

Review Article

# Electrode selection for hearing preservation in cochlear implantation: A review of the evidence



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## KEYWORDS

Electrode;  
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**Abstract** *Objective:* To review and assess the ideal length of electrode in cochlear implant patients for hearing preservation.

*Methods:* The English language literature was reviewed for studies including hearing preservation and speech understanding for electrodes of different lengths.

*Results:* One prospective trial was found, and there were no studies that randomized patients into different length electrodes with an intent to preserve hearing. Eight studies total included multiple length electrodes and contained data regarding hearing preservation.

*Conclusions:* Although there is some evidence that indicates that shorter electrodes may improve both short and long-term hearing preservation rates in cochlear implant patients, no study has directly compared implant length on hearing preservation in a similar patient population. A randomized trial of short and standard length electrodes for hearing preservation is warranted. In the interim, utilization of current electrodes measuring 20–25 mm could seem to be a prudent approach when seeking to preserve residual hearing without unduly compromising cochlear coverage.

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## Introduction

With improvements in cochlear implant technology and surgical techniques, patients are being implanted with increasing amounts of residual hearing. It is widely accepted that patients with sufficient residual hearing to allow for both electric and acoustic amplification perform better than those using electric-only stimulation.<sup>1</sup>

Hearing loss can occur at the time of surgery due to physical damage, as well as over time secondary to a chronic inflammatory response.<sup>2,3</sup> A significant amount of research has been conducted to address the hearing impact at the time of surgery, and to determine the best electrodes and surgical techniques to maximize the amount of residual hearing following implantation.

Some have advocated the use of shortened electrodes to reduce cochlear damage at the time of surgery as they would theoretically cause less damage to the healthy (low frequency) portion of the cochlea, and in fact several electrodes have been produced specifically for this reason. The use of shortened electrodes, however raises several issues. For example, the patient is a candidate for implantation due a significant, and most likely progressive, hearing loss. There is no reason to suspect that implantation would arrest whatever process has caused the hearing loss.

Therefore, even if the surgery and subsequent foreign body reaction caused no additional losses, the patient's hearing might continue to deteriorate to the point that bimodal amplification was no longer possible. In fact, it has been shown that ipsilateral progressive hearing loss is common following implantation and progresses faster than it would be expected to without implantation.<sup>4,5</sup> At this point, a patient would be relying entirely on electrical stimulation and there is evidence to suggest that patients who have lost their residual hearing perform less well with a shorter electrode.<sup>6</sup> Another study looked at outcomes following reimplantation with a standard length electrode after initial implantation with a shortened electrode and found improved speech understanding outcomes.<sup>7</sup>

The first electrodes designed specifically for hearing preservation were based on the Nucleus CI-24, included 6 electrodes, and were designed in 6 mm and 10 mm lengths.<sup>8</sup> More recent hearing preservation electrodes include the FLEX series by Med-El, and the Hybrid L24 by Cochlear Corporation.<sup>9</sup> The FLEX electrodes come in lengths from 20 to 31.5 mm, all have 19 electrodes with the distal electrodes unpaired to allow for a narrow, more flexible tip. The L24 is 16 mm long with optimal insertion angle of 250° and contains 22 electrodes. The Cochlear CI422/522 electrode is a 25 mm slim-straight electrode with 22 electrodes designed to minimize damage to intracochlear structures during insertion via the round window technique. This electrode can be fully or partially inserted.

This study aims to review the available literature on both hearing preservation and audiological outcomes based on electrode length in cochlear implantation of patients with residual hearing.

## Methods

The English language literature was searched for articles reporting hearing preservation outcomes following cochlear implantation. The primary articles of interest were those that reported outcomes from electrodes of different lengths in a single study.

## Results

There was only one prospective trial found, and there were no studies that randomized patients into different length electrodes with an intent to preserve hearing. The studies below represent those where comparison of electrodes of different lengths could be made.

Most recently, Suhling et al<sup>10</sup> investigated the hearing preservation rates with three different lengths of the Med-El Thin Flexible Electrode Array (TFEA): 20, 24, and 28 mm. Although hearing preservation rates were worse with increasing length of the electrode, the choice of electrode length was not randomized: "Subjects with normal low-frequency hearing thresholds received a short electrode in our study. Subjects with moderate to severe low-frequency HL received a longer electrode". Median hearing loss was 17.5, 20, and 24 dB for the TFEA20, TFEA24, and TFEA28, respectively at activation versus pre-operative testing. Additionally, hearing loss was stable at one year for the TFEA20 and TFEA24, but increased to 32.5 dB for the TFEA28. The percentage of patients that remained in the "good hearing preservation" group (<15 dB hearing loss) was 48.8%, 50%, and 15.8% at one year for the TFEA20, TFEA24, and TFEA28, respectively.

A 2015 study by Friedmann et al<sup>6</sup> found that there was a significant improvement in the rates of hearing preservation for subjects receiving the Cochlear L24 electrode versus the CI422 (70% vs 42%). However, in those subjects that lost residual hearing, there were much better speech understanding scores in the CI422 group (72% vs 15%).

A 2014 paper compared the hearing preservation outcomes of the Cochlear Hybrid L24 and the CI422 electrodes in 197 patients.<sup>11</sup> Subjects were not randomized between electrodes, but were assigned based on residual hearing present at the time of evaluation for implantation. Patients with the shorter L24 electrode showed decreased initial change in hearing as well as more stable hearing over time. The percentage of subjects with <15 dB hearing loss increased from 56.9% to 58.8% for the L24, and 21.4% to 28.6% for the CI422 group between activation and 24 months follow-up. However, the percentage of subjects with >30 dB hearing loss increased from 9.8% to 23.3% for the L24 group, and from 25.0% to 39.3% for the CI422 group over the same time period.

Cosetti et al<sup>12</sup> retrospectively reported all subjects at a single center that were implanted with any preoperative detectable hearing. Electrodes included the Nucleus Freedom and 512 as well as the Advanced Bionics HiFocus 1J with reportedly full insertions in all cases. An overall hearing preservation rate of 29% was found, however no correlation was found between residual hearing and speech understanding testing. Electrode type was not predictive of

hearing preservation, and the only patient factor that correlated with improved hearing preservation was younger age. Preservation rates were lower at one year than at three months of follow up.

A 2013 report compared the Nucleus Contour Advance, Nucleus Hybrid-L, and MED-EL Flex-EAS electrodes in 32 ears.<sup>13</sup> Hearing preservation (<30 dB change) was found to be 84%, 50%, and 50% for the Hybrid-L, Contour Advance, and Flex-EAS, respectively. Overall hearing did not change significantly between three months and one year of follow up, however two patients had sudden loss in the Hybrid-L group. The only subject with complete hearing loss was in the Contour Advance group.

In 2012, Radeloff et al<sup>14</sup> reported outcomes from four patients receiving the MED-EL Flex-soft, and two receiving Flex-EAS 20 — all with full insertion. All patients implanted with the Flex-soft lost all residual hearing, while one patient implanted with the shorted electrode had partial preservation and one had complete preservation.

In a review of patients included in their Flex-EAS study (20 mm electrode), Adunka et al<sup>15</sup> compared outcomes of 10 of these patients, to 10 matched patients with who had received a conventional (31 mm) electrode. They found no difference in speech outcomes in the electric only condition, but improved outcomes in the hearing preservation group that could utilize EAS.

Gantz and Turner<sup>8</sup> reported the first trial of electrodes designed specifically for hearing preservation in 2003. They implanted three patients each with a 6 or 10 mm electrode. Although audiologic data was not reported, it was noted that the patients receiving the 10 mm electrode showed significantly benefit over those receiving the 6 mm electrode.

## Discussion

There has been a significant amount of interest in determining an optimal electrode design for hearing preservation cochlear implantation. Anatomic studies have found increased cochlear damage with increased depth of insertion, and clinical studies have shown that increasing depth of insertion may result in worse hearing preservation rates.<sup>3,10,11</sup> However, there is no insertion depth that can guarantee preservation of hearing, thus, the benefits of increased chances of hearing preservation must be weighed against the evidence that increased cochlear coverage leads to better speech recognition scores.<sup>16</sup>

A prospective randomized trial evaluating speech understanding outcomes was reported by Buchman et al<sup>17</sup> in 2014. Patients were randomized to receive either a standard (26.4 mm) or medium (20.9 mm) length electrode array. This was not a hearing preservation trial and subjects were those that met standard cochlear implant qualifications. The trial was stopped early as the subjects with the standard length electrodes showed superior performance. This difference became significant upon retrospective review of standard length electrode recipients.

A recent meta-analysis found that increased insertion angle did correlate with worse low frequency hearing preservation, and found that the shortest electrode included for analysis (MedEL Flex 24) had the best

preservation rates.<sup>18</sup> In their discussion, however the authors caution against making the assumption that the shortest electrode is necessarily best, as the longest did not have the worst hearing outcomes. A second meta-analysis found no difference in hearing preservation based on length of electrode or electrode design.<sup>19</sup> The authors do mention that despite this finding there is no support in the literature for full insertion of full length electrodes in the setting of intended hearing preservation. Comparison of data between trials is problematic, however, as there is variability in inclusion criteria, methods for calculating the changes in hearing levels, and even definitions of “hearing preservation”.<sup>19,20</sup> Several authors have proposed standardization of hearing preservation reported, however, to date there remains much variability in the literature.<sup>21</sup>

Studies for slim-straight electrodes from both Med-El and Cochlear have found acceptable hearing preservation rates and post-operative speech understanding scores in the medium length range (20–25 mm).<sup>10,22</sup> This may represent a “sweet spot” for balancing cochlear trauma with cochlear coverage.

Hearing preservation with long electrodes is possible, albeit likely at lower rates than with shorter electrodes.<sup>20,23,24</sup> The increased risk of loss of residual hearing must be balanced, however with the poorer outcomes in electric-only stimulation with limited cochlear coverage. There is no clear “ideal” electrode length at this time, and it will likely depend on the individual anatomic features of the cochlea being implanted, the amount of residual hearing, the etiology of hearing loss, as well as numerous other patient factors that continue to be elucidated.

## Conclusions

Although there is some evidence that indicates that shorter electrodes may improve both short and long-term hearing preservation rates in cochlear implant patients, no study has directly compared implant length on hearing preservation in a similar patient population. We propose that given that the existing data does not point clearly to a direct inverse relationship between electrode length and hearing preservation, and that longer electrodes have shown improved outcomes in those where EAS is not possible, a randomized trial of short and standard length electrodes for hearing preservation is warranted. In the interim, utilization of current electrodes measuring 20–25 mm could seem to be a prudent approach when seeking to preserve residual hearing without unduly compromising cochlear coverage.

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