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Cochlear Implantation in Australia: A Retrospective Analysis of 23 Years of Activity

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ABSTRACT

Objectives: To report the number of cochlear implantation procedures and recipients in Australia since 2000 by age, and to estimate the adult uptake of cochlear implants.

Methods: This was a retrospective analysis of data, using publicly available data on private and public hospital procedures undertaken in Australia between 2000/01 and 2022/23. The main outcome measures were: (i) Number of cochlear implants per financial year, by paediatric, adult, or 10-year age groups, and population adjusted. (ii) Adult uptake rate of cochlear implants, adjusted for explantation and replantation rates, and bilateral implantation rates. This study followed STROBE guidelines for reporting.

Results: 25611 devices were implanted between July 2000 and June 2023, with annual numbers rising from 200 per year to over 1400 per year. Despite females having a 50% lower prevalence of hearing loss than males, approximately an equal number of males and females are implanted. Paediatric implantation has declined since 2016. The adult uptake rate of cochlear implants is estimated to be 10.5%.

Conclusions: Despite the known economic and social benefits of cochlear implants, and the rising number of people with hearing loss, the initial increase in rates of implantation appeared to have slowed, and the uptake rate remains low. Public health and hospital policy should be directed to improving public education, awareness, and referral and assessment pathways, especially for males.

1 | Introduction

It has been estimated that the one millionth person in the world received a cochlear implant in 2021 [1]. The cochlear implant has been shown to be effective in providing access to speech and environment sounds to people with severe to profound hearing loss [2]. The subsequent benefits of cochlear implants have been

reported to improve outcomes such as quality of life [3], health service utilisation [2], and impact of tinnitus [4].

Over time, candidacy criteria have widened to include younger children, people with significant levels of residual hearing, and those with moderately severe hearing loss, asymmetrical hearing loss, and single sided deafness. Bilateral implantation has

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Summary

- Cochlear implants provide economic and social benefits to recipients.
- The number of devices implanted in Australia since 2000 has steadily increased but plateaued since 2016.
- The uptake of cochlear implants by potentially eligible adults in Australia is estimated to be 10.5%.
- The uptake by females is higher than by males, despite the latter having higher rates of hearing loss.
- Greater public awareness of cochlear implants, and improved access to referral, assessment and surgical services are required.

also become common [5]. However, criteria are usually dependent on funding and candidacy guidelines at a local (e.g., state and provincial) level, and globally, implantation of children is given higher priority, with the uptake of cochlear implants amongst eligible children substantially higher globally than that of eligible adults [6].

An important population health outcome measure is the uptake of cochlear implants, which can be defined as the number of people who receive a cochlear implant in relation to the number of people who fit within the candidacy criteria. This is important for public health planning, particularly if it reveals information about particular groups of individuals. The number of people globally with hearing loss is estimated to be 1.5 billion, of whom approximately 30.7 million (or 0.4% of the population) are classified as having severe hearing loss, 17.2 million (0.2%) have profound hearing loss, and 12.6 million (0.2%) have complete hearing loss [7].

The uptake of cochlear implants has been previously estimated to be 10% in Australia [8], 5% in the UK [9], and 7.7% in the USA [10]. The methods employed to determine these estimates are often not clearly stated, and in the case of Australia, the estimate is outdated.

In Australia, all surgical procedures carried out in public and private hospitals must be reported to the National Hospital Morbidity Database; for cochlear implants these have been reported on an annual basis since 2000/1.

The aims of this study were: (i) to report on the overall and population-adjusted incidence of cochlear implantation in Australia by age and sex for the 23 years since 2000/1, and (ii) estimate the cochlear implant rate in adults in Australia between 2001/1 and 2021/2.

2 | Methods

This study utilised three primary sources of data: (i) the number and type of cochlear implant surgical procedures in Australian hospitals by year, age group and sex from the National Hospital Morbidity Database, administered by the Australian Institute for Health and Welfare (AIHW), (ii) estimates of annual population

by age and sex from the Australian Bureau of Statistics (abs.gov.au), and (iii) estimates of the prevalence of hearing loss in Australia collated in the Social and Economic Cost of Hearing Loss in Australia [11].

Population estimates: Estimates of the Australian population are available on a quarterly basis in 5-year increments and by sex. To best align with the reporting period of the surgical data, the population estimates in each quarter 2 (April to June) were retrieved.

Cochlear implant surgery data: AIHW reports all surgical procedures by Australian financial years (July to June), by age group for 0–1 year, 1–4 years, and then in 5-year increments, with a final group of those 85 years and over, by sex (male or female), using a standardised coding system.

Severity of hearing loss: The candidacy criteria for cochlear implantation are usually based on an assessment of speech perception, at times in combination with hearing thresholds, although many other factors, such as medical suitability, motivation, duration of hearing loss, onset of hearing loss, ability to utilise speech cues, social supports, etc. are usually considered [12]. The only population data available to estimate cochlear implantation uptake rate in the population is the prevalence of an appropriate severity of hearing loss. For this study, we used Global Burden of Disease Collaborative Network (<https://vizhub.healthdata.org/gbd-results/>) estimate for Australia of the prevalence of severe, profound, and complete hearing loss by age group and sex (Table 1).

1. Number of devices implanted: Simultaneous or sequential cochlear implants were authorised in Australia over the period that this analysis covers. Coding for implantation and explantation was recorded using the International Classification of Diseases (ICD-10) codes for the first two reported periods, and various editions of the Australian Classification of Health Interventions (ACHI) through to 2018/19. The ACHI 11th edition implemented in 2019/20

TABLE 1 | Estimated percentage prevalence of severe or greater hearing loss in Australia for males and females by age groups, from Global Burden of Disease Collaborative Group (2022).

Age (years)	Males	Females
0–4	0.0409	0.0788
5–14	0.0783	0.1351
15–24	0.1157	0.1785
25–34	0.1466	0.1921
35–44	0.1370	0.1731
45–54	0.2060	0.2901
55–64	0.5286	0.7578
65–74	1.1999	1.6861
75–84	3.0059	3.3334
85+	5.9285	5.5784

included a code for simultaneous bilateral cochlear implant surgery, and from 2002/3 included a code for a cochlear implant explant procedure (Table S1).

For the calculation of devices implanted each year, the annual numbers of simultaneous implants in 2019/20 and onwards were multiplied by two and added to the number of single implant procedures for that year.

The numbers of cochlear implants are reported for the following age groups (in years); 0–4, and then 10-year age groups. They are also reported separately for children (0–14 years) and adults (15+ years). These are reported in unit numbers, and by 100 000 population in Australia in the relevant year and for the relevant age range.

2. Uptake rate: The calculation of uptake of devices is based on the number of individuals implanted and the number of potential recipients. The uptake in children was not considered in this study, as it is generally considered to approach 100% in Australia [13].

An estimated 95% of explantation of devices results in reimplantation [14]. Therefore, 95% of explanted devices each year, per age group, were deducted from the number of implants the same year, the balance representing an estimate of those who are explanted but not reimplanted and thus not recipients. It is not possible with the available data to account for the time between implantation and explant, and therefore the explant (and potential re-implantation) may occur when the person falls in a later age group than when they were initially implanted.

Furthermore, to estimate the number of individual recipients, it is also necessary to account for bilateral implantation. The rate of bilateral implantation was estimated to be 20%, based on information from various public and unpublished Australian sources (see [Supporting Information](#)). Therefore, to estimate the number of implant recipients and subsequently the implant uptake rate, the total number of devices (adjusted for explantation) was divided by 1.20.

The estimate of the uptake rate of cochlear implants was determined by dividing the number of people with severe or greater hearing loss in 2022/23 by the number of cochlear implant recipients from 2000/01 to 2022/23, taking into account reimplantation and bilateral implantation. Note that this does not take into account those implanted before 2000/2001, nor those implanted since 2000/2001 who have since died. It also does not take into account those arriving in Australia with an implant.

This study was conducted and reported in accordance with the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines.

Ethics Statement: As this study uses publicly available data, no ethics approval was required.

3 | Results

A total of 25 234 devices were implanted in Australia between July 2000 and June 2023. The number of implant surgeries rose steadily from fewer than 200 in 2000/1 to almost 1400 per year

in 2017/8, after which the numbers appear to have plateaued (Figure 1a). When adjusted for population, the number of paediatric implantations peaked at about 6/100 000 in 2012/13, after which the numbers have declined over 8 years to about 4.5/100 000 (Figure 1b). A dip in the number of implantations in 2019/20 is noticeable, coinciding with the COVID-19 pandemic. An examination of implantation by 10-year age groups shows that the population-adjusted cochlear implants rose most in older adults aged 75–84 years (Figure 2). The total number of explants reported between 2001/02 and 2022/23 was 1258 (599 for females and 617 for males), with a maximum over the years of 107 in 2011/12.

After adjusting for bilateral implantation, explantation, and re-implantation, 5902 children and 16 417 adults were recipients of one or two cochlear implants. About a quarter of all implantations (24.4%) were paediatric recipients. Slightly more adult females (51.6%) than adult males were implanted (48.4%), and slightly fewer paediatric females (48.7%) than paediatric males (51.3%) were implanted. The uptake rate of one or two implants amongst adults with severe-profound hearing loss was estimated to be 10.5%.

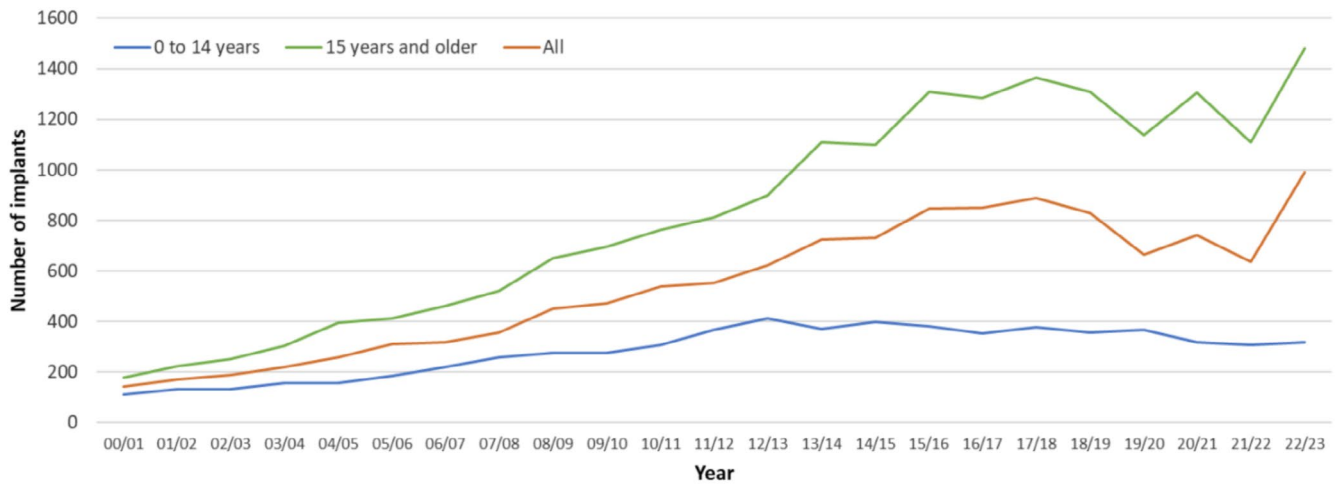
4 | Discussion

This study utilising publicly available data shows that (i) the number of cochlear implantations in Australia rose steadily from 2000 until about 2015, after which time there was a plateauing of numbers, most marked in children where the number of implants has been steadily decreasing; (ii) the number of implantations in older adults has risen in recent years; and (iii) the uptake rate of cochlear implants in adults in Australia is estimated to be about 10.5%.

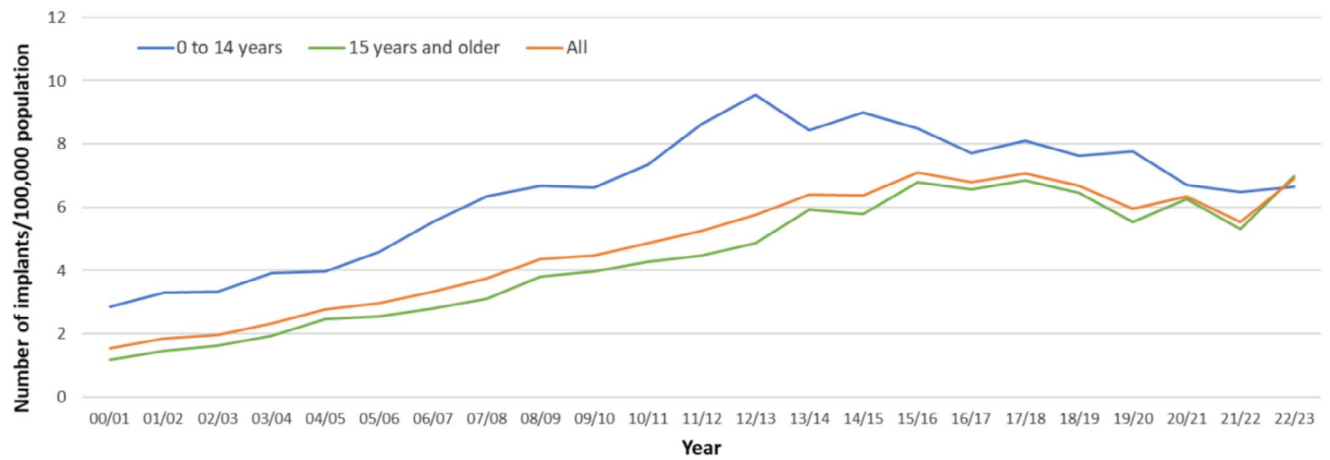
The rise in number of people being implanted in Australia until 2015 may be attributed to the widening of candidacy criteria over time [5, 15], and increasing public and clinical awareness of cochlear implants including the recent development of the Global CI taskforce for “Improving the standard of care for adults with hearing loss and the role of cochlear implantation: living guidelines” [16]. Whereas earlier implants were generally only considered for younger adults, children over 2 years of age, and those with more severe cases of bilateral hearing loss, the current implantation criteria include very young children, varying degrees of unilateral hearing loss and even single-sided hearing loss, and those with some residual hearing in the ear to be implanted. Furthermore, bilateral implantation has been shown to have additional benefit for the recipient [17], which is supported by the Australian health system in most states (Table 2).

There has been a relative increase in older adults (e.g., over 75 years) being implanted. Although there are mixed reports on the association between age at implantation and speech outcomes [18–20], the possibility of somewhat smaller gains in speech perception in older adults appears to be less decisive when clinicians and candidates consider the potential overall improvement in speech perception and quality of life.

The reasons for apparent plateauing in number of implantations post 2015 are not clear. When considering adult implantation,



(a)



(b)

FIGURE 1 | (a) Number and (b) per 100 000 population, of cochlear implants in Australia from 2000/1 to 2022/3, for adults (≥ 15 years of age) and paediatrics (0–14 years of age), and in total.

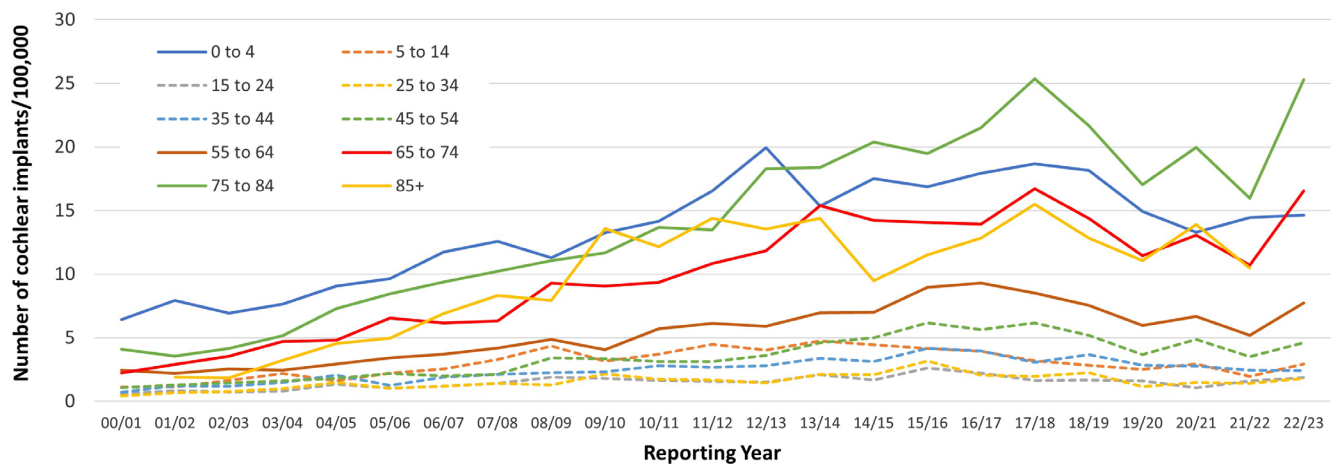


FIGURE 2 | Number of cochlear implantations per 100 000 people in Australia from 2000/1 to 2022/3, by age range (years), adjusted for explanation and estimated re-implantation rate.

it could reflect that “early adopters” and those with severe-profound hearing loss pre-2000 and in the early 2000s have now been implanted. Potential recipients may now be facing

barriers to cochlear implantation that outweigh potential benefits [12, 21]. The dip in implantation in 2019 and 2020 reflects lower surgical activity during COVID-19 lockdowns, but the

TABLE 2 | Funding in public hospitals for cochlear implant surgery, electrode, sound processor (initial only), and rehabilitation across the Australian states and mainland territories.

	Paediatrics			Adults		
	1st CI Bilat HL	2nd CI Bilat HL	1st CI SSD	1st CI Bilat HL	2nd CI Bilat HL	1st CI SSD
Australian Capital Territory ^a	Yes	Yes	Yes	Yes	C-by-C	C-by-C
New South Wales	Yes	Yes	Yes	Yes	C-by-C	C-by-C
Northern Territory ^b	Yes	Yes	Yes	Yes	C-by-C	No
Queensland ^c	Yes	Yes	Area Specific	Yes	No	No
South Australia ^d	Yes	Yes	Yes	Yes	C-by-C	C-by-C
Tasmania	Yes	Yes	Yes	Yes	Yes	Yes
Victoria	Yes	Yes	Yes	Yes	Yes	Yes
Western Australia	Yes	Yes	Yes	Yes	Yes	Yes

Note: Alternative funding is available through private health insurance and through the Department of Veterans Affairs. Abbreviations: Bilat HL: bilateral hearing loss; C-by-C: case-by-case; CI: cochlear implant; SSD: single-sided deafness.

^aMaximum of 45 adults per year.

^bMaximum of 6 or 7 adults per year.

^cMaximum of 125 adults per year.

^dMaximum of 50 adults per year.

declining trend commenced well before this time. Other factors that may play a role are insufficient hearing health professionals specialised in cochlear implants to meet the demand, the demand to provide long-term care for an increasing number of CI recipients leaving less time to assess and review CI candidates, and surgical capacity in hospitals not changing, or even reducing, proportionate to the demand.

The reason for the apparent decrease of paediatric implantation is also not known, despite now excellent access to newborn hearing screening. We could not find any evidence that fewer children are born in Australia with health conditions that may have implications for hearing, or that improved perinatal care has reduced the risk of hearing loss. However, vaccination programmes as a preventative measure or treatment can reduce the incidence of hearing loss [22]. Furthermore, there has been a small decrease over time in the number of births in Australia over the past 10 years, which is likely to contribute to the decrease in overall numbers of implants which we have observed.

Although the number of adult males with severe and profound hearing loss may be twice that of females, the number of female cochlear implant recipients is about the same as that for males. There is evidence from the UK that males are less likely to be referred for a cochlear implant assessment than females [23], and a study in Israel reports that 57% of adults evaluated for a cochlear implant assessment were female [24]. Aligned with our findings is a study in Sweden that has shown that 54.5% of adults with severe-to-profound hearing loss who were provided with audiological rehabilitation were females [25]. This highlights the need for more attention to be paid by medical professionals to the hearing health of their male patients.

The estimated uptake rate, at about 10.5%, is similar to that reported for Australia previously. Without details on how the

previous estimates were calculated, including those reported in other countries, comparisons are difficult. Our calculation is also subject to various assumptions that may over- or under-estimate this figure. The number of people arriving in Australia with an implant would be very difficult to establish, and we were unable to account for those implanted before 2000. The uptake rate figure is likely to be an under-estimation because it assumes that everyone who has received an implant over the past 23 years is still alive. However, the number of recipients aged 75 years and over in the early years of this dataset is relatively low.

A variable that is likely to be a greater influence is the estimates of severe and greater hearing loss. The Global Burden of Diseases Group does not include population estimates for moderately severe hearing loss, and those with single-sided deafness, some of whom will meet current cochlear implant candidacy guidelines in Australia. It should also be borne in mind that hearing loss as defined by pure-tone audiometry is not the only factor taken into account when determining who is a suitable candidate; speech perception, medical history, general health, and aetiology (as well as patient preference) all are taken into consideration before proceeding to implantation. Therefore, the uptake rate estimated by this study needs to be considered in light of a complex decision-making process. However, it also highlights that the uptake rate is low, and that there are many Australians who would potentially benefit from a cochlear implant who do not have one. Once referred for assessment, many do proceed to implantation depending on the configuration of their hearing loss, from 22% of those with single-sided deafness to 62% of those with symmetrical hearing loss [5].

This is the first country-wide report of cochlear implantation over time in Australia. The strength is that it is based on

a data source that accurately records all surgical procedures in Australia and a reliable Australian population data source.

This analysis has some limitations, especially for the calculation of uptake rate, some of which have already been mentioned. Most uncertain are the estimates of hearing loss in Australia. These estimates are based on a small number of relatively old population studies. A comprehensive population survey is required to obtain better data on the prevalence and incidence of hearing loss in Australia.

Author Contributions

Robert H. Eikelboom: conceptualisation, data curation, investigation, methodology, formal analysis, resources, writing – draft and revisions. **Catherine M. Sucher:** conceptualisation, investigation, methodology, formal analysis, writing – draft and revisions. **Sandra R. Bellekom:** conceptualisation, investigation, resources, writing – revisions. **Marcus D. Atlas:** conceptualisation, investigation, resources, writing – revisions.

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Ethics Statement

The authors have nothing to report.

Consent

The authors have nothing to report.

Conflicts of Interest

All authors are employees or associated with Ear Science Institute Australia, who provide private cochlear implant services in Western Australia. Ear Science Institute Australia has received research funding from Cochlear Ltd. (Sydney, Australia), Oticon Medical (Copenhagen, Denmark) and MEDEL (Innsbruck, Austria) for cochlear implantation research. Cochlear Ltd. provides financial support to provide some clinical support services. CS was the recipient of a REDI grant from MTPConnect, that involved a short-term industry placement at Cochlear Ltd. and is currently involved in two cochlear implant studies funded by Cochlear. No direct or indirect support was received for the work reported in this manuscript. SB previously held shares in William Demant and currently holds shares in Cochlear Ltd.

Data Availability Statement

The data that support the findings of this study are available in Australian Institute for Health and Welfare at <http://aihw.gov.au>. These data were derived from the following resources available in the public domain: Data cubes, <https://www.aihw.gov.au/reports/hospitals/procedures-data-cubes/contents/summary>.

Peer Review

The peer review history for this article is available at <https://www.webofscience.com/api/gateway/wos/peer-review/10.1111/coa.14334>.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section.