



# Cochlear implant candidacy in the United States: Prevalence in children 12 months to 6 years of age<sup>☆</sup>

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## Summary

**Objective:** Pediatric cochlear implantation has been demonstrated to be effective for children as well as cost effective for society. One of Healthy People 2010 goals is to increase the number of people who are deaf or significantly hard of hearing to begin to use a cochlear implant system. NIDCDs Healthy Hearing Progress Reports from 1999 reported that only 2 out of every 1000 adults who are deaf or hard of hearing received a cochlear implant. There were two main objectives for this study: (1) to estimate the number of children between the ages of 12 months and 6 years of age with severe to profound bilateral hearing loss who could benefit from a cochlear implant and (2) to determine if the number of children projected to be candidates received this medical care.

**Methods:** Using the 2000 US Census Data from children 12 months to 6 years, the number of children with severe to profound bilateral hearing loss was calculated. Children who would be considered “neurologically devastated” and the children with absent eighth nerves were excluded from the calculations.

**Results:** Based on the total population of slightly over 231 million, 15,219 children presented with severe to profound hearing loss. Taking into account some exclusions, 12,816 children would be considered cochlear implant candidates. Based on the number of children who were implanted in 2000, approximately 55% of the projected number of candidates received a cochlear implant.

**Conclusion:** Even though the estimates do not reflect a direct measure of actual candidates in the targeted age groups, the population who could benefit from this technology is still being significantly underserved in the United States. With a continued shortage of qualified personnel to serve these children, insufficient reim-

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bursement rates, and disparities in implantation rates based on ethnicity and socioeconomic status, the question remains can we truly meet the needs of these children?  
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## 1. Introduction

Technological advances, specifically cochlear implants, have significantly impacted the treatment of children with severe to profound hearing loss. Cochlear implant candidacy criteria include children 12 months to 17 years of age with bilateral profound hearing loss as well as children 2–17 years of age with bilateral, severe to profound hearing loss (pure tone average of 70 dB or more in both ears) who receive little or no benefit from hearing aids [1,2]. Pediatric cochlear implantation has been demonstrated to be effective treatment [3] as well as cost effective for society [4–6]. Yet, information about the number of children who could benefit from this technology remains limited. Davis et al. [7] projected the number of potential pediatric candidates in Europe to be 1656 annually with a total of 2269 cases by the time that birth cohort reached 5 years of age. No comparable study exists for the United States population.

One of the Public Health Application and Outreach goals from Healthy People 2010, Objective 28:13b [8], is to increase the number people who are deaf or very hard-of-hearing who use cochlear implants. This goal was established in an attempt to address the fact that, despite the substantial benefit the procedure can provide recipients, cochlear implantation is an underutilized service. Specifically, the NIDCDs Healthy Hearing Progress Report notes that in 1999 only 2 of every 1000 adults who are deaf or very hard-of-hearing received a cochlear implant. Statistics for cochlear implant utilization in children are not provided, but similar underutilization is implied [9].

The two main objectives for this study were to (1) estimate the number of children between the ages of 12 months and 6 years of age with severe to profound bilateral hearing loss who could benefit from a cochlear implant and (2) determine if the number of children projected to be candidates received this medical care.

## 2. Methods

### 2.1. Population data

United States census figures from 2000 served as the foundation for this study. For a detailed description of the collection of the United States Decennial

Census, which occurs every 10 years, please refer to the Technical Documentation [10]. Total population figures for children 12 months to 6 years of age were imported into an Microsoft Excel spreadsheet using the Census 2000 Summary File 1 (SF1) 100-Percent Data [11].

### 2.2. Prevalence of severe to profound hearing loss

For the purpose of this study, the National Health Interview Survey (NHIS) and Gallaudet Research Institute (GRI) independent analysis of the NHIS from 1997 through 2003 served as the data source for estimating the prevalence of severe to profound hearing loss in the United States [12]. Estimates of deafness was based upon self reported hearing difficulty and not audiometric data (i.e., good, a little trouble, a lot of trouble, or deaf). Specifically, 0.06% of the total population for children between the ages of 1 and 5 years were reported deaf and 0.09% of the total population for children age 6 years were reported deaf [12]. The estimated number of children with severe to profound hearing loss in the United States who were between the ages of 12 months and 6 years of age was calculated using the US Census figures for 2000 and GRI data.

### 2.3. Candidacy exclusions

Most implant teams would agree that not all children with severe to profound hearing loss are candidates for the procedure. The challenge, then, is to determine if a subset or subsets of the population of children with severe to profound hearing loss should be excluded from consideration a priori, in effect reducing that upper bound. Davis et al. [7] estimated that at most 33% of children with profound hearing loss would be excluded from implant candidacy based on two factors: (1) family opposition to having an implant and (2) the presence of cognitive disorders. However, these authors did not provide a rationale for how this percentage was derived.

Even though most children (90%) who are born with bilateral, severe to profound hearing loss have hearing parents [13], it is true that not all parents of children with bilateral, severe to profound hearing loss will choose implantation for their child. The decision to pursue cochlear implantation for a child is most appropriately parent driven. Even if trends

existed in the literature, a priori exclusion of a child from candidacy consideration based on presumed parental attitudes would be inappropriate. For this investigation, exclusion based on family opposition was not included.

Second, between 21% [14] and 26.3% [15] of children with significant hearing loss have also been diagnosed with mental retardation. In the past, these children would have been excluded from candidacy [7,16]. Even now, cognitive disabilities may make cochlear implantation inappropriate. Children with such disabilities, however, are no longer automatically excluded from candidacy [16] and thus were not included in the exclusion category.

Children who are neurologically devastated, however, would not be considered a candidate for a cochlear implant. Mason and Herrman [17] screened 10,372 children for hearing loss as newborns and only one child (0.0096%) was found to be both profoundly deaf and neurologically devastated. Thus, for the purpose of this study, 0.0096% of the severe to profound hearing loss population was subtracted.

Bilateral eighth nerve aplasia is a contraindication to cochlear implantation. Even though it is rare [18], the condition precludes perception of sound from the stimulation provided by a cochlear implant. No prevalence data regarding this condition exist so an aggregated estimate was calculated based on the literature [19–21]; see Table 1. The estimated number of children with severe to profound hearing loss was multiplied by 1.05% to calculate the number of children excluded from consideration.

A variety of severe medical conditions, including, but not limited to, respiratory issues, blood disorders, and cancer (0.17%) could foreseeably render a child too medically fragile or unstable to undergo the surgery required for cochlear implantation [22]. These conditions were also excluded from consideration.

These calculations generated estimates of the number of otherwise eligible children who were excluded from consideration for cochlear implant candidacy. Once calculated, both figures were com-

bined and subtracted from the initial estimate of the number of children with severe to profound hearing loss in the target age range. An estimate of the number of cochlear implant candidates in the United States between 12 months and 6 years of age resulted.

### 3. Results

Analysis indicated that in the United States in 2000 approximately 12,816 children between 12 months and 6 years of age were very likely to be cochlear implant candidates. Of the 23,354,958 children in the target age range in 2000, 15,219 were identified as having severe to profound hearing loss. A total of 2403 were excluded for either neurologic devastation, absence of the eighth nerve, or medically fragile, resulting in the figure of 12,816. The number of potential candidates in each age group ranged from 1866 for 2 years old to 3194 for 6 years old. Details of the analysis are presented in Table 2.

Using the same analysis procedure, estimates per state were also calculated (see Table 3). The state with the most potential pediatric cochlear implant candidates for children 12 months through 6 years of age was California with 1688 candidates. The least amount of potential candidates was in Washington DC with an estimated 22 candidates.

Each cochlear implant manufacturer provided data regarding the number of cochlear implant recipients in 2000 and between the ages of 12 months and 6 years. The total number of children implanted in 2000 was 7065 [23–26]. Comparison of this figure with actual implantation statistics suggests that just over half (55%) of those who were very likely candidates for the procedure in 2000 had actually been implanted.

### 4. Discussion

#### 4.1. Prevalence of hearing loss

While overall prevalence of severe to profound hearing loss in the United States is a viable starting point for determining the number of potential implant candidates in the country, prevalence is not well understood. Reported prevalence numbers can be affected by many factors including, but not limited to, the population being studied and the type and degree of hearing loss targeted for study, as well as the method or test used to identify the presence of hearing loss [3,27]. Therefore, any estimate of the number of potential cochlear implant candidates in the United States will be

**Table 1** Estimates of absent eighth nerve in the pediatric population

Source	Number of cases	Percentage
Shelton et al. [19]	2 of 138	1.45
Ray et al. [20]	1 of 42	2.38
Papsin [21]	2 of 298	0.67
Aggregate	5 of 478	1.05

**Table 2** Estimate of children very likely to be cochlear implant candidates

Age group	Population		Exclusions		
	Total <sup>a</sup>	SPHL <sup>b</sup>	Neurologic devastation <sup>e</sup>	Absent 8th nerve <sup>f</sup>	Implant candidates
1-Year old	3,820,582	2,292 <sup>c</sup>	367	24	1,901
2-Year old	3,790,446	2,274 <sup>c</sup>	364	24	1,886
3-Year old	3,832,799	2,300 <sup>c</sup>	368	24	1,908
4-Year old	3,926,323	2,356 <sup>c</sup>	377	25	1,954
5-Year old	3,965,103	2,379 <sup>c</sup>	381	25	1,973
6-Year old	4,019,705	3,618 <sup>d</sup>	386	38	3,194
Total	23,354,958	15,219	2243	160	12,816

<sup>a</sup> United States Census Bureau [11].

<sup>b</sup> SPHL: severe to profound hearing loss.

<sup>c</sup> 0.06% of total population; based on Mitchell [12].

<sup>d</sup> 0.09% of total population; based on Mitchell [12].

<sup>e</sup> 0.0096% of total population; derived from Mason and Herrmann [17].

<sup>f</sup> 1.05% of population with severe to profound hearing loss; derived from Shelton et al. [19], Ray et al. [20], and Papsin [21].

affected by the prevalence data used to generate that estimate.

In projecting the number of potential cochlear implant candidates in the UK, Davis et al. [7] assumed a prevalence rate for profound hearing loss of 0.037%. This prevalence rate was based on audiometric findings consistent with the presence of average hearing impairment of 95 dB HL or worse in a group of children 40–180 months (3–9 years) of age from three health districts in the United Kingdom. In contrast, this study assumed prevalence rates for severe to profound hearing loss of 0.06% and 0.09% depending on the age range in question [12]. Prevalence rates were based on parent/care giver-reported, functional descriptions of hearing status in statistical samples of children less than 6 years of age and 6–17 years of age from across the United States. These differences may account for the similarity in number of candidates identified in each birth cohort despite the dissimilar total population figures.

The 0.037% prevalence rate utilized by Davis et al. [7] is approximately half the rate quoted by other authors. Based on an incidence of 5 cases per 10,000 births, Blanchfield et al. [28] projected that in the United States a minimum of 5600 children birth to 2 years of age were profoundly hearing impaired. Van Naarden et al. [15] reported prevalence rates of 0.067–0.11% for 3–6 years old. The prevalence rates reported by the latter two studies are relatively consistent with the 0.06% and 0.09% rates used by this study, supporting the figure of 12,816 as a reasonable projection of the number of potential cochlear implant candidates in the 12 months to 6 years old age range in the United States.

**Table 3** Estimated number of pediatric cochlear implant candidates in the united states ( $n = 12,816$ )

State	Pediatric candidates
Alabama	198
Alaska	32
Arizona	251
Arkansas	119
California	1688
Colorado	195
Connecticut	151
Delaware	34
District of Columbia	22
Florida	636
Georgia	391
Hawaii	53
Idaho	65
Illinois	587
Indiana	280
Iowa	126
Kansas	124
Kentucky	176
Louisiana	211
Maine	49
Maryland	238
Massachusetts	267
Michigan	455
Minnesota	221
Mississippi	136
Missouri	247
Montana	37
Nebraska	78
Nevada	96
New Hampshire	52
New Jersey	379
New Mexico	87
New York	835
North Carolina	355

**Table 3** (Continued)

State	Pediatric candidates
North Dakota	27
Ohio	506
Oklahoma	155
Oregon	147
Pennsylvania	498
Rhode Island	44
South Carolina	175
South Dakota	34
Tennessee	248
Texas	1065
Utah	131
Vermont	24
Virginia	308
Washington	263
West Virginia	68
Wisconsin	231
Wyoming	21

#### 4.2. Critical period for cochlear implantation

For this study the age range was limited between the ages of 12 months and 6 years due to the critical period of maximizing the benefits for the cochlear implant system. Graham and Dickens [14] stated that preschool children should represent the largest group of ideal pediatric cochlear implant candidates. This assertion is supported by data substantiating the presence of a critical period for implantation of children with congenital deafness [29–31]. This study did not take into account benefits received by the cochlear implant. Even though the data reveals that there would be potentially more 6 years old as candidates for cochlear implantation, this is due to the total larger number of children in that age group compared to the younger age groups and does not account for decreased neural plasticity.

#### 4.3. Access to care

Predicting the number of patients who could benefit from cochlear implantation is important. This information can be used to educate health care providers, third-party payers, and policy makers with the intent of positively impacting public policy, health initiatives, and public awareness. The ultimate goal of these efforts is to improve access to care. Resources must be in place to meet the projected demand. In the case of cochlear implantation, technological advancements have resulted in improved outcomes for recipients and rapidly increasing demand for services.

With slightly over half of the potential number of pediatric cochlear implant candidates receiving this

medical intervention, the question remains how do we make this more accessible to patients who need this treatment in our current medical system. There is a shortages in the number of professionals qualified to provide the audiologic and speech-language services needed for implant recipients [32], reimbursement rates are insufficient to meet actual costs of service delivery [28,32], and there are disparities in implantation rates based on ethnicity and socioeconomic status [33]. Taken alongside the indication that young children who could benefit from cochlear implantation are being underserved, these reports suggest the presence of a stressed and inadequate service delivery system.

The figure of 12,816 potential cochlear implant candidates was derived based on an estimate of the prevalence of severe to profound hearing loss as well as estimates of candidacy exclusion. It does not reflect a direct measure of actual candidates in the target age group. This estimate of the prevalence of implant candidacy, therefore, has carried forward any sampling and statistical errors inherent to the data sets used to derive it. Further research is needed to establish prevalence rates for cochlear implant candidacy in young children that are based on actual head counts rather than derived figures. It is only then that important questions regarding service delivery to this population can be effectively addressed and the population as a whole adequately served.

## 5. Conclusion

The purpose of this study was to estimate the number of potential cochlear implant candidates for children between the ages of 12 months and 6 years of age. Based on our estimates, 12,816 children are considered to be cochlear implant candidates not taking into account parental choice of not pursuing a cochlear implant for their child, socioeconomic factors, or how cochlear implant teams decide who is a candidate or not. Furthermore, based on this finding, not all potential pediatric candidates are accessing this health care.

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