ACTA Otorhinolaryngologica Italica 2025;45:124-134; doi: 10.14639/0392-100X-N3077

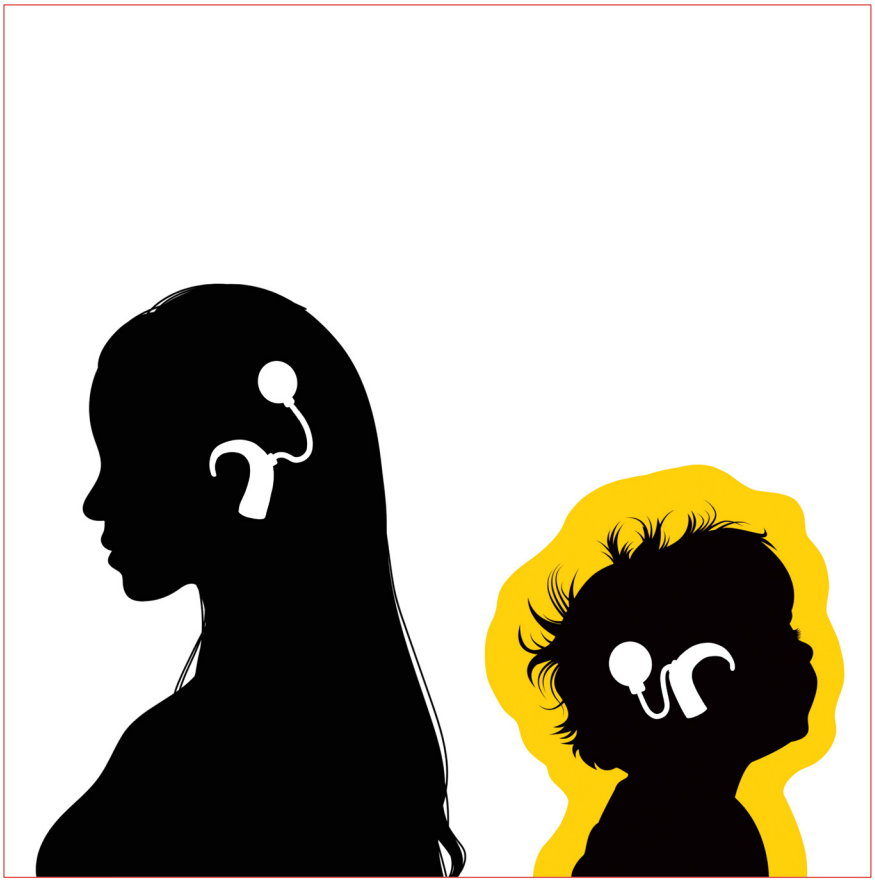
Cochlear Implant (CI) procedure. Italian Clinical Practice Guidelines of the Italian Society of Otorhinolaryngology (SIOeChCF) and Italian Society of Audiology and Phoniatrics (SIAF). Part 2: cochlear implants in children

Domenico Cuda[1,2], Stefano Berrettini[3], Silvia Minozzi[4], Franca Artioli[5], Umberto Barbieri[6], Cristian Borghi[7-9], Eliana Cristofari[10], Giorgio Conte[11,12], Davide Cornolti[13,14], Diego di Lisi[15], Anna Rita Fetoni[16], Simona Fiori[17,18], Elisabetta Genovese[19], Giorgia Girotto[20,21], Marinella Majorano[22], Pasquale Marsella[23], Emanuele Marzetti[24,25], Maria Nicastri[26], Gaetano Paludetti[27], Nicola Quaranta[28], Patrizia Trevisi[29], Diego Zanetti[30], Michela Cinquini[4], Sara Ghiselli[1], Francesca Forli[3,31]

Received: May 20, 2024
Accepted: August 5, 2024

Correspondence
Sara Ghiselli
E-mail: S.Ghiselli@ausl.pc.it

How to cite this article: Cuda D, Berrettini S, Minozzi S, et al. Cochlear Implant (CI) procedure. Italian Clinical Practice Guidelines of the Italian Society of Otorhinolaryngology (SIOeChCF) and Italian Society of Audiology and Phoniatrics (SIAF). Part 2: cochlear implants in children. Acta Otorhinolaryngol Ital 2025;45:124-134. https://doi.org/10.14639/0392-100X-N3077



Cover figure. Cochlear implant for children.

Summary

Objective. Cochlear implant (CI) is a well-established treatment for children with sensorineural hearing loss without benefit from hearing aids. The Italian guidelines date back 15 years; given the expansion of indications for CI (including single side deafness and asymmetrical hearing loss) it became necessary to establish updated guidelines.
Methods. Thirteen experts and 2 patient representatives selected the key questions and drew up recommendations. The document was developed following the GRADE methodology. The methodological team of the Mario Negri Pharmacological Research Institute performed systematic reviews for each question and supported the overall process.
Results. Four key questions were identified and recommendation formulated, with subgroups and implementation considerations.
Conclusions. Though the systematic research of scientific literature found a scarcity of randomised trials and an overall poor conduct and reporting quality of primary studies and systematic reviews, conditional recommendations in favour of CI have been formulated for different subgroups of children. Further studies should enrol a larger number of participants and use consistent instruments to evaluate hearing outcomes, in order to increase comparability of results and data pooling through meta-analysis.

Key words: cochlear implant, hearing loss, children, clinical practice guideline

[1] Department of Otolaryngology, AUSL Piacenza, Italy; [2] Department of Medicine and Surgery, University of Parma, Italy; [3] UO Otolaryngology, Audiology and Phoniatrics Unit, University of Pisa, Pisa, Italy; [4] Laboratory of Methodology of Systematic Reviews and Production of Guidelines. Istituto di Ricerche Farmacologiche Mario Negri, IRCCS, Milan, Italy; [5] Department of Otolaryngology-Head Neck Surgery, University Hospital of Modena, Modena, Italy; [6] Patient representative; [7] Amplifon Italia S.p.A.; [8] University of Padua, Padua, Italy; [9] University of Parma, Parma, Italy; [10] ENT Audio-Vestibology Unit, Ospedale di Circolo e Fondazione Macchi, Varese, Italy; [11] Neuroradiology Unit, Fondazione IRCCS Ca Granda Ospedale Maggiore Policlinico, Milan, Italy; [12] Department of Pathophysiology and Transplantation, University of Milan, Milan, Italy; [13] Associazione per la Sordità ed Impianti Cocleari - ODV (A.S.I.C.-ODV), Lucca, Italy; [14] Institute of Clinical Physiology (IFC), CNR, Pisa, Italy; [15] ENT Department, Martini Hospital, Turin, Italy; [16] Department of Neuroscience, Reproductive Science and Dentistry, Section of Audiology, University of Naples "Federico II", Naples, Italy; [17] Neuroscience Department, Meyer Children's Hospital, Florence, Italy; [18] University of Florence, Florence, Italy; [19] Department of Maternal and Child and Adult Medical and Surgical Sciences, University of Modena and Reggio Emilia; [20] Department of Medical, Surgical and Health Sciences, University of Trieste, Trieste, Italy; [21] IRCCS Burlo Garofolo, Trieste, Italy; [22] Department of Human Sciences, University of Verona, Italy; [23] Audiology and Otosurgery Department, "Bambino Gesù" Children's Hospital, Rome, Italy; [24] Fondazione Policlinico Universitario "A. Gemelli" IRCCS, Rome, Italy; [25] Department of Geriatrics, Orthopedics and Rheumatology, Università Cattolica del Sacro Cuore, Rome, Italy; [26] Department of Sense Organs, University Sapienza of Rome, Rome, Italy; [27] Department of Head, Neck and Sensory Organs, Catholic University of The Sacred Heart, Rome, Italy; [28] Otolaryngology Unit, Department of Translational Biomedicine and Neurosciences (DiBraiN), University "Aldo Moro" of Bari, Italy; [29] Section of Otorhinolaryngology-Head and Neck Surgery, Department of Neurosciences, University of Padua, Padua, Italy; [30] Audiology Unit, Department of Specialistic Surgical Sciences, Fondazione IRCCS Ca' Granda Ospedale Maggiore Policlinico, Milan, Italy; [31] Hearing Implant Section, Karolinska Institutet, Stockholm, Sweden

Introduction

This report summarises the recommendations of Clinical Practice Guidelines regarding Cochlear Implant (CI) procedure in children [1], drawn up according to the GRADE methodology [2] and promoted by the following scientific societies: Italian Society of Otorhinolaryngology (SIOeChCF) and Italian Society of Audiology and Phoniatrics (SIAF).

Current knowledge about CI procedures is translated into relevant practical recommendations following the rules and the methodology indicated by the Centro Nazionale per l'Eccellenza delle Cure (CNEC) and the Istituto Superiore di Sanità (ISS).
CI is a well-established, safe and effective treatment for paediatric patients with sensorineural hearing loss who do not sufficiently benefit from traditional hearing aids.

In children, if not treated early and properly, hearing loss irreversibly alters the processes of language acquisition and development, significantly impairing verbal communication, with consequences in cognitive development, psychological, learning and social development [3].

The US Food and Drug Administration (FDA) [4] approved the use of cochlear implants in children in 1990. Initially, CI was only dedicated to children with bilateral profound hearing loss. Subsequently, the indications for this procedure were expanded, mainly on the basis of extremely positive clinical evidence and technological advances that allowed for faster, safer and less invasive surgery, as well as better outcomes. Consequently, the procedure was also considered for children with greater residual hearing, asymmetric hearing loss, or even unilateral deafness (so-called single sided deafness, SSD). In addition, bilateral procedures are currently available in certain types of paediatric patients. However, some of the more recent areas of application of this procedure are still debated, as the evidence on clinical and cost-effectiveness is limited.

Although several guidelines have been published to date defining the indications for this procedure in paediatric patients, there is no uniformity on the criteria used by different groups to define indications and appropriateness criteria. Moreover, the guidelines available today are mostly national and their structure is not defined and universally shared.

In Italy, in 2009, guidelines for the CI procedure were published by a working group coordinated by the SIOeChCF [5]. These guidelines date back some 15 years and in some aspects are to be considered outdated, in addition to the fact that they do not consider some areas in which CI is currently indicated (e.g., SSD, asymmetric hearing loss, etc.). Furthermore, in 2011 a Health Technology Assessment (HTA) project, promoted by the Italian Ministry of Health, was concluded by a working group of experts coordinated by S. Berrettini [6] to outline the appropriateness criteria for cochlear implantation in adults and children. Even this document does not consider certain aspects, such as CI in asymmetric hearing loss and SSD, and does not reflect the criteria for a guideline.

For these reasons, it became necessary to establish new and updated guidelines on the criteria for selection and appropriateness of the CI procedure in adult and paediatric patients. In particular, as far as the paediatric patient is concerned, attention was paid to early treatment, to bilateral implantation, and to CI in asymmetric hearing loss and SSD.

Materials and methods

The panel was composed of 3 otolaryngologists, 2 audiologists and phoniatricians, one audiometrist, one hearing aid specialist, one speech pathologist, one child neuropsychiatrist, one geneticist, one geriatrician, one neuroradiologist, one psychologist and 2 patient representatives. The experts, indicated by the above-mentioned scientific societies and the patient representatives identified, by collegial discussion, the key questions that health care providers are frequently faced with, discussed the evidence provided by the methodological team and drew up guidelines.

This document was developed according to the rules of the CNEC of the Italian Ministry of Health with the support of the methodological team of the Laboratory of Methodology of Systematic Reviews and Guidelines production of the Mario Negri Pharmacological Research Institute. The key questions were developed according to the Population, Intervention, Comparison, Outcomes (PICO) acronym. For each PICO question, the literature on MEDLINE/PubMed, Embase and Cochrane Library databases was systematically searched with both thesaurus terms and free text up to June 2023 and included systematic reviews, randomised and non-randomised controlled trials and non-controlled studies. A further hand-search was performed on the bibliography of retrieved articles.

Recommendations were formulated applying the GRADE approach [2] according to the CNEC manual [7]. All aspects concerning questions, assessment of evidence and conclusions were discussed among panel members and voted. Before voting, members declared their potential conflict of interest (COI) relevant to the PICO question, and only those without COI voted. The online GRADEpro GDT tool was used to develop questions, assess evidence, and make decisions [8]. The certainty of evidence was assessed applying the tool for risk of bias in randomised trials (RoB) as suggested by Cochrane [9]. The methodological quality of systematic reviews was evaluated by the AMSTAR 2 checklist [10].

Results

Table I summarises PICO questions about treatment, recommendations, certainty of evidence, and strength of recommendation of the CI procedure in children recipients.

Key Question 1. In a child (age ≤ 18 years) with bilateral profound congenital hearing loss and inadequate results with hearing aids (inadequate auditory and communicative-linguistic outcomes relative age, developmental level, and cognitive abilities) is cochlear implantation indicated before 12 months of age?

Every year 1-2 infants in 1,000 are found to have bilateral profound congenital hearing loss [11]. In the first months of life, they are in a condition of complete hearing and lan-

Table I. PICO questions about CI procedure in adult recipients.

	PICO	Recommendation	Certainty of evidence	Strength of recommendation
1	In a child (age ≤18 years) with bilateral profound congenital hearing loss and inadequate results with hearing aids (inadequate auditory and communicative-linguistic outcomes relative age, developmental level, and cognitive abilities) is cochlear implantation indicated before 12 months of age?	For children (age ≤ 18 years) with bilateral profound congenital hearing loss and inadequate results with hearing aids (inadequate auditory and communicative-linguistic outcomes with respect to age, developmental level, and cognitive abilities) the panel suggests cochlear implantation before 12 months of age	Very low	Conditional in favour of cochlear implantation before 12 months of age
2	In a child (age ≤ 18 years) with bilateral severe-profound hearing loss (PTA* 0.5-1-2-4 KHz ≥ 75 dB) and inadequate results with hearing aids (auditory and communicative-linguistic outcomes inadequate with respect to age, developmental level, and cognitive abilities) is bilateral cochlear implantation (simultaneous or sequential) indicated *versus* unilateral cochlear implantation?	For children (age ≤ 18 years) with bilateral severe-profound hearing loss (PTA* 0.5-1-2-4 KHz ≥ 75 dB) and inadequate results with hearing aids (auditory and communicative-linguistic outcomes inadequate with respect to age, developmental level, and cognitive abilities) the panel suggests bilateral simultaneous or sequential cochlear implantation	Very low	Conditional in favour of bilateral simultaneous or sequential cochlear implantation
3	In a child (age ≤ 18 years) with asymmetric hearing loss (worse ear with hearing loss severe-profound i.e. PTA* 0.5-1-2-4 KHz ≥ 75 dB, better ear with PTA*> 30 dB and < 75 dB and interaural difference PTA ≥ 30 dB) and poor performance/unsatisfactory results with hearing aids is cochlear implantation indicated in the worse ear?	For children (age ≤ 18 years) with asymmetrical hearing loss (worse ear with severe-profound hearing loss i.e., PTA* 0.5-1-2-4 KHz ≥ 75 dB, better ear with PTA* > 30 dB and < 75 dB and interaural difference PTA ≥ 30 dB) and poor performance/unsatisfactory results with hearing aids, the panel suggests cochlear implantation in the worse ear	Very low for desirable outcomes, low for undesirable outcomes	Conditional in favour of cochlear implantation in the worse ear
4	In a child (age ≤ 18 years) with severe-profound hearing loss in the worse ear (so-called Single Sided Deafness) and hearing threshold in the better ear PTA* ≤ 30 dB, is cochlear implantation in the worse ear indicated?	For children (age ≤ 18 years) with severe-profound hearing loss in the worse ear and hearing threshold in the best ear PTA* ≤ 30 dB, the panel suggests cochlear implantation in the worse ear	Very low for desirable outcomes, low for undesirable outcomes	Conditional in favour of cochlear implantation in the worse ear

GRADE Working Group grades of evidence:
***High certainty**: we are very confident that the true effect lies close to that of the estimate of the effect.*
***Moderate certainty:** we are moderately confident in the effect estimate: the true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different.*
***Low certainty:** our confidence in the effect estimate is limited: the true effect may be substantially different from the estimate of the effect.*
***Very low certainty:** we have very little confidence in the effect estimate: the true effect is likely to be substantially different from the estimate of effect.*

guage deprivation until they undergo surgery for cochlear implantation. For a normal hearing child, the first year of life represents a crucial period in which the neurobiological foundations necessary for later language development are laid [12]. In fact, verbal processing, although not evident, is already underway in terms of word segmentation, word-object correspondence, and the acquisition of the fundamentals of syntactic structure [13]. The profoundly deaf child, on the other hand, is in a condition of auditory deprivation that leads to the suspension of linguistic development. The auditory-verbal communication channel is not activated even by any conventional hearing implant as this acts on the inner ear which is non-functional in these cases. A cochlear implant, on the other hand, bypasses the cochlea by directly stimulating the cochlear nerve, which in cases of childhood hearing loss is intact and capable of conducting auditory information to cortical centres. Cochlear implantation before the age of 12 months may allow language development to begin closer to that of the hearing child of the same age.

Twelve studies, with a total of 465 children, were analysed [14-25]. Regarding receptive capacities, all but 2 of the studies that compared cochlear implantation before and after 12 months of age or at different chronological ages, reported results in favour of early implantation. Six studies compared the

receptive abilities of children implanted before and after 12 months with those of children with normal hearing. Five studies [14-16,21,24] reported that children who received cochlear implantation by 12 months of age developed receptive abilities similar to peers with normal hearing, whereas children implanted later develop the same hearing abilities but later than their normal hearing peers. One study [20] reported that all children had delayed development of receptive abilities compared to their normal hearing peers, but the delay was less for those implanted before 12 months of age.
Regarding expressive abilities, a single study with 39 participants evaluated outcomes at different follow-up times from insertion in children implanted before and after 12 months of age [14] and showed language development comparable to normal hearing peers in children who received implantation before 12 months of age compared to those implanted at later ages that deviated from the norm by 2 standard deviations. Out of 6 studies comparing implantation at different chronological ages, 5 showed results in favour of implantation before 12 months. Five studies compared the expressive abilities of children implanted before and after 12 months of age with those of normal hearing children. Four of these [14-16,21] reported language development trajectories similar to those of hearing peers in children implanted before 12 months, while those implanted later developed language with a delay that was maintained over the 3 years following surgery.
Three studies [15,18,22] compared the frequency of severe anaesthesiology complications and admission to the paediatric intensive care unit (ICU) in children implanted before and after the age of 12 months: no serious anaesthesiologic complications were observed; admission to the ICU appears to be slightly more frequent in children operated on before the age of 12 months, probably related to the strict anaesthesiologic surveillance protocols applied at this age.
Four studies [15,16,18,22] evaluated the frequency of undesirable effects. Skin complications appeared indifferently distributed between the two implant groups. The frequency of otitis media also appeared to be low and similar in the 2 groups.

Cost-effectiveness

No study evaluating cost-effectiveness of cochlear implantation in children with bilateral profound congenital hearing loss before 12 months of age was identified.

Recommendation: For children (age ≤ 18 years) with bilateral profound congenital hearing loss and inadequate results with hearing aids (inadequate auditory and communicative-linguistic outcomes with respect to age, developmental level, and cognitive abilities) the panel suggests cochlear implantation before 12 months of age.

Certainty of evidence: very low.

Strength of recommendation: conditional in favour of cochlear implantation before 12 months of age.

Subgroup considerations: the recommendation applies to the so-called "well babies": children with bilateral profound deafness in the absence of other comorbidities. In the case of children presenting with clinical pictures of complicated deafness, although cochlear implantation is generally considered useful for overall improvement of the quality of life of patients and their families, this recommendation is not considered applicable without due consideration and exceptions. It is left to the individual assessment of the team whether early implantation is appropriate in children with malformations or other associated comorbidities, in premature children, in syndromic children, and in children with neuromotor developmental delay, in whom the multidisciplinary team assesses the benefit of the intervention in terms of communicative functional prognosis versus possible anaesthetic and surgical risks.
In contrast, the panel believes that the condition of deafness resulting from bacterial meningitis with incipient cochlear ossification should be treated very quickly even before 12 months, if there are no anaesthetic contraindications.
Regarding the presence of associated disabilities, cochlear implant surgery is particularly recommended in cases of deaf-blindness, and it is likely that the benefit of the surgery will be even greater if performed at an early age.

Key Question 2. In a child (age ≤ 18 years) with bilateral severe-profound hearing loss (PTA 0.5-1-2-4 kHz ≥ 75 dB) and inadequate results with hearing aids (auditory and communicative-linguistic outcomes inadequate with respect to age, developmental level, and cognitive abilities) is bilateral cochlear implantation (simultaneous or sequential) indicated versus unilateral cochlear implantation?

Permanent hearing loss in childhood can have negative consequences that occur throughout the entire life span of an individual [26,27]. An appropriate intervention that restores, whenever possible, a binaural hearing, should therefore be considered crucial to ensure the positive development of auditory skills, language, cognitive, academic, and social-emotional-relational skills of the child, as well as to safeguard family balance and well-being [28,29].
For the assessment of desirable effects, 27 studies with 673 participants included in 3 systematic reviews [30-32] have been included. Another 12 more recent studies with a total of 569 participants have been considered [33-44].

The evidence for the benefit of bilateral versus unilateral implantation changes depending on the domain of competence tested, but overall appears to be in favour of the bilateral implant.
The ability to localise the sound source appeared to be better in children with bilateral implantation in as many as 8 of the 12 observational studies considered. In the case of sequential implantation, the magnitude of the benefit may be influenced by the time interval between the first and second implantation, which appeared to be better when the time interval was shorter. The benefit, sometimes not immediately measurable in the first few months after activation, may be observable over the long term.
Nine of 16 studies measuring speech perception in quiet detected a benefit from bilateral implantation.
Studies in which speech perception was investigated in the presence of competitive noise appeared to be apparently less concordant in reporting the benefit of bilateral implantation. Nine of 23 studies evaluating this outcome reported results in favour of bilateral cochlear implantation, although the benefit varied depending on the position in space of the noise source and the primary signal.
Regarding the benefits on language development and school learning, the studies included reported promising results. Although no differences were measurable in basic language skills, differences in favour of bilateral implantation emerged when an assessment was made on more complex verbal skills, such as meta-phonological and morphosyntactic skills or the ability to generate definitions and/or find relationships between 2 words. Such differences were already evident at preschool age and persisted into school age.
In the case of sequential cochlear implantation, better language skills seemed to be achieved when the interval between the 2 interventions was shorter and earlier between the first and second implantation.
The positive effects of bilateral implantation on language skills also seemed to have positive repercussions on school learning in terms of oral expression, writing and mathematical skills.
Subjective assessment of the functional benefits of bilateral implantation in daily life, carried out by the children's parents, supported the benefits shown by the clinical evidence: family members of children with sequential bilateral implantation reported a significant improvements in localisation ability, speech perception in quiet and noise, and sound quality after activation of the second cochlear implant.
For assessment of undesirable effects, 5 systematic reviews have been included [45-49]. All reviews analysed the risks associated with cochlear implant surgery per se, without analysing the possible increased risk due to the double intervention.
Regarding vestibular function, the 2 reviews that considered this outcome [47,48] reported variable results depending on the type of measurement used (vestibular myogenic evoked potentials [VEMPs], caloric testing, head impulse testing [HIT], rotatory testing, and posturography), while reporting no increase in symptoms indicative of vestibular problems.
In relation to the occurrence of dizziness following surgery, a low risk was observed in subjects under 9 years of age, with a frequency of the event of 1.5%. The risk increased with the increase of chronological age at surgery, reaching 4.2% in the 10-19 year age group [46].

Cost-effectiveness

Three studies [50-52] were identified that assessed cost-effectiveness of simultaneous or sequential bilateral cochlear implantation compared to unilateral cochlear implantation in children with bilateral severe-to-profound hearing loss and unsatisfactory outcomes with hearing aids. One study, conducted in the UK [50], reported that, assuming that the gain from bilateral cochlear implantation is the same for children and adults, the incremental cost-effectiveness ratio (ICER) of simultaneous and sequential bilateral implantation, when compared to monolateral implantation, was of £40,410 and £54,098 per quality-adjusted life year (QALY), respectively. Similarly, another study conducted in Spain [51], reported that the ICER of simultaneous *versus* unilateral implantation is €10,323/QALY when performed in 1-year-old profoundly deaf subjects. For sequential bilateral implantation, the ICER rises to €11,733/QALY. Both interventions were judged cost-effective in the Spanish study, where the willingness to pay of the health care system was estimated at approximately €30,000/QALY. The third study [52] reported a favourable cost-effectiveness ratio for bilateral versus unilateral implantation, even in developing countries.

Recommendation: For children (age ≤ 18 years) with bilateral severe-profound hearing loss (PTA 0.5-1-2-4 kHz ≥ 75 dB) and inadequate results with hearing aids (auditory and communicative-linguistic outcomes inadequate with respect to age, developmental level, and cognitive abilities) the panel suggests bilateral simultaneous or sequential cochlear implantation.

Certainty of evidence: very low.

Strength of recommendation: conditional in favour of bilateral simultaneous or sequential cochlear implantation.

Subgroup considerations: bilateral simultaneous or sequential cochlear implantation should be particularly applicable:

- to individuals at risk of developing cochlear ossification (e.g., post-meningitic deafness, deafness sudden or from autoimmune diseases at risk of ossification);
- to deaf-blind/deaf-visually impaired individuals;
- to patients with progressive forms of hearing loss (e.g., enlarged vestibular aqueduct, Cytomegalovirus [CMV] infection forms) which can lead over time to hearing loss in the better ear and thus to a loss of hearing that cannot be restored with traditional hearing aids.

For patients with auditory neuropathy, patients with a long-time interval between first and second implantation (≥ 6 years) and/or longer auditory deprivation (first implantation at the age > 3 years), patients with major middle and inner ear malformations, auditory nerve alterations, and/or associated otologic pathologies, bilateral cochlear implantation is still recommended although sometimes the benefits achieved may be less. In such cases, eligibility and possible benefits should be carefully evaluated by the multidisciplinary team in charge of the subject. Risks and possible limitations of benefits should be discussed extensively with the child's parents or legal guardians.

The recommendation applies to children with bilateral severe-profound deafness in the absence of other comorbidities. In cases of children with clinical pictures of complicated deafness, this recommendation is not considered applicable without due consideration and exceptions. In particular, children with neurodevelopmental outcomes of extreme prematurity and syndromic cases with neuropsychological disorders or motor disorders require a diagnostic and surgical approach that varies from case to case and are subject to a highly variable functional prognosis.

Key Question 3. In a child (age ≤ 18 years) with asymmetric hearing loss (worse ear with hearing loss severe-profound i.e., PTA 0.5-1-2-4 kHz ≥ 75 dB, better ear with PTA > 30 dB and < 75 dB and interaural difference PTA ≥ 30 dB) and poor performance/unsatisfactory results with hearing aids is cochlear implantation indicated in the worse ear?

Children with asymmetric hearing loss (AHL), which impair binaural hearing, are at risk of having significant difficulties with spatial listening and particularly in localising sounds, perceiving the distance of sound sources, understanding speech in noise, and analysing complex auditory scenes [53]. In the absence of appropriate and timely intervention to restore binaural hearing, such individuals are at risk of manifesting alterations in language acquisition over time [54], which, together with difficult perception in noise and subsequent hearing fatigue, impact negatively on their attentional, mnestic and school learning abilities [55].

In addition, some studies reported impairment in cognitive quotient and on quality of life [56].

For the assessment of desirable effects, only 5 case series with a total of 146 participants, and reported in 6 publications, were retrieved [54,57-61]. The only outcomes evaluated in more than one study and with acceptable numbers of participants were speech perception in quiet, assessed in 3 studies with 115 participants [58,59,61] and language development, assessed in 2 studies with 71 participants [54,61]. All the studies reported results in favour of cochlear implantation for both outcomes.

For the assessment of undesirable effects, the results of systematic reviews included for children with bilateral symmetric hearing loss also apply to children with asymmetric hearing loss.

Cost-effectiveness

No study evaluating cost-effectiveness of cochlear implantation in children with asymmetrical hearing loss was identified. The panel members judged that, since the cost-effectiveness in favour of the intervention has been demonstrated in the adults with this condition, and considering that in the child the disability situation is much more severe, it can be expected that the cost-effectiveness ratio in the paediatric patient is even more advantageous in favour of the intervention.

Recommendation: for children (age ≤ 18 years) with asymmetrical hearing loss (worse ear with severe-profound hearing loss i.e., PTA 0.5-1-2-4 kHz ≥ 75 dB, better ear with PTA > 30 dB and < 75 dB and interaural difference PTA ≥ 30 dB) and poor performance/unsatisfactory results with hearing aids, the panel suggests cochlear implantation in the worse ear.

Certainty of evidence: very low for desirable outcomes, low for undesirable outcomes.

Strength of recommendation: conditional in favour of cochlear implantation in the worst ear.

Subgroup considerations: the subgroup considerations suggested for children with bilateral severe to profound hearing loss are also valid for children with asymmetric hearing loss.

Key Question 4. In a child (age ≤ 18 years) with severe-profound hearing loss in the worse ear (single sided deafness, SSD) and hearing threshold in the better ear PTA ≤ 30 dB, is cochlear implantation in the worse ear indicated?

Single sided deafness (SSD) causes hearing difficulties in certain environmental conditions: the subject, especially in the presence of noise, cannot perceive speech from the side

of the deficit, cannot locate the source of the sound, and cannot identify who is speaking if they are in a group of people [62]. The child in the early years of life is exposed to speech in both direct and indirect ways, that is he or she listens to those who communicate to him or her directly, but also casually listens to all the conversations that take place between people near him or her (incidental listening). Overhearing seems to constitute about 80-90% of language exposure in this age range [63]. Consequently, a reduction in daily language exposure, which is the basis for regular language development and learning, may be the cause of a language disorder [64]. In addition, at school age, listening difficulties reflect negatively on the student's learning abilities and participation and attention behavior in the classroom. The critical age at which there is evidence of a decline in academic performance is from 12 to 18 years of age [65-67].
For the assessment of desirable effects, one systematic review [68] including 12 studies with a total of 119 participants was considered. For speech perception in quiet, the review reported an improvement in 81% of children (6 studies, 42 participants). Similarly, the review reported a benefit in 79.6% of children for speech perception in noise (8 studies, 49 participants). In terms of sound localisation ability, 3 studies with 19 participants reported an average reduction in localisation error of 28°, while 3 studies reported a general improvement in 88.7% of children. Finally, improvement on all sub-scales of the Speech, Spatial, Qualities (SSQ) questionnaire after CI was reported in both children with congenital (3 studies, 32 participants) and acquired (2 studies, 26 participants) hearing loss.
For the assessment of undesirable effects, the results of the systematic reviews included for children with bilateral symmetric hearing loss also apply to children with SSD.

Cost-effectiveness

No study evaluating cost-effectiveness of cochlear implantation in children with SDD have been identified. The panel members judged that, since the cost-effectiveness in favour of the intervention has been demonstrated in the adults with this condition, and considering that in the child the disability situation is much more severe, it can be expected that the cost-effectiveness ratio in the paediatric is even more advantageous in favour of the intervention.

Recommendation: for children (age ≤ 18 years) with severe-profound hearing loss in the worse ear (so-called SSD) and hearing threshold in the best ear PTA ≤ 30 dB, the panel suggests cochlear implantation in the worse ear.

Certainty of evidence: very low for desirable outcomes, low for undesirable outcomes.

Strength of recommendation: conditional in favour of cochlear implantation in the worse ear.

Subgroup considerations: the recommendation applies to children with SSD in the absence of other comorbidities. In cases of children with clinical pictures of complicated deafness, this recommendation is not considered applicable without due consideration and exceptions. In particular, children with neurodevelopmental outcomes of extreme prematurity, syndromic cases with neuropsychological disorders or motor disorders require a diagnostic and surgical approach that varies from case to case and are subject to a highly variable functional prognosis.
Given that up to 50% of individuals with SSD have an anatomical malformation such as a hypoplasia/aplasia of the cochlear nerve and that such a malformation is associated with poor cochlear implantation efficacy, a comprehensive evaluation by an expert team including an MRI study of the inner ear and cochlear nerve is required before proceeding. The panel believes that cochlear implantation is not indicated in cases of cochlear nerve hypoplasia/aplasia.
Conversely, the panel believes that the deaf condition resulting from bacterial meningitis with incipient cochlear ossification should be treated very early if there are no anaesthetic contraindications.
In addition, cochlear implantation in a child with SSD is particularly indicated in forms of progressive hearing loss where there is a risk of threshold worsening in the healthy ear (e.g., congenital CMV infection).

Equity, feasibility and acceptability of cochlear implantation

The panel judged that cochlear implantation has probably no impact on equity as adequate care is fairly guaranteed throughout Italy, that it is overall well accepted, although parents' worries about complications of surgical intervention may be a concern in some cases, and that there are no issues of feasibility.

Implementation considerations

For all 4 questions the panel indicates that the centre performing the procedure has a multidisciplinary team (audiologist, otolaryngologist, otosurgeon, audiometrist, speech pathologist, radiologist, neuropsychiatrist child/developmental age psychologist, hearing aid specialist) experienced in diagnosing childhood deafness. In particular for Key Question 1 it is indicated that the multidisciplinary team has experience in diagnosing childhood deafness in the first months of life.
It is indicated that at least one pre-cochlear implant audiological assessment be carried out: auditory evoked poten-

tials; impedance testing; evoked acoustic otoemissions; assessment of audiometric threshold and hearing aids benefit by method appropriate to the child's age and/or cognitive functioning (VRA, CPA or classical tonal audiometric examination); assessment of perceptual skills and functional listening by direct observation by the clinician and through administration of validated questionnaires to caregivers; and administration of perception tests when the child's age and verbal skills allow. Audiological assessment should be coupled with the administration of standardised tests to assess the development of communication and language skills and of cognitive functioning.

The evaluation should be complemented by aetiological research and CT/MRI evaluation, to investigate the anatomical status of the cochlea and vestibulocochlear nerve to highlight alterations that may compromise the success of the surgery and the achievement of functional auditory outcomes.

Postoperatively, children should be followed up by an appropriate team at the CI centre and have access to the rehabilitation services needed to optimise the process of achieving the expected outcomes according to the child's level of cognitive functioning, medical history, duration of hearing deprivation and presence or absence of pathologies associated with the hearing loss.

Only for Key Question 1, given the young age of the children (< 12 months), the panel indicates that the centre performing the procedure should have a paediatric anesthesiology team or with proven experience with paediatric patients, possibly with the availability of a paediatric ICU and a surgical team with proven experience in paediatric surgery.

Discussion and conclusions

The systematic research of the available scientific literature found the paucity of randomised trials and an overall poor quality of conduct and reporting of both primary studies and systematic reviews. However, in this field, uncontrolled case series with evaluation of outcomes before and after implantation may provide acceptable evidence given the stable and chronic nature of the condition, further studies should enrol a larger number of participants and use consistent instruments and scales to evaluate hearing outcomes, in order to increase comparability of the results across the studies and pool data through meta-analysis.

Acknowledgements

The authors thank Marta Monteforte, Veronica Andrea Fittipaldo, Marien Gonzalez Lorenzo (Oncology Department, Istituto di Ricerche Farmacologiche Mario Negri) for the methodological support.

Conflict of interest statement

MM: research grants (to Institution) from Cochlear srl; DZ: registration fees for scientific conferences and reimbursement of travel or living expenses. Co-funding to Fondazione IRCCS Cà Granda Ospedale Maggiore Policlinico di Milano for scholarship for the purpose of supporting research. Medel Italia, Cochlear Italia, Amplifon, Audionova, Audiomedica, Fonema. The other authors declare no conflict of interest.

Funding

Funding for this study was provided by the AOOI (Associazione Otorinolaringoiatri Ospedalieri Italiani) Foundation.

Author contributions

SG, PM, DZ, PT, FA, CB, MN, SF, GG, EM, GC, MM, DC, UB, FF: formed the Panel Group. The authors equally contributed to the critical appraisal of the evidence and the formulation of recommendations; SG, FF, PT, MN: wrote the draft of the manuscript, all the authors critically revised and gave important intellectual content and final approval of the version to be published; SM, MC: chaired the method group: they performed the systematic review of literature and guided the panel to develop the statements.

Ethical consideration

Not applicable.

References

1 https://www.iss.it/web/guest/-/impianto-cocleare-adulto-bambino. Accessed April 17, 2024.

2 Guyatt GH, Oxman AD, Vist GE, et al. GRADE Working Group. GRADE: an emerging consensus on rating quality of evidence and strength of recommendations. BMJ 2008;336:924-926. https://doi.org/10.1136/bmj.39489.470347.AD

3 Berrettini S, Baggiani A, Bruschini L, et al. Systematic review of the literature on the clinical effectiveness of the cochlear implant procedure in adult patients. Acta Otorhinolaryngol Ital 2011;31:299-310.

4 FDA, US Food and Drug Administration (2022). Cochlear implants. 26 ottobre 2023. https://www.fda.gov/medical-devices/implants-and-prosthetics/cochlear-implants. Accessed April 17, 2024

5 Quaranta A, Arslan E, Burdo S, et al. Documento del Gruppo S.I.O. Impianti cocleari: linee guida per l'applicazione dell'impianto cocleare e la gestione del centro impianti cocleari. Acta Otorhinolaryngol Ital 2009;3:1-5.

6 Berrettini S, Arslan E, Baggiani A, et al. Analysis of the impact of professional involvement in evidence generation for the HTA Process,

subproject “cochlear implants”: methodology, results and recommendations. Acta Otorhinolaryngol Ital 2011;31:273-280.

[7] CNEC - Centro Nazionale per l’Eccellenza delle Cure Manuale metodologico per la produzione di linee guida di pratica clinica, Roma: ISS - Istituto Superiore di Sanità; 2023. Available at https://www.iss.it/documents/20126/7949265/Manuale+Metodologico+-+marzo+2023.pdf/01f4bc8e-f3e6-66ec-bbe1-e80186908c6c?t=1679921943422 Accessed April 17, 2024.

[8] GRADEpro gdt [Computer program] mcmaster university (developed by evidence prime) GRADEpro gdt, Hamilton (ON): McMaster University; 2021. Version accessed 25 March 2024 developed by Evidence Prime. https://www.gradepro.org

[9] Higgins JPT, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 [updated March 2011]. The Cochrane Collaboration, 2011. Available from www.handbook.cochrane.org. Accessed April 17, 2024

[10] Shea BJ, Reeves BC, Wells G, et al. AMSTAR 2: a critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. BMJ 2017;358:j4008. https://doi.org/10.1136/bmj. j4008

[11] Mitchell R, Karchmer M. Chasing the mythical ten percent: parental hearing status of deaf and hard of hearing students in the United States. Sign Language Studies 2004;4:138-163.

[12] Houston DM, Stewart J, Moberly A, et al. Word learning in deaf children with cochlear implants: effects of early auditory experience. Dev Sci 2012;15:448-461. https://doi.org/10.1111/j.1467-7687.2012.01140.x

[13] Levine D, Strother-Garcia K, Michnick Golinkoff R, et al. Language development in the first year of life: what deaf children might be missing before cochlear implantation. Otol Neurotol 2016;37:E56-E62. https://doi.org/10.1097/MAO.0000000000000908

[14] Ching TY, Dillon H, Day J, et al. Early language outcomes of children with cochlear implants: interim findings of the NAL study on longitudinal outcomes of children with hearing impairment. Cochlear Implants Int 2009;10(Suppl 1):28-32. https://doi.org/10.1179/cim.2009.10

[15] Colletti L, Mandalà M, Colletti V. Cochlear implants in children younger than 6 months. Otolaryngol Head Neck Surg 2012;147:139-146. https://doi.org/10.1177/0194599812441572

[16] Dettman SJ, Pinder D, Briggs RJ, et al. Communication development in children who receive the cochlear implant younger than 12 months: risks versus benefits. Ear Hear 2007;28(Suppl 2):11S-18S. https://doi.org/10.1097/AUD.0b013e31803153f8

[17] Guo Q, Lyu J, Kong Y, et al. The development of auditory performance and speech perception in CI children after long-period follow up. Am J Otolaryngol 2020;41:102466. https://doi.org/10.1016/j.amjoto.2020.102466

[18] Hoff S, Ryan M, Thomas D, et al. Safety and effectiveness of cochlear implantation of young children, including those with complicating conditions. Otol Neurotol 2019;40:454-463. https://doi.org/10.1097/MAO.0000000000002156

[19] Holman MA, Carlson ML, Driscoll CL, et al. Cochlear implantation in children 12 months of age and younger. Otol Neurotol 2013;34:251-258. https://doi.org/10.1097/mao.0b013e31827d0922

[20] Holt RF, Svirsky MA. An exploratory look at pediatric cochlear implantation: is earliest always best? Ear Hear 2008;29:492-511. https://doi.org/10.1097/AUD.0b013e31816c409f

[21] Leigh J, Dettman S, Dowell R, et al. Communication development in children who receive a cochlear implant by 12 months of age. Otol Neurotol 2013;34:443-450. https://doi.org/10.1097/MAO.0b013e3182814d2c

[22] Lesinski-Schiedat A, Illg A, Heermann R, et al. Paediatric cochlear implantation in the first and in the second year of life: a comparative study. Cochlear Implants Int 2004;5:146-159. https://doi.org/10.1179/cim.2004.5.4.146

[23] Mitchell RM, Christianson E, Ramirez R, et al. Auditory comprehension outcomes in children who receive a cochlear implant before 12 months of age. Laryngoscope 2020;130:776-781. https://doi.org/10.1002/lary.28061

[24] Oziębło D, Obrycka A, Lorens A, et al. Cochlear implantation outcome in children with DFNB1 locus pathogenic variants. J Clin Med 2020;9:228. https://doi.org/10.3390/jcm9010228

[25] Tajudeen BA, Waltzman SB, Jethanamest D, et al. Speech perception in congenitally deaf children receiving cochlear implants in the first year of life. Otol Neurotol 2010;31:1254-1260. https:doi.org/10.1097/MAO.0b013e3181f2f475

[26] Jackson CW, Wegner JR, Turnbull AP. Family quality of life following early identification of deafness. Lang Speech Hear Serv Sch 2010;41:194-205. https://doi.org/10.1044/0161-1461(2009/07-0093)

[27] Lieu JEC, Kenna M, Anne S, et al. Hearing loss in children: a review. JAMA 2020;324:2195-2205. https://doi.org/10.1001/jama.2020.17647

[28] Ching TYC, Dillon H, Leigh G, et al. Learning from the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study: summary of 5-year findings and implications. Int J Audiol 2018;57(Suppl 2): S105-S111. https://doi.org/10.1080/14992027.2017.1385865

[29] Molla M, Asha N, Kamrujjaman M. Parents perceived quality of life for children with cochlearimplants. Int J Otolaryngol Head Neck Surg 2019;8:13-24. https://doi.org/10.4236/ijohns.2019.81003

[30] Lammers MJ, van der Heijden GJ, Pourier VE, et al. Bilateral cochlear implantation in children: a systematic review and best-evidence synthesis. Laryngoscope 2014;124:1694-1699. https://doi.org/10.1002/lary.24582

[31] Sparreboom M, van Schoonhoven J, van Zanten BG, et al. The effectiveness of bilateral cochlear implants for severe-to-profound deafness in children: a systematic review. Otol Neurotol 2010;31:1062-1071. https://doi.org/10.1097/MAO.0b013e3181e3d62c

[32] Forli F, Arslan E, Bellelli S, et al. Systematic review of the literature on the clinical effectiveness of the cochlear implant procedure in paediatric patients. Acta Otorhinolaryngol Ital 2011;31:281-298.

[33] Almeida GFL, Martins MF, Costa LBAD, et al. Sequential bilateral cochlear implant: results in children and adolescents. Braz J Otorhinolaryngol 2019;85:774-779. https://doi.org/10.1016/j.bjorl.2018.07.008

[34] Asp F, Mäki-Torkko E, Karltorp E, et al. A longitudinal study of the bilateral benefit in children with bilateral cochlear implants. Int J Audiol 2015;54:77-88. https://doi.org/10.3109/14992027.2014.973536

[35] Baron S, Blanchard M, Parodi M, et al. Sequential bilateral cochlear implants in children and adolescents: outcomes and prognostic factors. Eur Ann Otorhinolaryngol Head Neck Dis 2019;136:69-73. https://doi.org/10.1016/j.anorl.2018.09.004

[36] Bianchin G, Tribi L, Formigoni P, et al. Sequential pediatric bilateral cochlear implantation: the effect of time interval between implants. Int J Pediatr Otorhinolaryngol 2017;102:10-14. https://doi.org/10.1016/j.ijporl.2017.08.025

[37] Cullington HE, Bele D, Brinton JC, et al. United Kingdom national paediatric bilateral project: results of professional rating scales and parent questionnaires. Cochlear Implants Int 2017;18:23-35. https://doi.org/10.1080/14670100.2016.1265189

[38] Forli F, Bruschini L, Franciosi B, et al. Sequential bilateral cochlear implant: long-term speech perception results in children first implanted at an early age. Eur Arch Otorhinolaryngol 2023;280:1073-1080. https://doi.org/10.1007/s00405-022-07568-4

[39] Galvin KL, Dowell RC, van Hoesel RJ, et al. Speech detection in noise for young bilaterally implanted children: is there evidence of binaural

benefit over the shadowed ear alone? Ear Hear 2017;38:E325-E334. https://doi.org/10.1097/AUD.0000000000000442

40 Reeder RM, Firszt JB, Cadieux JH, et al. A Longitudinal Study in children with sequential bilateral cochlear implants: time course for the second implanted ear and bilateral performance. J Speech Lang Hear Res 2017;60:276-287. https://doi.org/10.1044/2016_JSLHR-H-16-0175

41 Sturm JJ, Kuhlmey M, Alexiades G, et al. Comparison of speech performance in bimodal versus bilateral cochlear implant users. Laryngoscope 2021;131:E1322-E1327. https://doi.org/10.1002/lary.29062

42 Yıldırım Gökay N, Yücel E. Bilateral cochlear implantation: an assessment of language sub-skills and phoneme recognition in school-aged children. Eur Arch Otorhinolaryngol 2021;278:2093-2100. https://doi.org/10.1007/s00405-020-06493-8

43 Sarant J, Harris D, Bennet L, et al. Bilateral versus unilateral cochlear implants in children: a study of spoken language outcomes. Ear Hear 2014;35:396-409. https://doi.org/10.1097/AUD.0000000000000022

44 Sarant JZ, Harris DC, Bennet LA. Academic outcomes for school-aged children with severe-profound hearing loss and early unilateral and bilateral cochlear implants. J Speech Lang Hear Res 2015;58:1017-1032. https://doi.org/10.1044/2015_JSLHR-H-14-0075

45 Ekman B, Laureano J, Balasuriya B, et al. Comparison of adult and pediatric cochlear implant wound complications: a meta-analysis. Laryngoscope 2023;133:218-226. https://doi.org/10.1002/lary.30168

46 Hänsel T, Gauger U, Bernhard N, et al. Meta-analysis of subjective complaints of vertigo and vestibular tests after cochlear implantation. Laryngoscope 2018;128:2110-2123. https://doi.org/10.1002/lary.27071

47 Yong M, Young E, Lea J, et al. Subjective and objective vestibular changes that occur following paediatric cochlear implantation: systematic review and meta-analysis. J Otolaryngol Head Neck Surg 2019;48:22. https://doi.org/10.1186/s40463-019-0341-z

48 Gerdsen M, Jorissen C, Pustjens DCF, et al. Effect of cochlear implantation on vestibular function in children: a scoping review. Front Pediatr 2022;10:949730. https://doi.org/10.3389/fped.2022.949730

49 Pakdaman MN, Herrmann BS, Curtin HD, et al. Cochlear implantation in children with anomalous cochleovestibular anatomy: a systematic review. Otolaryngol Head Neck Surg 2012;146:180-190. https://doi.org/10.1177/0194599811429244

50 Bond M, Mealing S, Anderson R, et al. The effectiveness and cost-effectiveness of cochlear implants for severe to profound deafness in children and adults: a systematic review and economic model. Health Technol Assess 2009;13:1-330. https://doi.org/10.3310/hta13440

51 Pérez-Martín J, Artaso MA, Díez FJ. Cost-effectiveness of pediatric bilateral cochlear implantation in Spain. Laryngoscope 2017;127:2866-2872. https://doi.org/10.1002/lary.26765

52 Swami H, Ap A, Shivanand S. Cost-effectiveness of pediatric unilateral/bilateral cochlear implant in a developing country. Otol Neurotol 2021;42:E33-E39. https://doi.org/10.1097/MAO.0000000000002862

53 Thompson NJ, Brown KD, Dillon MT. Cochlear implantation for paediatric and adult cases of unilateral and asymmetric hearing loss. Curr Opin Otolaryngol Head Neck Surg 2022;30:303-308.https://doi.org/10.1097/MOO.0000000000000838

54 Malhotra PS, Densky J, Melachuri M, et al. The impact of cochlear implantation on speech and language outcomes in children with asymmetric sensorineural hearing loss. Int J Pediatr Otorhinolaryngol 2022;152:110979. https://doi.org/10.1016/j.ijporl.2021.110979

55 Schmithorst VJ, Plante E, Holland S. Unilateral deafness in children affects development of multi-modal modulation and default mode networks. Front Hum Neurosci 2014;8:164. https://doi.org/10.3389/fnhum.2014.00164

56 Purcell PL, Shinn JR, Davis GE, et al. Children with unilateral hearing loss may have lower intelligence quotient scores: a meta-analysis. Laryngoscope 2016;126:746-754. https://doi.org/10.1002/lary.25524

57 Cadieux JH, Firszt JB, Reeder RM. Cochlear implantation in nontraditional candidates: preliminary results in adolescents with asymmetric hearing loss. Otol Neurotol 2013;34:408-415. https://doi.org/10.1097/MAO.0b013e31827850b8

58 Gratacap M, Thierry B, Rouillon I, et al. Pediatric cochlear implantation in residual hearing candidates. Ann Otol Rhinol Laryngol 2015;124:443-451. https://doi.org/10.1177/0003489414566121

59 Perkins EL, Nguyen M, Woodard J, et al. Treating the individual ear in children: results of cochlear implantation in children with asymmetric sensory hearing loss. Otol Neurotol 2020;41:E700-E770. https://doi.org/10.1097/MAO.0000000000002661

60 Sadadcharam M, Warner L, Henderson L, et al. Unilateral cochlear implantation in children with a potentially useable contralateral ear. Cochlear Implants Int 2016;17(Suppl 1):55-58. https://doi.org/10.1080/14670100.2016.1155832

61 Schaefer SM, de Kruijf M, Henderson L, et al. Improved speech and language development after unilateral cochlear implantation in children with a potentially useable contralateral ear. Cochlear Implants Int 2019;20:39-46. https://doi.org/10.1080/14670100.2018.1536408

62 Welsh LW, Welsh JJ, Rosen LF, et al. Functional impairments due to unilateral deafness. Ann Otol Rhinol Laryngol 2004;113:987-993. https://doi.org/10.1177/000348940411301209

63 Foushee R, Xu F. Active overhearing: development in preschoolers' skill at 'listening in' to naturalistic overheard speech. Cognitive science 2016. https://api.semanticscholar.org/CorpusID:2353545 Accessed 17 April 2024.

64 Litovsky R. Development of the auditory system. Handb Clin Neurol 2015:129:55-72. https://doi.org/10.1016/B978-0-444-62630-1.00003-2

65 Lieu JE. Speech-language and educational consequences of unilateral hearing loss in children. Arch Otolaryngol Head Neck Surg 2004;130:524-530. https://doi.org/10.1001/archotol.130.5.524

66 Lieu JE. Unilateral hearing loss in children: speech-language and school performance. B-ENT 2013;(Suppl 21):107-115.

67 Lieu JEC. Permanent Unilateral Hearing Loss (UHL) and childhood development. Curr Otorhinolaryngol Rep 2018;6:74-81. https://doi.org/10.1007/s40136-018-0185-5

68 Benchetrit L, Ronner EA, Anne S, et al. Cochlear implantation in children with single-sided deafness: a systematic review and meta-analysis. JAMA Otolaryngol Head Neck Surg 2021;147:58-69. https://doi.org/10.1001/jamaoto.2020.3852