

Lack of Financial Barriers to Pediatric Cochlear Implantation

Impact of Socioeconomic Status on Access and Outcomes

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Objectives: (1) To analyze if socioeconomic status influences access to cochlear implantation in an environment with adequate Medicaid reimbursement. (2) To determine the impact of socioeconomic status on outcomes after unilateral cochlear implantation.

Design: Retrospective cohort study.

Setting: University Hospitals Case Medical Center and Rainbow Babies and Children's Hospital (tertiary referral center), Cleveland, Ohio.

Participants: Pediatric patients (age range, newborn to 18 years) who received unilateral cochlear implantation during the period 1996 to 2008.

Main Outcome Measures: Access to cochlear implantation after referral to a cochlear implant center, postoperative complications, compliance with follow-up appointments, and access to sequential bilateral cochlear implantation.

Results: A total of 133 pediatric patients were included in this study; 64 were Medicaid-insured patients and 69 were privately insured patients. There was no statistical difference in the odds of initial cochlear implantation, age at referral, or age at implantation between the 2 groups.

The odds of prelingual Medicaid-insured patients receiving sequential bilateral cochlear implantation was less than half that of the privately insured group (odds ratio [OR], 0.43; $P = .03$). The odds of complications in Medicaid-insured children were almost 5-fold greater than the odds for privately insured children (OR, 4.6; $P = .03$). There were 10 complications in 51 Medicaid-insured patients (19.6%) as opposed to 3 in 61 privately insured patients (4.9%). Medicaid-insured patients missed substantially more follow-up appointments overall (35% vs 23%) and more consecutive visits (1.9 vs 1.1) compared with privately insured patients.

Conclusions: In an environment with adequate Medicaid reimbursement, eligible children have equal access to cochlear implantation, regardless of socioeconomic background. However, lower socioeconomic background is associated with higher rates of postoperative complications, worse follow-up compliance, and lower rates of sequential bilateral implantation, observed herein in Medicaid-insured patients. These findings present opportunities for cochlear implant centers to create programs to address such downstream disparities.

Arch Otolaryngol Head Neck Surg. 2010;136(7):648-657

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COCHLEAR IMPLANTATION IS a powerful tool for helping children with severe to profound sensorineural hearing loss gain the ability to hear, achieve age-appropriate reading skills, and develop communication skills



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equal to those of their hearing counterparts.^{1,2} Owing to cochlear implant's well established societal cost-effectiveness, the US Department of Health and Health Services included cochlear implantation as a

point of emphasis of Healthy People 2010.³ Recent work by Bradham and Jones,³ however, estimates that only 55% of all candidates for cochlear implants aged 1 to 6 years receive cochlear implants. By correlating the zip codes of implant recipients and median income levels in those areas, Stern et al⁴ suggest that children with higher socioeconomic status (SES) are more likely to undergo implantation. This finding is despite a higher prevalence of hearing loss in low-income households compared with households with higher income levels.⁵

Inadequate Medicaid reimbursement leading to negative financial pressures on hospitals has been suggested to limit access to cochlear implants.^{6,7} Medicaid status, with its income eligibility require-

ments based on federal poverty guidelines, has been used effectively as a proxy measure of SES.⁸⁻¹⁰ The disparity that exists in cochlear implantation owing to socioeconomic factors has been partly attributed to inadequate insurance reimbursement in patients with lower income.⁷ It is well known that there is wide variability in Medicaid reimbursement for cochlear implantation throughout the United States, with some states compensating below cost and others covering costs.^{6,11} Thus, depending on the state, some cochlear implant centers stand to incur tremendous losses by serving those with lower SES (ie, those insured by Medicaid).^{6,11} However, these financial barriers are mitigated in states where Medicaid reimbursement adequately covers the hospital costs of implant purchase and implantation. As a result, Medicaid-insured cochlear implant procedures in such venues do not necessarily create substantial financial losses compared with their privately insured counterparts. There is currently no evidence to show that improved reimbursement can overcome other factors influenced by SES, such as lack of information on cochlear implantation or lack of proximity to cochlear implantation programs.

To evaluate the correlation between income level and access to cochlear implantation, we reviewed our cochlear implant program, which accepts children who carry both private and public insurance (ie, Medicaid). Medicaid coverage is available for all eligible children in Ohio, which, unlike many other states, has full cochlear implant benefits with mechanisms for adequate reimbursement of cochlear implant services, including surgery and implant cost recovery. Despite other potential factors contributing to the socioeconomic disparity in cochlear implantation (eg, referral patterns and lack of availability of knowledge regarding the technology), we sought to elucidate whether sufficient compensation would neutralize disparities in implantation rates. Thus, we hypothesize that in this environment of adequate reimbursement, pediatric patients of lower SES are afforded access to cochlear implantations similar to that of privately insured patients.

There is a perceived disparity in outcomes based on SES according to audiologists, who play an integral role in providing auditory rehabilitation and contributing to the successful long-term outcome of cochlear implant recipients.¹² Studies¹³⁻¹⁶ investigating the impact of factors such as SES on pediatric cochlear implant recipients have primarily focused on various aspects of communication skills with findings showing low SES associated with worse outcomes. We investigated potential factors contributing to the disparity in outcomes, including compliance with important postimplant follow-up. Medicaid-insured infants, who are eligible for hearing aids, have been reported to be more likely to be lost to follow-up than privately insured infants.¹⁷ We hypothesized that, after cochlear implantation, SES has a negative impact on compliance with follow-up visits, postoperative complications rate, and sequential bilateral cochlear implantation.

In this study, we retrospectively reviewed our cochlear implant program's pediatric population and compared access to cochlear implantation, compliance with follow-up visits, postoperative complications, and sequential bilateral cochlear implantation between patients insured with Medicaid and those with private insurance.

STUDY PARTICIPANTS

A database of all patients referred for cochlear implant evaluation and implantation has been compiled since the initiation of the cochlear implantation program at the University Hospitals Case Medical Center (UHCMC) and Rainbow Babies and Children's Hospital (RBCH) in 1996. Pediatric patients from this database, from newborns to those aged 18 years, were identified in this retrospective cohort study and their medical records reviewed. The cutoff for study eligibility was implantation no later than the end of 2008 to allow for an adequate follow-up period. The study design was reviewed and approved by the UHCMC institutional review board.

DATA COLLECTION

Demographic information collected includes verification by history of prelingual vs postlingual deafness, age at referral or evaluation, age at implantation, sex, insurance status, and age at bilateral implantation, if applicable. In addition, etiology of deafness and comorbid conditions (eg, premature birth and history of meningitis) were also assessed. Preoperative imaging of the inner ear was reviewed, and abnormalities were documented. Audiologic performance measures including pure tone average (500, 1000, and 2000 Hz), auditory brainstem response, and speech detection threshold were analyzed before and after cochlear implantation, when applicable. In instances where both ears were tested, the best response was used for analysis because the best ear determined the degree of overall hearing loss. Since 2001 at UHCMC and RBCH, patient appointments have been compiled and managed on an electronic database. Using this system, the follow-up therapy and programming appointments scheduled for each patient were reviewed. Finally, postoperative complications after cochlear implantation were documented. Medicaid cochlear implant reimbursement policies for various states across the United States, including Ohio, were analyzed by communication with the reimbursement division of Cochlear Corp (Denver, Colorado). Reimbursement data for Ohio were confirmed by team members with expertise in Ohio Medicaid reimbursement policy and coding for cochlear implants.

ACCESS TO COCHLEAR IMPLANTATION

Patients in the study were separated into 2 groups based on Medicaid or private insurance, our proxy for SES. Access to cochlear implantation was measured by referral to our program as well as successful implantation after the determination of audiometric and medical candidacy. Patients who were not deemed to be cochlear implant candidates based on audiology results or medical contraindications were removed from our study. The mean age at cochlear implant referral and evaluation and the mean age at implantation between the 2 insurance groups were compared. In addition, patients with prelingual deafness were separated for subgroup analyses and evaluated to assess efficiency of community identification and referral of children with congenitally severe to profound hearing loss. Patients without implants were analyzed for factors contributing to not receiving cochlear implantation.

COCHLEAR IMPLANTATION OUTCOMES

Analysis of outcomes after cochlear implantation included determining the likelihood of sequential bilateral cochlear implantation, incidence of postoperative complications, and compliance with follow-up medical and therapy (aural, oral, and programming) appointments.

Table 1. Characteristics of the 133 Study Participants^a

Characteristic	Value
Sex	
Male	66 (50)
Female	67 (50)
Insurance type	
Private	69 (52)
Medicaid	64 (49)
With implants	114 (86)
With sequential bilateral implantation	54 (47)
Age at referral, mean (SD), y	4.8 (4.5)
Age at implantation, mean (SD), y	5.2 (4.3)
Onset of deafness ^b	
Prelingual	123 (94)
Postlingual	8 (6)
Etiologies and comorbidities, No.	
Prematurity	39
Ototoxic antibiotics	17
Connexin 26 mutation	13
Developmental delay	13
Meningitis	12
Prenatal infection (eg, CMV, rubella)	9
Syndromic HL	9
Inner ear abnormalities	30
Audiology results, mean (SD), dB	
PTA	97 (13)
Aided PTA	61 (19)
ABR	94 (10)
SDT	86 (17)
Aided SDT	56 (18)

Abbreviations: ABR, auditory brainstem response; CMV, cytomegalovirus; HL, hearing loss; PTA, pure-tone average; SDT, speech detection threshold.

^aData are given as number of subjects (percentage) unless otherwise specified.

^bDate of onset of deafness was unknown for 2 patients without implants.

The incidence of sequential bilateral cochlear implantation was determined by examining the pediatric patients who received unilateral cochlear implantation and calculating the number of these patients who received a second side cochlear implant. This was compared between the Medicaid-insured group and privately insured group.

Complications were classified into major vs minor complications and immediate (<1 week) vs delayed (≥1 week) events. Major complications included those requiring hospitalization, intravenous antibiotics, or surgery. Minor complications were those treated by outpatient medical care, such as oral antibiotics. Complications were compared between the Medicaid-insured group and privately insured group.

Because compliance with regular cochlear implant programming in addition to both oral and aural rehabilitation is paramount to successful long-term outcomes in the pediatric group, the percentage of missed follow-up appointments was calculated by dividing the number of cancelled or no-show appointments by the total number of scheduled appointment for the period beginning after cochlear implantation.¹⁸ Missed appointments represented visits that were cancelled and rescheduled as well as those missed altogether. Patients who demonstrate good follow-up should be seen at recommended intervals and be reliable in their follow-up visits. The percentages of missed follow-up were determined after the first cochlear implantation and after sequential bilateral implantation, and were merged to calculate the percentage for total missed appointments. A second measure of follow-up compliance was the number of times consecutive appointments were missed. Each count represented more than 2 appointments missed consecutively. A final measure used

to evaluate follow-up compliance was the number of days between implantation and initial cochlear implant activation after unilateral cochlear implantation and after sequential bilateral implantation. Because the protocol for all cochlear implant patients is activation 1 month after cochlear implantation, this allowed another measure of compliance. Patients who did not have their follow-up audiology and surgical visits managed at UHCMC and RBCH or had follow-up appointments prior to the institution of the electronic database were excluded from the follow-up compliance analysis.

STATISTICAL ANALYSIS

An analysis of the relationship between the insurance status (ie, Medicaid and private insurance) and various outcome responses, including cochlear implantation (yes/no), bilateral implantation (yes/no), and complications (yes/no), was performed using binary logistic regression. Insurance status was treated as a categorical variable. The results of the logistic regression analysis were reported as an odds ratio (OR) with a 95% confidence interval (CI). The analysis of the relationship between insurance status (ie, Medicaid vs private insurance) and outcome variables such as mean age at referral, mean age at first and second implantations, number of complications, and percentage of post-cochlear implant missed follow-up visits was performed by analysis of variance and the Tukey post hoc test for multiple comparisons. Results were reported as mean (SD). $P < .05$ was considered statistically significant. All statistical analyses were performed using Minitab statistical software (Minitab Inc, State College, Pennsylvania).

RESULTS

PATIENT CHARACTERISTICS

A total of 133 pediatric patients (age range, newborn to 18 years old) referred to UHCMC and RBCH were included in this study. **Table 1** shows the characteristics of these study patients, including demographics, comorbidities, and audiology results. There was an equal number of boys to girls in our pediatric patient population. The mean age of the population when initially referred for cochlear implant was 4.8 years. The mean age of the patients at implantation was 5.2 years. Ninety-four percent of the patients were prelingually deaf. Etiologies of hearing loss that were of highest prevalence in our cohort included ototoxic antibiotic use (17 patients), Connexin 26 genetic mutation (13 patients), meningitis (12 patients), and comorbidities, including prematurity (39 patients) and developmental delay (13 patients). Inner ear abnormalities, such as enlarged vestibular aqueduct, Mondini malformation, and cochlear ossification, were found in 30 of the patients. Audiology results for both Medicaid-insured and privately insured patients at cochlear implant evaluations showed similar levels of hearing impairment; however, Medicaid-insured patients showed poorer aided test results (**Table 2**).

ACCESS TO COCHLEAR IMPLANTS

All Patients

The analysis of access to cochlear implantation with patients divided into their respective Medicaid and private in-

Table 2. Comparison of Patients With Medicaid and Private Insurance Before Implantation, at Implantation, and After Implantation^a

Characteristic	Medicare		Private Insurance		P Value
	Mean (SD)	No.	Mean (SD)	No.	
All patients					
Pre-cochlear implant audiology results, dB					
PTA	98 (14)	60	96 (13)	63	.35
Aided PTA	66 (19)	55	58 (17)	65	.02 ^a
ABR	92 (12)	8	95 (10)	16	.45
SDT	88 (17)	60	83 (18)	61	.15
Aided SDT	61 (17)	54	51 (17)	59	.004 ^a
Age at referral, all patients, y	4.8 (4.0)	64	4.8 (4.8)	69	.97
Ages of patients with implants, y					
At referral	4.0 (3.5)	52	5.2 (4.9)	62	.16
At implantation	4.5 (3.5)	52	5.8 (4.9)	62	.11
At bilateral implantation	5.4 (3.2)	20	6.9 (4.4)	34	.20
Ages of patients without implants, y					
At referral	8.0 (4.7)	12	1.3 (1.9)	7	.002 ^a
Prelinguals					
At referral	4.7 (4.0)	62	4.0 (4.4)	61	.35
At implantation	4.5 (3.5)	52	4.9 (4.5)	54	.60
At bilateral implantation	5.4 (3.2)	20	6.6 (4.4)	32	.30
Outcomes					
First implant, missed follow-up appts, %	33 (17)	51	23 (14)	53	.001 ^a
Second implant, missed follow-up appts, %	26 (17)	20	19 (13)	29	.09
Total missed follow-up appts, %	35 (15)	51	23 (13)	53	<.001 ^a
Consecutive missed appts, No.	1.9 (1.6)	51	1.1 (1.5)	53	.009 ^a
Days to initial stimulation, first implant	35 (7)	50	32 (7)	52	.10
Days to initial stimulation, second implant	36 (8)	20	36 (8)	28	.95

Abbreviations: ABR, auditory brainstem response; appts, appointments; PTA, pure-tone average; SDT, speech detection threshold.

^a $P < .05$.

Table 3. Logistic Regression Analysis of Access and Outcomes Between Medicaid-Insured and Privately Insured Patients

Type of Patient	Type of Insurance, No.		OR (95% CI) ^a	P Value
	Medicaid	Private		
All patients				
Male	31	35	0.91 (0.46-1.80)	.79
Female	33	34		
Prelingual	62	61		.007 ^b
Postlingual	0	8		
First cochlear implantation	52	62	0.49 (0.18-1.33)	.16
Nonrecipients	12	7		
Sequential bilateral implantation	20	34	0.51 (0.24-1.09)	.08
Second implant nonrecipients	32	28		
Patients with implants				
Complications, No. (%)	10 (19.6)	3 (4.9)	4.6 (1.2-17.7)	.03 ^b
Prelingually deaf patients				
First cochlear implantation	52	54	0.67 (0.24-1.90)	.46
Nonrecipients	10	7		
Sequential bilateral implantation	20	32	0.43 (0.2-0.94)	.03 ^b
Second implant nonrecipients	32	22		

Abbreviations: CI, confidence interval; OR, odds ratio.

^aLack of result represents unstable statistical analysis with an OR that is very high owing to zero postlingual Medicaid-insured patients.

^b $P < .05$.

insurance groups is shown in Table 2 and **Table 3**. Two patients were initially referred and evaluated at our program but eventually received cochlear implants at other facilities; however, because both their implant and insurance status are both well described, they were included in our analysis. Of the 133 patients in this study, 64 had Medicaid insurance, whereas 69 had private insurance, corresponding to 48% and 52% of the entire cohort, respectively. There was no difference between the number of girls

and boys in each insurance group referred for cochlear implant evaluation. Likewise, there was no statistical difference between Medicaid-insured and privately insured children for mean age at cochlear implant referral (4.8 years) and the likelihood that they would undergo cochlear implantation. **Figure 1** shows the age distribution of the study participants in each insurance group who were referred for cochlear implant evaluation and subsequently received implants. The youngest (<2 years) and oldest (>6 years) pa-

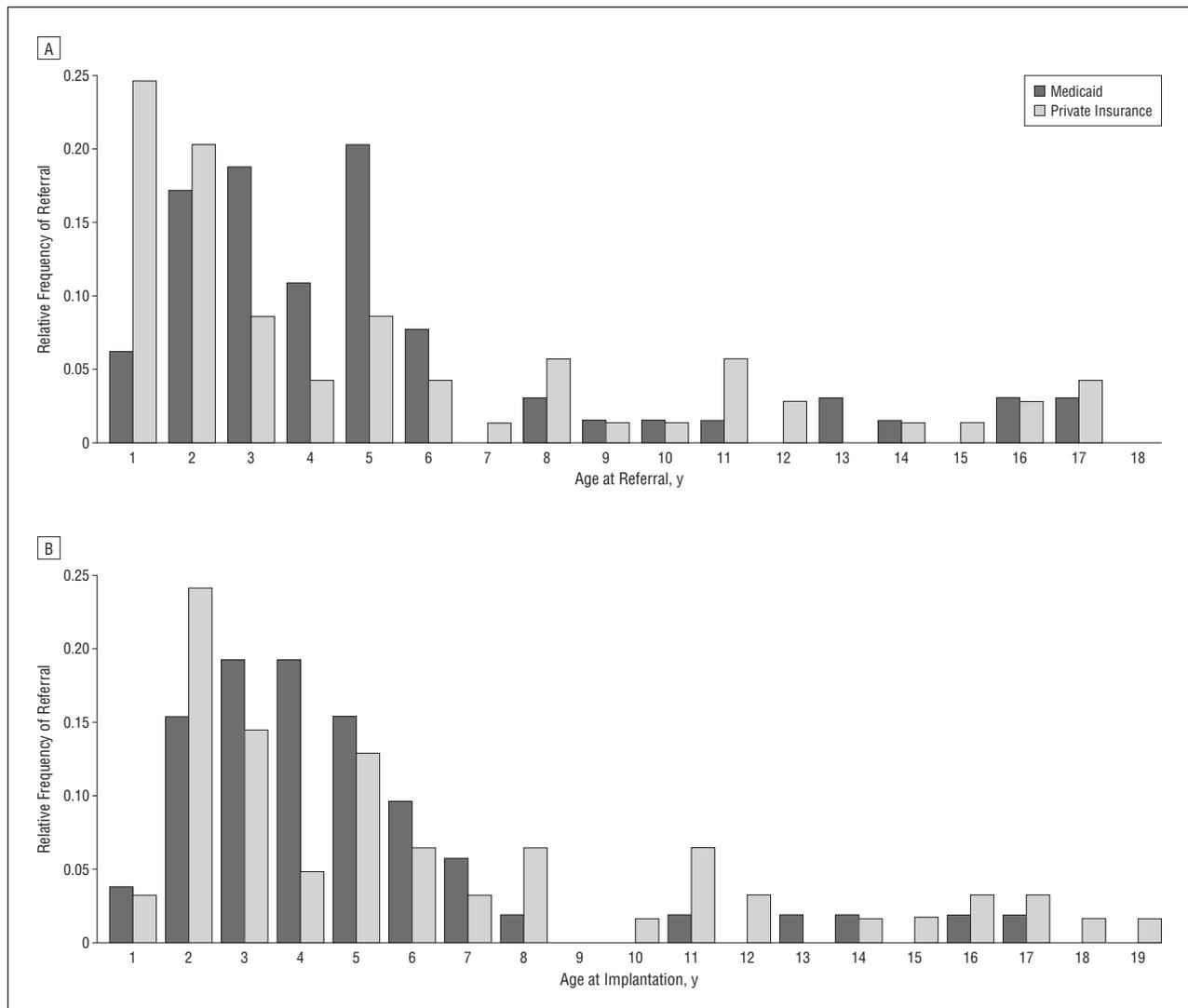


Figure 1. Age distribution of patients. A, Patients referred for cochlear implant evaluation (n=133), and B, patients who underwent implantation (n=114) at University Hospitals Case Medical Center and Rainbow Babies and Children's Hospital, Cleveland, Ohio.

tients referred are, to a greater extent, insured by private insurance, whereas Medicaid-insured patients constitute a higher percentage of patients aged 2 to 6 years (Figure 1A). When the data for patients with implants were analyzed, Medicaid-insured patients were younger by approximately 1 year compared with privately insured patients at both referral and at cochlear implantation, although the difference was not statistically significant ($P=.16$ and $P=.11$, respectively) (Table 2).

Prelingually Deaf Patients

In this study, 123 children (94%) were prelingually deaf. Among these, Medicaid-insured patients were just as likely to undergo implantation as their privately insured counterparts (OR, 0.67; $P=.46$) (Table 3). Age at referral as well as age at cochlear implantation was also similar between the 2 insurance groups: 4.7 vs 4.0 years old at referral ($P=.35$) and 4.5 vs 4.9 years old at implantation ($P=.60$) for Medicaid-insured patients compared with privately insured patients, respectively (Table 2).

Patients Without Implants

There was a total of 19 patients in the study who were referred or evaluated for cochlear implantation and did not undergo implantation at our facility. Analysis of referrals in this subgroup is shown in Table 2 and Table 3. Although more Medicaid-insured patients were in this group (12 vs 7), the odds of Medicaid-insured patients to be in this group was statistically similar to the odds of privately insured patients (OR, 2.04; $P=.16$). The difference in the average age of Medicaid-insured patients in this group without implants vs privately insured patients was significant at age 8 years compared with age 1.3 years, respectively ($P=.002$).

A comparison of the patients with implants vs those without is shown in **Table 4**. In general, the age at which nonrecipients were referred was similar to that of the groups with implants. However, a closer examination of the Medicaid-insured patients in these 2 groups showed that the nonrecipient Medicaid-insured patients were older than the Medicaid-insured patients who received implants by 4 years (8 years vs 4 years; $P=.002$). Conversely, nonre-

Table 4. Comparison of Age at Referral Between Children With and Without Implants

Patients	Without Implant		With Implant		P Value
	Age at Referral, mean (SD), y	No.	Age at Referral, mean (SD), y	No.	
All patients	5.5 (5.1)	19	4.7 (4.4)	114	.45
Patients with Medicaid	8.0 (4.7)	12	4.0 (3.5)	52	.002 ^a
Patients with private insurance	1.3 (1.9)	7	5.2 (4.9)	62	.04 ^a

^a $P < .05$.

patient privately insured patients were nearly 4 years younger (1.3 years vs 5.2 years; $P = .04$). The reasons for cochlear implant candidates to not proceed with cochlear implantation at our program can be separated into 3 groups: (1) refusal of implant, (2) failure to complete cochlear implant evaluation or return for follow-up, and (3) interest in proceeding at other facilities. Patients who were classified in categories 1 and 3 were determined based on informal survey of families by communication during pre-cochlear implant follow-up. Group 2 patients were determined based on termination of pre-cochlear implant follow-up. In group 1, 3 were Medicaid-insured patients, whereas none were privately insured. In group 2, 9 were Medicaid-insured patients, whereas 4 were privately insured. In group 3, none were Medicaid-insured patients, whereas 3 were privately insured.

COCHLEAR IMPLANT OUTCOMES

Sequential Bilateral Implantation

Of the patients who received implants, 47% received sequential bilateral cochlear implantation. This is an option offered to all patients after successful performance with the primary implant. Analysis for this group is shown in Table 2 and Table 3. Although there was a trend for more privately insured patients to receive sequential bilateral implants compared with Medicaid-insured patients (34 and 20, respectively), this did not reach statistical significance (OR, 0.51; $P = .08$). The difference in age between sequential patients who received implants insured by Medicaid or private insurance was also not statistically significant. However, evaluating only the prelingually deaf children, who accounted for 94% of all the children in the study, the odds of Medicaid-insured patients receiving sequential bilateral cochlear implants was less than half as likely as the privately insured group (OR, 0.43; $P = .03$). There was no substantial age difference at sequential bilateral implantation between the 2 groups.

Postoperative Complications

Complications that occurred after cochlear implantation surgery included surgical wound issues, infections around or at the implant magnet site, trauma involving the implant site, device extrusion, and device failure, with or without the need for revision surgery. The odds of complications occurring in Medicaid-insured patients were almost 5 times more likely than for privately insured children (OR, 4.6; $P = .03$), with 10 complications occurring in 51 Medicaid-

insured patients (19.6%) as opposed to 3 complications occurring in 61 privately insured patients (4.9%) (Table 3). Analysis of data for the patients with complications is presented in more detail in **Table 5**. There were more major complications in the Medicaid group compared with the privately insured children (6 [11.8%] vs 2 [3.3%]). Similarly, there were more minor complications in the Medicaid group compared with children who were insured privately (4 [7.8%] vs 1 [1.6%]). The 3 total incidences of device failure occurred solely in the Medicaid population. It is worth noting that there were no cases of postimplant meningitis in either insurance group of our patient population.

Compliance With Follow-up

Appointments after cochlear implantation for surgery and audiology were analyzed in terms of time to initial implant activation, missed follow-up percentage, and the frequency of consecutive missed appointments. Findings are summarized in Table 2 and illustrated in **Figure 2**. Medicaid-insured and privately insured patients showed similar adherence with initial 1 month post-cochlear implant activation after unilateral as well as sequential bilateral cochlear implantation ($P = .10$ and $P = .95$, respectively). The percentage of missed or cancelled appointments was higher for Medicaid-insured patients compared with privately insured patients. After unilateral implantation, Medicaid-insured patients missed 33% of scheduled follow-up appointments, whereas privately insured patients missed 23% of follow-up appointments ($P = .001$). After sequential bilateral implantation, although Medicaid-insured patients once again missed a higher percentage of appointments than privately insured patients, the difference was not statistically significant ($P = .09$). With all follow-up appointments taken into account, Medicaid-insured patients had a greater percentage of missed appointments than patients with private insurance (35%-23%; $P < .001$). These percentages correspond to Medicaid-insured patients missing more than 1 of every 3 follow-up visits and privately insured children missing less than 1 of every 4 follow-up appointments. Evaluation of consecutive missed appointments showed a similar trend in that Medicaid-insured children failed to show for consecutive follow-up appointments at 2 separate occasions compared with a single occasion for children with private insurance (1.9 vs 1.1; respectively, $P = .009$). The higher percentage of missed appointments and greater number of missed consecutive appointments together suggests a longer time interval between follow-up visits in Medicaid-insured patients.

Table 5. Complications and Associated Compliance With Follow-up Appointments

Type of Insurance and Complication	Complication Classification	Missed Follow-Up, %	Consecutive Missed Visits, No.	Days to Stimulation	
				First Implant ^a	Second Implant ^b
Private insurance					
Trauma leading to mastoiditis, magnet displacement, and surgical replacement of magnet	Delayed major	2	0	30	37
Mastoiditis and abscess that did not involve the implant	Delayed minor	33	2	35	42
Tight magnet leading to ulceration, infection, debridement, and implant revision	Delayed major	16	1	40	33
Total, major/minor, No. (%)	2.0 (3.3)/1.0 (1.6)				
Mean		17	1	35	37
Medicaid insurance					
Otitis media leading to mastoiditis at implant site	Delayed minor	26	2	51	44
1. Wound dehiscence prior to postop follow-up	1. Immediate minor	27	2	34	34
2. Trauma leading to skull fracture at magnet, wound infection involving cochlear implant resulting in implant removal	2. Delayed major				
Device failure with revision	Delayed major	69	3	43	
Fall resulting in skull fracture and CSF leak into implant bed	Delayed minor	34	3	37	
Mastoiditis of implanted side requiring I&D and IV antibiotics	Delayed major	44	5	31	
Internal device failure within 1 wk of turning on with revision surgery	Delayed major	68	3	35	
Device failure after 2 y with revision	Delayed major	50	1	45	16
Auricular hematoma with smashed external implant unit	Delayed minor	39	1		38
Trauma leading to infection, implant extrusion, revision mastoidectomy, and debridement	Delayed major	46	2	24	
Total, major/minor, No. (%)	6.0 (911.8)/4.0 (7.8)				
Mean		45	2	38	33

Abbreviations: I&D, incision and drainage; IV, intravenous; postop, postoperative.

^aThe empty cell indicates that first implant activation prior to institution of the electronic database for patient appointments.

^bEmpty cells indicate that the patient did not receive sequential bilateral implantation.

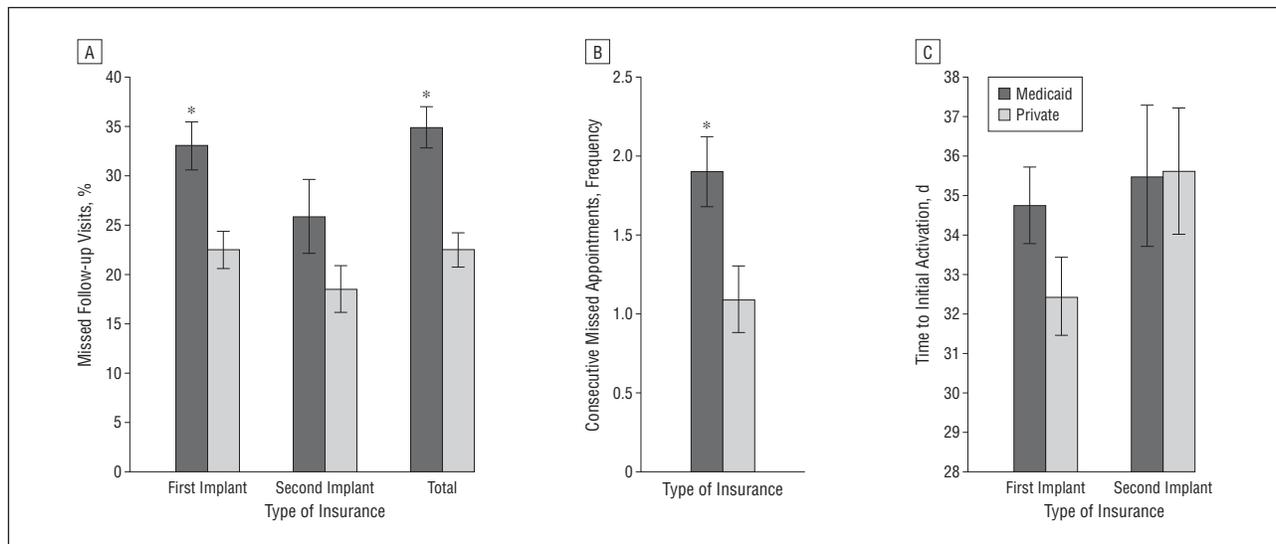


Figure 2. Comparisons of compliance. A, Comparison of compliance by percentage of missed follow-up visits; B, by consecutive missed appointments; and C, time to first cochlear implant activation between Medicaid-insured and privately insured children. Data are given as the mean ± standard error of the mean. The asterisk indicates $P < .05$.

Evaluation of compliance with follow-up in the pediatric population that experienced complications is shown in Table 5. On average, privately insured patients with complications were no different than privately insured patients without complications in terms of follow-up compliance (eg, 17%-23% missed appointments and 1 occurrence of consecutive missed appointments in both groups).

However, children in the Medicaid-insured group with complications, on average, showed poorer follow-up compliance compared with all children in the Medicaid-insured group, with or without complications (45% vs 35% missed appointments and a total of 2.4 vs 1.9 number of consecutive appointments missed), and much worse compliance compared with their privately insured counter-

parts (45% vs 17% missed appointments and a total of 2.4 vs 1 consecutive missed appointments).

COMMENT

We analyzed whether SES has an impact on access to cochlear implantation when all pediatric patients are viewed equally in regard to reimbursement level. A second aim was to determine whether SES would affect outcomes such as likelihood of sequential bilateral cochlear implantation, postoperative complications, and compliance with follow-up appointments once cochlear implants were received. These aims were accomplished by retrospectively analyzing the pediatrics population in our cochlear implant program database at the UHCMC and RBCH. To our knowledge, this is the first study to analyze evaluation, unilateral cochlear implantation, second side implantation, postoperative complications, and follow-up compliance in an environment without financial barriers to cochlear implantation in pediatric patients. Overall, we found that SES did not make a significant difference in regard to access because Medicaid-insured and privately insured patients were referred, evaluated, and received implants at similar rates. Implantation numbers seemed to minimally favor privately insured patients, but accessibility to cochlear implantation was not an issue because all of the nonrecipients covered by Medicaid insurance failed to either follow up with pre-cochlear implant appointments or declined the implant. Analysis of sequential bilateral cochlear implantation, postoperative complications, and compliance with follow-ups after unilateral cochlear implantation demonstrated a significant difference between the 2 insurance groups, namely, implications for poorer outcomes in Medicaid-insured children.

Our results are not in agreement with previous studies that focused primarily on national cochlear implantation data. Stern et al⁴ found, in analyzing a national cohort of children who received implants in 1997, that patients from lower-income families had lower rates of implantation compared with higher-income groups. Fortnum et al¹⁹ had findings similar to those of Stern et al⁴ in terms of higher implantation rates for patients of affluent families when analyzing the population of hearing-impaired children in the United Kingdom. Both of these studies relied on zip codes or postcodes to estimate income level, the accuracy of which has been called into question.^{20,21} Using insurance type in our study allowed a more direct correlation with income levels because Medicaid eligibility is based on federal poverty guidelines.^{8,9} Wide state-to-state variability in Medicaid reimbursement may also be a factor in the differences of our study findings compared with those of others.^{6,11} Our findings are consistent with those of a recent study by Wiley and Meinzen-Derr²² at the University of Cincinnati, Ohio, demonstrating that SES was not a significant factor influencing referral rates from audiology for cochlear implant evaluation.

Because the disparity in access described in the introductory paragraphs has at least been partly attributed to inadequate reimbursement, we contacted Cochlear Corp for their data on state reimbursement variation. On the one hand, various states, including Massachusetts, Colorado,

and Utah, are currently compensating well below costs. On the other hand, states such as California and Mississippi seem to sufficiently cover cochlear implantation costs; in California, cochlear implant devices are reimbursed at invoice costs, whereas Mississippi reimbursement of cochlear implantation costs are the lower of either 75% of charges or cost-to-charge ratio (Cochlear Corp; oral communication; July 2, 2009). As mentioned, Ohio is another state where reimbursement does not create a financial disincentive to cochlear implantation because it covers the costs of high-priced procedures via a mechanism that allows hospitals to recover surgery and device costs (Cochlear Corp; oral communication; July 2, 2009). We speculate that states with lower Medicaid reimbursement would likely have lower rates of cochlear implantation because financial losses would result in limited access to cochlear implantation. This would have a negative impact on those of lower SES because those of higher SES could afford to search for other out-of-state centers. A survey of state-by-state implantation rates, however, is outside the scope of the present study and represents an opportunity for further investigation.

Optimal outcomes after cochlear implantation depend not only on access but also on timing. Studies have shown that younger children who received implants experience faster rates of improvement in outcome measures and higher likelihood of age-appropriate speech, language, reading skills, and speech perception. Implantation in children older than 6 years has been correlated with poorer speech perception and slower progress in skill development, potentially owing to a loss of plasticity of the central auditory system.²³⁻²⁷ The difference in outcomes is particularly pronounced in prelingually deaf children.^{1,27} Figure 1 demonstrates that most of our patients undergo implantation before they are 6 years old, hopefully giving them the best opportunity for development of language skills and speech perception. Prelingually deaf patients also underwent implantation at a statistically similar age regardless of insurance status: a mean age of 4.5 years for Medicaid-insured children and 4.9 years for privately insured children. Although there was a higher mean age at referral in our Medicaid-insured patients who ultimately did not receive implants, the extremely small number of nonrecipients in this part of the analysis makes it difficult to generalize this trend. All of these results suggest that our lower-income patients are not at a disadvantage in terms of speech and language development, based on age at implantation when compared with children of higher SES. However, this conclusion lies outside the scope of the current study and represents a potential area of further investigation.

Postlingually deaf patients have been shown to gain benefits in speech perception after cochlear implantation.^{25,28} In our patient population, a total of 8 postlingually deaf patients received cochlear implantation, and all 8 were privately insured. This difference most likely reflects a difference in SES. Families with higher SES may have more access to information regarding the benefits of cochlear implantation for postlingual deafness and more resources to pursue cochlear implantation. The finding that Medicaid-insured congenitally deaf patients are not at a disadvantage in receiving cochlear implantation makes this finding interesting. The newborn hearing screen permits success-

ful early identification of Medicaid-insured congenitally deaf patients, alerting the families of the need for further evaluation and thus directing the family to the proper resources. The system that identifies and supports children with postlingual hearing loss may not be adequately effective, resulting in Medicaid-insured children not getting the appropriate help or sufficient information. The specific reasons for the lack of postlingually deaf Medicaid-insured patients who pursue cochlear implantation are not discernible from our current study. Further investigation may be warranted because this may signify a need to increase accessibility of cochlear implantation for postlingually deaf children of lower SES. To better address their needs, it may also be worthwhile to examine the outcomes of these Medicaid-insured postlingually deaf children.

Our analysis of cochlear implant candidates who were nonrecipients yielded other interesting results worth highlighting. Although unconfirmed, 4 of 7 privately insured nonrecipients were also evaluated by other cochlear implant facilities and potentially received implants at other institutions. Reliability of logistical regression analysis of differences in reasons for not receiving the cochlear implant is relatively low owing to the limited numbers in the nonrecipients group. There is a trend for a greater number of Medicaid-insured patients compared with privately insured families who fail to follow up for cochlear implant evaluation. The reasons for this trend may include transportation difficulties, lack of proximity to medical facilities, lack of access to specialists, and lack of access to information. Our findings are in line with a study of hearing eligible infants by Spivak et al,¹⁷ which showed that Medicaid-insured infants were more likely to be lost to follow-up. The older age at referral and poor referral follow-up suggests the need to provide additional information and resources to eligible children of lower SES to foster earlier and easier access to cochlear implantation. That issue cannot be adequately addressed in this study and represents another potential area for further investigation.

Complications were more likely to occur in children from lower-income families than in children from families with higher income level. Compared with the incidence of complications reported in the literature for patients of all income levels, our privately insured patients experienced fewer complications, whereas our Medicaid-insured patients experienced comparable rates of complications. Bhatia et al²⁹ reviewed complications of 300 pediatric patients and reported an overall rate of 18.3%, with major complications accounting for 2.3% and minor complications accounting for 16%. Migirov et al³⁰ reported a 17.5% rate for major complications and a 21.1% rate for minor complications for toddlers (38.6% overall). Venail et al³¹ studied 322 children and reported an overall complications rate of 14.6% with major and minor complication rates of 10.6% and 4.0%, respectively.

Medicaid-insured patients adhered to the protocol for initial cochlear implant activation but were more likely to miss important follow-up appointments and to be seen at longer intervals of time. In our analysis, Medicaid-insured children who experienced complications were found to exhibit worse compliance with follow-up relative to the overall group of Medicaid-insured children as well as to privately insured children. Privately insured patients who

experienced complications showed similar compliance with follow-up compared with all privately insured patients. These findings suggest an association between poor follow-up compliance and an increased rate of complications, putting children from lower-income households at risk for less optimal language development and speech perception as well as more serious medical consequences.

According to audiologists, there is a perceived disparity in outcomes based on SES.¹² Previous research on cochlear implant outcomes in children primarily focused on various aspects of communication skills and found lower income levels or lower SES to be negatively correlated with language, reading and speech development.¹³⁻¹⁶ Even though our study analyzed different aspects of outcomes after cochlear implantation, our findings were similar with regard to the negative impact of lower SES. We have now quantitatively shown factors such as poor follow-up and increased postoperative complications to be possible contributors to the disparity in outcomes. This suggests an opportunity for cochlear implant programs such as ours to reassess our care protocols to identify ways to minimize these adverse outcomes. Potential ideas may include providing more intensive training and education; social support services, especially to single-parent families; automated telephone calls for more frequent follow-up checks; or more hands-on, longitudinal care, such as the successes detailed in the literature for diabetes mellitus care.³²⁻³⁵

The benefits of bilateral implantation include improved speech perception in the second implanted ear, sound localization, speech perception in noise, and continuous access to sound.^{36,37} Despite discussing these benefits with all successful unilateral candidates in our program, our results show that Medicaid-insured patients are still less likely to receive a second implant. As with unilateral cochlear implantation, Medicaid-insured children in Ohio benefit from coverage of sequential bilateral implantation. The basis of this disparity is unclear and is worthy of further study.

There were several limitations to our study pertaining to the retrospective study design. Because data were extracted solely from medical chart review without other access to each patient, we were unable to account for patient outcomes neither after the study period nor for patients who did not follow up for pre-cochlear implant or post-cochlear implant evaluations. This included several patients lost to follow-up after initial consultations for whom there are unconfirmed reports that they ultimately underwent implantation at a different facility. Also, data not included in patient medical files, such as family income level or more complete information regarding reasons for missed appointments, were not accessible. In addition, it is important to note that our study results are correlative but not necessarily causative; this would require a prospective design and a larger sample size.

In conclusion, cochlear implantation is a powerful tool to help children with profound sensorineural hearing loss gain the ability to hear and is not effected by SES, in our experience. Given the excellent Medicaid coverage in Ohio, our results suggest that eliminating the definite financial obstacle that currently exists in other states across the nation for children from lower-income households would allow all eligible children, regardless of socioeconomic background, access to this powerful technology. How-

ever, despite equal access among Medicaid-insured and privately insured patients, there seem to be important differences between the groups postimplantation that influence outcome, namely, decreased follow-up compliance, increased incidence of minor and major complications, and decreased rates of sequential bilateral implantation. Taken together, these results indicate that centers should further investigate opportunities to minimize these downstream disparities. Our findings have motivated our cochlear implant team at UHMC and RBCH to enlist the involvement of the social work department in the care of our cochlear implant patients.

Submitted for Publication: September 21, 2009; final revision received November 26, 2009; accepted January 13, 2010.

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Author Contributions: Dr Chang had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. *Study concept and design:* Ko, Murray, and Megerian. *Acquisition of data:* Chang, Ko, Murray, and Arnold. *Analysis and interpretation of data:* Chang, Ko, Murray, Arnold, and Megerian. *Drafting of the manuscript for important intellectual content:* Chang, Ko, Murray, Arnold, and Megerian. *Statistical analysis:* Chang. *Administrative, technical, and material support:* Ko, Murray, and Megerian. *Study supervision:* Ko, Murray, and Megerian.

Financial Disclosure: Dr Megerian is a member of the Surgeon's Advisory Board of Cochlear Corp.

Additional Information: The UHMC and RBCH Cochlear Implant Team includes Dr Megerian; Robin Piper, AuD, CCC-A; Gail Murray, PhD, CCC-A; Katie Strange, AuD, CCC-A; Lindsay Zombek, MA, CCC-SLP; and Rachel Tangen, PhD.

Additional Contributions: The Cochlear Corp assisted by providing Medicaid reimbursement data.

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