Bilingualism: A Pearl to Overcome Certain Perils of Cochlear Implants

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Cochlear implants (CI) have demonstrated success in improving young deaf children's speech and low-level speech awareness across a range of auditory functions, but this success is highly variable, and how this success correlates to high-level language development is even more variable. Prevalence on the success rate of CI as an outcome for language development is difficult to obtain because studies vary widely in methodology and variables of interest, and because not all cochlear implant technology (which

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continues to evolve) is the same. Still, even if the notion of treatment failure is limited narrowly to those who gain no auditory benefit from CI in that they cannot discriminate among ambient noises, the reported treatment failure rate is high enough to call into question the current lack of consideration of alternative approaches to ensure young deaf children's language development. Recent research has highlighted the risks of delaying language input during critical periods of brain development with concomitant consequences for cognitive and social skills. As a result, we propose that before, during, and after implantation deaf children learn a sign language along with a spoken language to ensure their maximal language development and optimal long-term developmental outcomes.
Key Words: cochlear implants, bilingualism, sign language, critical periods, first language acquisition

INTRODUCTION

The primary motivation for providing cochlear implantation to young children with hearing loss is based on research findings that cochlear implants increase deaf children's awareness to environment sounds and aid speech development (Niparko, 2009). This is thought to enhance deaf children's quality of social interaction within a predominantly spoken language community (Cooper & Craddock, 2006). As a result, cochlear implants have become the most sought-after intervention tool for children with severe-to-profound hearing loss, with an 80% implantation rate in developed countries (Brentari, 2010).

Whereas increased phonological and speech awareness and enhanced speech development are meritorious outcomes of cochlear implants in young deaf children, these outcomes unfortunately do not necessarily translate into long-term language development (Geers et al., 2008). When compared with hearing peers, deaf children with cochlear implants continue to perform at a lower level, with a significant portion who do not develop strong language fluency (Marschark, Sarchet, Rhoten, & Zupan, 2010). In cases where children's language fluency is not well developed, communication becomes difficult and creates stress between deaf children and their parents/ social partners (Mellon, 2009). Such difficulties negatively impact the deaf child's perceived quality of life and create barriers in the child's environment (Christiansen & Leigh, 2002; Kushalnagar, Topolski, Schick, Edwards, Skalicky, & Patrick, 2011). If these issues are not addressed early, risks to normal cognitive and psychosocial development arise; these are the perils addressed in this article.

As language development is central in impacting many other areas of young children's development, overlooking or underemphasizing language development at the expense of speech awareness and speech development in deaf children, especially during critical periods of brain development, carries great risks for long-term adverse psychosocial and developmental outcomes. For this reason, protecting deaf children's human right to early language access is critical to ensuring their overall quality of life.

We posit that the primary objectives of cochlear implantation, which focus on increasing speech awareness and speech development in young deaf children, unfortunately can result in important unintended consequences that crucially need to be better understood by all involved, including professionals, parents, caregivers and others. During the first few years of life, developing a young human being's ability to recognize and produce sounds in a structured, instructional manner is not the same as developing that child's language through adequate exposure to a fluent model in an accessible language. Whereas cochlear implantations do not allow most young deaf children to be exposed to a fluent language model through a spoken language quickly or easily enough to ensure strong language development, almost all young deaf children could be exposed to a fluent language model through a sign language with ease.

Additionally, as a child learns a sign language, the child is aided in the quest to acquire a spoken language because of improved visual communication and the enhancement that a sign language brings to a visual learning environment. Through both sound and vision, the environment for social interaction, language and cognitive development, and cultural participation is enriched and primed for activity. Simultaneous development of two languages, one signed and one spoken, allows transfer between the two. In other words, proficiency in one

language promotes proficiency in the other (Cummins, 1981).

Therefore, we propose that, along with maximal access to their ambient spoken language through cochlear implantation, speech, and print, all deaf children be provided with full access to their ambient sign language in order to guarantee their maximal language development. In this paper, we discuss evidence that bilingual language development should be incorporated into children's before- and after–implant plans. Promoting fluency in both maximizes opportunity for language development for deaf children and their families. Bilingual proficiency helps minimize deaf children's risks of adverse long-term developmental, psychosocial, and quality of life outcomes associated with being deaf or hard of hearing.

EPIDEMIOLOGY AND CI: A GLOBAL ISSUE

Elderly adults are the largest population group experiencing hearing loss, about one-third of people over age 65 and about half of people over age 80, where most of that is sensorineural hearing loss (SNHL) (Sprinzl & Riechelmann, 2010). We are not concerned here with this group, however; our focus is on the right of young deaf children to have accessible language. People who were born with normal hearing ability and then experienced hearing loss during adulthood already have acquired a language. Although the concerns and needs of late-deafened individuals with an intact language are important and complex, we leave them for others to address.

Globally, SNHL is among the most common of birth conditions the medical profession generally has labeled "defects.. Profound SNHL occurs in 2 to 3 out of 1,000 newborns in North America (NIH Publication No. 11-4968, May 2011) and is as high as 3 out of 1,000 depending on the severity threshold used in a given study and whether or not unilateral hearing loss is included (Kozak, Ospina, & Fandino, 2009; Spivak, 2007). In Germany, profound SNHL occurs in 1 to 3 out of 1,000 newborns (Schnell-Inderst et al., 2006). In Nigeria, a striking number of 28 per 1,000 infants have permanent congenital and early-onset hearing loss (Olusanya, Wirz, & Luxon, 2008). Postnatal causes of SNHL include bacterial meningitis, beta-hemolytic streptococcal sepsis, toxins, trauma, and late onset due to gene mutation (Paqarkar, Bitner-Glindzicz, Knight, & Sirimann, 2006); by school age, 6 to 7 out of 1,000 children have permanent hearing loss, most of which is SNHL (Bamford et al., 2007). Given these data, it is clear that a significant number of children in the world have SNHL.

In industrialized nations, CI is a popular and widely sought-after medical procedure for treatment of profound SNHL. Although CI technology continues to be relatively rare in developing countries (World Health Organization, 2010), this procedure is becoming more common (Baird & McConachie 1995; Moores & Miller 2009). Unfortunately, post-CI habilitation care in these countries might not approach the standards expected in developed countries (Saunders & Barrs, 2011; Zeng, 1996).

In the context of cultures where individuals with a disability, such as deafness, are viewed as inferior, there is an overemphasis on CI to "restore hearing ability" and an under-emphasis on early language access, that is, a focus on speech rather than on language. In North America and Europe, the identification of children with deafness has now evolved into an almost completely automatic system, with instant referral of any newborn who screens positive for possible hearing problems to audiologists and subsequently surgeons (of whom nearly all are hearing professionals), and almost never to successful deaf professionals with experience and expertise in sign language and bilingual education. As a result, CI is now the treatment of choice for most children with SNHL (Niparko, 2009), and sign language is seen as a symptom of treatment failure (Broesterhuizen & Leuven, 2008).

Hearing parents faced with a deaf newborn or newly deafened child often grieve their child's hearing loss and may have no exposure to deaf people or deaf communities in general (Kurtzer-White & Luterman, 2003). These parents tend to focus on "normalizing" their deaf child by attempting to improve their child's hearing capacity and speech ability as much as possible. Unfortunately, the training regimes that are suggested to parents for their deaf children to accomplish this often stress investments of time and focus on speech at the expense of their child's underlying language development and psychosocial adjustment.

Likewise, most studies of pediatric CI focus on assessing speech and auditory skills, rather than on assessing language and communication ability (Thoutenhoofd et al., 2005). This might be in part due to the tendency of hearing people (who are accustomed to the ubiquity of spoken language access) to perceive speech and language development as being essentially the same. The pursuit becomes speech above all—and behind this pursuit might also be hesitancy about sign language.

Many families, and the professionals who advise them, are still unaware that sign language is bona fide language, many adults are reluctant to take on learning a new language, many fear that use of sign language will make their child even more different from hearing children, and perhaps even ostracized (Meadow-Orlans 1980; Medwid & Chapman Weston, 2002; Ogden, 1996). When these common misconceptions are left uncorrected, it is not surprising that in most places the referral process encourages hearing parents to seek out medical treatment intended to help normalize their child's hearing and speech development rather than to consider integrated or additive approaches that might more effectively address their deaf child's underlying language development challenges.

POTENTIAL BENEFITS OF CI

Children with hearing loss who have a CI will have enhanced awareness of sounds in their environment. Many also show increased awareness of speech sounds, particularly if they have an assistive device on the other ear as well (hearing aid or CI, Dunn et al., 2006). In particular, CI allows deaf children to discriminate between loud and soft sounds, between continuous and interrupted sounds, and between long and short sounds. CI also can enable deaf children to differentiate number of sounds, number of sounds in a word, and number of syllables in a sentence. Furthermore, CI allows many deaf children to differentiate among various sounds in the environment (a knock on a door from an ambulance siren, for example). In addition, CI allows some deaf children to recognize speech in a closed-set environment (such as words read aloud from a multiple choice list). Finally, for fewer deaf children, CI allows them to recognize speech in an open-set environment (words spoken aloud without a list) (Roeser & Downs 2004). In a follow-up study of CI recipients who previously participated in a CI outcomes study (8 to 9 years old in the first study and 15 to 18 years old in the second study), there were age-related improvements in speech performance (Davidson et al., 2011). However, these CI participants did not do as well on a speech perception task under demanding listening conditions.

The hope is that a CI will aid deaf children's speech production and reception and thus allow social, academic, and professional interaction through spoken language with hearing people and improve social and career opportunities. One hopes further that the CI will somehow lead to literacy development. Some studies show a correlation between a deaf person's phonological awareness and their reading skills (Dillon, de Jong, & Pisoni, 2011; Nielsen & Luetke-Stahlman, 2002, 2003; Sterne & Goswami, 2000). However, what might be less understood is how this phonological awareness is achieved. One is not required to access sound to have such awareness, given that phonological awareness is of rules, not of sounds themselves. Indeed, sign language fluency is correlated with reading achievement and reading achievement itself may affect phonological awareness, all of this suggesting that there are complex and varied considerations in approaches to literacy development for deaf children (Chamberlain & Mayberry, 2000; Goldin-Meadow & Mayberry, 2001; Moores, 2006). Bilingual abilities (that is, abilities in a sign language plus the ambient spoken language) correlate to better reading skills (Clark, Begue, Gilbert, & Weber, 2008; Freel et al., 2011) and good skills (that is, with developed syntax) in either a sign language or a spoken language correlate to better reading skills (Allen, Hwang, & Stansky, 2009). In sum, production and perception of speech is only one of the possible factors in reading development and, given the large number of deaf children who do not achieve fluent speech production or perception, it should not be the one on which all hope should rest and all attention should be focused. Rather, good language development (in a sign language or a spoken language) is the key to reading (Mayberry, 2007).

POTENTIAL PERILS OF CI, PARTICULARLY IN THE ABSENCE OF SIGN LANGUAGE

Critical review of cochlear implantation is imperative not only because it is major surgery involving young children but also because it has limitations and constraints, some of which are known. The CI devices in use today have various technical limitations. The medical procedures to implant them pose risks. But it is the planning for the deaf child's development before and after the implant that is most crucial and also most problematic.

Success with cochlear implants is variable (Fink et al., 2007; Peterson, Pisoni, & Miyamoto, 2010; Szagun, 2008). The factors involved in CI success are not well understood, although age of the patient (Nicholas & Geers 2007; Tomblin et al., 2005; Vermeire et al., 2005), duration of deafness (Gantz et al., 1993; Green et al., 2007; Leung et al., 2005),

and coding strategies (Skinner et al., 2002) are relevant. Recently, a relationship also has been established between surgical technique and CI outcomes (Meshik et al., 2010).

Additionally, higher socioeconomic status of the parents generally correlates to better success (Svirsky, Theo, & Neuburger, 2004; Szagun, 2008) and continued attention to the rehabilitation process is crucial (O'Reilly, Mangiardi, & Bunnell, 2008). Rehabilitation is necessary because CIs do not replace all the normal functions of the ear or allow one to understand speech immediately (Møller, 2006: 279). CIs and cochlear nucleus implants activate the auditory nervous system in a way that is different from what occurs in the normal ear and they do not activate all the parts of the auditory nervous system that are normally activated by sound. This requires the nervous system to "learn" a new code. It has been known for a long time that expression of neural plasticity helps to regain function after trauma or insults, such as from strokes. Expression of neural plasticity that enables the auditory nervous system to adapt to changing demands plays an important role in the success of cochlear and cochlear nucleus implants. Training is a powerful method for activating neural plasticity and training is a part of all cochlear and cochlear nucleus implant programs.

This plasticity is greatest immediately after birth. If the central auditory system is congenitally deprived of auditory experience, it either cannot mature normally or degenerates rather quickly. With this, we have an account of why CI has more success with younger patients (Kral, Hartmann, Tillein, Heid, & Klinke., 2001, p. 358). Nevertheless, the importance of rehabilitation training cannot be overstated. Some go so far as to take the position that the success of CI is due as much to the information and support team as to the technology itself, where follow-up schedule and therapy after surgery must be intense (Paul & Whitelaw, 2010, pp. 281–282).

However, what these discussions refer to as "rehabilitation" and "training" may focus on learning to use the implant (learning to interpret or translate the sound that the device transmits into recognizable speech, perhaps) or, instead, may focus on communicating in the kind of language environment in which the child will be immersed post-implant. There is a peril here in perception of the task at hand as "rehabilitation" only. All children, no matter who they are, deaf or hearing, with CI or without CI, need and must have a natural language environment in order to develop language. Language development is not a training process or a rehabilitative process; training and rehabilitation are concepts of remediation, not of development. Perception of the child as a language learner, rather than someone in need of rehabilitation or training, is a different construct of what needs to be done post-implant and allows for more flexibility and involvement of factors other than speech that contribute to language and literacy development.

For the CI recipient, speech recognition in sound-proof booths (or quiet environments) can be quite high, but when background noise is present, speech recognition diminishes; high resolution spectral information is necessary for good speech recognition in poor listening conditions, but CI listeners "appear to utilize only four to seven channels of spectral information no matter how many electrodes are available in their implant" (Shannon et al., 2004, p. 364) although the reason for this remains unclear. One attempt to deal with this is to give binaural CIs. However, the fitting process is difficult in terms of matching the two devices with respect to cochlear place and linking the amplitude compression schemes used in the two implant speech processors. Even then, some patients do not have sufficient residual auditory capacity in the central nervous system to usefully exploit the binaural cues. It is difficult and risky to predict who might benefit from binaural CI prior to surgery (Shannon et al., 2004, p. 366). This difficulty to predict is in itself a peril of implants. "Fixes" such as binaural implantation carry inherent problems as well. Regardless of the causes for the variability in CI success, the fact is, people who receive CIs range from gaining no linguistic aid to being able to interact in a hearing environment with good ability and facility (O'Reilly, Mangiardi, & Bunnell, 2008; Uziel et al., 2007). Additionally, there is evidence that the CI recipient's language development might not just be delayed, but might also be atypical with disordered or impaired neural reorganization (Pison et al., 2008; Pisoni & Cleary 2003; Pisoni & Geers, 2001;). This comes with the fact that immediate memory pertinent to language interactions is different for even the most skilled CI recipients (the "stars") (Pisoni & Cleary, 2004). This is a serious finding.

Furthermore, a cochlear implant neither restores nor effects normal hearing even for the CI stars. The child receives no benefit when the implant malfunctions or when the external apparatus must be removed, such as for sports events or sleeping (which can be interrupted by an emergency requiring communication). A child's commu-

nication abilities still need to be supplemented by contextual clues and speechreading in the absence of a sign language. In other words, use of an implant is a constant task requiring focused attention and substantial effort with variable yield in terms of communication. Lisa Herbert (Herbert, 2008, p. 127) reports from personal experience that her sister "would discreetly summarize the family discussion for me at dinnertime, if necessary, or ask if I wanted her to repeat someone's joke that I had missed." Here Herbert is describing a loving family where every effort is made to include her as an oral CI child. Such problems are magnified in environments outside of home such as at school where it is improbable that teachers and fellow classmates will provide as great an effort. The mental effort that is required in using the implant also tends to cause fatigue, so that a school-age child struggling to cope with the overload has trouble sustaining attention and processing information equivalently to hearing peers with detrimental effects on academic performance and often on behavior (Hicks & Tharpe, 2002). Indeed, in-depth interviews with 49 adolescents, including some with CI, (26% mild/moderate; 26% mod-severe/severe; 47% profound hearing loss) revealed that keeping up with information and feeling limited were among common themes that these adolescents perceived as having significant impact on their hearing-related qualities of life (Skalicky, Kushalnagar, Topolski, Schick, Edwards, Sie, & Patrick., 2010, p. 39). Quotations included, "I feel it is hard for me to understand what people are saying" and "I feel lost in large groups because it is hard to follow the conversation." In a larger quality-of-life deaf-and-hard-of-hearing youth study (Kushalnagar et al., 2011), investigators found that deaf and hard-of-hearing individuals who had low scores in the participation domain also had low perceived qualities of life.

Unfortunately, initial gains in school related to CI are not always maintained and many implanted children soon fall behind their hearing peers (Geers, 2008; Marschark, Rhoten, & Fabich, 2007). Teachers of implanted children who are doing well often assume that their students are fully able to receive and process all academic materials through speech, and they may overlook when their deaf students need help coping with the abstractions, technicalities, and complexities involved in academic language and classroom discussions. The unintended result is a high risk of underachievement in these deaf children (Baker, 1997).

Giving the deaf child with a CI oral input exclusively without any sign input is not the optimal situation in terms of general learning. The idea that children vary in which mode of learning works best, visual, auditory, kinesthetic, or tactile, is now widely discussed. A multimodal approach is likely to produce the best results with the most children (Clark & Lyons, 2010; McClincy, 2010) and common sense dictates that a multimodal approach would best serve all at-risk children, including deaf children.

The Greater Peril of CI without a Sign Language: Linguistic Deprivation

Too often, when people think of language, they think of speech. However, the language faculty in the brain is flexible with respect to modality. Both spoken and sign languages can nurture that faculty and are governed by that faculty, as is shown by much research on the structure of particular spoken and sign languages and on language universals (see a multitude of articles in many linguistics journals, including *Sign Language and Linguistics* and *Sign Language Studies*), on language acquisition (Meier & Newport, 1990; Petitto & Marentette, 1991; among many following), on language processing (Emmorey, 2001; among many following), on neurolinguistics (Neville, 1995; Poizner, Klima, & Bellugi, 1987; among many following), on language pathologies (Corina, 1998; among many following), and on second language learning (Newport, 1990).

The language faculty is a biological mechanism initially with a great amount of plasticity, However, that plasticity changes at certain critical or sensitive periods, with concomitant effects on certain cognitive abilities (Lenneberg, 1967). The earliest critical period that has been argued for in the literature and that is relevant to our argument occurs around six months of age. Language input within the first six months of the child's life is crucial to the development of the central nervous system. Best results on learning to process auditory information come if a child is exposed to auditory input before that age (Yoshinaga-Itano, 1999). Best results on learning any natural language (spoken or sign) come if a child is exposed to it before that age (Hall & Johnston, 2009). This is the primary thrust for early intervention starting as soon as hearing loss is detected and for the recent push to implant children during the first year of life (Waltzman & Roland, 2005; Yoshinaga-Itano et al., 1998; Yoshinaga-Itano, Coulter, & Thomson, 2000; among many, but see Szagun, 2008, for other results). The next critical period relevant to our argument, and one on which a vast amount of research has been

done, occurs around the age of five or six. If a child has not been exposed regularly to accessible natural language by then, the likelihood of that child ever having complete fluency in any language is negligible (Krashen, 1973). Deaf children who were first exposed to an accessible language (i.e, a sign language) at varying ages show varying degrees of mastery of language as they age; crucially, early learners do far better than late learners overall (Boyes Braem, 1999; Cormier et al., 2012; Galvan, 1999; Helmuth, 2001; Johnson & Newport, 1989; Morford & Hänel-Faulhaber, 2011; Newport, 1990, 1991; Newport et al., 2001; Newport & Supalla, 1987; Singleton & Newport, 2004; Wood, 2011; Skotara et al., 2012). The fact that plasticity changes are relevant to language in this way means that natural language input as early in a child's life as possible is crucial to the development of the language faculty (Lenneberg, 1964. Mayberry, 1994, 1998, 2007; Mayberry & Eichen, 1991). Therefore, delayed exposure to fluent language interaction at an early age risks linguistic deprivation.

The language faculty is relevant to memory organization (Ronnberg, 2003), mastery of cognitive skills such as numeracy and literacy (MacSweeney, 1998), and many other aspects of cognitive development, including the development of Theory of Mind (Courtin, 2000; Morgan & Kegl, 2006; Remmel & Peters, 2009) and the development of higher order cognitive processing called executive functions (Figueras, Edwards, & Langdon, 2008; Marschark & Hauser, 2008). Thus, delayed exposure to a fluent and accessible language model at an early age risks long-term cognitive difficulties.

The ability to communicate and maintain good social interaction with others and the youth's own perception of ability to participate in communication with ease is critical to psychosocial well-being (Kushalnagar et al., 2011; Schick, Marschark, & Spencer, 2006; Yoshinaga-Itano, 2002). The lack of this ability or perceived communication difficulties can lead to frustration (Gregory, 1995) and depression (Turner, Windfuhr, & Kapur, 2007), both of which are associated with low perceived quality of life. Language interactions are among the most common human activities, and limitations on such activity are predictive of psychosocial difficulties they will experience (Eide & Røysamb, 2002). Language delay risks serious problems for the individual with a CI in forming a healthy identity and positive perceived quality of life.

Finally, the lack of ability to communicate puts one at much higher risk of being physically, emotionally, and sexually abused (Knutson, Johnson, & Sullivan, 2004; Kvam, 2004; Sullivan & Knutson, 2000). The lack of ability to communicate puts one at risk for being exploited for criminal activities as well (Kleimenov & Shamkov, 2005). Children who experience such abuse are at higher risk of mental health problems throughout life (Downs & Harrison, 1998; Macmillan et al., 2001; Read, 1998). Mental health status is strongly associated with perceived quality of life among youths (Sawatzky, Ratner, Johnson, Kopec & Zumbo, 2010). When the child perceives her/his own quality of life to be poor, the child is more likely to report engagement in health-risk behaviors such as tobacco/alcohol usage and high-risk sexual activity (Topolski, Patrick, Edwards, Huebner, Connell, & Mount , 2001).

In sum, protecting the language faculty—ensuring that a person receives regular and frequent exposure to an accessible natural language beginning at birth—is a societal responsibility. To do otherwise is to ignore all of these warnings and place large numbers of young children at high risk.

BIMODAL-BILINGUALISM: THE OPTIMAL APPROACH

Bimodal-bilingualism for a person with a CI is a global solution that can be implemented on a clinical and system level to support families to ensure best possible long-term developmental outcomes for all deaf children in an auditory-dominant society. When people discuss bimodal-bilingualism in deaf children, they usually mean proficiency in a sign language as well as a spoken language (in at least its printed form). This means that the child develops sign language fluency and spoken language fluency, and literacy in both languages is emphasized. Some deaf children will be able to demonstrate spoken language fluency through speech, and some will be better able to demonstrate it through the printed form of that spoken language. Either way, it is fluency in the spoken language that is imperative, along with the signed language. The advantages of bimodal-bilingualism for deaf children are many. Some are outlined below to show how a bimodal and bilingual experience can be a part of deaf children's cochlear implant development plan.

Bimodal-Bilingualism and Language Development

First and foremost, bimodal-bilingualism is an effective approach to address and maximize both

speech and language development. A bimodal-bilingual approach helps parents, caregivers, and professionals to maintain their focus on deaf children's language development, not just their speech development, and provides maximal language exposure through both spoken and signed languages during critical periods of deaf children's language development. A sign language is a natural human language, and it is accessible to any child, even a blind child, who accesses it through tactile means. Numerous studies show that deaf infants acquire sign languages in the same pattern and stages as hearing children acquire spoken languages (even babbling in sign; Newport & Meier, 1985; Petitto & Marentette, 1991). Exposure of deaf children to a sign language at a very early age is a guaranteed way of ensuring healthy formation of the language faculty; in contrast, giving the child sign language at a later age (in response to lack of progress in spoken language) does not ameliorate language difficulties due to lack of accessible language before that (Mayberry, 2002). Furthermore, exposure to multiple languages has its own advantages; studies show enhanced language development in children who have grown up with and use more than one language (Gort, 2008; Hoff, 2005; Nicoladis, 2010).

Second, a bimodal and bilingual approach enhances multimodal access to language and is most likely to be effective for all deaf children, regardless of their learning preference (that is, whether they are visual, auditory, kinesthetic, or tactile learners). Visual learning is used during language development by any sighted child, whether deaf or hearing. From a cognitive neuroscience perspective, rapid synaptic formation for lower-order somatosensory and visual cortices pave the way for higher order association cortices; all this takes place during the first four months of life and begins to plateau after eight months (Gogtay et al., 2001; Huttenlocher, 1990). Deaf infants stand to gain from early sign language exposure since the strengthening of sensorimotor pathways involved in sign language development (forming and attending to hands that carry meaning, and moving in the visual field, as discussed in Cheek, Morier, Repp, & Meier, 2001 and Morgan, Barrett-Jones & Stoneham, 2007) might facilitate early development of spatial attention and receptive understanding of the visual communication modality. Infant spatial attention plays an essential role in early language development, whether spoken or signed, and promotes healthy parent-infant attachment (Baldwin, 1995). With visual attention and language mapping in place, the deaf child's brain is in normal language development mode and better positioned to acquire spoken language with a CI. In this sense, visual clues bolster spoken language production: for example, sighted hearing children produce labials such as the [b] in *ball* before other sounds, as the movement of the lips is visually apparent, but blind children do not (Vihman, 1996). As sign language experience fosters development of neural pathways associated with visual attention abilities as well as language abilities, it is actually useful for learning to produce speech. Learning a sign language at the earliest possible age is a pathway to learning a spoken language, and learning a spoken language is a prerequisite to learning to speak it. The best of all worlds for a deaf child, then, is a bimodal, bilingual world.

Third, early sign language exposure as part of bilingual CI development takes advantage of infants' natural inclination to use and respond to gesture before spoken language (even in hearing infants). Regardless of hearing status, the child reaches expressive language milestones earlier in gesture-based communication systems than spoken language (Acredolo & Goodwyn, 1985; Goodwyn & Acredolo, 1993, 1998, 1990; Griffith, 1985; Meier & Newport, 1990; Newport & Meier, 1985; Pizer, Walters, & Meier, 2007; Wilbur & Jones, 1974; Meier,1991). Therefore, the very young child who signs has a communicative advantage regardless of the child's ability to hear or not. This very advantage is likely the reason why it is popular today to teach signs to hearing infants.

Bimodal-Bilingualism and Academic Achievement

Bilingual proficiency and bi-literacy have been shown to be positively associated with academic achievement. Deaf children who use sign language, with or without CI and regardless of familial background (such as whether their parents are deaf or hearing and whether or not they use assistive hearing devices and/or oral training), demonstrate greater academic and reading achievements than deaf children who do not use sign language (Fischer, 1998; Hoffmeister, 2000; Mayer & Akamatsu, 2003; Padden & Ramsey, 2000; Paul, 2003; Schick, 2003; Strong & Prinz, 2000;Wilbur, 2008). In particular, signing skill correlates strongly with reading achievement above all other possible factors (Chamberlain & Mayberry, 2008; Hermans, Ormel, Knoors, & Verhoeven, 2008; Wilbur, 2001). For all these reasons, many have been promoting

bilingualism/ biculturalism in an academic setting for years, even decades (Davies, 1991; Grosjean, 1982; Humphries & Allen, 2008; Humphries, Martin & Coye, 1978;Johnson, Liddell, & Erting, 1989; Parasnis, 1996;among many).

Bimodal-bilingualism for deaf children develops skills useful to academic achievement. First, deaf bilinguals show more creative verbal processes in terms of the syntactic structures they use (Prinz & Strong, 1998). Second, deaf bilinguals show more creative thinking, particularly in problem solving (Baker, 2006). Third, deaf bilinguals show increased syntactic complexity; in a Dutch longitudinal study, both the sign language and the spoken language of bilingual deaf children involved more syntactic complexity than those of their monolingual peers (Klatter-Folmer, 2006). Fourth, in a computerized attention study, deaf adult bilinguals with high proficiency in both English and ASL demonstrated significantly higher accuracy in attention switching performance than deaf adults with unbalanced proficiency in both languages (Kushalnagar, Hannay, & Hernandez, 2010). Indeed, bilingualism results in better mental flexibility and cognitive control throughout life and may delay the onset of dementia by as much as four years (Bialystok, Craig, Klein, & Viswanathan, 2004; Bialystok, Craik, & Freedman, 2007).

Bimodal-bilingualism is advantageous for children's cognitive development and, therefore, academic achievement regardless of what languages are involved and regardless of whether the children are hearing or deaf. Bilingual children outperform their monolingual peers in tests of spatial ability and general reasoning (Cummins & Gulustan, 1974) and in reading (Clark, Begue, Gilbert, & Weber, 2008; Freel et al., 2011). Learning sign language offers particular advantages; hearing children who learn a sign language show better attention abilities, visual discrimination, and spatial memory (Capirci, Cattani, Rossini & Volterra, 1998) and there is no reason not to expect use of a sign language to develop these same skills in deaf children.

Bimodal-Bilingualism and Social/ Psychosocial Well-Being

Learning a sign language and becoming bilingual at an early age enhances social opportunities for deaf people. Deaf people who are able to sign and speak can communicate and socialize with both deaf and hearing people. The advantage of being able to communicate with other deaf and hard-of-hearing people who might use a sign language primarily turns out to be not just a social advantage, but a psychological one.

Bimodal-bilingualism promotes positive long-term psychosocial outcomes in deaf people (Christiansen & Leigh, 2002). Deaf people sometimes experience a certain amount of anxiety and depression in many cultures due to discrimination and stigma (Kvam, Loeb, & Tambs, 2006). However, young deaf people who use speech only are subject to greater perceived stigma associated with being deaf or hard of hearing than other young people who report using a combination of speech and sign as their preferred mode of communication (Kushalnagar et al., 2011). Deaf children who have a strong culturally Deaf identity (meaning that they sign fluently and participate in a Deaf community) or who have a strong bilingual/bicultural identity have the highest self-esteem and best mental health throughout life (Leigh & Pollard, 2003).

Bimodal-Bilingualism and Social Justice

A bilingual approach to raising a deaf child is an approach that lessens or prevents the social inequities associated with CI for deaf children. We noted above that success with CI is variable, from very low success to quite high success, with many people gaining little to no access to human speech (Fink et al, 2007; O'Reilly, Mangiardi, & Bunnell, 2008; Uziel et al., 2007). A societal injustice is built into this variability: successful CI outcomes best correlate with higher socioeconomic status and parental speech characteristics, specifically mean length of utterance (Svirsky, Theo, & Neuburger, 2004; Szagun, 2008). Adding a sign language from the beginning of detection of deafness, with or without a CI, is most likely to reduce the effects of this variability and lessen the gap between lower and higher socioeconomic groups.

Hearing loss is more prevalent among those of lesser economic means. Many maternal-related factors particularly correlate to a child's likelihood of having SNHL, including age, educational and literacy level, marital status, substance abuse, smoking, number of children at home, insurance status, family history of hearing loss, prenatal care, and poverty level (American Speech-Language-Hearing Association, 2008). Poverty, combined with many of these factors, produces higher levels of SNH; lower socioeconomic areas around the world are home to higher numbers of people with SNHL (for Canada, see Bowd, 2005; for India, see Reddy et al., 2006; for Malawi, see Hasselt & Kreten,

2002; for Pakistan, see Musani et al., 2011; for the United States, see many, especially Oghalai et al., 2002 and Prince et al., 2003). Moreover, most hearing impaired children live in developing countries (Jauhiainen, 2001;Tucci, Merson, & Wilson, 2010). This is one reason why America's Head Start's long-standing commitment to sensory screening is so important (Eiserman & Shisler, 2011).

With so many deaf children at risk due to poverty and other factors it is critically important that they be able to access a visual, signed language in a cost-effective and successful approach to intervention, such as a bimodal-bilingual approach. Teaching all deaf children a sign language ensures that social inequities will not be exacerbated among deaf people due to other factors. For many, it may be the only hope for genuine social and educational opportunity. A CI-only, monolingual-spoken-language approach cannot offer the safety that a sign language offers.

Among deaf people in higher socioeconomic situations, there is also a social justice issue. We note that many deaf children raised in spoken-language-only environments, with or without CIs, are frequently regretful of their lack of social and career opportunities due to not knowing sign language and, therefore, not having social relationships with signers, or the ability to use sign language interpreting services in higher education or job settings, services that they do need even though they have implants. And many regret that they did not learn much in school using a monolingual, spoken-language-only approach. By contrast, almost no deaf person ever regrets learning a sign language. Deaf people are often denied basic rights and are discriminated against despite laws that protect their rights. The right that needs consideration most of all is the right of every child to a natural language that they find accessible.

Bimodal-Bilingualism and Personal Justice

A bimodal-bilingual approach is based on the evidence that sign language is a natural language and is visually accessible for a child who does not hear. All children need and deserve a language they can learn and use with ease. A CI intervention that restricts the child to using spoken language as the single mode of communication does not give that "ease of language usage" to the deaf child. While the child is learning to maximize the benefits of a CI, if they ever do come, time is passing and this is valuable time in terms of language acquisition and cognitive development. We should not expect deaf infants and young children to depend completely on filtering sounds through a less-than-perfect device to develop language during critical periods of brain development.

Furthermore, the deaf child, even the implanted child who has good success in a hearing environment, needs to be fluent in a sign language so she or he might also participate in social interaction with other deaf people who use a sign language. Sign language proficiency allows the deaf child to use more accommodation-related resources, such as a sign language interpreter who is able to move around with the deaf child and interpret social interaction with other hearing children.

All children also need and deserve a natural language. In fact, the right to language is arguably the most crucial of human rights (Humphries et al., forthcoming). The deaf child's right to access language visually can only be met through a sign language, and the deaf child's right to access the language of the ambient hearing majority can only be met through development of the child's speech and sound awareness and through literacy skills. That the deaf child finds visual-gestural language accessible and advantageous is clear: deaf children, who are not exposed to sign and cannot access spoken language will still engage in production of a gestural communication system that has language-like features (Goldin-Meadow, 2003). This is how powerful the human drive to acquire language is, so powerful that in the absence of language input, the children will begin the process of creating language from the raw material of gesture. It is far better for their cognitive development and communicative range for deaf children to have access to an actual sign language.

Implementing Bimodal-Bilingualism as a Clinical and System Intervention

A recent study found that bimodal-bilingualism is already used by 25 to 30% of children who have CIs and that these children move comfortably between communication modes. Although the major goal of implanting the children in this study was the development of spoken communication, their parents and teachers report positive impact of sign language knowledge on their personal, social, and academic achievement (Hyde & Punch, 2011). This finding suggests that it is time to promote bimodal-bilingualism as a clinical and system intervention. There are two crucial steps that will help achieve this.

Step One: Education of Professionals, Families, and the Public

We must educate the general public to the fact that language development begins before speech development and that the crucial language development period is the first few years of life. Speech development does not equate to language development and acquisition, especially for deaf children. The deaf child may speak very clearly and identify spoken vocabulary or short sentences in sound-proof booths, but the same child continues to lag behind in language and reading and to struggle in understanding conversations in a busy home, social or school environment. The same child who demonstrates some speech facility can demonstrate delay in acquisition of vocabulary, internal language processes, and syntax. Language development must be the highest priority in order to ensure the cognitive and psychosocial wellbeing of the child. The family of a deaf newborn or newly deafened child needs support to give their child regular and frequent exposure to sign language with fluent language models (Schick, Marschark, & Spencer, 2006). However, the family also needs to be encouraged to learn sign; deaf children who sign with their hearing mothers show early language expressiveness on a par with hearing children of the same age (Spencer, 1993). Children, both hearing and deaf, often use private language (that is, language directed at themselves) when they are faced with tasks they find difficult, and the more they use this private language, the more success they have at the tasks (Vgotsky, 1962). Deaf children who sign with their parents use more complex private language with more positive outcome than those who do not sign (Jamieson, 1995). Hearing parents should not be made to feel that they have to become perfect linguistic models of sign language for their deaf child, or even become language teachers or trainers themselves. Rather, they should simply aim to be good parents, and that means they need to be able to communicate well with the child in the language(s) the child clearly understands and uses.

We must also educate hearing professionals in the fields of audiology, speech-language pathology, and related professions as to the benefits of raising a deaf child bimodally and bilingually, and we must recruit professionals into these fields who advocate, based on a very clear understanding of the research basis and evidence for doing so, the use of a sign language in conjunction with CI and therapeutic situations to practice speech. The historical medical profession's narrow view of deafness as a pathology in need of a cure, if unchallenged, can do harm (Staley & Hecht, 2005). Audiologists and speech-language professionals need to take the lead in informing themselves and updating their sciences to include more recent findings since the first approval of the implant device. Much new evidence has emerged that suggests that the implant device needs to be augmented by a sign language.

It is essential that all health professionals a family is likely to turn to for guidance also be educated about the advantages of bimodal-bilingualism for all deaf people and the critical importance of early exposure to both sign and speech for children. New training models for future professions need to include knowledge about how this approach works in real time so that parents, therapists, and educators can use them to promote all aspects of the deaf child's social life and education. Thus, pediatricians, primary care physicians, family doctors, and surgeons who perform CIs should have the knowledge that allows them to be ready to assist the family appropriately, including going through the steps outlined in Kushalnagar, Mathur, Moreland, Napoli, Osterling, Padden, and Rathmann (2010), such as: (1) ensuring hearing screening and appropriate follow-up, (2) referring the families to appropriate healthcare specialists, (3) identifying warning signs that children are not thriving with their present language situation, (4) collecting and disseminating accurate information on deaf issues, (5) advocating for the child while supporting the parents at the same time, and (6) providing families with information on learning sign languages and on the educational rights of their children. These topics should be well covered in medical school curricula.

Step Two: Cooperation and Coordination

Health professionals should cooperate with the Deaf community for the benefit of all deaf children. The medical system should link to available and accessible community resources to recruit bilingual deaf adult role models to consult with hearing parents of babies recently diagnosed with significant hearing loss (Paludneviciene, 2009). Families should also be referred to community support groups such as deaf advocacy groups, local deaf and hard-of-hearing community centers, and local and/or state deaf services bureaus. Health professionals must begin to interact with and learn from the community of signers. These signers are no longer children, patients, clients, nor subjects of experimentation. Rather, these signers have grown up

deaf and carry important lessons about how best to meet the needs of deaf children.

Health professionals should also coordinate their efforts across the board to ensure consistent and coherent care of the child. Local and state public health departments need to implement changes in the referral process following a newborn hearing screening that detects hearing loss to include information, resources, and consultation on bimodal-bilingualism, and not just on either an oral or a sign language approach exclusively.

Health professionals should also advocate for local, state, and federal government support of bimodal-bilingualism for the deaf child. Raising the deaf child bilingually is the growing trend globally, so much so that it is considered a "mega trend" (Munoz-Baell et al., 2008). Multiple Internet sites give information on the feasibility and cost-effectiveness of bimodal-bilingualism for deaf children (and see Ahlgren & Hyltenstam, 1994), so there is no doubt that when health professionals and government work together, a functioning, successful bilingual information system can thrive.

FUTURE WORK AND PRESENT ACTION

This paper suggests that much research is needed to understand the risks of implants. We do not believe there is reliable data on the success of CIs or even a sensible definition of success with regard to CIs. The effects of the plans, interventions, paths, therapies, and practices used after implantation are also not clearly outlined nor understood in research. Further work needs to be done to track, acknowledge and alleviate the condition of children of various ages who have implants and still are not meeting or even nearly meeting important language and literacy milestones. The bimodal-bilingual approach itself needs to be better understood, and best practices in such an approach with deaf children need to be defined and institutionalized, starting with ways to make sign language available to parents and their deaf children immediately. To this end, new models are needed for training educators who will work with parents to understand and use these best practices.

CONCLUSIONS

Raising a deaf child with CI and exclusively spoken language risks delay in language and associated cognitive development as well as academic and psychosocial difficulties. The degree of risk varies depending on multiple factors that are not easily amendable or predicted, including the child's socioeconomic status. Raising a deaf child with CI and spoken language along with a sign language capitalizes on bimodal-bilingual language development that encompasses the multiple variables and factors we have discussed in this paper. Using a bimodal-bilingualism approach for children with CI is the safest method to ensure that those children, regardless of socioeconomic status or any other factors, are provided with the best opportunity for maximal language development, and, hence, the optimal chance for good cognitive development, academic success, and psychosocial well-being.

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