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Research Article

# Postoperative Systemic Corticosteroids and Hearing Preservation in Cochlear Implantation

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## Abstract

### Objective

To evaluate the effect of systemic postoperative steroids on residual hearing in patients who received a cochlear implant with a soft surgery technique.

### Study design

Retrospective case-control study.

### Setting

Academic tertiary care hospital.

### Patients

Forty-seven patients who had bilateral sensorineural hearing loss with pure-tone thresholds better than or equal to 75 dB HL in at least one of the 250, 500, 1000 Hz frequencies.

### Intervention

Cochlear implantation with soft surgery approach and receiving postoperative oral steroids 25 mg twice a day for 2 days.

### Main Outcome Measure

Difference of pre- and postoperative low frequency pure tone average (PTA), degree of hearing preservation compared in steroid and non-steroid group.

### Results

No significant effect of postoperative steroid use when compared pre and post low frequency PTA difference scores, 24.6 dB HL and 27.9 dB HL in steroid and non-steroid group respectively (p-value=0.5). We could preserve hearing in 85% (22/26) in steroid group and 76% (16/21) in non-steroid group. The difference was not statistically significant.

### Conclusions

Additional postoperative oral steroid did not affect the residual hearing in cochlear implantation candidates who had low frequency residual hearing.

**Key words:** Cochlear Implantation; Hearing Preservation; Corticosteroids

## Introduction

Hearing preservation has become a specific goal during cochlear implantation since the criteria have been expanded to include patients with insufficient benefit of conventional hearing aids and residual hearing [1-5]. Preservation of low-frequency hearing facilitates the application of electroacoustic stimulation (EAS), improved speech perception in background noise [6-8], increased music perception and appreciation [7,9-11]. From the literature we also know that preoperative residual hearing is a significant predictor of performance outcome [1,12,13].

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Soft surgery (with exact location of the cochleostomy at the scala tympani, preservation of the endosteum as long as possible and the use of Sodium hyaluronate) was developed as a technique to protect residual hearing [14]. In addition, electrodes have been revised to minimize trauma during intracochlear insertion [7,15]. Several studies have shown that the percentage of complete loss of residual hearing after cochlear implantation approximates 10-30% [8,16-18]. During insertion of the electrode, direct mechanical trauma to the structures of the inner ear may induce intracochlear inflammation, followed by oxidative stress-induced apoptosis of hair cells and auditory neurons [19,20]. Glucocorticoids can be applied during surgery to protect residual hearing by their anti-inflammatory and anti-apoptotic properties [21]. They may be administered locally or systemically.

Animal experiments have demonstrated that the application of systemic steroids protects hearing during cochlear implantation [22,23]. So far, only one study in human mentioned the use of intravenous high dose prednisolone and local triamcinolone as being part of the surgical procedure. This resulted in a successful preservation of hearing in 12 out of 14 patients (80%) [17]. Also a limited number of other studies advocate the use of corticosteroids during surgery, some in combination with postoperative corticosteroids [24].

In our tertiary care hospital, all of our patients receive a high-dose of methylprednisolone during surgery when preservation of cochlear and/or vestibular function is relevant. In addition, due to the personal preference of some surgeons and inspired by results of animal studies [23], numerous patients also received 25 mg prednisolone twice a day for two days postoperatively.

The present study aims to evaluate the effect of the administration of systemic post-operative steroids on residual hearing in patients who underwent cochlear implantation with a soft-surgery approach.

## Patients and Methods

### Patients

Fifty patients were selected from the database of the Hearing & Implants Centre at the Radboud university medical center in Nijmegen. They received their cochlear implant between January, 2011 and December, 2012. All patients had pre-operatively a severe hearing loss and met the criteria for cochlear implantation. To be included in this study there had to be a bilateral sensorineural hearing loss with pure-tone thresholds better than or equal to 75 dB HL in at least one of the 250, 500 or 1000 Hz frequencies. Patients selected for this study received a Nucleus freedom (contour advance), Nucleus CI422 (Cochlear), HiRes 90K (Advanced Bionics), Concerto Flex 28 and Flex soft (Med-El). Of the 50 patients we selected, three patients were excluded: one patient had diabetes mellitus and in two other patients exact information on the use of postoperative steroids was lacking.

### Surgery

Cochlear implantations were performed by four experienced otologic surgeons. The surgical procedure comprised a postauricular incision, mastoidectomy and posterior tympanotomy. The facial recess was opened, wide enough to clearly see the round window niche. Standard, a soft surgery approach was used to prevent cochlear trauma. At least thirty minutes before opening the cochlea, 1.8 mg/kg of methylprednisolone was administrated intravenously. The cochleostomy was performed antero-inferior to the round window membrane using a 1.2 mm diamond burr. The endosteum of the cochlea was opened with a sharp needle in most cases. There were five patients in which the electrode was inserted through round window (one with Concerto flex soft electrode from Med-El and the others with CI422 from Cochlear). After opening the endosteum of the cochlea or round window membrane, suctioning of perilymph was avoided and hyaluronic acid was placed over the cochlear opening to lubricate the electrode array and to prevent blood or bone dust entering the cochlea. After insertion of the electrode array into the cochlea, the cochleostomy was sealed with periosteum and fibrin glue to prevent leakage of perilymphatic fluid. Patients in the 'post operative steroid group' received prednisolone 25 mg twice a day in 2 postoperative days.

### Audiometry

Audiometry was performed by using a standard audiometer (Interacoustics AC40) with TDH49-P headphones and a maximal audiometric output of 120 dB HL in all frequencies. Audiometric data comprised unaided pure-tone air perceptual hearing thresholds. Pre- and postoperative thresholds from 250 to 8000 Hz were measured with appropriate masking (there were no air-bone gaps in our patients). The preoperative low-frequency pure tone average (PTA) at 250, 500, 1000 Hz was calculated and compared to the audiometric data obtained 7 weeks in average (range 4-12 weeks) after operation (called "difference of PTA" or "PTA loss"). The data were reported as mean (+/- standard deviation) and were analyzed with GraphPad Prism (version 6.0). The difference of PTA was categorized to complete hearing preservation (0-10 dB), partial preservation (11-40 dB) and no preservation (>40dB).

## Results

Of the 47 patients included, 31 were female and 16 were male. The mean age was 57 years with a range of 27 to 80 years. There was a mean preoperative low frequency PTA of 78.4 dB HL (SD=10.2 dB HL) and a postoperative PTA of 104.5 dB HL (SD=13.8 dB HL) and a mean PTA difference (PTA loss) of 26.1 dB HL (SD=13.8 dB HL) in Table 1. There was no difference in age and pre-operative PTA between the 'post-op-steroid' and 'post-op-non-steroid' group.

**Table 1.** Study characteristics and low frequency PTA loss in steroids and non-steroids group.

| | Post-operative | |
|---|---|---|
| | steroids | non-steroids |
| N = | 26 | 21 |
| Male/Female | 8/18 | 8/13 |
| mean age [years] | 58 | 56 |
| range [years] | 27-80 | 33-78 |
| mean pre-op low PTA [dB] | 79 | 77 |
| range [dB] | 58-95 | 50-98 |
| Stand Dev | 9.2 | 10.9 |
| mean post-op low PTA [dB] | 103.8 | 105.2 |
| range [dB] | 65-122 | 77-122 |
| Stand Dev | 13.5 | 13.8 |
| mean PTA loss [dB] | 24.6 | 27.9 |
| range [dB] | 0-45 | 5-58 |
| Stand Dev | 12.5 | 14.9 |

Residual hearing deteriorated in both groups. No difference was seen between the steroids and non-steroids group. (Figure 1)

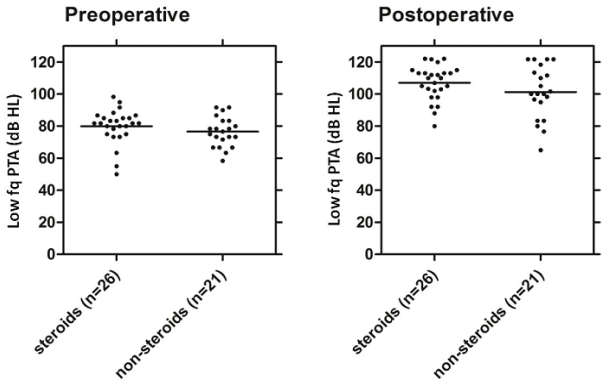


**FIG 1.** Pre and post- operative low frequency PTA in steroid and non-steroid group.

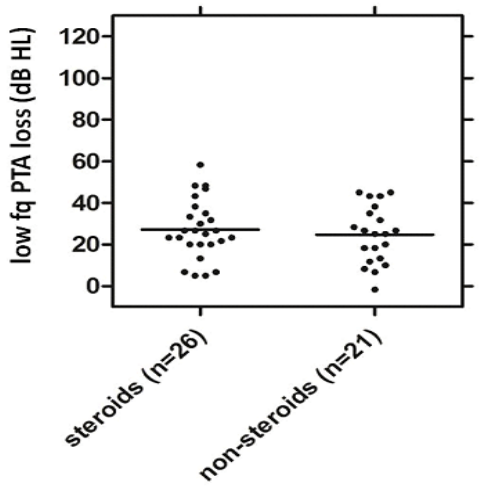


**Figure 2.** Pre- and postoperative low frequency PTA loss in steroids and non-steroids group.

We found no significant effect of post-operative steroid use when calculating the pre and post low frequency PTA difference scores (see Figure 2). The mean PTA difference was 24.6 dB HL in the group that received steroids and 27.9 dB HL in the group that did not receive steroids (paired t-test; p-value=0.5).

The PTA loss is shown for each frequency in figure 3. When comparing the steroid with the non-steroid hearing loss for 250 Hz, 500 Hz and 1000 Hz respectively, p-values were 0.82, 0.55 and 0.47. No significant difference was found.

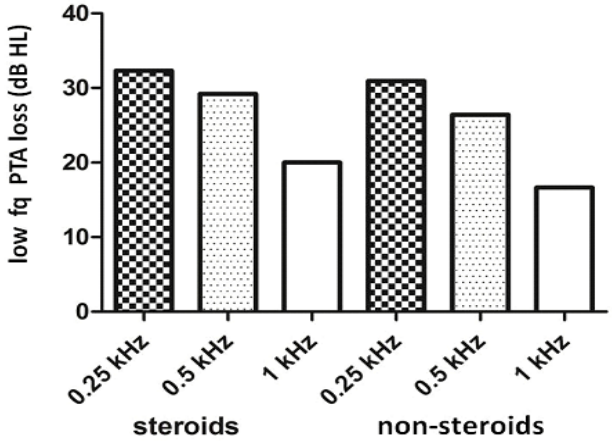


**Figure 3.** Postoperative PTA loss in each frequency between steroids and non-steroids group

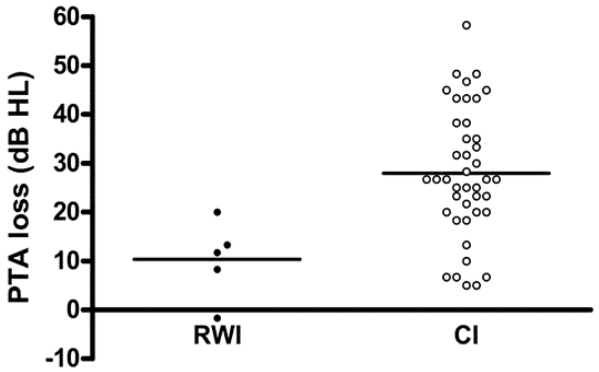


**Figure 4.** Comparison PTA loss between round window and cochleostomy insertion of electrode.

Complete hearing preservation (difference of PTA ≤ 10 dB HL) was achieved in 8/47 patients (17%), partial preservation (difference of PTA 11-40 dB HL) was seen in 30/47 patients (64%) and complete loss of residual hearing (difference of PTA >40 dB HL) was observed in 9/47 patients (19%). However 4/26 patients (15%) in the postoperative steroid group and 5/21 (24%) in the non-steroid group lost the residual hearing completely. The overall conservation of hearing was 81% (Table 2).

In patients who the electrode were inserted through round the window (RWI), we found a significantly better preservation of hearing in comparison to the cochleostomy group (paired t-test; p-value<0.05) (figure 4).

Most of the devices used for the round window insertion were a Nucleus CI422.

A Nucleus CI422 was used 4 times in the round window insertion group and 3 times in the cochleostomy group. No difference in low PTA loss was found between these (small) groups.

Figure 5 describes the correlation between preoperative pure tone average and the postoperative PTA loss. The general trend is the better the preoperative PTA, the more is postoperative loss.

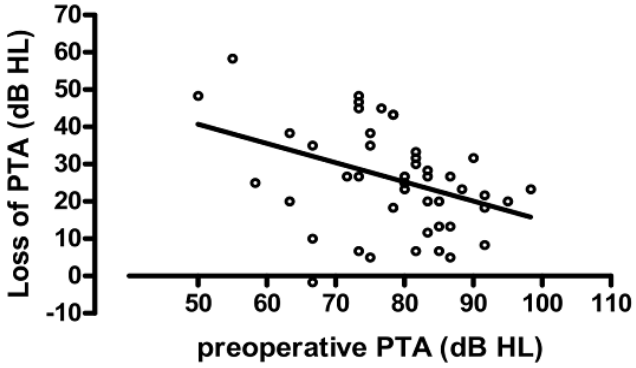


**Figure 5.** The correlation of preoperative pure tone average and the PTA loss.

## Discussion

In this study we could not find a difference in hearing preservation between the post-operative steroid and non steroid group, neither in low frequency PTA nor in separate low frequencies. Since it is known that residual hearing can be maintained in a number of patients after cochlear implantation with conventional/long electrodes, studies have been undertaken to identify the factors that are responsible for this phenomenon. Except for a soft surgery technique, newer types of a-traumatic electrode arrays and the prolonged use of antibiotics, also the effect of corticosteroids on hearing preservation has been evaluated the last decade.

Up till now the main conclusion is that the pre/intra-operative use of corticosteroids and the use of steroid-eluting electrode arrays may result in partial or complete hearing preservation. It seems that local steroids are more effective than systemic steroids but most of these studies however have been done on animals, mainly guinea pigs and gerbils [22-23, 25-28]. The number of human studies on hearing preservation and corticosteroids is still very limited. A few studies describe the use of intraoperatvie systemic steroids alone [16,24] and four other papers report on intraoperative steroids in combination with intratympanic or postoperative corticosteroids [17, 24, 29-30]. In our study, which is to our knowledge the first comparative study ever on this subject, 1.8 mg/kg methylprednisolone was intravenously administrated at least thirty minutes before cochleostomy. In this way we could preserve the residual hearing in 16/21 patients (76%). In the group we additionally prescribed 50 mg of oral prednisolone for 2 postoperative days, the hearing was preserved 22/26 patients (85%). Although it seems that the postoperatively treated group has a better outcome, the difference is not statistically significant. Whether this is due to an insufficient dose or to an insufficient time of administration is not clear. As we calculated the equivalent dose [31], 50 mg prednisolone was apparently lower than the effective dose from experimental study [27]. On the other hand, we should be careful of the adverse effect of high dose steroid even prescribed for short duration.

In the whole group, complete hearing preservation after soft surgery cochlear implantation was seen in 1 out of 6 recipients and partial preservation in 4 out of 6. Although these results are a little unfavourable compared to those in literature [32], three remarks can be made. Firstly the definition of hearing preservation is not unique. Most of the studies agree on the term complete hearing preservation (<10 dB difference with the preoperative threshold) but the definition of partial preservation differs (between 10 – 20 dB, between 10-40 dB or as a percentage of the preoperative hearing). Moreover the evaluated frequencies also differ. We are dependent on our own audiograms and therefore 750 Hz and 3000 Hz are frequencies which are normally not evaluated. The last point regarding the measurement of hearing preservation is the follow up time. We have evaluated our patients after a mean of 7 weeks (range 4-12 weeks). Long term hearing outcomes obviously may influence the final outcome.

In our study, there were 9 patients (19%) with a complete loss of residual hearing. This percentage is comparable to the those reported before in the literature [8, 16-18].

In 5 patients in which the electrode was inserted through round window membrane, one patient received a Concerto Flex Soft model and did not get postoperative steroids, the others received CI422 and all got postoperative 50 mg of prednisolone for 2 days. Comparing the PTA loss of these patients with the patients who had an insertion after creating a cochleostomy, we found a significant difference in hearing preservation in the round window approach's group (p-value <0.05) (Figure 4). Round window insertion possibly provides less mechanical trauma from drilling and noise-induced hearing loss. Moreover histological studies conclude that the round window insertion minimize initial intracochlear trauma and new tissue formation compared with cochleostomy insertion [33]. On the other hand, from a systematic review, there was no clinical study directly showing a benefit of round

window insertion over cochleostomy [34]. On the contrary, even a recent meta-analysis on hearing preservation in cochlear implantation [32] stated that a cochleostomy is associated with better hearing preservation in comparison to the round window approach.

Looking more carefully to our data, we also compared hearing preservation with the same small electrode (Nucleus CI422) applied through the round window membrane (n=4) and through a cochleostomy approach (n=3) and could not find a statistically significant difference (p=0.46). So the significant better results of the round window applications may be due to the implant device rather that to the insertion technique because a Nucleus CI422 tends to do also better after cochleostomy insertion. In summary, obviously the number of our patients in which a RWI was applied is too small to draw any conclusions regarding the difference in hearing preservation in relation to the cochleostomy approach.

We also found that the more residual hearing the patient had, the more hearing loss occurred after implantation (Figure 5); lower frequencies seemed to be more prone to deterioration than the higher frequencies. We think that this is more a biased phenomenon than that it can be explained from pathophysiology. We selected cochlear implant candidates with a residual hearing (i.e. in the lower frequencies): in the higher frequencies the hearing was very limited or absent. It is obvious that when you have little hearing left, you have little to lose.

One of the limitations of this paper is that it concerns a retrospective study. As a result we were not able to control some influencing variables e.g. cochlear implant device model, surgical insertion technique or postoperative corticosteroid administration. Furthermore, we did not go into the postoperative speech performance of these patients. Overall the sample size in our study is quite small, especially when we consider the variability in cochlear implant model.
These are shortcomings that will be dealt with in a future study. Obviously a prospective study will eliminate a number of these disadvantages.

## Conclusion

Based on these findings we concluded that the additional postoperative prednisolone, 25mg twice a day for 2 days, did not affect the residual hearing. The data suggest that we will stop prescribing the postoperative prednisolone at this dose and time-interval. Otherwise we will continue the administration of intra-operative methylprednisolone.

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