Results of Hearing Preservation Technique in Cochlear Implants

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Abstract

Introduction: Residual hearing preservation in cochlear implantation through soft surgery was first described in 1993. The technique didn’t gain wide acceptance because the advantages of residual hearing in cochlear implants candidates were questionable. In 1999, the positive effect of combined electric acoustic stimulation (EAS) of the auditory nerve on speech discrimination was first demonstrated and confirmed later in many publications. Higher rate of hearing preservation becomes possible through maturation of the soft surgery technique.

Aim of Work: To find different factors that can affect the preservation of residual hearing in cochlear implant surgery and combined EAS.

Material and Methods: This study was carried out in Kasr Al-Aini Cairo University Hospital and Mafraq Hospital, Abu Dhabi, UAE where eight cochlear implants patients with residual hearing in the low frequencies were operated using the soft surgery technique aiming at preservation of their residual hearing. Patients with preserved postoperative hearing were subjected to EAS through simultaneous use of hearing aid and cochlear implants. Factors that can affect hearing preservation were determined. The results of combined electric acoustic hearing were also analyzed.

Results: Hearing could be preserved either partially or completely in 5 out of 8 patients (62.5%). Factors that were found to affect the outcome of hearing are site of cochleostomy, the local use of dexamethasone and the depth of electrode insertion. Combined EAS was tried in the 5 patients with postoperative residual hearing. Two patients showed increase in their word discrimination score (WDS) under combined EAS compared to cochlear implants only. Their mean residual hearing threshold should be below 62.5 dB in the 250 Hz and 500 Hz. The other three didn’t benefit from the combined EAS. Their mean residual hearing threshold was 80 dB in the 250 Hz and 500 Hz.

Conclusion: Hearing can be preserved through soft surgery technique. Patients can benefit from combined EAS in term of increased WDS compared to cochlear implants only.

Key Words: Hearing preservation – Cochlear implants – Soft surgery – Combined electric acoustic stimulation – Residual hearing.

Introduction

THE first thoughts for residual hearing preservation during cochlear implants (CI) surgery have to be credited to Lehnhardt who was the first to describe it in 1993 [1]. Through a specific technique named "soft surgery" he could preserve the residual hearing in three patients. The idea behind residual hearing preservation was to preserve as much of the sensory hearing structures inside the cochlea for better postoperative outcome [2]. This was followed by many publications showing the effectiveness of soft surgery in preservation of residual hearing [3-6]. However, there was no evidence that soft surgery is associated with improved patients’ performance even in patients with some residual hearing [7]. Thus the technique didn't gain wide acceptance until von Illberg et al., in 1999 published the concept of combined electroacoustic stimulation (EAS) of the auditory system [8]. They proved that in patients with residual hearing especially in low frequencies, combined stimulation using acoustic signals (via hearing aid) and electric signals (via cochlear implants) results in better performance than either mode alone. The acoustic hearing can be in the implanted ear or the contralateral ear. The aim of this study was to determine factors that can improve the rate of hearing preservation during cochlear implant surgery and the results of combined EAS of the auditory system.

Material and Methods

Eight cochlear implants candidates were recruited for this study. They were implanted between 2005 and 2008 in Kasr Al-Aini Hospital, Cairo, Egypt and Al-Mafraq Hospital, Abu Dhabi, UAE. Besides the routine preoperative evaluation, full audiological and language evaluation were done including aided and non-aided pure tone audiogram (PTA) and aided and non-aided words discrimination score (WDS) using monosyllabic phonetically balanced word list in audition only [9]. All patients were typical candidates for cochlear implants with severe to profound deafness at high frequency (≥1 kHz) and a variable degree of residual hearing in
low frequencies (<1 KHz). WDS in the best aided condition was 40% or less.

In case of asymmetrical PTA curves, the ears with worse hearing thresholds were chosen for implantation.

All patients were implanted with Nucleus® implant system (Cochlear Corp. Australia). Two patients were implanted with the Nucleus 24 system and the rest with Nucleus Freedom system. Regarding the electrodes design, one patient implanted with straight electrode and the rest with Contour Advanced (CA) electrode design.

Surgical technique:

The principles of soft surgery after Lehnhardt [1] and the added modifications published later by others were strictly followed during surgery [10,11, 12]. Preoperative prophylactic IV antibiotic (3rd generation cephalosporin) was given to the patients and also added to the irrigation solution that was used during bone drilling. IV corticosteroid (hydrocortisone) was also given prior to skin incision to increase the level of the drug in the perilymph prior to cochleostomy. The masto-oidectomy, posterior tympanotomy approach was used in all patients through a small postauricular skin incision. Care must be taken not to touch the ossicles to prevent acoustic trauma to the inner ear. The middle ear was approached via posterior tympanotomy which was made between the corda tympani and the facial nerve. The posterior tympanotomy was widened until the round window niche became visible. If the round window membrane (RWM) was not visible, the superior lip of the niche was drilled to expose the membrane. Then small gel foam pledge soaked with dexamethasone was placed over the membrane. The mucous membrane over the promontory was incised using a sharp needle and removed over the cochleostomy site. At this stage complete haemostasis must be ensured. If there was bleeding from the mucosal incision at the cochleostomy site, this could be controlled by placing a piece of gel foam soaked with adrenaline 1:100,000. Then cochleostomy began by flattening the promontory bone using low speed 1.4 mm diamond burr. The bone was removed slowly inferior and slightly anterior to the RWM. This site ensures opening the Scala tympani (ST) and avoids injury of spiral ligament and basilar membrane and/or entering scala vestibuli or scala media. All bone dust must be removed using copious irrigation. Drilling was continued until the fibrous layer that lines the Scala tympani (endosteal layer) became visible (Fig. 1). The cochleostomy was widened using the 1 mm and 0.6 mm diamond burr to the required size (1.2 mm for the CA electrode and 1 mm for the straight electrode). Efforts were given not to injure the fibrous layer during drilling to prevent bone dust and blood from entering the inner ear. Then a drop of dexamethasone was placed locally over the cochleostomy and left for a while to give chance for drug penetration then followed by a drop of hyaluronic acid (Helon®) to prevent entry of blood and bone dust into the ST and escape of perilymph (Fig. 2). A needle was used to open scala tympani through incision of the fibrous layer (Fig. 3). Suction was prohibited to prevent loss of perilymph. The electrode was introduced gently into the ST (Fig. 4). Care was taken not to contaminate the electrode with blood or bone dust. In case of straight electrode (one patient) insertion is done up to the first stiffening ring. The CA electrode was introduced up to the first (most distal) silicon rib (that equals approximately 17 mm of the electrode inside the cochlea) using the advanced off-stylet (AOS) technique except in two patients where it was inserted up to the third (most proximal) rib. After insertion, the array was stabilized at the cochleostomy by sealing with fascia or periosteum.

The AOS technique was designed and recommended by the manufacturer for non-traumatic introduction of the electrode array and avoidance of significant contact with the lateral wall of the cochlea. The CA electrode is a perimodiolar pre-curved electrode that is held straight before insertion by a metal stylet. The electrode is inserted firstly about 8.5 mm into the ST. This length is indicated by a white dot placed on the electrode. The half-band electrode contacts must be oriented toward the modiolus. At this point, the stylet is held still using a forceps and the silicon electrode carrier was pushed off the stylet so that it follows the curvature of the cochlea. After full insertion the stylet is removed completely to allow the electrode to take its pre-curved shape and perimodiolar position. This method minimizes the force against the outer lateral wall.

Postoperative care:

All patients were kept in the hospital for at least 5 days with IV antibiotics and IV dexamethasone. X-ray cochlear view was done before discharge to verify the proper electrode position [13].

The first CI programming session was done at least one month postoperatively to allow oedema over the implant site to subside. Then patients were allowed to use only CI for at least three months. Speech rehabilitation was started immediately after programming.
Fig. (1): The bone over the promontory is removed until the endost of the ST becomes exposed.

Fig. (2): Dexamethasone and Hyaluronic acid is placed over the endosteal layer.

Fig. (3): A needle is used to open the endosteal layer.

Fig. (4): The straight electrode is inserted gently into the cochlea.

After variable postoperative periods (6-12 months) patients were asked about their experience with CI compared to the preoperative HA in the implanted ear. They were retested regarding their residual hearing in the implanted ear and their WSD with the implant. Patients who still had residual hearing (6 patients) they were fitted with their hearing aids in the operated ear. A BTE speech processor was replaced temporarily with a body worn one. For combined EAS patient was given a new map (MAP 2) where low-frequency information is provided only via the hearing aid and only high frequency information by the CI. This was achieved by switching off the low-frequency channels and shifting the frequency-to-electrode allocation so that apical electrodes are in use. Patients were kept with the new setting (combined EAS with cochlear implant and ipsilateral hearing aid) for one month. Then the words speech discrimination was retested under EAS condition. Results were compared with CI only condition.

Results

Table (1) summarizes patient's data. There were eight patients; five males and three females. Age ranged from 7 years to 43 years with mean of 19 years.

The mean duration of deafness was 10 years and ranged from 3 years to 21 years. Preoperative PTA results showed variable degrees of residual hearing at low-frequencies (mean values at 250 Hz and 500 Hz ranged from 45 dB to 70 dB). All patients lost their hearing after language acquisition (postlingual) and have been managed early with powerful hearing aids and intensive speech rehabilitation. The mean preoperative monosyllable WDS in audition only was 16% and ranged from 8% to 28%.

In all patients no complications were recorded during hospital stay or after discharge. One child complained of pain over the implant's site that occurred after hours of continuous implant usage. It was found that the magnet was protruding a little and compressing over the skin that led to pain. The magnet was re-placed properly with no skin contact. This resulted in no more pain.

Postoperative x-ray cochlear view showed complete insertion of all active contacts and perimodiolar position of all CA electrodes.
Postoperative hearing test in the operated ear showed that three patients (37.5%) lost their preoperative hearing completely. Complete hearing preservation (shift of the postoperative hearing within 10 dB of the preoperative threshold) occurred in one patient (12.5%). The rest (four patients = 50%) had variable degrees of partial hearing preservation, thus the overall hearing preservation rate in this study was 62.5%. The mean preoperative/postoperative threshold differences at 250 Hz and 500 Hz in the 5 patients with hearing preservation was 17 dB and ranged from 5 dB to 35 dB.
All patients reported improved hearing with the cochlear implant compared to their preoperative experiences with hearing aids in the implanted ear. Postoperative WDS evaluation using the cochlear implants alone showed improved scores relative to the preoperative values with mean postoperative word discrimination score value which was 50.5% and ranged from 32% to 68% six to twelve months postoperatively. Combined EAS was tried in patients with postoperative residual hearing (five patients). It showed no benefits in term of improved WDS in three patients. Their residual hearing mean hearing threshold was 80 dB at 250 Hz and 500 Hz. In the remaining two patients the WDS increased 8% (patient number 4) and 12% (patient number 6) respectively under EAS condition compared to CI only condition. Their residual hearing mean hearing threshold was 62.5 dB at 250 Hz and 500 Hz.

Discussion

Cochlear implants can considerably improve speech discrimination scores in patients with bilateral profound perceptive deafness [14-16]. In this study cochlear implantation improved mean WDS from 16% to 50.5% within 6 to 12 months postoperatively. Due to improved technology of cochlear implants over the last decades, favorable outcome is now more predictable. Thus more patients with residual hearing are considered candidates for cochlear implantation [17].

Hearing preservation during cochlear implantation became possible since Lehnhardt described his original soft surgery technique in 1993 [1]. The technique has been recently revised and modified that resulted in more predictable outcomes and more hearing preservation rate that reached up to 86% in one study [10]. Four key elements were behind improved outcome of hearing preservation since its first description by Lehnhardt namely; improved electrode design, avoidance of deep insertion, change the site of cochleostomy and the use of local corticosteroids [18].

Recent years have witnessed huge advances in electrode design by CI manufactures aiming at the decrease of the trauma to the delicate intracochlear structure during insertion. Cochlear Corp. Australia has recently released the CA electrode and described the AOS technique as the recommended insertion technique to minimize intracochlear trauma. Independent temporal bone and clinical studies have proved the less traumatic nature of the electrode and the AOS technique [12,19,28]. Med-El Corp. Austria has also released a less traumatic electrode design for maximum hearing preservation named FLEXEAS which is softer, thinner and shorter than the standard electrode. Again independent studies proved the less traumatic nature and the more hearing preservation capability of the electrode [20,21]. In our study the Nucleus CA electrode and the ASO insertion technique were used in seven patients. In one patient the straight electrode was used. The sample size is small to conclude any differences in results based on electrode design.

Cochleostomy site can greatly influence the status of residual hearing. Incorrect cochleostomy site can place the electrode in scala vestibuli or scala media instead of scala tympani. This can result in trauma to the basilar membrane and spiral ligament which can affect negatively the residual hearing [22].

The original site described by Lehnhardt is anterior and slightly inferior to the RW niche [1]. This is also the site recommended by CI manufactures in their surgical manuals. In a survey done for North American cochlear implants surgeons about their preferred site for scala tympani cochleostomy, 20% selected cochleostomy location superior to the RWM [23]. Aschendorff et al., in 2005 using rotational tomography postoperatively discovered non-expected higher rates of scala vestibuli insertion when cochleostomy was done in the classic described site i.e. anterior and slightly inferior to the RWM [24]. Based on temporal bone studies, the ideal site of cochleostomy for a less traumatic scala tympani insertion has been found to be inferior and slightly anterior to the RWM [11, 22,25,26,27]. The technique described in this study followed these rules for cochleostomy site, i.e. drilling began inferior to the round window membrane and the cochleostomy was widened antero-inferior so that the final cochleostomy site was inferior and slightly anterior to the RWM. If the RWM was not visible, the bony overhang over the niche was drilled until the membrane became visible. The only exception was the first patient where cochleostomy was done anteriorly and slightly superior to the RWM. Hearing couldn't be preserved in this patient.

Glucocorticoids have been demonstrated through animal experimentation to reduce cochlear damage and loss of hearing that result after insults from exposure to ototoxic drugs, ischemia, mechanical trauma, and noise exposure [29-33]. In a recent study, the immediate and one month postoperative protective effect of dexamethasone against electrode insertion induced hearing loss
Another important factor for hearing preservation and decrease of the intracochlear trauma is to limit the length of electrode insertion to protect the apical region and the low frequency hearing from being damaged by the electrode. Aduka and Kiefer in 2006 studied the impact of insertion depth on intracochlear trauma in temporal bones [35]. They found that intracochlear trauma increases with deep insertions due to increase in insertion force. Insertion force greatly increased beyond insertion depths of about 18 mm to 20 mm. On the other hand shallow insertion may affect the performance in a negative way [36]. The insertion depth used in this study varied between 17 mm and 22 mm where 17 mm was considered an optimum depth for both hearing preservation and good performance [12]. In three patients hearing couldn’t be preserved. In the first patient (patient number one) analysis of the operative notes revealed three possible factors behind damage of residual hearing namely; relatively deep insertion, superior cochleostomy site and the non use of local corticosteroids. In the other two cases, deeper insertion of the CA electrode up to the third silicon rib (most proximal rib) may be the possible factor.

It is clear now that hearing preservation is possible either partial or complete through soft surgery technique. The hearing could be preserved in this study in 5 out of 8 patients (62.5%). Hearing preservation rates described in literatures varied from 44% to 86% when soft surgery principles was applied [5,6,12,18,37,38].

The impact of soft surgery and hearing preservation on postoperative performance was a matter of debate for long period. Proponents claim that through soft surgery technique, intracochlear hearing sensory structures are preserved and this prevents retrograde neuronal degenerations, thus higher numbers of spiral ganglion neurons are available for electrical stimulation. Also the intracochlear fibrosis and ossifications are decreased which can also responsible for long term favorable results [2,18]. On the other hand, opponents of soft surgery stated that assumption of improved postoperative performance with electric stimulation due to soft surgery is theoretical and never proven in a well controlled study [7]. In addition, there were reports that founded no correlation between spiral ganglion cell count or the amount of intracochlear new tissue formation and the postoperative performance [39-42].

The results of combined electric acoustic stimulation (EAS) were first published in 1999 [8]. In this technique, the low frequency information is delivered to the ear acoustically via hearing aids, while the mid and high frequency information are delivered electrically through cochlear implant. The results are improved speech discrimination especially in noise. Speech discrimination in noise constitutes a challenging task for cochlear implant patients. The importance is that such noisy environments constitute the every-day listening conditions faced by cochlear implants candidates.

Since its first description in 1999, many researches have published their results about EAS and demonstrated its positive impact on speech discrimination [5,6,12,18,38,43-52]. In our study the effect of combined EAS over WDS was successful in patients with mean hearing threshold around 60 dB in low frequencies and not successful in patients with their mean hearing threshold around 80 dB in low frequencies. This is in accordance with Kiefer et al., in 2005 who described that patients whom their postoperative residual hearing was better than 60 dB in low frequencies benefit of more than 70% improvement in the EAS mode as compared to cochlear implant alone [37]. On the other hand, Fraysse et al., 2006 found that patients with higher hearing threshold (up to 80 dB) can get benefit from combined EAS [12].

Conclusion:

Residual hearing preservation during cochlear implant surgery is possible in cases with residual low frequency hearing using soft surgery technique. Four key elements seem to play important role in improvement of hearing preservation rates during the recent years namely; improved electrode design, avoidance of deep insertion, cochleostomy inferior to the RWM and the use of local corticosteroids. Patients with preserved low frequency hearing (250 and 500 Hz) can benefit from combined EAS provided that the mean postoperative residual hearing threshold is less than 80 dB.

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