

Racial and Insurance Inequalities in Access to Early Pediatric Cochlear Implantation

Xinliang Liu, MBBS, PhD, MS¹, Linda I. Rosa-Lugo, EdD, CCC-SLP², Janel L. Cosby, AuD, PhD, CCC-A², and Cedric V. Pritchett, MD, MPH^{3,4}

Otolaryngology–
Head and Neck Surgery
1–8

© American Academy of
Otolaryngology–Head and Neck
Surgery Foundation 2020
Reprints and permission:
sagepub.com/journalsPermissions.nav
DOI: 10.1177/0194599820953381
http://otojournal.org



Abstract

Objective. To evaluate the association between race/ethnicity and insurance status on the access to early cochlear implantation.

Study Design. Population-based retrospective analysis of pediatric cochlear implantation procedures.

Setting. State Ambulatory Surgery and Services Databases of Florida from 2005 to 2017.

Methods. All children aged 18 years or younger in the state of Florida undergoing cochlear implantation were identified. The outcome measures were access to early cochlear implantation (before 1 and 2 years of age). Descriptive and multivariate logistic regression analyses were conducted.

Results. Among 1511 pediatric cochlear implantation procedures with complete data, 65 (4.3%) procedures were performed by 1 year of age and 348 (23.0%) by 2 years of age. Black children (odds ratio [OR], 0.44; 95% CI, 0.28-0.70), Hispanic children (OR, 0.70; 95% CI, 0.52-0.94), and children with Medicaid (OR, 0.64; 95% CI, 0.48-0.84) were significantly less likely to be implanted before 2 years of age. Even when insured by private insurance, black and Hispanic children were still less likely to be implanted before 2 years of age compared to white children with private insurance. Greater racial and insurance disparities existed in access to cochlear implantation before 1 year of age compared to implantation before 2 years of age.

Conclusion. Racial/ethnic and insurance disparities in pediatric cochlear implantation can be observed at the population level. To address these racial and insurance inequalities, a multidisciplinary care team is needed and priorities should be given to research endeavors and policy interventions that target these disparities.

Keywords

pediatric, cochlear implantation, disparities, race, insurance, State Ambulatory Surgery and Services Databases (SASD)

Received May 14, 2020; accepted July 27, 2020.

Hearing loss is the most common congenital defect, with about 2 out of every 1000 children in the United States born with confirmed hearing loss.¹

Profound, early onset sensorineural hearing loss is present in 4 to 11 per 10,000 children, and greater than 90% of these children are born to hearing parents.^{2,3} This places these children at a higher risk for social isolation and more limited opportunities for educational advancement and/or employment possibilities.⁴

Cochlear implantation is an important treatment option for children with severe to profound hearing loss and has revolutionized the speech and language outcomes in this demographic. Children undergoing cochlear implantation at a young age, specifically before 2 years of age, can achieve normal peer-appropriate developmental milestones.⁵ Early implantation is associated with higher auditory performance scores, greater quality-of-life improvements, increased mainstream classroom placement, and higher educational and employment levels.⁶⁻⁹ As the child ages and the period of auditory deprivation increases, the neuroplasticity decreases and, with it, a consequential reduction in ability of auditory association areas to process sound stimuli.^{10,11} It is this principle—substantiated by superior performance outcomes and the growing evidence for safety in implanting in infancy—that is supporting the growing practice of pediatric implantation within the first 2 years of life.^{12,13}

Unfortunately, all children do not have equal access to early cochlear implantation. Previous studies have found that children in certain social groups are less likely than others to receive cochlear implantation early in life. For example, children living in rural locations and having public insurance or no insurance at all have been identified at a higher risk of

¹Department of Health Management and Informatics, College of Community Innovation and Education, University of Central Florida, Orlando, Florida, USA

²School of Communication Sciences and Disorders, College of Health Professions and Sciences, University of Central Florida, Orlando, Florida, USA

³College of Medicine, University of Central Florida, Orlando, Florida, USA

⁴Division of Pediatric Otolaryngology, Nemours Children's Hospital, Orlando, Florida, USA

This article was presented at 2019 American Society of Pediatric Otolaryngology Annual Meeting; May 3, 2019; Austin, Texas.

Corresponding Author:

Cedric V. Pritchett, MD, MPH, Division of Pediatric Otolaryngology, Nemours Children's Hospital, 6535 Nemours Parkway, Orlando, FL 32827, USA.

Email: Cedric.Pritchett@Nemours.org

delay in receiving cochlear implantation compared with those from urban/suburban areas.^{14,15} Additional evidence exists that median household income, racial/ethnic heritage, and primary payer status can affect access to implantation in this pediatric demographic.^{16,17} However, these studies are all single-site studies and based on small study samples size ranging from 40 to 133 children.¹⁴⁻¹⁷ Using a population-based large administrative database, this study represents the largest study of its kind to evaluate the effects of race/ethnicity, insurance status, and the combined effect of race and insurance on access to early pediatric cochlear implantation. We hypothesized that there would be racial and insurance inequalities in access to early pediatric cochlear implantation. In addition, we hypothesized that there would be a combined effect of race and insurance on access to early pediatric cochlear implantation.

Methods

This study was a cross-sectional analysis of pediatric cochlear implantation performed in the outpatient setting. The primary data source was the State Ambulatory Surgery and Services Databases (SASD) of Florida from 2005 to 2017, with the study sample consisting of cochlear implantation procedures performed on patients aged 18 years or younger (*Current Procedural Terminology* [CPT] code 69930, Implant cochlear device). The SASD are compiled by the Healthcare Cost & Utilization Project (HCUP) and sponsored by the Agency for Healthcare Research and Quality (AHRQ).¹⁸ The SASD provide publicly available, deidentified data, including discharge information for patients, regardless of payers, who receive surgical procedures performed in hospital outpatient departments or free-standing surgical centers. The study was exempt from the University of Central Florida's Institutional Review Board approval. Per the Data Use Agreement with HCUP/AHRQ, individual cell counts of less than or equal to 10 were replaced with the term *DS* in tables in this study to preserve patient confidentiality.

Variables from the SASD included patient demographic characteristics, including race/ethnicity, *International Classification of Diseases (ICD)* diagnosis codes, CPT codes, discharge status, expected payment sources, and the identifier of the facility in which the patient received treatments. Currently, 35 states participate in SASD, including Florida.¹⁸

Access to early cochlear implantation, as the primary outcome variable, was operationalized as a binary variable (cochlear implantation before 2 years of age, yes/no). A secondary outcome variable was created to examine whether the procedure was performed during infancy (cochlear implantation before 1 year of age, yes/no). The main independent variables included race/ethnicity (non-Hispanic white, non-Hispanic black, and Hispanic) and insurance status (private insurance, Medicaid, and self-pay). The handful of cases associated with other racial/ethnic (ie, Asian or Pacific Islander, Native American, or other) and insurance groups (ie, Medicare or other) were excluded from analysis

due to relatively small numbers. To examine the combined effect of race/ethnicity and insurance, a categorical variable was created to stratify patients into 9 groups: privately insured non-Hispanic white patient, privately insured non-Hispanic black patient, privately insured Hispanic patient, non-Hispanic white patient with Medicaid, non-Hispanic black patient with Medicaid, Hispanic patient with Medicaid, self-pay non-Hispanic white patient, self-pay non-Hispanic black patient, and self-pay Hispanic patient.

Secondary independent variables examined included patient sex (male/female), median household income state quartile calculated based on patient ZIP code (first through fourth quartiles), and patient location (large metropolitan area with at least 1 million residents, small metropolitan area with fewer than 1 million residents, micropolitan area, or rural area). We created an additional variable, high-volume hospital, to indicate whether the procedure was performed at one of those medical centers accounting for a cumulative 80% of the cochlear implantation volume over the study period.

Descriptive statistics, including counts and percentages by cochlear implantation before 1 and 2 years of age, were used to describe patient characteristics and access to early cochlear implantation. Chi-square test was used to assess the statistical significance of differences across groups with or without access to early cochlear implantation. We conducted multivariate logistic regression analyses to investigate the effects of race/ethnicity, insurance status, and the combined effect of race and insurance on access to early pediatric cochlear implantation, controlling for patient characteristics. While the total number of surgeries during the study period was identified, those with missing data for any of the above-mentioned variables were not included in the final statistical analysis. Sensitivity analyses using all available cases revealed no substantial differences in bivariate analysis; therefore, results based on cases with complete data were presented. All statistical tests were 2-sided, with a significance level of $P \leq .05$. Data management and statistical analyses were performed in SAS software, version 9.4 for Windows (SAS Institute).

Results

Between 2005 and 2017, a total of 1965 cochlear implantation procedures received by children 18 years of age or younger were identified in the SASD of Florida. After review of the data, 454 cases were eliminated for missing values of sex, race/ethnicity, insurance status, income quartile, or urban/rural location. **Table 1** describes race/ethnicity and insurance status of the study population of the remaining 1511 procedures.

Sixty-five procedures (4.3%) were performed in children before their first year of life, and 348 procedures (23.0%) were performed before their second birthday. Approximately 50% of the procedures were performed in children 3 years of age or younger with an overall median of 3 years and mean of 5.12 years at time of implantation (**Figure 1**). The number of cochlear implantation procedures in children

Table 1. General Demographics for Pediatric Cochlear Implantation in Florida 2005-2017.^a

Year	No. of procedures	White, No. (%)	Black, No. (%)	Hispanic, No. (%)	Private, No. (%)	Medicaid, No. (%)
2005	79	62 (78.5)	DS	DS	53 (67.1)	22 (27.9)
2006	117	84 (71.8)	13 (11.1)	20 (17.1)	82 (70.1)	28 (23.9)
2007	94	67 (71.3)	DS	DS	64 (68.1)	24 (25.5)
2008	109	78 (71.6)	DS	DS	79 (72.5)	26 (23.9)
2009	112	66 (58.9)	18 (16.1)	28 (25.0)	57 (50.9)	53 (47.3)
2010	112	74 (66.1)	DS	DS	58 (51.8)	51 (45.5)
2011	99	55 (55.6)	16 (16.2)	28 (28.3)	53 (53.5)	46 (46.5)
2012	91	47 (51.7)	20 (22.0)	24 (26.4)	45 (49.5)	44 (48.4)
2013	127	59 (46.5)	21 (16.5)	47 (37.0)	63 (49.6)	64 (50.4)
2014	138	66 (47.8)	24 (17.4)	48 (34.8)	72 (52.2)	65 (47.1)
2015	132	72 (54.6)	12 (9.1)	48 (36.4)	74 (56.1)	58 (43.9)
2016	143	59 (41.3)	21 (14.7)	63 (44.1)	79 (55.2)	64 (44.8)
2017	158	73 (46.2)	30 (19.0)	55 (34.8)	77 (48.7)	78 (49.4)

^aNumbers reflect data inclusive only of cases with complete demographic variables. DS indicates data suppressed due to a cell size less than or equal to 10 per the Data Use Agreement with the Healthcare Cost & Utilization Project/Agency for Healthcare Research and Quality.

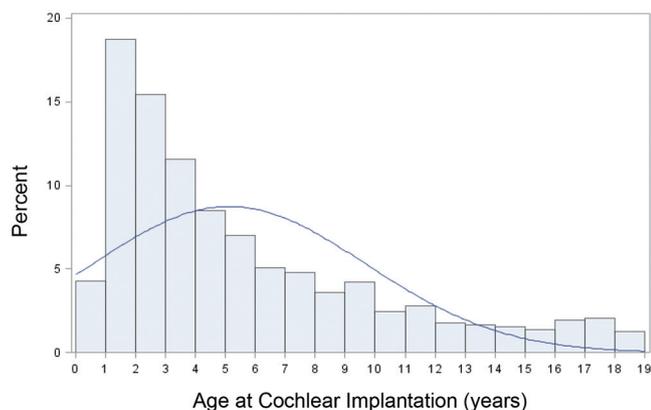


Figure 1. The distribution of age at cochlear implantation in Florida.

under 2 years of age increased during the study period, but the proportion of those being implanted at earlier ages was not statistically different (**Figure 2**).

Bivariate analysis revealed access to early cochlear implantation differed significantly among different groups. Significant associations were seen on bivariate analysis between race/ethnicity and insurance status and access to early cochlear implantation. While 6.4% and 27.4% of non-Hispanic white children received a cochlear implant before 1 and 2 years of age, none of the non-Hispanic black children received the procedure before 1 year and 12.7% before 2 years of age ($P < .001$). The number for cochlear implantation before 2 years of age was 19.4% among Hispanic children. Among children with private insurance, 6.9% and 27.5% received a cochlear implant before 1 and 2 years of age while only 17.2% of children with Medicaid received the procedure before 2 years of age ($P < .001$). When combining race/ethnicity and insurance, 30.3% of non-Hispanic white children with private insurance received a cochlear

implant before 2 years of age, following by Hispanic children with private insurance (22.8%), white children with Medicaid (21.0%), black children with private insurance (17.3%), Hispanic children with Medicaid (16.8%), and black children with Medicaid (10.2%, $P < .001$). Similar patterns were observed across different racial and insurance groups in the percentage of cochlear implantation before 1 year of age. Moreover, children with higher median household income quartile at the ZIP code level were significantly more likely to receive implantation before both 1 year of age ($P = .001$) and 2 years of age ($P = .022$). Five hospitals accounted for 81% of the pediatric implantation procedures over the study period and were categorized as high-volume hospitals. In 2005, these hospitals implanted 69 of 79 (87.3%) children, but this percentage decreased over the study period to 100 of 158 (63.9%) children in 2017. The percentages of children receiving cochlear implantation before 1 year and 2 years of age in high-volume hospitals were not significantly different from those percentages in other hospitals. Patient sex and urban/rural location were not significant factors (**Table 2**).

Multivariable logistic regression analyses identified significant associations between race/ethnicity, insurance status, and access to early cochlear implantation. Compared to white children, black children (odds ratio [OR], 0.44; 95% CI, 0.28-0.70; $P < .001$) and Hispanic children (OR, 0.70; 95% CI, 0.52-0.94; $P < .018$) were significantly less likely to be implanted before 2 years of age. Compared to children with private insurance, children with Medicaid were less likely to be implanted before 2 years of age (OR, 0.64; 95% CI, 0.48-0.84; $P < .002$). Controlling for insurance type, black and Hispanic children were still less likely to be implanted before 2 years of age compared to their white counterparts. Even greater racial and insurance disparities were observed when examining access to cochlear implantation before 1 year of age (**Table 3**).

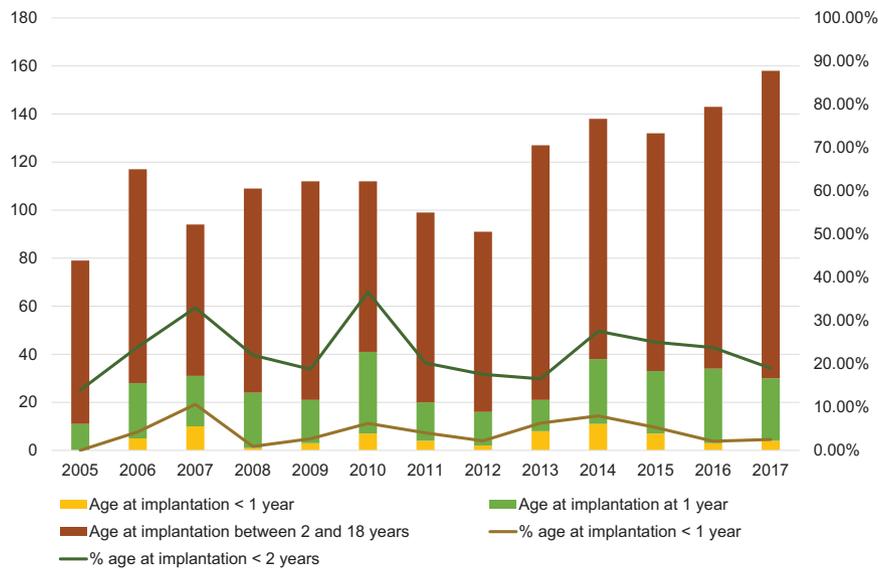


Figure 2. Access to early cochlear implantation in Florida, 2005-2017.

Discussion

Thirty years ago, cochlear implantation in children received US Food and Drug Administration (FDA) approval. The adaptation of this neuroprosthetic has transformed the lives of thousands of children and their families globally, especially in industrial, developed countries. This is certainly true in the United States where, as of December 2012, 38,000 implants in pediatric population were reported.¹⁹ Yet the performance of a society's health system should not be measured solely by its innovation and technologic achievements (of which pediatric cochlear implantation is a prime example) but also by the equitable distribution of those achievements to individuals of need in their society. For the prelingually deaf child, early access to sound by cochlear implantation is crucial to maximizing the greatest benefit from this medical innovation.

Our study represented the first population-based study that systematically examined racial and insurance disparities in access to early cochlear implantation. A study by Stern et al²⁰ and a recent follow-up by Tampio et al²¹ identified children who underwent cochlear implantation in the HCUP Kids' Inpatient Database and estimated the racial disparities in receiving cochlear implantation before 18 years of age. However, these 2 studies did not further investigate disparities in access to early implantation within the first 2 years of life. Huang et al²² examined the 2011 SASD of 5 states, including Florida; however, their study only compared the racial makeup and payer mix of cochlear implantation recipients across different states. Using a large administrative database of Florida from 2005 to 2017, we identified 1511 cochlear implantation procedures and documented racial and insurance disparities in access to early cochlear implantation at the population level. Our findings confirmed that race/ethnicity and insurance were independent factors for receiving a cochlear implant before 2 years of age, as documented by

some single-center studies.¹⁴⁻¹⁷ With a relatively large sample, we were able to examine the combined effect of race and insurance and found that even with the same type of insurance, racial/ethnic minorities were much less likely to receive a cochlear implant before 2 years of age. Finally, while traditional clinical practice guidelines recommend cochlear implantation to be performed in patients ages 12 to 24 months or older, a substantial number of patients received this procedure before 1 year of age throughout the study period. We observed greater racial and insurance disparities when examining access to cochlear implantation before 1 year of age compared to implantation before 2 years of age.

Increasingly more attention has been directed to health care inequities in the United States.^{23,24} Gaps in access to hearing health care and rehabilitation based on socioeconomic factors are realities specifically recognized in the national disparity conversation. Healthy People 2020 (HP2020), a national framework with benchmarks, included in their report several objectives relative to this patient population, namely, a 10% increase relative to universal newborn hearing screening (NBHS) projections and an increase in the number of new cochlear implants provided to individuals who are deaf and hard of hearing.²⁵ In 2005, Stern et al²⁰ published the first article examining disparities in pediatric cochlear implantation in the United States; this was preceded a few years earlier by Fortnum et al²⁶ in the United Kingdom, arriving at similar conclusions. Since that time, other distinguished teams have written on the topic, examining the effect of geography, race, socioeconomic status, insurance, and primary spoken language on access to/achievement of cochlear implantation in the children of this country.^{14-16,21,22,27,28} Our study, building on these earlier studies, focused on disparities in access to cochlear implantation within the first 2 years of life.

In our study, an average of 41.2% of children had Medicaid insurance with the percentage increasing from

Table 2. Descriptive Statistics of the Study Population by Timing of Cochlear Implantation (Younger Than 1 Year and 2 Years).^a

Characteristic	All patients, No.	Age at implantation <1 year			Age at implantation <2 years		
		Count	%	P value	Count	%	P value
Sex							
Male	793	32	4.04	.5916	178	22.45	.5705
Female	718	33	4.60		170	23.68	
Race/ethnicity							
Non-Hispanic white	862	55	6.38	<.0001	236	27.38	<.0001
Non-Hispanic black	205	0	0.00		26	12.68	
Hispanic	444	DS	DS		86	19.37	
Insurance status							
Private insurance	856	59	6.89	<.0001	235	27.45	<.0001
Medicaid	623	DS	DS		107	17.17	
Self-pay	32	DS	DS		DS	DS	
Insurance status and race/ethnicity							
Privately insured non-Hispanic white patient	584	51	8.73	<.0001	177	30.31	<.0001
Privately insured non-Hispanic black patient	75	0	0.00		13	17.33	
Privately insured Hispanic patient	197	DS	DS		45	22.84	
Non-Hispanic white patient with Medicaid	252	DS	DS		53	21.03	
Non-Hispanic black patient with Medicaid	127	0	0.00		13	10.24	
Hispanic patient with Medicaid	244	DS	DS		41	16.80	
Self-pay non-Hispanic white patient	26	DS	DS		DS	DS	
Self-pay non-Hispanic black patient	DS	0	0.00		0	0.00	
Self-pay Hispanic patient	DS	0	0.00		0	0.00	
Median household income state quartile for patient ZIP code							
First quartile	350	DS	DS	.0010	72	20.57	.0215
Second quartile	313	DS	DS		60	19.17	
Third quartile	391	17	4.35		89	22.76	
Fourth quartile	457	33	7.22		127	27.79	
Patient location							
Large metropolitan area with at least 1 million residents	1028	45	4.38	.2838	239	23.25	.7809
Small metropolitan area with less than 1 million residents	407	20	4.91		93	22.85	
Micropolitan area	46	0	0.00		DS	DS	
Rural area	30	0	0.00		DS	DS	
High-volume hospital							
Yes	1225	54	4.41	.6732	286	23.35	.5462
No	286	11	3.85		62	21.68	

^aDS indicates data suppressed due to a cell size less than or equal to 10 per the Data Use Agreement with the Healthcare Cost & Utilization Project/Agency for Healthcare Research and Quality.

27.9% to 49.4% over the study period, which is similar to the numbers reported by others.²¹ During the study period, the percentage of private insurance declined from 67.1% to 48.7%. Insurance status is a dominant factor for the care of pediatric cochlear implant recipients, influencing not only access to surgical intervention but also postimplantation speech and language development.^{16,27-31} While children from families with private insurance face financial and logistic challenges (eg, out-of-pocket expenses for hearing aids and caregiver job restrictions),¹⁶ the barriers to care in those with no insurance or public insurance seem to be even more insurmountable. The literature consistently identifies and our study supports the lack of private insurance as a

negative determinant in the timing of appropriate surgical intervention.^{16,27}

The combined effect of insurance and race/ethnicity is noteworthy. Using this large study population, we uncovered that race, especially being black, had a more consequential impact on access to early cochlear implantation than insurance status. For example, 0% of black children in our study received a cochlear implant before 1 year of age. Furthermore, white children with Medicaid or self-pay both were more likely than black children with private insurance (21.0% and 23.1% vs 17.3%, $P < .001$) to receive a cochlear implant before 2 years of age. These findings are consistent with those of Stern et al,²⁰ who examined large population

Table 3. Risk-Adjusted Odds Ratio (OR) of Early Cochlear Implantation (Before 1 or 2 Years of Age) by Race/Ethnicity, Insurance Status, and Race/Ethnicity and Insurance Status Combined.^a

Characteristic	Age at implantation <1 year		Age at implantation <2 years	
	OR (95% CI)	P value	OR (95% CI)	P value
Race/ethnicity (reference: Non-Hispanic white)				
Non-Hispanic black	—	—	0.44 (0.28-0.70)	.0005
Hispanic	0.48 (0.24-0.98)	.0426	0.70 (0.52-0.94)	.0177
Insurance status (reference: Private insurance)				
Medicaid	0.13 (0.04-0.36)	<.0001	0.64 (0.48-0.84)	.0016
Self-pay	0.86 (0.20-3.77)	.8425	0.56 (0.23-1.40)	.2152
Insurance status and race/ethnicity (reference: Privately insured non-Hispanic white patient)				
Privately insured non-Hispanic black patient	—	—	0.49 (0.26-0.93)	.0286
Privately insured Hispanic patient	0.44 (0.20-0.96)	.0386	0.68 (0.46-0.99)	.0449
Non-Hispanic white patient with Medicaid	0.09 (0.02-0.39)	.0012	0.63 (0.44-0.90)	.0109
Non-Hispanic black patient with Medicaid	—	—	0.26 (0.14-0.49)	<.0001
Hispanic patient with Medicaid	0.09 (0.02-0.37)	.0010	0.47 (0.32-0.70)	.0002
Self-pay non-Hispanic white patient	0.89 (0.20-3.90)	.8721	0.66 (0.26-1.68)	.3864
Self-pay non-Hispanic black patient	—	—	—	—
Self-pay Hispanic patient	—	—	—	—

^aSome odds ratios are missing due to the absence of cases in certain outcome categories.

data, but differ from studies such as Armstrong et al,¹⁶ who, in publishing single-center outcomes, reported a difference in age of implantation related to insurance status but not race.

High-volume hospitals were identified in this study to query variation in practice pattern related to institutional characteristics. While 5 centers accounted for 81% of the pediatric implantation procedures during the study period, there were no statistically significant differences in the percentages of children implanted before 1 or 2 years of age based on this volume stratification. Our study does not address surgical outcomes, and these data should not be interpreted to suggest parity in the patient experience or clinical outcomes when comparing high- and low-volume implantation centers, especially the more complex cases. However, this finding may suggest that there is little difference either in what is believed to be an acceptable age for implantation, or there are remarkably similar challenges and/or checkpoints that must be negotiated regardless of the implantation center's volume and experience.

Several limitations are evident in this study. First, we examined the data from 1 state. Nevertheless, our population-based study sample consisted of 1511 cochlear implantation procedures over a 13-year period, which to our knowledge represents the largest sample of cochlear implantation procedures. Florida has the fourth largest pediatric population in the country, averaging over 219,000 live births yearly over the past decade,²⁹ and 255 newborns (range: 192-315) were screened positive for permanent hearing loss during 2006 to 2016.³² Second, this study was limited to the variables included in the SASD. While we reported on *what* has happened, this administrative database prevented us from determining the age of hearing loss identification (ie,

the *when*). It is therefore impossible to know if differences in the timing of cochlear implantation were secondary to delayed identification in the first place or perhaps even a difference in the incidence of delayed onset hearing loss in the varying populations. Health care professionals' bias—including racial bias—could be a contributing factor to delayed utilization, as has been recognized with overutilization (eg, hysterectomy) and underutilization (eg, thrombolysis) among racial/ethnic minority groups.^{33,34} In addition, other patient/parent characteristics such as educational level and social support may play an important role. In the absence of individual patient data, we could not pinpoint with certainty what barriers contributed to untimely implantations. Finally, we included only data from cochlear implantation cases where complete demographic data were available. This resulted in 454 procedures during the study period being excluded. This decision certainly affected the sample size. However, as noted previously, including these additions did not substantively change the results reported above.

Conclusion

Racial and insurance disparities in pediatric cochlear implantation can be observed at the population level. Children from racial/ethnic minority groups and those with Medicaid appear to be at an increased risk for delay in cochlear implantation in the management of their sensorineural hearing loss. Children at the intersection of some racial and insurance groups (ie, black children with Medicaid) are more disadvantaged than others in access to early cochlear implantation. These racial and insurance inequalities emphasize the need for multidisciplinary care teams—comprising otolaryngologists, pediatricians, audiologists, speech-language pathologists,

psychologists, nurses, social workers, and educators—to address the full spectrum of the social and medical determinants of health in children with hearing loss. Priorities should be given to research endeavors, policy interventions, and innovative care delivery models that target these disparities to ensure equitable access to pediatric cochlear implantation.

Author Contributions

Xinliang Liu, study conception, data acquisition, analysis and interpretation, manuscript draft and critical revision; **Linda I. Rosa-Lugo**, study conception, manuscript draft and critical revision; **Janel L. Cosby**, study conception, manuscript draft and critical revision; **Cedric V. Pritchett**, study conception, data interpretation, manuscript draft and critical revision.

Disclosures

Competing interests: None.

Sponsorships: None.

Funding source: None.

References

- Centers for Disease Control and Prevention. Summary of 2017 national CDC EHDI data. Published 2019. Accessed May 5, 2020. <https://www.cdc.gov/ncbddd/hearingloss/2017-data/documents/01-2017-HSFS-Data-Summary.pdf>
- Marazita ML, Ploughman LM, Rawlings B, Remington E, Arnos KS, Nance WE. Genetic epidemiological studies of early-onset deafness in the U.S. school-age population. *Am J Med Genet.* 1993;46(5):486-491.
- Mitchell R, Karchmer M. Parental hearing status and signing among deaf and hard of hearing students. *Sign Language Studies.* 2005;5:83-96.
- Jung D, Bhattacharyya N. Association of hearing loss with decreased employment and income among adults in the United States. *Ann Otol Rhinol Laryngol.* 2012;121(12):771-775.
- Osberger MJ, Zimmerman-Phillips S, Koch DB. Cochlear implant candidacy and performance trends in children. *Ann Otol Rhinol Laryngol Suppl.* 2002;189:62-65.
- Colletti V, Carner M, Miorelli V, Guida M, Colletti L, Fiorino FG. Cochlear implantation at under 12 months: report on 10 patients. *Laryngoscope.* 2005;115(3):445-449.
- Archbold S, Nikolopoulos TP, O'Donoghue GM, Lutman ME. Educational placement of deaf children following cochlear implantation. *Br J Audiol.* 1998;32(5):295-300.
- Venail F, Vieu A, Artieres F, Mondain M, Uziel A. Educational and employment achievements in prelingually deaf children who receive cochlear implants. *Arch Otolaryngol Head Neck Surg.* 2010;136(4):366-372.
- Semenov YR, Yeh ST, Seshamani M, et al. Age-dependent cost-utility of pediatric cochlear implantation. *Ear Hear.* 2013; 34(4):402-412.
- Nishimura H, Hashikawa K, Doi K, et al. Sign language 'heard' in the auditory cortex. *Nature.* 1999;397(6715):116.
- Cole EB, Flexer C. *Children With Hearing Loss: Developing Listening and Talking, Birth to Six.* Plural Publishing; 2019.
- Madell JR, Flexer C, Wolfe J. *Pediatric Audiology: Diagnosis, Technology, and Management.* Thieme; 2019.
- Kalejaiye A, Ansari G, Ortega G, Davidson M, Kim HJ. Low surgical complication rates in cochlear implantation for young children less than 1 year of age. *Laryngoscope.* 2017;127(3): 720-724.
- Bush ML, Burton M, Loan A, Shinn JB. Timing discrepancies of early intervention hearing services in urban and rural cochlear implant recipients. *Otol Neurotol.* 2013;34(9):10. 1097/MAO.1090b1013e31829e31883ad.
- Bush ML, Osetinsky M, Shinn JB, et al. Assessment of Appalachian region pediatric hearing healthcare disparities and delays. *Laryngoscope.* 2014;124(7):1713-1717.
- Armstrong M, Maresh A, Buxton C, et al. Barriers to early pediatric cochlear implantation. *Int J Pediatr Otorhinolaryngol.* 2013;77(11):1869-1872.
- Lester EB, Dawson JD, Gantz BJ, Hansen MR. Barriers to the early cochlear implantation of deaf children. *Otol Neurotol.* 2011;32(3):406-412.
- Agency for Healthcare Research and Quality (AHRQ). Introduction to the HCUP State Ambulatory Surgery and Services Databases (SASD). Published 2017. Updated December 20, 2017. Accessed February 12, 2018. https://www.hcup-us.ahrq.gov/db/state/sasddist/Introduction_to_SASD.pdf
- National Institute on Deafness and Other Communication Disorders. Cochlear implants. Published 2016. Updated March 6, 2017. Accessed September 28, 2017. <https://www.nidcd.nih.gov/health/cochlear-implants>
- Stern RE, Yueh B, Lewis C, Norton S, Sie KC. Recent epidemiology of pediatric cochlear implantation in the United States: disparity among children of different ethnicity and socioeconomic status. *Laryngoscope.* 2005;115(1):125-131.
- Tampio AJF, Schroeder Ii RJ, Wang D, Boyle J, Nicholas BD. Trends in sociodemographic disparities of pediatric cochlear implantation over a 15-year period. *Int J Pediatr Otorhinolaryngol.* 2018;115:165-170.
- Huang Z, Gordish-Dressman H, Preciado D, Reilly BK. Pediatric cochlear implantation: variation in income, race, payer, and charges across five states. *Laryngoscope.* 2018; 128(4):954-958.
- Gibbons MC. A historical overview of health disparities and the potential of eHealth solutions. *J Med Internet Res.* 2005; 7(5):e50.
- Fiscella K, Franks P, Gold MR, Clancy CM. Inequality in quality: addressing socioeconomic, racial, and ethnic disparities in health care. *JAMA.* 2000;283(19):2579-2584.
- US Department of Health and Human Services. 2020 Topics & objectives: hearing and other sensory or communication disorders. Published 2010. Accessed May 5, 2020. <https://www.healthypeople.gov/2020/topics-objectives/topic/hearing-and-other-sensory-or-communication-disorders/objectives>
- Fortnum HM, Marshall DH, Summerfield AQ. Epidemiology of the UK population of hearing-impaired children, including characteristics of those with and without cochlear implants—audiology, aetiology, comorbidity and affluence. *Int J Audiol.* 2002;41(3):170-179.

27. Su BM, Park JS, Chan DK. Impact of primary language and insurance on pediatric hearing health care in a multidisciplinary clinic. *Otolaryngol Head Neck Surg.* 2017;157(4):722-730.
28. Yang CQ, Reilly BK, Preciado DA. Barriers to pediatric cochlear implantation: a parental survey. *Int J Pediatr Otorhinolaryngol.* 2018;104:224-227.
29. Tolan M, Serpas A, McElroy K, et al. Delays in sound recognition and imitation in underinsured children receiving cochlear implantation. *JAMA Otolaryngol Head Neck Surg.* 2017;143(1):60-64.
30. Noblitt B, Alfonso KP, Adkins M, Bush ML. Barriers to rehabilitation care in pediatric cochlear implant recipients. *Otol Neurotol.* 2018;39(5):e307-e313.
31. Park LR, Gagnon EB, Thompson E, Brown KD. Age at full-time use predicts language outcomes better than age of surgery in children who use cochlear implants. *Am J Audiol.* 2019;28(4):986-992.
32. Florida Department of Health (FDOH). Inpatient hearing screening information. Published 2019. Accessed May 6, 2020. <http://www.floridahealth.gov/programs-and-services/childrens-health/newborn-screening/nbs-hear-ip.html>
33. Powell LH, Meyer P, Weiss G, et al. Ethnic differences in past hysterectomy for benign conditions. *Womens Health Issues.* 2005;15(4):179-186.
34. Green AR, Carney DR, Pallin DJ, et al. Implicit bias among physicians and its prediction of thrombolysis decisions for black and white patients. *J Gen Intern Med.* 2007;22:1231-1238.