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Revision Surgery Following Minimally Invasive Image-Guided Cochlear Implantation

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Abstract

Minimally invasive image-guided cochlear implantation (CI) research continues to progress. We previously performed the procedure in nine patients. Herein, we describe the first revision operation for device failure following minimally invasive image-guided CI. It was possible to re-use the original drill channel, obviating the need to convert to a wide-field mastoidectomy. Revision surgery, if required, can therefore be performed safely after minimally invasive image-guided CI.

Keywords

Minimally invasive; image-guided surgery; cochlear implantation; percutaneous cochlear implantation

Introduction

Cochlear implantation (CI) has become a widespread intervention for hearing-impaired patients across the globe. In the United States alone, the procedure had been performed in roughly 96,000 patients as of December 2012 (the most recent numbers reported by the Food and Drug Administration)¹, but most in the field believe the number of recipients within the US is at least 200,000 and growing. The procedure traditionally involves mastoidectomy with a facial recess approach to facilitate access to the cochlea via the round

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Conflicts of Interest:

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window or a separate cochleostomy. The wide-field approach is advocated to identify and avoid vital anatomy and allow insertion of the electrode array.

Minimally invasive approaches have been described for CI including, perhaps most notably, the suprameatal approach^{2,3}, but image-guided approaches through the facial recess have also been described. Proponents cite potential benefits including less tissue dissection, more precise alignment of insertion vector, and standardization of the surgical procedure. Challengers cite limited field of exposure making identification of anatomy more difficult and potentially making revision operations more difficult. Given that failure rates for CI are small but not insignificant at approximately 3.8%^{4,5}, CI failure and revision surgery are likely to be encountered with minimally invasive approaches.

In 2014, our lab reported the first ever use of a minimally invasive image-guided approach for routine CI using techniques we developed over the prior decade⁶⁻⁹. Since that time, other groups have developed similar techniques and incorporated the use of robotic rather than manual drilling techniques^{10,11}. Nine patients were included in the cohort we initially reported⁶. Herein, we update that experience with the first description of a revision operation for a device failure in a patient who originally underwent minimally invasive image-guided CI.

Case Report

A male patient in his fifth decade of life had a history of bilateral sensorineural hearing loss meeting FDA audiologic criteria for CI, with best aided performance for open-set sentence recognition less than 60% correct. In 2012, he underwent CI on the left side, his worse-hearing ear, with a MED-EL CONCERT with medium length electrode array (24mm; MED-EL, Innsbruck, Austria). This was performed by the senior author (RFL) using the minimally invasive image-guided method we previously described⁶ in which a custom microstereotatic frame was created to constrain a drill to a specified path through the facial recess. This provided access to the round window without the need for traditional mastoidectomy.

The operation had no complications, and the cochlear implant was activated on postoperative day one. The patient returned to work as a physical therapist two days after surgery. Postoperative computed tomography (CT) scan showed an angular insertion depth of 591°. The patient derived excellent benefit from the device with postoperative hearing sensitivity in the normal to mild hearing loss range. His AzBio sentence recognition score in quiet¹² improved from 2% preoperatively to 48% at 12 days postoperatively with the CI alone and then to 96% at one year. Unfortunately, the patient's device failed roughly five years postoperatively for unknown reasons. Speech recognition worsened and high impedances were noted from 4 of 12 electrodes (electrodes 1, 4, 5, and 10). Integrity testing was performed by the device manufacturer and replacement was recommended.

Revision surgery was performed by the same surgeon six years after the original minimally invasive CI. The surgeon recommended a wide-field revision with traditional mastoidectomy because replacement through the existing drill channel was thought to be impossible due to

scar formation. The patient, however, was adamant about attempting a minimally invasive approach given his desire to maintain his mastoid contour, be activated as soon as possible, and have as little down time as possible.

Intraoperatively, after the postauricular incision was made, the transmitting wires from the internal receiver were followed, intact, to the existing minimally invasive drill channel. The middle ear was entered by lifting the skin of the posterior external auditory canal (EAC) forward. The old electrode array was found to be fully inserted with the distal rib of the array seated in the extended round window cochleostomy. The old array was intentionally transected in the middle ear to allow removal of the internal receiver and the transmitting wires without dislodging the intracochlear electrode array. The internal receiver and transmitting wires, while not recessed below the surface of the bone, were covered by soft tissue and without evidence of damage. The existing minimally invasive drill channel traveling from the mastoid surface to the middle ear was found to be lined with soft tissue creating a pseudo-capsule tunnel. The CI test electrode/insertion depth gauge was passed into this tunnel and slid easily into the middle ear and targeted the round window.

Given this fortuitous intraoperative finding, a decision was made to attempt reinsertion via this route. The new implant, a MED-EL SYNCHRONY with medium length electrode array (24mm), was opened and secured in the prior subtemporalis pocket with good fit given similar footprint. The new array was manually threaded through the pseudo-capsule tunnel until it exited the tunnel and into the middle ear. Next, the existing electrode array was grasped with a side-grasping cupped forceps and removed from the cochlea. Following this, the distal transmitting wire of the replacement cochlear implant was grasped at the surface of the mastoid with an angled CI forceps and slowly advanced directly into the cochlea (without the need for any instrumentation in the middle ear) until complete insertion to the distal rib was achieved. No resistance was encountered. Figure 1 illustrates the new electrode array entering the mastoid via the previously drilled tunnel and also shows the electrode emerging from the tunnel into the middle ear. (A video demonstrating this insertion is available online as supplemental material.) The transmitting wire was placed into the soft tissue groove on the surface of the mastoid created from the prior implant, and soft tissue was mobilized and secured over the electrode array to hold it in this groove. The wound was closed in layers and the skin of the EAC and tympanic membrane repositioned and held in place by filling the EAC with mupirocin ointment.

Electrically-evoked compound action potentials were measured intraoperatively and found to be excellent at all recording electrode pairs. Impedances were normal. Intraoperative CT scan was obtained (XCAT, Xoran Technologies LLC, Ann Arbor, MI) and showed an angular insertion depth of 584°. The automated methods we have previously described allowed rapid segmentation of the postoperative scan, allowing review of electrode positioning and confirmation of full scala tympani insertion without tip fold-over (see Figure 2). No clear etiology for failure of the original device was identified during the revision operation, and the original implant was sent to the company for further investigation. The patient's device was activated on postoperative day one, and AzBio sentence score in quiet was 82% with the CI alone. The patient returned to work four days after the operation.

Discussion

It appears likely that minimally invasive CI will continued to be pursued. With a 3.8% cumulative failure rate for CI devices^{4,5}, revision surgery for minimally invasive approaches will also likely have to be undertaken. We describe herein our experience with a revision operation in a patient who originally underwent minimally invasive image-guided CI six years prior. This is the first description of such an operation in the literature. It is perhaps even more noteworthy given that the surgeon, who had performed the original minimally invasive approach, anticipated that the revision operation would require conversion to a traditional wide-field mastoidectomy. The patient repeatedly requested that the minimally invasive drill channel be used given his desire to avoid the mastoid depression and to be activated on postoperative day one with a quick return to work. The intraoperative findings were surprising even to the surgeon who performed the first minimally invasive approach. By reinserting via the tissue-lined tunnel, operative time was decreased and damage to vital tissue (e.g. the facial nerve) was minimized. The medium length lateral wall electrode array was fully inserted into scala tympani to an angular insertion depth of 584°, which compares favorably to the original depth of 591°.

Notably, the CI did not appear to have suffered any long-term damage from the minimally invasive approach. The transmitting wire located on the surface of the mastoid was without gross damage. The bony tunnel was preserved over the six intervening years and had become lined with soft tissue. The electrode array could be easily withdrawn through the drill channel, and a new array inserted through this same passage.

Conclusion

Minimally invasive image-guided CI research continues to progress. We have previously demonstrated that the procedure can be performed safely, and we update our experience herein with the description of a revision operation for a device failure. If required, revision surgery can safely be performed after minimally invasive image-guided CI. We show here that it is possible in at least one case to re-use the original drill channel, obviating the need to convert to a wide-field mastoidectomy.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1.

In the left panel, the new electrode array is seen entering the mastoid at the drill channel. At the top of the image, the electrode array is seen emerging from the drill channel into the middle ear space. The middle ear portion is illustrated in the right panel. (Better visualized in video available online as supplemental material.)

Figure 2.

3D reconstructions of new electrode array entering the cochlea. The array was positioned entirely within the scala tympani with an angular insertion depth of 584° . Scala tympani is shown in green, scala vestibuli in blue, modiolus in yellow (colored image available online). The electrode is depicted in gray on top and in red in the three images along the bottom.