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CHILDREN THEN, ADULTS NOW: LONG-TERM OUTCOMES - PERFORMANCE AT 15, 20, AND 25 YEARS OF COCHLEAR IMPLANT USE

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1. Introduction: Since the 1990s, with the approval of cochlear implantation in children over 2 years of age by the Food and Drug Administration (FDA), the number of children who use cochlear implants (CIs) has been increasing. This fact, in parallel with the scenario of the expansion of the indication criteria for cochlear implantation in the pediatric population, the technological development in CI manufacturing, and assessment processes, has allowed the development of several research studies and clinical studies that seek to evaluate the results provided by cochlear implantation and explore the different variables that influence these results (1–6). There is also increasing scientific evidence of the influence of age at implantation on better speech, language and academic performances, influenced by brain plasticity, which has its critical acquisition period up to 4 years of age (7–9). The results obtained in the study published by Grandon et al. (10) show that (1) children with CIs have lower intelligibility, (2) early implantation is a predictor of good intelligibility, and (3) late implantation after two years of age does not prevent the children from eventually reaching good intelligibility (10). In 2000, the FDA approved cochlear implantation in children aged 12 months and older (11) and, in 2020, the FDA changed the minimum age for bilateral cochlear implantation to 9 months of age, using specific cochlear implant equipment, in children with bilateral profound sensorineural deafness (12). Follow-up studies of children after long periods of CI use become essential to inform professionals and families, both regarding therapy and expectations, as well as to better understand the factors involved in the process of developing the communicative, academic, and occupational skills of children who grew up using CIs (6, 13, 14). In their study from 2023, Gordon et al. confirm the importance of providing hearing through CIs early in development. The study also reveals the need for ongoing reporting of long-term effects of CIs in children given the remaining statistical uncertainties and the evolution of CI technology and candidacy (15). Waltzman et al. (16) presented a study with results that reveal significant gains in speech perception, use of oral language, and ability to function in a mainstream environment. In the same study, there was no decrease in performance over time and no significant incidence of device or electrode migration or extrusion, and device failure did not cause a deterioration in long-term outcome (16). Some studies report that speech and language results remain stable in patients with more than 10 years of CI use (17, 18), or even up to 15 years (19). These authors also present data on the academic degree achieved by the patients who use CI, showing better results associated with early intervention. Geers et al. studied a group of teenagers who exhibited long-term benefits from cochlear implantation that extended into their high school years. Increases in performance were observed between elementary and high school students for the students who attended mainstream classrooms and for students using primarily spoken

language. Most of the teenagers were placed at an age-appropriate grade level in high school (20). Beadle et al. (21) presented results suggesting that cochlear implantation provides long-term communication benefits to patients that do not plateau for some subjects even after reimplantation. The results further indicate that cochlear implant centers should create the structure and funding to provide long-term support, counseling, audiologic follow-up, rehabilitation, and device monitoring to every implanted child (21). In the study published by Angelika et al. (22), which presents data from implanted subjects with up to 17.75 years post implant (SD = 3.08; range 13–28), it was demonstrated that the majority of participants who underwent implantation at an early age achieved discrimination of speech sounds without lipreading. Educational, vocational, and occupational levels achieved by this cohort were significantly poorer compared with the German and worldwide population average. Children implanted today who are younger at implantation, and with whom more advanced up-to-date CIs are used, are expected to exhibit better auditory performance, and have enhanced educational and occupational opportunities (22). In their study, Punch and Hyde (23) mention that the use of telephones, and in particular mobile/cell phones, plays a key role in the social lives of many of these patients, being an integral part of their relationships with friends. Their findings indicate that many children and adolescents, even when they had been using cochlear implants since their first or second year of life, had difficulties using a telephone. Parents reported that their children would use the telephone with people they knew well, but struggled to converse, and lacked confidence, with people they were less familiar with. For older adolescents, this could also be relevant for employment situations (23).

Pediatric cochlear implants program of the ENT Service at CHUC Since the beginning of the pediatric cochlear implant program in the Otolaryngology Department of the (then) Centro Hospitalar de Coimbra, in 1992, the intervention through a multidisciplinary team, the early and timely process of cochlear implantation, and the intensive (re)habilitation were preponderant aspects for the program implementation. Regarding the team, it consisted of several otorhinolaryngologists with experience in ear surgery, special education teachers (later replaced by speech and language therapists), and audiologists, and there was a close collaboration with computer engineers, imaging doctors, neurodevelopment pediatricians, among other specialties. For early identification and intervention, and since the Service is also the Audio-phonology Center of the Central Region of the country, a network was created for referring patients by general practitioners, schools, and other ENT Departments, which allowed patients to arrive at CHUC at earlier ages. The implementation of this rehabilitation method motivated the team to create an intervention program that involved intensive training with the child staying in the department for an average period of 3 months, during which the programming of the speech processor was carefully conducted, and intensive sessions were carried out to maximize the auditory, language, and speech development. After those average first 3 months of intervention, a first assessment was carried out and the patient returned to his area of residence, where he/she would have speech therapy and special education. Then, the patient would return to the center for new assessments at 6, 9, 12, 18, and 24 months after the activation of the speech processor. After 24 months, and depending on the need for new patient assessments, they would return to the center once a year, at 3, 4, 5, …, 15, 20, and 25 years after the activation of the speech processor. Whenever it was necessary for patients to come in other moments or stay for longer periods of time for intensive sessions, the patient's situation was studied individually so that the best response to the situation could be arranged. This approach to the post CI (re) habilitation process has remained similar over time, although keeping up with the advances in technology and intervention approaches.

2. Methods: The study is an exploratory retrospective, in which the performance of the patients in the sample was compared at 15, 20, and 25 years of cochlear implant use, with the patients having been divided into two groups: Group 1 with implant age equal to or less than 36 months, and Group 2 aged over 36 months when implanted. The following assessment instruments were used: Monosyllables, Numbers, and Sentences Tests (24), Sentences on the telephone test, Common words test, Common words on the telephone test, minimal Pair Discrimination test (25), and Consonant test (26). In addition, data were collected regarding the academic level of each participant. The patients were asked to listen and repeat each of the tests' stimuli. The tests were presented in a soundproof room with the patient sitting one meter away. The number of correct answers was retained, and the percentage of correct answers was obtained dividing it by the number of stimuli integrating the test. Through the assessments, the following questions were examined:
Q1: Is there a positive effect of early cochlear implantation on the auditory performance of children (now adults) who use cochlear implants?
Q2: Is there performance improvement even after 10 years of cochlear implant use?
Q3: Is there an effect of early implantation on telephone use performance?
Q4: If there is a positive effect of early cochlear implantation on auditory performance, is that effect similar for all assessed skills?
3. Results: The results show that there is a positive effect, with statistical significance, of early implantation on auditory performance, and telephone use. In both groups, there is an increase in performance over time, but it tends to stabilize after 20 years of CI use.
4 Discussion: The results obtained in this work support the
importance of early intervention in patients with severe to profound hearing loss
who are cochlear implant users and show that CI is an effective and reliable
method in the treatment of these patients, contributing to their improved socio-educational integration, and that the benefits last over time.
5. Conclusion: The results obtained support the hypothesis that the cochlear implant is an effective method in the treatment of severe to profound hearing loss and that the results obtained are positively influenced by early intervention. The results also show that there may be performance improvement after long years of use and that the follow-up and support of these patients is reflected in their success.
Ethics statement: The studies involving humans were approved by Comissão de Ética para a Saúde do Centro Hospitalar Universitário de Coimbra—the Ethics Committee for Health of the CHUC. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the
participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable data included in this article.