of age, as the infants made little progress in oral language development while using hearing aids. The reduced amount of auditory signal available to them prior to implantation may be the determining factor in their inability to follow typical rates and patterns of development. However, rates of development with the implant were not straightforward and further research on this population is needed. Universal neonatal screening programs for hearing loss will potentially provide a larger population of early identified infant for future research. This will create the opportunity for large scale, prospective, longitudinal, studies examining the acquisition of speech and oral language development.

Limitations of this study, tracking the early stages of speech and language development over a two year period are identified. Future studies are needed to follow the infants for a longer time to determine if their rate of development is sufficient for them to catch up in areas of delay and maintain their performance in areas where they match their typically developing peers.

Submission Statement

None of the work contained within this thesis has been submitted to any other university or institution. The conduct of this research was approved by the University of Sydney Ethics Committee; Reference Number 00/06/20. It was also approved by the Ethics Committee at the Children's Hospital Westmead; project number 99070.

Maree Doble

Date:

This is to certify that the thesis "Prelinguistic and Early Communication Development of Infants with a Profound Hearing Loss in Early Auditory Intervention: Pre- and Post-Cochlear Implantation" submitted by Maree Doble in fulfilment of the requirements for the degree of Doctor of Philosophy is ready for examination.

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May the roads always be winding.

**PUBLICATIONS AND PRESENTATIONS ARISING
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Conference Presentations

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Wright, M., Purcell, A., & Reed, V. A. (2001). Communicative intents of infants and toddlers with profound hearing loss pre- and post-cochlear implantation (poster). Symposium on Research in Child Language Disorders, Madison, USA.

Wright, M., Purcell, A., & Reed, V. A. (2001). Cochlear implants and babies: Expectations and outcomes (conference presentation). 8th Paediatric Cochlear Implant Symposium, Los Angeles, USA.

Wright, M., Purcell, A., & Reed, V. A. (2000). Prelinguistic development of infants pre and post cochlear implantation (conference presentation). International Conference for Educators of the Deaf, Sydney, Australia & European Paediatric Cochlear Implant Symposium, Antwerp, Belgium.

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Wright, M., Purcell, A., & Reed, V. A. (2001). Cochlear implants and babies: Expectations and outcomes. 8th Paediatric Cochlear Implant Symposium, Los Angeles, USA.

Wright, M., Purcell, A., & Reed, V. A. (2000). Prelinguistic development of infants pre and post cochlear implantation. International Conference for Educators of the Deaf, Sydney, Australia & European Paediatric Cochlear Implant Symposium, Antwerp, Belgium.

Wright, M., Purcell, A., & Reed, V. A. (2000). Prelinguistic development of infants pre and post cochlear implantation. Speech Pathology Australia Conference, Adelaide, Australia.

Research Seminars / Lectures

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