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To investigate Cortical Auditory Evoked Potentials as an objective method for optimising cochlear implant fitting in young children.

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Signed: Catherine Morgan… Dated: 7/06/06…
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INTRODUCTION

“We live now and in the foreseeable future a society in which the primary means for economic, social, and psychological success is the ability to communicate. We are now in a ‘communication society based on language” (Ruben RJ. 1999)

Hearing is essential in learning spoken language. Young children diagnosed with a severe to profound congenital or pre-lingual (before speech acquisition) hearing impairment have been shown to experience significant delays in their ability to develop all aspects of spoken language (Stelmachowicz et al., 1995). In spite of this, there is evidence that shows that better language outcomes measured at 3-5 years of age occur for children who receive intervention prior to 6 months than for children who receive treatment after 6 months (Yoshinago-Itano 1989).

This has lead to the implementation of universal newborn hearing screening programmes throughout the world which in turn has increased the need for reliable, objective techniques for fitting and evaluating cochlear implants and hearing aids in young infants. Infants found to have a hearing loss as a result of newborn hearing screening, intervention is typically occurring by age 6-8 weeks. It is difficult to assess cochlear implant or hearing aid effectiveness using behavioural techniques in such young infants. Cortical auditory evoked potentials provide an non-invasive objective measure of the brain’s response to sound and are a tool that can be used to assess auditory function in infants, with as well as without a cochlear implant, while the child is awake.

ACKNOWLEDGEMENTS

It has been my privilege to receive a Churchill Fellowship Award. It has provided me with an opportunity travel to centres of excellence in Auditory Electrophysiology and work with leaders in the field of clinical auditory neurophysiology. This award has inspired me to fresh endeavours; I am keen to develop my skills in the area of auditory electrophysiology. The Fellowship has provided financial assistance, which has subsequently enabled me to meet with experts in this area of research to discuss and acquire optimal methods for analysis of auditory evoked potentials, particularly in young hearing-impaired children.

This Churchill Fellowship has enabled me to acquire the skills to be able to implement an objective method for optimising cochlear implant fitting in babies, by working with Associate Professor Suzanne Purdy of The University of Auckland. Dr Purdy is Director of Speech Science (Department of Psychology) and a world leader in the field of auditory evoked potentials.
EXECUTIVE SUMMARY

Catherine Morgan
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For my Churchill Fellowship I travelled to The University of Auckland, New Zealand to work with Associate Professor Suzanne Purdy for 8 weeks from January 23 to March 16 2006.

The aim was to investigate Cortical Auditory Evoked Potentials (CAEP) as an objective method for optimising cochlear implant (CI) fitting in young children. The picture shows CAEPs recorded to speech sounds in young infants. CAEPs allow clinicians to evaluate the effectiveness of a hearing device by showing whether speech sounds can be heard and discriminated. The use of CAEPs for CI programming will enable efficient optimisation of the device in infants and other children who are unable to provide feedback to the clinician about what they hear. CAEPs will help clinicians to quickly determine whether the auditory information received from a CI is sufficient for speech and language development so that the habilitation program can be optimised. Ultimately, CAEP testing may be useful clinically for predicting a child’s performance with a CI and for comparative purposes during habilitation.

Highlights included:
- Working alongside leaders in the field of auditory evoked potentials. Ass. Prof Purdy, Dr Sharma, Dr Munro.
- Establishing new friendships and associations with leaders in the field of auditory evoked potentials.
- Learning a new technique for evaluating cochlear implant benefit in young children.
- Establishing a method of acquiring CAEP in cochlear implantees with limited device artifact interference

Recommendations:
- CAEPs will help clinicians to quickly determine whether the auditory information received from a CI is sufficient for speech and language development so that the habilitation program can be optimised. Congenital hearing loss, by its impact on spoken language acquisition, has far-reaching implications for intellectual and social development, literacy, educational attainment, employment and quality of life.
- CAEP testing may be useful clinically for predicting a child’s performance with a CI and for comparative purposes during habilitation.

Implementation & Dissemination:
- Knowledge will be used to advise families, clients and colleagues in current employment as a paediatric audiologist with Australian Hearing.
- Information to be published in peer review journal and Audiological Society of Australia journal.
- Presentations at national/international conferences and seminars.
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<td>Meet Ass. Prof. Suzanne Purdy, Dr Sharma &amp; staff.</td>
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<td>Public Holiday. Lunch: group of NZ Audiologists</td>
<td>Baby CAEP testing</td>
<td>Med-El Cochlear implant seminar</td>
<td>Meet Dr Munro Visiting from Manchester University</td>
<td>Baby CAEP testing</td>
<td>Equipment calibration. 2nd trimester ultra-sound</td>
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<td>Equipment Calibration</td>
<td>Baby CAEP testing</td>
<td>Baby CAEP testing</td>
<td>Baby CAEP testing</td>
<td>Review Baby CAEP results, with Dr Mridula Sharma</td>
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<td>Baby CAEP testing</td>
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<td>Mtg Suz Purdy, prepare CAEP testing CI children</td>
<td>Child with CI CAEP testing</td>
<td>Devonport Food festival</td>
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<td>Child with CI CAEP testing.</td>
<td>Review CAEP results from CI children with Suz &amp; Mridula</td>
<td>Mtg with Dr Thorn Head of school of Audiology Auckland University</td>
<td>CI child CAEP testing</td>
<td>Baby CAEP Testing</td>
<td>GnResound Lecture</td>
<td>CI baby CAEP testing</td>
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<td>CI baby testing</td>
<td>Car accident, day spent in Hospital.</td>
<td>fMRI &amp; CAEP lecture &amp; demonstration</td>
<td>Baby CAEP testing</td>
<td>CI child CAEP testing</td>
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<td>Mtg Dr Kelly Linguist lecturer Discuss speech &amp; CI</td>
<td>Visit Hearing House. Meet families of children with CI</td>
<td>CI child CAEP testing</td>
<td>CI child testing</td>
<td>Auditory Evoked potentials seminar</td>
<td>Baby CAEP testing</td>
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<td>Mtg Suz &amp; Mridula review CAEP results</td>
<td>Baby CAEP testing</td>
<td>Mtg Suz review progress in CAEP testing &amp; interpretation of results</td>
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<td>Farewell lunch.</td>
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Universal newborn hearing screening has dramatically reduced the age of hearing loss diagnosis. In that congenital deafness is now routinely identified and confirmed in the first few weeks after a baby’s birth, enabling the process of hearing rehabilitation to begin prior to the age of 3 months. The benefits of early identification and intervention in hearing impaired children is supported by results showing that a shorter duration of deafness is correlated with better speech and language performance/acquisition.

During the first year of the NSW Newborn Hearing Screening program, the average age of diagnosing a hearing impairment in babies fell from 18 months to 6 weeks. As a result, the average age of these babies first being fitted for a hearing aid and/or cochlear implant fell from 22 months to just over three months old. Currently, more than 95% of the state’s newborn babies are screened for hearing loss. Early management of hearing loss is essential to a child’s social, academic, speech and language development. Hearing is essential for learning to talk and the most critical period for acquiring spoken language is from birth to three years of age.

Age of identification and improved technology carry important implications for cochlear implant candidacy, however clinical advances such as evaluation of device fitting carry implications for the safety of early implantation and the services that encourage a child to use this technology to its fullest extent. Evaluating hearing device benefit in these young children poses significant challenges.

When hearing aids provide minimal benefit, cochlear implants (CIs) can provide access to the speech sounds needed for the acquisition of spoken language. As babies have limited language skills, the process of programming the CI can be challenging and time consuming. Cortical Auditory Evoked Potentials (CAEPs) are brain waves representing higher-level activity in auditory areas of the brain, measured using sensors placed on the head. CAEPs can be used to assess the cognitive processing involved in the identification and discrimination of speech sounds. CAEPs can be reliably recorded in infants and therefore are a useful tool for objectively evaluating CI benefit in this population. Interpretation of these brain waves needs to be carried out by an experienced and skilled Audiologist, as the main problem to overcome is identifying and reducing the CI electronic artifact present in the waveforms recorded. In addition the CAEP brain wave changes with age, as the brain pathways mature.

A cochlear implant is a small, electronic device that can help to provide a sense of sound to a person who has a severe to profound hearing loss. The implant is surgically placed under the skin behind the ear. An implant does not restore or create normal hearing. Instead, coupled with intensive post-implantation therapy, can help young children to acquire speech, language, developmental, and social skills.

Below diagram (A) is of the human ear with a cochlear implant (Cochlear Ltd, Nucleus 24) inserted in to the hearing sensory organ known as the cochlea. Diagram (B) is the cochlear enlarged showing the implanted cochlear implant electrode array, which collect the impulses from the stimulator and send them to the brain.
The journey from silence to sound begins when the implant processor is activated three to four weeks after surgery. Hearing sound through a cochlear implant during those first months is often unstable as thresholds change and unpredictable as the quality of sounds change.

It all begins when the cochlear implant processor is programmed (MAPped). Each electrode along the array is stimulated one at a time to find the lowest level of current needed to barely hear a sound to establish a threshold. The second step is to find the upper level of stimulation by stimulating each electrode individually and raising the current to find a level that is the comfortably loud, and balancing the level of current across all electrodes. For small babies with limited language skills, the process of programming the processor can be challenging and time consuming.

The ability of young hearing-impaired children to hear speech sounds adequately is important for oral language acquisition and speech development (Miyamoto et al., 2003). When a hearing impaired child does not hear particular speech sounds optimally, atypical pronunciation of these sounds may occur (Borg et al., 2002). Furthermore, studies of the speech of deaf adults have shown a strong link between perception and production (Palethorpe et al., 2003). Currently, it is difficult for to assess cochlear implant effectiveness using behavioral techniques in such young infants and difficult-to-test clients. Auditory evoked potentials provide an objective measure of the brain's response to sound essentially assessing auditory function.

Auditory Evoked Potentials (AEP) are brain waves (electrical potentials) recorded from the scalp of the subject, evoked by a sound stimulus. The obligatory cortical evoked potentials (CAEP) P1-N1-P2 occur within approximately 300ms after stimulus onset in adults, as mentioned previously the CAEP is different in infants and children. The CAEP is referred to as obligatory because it is primarily determined by the physical properties of the stimulus and is typically recorded when sound is detected by the subject (Hyde, 1997). The opportunity to work with experienced electro-physiologists, and leaders in this field enabled me to acquire the skills necessary to interpret the CAEP waveforms in infants and children with normal hearing and then progress onto infants and children with severe to profound hearing impairment, with cochlear implants.

The presence of the CEAP response and/or the response characteristics allow us to infer conclusions about the subject's hearing ability or the performance of their auditory pathways. Cortical Auditory Evoked Potentials (CAEP) are a measure of higher level brain activity used to assess cognitive processing of sensory stimuli involved in the identification and discrimination of sound. CAEPs can be reliably recorded in young
infants and therefore provide a useful tool for objectively evaluating cochlear implant benefit in this population and in children who are difficult to test behaviourally.

Above is a picture of Catherine Morgan and child subject with scalp electrodes attached for CAEP recording.

CAEP will assist to determine if the auditory information received from the CI is sufficient to facilitate normal speech & language development and facilitate in creating an optimal speech process program (Map). It is possible that an advantage for children who received a cochlear implant in infancy may not be achieved because of insufficient auditory input during the first months of using the device, due to the difficulty in obtaining behavioural responses needed for creating an optimal implant map.

For example the above figure shows aided versus unaided CAEP waveforms recorded.
in a 3½ year old child with severe developmental delay. This child wears bilateral high-powered hearing aids. No unaided response was obtained but, as illustrated in Figure 2, a cortical response was obtained while the child was wearing the hearing aids (see P1). The test stimulus in this example was an 80 dB SPL tone burst at 1000 Hz delivered to both ears. In this case there is no other evidence that the hearing aids are providing any benefit because behavioural testing is not possible and the child has not developed any speech. Cortical evoked potential testing was helpful in demonstrating that the hearing aids are amplifying sufficiently to produce neural activity at the level of the auditory cortex and therefore at least loud sounds should be perceived (Purdy et al., 2001).

In the literature CAEP have been recorded using a wide range of stimuli including tone-bursts of specific pitch, clicks (broadband sound) and speech stimuli. There is evidence that CAEPs in infants evoked by different speech phonemes differ in latency (timing) and morphology (shape) (Kurtzberg, 1989; Sharma et al, 2000; Oates et al., 2002; Purdy et al., 2001). CAEP differences between stimuli are an indication of different underlying neural representations of speech sounds and suggests that the information needed to discriminate the different stimuli is available to the listener. At the University of Auckland I had the opportunity to not only create my own different speech stimuli and test this theory. As without this skill one could not carry out CAEP testing, I also had the opportunity to advance the current knowledge of how a cochlear implant recipient functions and discriminates speech in noise by carrying out CAEP testing in background noise in children with CI. Listening in background noise is a realistic listening situation we face everyday.

Improvements in electro-physiology used to evaluate CI effectiveness and establish new programming methods, coupled with cochlear implant technology mean that more young children with significant hearing impairment are gaining access to the world of sound and have the opportunity to reach their full potential.

**RECOMMENDATION**

CAEP can be reliably recorded in young infants and therefore provide a useful tool for objectively evaluating hearing aid success in this population and in children who are difficult to test behaviourally. Clinical evoked potential systems can be used for this purpose with the addition of a good quality loudspeaker (and external amplifier) to deliver the stimuli to the cochlear implant. It is important that CAEP testing is carried out by experienced and skilled Audiologists to avoid misinterpretations of results.
Above is a picture of a baby with scalp electrodes attached for CAEP recording.

As a result of universal newborn hearing screening and improved diagnostic tools, many children with severe to profound hearing loss are being diagnosed as infants. This affords the opportunity to provide these children access to early cochlear implantation, although audiological challenges must be addressed such as device evaluation. The purpose of the Churchill Fellowship was to investigate an audiological method/tool to evaluate the efficacy of CI in young children.

Cortical Auditory Evoked Potentials will provide a method for evaluating the cochlear implant for infants and children unable to give the clinician feedback and will enable efficient optimization of the hearing device. Speech audibility is a necessity for speech and language acquisition.

Ultimately, the test may be used by experienced Audiologists clinically for predicting the child’s performance with a cochlear implant in various listening conditions (in quiet, or in the presence of a competing signal) and for comparative purposes during habilitation as speech audibility is a necessity for speech and language acquisition.

REFERENCES


