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Original scientific paper

Long-Term Functional Outcomes after 10 Years of Bilateral Cochlear Implantat Use

Robert Trotić[1], Mirjana Kostić[2], Mihael Ries[1], Petar Drviš[1], Jakov Ajduk[1] and Igor Petrović[3]

[1] University of Zagreb, »Sestre milosrdnice« University Hospital Centre, Department of Otorhinolaryngology & Head and Neck Surgery, Zagreb, Croatia

[2] Croatian Institute for Health Insurance, Zagreb, Croatia

[3] University of Zagreb, Zagreb University Hospital Centre, Department of Surgery, Zagreb, Croatia

A B S T R A C T

The aims were to determine the benefit of bilateral cochlear implantation in a 20 years old patient implanted in Croatia on hearing and speech development. The male patient, after 10 years of deafness, got cochlear implants Med-EL Combi 40+ on both sides in one-stage surgery. The etiology of his deafness was posttraumatic meningitis. Auditory capacity and speech recognition tests were performed for both ears separately and together. Average hearing level on the right ear with right cochlear implant switched on started at 62 dB 1 month after the cochlear implantation and was on 55 dB after 10 years. Average hearing level on the left ear with left cochlear implant switched on started at 55 dB 1 month after the cochlear implantation and was on 32 dB after 10 years. Average hearing level on the both ears with 2 cochlear implants switched on started at 35 dB 1 month after the cochlear implantation and was on 27 dB after 10 years. Long-term functional outcomes with bilateral cochlear implantation provides advantages over unilateral implantation including improved hearing level, speech perception in noise and improved sound localization.

Key words: *hearing loss, deafness, Cochlear implant, , hearing perception*

Introduction

Cochlear implantation started in Croatia in 1996. First cochlear implant was MED-EL Combi 40, implanted in the Department of Otorhinolaryngology & Head and Neck Surgery, »Sestre milosrdnice« University Hospital Center in Zagreb. Since than, cochlear implantation started also in Salata ENT department, and in ENT departments in Rijeka and Split. Several cochlear implants are commercially available in Croatia: the Nucleus® family of devices, manufactured by Cochlear™ Corporation, the Clarion® family of devices, manufactured by Advanced Bionics®; and the Med El Combi 40+ and Sonata device, manufactured by Med El Corporation. While cochlear implants have typically been used mono laterally, in recent years, interest in bilateral cochlear implantation has arisen[2–4]. The proposed benefits of bilateral cochlear implants are to improve understanding of speech in noise and localization of sounds[1]. Improvements in speech intelligibility may occur with bilateral cochlear implants through binaural summation; i.e., signal processing of sound input from two sides may provide a better representation of sound and allow one to separate out noise from speech[7,9]. Speech intelligibility and localization of sound or spatial hearing may also be improved with head shadow and squelch effects, i.e., the ear that is closest to the noise will be received at a different frequency and with different intensity, allowing one to sort out noise and identify the direction of sound[10,11]. Bilateral cochlear implantation may be performed independently with separate implants and speech processors in each ear or with a single processor[19,20,22]. Unilateral or bilateral implants with FDA-approved cochlear implant(s) and associated aural rehabilitation may be considered medically necessary when all of the following criteria are met: age one year or older, severe to profound pre-or postlingual hearing loss, defined as a hearing threshold of 70 decibels (dB) or above and limited benefit from hearing aids unless hearing aids are unreasonable[5,6,15]. Contraindications for cochlear implantation include: deafness due to lesions of the acoustic nerve or central auditory pathways, otitis media or other active, unresolved

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ear problems, radiographic evidence of absent cochlear development and inability or lack of willingness to participate in post-implantation aural rehabilitation[8,16,18].

Cochlear Implant Device

A cochlear implant provides direct electrical stimulation to the auditory nerve, bypassing the usual transducer cells that are absent or non-functional in deaf cochlea. The basic components of a cochlear implant include both external and internal components. The external components include a microphone, an external sound processor, and an external transmitter. The internal components are implanted surgically and include an internal receiver implanted within the temporal bone, and an electrode array that extends from the receiver into the cochlea through a surgically created opening in the round window of the middle ear. Sounds that are picked up by the microphone are carried to the external signal processor, which transforms sound into coded signals that are then transmitted transcutaneously to the implanted internal receiver. The receiver converts the incoming signals to electrical impulses that are then conveyed to the electrode array, ultimately resulting in stimulation of the auditory nerve[29,30,33].

Cochlear Implant Surgery

Cochlear implant surgery lasts about two to three hours and is performed while the patient is under general anesthesia. After mastoidectomy, posterior tympanotomy and cochleostomy, the electrode array is inserted into the cochlea. The receiver/stimulator is secured to the skull on the temporal bone. At the end of the operation the implant is tested by attaching it to the processor and making sure that it is functioning well[12,13,15,34].

Rehabilitation

A post-cochlear implant rehabilitation program is necessary to achieve benefit from the cochlear implant. The rehabilitation program start one month after surgery and includes development of skills in understanding running speech, recognition of consonants and vowels, and tests of speech perception ability by the use of SUVAG's verbo-tonal method of rehabilitation[21,23,24,26,28].

Results

20 years old male patient underwent two simultaneously – implanted bilateral cochlear implant surgery. Figure 1 shows preoperative pure tone audiometry (PTA) in 20 years old male patient. Hearing level (HL) on the left ear was between 85 dB on 125 Hz and 120 dB on 1000 Hz. On the right ear HL was between 80 dB on 125 Hz and 120 dB on 2000.

Figure 2 shows PTA 6 months postoperativelly with separate bilateral CI swithed on. When left CI was switched on and right CI switched off HL on the left ear was between 20 dB and 50 dB. The mean PTA on 4 frequencies (500, 1000, 2000 and 4000 Hz) was 30 dB HL (SD=20). When right CI was switched on and left CI switched off HL on the right ear was between 25 dB and 90 dB. The mean PTA was 56 dB HL (SD=34).

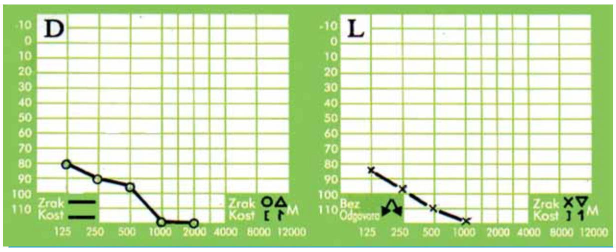

Fig. 1. Preoperative PTA.

Figure 3 shows PTA 6 months postoperativelly with both CI swithed on. HL on the left ear was between 20 dB and 70 dB. The mean PTA was 28 dB HL (SD=42). HL on the right ear was between 20 dB and 70 dB. The mean PTA was 30 dB HL (SD=40).

Figure 4 shows speech audiogram 6 months postoperativelly with both CI swithed on. HL was on 25 dB, and 70% recognition was on 45 dB.

As the result of the speech recognition in the presence of noise, we found in this simultaneously – implanted bilateral cochlear implant user, that he was able to sustain a 50% correct score on the BKB-SIN test at a lower signal-to-noise (SNR) ratio using his bilateral implants than when using only one of his implants. When only one im-

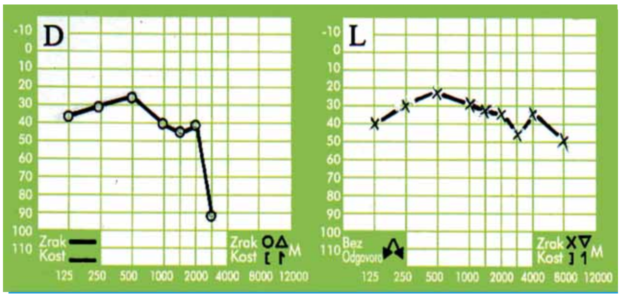

Fig. 2. PTA 6 months postoperativelly with separate bilateral CI swithed on.

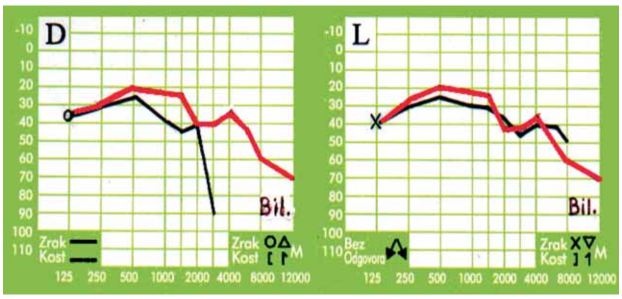

Fig. 3. PTA 6 months postoperativelly with both CI switched on.

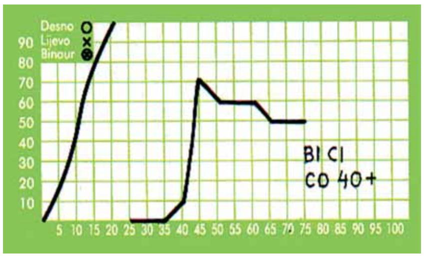

Fig. 4. Speech audiogram 6 months postoperativelly with both CI switched on.

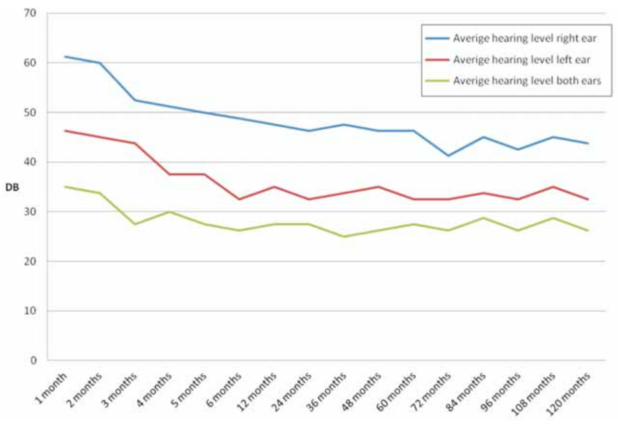

Fig. 5. Average hearing level 1–120 months after bilateral cochlear implantation.

plant was used, the SNR had to be increased to more favourable levels in order for the subjects to sustain that same performance level. In each of the three test conditions (noise from the left, noise from in front, noise from the right), these results were statistically significant after 3-months of bilateral implant use, with scores increasing further at the 6 month test. The bilateral fitting condition was superior regardless of the location of the noise. This confirms the superiority of bilateral cochlear implant use in recognizing speech in the presence of noise.

Discussion

While use of a monolateral cochlear implant in patients with severe to profound hearing loss has become standard clinical practice, bilateral cochlear implants has been less common. A literature review through December 18, 2007 identified a number of studies that are relevant to the use of bilateral cochlear implants. Sharma and colleagues report that central auditory pathways are maximally plastic for a period of about 3.5 years[8,9,37]. Stimulation delivered within this period results in auditory evoked potentials that reach normal values in three to six months. However, when stimulation occurs after seven years, changes occur within one month, but then have little to no subsequent change. Sharma and Dorman also reported on auditory development in 23 children with unilateral or bilateral implants.8 In one child who received a bilateral device with later (after age seven) implantation of the second ear the auditory responses in the second device were similar to that seen in »late-implanted« children. A review of the peer-reviewed literature on MEDLINE from the period of 1995 through April 2006 identified 13 case reports on patients with bilateral cochlear implants[14,35]. The case reports identified range in size from 1 to 10 patients and most, but not all, patients reported slight to modest improvements in sound localization and speech intelligibility with bilateral cochlear implants especially with noisy backgrounds but not necessarily in quiet environments. When reported, the combined use of binaural stimulation improved hearing in the range of 1–4 decibels or 1–2%. While this improvement seems slight, any improvement in hearing can be considered beneficial in the deaf[25,27,32]. However, this improvement appears marginal at best, and may not outweigh the significant risks of a second implantation. In addition, similar binaural results can be achieved with a contralateral hearing aid, assuming the contralateral ear has speech recognition ability[16]. A number of studies have also reported results with bilateral cochlear implants. Litovsky reported that nine of 13 (70%) children with bilateral cochlear implants discriminated source separations of equal to or less than 20 degrees and seven out of nine performed better when using bilateral (versus unilateral) devices[4,10]. Schoen and colleagues reported that bilateral cochlear implants were able to restore spatial hearing in eleven cochlear implant patients[14]. Litovsky and colleagues reported on a multi-center prospective study of 37 adults with post-lingual bilateral hearing loss[12]. Bilateral benefit (speech understanding in quiet and noise) was seen in 32/34 subjects. Questionnaire data (subjects used only the best unilateral device for three weeks) also indicated that bilateral users perceived their performance to be better than when using a single device. Ricketts and colleagues reported on 16 similar adults with post-lingual bilateral hearing loss[6]. They found a small but significant advantage for bilateral implants for speech recognition in noise. While a training effect was noted over time for a subset of patients followed up to 17 months, a consistent bilateral advantage was noted. Ramenden and colleagues reported on 30 adults in England who had bilateral cochlear implants and received their second implant a mean of three years after the first. At nine months a significant (12.6%, p=less than 0.001) binaural advantage was seen for speech and noise from the front. They were not able to predict when the second ear would be the better performer. Sequential implantation with long delays between ears resulted in poor second ear performance for some of their subjects. Kuhn-Uinacker reported on a group of 39 European children who had bilateral cochlear implants[13]. From qualitative and quantitative data, they concluded that bilateral implants improve the children's communicative behavior, especially in complex listening situations. Numerous positive benefits of bilateral cochlear implantation have been confirmed[38–40]. Patients receive significant head shadow benefit from bilateral implantation, and obtain nominal benefits from summation and squelch effects. Sound localization benefits have been confirmed. Speech perception in noise with bilateral implantation is significantly better than unilateral implantation and continues to improve 24 months after implantation. Areas for further improvement have also been identified. Despite technological improvements in speech processing strategies, measured intraaural time differences in bilateral cochlear implant recipients remain considerably greater than those with normal hearing. Programming challenges persist to optimize sound processing with bilateral implants[31,35,36]. Vestibular effects of bilateral cochlear implantation appear safe but need further study. Important considerations including the duration of implant function, long-term complication rate, and improvements in implant technology will continue to strongly influence the role of bilateral cochlear implantation. There has been also some arguments against simultaneous bilateral cochlear implantation: operative time/risk of anaesthesia, increased surgical risk, damage to residual hearing, financial expense, ability to utilize future technological advancements and ability to utilize future medical treatments-hair cell regeneration/stem cell treatments. But, now we doing bilateral simultaneous bilateral cochlear implantation in 2½ to 2¾ hours, so operative time is not an issue. The risks are minimal with cochlear implantation and the most common side effect we see is dizziness. Patients who get bilateral simultaneous implants do not have any more problems with their balance than unilateral implant patients. The concern about destroying residual hearing is out of question, because recent studies showed residual hearing after the cochlear implantation too. And about costs-getting a bilateral simultaneous implantation saves you the cost of two hospital stays, two recovery times, and twice the anaesthesia. Because of that, many Institutes for Health Insurance in european countries approve two implants for deaf people. And, we can say that cochlear implant technology has improved tremendously over the years. And there is no fear about utilizing future technological advancements and future medical treatments-hair cell regeneration/stem cell treatments[17,35].

Conclusion

Bilateral cochlear implantation provides advantages over unilateral implantation including improved speech perception in noise and improved sound localization. Further research is needed to define the optimal indications and to maximize the benefit of bilateral implantation.

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R. Trotić

University of Zagreb, »Sestre milosrdnice« University Hospital Centre, Department of Otorhinolaryngology & Head and Neck Surgery, Vinogradska 29, 10000 Zagreb, Croatia
e-mail: trotic@gmail.com

DUGOROČNI FUNKCIONALNI DESETOGODIŠNJI REZULTATI OBOSTRANE UGRADNJE UMJETNIH PUŽNICA

S A Ž E T A K

Ciljevi su bili odrediti prednosti razvoja slušanja i govora nakon obostrane ugradnje umjetnih pužnica kod 20-godišnjeg pacijenta u Hrvatskoj. Muški pacijent je dobio umjetne pužnice na oba uha, tipa Med-El Combi 40+, nakon 10 godina gluhoće, u kirurškom zahvatu obostrane ugradnje tijekom jednog kirurškog zahvata. Uzrok njegove gluhoće bio je posttraumatski meningitis. Audiološki i govorni testovi napravljeni su posebno za svako uho, kao i za oba uha. Prosječni prag sluha na desnom uhu, s uključenom desnom umjetnom pužnicom, bio je 62 dB mjesec dana nakon ugradnje umjetnih pužnica te 55 dB 10 godina nakon ugradnje umjetnih pužnica. Prosječni prag sluha na lijevom uhu, s uključenom lijevom umjetnom pužnicom, bio je 55 dB mjesec dana nakon ugradnje umjetnih pužnica, te 32 dB 10 godina nakon ugradnje umjetnih pužnica. Prosječni obostrani prag sluha, s uključene dvije umjetne pužnice, bio je 35 dB mjesec dana nakon ugradnje umjetnih pužnica te 27 dB 10 godina nakon ugradnje umjetnih pužnica. Dugoročni funkcionalni rezultati 10 godina nakon ugradnje obostranih umjetnih pužnica pokazuju da obostrana ugradnja umjetnih pužnica ima prednost pred jednostranom ugradnjom, uključivši bolji prosječni prag sluha, bolju razabirljivost u buci i bolju lokalizaciju zvukova.