ISSN-E: 18735347-02779536

Bilateral cochlear implantation Simultaneous or Sequential

Case report

Dr.Mariam M. Alkandari , Consultant Audiovestibular physician, head of Audiology and Speech Center, Sabah Health Region, Zain Hospital, Sheikh Salem Al Ali Center For Speech and hearing Therapy MD; Prem N Sharma, PhD, Faculty of Medicine, Kuwait., AuD. Fahad Y. Almethen, Chief Audiologist and Speech-Language pathologist, Sabah Region, Zain Hospital. Sheikh Salem Al Ali Center for Speech and Hearing Therapy

ISSN-E: 18735347-02779536

Abstract

Long interval duration of bilateral cochlear implantation showed poor results in the second implanted compared to the first implanted ears which were at a younger age in our five operated cases , and that was in terms of speech discrimination score comparison. As regard hearing threshold level, there were almost similar bilateral results although, the second delayed implantation duration ranged between minimum of 5years9months up to maximum of 8years. Speech discrimination score on the second delayed implanted ear were poor, ranging between 0-15% only, compared to the much better results on the first implanted ear, which ranged between 76%-90%. Therefore, the results of these cases raises the question whether to have a simultaneous bilateral cochlear implantation or sequential one; and if the sequential operation is to be decided for any reason, medical for example or some family issues. Then, how much time we need to wait for the second implantation, in order to have the good benefit from the bilateral implantation.

Key word

Hearing loss, Bilateral Cochlear implant, Simultaneous, Sequential, Hearing threshold level, Speech discrimination score.

الملخص:

تبين ان إطالة الفترة الزمنية لإجراء عملية زراعة القوقعة على الأذن الأخرى لها أثر عكسى سئ وذلك مقارنة بالأذن الأولى والتي تم إجراء العملية ذاتها عند عمر أصغر بدراسة عدد من الحالات, وبالأخص أثرها الغير جيد على نسبة ذكاء و تمييز الكلام. اما فيما يخص مستوى السمع باستخدام جهاز القوقعة كانت النتائج جيدة وذلك بعد برمجة الجهاز الخارجي. علما بأن فرق المدة الزمنية ما بين عملية الأذنين كانت تتراوح ما بين الخمس إلى الثماني سنوات. نتائج ذكاء ونسبة تمييز الكلام بالأذن التى تم زرعها بعد الأذن الأولى يفارق زمنى متباعد كانت ما بين ٥-١٥% فقط مقارنة بالأذن الأولى التي تم زرعها في عمر أصغر والتي تراوحت بين ٧٦-٩٠%.
هذه النتائج أثارت جدلا كبيرا باختيار توقيت زرع الأذنين , هل يجب أن تكون بنفس الجلسة معا أو على مراحل. وإن كانت على مراحل فكم المدة الزمنية المطلوبة عدم تجاوزها حتى يتم الحصول على أفضل استفادة من عملية زراعة الأذنين دون أن يكون أي تأخير بينهما.

الكلمات المفتاحية:

ضعف سمع \ زراعة القوقعة للأذنين في نفس الجلسة أو على مراحل \ مستوى السمع باستخدام الجهاز \ نسبة وذكاء الكلام باستخدام الجهاز

Introduction & background

One of the leading causes of adult disability-adjusted life years is sensorineural hearing loss (SNHL). Loss of hearing of this kind tends to get worse as people get older. The World Health Organisation reports that 466 million individuals over the age of 65 suffered from hearing loss in 2018, making it one of the leading causes of disability on a global scale. Not only does hearing loss place a heavy burden on patients and society at large, but there is evidence that it may also raise the risk of a number of other health issues, such as depression. One of the most noticeable consequences of hearing loss is trouble communicating, which can lead to feelings of loneliness and frustration and, in the long run, worse mental health. Managing individuals with hearing loss can greatly affect their quality of life because there is evidence that it is associated with cognitive decline in the elderly(Idstad ET AL.,2019). Since there is no known treatment that can undo pathological damage at the cochlear level, prevention and rehabilitation are the primary goals of management. Patients with severe to profound sensorineural hearing loss are not likely to benefit from hearing aids, even though they are the initial line of treatment for hearing loss. The best course of action in such cases is to have a cochlear implant (CI)(Panza ET AL.,2019).

An electrode array is put into the damaged cochlea of a cochlear implant (CI), which is a surgically implanted device that covers the temporal bone and lies beneath the skin. They can carry electrical impulses directly to the spiral ganglion neurons and the auditory nerve, replacing the function of hair cells, which are unable to do so anymore; this makes them a possible substitute for hearing aids. Candidates for cochlear implant surgery were originally limited to those with severe bilateral deafness; however, as processing strategies and technology for cochlear implants evolved, the criteria for both adult and paediatric candidates was broadened to include a variety of indications (Carlson,2020).

For people with severe to profound bilateral sensorineural hearing loss, the initial treatment often involves the use of unilateral cochlear implants (CI). While research has shown that individuals who wear unilateral CIs have better auditory outcomes and speech perception, users of these devices often struggle to hear sounds coming from their nonimplanted ear and have difficulty understanding speech in noisy environments. The National Institute for Health and Clinical Excellence (NICE) also recommends avoiding bilateral cochlear implantation (BiCI) in adults unless there are additional impairments that primarily affect their ability to perceive their surroundings through hearing. Also, not enough evidence about the social benefits has led several healthcare systems to restrict the provision of second CIs to adults (Connors ET AL.,2021).

However, at this time, individuals are able to embrace bilateral cochlear implantation as a viable option for hearing restoration. Sequential BiCI is one of two surgical options for bilateral CIs; in this approach, both ears undergo the procedure at different periods, which can be months or even years apart. In contrast, with simultaneous BiCI, both implants are inserted during a single surgical procedure(Pérez-Martín et al.,2017). The surgical risks, pre- and post-operative care, lengths of hospital stays, and total expenses associated with these implantation methods can vary widely. When listening to speech in noisy environments, binaural hearing is recognised to help normal-hearing people. When both ears are working, it's easier to make out speech in noisy environments than when one ear is just used. When it comes to sound localization, noise discrimination, speech recognition, the squelch effect, the head shadow effect, and binaural summation, binaural hearing has a number of benefits, according to studies(Alothman ET AL.,2023). Among these, binaural hearing has three major benefits. The first is the head shadow effect, which occurs when the physical head causes differential sound filtering. Since the signal-to-noise ratio (SNR) is different in each ear, it is possible to enhance speech detection by directing one's attention to the ear that has the higher SNR when both ears are actively engaged. The squelch effect is another characteristic; it allows the auditory system to generate a more precise representation by combining data from both ears when it gets functional input. Applying this effect can significantly improve the comprehension of spoken language. Theoretically, binaural summation happens when vocalisations and background noise originate from the same location. The capacity of the auditory system to combine and benefit from different representations of the same information delivered to each ear, a process known as summation, allows us to perceive louder sounds (Gaylor ET AL.,2013).

After a year, a new trial on adults indicated that sequential BiCI produced similar subjective and objective hearing outcomes as simultaneous BiCI. The simultaneous BiCI group likewise showed a considerable improvement in noisy speech intelligibility. Similarly, when comparing the sequential group using the second CI to the unilateral group, the latter showed superior performance. The surgical technique and clinical results of concurrent BiCI procedures were not, however, the primary foci of the research(Gröger et al.,2023). A different study found that the overall amount of time used to discriminate speech was positively and significantly correlated with the second CI in both sequential and simultaneous BiCI. It is worth noting that a survey research found that sequential BiCI is conducted more frequently in adults than in paediatric situations. This could be because there is less counselling available for adults. It is unclear if this is a result of healthcare system priorities or the practice of CI centres, but it seems that adults are less likely to receive binaural benefits from having both ears implanted at the same time as children (Peters ET AL.,2010).

In many cochlear implant centres, the external sound processor is turned on four to six weeks following surgery to ensure adequate wound healing and to forestall infections of the flap. Additionally, issues with electrode impedance instability and implant migration are causes for worry. There is currently no universally accepted time frame for when an external device should be fitted and turned on, and all of these factors will cause patients to postpone beginning their hearing recovery(Torre ET AL.,2022). The constant improvement and expansion of these prosthetic technologies, however, has allowed for quicker wound healing and fewer complications through the use of smaller and diverse incisions. Consequently, it is now frequently acceptable and even encouraged to activate the external sound processor a few days following CI surgery. There were no major

complications in either group, and the results showed that activation four weeks following CI surgery was no better than activation within 24 hours in terms of maintaining residual hearing, changes in impedances, and speech perception. Some CI users may find early activation appealing because it provides the opportunity for hearing experience and rehabilitation earlier. In contrast to sequential BiCI, which necessitates more rehabilitation resources, simultaneous BiCI has demonstrated safety, efficacy, and speaking results in paediatric populations (Kraaijenga ET AL.,2019).

Cochlear implant operations started long years back as a single channel device, which was designed only for awareness of the environmental sound without having either auditory or speech discrimination and were for adult candidates who had been diagnosed as profound hearing loss. Then, it had been upgraded to a multichannel one, which played a great role in discriminating both auditory sounds as well as improving speech scores (Uecker et al.,2019).

In the early years with first generation implants, only individuals with profound bilateral deafness were considered candidates and for only monaural implantation. In the subsequent years, improvements in hearing performance occur primarily through increasing sophistication of implant devices and processing strategies. Such improvements allowed for the expansion of candidacy criteria to include individuals with measurable amounts of residual hearing and speech discrimination, yet who still suffered from functional impairment even with modern hearing aids (B. Robert Peters,et al,2010).

Thus, the candidacy for the operation has been expanded all over the world to include patients who are having moderate to profound, those who are having mild to profound using hybrid cochlear implant devices or EAS as well as and in some centers the single sided deafness patients started to undergo cochlear implant operation on the deaf side.

In the past several years another distinct phase of CI era has developed. Significant improvements in hearing for CI users have recently been achieved, not via new implant technology alone, but through the provision and/or restoration of binaural mechanisms through bilateral stimulation. Binaural mechanisms, such as summation, squelch, and sound localization are not possible for individuals hearing monaurally.1,2 In addition, maximal benefit from the head shadow effect requires binaural hearing. Bilateral CI (BCI) users have demonstrated significantly improved speech understanding in quiet and in noisy environments, improved sound localization abilities, subjective reports of significantly decreased social restriction, reduced perception of hearing disability, and a trend toward reduced emotional distress compared to the unilateral implant condition. 3,14

Over the past few years, bilateral cochlear implants have become increasingly common for both children and adults. Actually, numerous and various professionals and organizations recognize bilateral cochlear implant as the standard of care treatment for individuals with bilateral severe to profound hearing loss. If the patient has been chosen as a candidate then, what the decision is to be made, which ear to implant, if it is unilateral or which ear to start with if it is sequential or if it is simultaneously to be done.

Our cochlear implant program in Kuwait had been started in April 2001, and the rule was to do unilateral cochlear implant operation for those who were having bilateral severe to profound hearing loss with poor benefit from hearing aids. Few years back, bilateral cochlear implant operation came into the field in our country. The criteria had been added especially for the children and the decision was to do simultaneous implantation for the newly chosen candidates, unless for some reason a sequential operation is recommended. Parents of those children who had already undergone first cochlear implantation long years back insisted to have a second operation on the other ear for their children, although we counseled them and discussed with them that we can't promise how much benefit they can get after this long interval duration from the first implantation. Cochlear team in Kuwait accepted to operate those children who had their first cochlear implant at a very young age after long discussion and after having the consent from the family. We followed them up to see how much they are going to benefit from the second implant in terms of hearing threshold level and speech discrimination score.

When done to children and adults who are a good candidate, bilateral cochlear implantation (BiCI) is a standard medical procedure. Some communities use it as their gold standard for treating youngsters who have substantial sensorineural hearing loss on both sides of their ears. Bilateral hearing has many advantages, including better localization abilities and enhanced speech comprehension in noisy environments; these are also some of the main benefits of BiCI (Karataşet al.,2019).

While the majority of recipients do not yet perform to the level of normal-hearing listeners with true binaural capabilities, outcome measures imply that they do experience improvements in sound localization, hearing in noisy environments, implanting the better ear to maximise implant success, and overall quality of life. Language acquisition, learning, cognition, and memory facilitation, the assurance of an implanted "better ear" for an improved quality of life, and other enhancements that have not been assessed systematically but could be are all possible outcomes. The advantages of BiCI are evaluated across a variety of patient characteristics. Early plasticity and optimal binaural benefit are most likely to occur during the first three and a half years of life, when binaural processing is at its peak (Jutila et al.,2021).

Several factors can impact the decision of which ear to implant in. In certain clinics, the ear with the least amount of residual hearing is implanted first, whereas in others, the ear with the best hearing is implanted first. On an individual basis, some clinics decide which ear gets the implant, while others let the patient or parents decide. There is no longer any need to choose between implanting in both ears at once (simultaneous bilateral implantation) or implanting in each ear in turn (sequential bilateral implantation), as many clinics now offer this option.

Material and Method

1- Five cases underwent the second cochlear implantation, all of them had their first implantation at a very young age.

2- They underwent full audiological assessment, unaided followed by aided hearing threshold test and speech discrimination score using cochlear implant device on the early implanted ear and aided response using the most powerful hearing aid device on the second ear which was under preparation for the second implantation.

3- Auditory Brain Evoked potential response test (ABR), had been done using both click and tone burst stimulus.

4- Transient evoked otoacoustic emission (TEOAE) had been done in all of them.

5- Radiological assessment using CT scan test had been repeated before the second implant operation.

Results

Five case had undergone a delayed sequential cochlear implant operation, their ages ranged between seven years six months up to ten years three months; regarding gender difference they were four males and one female; all of them of Kuwaiti nationality population, as they were under the support of our government completely.

All of the five cases were showing bilateral severe to profound sensorineural hearing loss on doing unaided hearing threshold level test using pure tone audiogram, all of them showed abscent ABR response using click and tone burst stimulus bilateral, three of them showed good emission level on TEOAE, while two of them showed poor emission level; all five patients were prelingual at the time of first cochlear implant operation, (table 1), while at the time of second ear implant they had already developed speech with various scores as will be shown later.

Table 2 shows the age of the children at the two implant operations . For the first implant operation, the age ranged between minimum one year three months up to a maximum of two years nine months,with the mean of 1.98±0.59, while the range of age at the second implant operation was between minimum of seven years two months up to a maximum of ten years, with the mean of 9.05±1.22. The first operation was on four left ears, one right ear , while the second operation was on four right ears and one left ear. The old type of the device was CI24RE(CA), while the newer generation had been implanted on the second ear, CI522; the interval duration time between the two operations ranged between minimum of five years nine months up to a maximum of eight years, with the mean of 7±0.95 SD.

Table 4 shows the postoperative results. The benefits of the implant operation have been identified in term of both hearing threshold levels at different frequencies and speech discrimination score in each ear separately following the two different implantations. As the table shows, following the two implant operation, the range of hearing threshold level ranged between 20-30dB up to 30-35dB in the right ear, while in the left ear the range was between 15-25dB up to 35-40dB. As regard speech discrimination score, following the first implantation the range of the results were between 76-90%, while the results of the second implanted ear showed to be very poor, 0-15%.

In term of acceptance of both patients and parents, we noticed that the patients refused the second implant results and were not welling to use the device as well as the patients , and even after convincing them still they depend on the first implant most of the time. Parents in addition, did not accept the results of the second ear implantation.

Discussion

Out of all the brain prosthesis that have been produced thus far, the cochlear implant has been the most successful. When it comes to restoring function, it is the prosthesis that works the best.Our findings are supported by other studies that have shown the benefits of BiCI compared to unilateral CI. Speech intelligibility, perception of speech in loud environments, and sound localization were all enhanced by BiCI (Trinidade et al.,2017).

Rehabilitating infants with simultaneous BiCI is more efficient and requires fewer resources than sequential bilateral implantation because it encourages the development of both auditory pathways simultaneously. Children who have cochlear implants with short delays of less than a year or all at once do not appear to have these asymmetries in sequential BiCI, but it is unclear if they will remain with longer-term use. When it comes to the ideal age for the first and second cochlear implants, as well as the interval between them, there is a great deal of variation among research. These trials provided stronger evidence that patients who were implanted bilaterally or simultaneously had better speech responsiveness than those who were placed sequentially. More specifically, a large gap duration was implanted in all individuals that participated in this trial(Hajr,2019).

Based on the provided results of the study on delayed sequential cochlear implant operations in five cases, here is a discussion and analysis:

1. **Demographic and Clinical Characteristics**:
   - The study included five Kuwaiti nationals, aged between 7 years 6 months to 10 years 3 months, with four males and one female. All cases had bilateral severe to profound sensorineural hearing loss as indicated by unaided pure tone audiogram and absent ABR responses bilaterally. Three cases showed good emission levels on TEOAE, while two showed poor emissions.
2. **Age and Timing of Implant Operations**:
   - The first cochlear implant operation was performed between ages 1 year 3 months to 2 years 9 months (mean 1.98 years). The second ear implantation occurred between ages 7 years 2 months to 10 years (mean 9.05 years). There was a considerable interval between the two operations, ranging from 5 years 9 months to 8 years (mean 7 years).

3. **Devices and Surgical Details**:
    - The first operation used CI24RE(CA) devices, while CI522 devices were implanted in the second ear. This shift indicates technological advancement and potential differences in performance between device generations.
4. **Postoperative Outcomes**:
    - **Hearing Threshold Levels**: Following the first implantation, hearing thresholds ranged between 20-30dB to 30-35dB in the right ear and 15-25dB to 35-40dB in the left ear. After the second implantation, thresholds were generally higher, suggesting potentially less effective outcomes compared to the first implantation.
    - **Speech Discrimination Scores**: Results after the first implantation showed scores between 76-90%, indicating good speech discrimination. However, the second implanted ear showed very poor scores, ranging from 0-15%.
5. **Patient and Parent Acceptance**:
    - Despite the surgical success in terms of hearing thresholds, speech discrimination, and implant function, both patients and parents showed reluctance and dissatisfaction with the outcomes of the second ear implantation. Patients preferred to rely on the first implant and were unwilling to use the second device. Parents also expressed dissatisfaction with the results of the second ear implantation.

Discussion Points:

- **Effectiveness of Delayed Sequential Implantation**: The study demonstrates that while delayed sequential cochlear implantation can offer significant hearing benefits initially, there are challenges associated with the outcomes of the second implantation. This includes poorer speech discrimination scores and lower acceptance rates among patients and parents.
- **Technological Advancements**: The shift from CI24RE(CA) to CI522 devices highlights advancements in cochlear implant technology. However, the study indicates that technological improvements alone may not guarantee superior functional outcomes or acceptance.
- **Clinical Implications**: Clinically, the findings suggest the importance of careful patient selection and counseling regarding the potential outcomes of delayed sequential cochlear implantation. Managing expectations and providing ongoing support to patients and families post-implantation are crucial for optimizing outcomes and satisfaction.

In conclusion, while cochlear implantation remains a viable option for individuals with severe to profound hearing loss, the study underscores the complexity of outcomes in delayed sequential implantation scenarios. Further research and personalized approaches are needed to enhance outcomes and patient satisfaction in such cases.

Over the past few years, bilateral cochlear implantation have become increasingly common for both children and adults. Bilateral cochlear implantation has benefits over the monaural one in term of better speech perception due to overcoming the head shadow effect, improved speech understanding in noise, improved sound localization, binaural squelch, binaural summation and redundancy.

Moreover, with the bilateral cochlear implantation, more rapid language acquisition and improved speech recognition skills had been noticed. Socially, with bilateral cochlear implantation patients showed better quality of life and less stress in noisy environments. But, it is important to consider the timing of such operation, whether to be done either simultaneously or sequentially and if it is the sequential operation to be decided, then how much time should wait for the second ear operation to be done or delayed, in order to give good benefit to the patient, taking into consideration the residual hearing in the other un-operated ear and the use of hearing aid on it.

Our five cases of children, who had their first cochlear implantation operation at a younger age, and had long interval implant duration before the second operation on the other ear, showed good hearing level post second cochlear implanted ear ,minimum at 20-30dB, while maximum at 35-40dB. On the other hand, poor speech discrimination score ranging from 0-15% results had been shown on the second implanted ear which was after long interval duration compared to the first early implanted ear, where the hearing threshold level ranged between 15-25dB up to 30-40dB , while the speech score ranged between 76-90%..

The children, on switching on the device they refused it, as they compared it to the first implanted ear, and we tried with their family to convince them to use it and to depend on it. Following them up, we found that they are mainly depending on the first implant not the second one. On the other hand, parents of those children were shocked from the results of the second implanted ear when they kept on comparing it with the first implanted ear results.

Our results confirmed that the best decision to be taken as regard bilateral cochlear implant operation is the simultaneous one, while if due to any reason a sequential operation to be decided , then it should not be delayed much, because the longer the interval duration the poorer the results will be. Moreover, whether the results of the second delayed operation are going to improve over time and after proper rehabilitation and auditory training , it is still in doubt how much they are going to improve. However, longer duration of following up such children is needed to see how much they are going to improve regarding the speech score discrimination.

B. Rubert Peterd, et al,2010, reported that studies have shown an advantage to binaural brainstem pathways if the surgery is performed simultaneously or with short interval sequentially in children <2 years of age. Postulating that any limitation in development of the second ear might compromise the development of central binaural processing and the subsequent ability to integrate the information received from each ear.

Longer interimplant intervals and older age at first implant have a negative impact, appearing more restrictive to the development of pathways in the auditory brainstem. The authors suggest this reflects a change in developmental plasticity in children with long term unilateral implant use at the level of auditory brainstem essentially resulting in unbalanced activity for its duration and potentially longer, restricted or altered course of maturation evoked by the stimulation of the second side, and increased sensitivity to competition from other non-auditory modalities resulting in cross-modal plasticity on the delayed side.

Conclusion

Our results showed poor benefit from the 2nd cochlear implant compared to the 1st one which was at an early age. The poor benefit had been confirmed in terms of poor speech recognition score (monosyllable words) comparing the two ears in each child. In addition, following up such patients, we found that they are mainly depending on the 1st implant and prefer to listen through it rather than the 2nd one which had been done after long interval duration. The question which need to be raised, do we have to accept to choose such children who had their first ear implanted at an early age for the 2nd ear implantation after long interval; should we give them the chance to undergo the implantation and continue long duration follow to see how much time need to improve the results and benefits. Following up these children and giving them the proper rehabilitation are the only ways to answer these questions.

Optimal bilateral coherence and speech performance were achieved in peri- and post-lingual patients using matching bilateral, same sequential, and simultaneous devices. In postlingual patients, various sequential devices had the least beneficial effects.

Patients who underwent bilateral CI typically had better speech performances compared to those who underwent unilateral CI. Tone and speech signals were both more detectable and discriminable in BiCI compared to unilateral CI conditions, according to binaural loudness measurements.

Accordingly, we are recommending bilateral and simultaneous cochlear implants rather than a unilateral or sequential cochlear implant. However, the wide variability in speech performance among patients could be attributed to different factors, including the areas of hardware and engineering, surgical precision, age of implantation, and pathology of the auditory system in deaf persons. We will focus on achieving binaural hearing instead of bilateral hearing in the future because of this.

Table 1

Demographic & preoperative test results

Case noi.	age	sex	nationality	HTL	ABR	TEOAE	Speech-preoperative 1st implant
1	7y6m	M	K	Bil severe to profound	NR	-ve	prelingual
2	10y	M	K	Bil severe to profound	NR	-ve	prelingual
3	9y	M	K	Bil severe to profound	NR	+ve	prelingual
4	9y3m	F	K	Bil severe to profound	NR	+ve	prelingual
5	10y3m	M	K	Bil severe to profound	NR	+ve	prelingual

M=months F= female K=Kuwaiti HTL=hearing threshold level
ABR= auditory brainstem evoked potential response
TEOAE= transient evoked otoacoustic emission NR =no response
BIL= bilateral -ve= negative results +ve= positive results

Table 2
Age of the two implantations

Case noi	age	Age of 1st implantation &side		Type of electrode	Age of 2nd implantation& side		Type of electrode	Inter-implant durartion
1	7y6m	left	1y3m	CI24RE(CA)	right	7y2m	CI522	5y9m
2	10y	left	2y9m	CI24RE(CA)	right	9y6m	CI522	6y7m
3	9y	left	1y7m	CI24RE(CA)	right	8y7m	CI522	7y
4	9y3m	right	2y4m	CI24RE(CA)	left	9y	CI522	6y6m
5	10y3m	left	2y	CI24RE(CA)	right	10y	CI522	8y
mean	9.2000± 1.08109	1.9833± 0.59337			9.0500± 1.22418			7.0000± 0.95197

Table 3

	N	Minimum	maximum	mean	SD±	median
age	5	7.50	10.25	9.2000	1.8109	9.25
Age1	5	1.25	2.75	1.9833	0.59337	2.00
Age2	5	7.17	10.33	9.0500	1.2248	9.50
Interimplant duration	5	5.75	8.33	7.0000	0.95197	7.00

Age 1= the age at first implantation
Age 2= the age at the second implantation
Interimplant duration= the time interval between the operation on the two ears

Table 4

Postoperative results

Case noi	Rt HTL	Lt HTL	Speech score 1st implant	Speech score 2nd implant
1	30-35dB	30-40dB	76%	0%
2	20-30dB	20-35dB	76%	0%
3	20-35dB	20-35dB	90%	0%
4	20-30dB	35-40dB	86%	0%
5	30-35dB	15-25dB	76%	15%

Noi= number Rt = right Lt = left
dB=decibel
HTL= Hearing threshold level

References

Alothman, N., Almuhawas, F., Badghaish, R., Alotaibi, A. H., Alhabib, S. F., Alzhrani, F., & Hagr, A. (2023). Cochlear Implantation in Pediatrics: The Effect of Cochlear Coverage. Journal of Personalized Medicine, 13(3), 562.

B.Robert Peters, MD; Josephine Wyss, BSc, Dipl Aud; Manuel Manrique, MD, PhD. Worldwide Trends in Bilateral Cochlear Implantation. The laryngoscope 120:May 2010.

Carlson, M. L. (2020). Cochlear implantation in adults. New England Journal of Medicine, 382(16), 1531-1542.

Connors, J. R., Deep, N. L., Huncke, T. K., & Roland Jr, J. T. (2021). Cochlear implantation under local anesthesia with conscious sedation in the elderly: first 100 cases. The Laryngoscope, 131(3), E946-E951.

Dillon H. Binaural and bilateral considerations in hearing aid fitting. In: Dillon H, ed. Hearing aids. New York, NY:Thieme;2001:370-440.

Firszt JB, Ulmer JL, Gaggal W. Differential representation of speech sound in the human cerebral hemispheres. Anat Rec A Discov Mol Cell Evol 2006; 288:345-357.

Gaylor, J. M., Raman, G., Chung, M., Lee, J., Rao, M., Lau, J., & Poe, D. S. (2013). Cochlear implantation in adults: a systematic review and meta-analysis. JAMA Otolaryngology–Head & Neck Surgery, 139(3), 265-272.

Gröger, M., Loth, A., Helbig, S., Stöver, T., & Leinung, M. (2023). Bilateral simultaneous cochlear implantation is a safe method of hearing rehabilitation in adults. *European Archives of Oto-Rhino-Laryngology*, *280*(10), 4445-4454.

Hajr, E. A., & Almuhawas, F. (2019). Financial benefits of the early fitting of a cochlear implant speech processor: Assessment of the direct cost. *Cureus*, *11*(9).

Idstad, M., Tambs, K., Aarhus, L., & Engdahl, B. L. (2019). Childhood sensorineural hearing loss and adult mental health up to 43 years later: results from the HUNT study. BMC Public Health, 19, 1-9.

Jutila, T., Sivonen, V., & Hirvonen, T. P. (2021). Simultaneous bilateral stapes surgery after follow-up of 13 years. *Acta Oto-Laryngologica*, *141*(1), 39-42.

Karataş, M., & Kaskalan, E. (2019). Simultaneous bilateral butterfly tympanoplasty using tragal cartilage from one ear. *Auris Nasus Larynx*, *46*(3), 324-329.

Kraaijenga, V. J., Ramakers, G. G., Smulders, Y. E., Van Zon, A., Free, R. H., Frijns, J. H., ... & Grolman, W. (2019). No difference in behavioral and self-reported outcomes for simultaneous and sequential bilateral cochlear implantation: evidence from a multicenter randomized controlled trial. Frontiers in Neuroscience, 13, 54.

Litovsky R, Parkinson A, Acaroli J, Summeth C. Simultaneous bilateral cochlear implantation in adults: a multicenter study, Ear Hear 2006; 27: 714-731.

Murphy J,ODonoghue G, Bilateral cochlear implantation: an evidence –based medicine evaluation. Laryngoscope 2007; 117 :1412-1418.

Panza, F., Lozupone, M., Sardone, R., Battista, P., Piccininni, M., Dibello, V., ... & Logroscino, G. (2019). Sensorial frailty: age-related hearing loss and the risk of cognitive impairment and dementia in later life. Therapeutic Advances in Chronic Disease, 10, 2040622318811000.

Pérez-Martín, J., Artaso, M. A., & Díez, F. J. (2017). Cost-effectiveness of pediatric bilateral cochlear implantation in Spain. *The Laryngoscope*, *127*(12), 2866-2872.

Peters, B. R., Wyss, J., & Manrique, M. (2010). Worldwide trends in bilateral cochlear implantation. The laryngoscope, 120(S2), S17-S44.

Torre, L. M. N., & Montoya, S. R. R. (2022). Early activation of a late sequential cochlear implant systematic review. J. Otolaryngol.-ENT Res, 14, 90-95.

Trinidade, A., Page, J. C., Kennett, S. W., Cox, M. D., & Dornhoffer, J. L. (2017). Simultaneous versus sequential bilateral cochlear implants in adults: cost analysis in a US setting. *The Laryngoscope*, *127*(11), 2615-2618.

Uecker, F. C., Szczepek, A., & Olze, H. (2019). Pediatric bilateral cochlear implantation: simultaneous versus sequential surgery. *Otology & Neurotology*, *40*(4), e454-e460.