Robotic cochlear implantation in post-meningitis ossified cochlea

Al Saadi, Mohammad; Heuninck, Emilie; De Raeve, Leo; Van de Heyning, Paul; Topsakal, Vedat

Published in:
American journal of otolaryngology

DOI:
10.1016/j.amjoto.2022.103668

Publication date:
2023

Citation for published version (APA):
Al Saadi, M., Heuninck, E., De Raeve, L., Van de Heyning, P., & Topsakal, V. (2023). Robotic cochlear implantation in post-meningitis ossified cochlea. *American journal of otolaryngology*, *44*(1), [103668]. https://doi.org/10.1016/j.amjoto.2022.103668

Robotic Cochlear Implantation in Post-Meningitis ossified Cochlea

Running head: ROBOTIC IMPLANTATION IN OSSIFIED COCHLEA

Mohammad Al Saadi[1], Emilie Heuninck [1], Leo De Raeve[2], Paul Van de Heyning[3], Vedat Topsakal[1]

[1] Vrije Universiteit Brussel (VUB), Universitair Ziekenhuis Brussel (UZ Brussel), Department of Otolaryngology Head and Neck surgery, Laarbeeklaan 101, Brussels Health Campus, 1090 Brussels, Belgium.

[2] ONICI, Independent Information Centre on Cochlear Implantation, Waardstraat 9, 3520 Zonhoven, Belgium

[3] Antwerp University Hospital, Department of Otolaryngology Head and Neck Surgery, University of Antwerp, 2650 Antwerp, Belgium.

Correspondence author:

Mohammad Al Saadi, **M.D.**

Universitair Ziekenhuis Brussel (UZ Brussel)

Laarbeeklaan 101, 1090 Brussels, Belgium

Email: moalsaadi@msn.com

Orcid: 0000-0003-0285-2349

Tel: +32 2 477 6882

Fax: +32 2 4776880

Conflict of interest: The authors declare no conflict of interest.

Funding: This study did not receive any specific grant from the public, commercial, or not-for-profit funding agencies.

Abstract

Aim: To report the experience of an image-guided and navigation-based robot arm as an assistive surgical tool for cochlear implantation in a case with a labyrinthitis ossificans.

Patient: A 55-years-old man with a history of childhood meningitis whose hearing deteriorated progressively to bilateral profound sensorineural hearing loss.

Intervention: Robotic Assisted Cochlear Implant Surgery (RACIS) with a straight flexible lateral wall electrode.

Primary outcome measures: Electrode cochlear insertion depth with RACIS with facial recess approach and autonomous inner ear access with full electrode insertion of a flexible straight cochlear implant array.

Conclusions: Intra cochlear ossifications pose a challenge for entering the cochlea and full-length insertion of a cochlear implant. RACIS has shown that computations of radiological images combined with navigation-assisted robot arm drilling can provide efficient access to the inner ear.

Keywords

Sensorineural hearing loss, cochlear implantation, Meningitis ossificans, Robotic-assisted cochlear implanted surgery, image-guided surgery.

Introduction

Labyrinthitis ossificans (LO) is the formation of fibrous tissue and new bone in the membranous labyrinth. It often occurs after a severe inflammatory process to the inner ear, such as infections, far advanced otosclerosis, and immune-mediated inner ear diseases[1]. Meningitis is the most common cause of LO, mainly caused by Streptococcus Pneumonia [2]. Five percent of streptococcus meningitis may be associated with profound sensorineural hearing loss (SNHL). LO may occur as early as 3 to 21 days after meningitis[2]. Therefore, the hearing should be evaluated as soon as possible in meningitis patients, and a long follow-up period is advisory for late-onset SNHL. The ossification is best evaluated in the early stage with magnetic resonance imaging (MRI). A loss of liquid density on an MRI may hint toward early fibrosis and already challenging surgical Cochlear implant (CI) placement[3]. Bony ossification is also visible on CT scans. Some consensus and protocols suggest the best timing of the surgery is during the first month to avoid the risk of incomplete electrode insertion because of fibrosis or ossification, but it remains very challanging[3].

For years, cochlear ossification was considered a contraindication for cochlear implant (CI) surgery, not only because of the difficulty of inserting the electrode through the ossified cochlea but also because it had been thought that surviving spiral ganglion cells would be affected for adequate stimulation[1]. Years ago, surgical techniques were developed to insert the array even in patients with totally cochlear ossification. However, it remains challenging for otolaryngologists and audiologists to gain auditory benefits.[4] In the surgical context, technological innovations have always been of interest to surgeons to overcome challenges of access to the inner ear.

Here we report an autonomous robotic system for inner ear access of 1.0 mm diameter by a trajectory passing through the facial recess with a keyhole tunnel of 1.8 mm diameter[5]. Pre-operative planning was performed with dedicated software that can segment and reconstruct CT imaging of the temporal bone to obtain an accurate cochlear view, calculate the estimation of cochlear duct length (CDL) to predict the electrode insertion depth, and find the best keyhole trajectory. The most optimal trajectory to access the cochlea simulated for robotic keyhole surgery is the best alienation with the basal turn of the cochlea[6]. We have planned this trajectory with dedicated software (Otoplan® CAScination, Bern, Switzerland) and have performed a robotic surgical procedure in a challenging case with a post-meningitis partial cochlear ossification[6]. We report intracochlear findings during this Robotic-Assisted Cochlear Implant Surgery (RACIS) that was proven safe and efficient for the surgical placement of a flexible lateral straight electrode.

Case Presentation

An otherwise healthy 55-year-old male with profound bilateral SNHL was referred for cochlear implant candidacy. His medical history involved childhood meningitis. He became hearing aid dependent. Work-up for Cochlear Implantation was performed when his hearing thresholds deteriorated over time. It included audiological tests, imaging, and psychological evaluation. The pure-tone audiometry and speech audiometry in quit showed profound bilateral deafness. A high-resolution temporal bone CT scan showed a bilateral cochlear ossification in the basal turn. The basal turn ossification on the left side was limited to 4 mm at the level of the round window (Figure 1). MR imaging confirms the lack of T2 signal in the membranous labyrinth on both sides. The patient is consulted for CI surgery with explicit consent for poor speech recognition results and, at bests, a signaling function of the CI. The informed consent is obtained for the robotic procedure. A lateral wall flexible electrode of 28 mm length was chosen after calculating the CDL (37.8mm) (Flex 28, Med-EL, Innsbruck, Austria). The patient underwent RACIS with round window access using HEARO robotic system (CASCINATION AG, Switzerland) to perform a drill out in the set direction to basal turn.

After successful inner ear access was acquired, a customized endoscope was used to inspect the keyhole trajectory. This recording also demonstrated some more trabecular ossification in the basal turn of the cochlea (Figure 2, upplemental digital video). Trabecular bone was fractured with a pick to allow the complete array insertion up to 609 degrees (Figure 3). Evoked compound action potential response was detectable on all electrodes with intraoperative telemetry. There were no postoperative complications. The audiological tests one and two years after the initial fitting of the processer showed improvement in the hearing on pure-tune audiometry PTA (46 and 53 dB HL, respectively) (Figure 4). After a rehabilitation period of 1.5 years (during COVID-19 pandemic restrictions), the patient's speech understanding is only possible with visual support such as lip-reading. Sound detecting is present and sound recognition is still improving. The patient is subjectively satisfied with his CI. Subjective results have been investigated preoperatively and 12 months post-implantation using the SSQ12 and NCIQ questionnaire[7,8]. The SSQ12 score improved from 1.4 preoperatively to 4.2 one year after implantation. The NCIQ scores improved one year after implantation in basic sound perception, advanced sound perception, speech production, and self-esteem.

Discussion

The primary goal of CI surgery is a full and atraumatic insertion of the electrode array. Cochlear ossification is a challenge for otologists where atraumatic is less of a focus than full insertion.

The insertion of the array is extremely complex due to the ossification and fibrosis, and damage to remaining neurosensory cells should be reduced.

Several approaches have been reported to increase the insertion part of the electrode: drilling out the ossified part of scala tympani[9], inserting CI in the scala vestibuli[10], double array CI with two cochleostomies[11], and using an image-guided approach[5]. Nevertheless, correct positioning is sometimes impossible, and the audiological results are variable and poor in many cases. These cases are less reported in the literature. In 2013, Wanna and colleagues[12] evaluated the benefit of an image-guided approach for a cochlear implant drill-out procedure. Here we combine image-guided surgery with a robot arm, allowing a precision within a tenth of a millimeter for the keyhole trajectory. Access into the inner ear through the round window to insert the electrode array was robotically drilled. The electrode could be inserted completely, and the audiological outcome of the present case was up to the patient and healthcare workers' expectancies. Furthermore, the reconstructed post-operatively CT images allowed us to correlate the insertion depth to the audiological postoperative thresholds.[10]

Conclusion

Only a very experienced otologist can manage challenges such as cochlear ossification. The robotically assisted surgery applied in the present case provides a novel and efficient approach with high safety and accuracy during the insertion of the array that is much more based on image guidance rather than surgical experience. Cochlear ossification is no longer considered a surgical contraindication for CI. Despite unpredictable audiological outcomes due to the challenge of signal transduction, the indication should be evaluated by a team at a comprehensive cochlear implant center.

References

1. Green, J. D., Marion, M. S. & Hinojosa, R. Labyrinthitis Ossificans: Histopathologic Consideration for Cochlear Implantation. *Otolaryng Head Neck* **104**, 320–326 (1990).

2. Tinling, S. P., Colton, J. & Brodie, H. A. Location and Timing of Initial Osteoid Deposition in Postmeningitic Labyrinthitis Ossificans Determined by Multiple Fluorescent Labels. *Laryngoscope* **114**, 675–680 (2004).

3. Merkus, P. *et al.* Dutch Cochlear Implant Group (CI-ON) Consensus Protocol on Postmeningitis Hearing Evaluation and Treatment. *Otol Neurotol* **31**, 1281–1286 (2010).

4. Balkany, T. *et al.* Surgical technique for implantation of the totally ossified cochlea. *Laryngoscope* **108**, 988–992 (1998).

5. Topsakal, V. *et al.* First Study in Men Evaluating a Surgical Robotic Tool Providing Autonomous Inner Ear Access for Cochlear Implantation. *Front Neurol* **13**, 804507 (2022).

6. Topsakal, V. *et al.* Comparison of the Surgical Techniques and Robotic Techniques for Cochlear Implantation in Terms of the Trajectories Toward the Inner Ear. *J Int Adv Otology* **16**, 3–7 (2020).

7. Hinderink, J. B., Krabbe, P. F. M. & Broek, P. V. D. Development and application of a health-related quality-of-life instrument for adults with cochlear implants: The Nijmegen Cochlear Implant Questionnaire. *Otolaryngology- Head Neck Surg* **123**, 756–765 (2000).

8. Gatehouse, S. & Noble, W. The Speech, Spatial and Qualities of Hearing Scale (SSQ). *Int J Audiol* **43**, 85–99 (2009).

9. Balkany, T., Gantz, B. & Nadol, J. B. Multichannel Cochlear Implants in Partially Ossified Cochleas. *Ann Otology Rhinology Laryngology* **97**, 3–7 (1988).

10. Steenerson, R. L., Gary, L. B. & Wynens, M. S. Scala vestibuli cochlear implantation for labyrinthine ossification. *Am J Otology* **11**, 360–3 (1990).

11. Lenarz, T. *et al.* The Nucleus Double Array Cochlear Implant: A New Concept for the Obliterated Cochlea. *Otol Neurotol* **22**, 24–32 (2001).

12. Wanna, G. B. *et al.* Implantation of the Completely Ossified Cochlea. *Otol Neurotol* **34**, 522–525 (2013).

Figures

Figure 1: Reconstructed CT (axial, coronal, and sagittal) shows a basal turn ossification (4 mm). The 3D reconstruction shows the trajectory of the RACIS (sky-blue) through the facial recess and next to the facial nerve (yellow), and corda tympani (orange). The green dots refer to the center of the round window and the furthest point in the opposite wall of the cochlea. The blue dots refer to the inferior and superior points of the lateral wall. The red dots refer to the height of the cochlea.

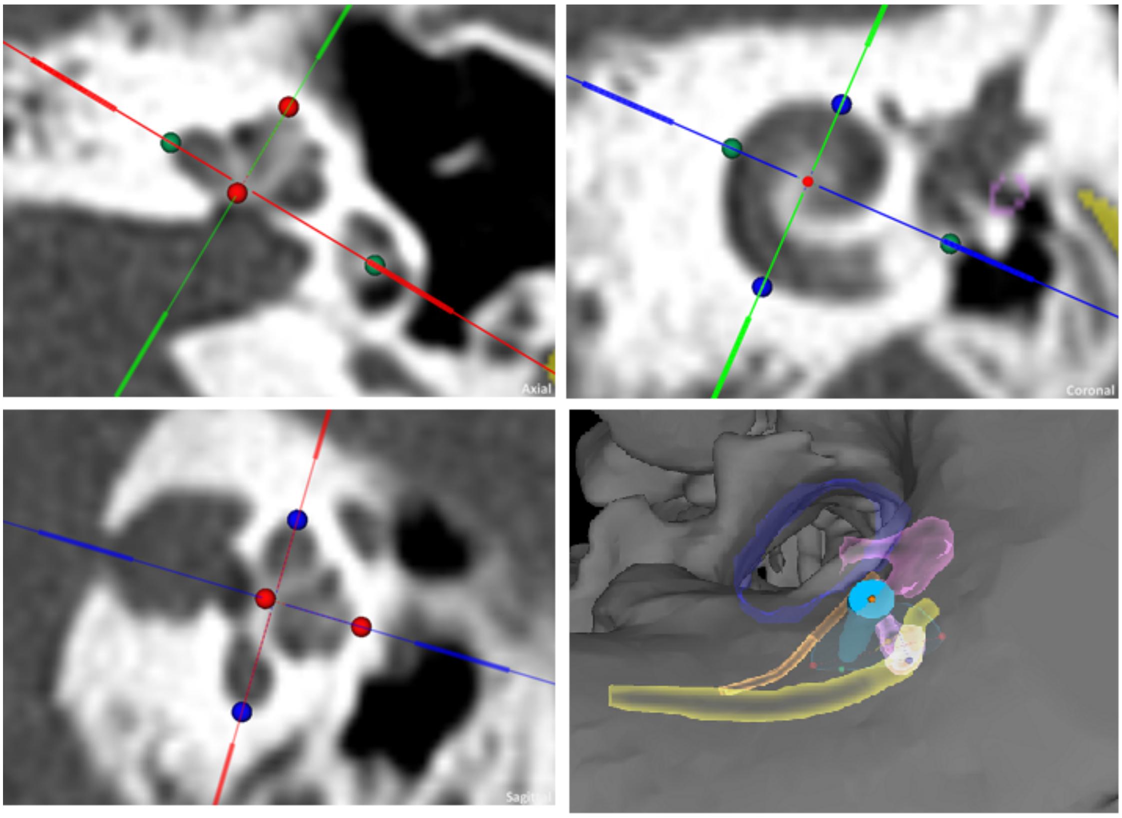
Figure 2: ossification in the basal turn of the cochlea captured by a customized endoscope through the keyhole trajectory (see the full video in the Supplemental Digital Content).

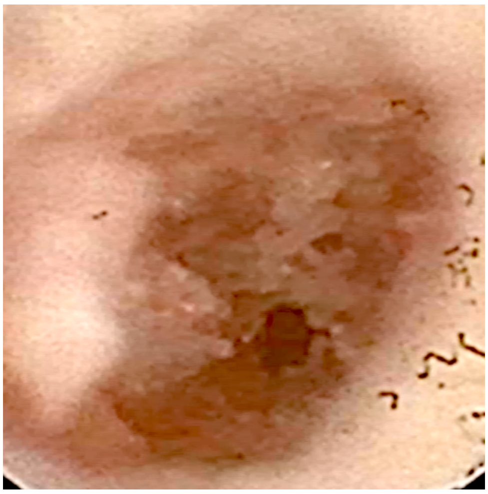
Figure 2: Reconstruction of the postoperative CT shows the full insertion of the electrode (orange).

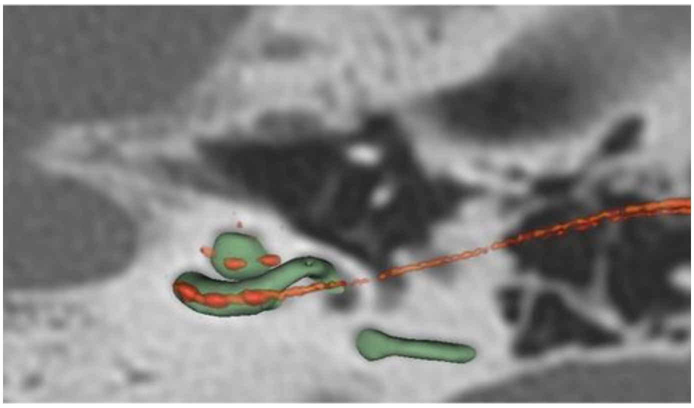
Figure 4: Postoperative pure-tune audiometry.

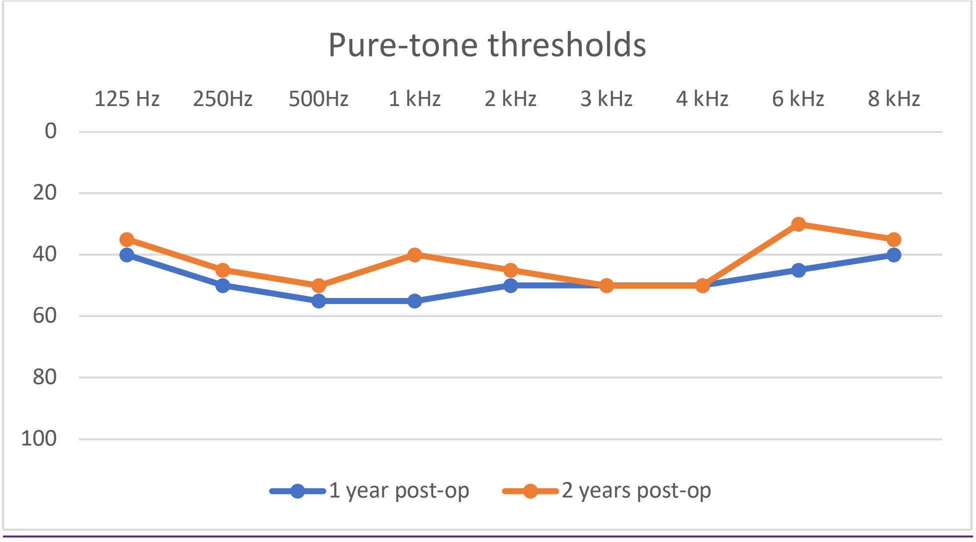
List of Supplemental Digital Content:

- trajectory endoscopy.mp4


Axial
Coronal
Sagittal






Pure-tone thresholds
125 Hz
250Hz
500Hz
1 kHz
2 kHz
3 kHz
4 kHz
6 kHz
8 kHz
0
20
40
60
80
100
1 year post-op
2 years post-op