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ECONOMIC EVALUATION OF THE COCHLEAR IMPLANT

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Abstract

Objective: To examine the economic efficiency of current cochlear implant technology under Australian conditions in profoundly deaf adults, partially deafened adults, and children.
Methods: Cost-utility study, with weights based on judgments from persons experienced with the technology, and cost data from Australian sources.
Results: Quality-of-life improvements due to functional consequences of hearing improvement were greater than those due to amelioration of hearing disability. Costs in Australian dollars per QALY (15-year assessment) ranged from $5,070–$11,100 for children, $11,790–$38,150 for profoundly deaf adults, and $14,410– $41,000 for partially deaf adults.
Conclusions: Results suggest cochlear implantation is acceptable value for money when compared with other health programs to which resources are committed in Australia.

Keywords: Cochlear implant, Economic appraisal, Cost-effectiveness

In 1991 the Australian Institute of Health (AIH) published a monograph on the cochlear implant that described the current status of the technology and discussed directions for future research (9). The monograph included a preliminary economic assessment of the technology that indicated that, should the implantation process result in a 10% increase in quality of life, then costs per quality-adjusted life-year (QALY) might be of the order of Australian (AU) $14,000 for children and $22,000 for adults, suggesting that the technology held promise of being good value for money (9;10).

Since then, there have been a number of technical developments (20), some extension of indications for implantation, and further economic appraisals have been published (17;23). The present paper extends the economic analysis in the earlier report, including a more comprehensive costing and quality-of-life assessment, sensitivity analysis, and consideration of partially deafened adults.

At the time of the AIH study, the cochlear implant was well established, with 5,000 to 6,000 procedures having been undertaken worldwide, including 300 in Australia. Some of the matters being debated at that time were the variation in

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hearing gain in response to an implant, the benefits of cochlear implantation for prelingually deafened children, long-term safety of the device, changing selection criteria for implantation of severely deafened adults and children, and the need for measures of the quality-of-life changes to implantees (9). Further results have since emerged in all these areas as additional experience has been gained with the procedure, and results have started to become available from longer term follow-up of implantees. At the time of the study reported in this paper, more than 10,000 procedures had been undertaken worldwide, and the Australian total was over 500.

Available data show that the most widely used type of implant (the Nucleus 22 channel implant) is highly reliable, and that reliability will probably increase in the future as a result of design modifications (6;13;16;18;20;21). For the purposes of the analysis, no provision was made for equipment failure or replacement, beyond inclusion of regular processor upgrades and ongoing electrical maintenance. Safety of the implant procedure appears to be good, with some potential risks capable of being minimized as further experience is gained (1;3;11). For the purposes of this study, no account was taken of possible adverse effects when deriving the utility weights.

Outcomes for children who have cochlear implants are good, and have now been obtained with follow-up over several years (5;13;16;18;21;24). Achievement of a sensation of hearing is only one of the benefits from cochlear implantation. Additional, and greater, degrees of benefit are obtained from other consequences of the implant procedure (6;8;22). Estimates of loss of quality of life due to hearing loss and of the degree of restoration of quality of life due to implantation give added confidence in the validity of the utility weights used in the present study (8;17).

METHODS

The research task was to assess the net costs and net outcomes of current cochlear implantation technology compared with no implantation program. The study is not part of a randomized controlled trial or demonstration project, but rather assesses the literature to evaluate effectiveness of cochlear implantation and expert judgment to assess anticipated quality-of-life changes. The analysis was undertaken within the context of Australian implantation programs from the perspective of the government/service provider and focused on the costs associated with the selection of implant recipients, surgery/implantation, and rehabilitation/implant maintenance over the useful life of the implant.

Costs for recipients and their families are included only insofar as they are related to the funder/service provider perspective. Costs borne purely by patients (travel time, forgone income, home expenditures) are not included in the analysis. Similarly, benefits enjoyed by the deaf community from their own culture and use of sign language are not considered.

Outcome Measure

The measure of outcome chosen for the preliminary economic assessment of the cochlear implant (9), and for this assessment, is the likely improvement in the quality of life for recipients over the useful life of the implant.

In the preliminary assessment, the Quality of Well-Being Scale (QWBS) described by Kaplan and Anderson (7) was used to obtain an indication of the impact of cochlear implantation on quality of life for the profoundly deaf. The performance achieved following cochlear implantation is variable, ranging from using the device

to supplement lip reading to being able to converse effectively on the telephone. The preliminary assessment therefore assumed two levels of improvement in quality of life based on the QWBS — 15% and 7.5%. Weights used in the QWBS are from the general community, not from recipients of cochlear implants or from the deaf community.

Community values were also used to derive the utility weights in the study reported here. Several of the available health-related quality-of-life instruments were considered. These included the QWBS (7), the EuroQol (4), the McMaster Multi-Attribute Utility instrument (19), and the Sintonen HRQOL-15D (14;15). Because of its sensitivity for application to evaluation of the cochlear implant and because of the superiority of its validation in the context of economic evaluation, it was decided to use the HRQOL-15D.

The HRQOL-15D has a specific hearing dimension, together with a range of functional consequences relevant to a hearing disability (such as speech, usual activities, and distress). Each dimension has five item responses or descriptive statements by which the level of the relevant dimension can be identified. The design of the HRQOL-15D provides high sensitivity in that it allows a great number of health-related quality-of-life states to be defined. Decisions on the appropriate dimensions to include and the pre/postimplantation values for each dimension for three classes of implantees (profoundly deafened adults, partially deafened adults, and children) reflected the judgment of a doctor experienced in clinical aspects of cochlear implantation and of a researcher in the routine use and outcomes of the technology.

There was substantial agreement between the two assessors. Their judgments were combined into one set of results, organized as a low value, a middle value, and a high value. The known variability in the improvement in quality of life attributable to cochlear implantation is reflected both in the number of dimensions included in each value and the extent of the health state improvement within each dimension.

The low value is based on scores for four core dimensions (hearing, speech, usual activities, and distress); the middle values on scores for the four core dimensions, plus sleeping, depression, and vitality; and the high value on scores for 12 of the 15 available dimensions. These were the seven middle value dimensions plus mobility (for children and profoundly deaf adults), mental function, discomfort/symptoms (for adults, from cessation of tinnitus), sexual activity (for adults), and vision (children only for reading-related improvements).

Cost Analysis

Calculation of the cost data for the three patient groups follows the approach taken in the earlier work by Lea (9). For each group (profoundly deaf adults, partially deaf adults, and children), ongoing costs for consecutive cohorts of patients were calculated over the effective life of the implant, with the first cohort starting in 1994. Calculations were based on cohort sizes of 40 adults and 40 children, which are similar to the annual number of implants that can be undertaken in Australia, given supply constraints.

In the earlier analysis (9), a 10-year period was covered. In the present work, cohorts have also been followed for 15 and 20 years to take account of changes in the expected lifetime of the device. In the case of children, account was also taken for each cohort of the offsetting savings achieved through being able to attend ordinary schools rather than requiring special education.

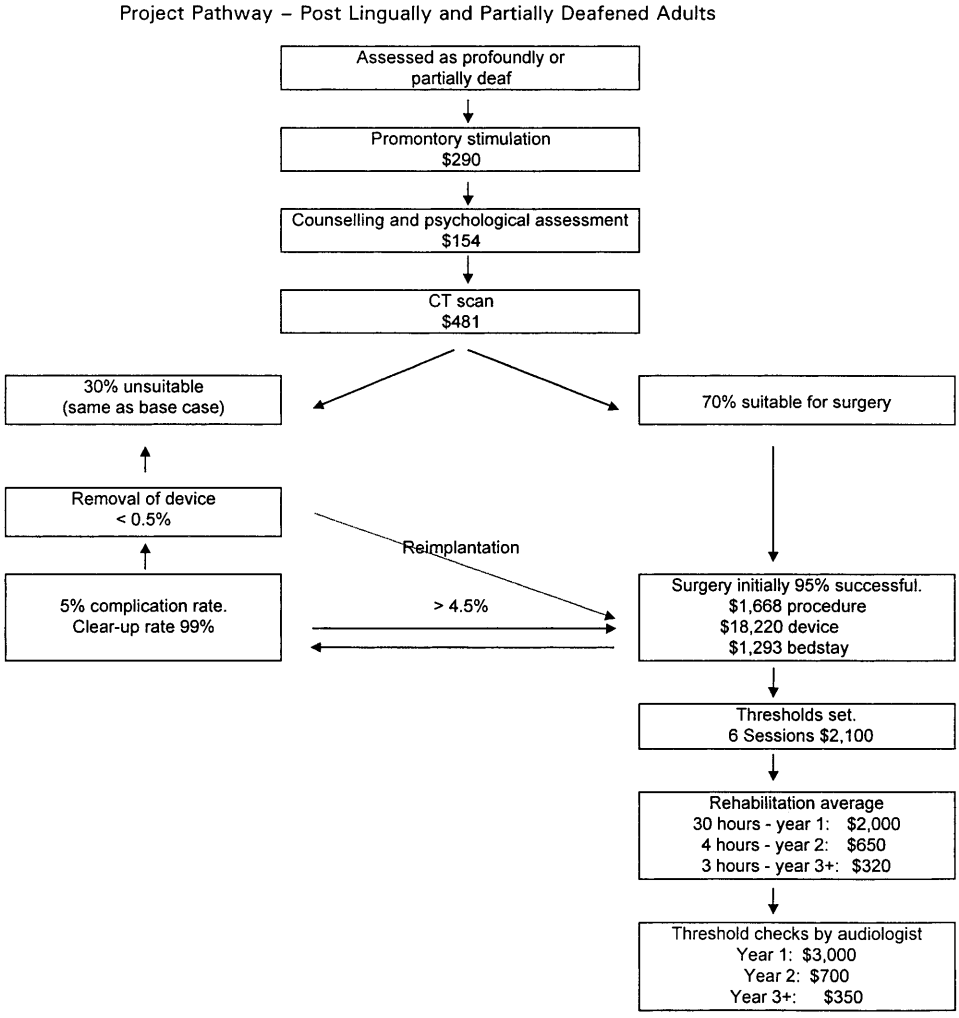

Figure 1. Project pathway for postlingually and partially deafened adults.

The ongoing costs for each cohort were discounted back to the various starting years, and the sums of these discounted costs then discounted back to 1994. A discount rate of 5% has been used for both costs and life-years.

The project pathways (Figures 1 and 2) show the costs and probabilities used for adults and children.

A number of other assumptions were made in this model:

- A 3-day bed stay is associated with the surgery at AU $431 per day.
- The potential cost savings following implantation of children through mainstreaming their education does not commence until 18 months following implantation. The figure used for the savings (AU $7,978 per child) was derived from the public school costs (12) and applied to 65% of the children in each cohort. This figure was adjusted according to the Consumer Price Index to 1994 dollars.
- For the savings in secondary school it is assumed that a 100% retention rate is achieved for grades 10 to 12.

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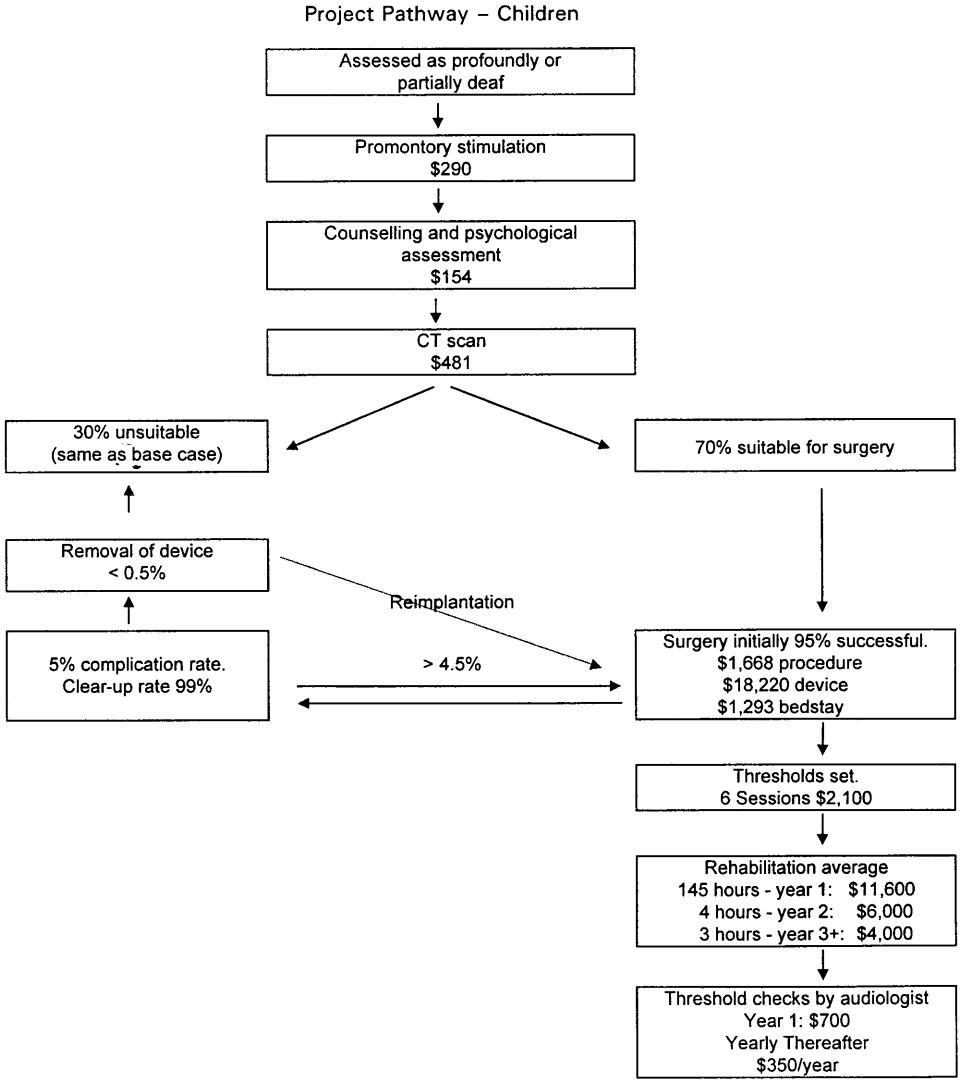

Figure 2. Project pathway for children.

- Provision was made for a complication rate of 5% in the first year.
- A tertiary education entrance rate of 20% is included in the 20-year model for children. The savings included for tertiary education are derived from those given by Andrews and Smith (2).
- No savings through education apply to adults.
- Processor upgrades are accepted by 100% of users at AU $4,378 per upgrade every 5 years.
- Electrical maintenance costs AU $400 per year, commencing after the first year.

Cost-utility Analysis

The estimates of costs derived from the model were used with the utility scores to calculate costs per QALY for each type of patient over periods of 10, 15, and 20 years. A sensitivity analysis was undertaken using the estimates derived for each

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patient group for the 15-year period and the middle value for the quality-of-life changes. Variations were made to the discount rate and to the cost of the device for all patient categories. In addition, variations were made to the rate of long-term rehabilitation and to the proportion of children in mainstream schooling.

RESULTS

For profoundly deafened adults, the improvement in health-related quality of life ranges from 11% (low value) to 37% (high value). Amelioration of the hearing disability itself contributes 3–4%, while the functional consequences of the hearing improvement result in a further 8–33%. A similar pattern is exhibited by the results for partially deafened adults (2% hearing improvement and 9–28% improvement due to functional consequences) and for children (4–5% hearing improvement and 13–32% improvement due to functional consequences). The detailed quality-of-life scores and the utility values are illustrated for children in Table 1.

It is clear for all patient categories that the variability in the outcome measure is not so much due to the value placed on hearing per se as to the impact hearing has on other dimensions of quality of life (such as carrying out usual activities, mental and emotional well-being, and social outcome measures for relationships with others).

The cost-utility results are presented in Table 2. They compare favorably with the values of AU $15,067–$30,135 for adults and $9,400 to $18,800 for children obtained in the preliminary study (9), particularly given the inclusion of regular software upgrades and electrical maintenance costs. It is of interest that, when a discount rate is applied, extending the lifetime of the implant to 20 years makes comparatively little difference to the cost per QALY results for adults.

Results of the sensitivity analysis are shown in Table 3. The estimates are relatively insensitive to changes in the cost of the device but moderately sensitive to increases in the discount rate. Even a doubling of the interest rate to 10%, however, still yields results that would normally be regarded as reasonable to good value for money in Australia when compared with other health programs to which resources are committed. The estimated costs per QALY for children are sensitive to the assumptions made on the rates of long-term rehabilitation required and to the proportion of implantees who are able to attend normal schools, but again, all results fall in the range that would normally be regarded as good value for money.

DISCUSSION

The results of this study reflect the further development of cochlear implantation and give a strong indication that it is an effective technology that is acceptable value for money in Australia. The improvements in the reliability and lifetime of the technology, and the increasing evidence of benefits in children after several years of follow-up, are important factors.

The HRQOL-15D instrument has proved useful in providing a means of considering a number of quality-of-life attributes associated with cochlear implantation. The quality-of-life measures derived indicate that achievement of hearing sensation is an important but minor component of improvements to quality of life following implantation. As with other technologies for managing disability, the benefits of using the cochlear implant extend well beyond alleviation of an impairment and include major improvements to several aspects of everyday living.

Table 1. Quality-of-life Outcome Measures for Children[a]

Dimensions	Low value		Middle value		High value	
	Change in level	Value	Change in level	Value	Change in level	Value
Mobility					2-1	0.0264
Vision (reading)			2-1	0.0074	3-1	0.0209
Hearing[b]	5-2	0.0434	5-2	0.0434	5-1	0.0484
Breathing						
Sleeping			3-1	0.0304	3-1	0.0304
Eating						
Speech[b]	3-1	0.0387	3-1	0.0387	4-1	0.0508
Elimination						
Usual activities[b]	4-1	0.0623	4-1	0.0623	5-1	0.0712
Mental function					2-1	0.0407
Discomfort symptoms					N/A Children	
Depression			3-2	0.0108	3-2	0.0108
Distress[b]	4-2	0.0284	4-2	0.0284	4-2	0.0284
Vitality			4-2	0.0357	4-1	0.0517
Sexual activity					N/A Children	
Total change in score		0.1728		0.2571		0.3797
Quality-of-Life Improvement	Hearing Disability 4%	17% ↙↓ 13% Consequences	Hearing Disability 4%	26% ↙↓ 21% Consequences	Hearing Disability 5%	38% ↙↓ 32% Consequences

[a] Quality-of-life scores based on the Sintonen HRQOL-15D instrument.
[b] These are the four core dimensions.

Table 2. Cost Per Quality-Adjusted Life-Year (QALY)

	Cost per QALY (in Australian dollars)		
Quality-of-life factor	10 years	15 years	20 years
Profoundly deafened adults			
Low value	$45,630	$38,150	$35,250
Middle value	22,045	18,435	16,825
Upper value	14,115	11,790	10,895
Partially deafened adults			
Low value	49,070	41,000	37,915
Middle value	34,920	29,175	26,995
Upper value	17,240	14,410	13,310
Children			
Low value	13,020	11,100	3,465
Middle value	8,440	7,480	2,330
High value	5,940	5,070	1,580

The results obtained indicate that implantation is especially good value for profoundly deaf children. The sensitivity of the estimates for children to changes in the rate of long-term rehabilitation and to the proportion who are able to attend regular schools gives an indication of the importance of good quality support services following implantation.

Souliere et al. (16) have published a detailed review of implantation in children, drawing attention to critical issues involved in such programs. They comment that criteria for treatment are in evolution and that implantation, particularly in children, requires a team commitment from many types of health care professionals. Postoperative rehabilitation requires a bigger commitment from the patient, the patient's family, and the implant team than does adult rehabilitation.

Table 3. Sensitivity Testing for Estimates of Costs per Quality-Adjusted Life-Year (QALY) over 15 Years[a]

	Cost per QALY (in Australian dollars)		
Factor	Profoundly deaf adults	Partially deaf adults	Children
Unchanged values	18,435	29,175	7,480
Increase discount rate to 7.5%	19,820	31,422	9,750
Increase discount rate to 10%	21,270	33,700	12,110
Increase cost of device to $22,500 (24% increase)	20,110	31,820	8,820
Increase electrical maintenance to $800/year	19,975	31,610	8,900
Increase cost of upgrades to $6,000/5 years	19,680	31,680	8,625
Year 1: Rehabilitation increased to 200 hrs	—	—	9,055
Year 1: Rehabilitation increased to 200 hrs; years 2 & 3 to 100 hrs; and year 4 to 75 hrs	—	—	16,125
Decrease proportion in mainstream schooling to 50%	—	—	13,680

[a] Analysis based on estimates using the middle values for quality of life.

The costs per QALY values calculated for each of the patient groups in this study confirm earlier assessments of the status of the technology as representing reasonable to good value for money. An analysis in the United Kingdom (17) placed adult cochlear implantation in the middle range of cost-utility for health technologies in that country. The study reported a cost per QALY between £8,624 and £25,871, based on an average age at implantation of 49 years, and an accumulated net gain in quality of life between 1.3 and 3.9 QALYs. These estimates did not take account of factors such as time off work and potential cost savings in education of children or from reduced dependency on social services. A U.S. estimate of cost-utility of adult implantation (23) suggested that the cost per QALY was approximately US $9,325, with sensitivity analysis suggesting a true value of between US $7,988 and $11,201.

Various assumptions were made in deriving our estimates that warrant comment. Although cochlear implant devices now have high reliability, there will be some equipment failures over and above our provisions for procession upgrades and electrical maintenance. These were ignored in our cost analysis, although the results of the sensitivity analysis indicate that the effect on the overall results would be minor. Cost implications of complications from implantation have been considered in our analysis, but there would also be quality-of-life implications that have not been addressed here. Also, there are less easily analyzed consequences, such as the inability of implantees to have magnetic resonance imaging examinations, at least with current technology, and impairment of vestibular function in some persons.

The weights assigned to the quality-of-life dimensions used in the analysis were derived for another country (Finland), and it may be that some modification might be needed to reflect values elsewhere. This would require locally based survey work, preferably with a randomly selected sample of the general population.

The improvements in the quality-of-life dimensions used here reflect the perspective of experts in the field of cochlear implantation. It would be of interest to extend the analysis to take account of the perceptions of other groups, including implantees and their families and possibly the deaf community. The impact on the families and caregivers of implantees could extend to major improvements in everyday living. Further, there may be an overall impact of the technology on health and education programs. Both areas would provide important topics for future economic assessment.

A limitation of the study is that no account is taken of the adaptability of children to the existence of an impairment and, as a consequence, what the correct quality-of-life comparator is for children who have the implantation. The deaf community might argue, for example, that profoundly deaf children can have a normal, healthy lifestyle. Others might consider that profoundly deaf children are often born to hearing adults, who never really learn or cope with sign language, and that significant quality-of-life improvements are possible with implantation.

An area of continuing debate is the extent to which improvements to quality of life after implantation are due to the attention given to recipients of the device during the assessment and rehabilitation process. Studies comparing quality of life of implantees with that of a control population of profoundly deaf persons are uncommon. A consideration is that profoundly deaf individuals who have not received an implant may themselves receive additional attention, including special schooling and other services. We did not consider such a comparison with a control group in the present study, and this would be a worthwhile area for future work.

A further uncertainty is the extent to which some of the outcomes of cochlear implantation could be considered placebo effects. It may be that influences on some attributes of quality of life are not due directly to the electrophysiological effects of the implant. If this is so, whether they should be regarded as placebo effects is uncertain. An alternative view would be that the intervention is producing benefits of different kinds, and these will be accepted as valuable whatever their source. This also would be an interesting area for future study.

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