

Invited Commentary

Technology Alone Cannot Promote Optimal Childhood Development—Why Cochlear Implantation Must Be Accompanied by Social Intervention

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Cochlear implants are among the most transformative biomedical technologies ever invented. When harnessed during the unparalleled period of neuroplasticity in early childhood, cochlear implants can revolutionize the language and academic development of children born deaf or hard of

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hearing, presenting them the option to achieve outcomes comparable to their hearing peers.¹ Yet, there are limitations to technology's impact on human development; auditory access alone is insufficient to unlock every child's full potential.¹ In fact, patients' outcomes vary dramatically. In *JAMA Otolaryngology-Head & Neck Surgery*, Mueller et al² explore those disparities and quantify the link between children's socioeconomic conditions and their postimplant outcomes. In this systematic review and meta-analysis of 20 studies comprising 1905 children, Mueller et al² found that while low socioeconomic status (SES), parental education, and parental involvement were significantly associated with a patient's postimplant language outcomes ($\beta = -0.47$ [95% CI, -0.83 to -0.10]; $\beta = 0.45$ [95% CI, 0.29 - 0.62]; $\beta = 0.30$ [95% CI, 0.13 - 0.48], respectively), age of implantation did not hold the same significance ($\beta = -0.30$ [95% CI, -0.43 to -0.17]). This is a surprising finding, given the field's emphasis on early implantation (though most included studies had a mean age of implantation >2 years). Together, these results underscore the powerful impact of social determinants of health on a child's postimplant development and the importance of addressing those factors with targeted interventions, just as the child's sensorineural hearing loss is addressed with cochlear implantation.

Mirroring the Population at Large

The study by Mueller et al² suggests that achieving equitable outcomes for all children involves addressing nonsurgical, early environmental factors in a child's life. In understanding how to optimize those factors and improve children's outcomes, it is beneficial to situate the experience of cochlear implant recipients within the broader scientific exploration of how SES impacts children's foundational brain development, language acquisition, and educational trajectories. The SES-related disparities described by Mueller et al² closely mirror those observed in the general population,^{3,4} underscoring that the challenges faced by children with cochlear implants are part of a larger societal issue. While there are unique challenges specific to children with cochlear implants, such as wear time,⁵ the SES-related disparities among children with and without hearing loss likely stem from similar underlying mechanisms.

The Role of Parents and Caregivers

For all children, whether hearing or those with cochlear implants, the linguistic interactions they share with their

caregivers—also known as “serve and return” exchanges—are crucial during their early years.¹ These enriching interactions fuel approximately 1 million new neural connections per second, laying the foundation for language, literacy, and long-term educational outcomes.¹ In examining the association between SES, caregiver inputs, and academic disparities, Noble et al⁶ highlight 2 key caregiver-related factors that mediate SES impact and correlate with observed language and behavioral outcomes: (1) disparities in the quantity and quality of the early language environment and (2) the level of stress, particularly toxic stress, within the household. It is clear how parental involvement, parental education, and SES, identified by Mueller et al² as significant social determinants of health related to language outcomes, align closely with the variables noted by Noble et al.⁶

Thus, the study supports the notion that the presence of rich linguistic input and supportive interactions from parents and caregivers are essential for translating a child's access to sound into meaningful developmental gains. Their work illustrates the critical roles of both parents or caregivers and the home language environment for children's optimal development and reinforces a simple yet profound axiom: child outcomes are inextricably tied to the support they receive from their parents or caregivers early in the child's life.

However, it is important to note that the mediation pathway that explains the connection between nurturing language inputs and future academic outcomes does not rely solely on mechanisms specific to the individual. A rich body of research makes it clear that structural and systemic factors, such as poverty, housing instability, racism, and more, interact with individual mechanisms to disparately impact child outcomes (for a review, see Neckerman⁴).

Charting a Path Forward: The Need for Individual and Systemic Support

How do we move forward once we have acknowledged the deep-seated educational disparities that exist? We have a unique opportunity not only to learn from the broader scientific literature but also to contribute to it, using insights from our specific field to drive change across the board. Progress will require a multifaceted approach that considers the broader social context in which children are raised, as well as interventions at both the individual and population levels.

At the individual level, research has found that (1) improving parental knowledge of child development and (2) helping parents develop strategies for engaging in brain-building behaviors, particularly nurturing talk and interaction, are effective mechanisms for improving child outcomes.¹ Thus, evidence-based behavioral interventions designed to disseminate information across these 2 areas are worthwhile and should be made available to parents of children with and without hearing loss.

All the same, individual intervention is not a sufficient or efficient means of alleviating developmental disparities. Such efforts must be accompanied by a constellation of social policies that provide parents with the time and security needed to optimize their children's healthy development. While any number of policies have a role to play, it is helpful to prioritize those that provide parents with 3 essential supports: time, enrichment, and protection. Ensuring parents have these needs met will allow them, in turn, to meet their children's parallel needs.

- Children need time with responsive caregivers to engage in brain-building, nurturing interaction. Parents need time that allows them to be responsive caregivers. Policies that can help meet this need include paid family leave and sick leave.
- Children need enrichment in the form of nurturing talk and interaction. Parents deserve enrichment in the form of education about child development and the support and tools that help them put that knowledge to use. Policies that can help meet this need include parent education and outreach programs that begin the day an infant is born (or before), as well as high-quality, affordable child care for any parent who wants or needs care that complements their own efforts.
- Children need protection from the toxic stress that can impede their healthy development. Parents need protection

from the social and economic forces that impede their ability to parent optimally. Policies that can help meet this need include a livable minimum wage, housing assistance, and more.

Activists and academics often position individual and systemic solutions against one another, suggesting that only one is the correct means of addressing inequitable child development. A recent study⁷ suggests that recipients of such support disagree. When asked to assess the value of various interventions, mothers with young children and low incomes rated structural interventions as only slightly more helpful than individual interventions,⁷ underscoring the importance of pulling all available levers in our collective effort to alleviate developmental disparities.

Conclusions

Mueller et al² have helped shine meaningful light on the needs of pediatric cochlear implant recipients and, in particular, on the role that social determinants of health play in their development. Understanding those needs, and the ways in which they mirror the larger population, is vital for developing effective interventions that can mitigate disparities and ensure that all children, regardless of SES or hearing status, have the opportunity to thrive.

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