CLINICAL EXPERIENCE

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Robot-assisted cochlear implant surgery in a patient with partial ossification of the basal cochlear turn: A technical note

1 | INTRODUCTION

Cochlear implantation (CI) has become the standard treatment for people with no functional hearing.[1] Within recent years, minimally invasive procedures performed with a robot have been developed for neurotological surgeries.[2,3] The goal of robot-assisted CI surgery is to avoid extensive drilling of the mastoid bone, preserve residual hearing through more consistent insertion techniques and to enable implantation in complex anatomic cases, such as malformed middle and inner ears. To access the inner ear and cochlea, a tunnel bordered by the facial nerve and chorda tympani is drilled directly through the mastoid to the round window.[3,4] A safe trajectory is planned with an otological software based on image data of the temporal bone. In 2016, Caversaccio et al. performed the first robotic middle ear access for CI in a patient with a self-developed robotic system that was later commercialised as HEARO® system (CASCINATION AG, Bern, Switzerland and MED-EL GmbH, Innsbruck, Austria).[5] Since then, a few patients have been successfully implanted with the robot.[6] The first robotic inner ear access was subsequently performed in Belgium. In 2020, a European CE mark was obtained for the HEARO® robot for its use in patients above the age of 18 and it has thus become available in Austria. Here, we report on our departments experience with the HEARO® robotic system in a patient with a partially ossified basal cochlear turn.

2 | TECHNICAL DESCRIPTION

A 56-year-old male patient was recruited and consented to the robotic CI surgery on the left ear with the HEARO® system. Clinical routine work-up included audiological, medical and radiological examinations. The patient suffered from left-sided progressive sensorineural hearing loss with an unaided pure-tone average of 85 dB hearing level for octave frequencies ranging from 0.5 to 4 kilohertz and a word recognition score of 0% at 100 dB using the Freiburg monosyllable test. Complete deafness was present in his contralateral ear since an infection of the middle ear at the age of 5. Feasibility of HEARO® robotic procedure was evaluated based on the preoperative cone beam computed tomography (CBCT) dataset with OTOPLAN software (CASCINATION AG, Bern, Switzerland

in collaboration with MED-EL GmbH,). Initially, image data were transferred to OTOPLAN through use of the Digital Imaging and Communications in Medicine (DICOM) file format. Imaging of the patient showed an ossification of the first 4 millimetres (mm) of the basal cochlear turn (Figure 1 left). Consequently, the milling depth was set to the end of the ossification (Figure 1 right). The surgery was performed under general anaesthesia on September, 17th 2021 at the department of Otorhinolaryngology, Head and Neck Surgery at a tertiary care hospital.

The HEARO® carbon fibre head rest was used for positioning and immobilising the patient's head on the operating table. Needle electrodes were inserted into the perioral and periorbital muscles for controlled and free running facial neve monitoring. A C-shaped retro-auricular incision was performed. Four fiducial screws were placed onto the bone and served as landmarks for registration (Figure 2). The correct position of the fiducial screws had been estimated preoperatively on a 3D print of the patient's temporal bone. Upon the placement of the screws, an intraoperative CBCT image was acquired with 0.1 mm spatial resolution (xCAT XL, Xoran Ltd.,; Figure 3 left).

Using OTOPLAN software, a safe trajectory was planned through the facial recess to the middle ear cavity. The safety margins of the planned trajectory to critical anatomical structures are shown in Table 1. The drilling depth was calculated to 33.4 mm, including the milling of 4 mm ossification within the basal cochlear turn. The planned trajectory would result in a cochleostomy with direct access to the scala tympani. While the planning procedure was performed, a tympanomeatal flap was created for later visualisation of the electrode insertion. The planned trajectory was transferred to the HEARO® robot and drilling started with a 1.8 mm drill bit from the mastoid surface with 1000 rev/min and a feed forward rate of 0.5 mm per second. Regular pecking and irrigation were performed by the system to cool and clean the drill bit. Three millimetres before entering the facial recess, the robot stopped for acquisition of a second CBCT image, for which a titanium rod was inserted into the tunnel to allow for visualisation of the drilled trajectory on the image (Figure 2 right). The accuracy of the drilling trajectory with respect to the planned trajectory was then evaluated with the software. With respect to safety margins, differences of the initially planned and the actual drilled trajectory are shown in Table 1. Bilinear interpolation

between voxels provides a spatial signal approximation denser than the spatial resolution of 0.1 mm used in the CBCT. The system accuracy at the level of the facial nerve, the level of entrance (i.e. the point on the surface of the mastoid at which the drill bit enters the temporal bone) and the level of target (i.e. the point at which the drill stops) was calculated as 20, 30 and 100 µm (micrometre) respectively (Figure 2). Subsequent drilling through the facial recess was then performed and the controlled facial nerve monitoring was performed at 5 points along the facial recess as a safety feature. After middle ear access was obtained, a 1-mm diamond burr was used to gain inner ear access up to the end of the basal ossification. Prior to electrode insertion, all fiducial screws were removed and an implant bed was drilled manually. A MED-EL Synchrony 2 implant was then fixated to the skull and a Flex 28 electrode was inserted manually through a protective barrier placed into the drilled tunnel. This step was visualised by microscopic view via the previously created

Key Points

- Robotic cochlear implant surgery is a new and safe technique.
- A system for robotic cochlear implant surgery has become available in Europe.
- Robotic cochlear implant surgery can be successfully performed in partially ossified basal cochlear turns.
- Adaption of the planning procedure by increasing the milling depth enables robotic cochlear implant surgery in ossified basal cochlear turns.
- By adaption of the planning procedure, more complex anatomical variations will become implantable in the future.
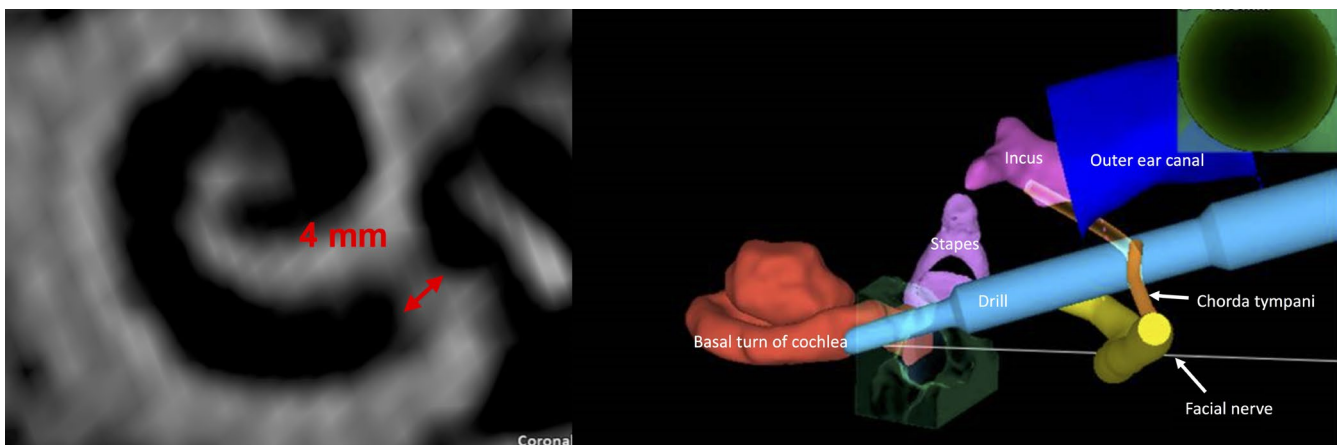
FIGURE 1 Partially ossified cochlear basal turn (left) and access to the scala tympani with adapted drill depth in the planning software (right) [Colour figure can be viewed at wileyonlinelibrary.com]
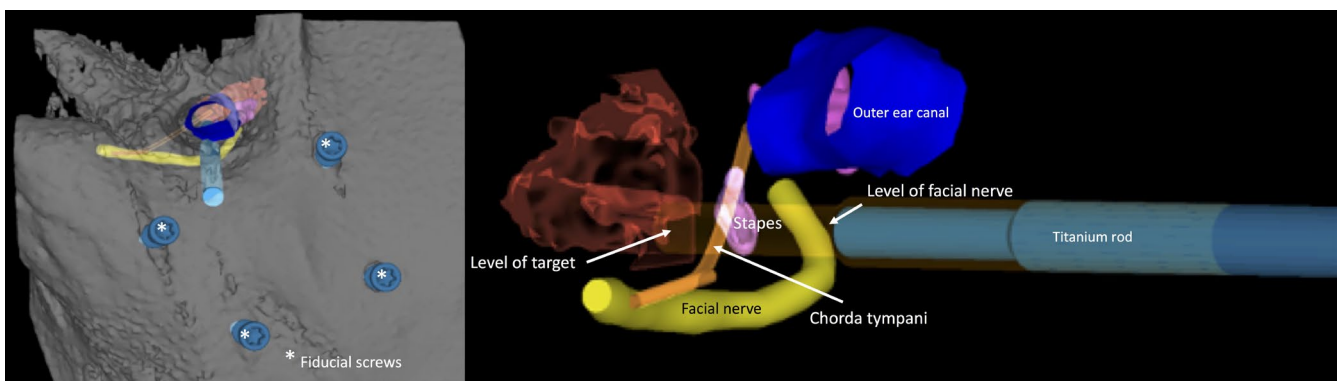
FIGURE 2 Fiducial screws positioning (left) and intraoperative system accuracy measurements after insertion of a titanium rod (right). The level of entrance is the point on the surface of the mastoid where the drill bit enters the temporal bone. The level of target (round window) as well as the chorda tympani (orange colour) are indicated by arrows [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 1 Safety margins of planned and drilled trajectories to anatomical structures and the resulting differences (accuracies) in millimetres

Accuracy at the level of:	Planned Trajectory (mm)	Drilling Trajectory (mm)	Difference (Accuracy in mm)
Ear canal	0.70	0.73	+0.04
Incus and Malleus	2.11	2.18	+0.07
Stapes	0.36	0.43	+0.07
Facial nerve	0.51	0.50	−0.02
Chorda tympani	1.82	1.83	+0.02

tympanomeatal flap. The surgery took 6 h and 41 min in total. A final CBCT image was acquired after insertion to confirm intracochlear positioning of the electrode array (Figure 3). A full insertion corresponding to 619 degrees was achieved. Postoperatively, the patient reported on an altered taste and the facial nerve function was rated as I on a House-Brackmann Scale.

3 | DISCUSSION

Robotic CI surgery is a new and promising technique which was recently CE marked. Current challenges in robotic CI surgery include prolonged duration of the surgery compared to conventional techniques and exclusion of children. The HEARO® procedure has yet to be evaluated in patients with more complex anatomical conditions. We showed that robotic CI surgery can be also successfully performed in cases with partially ossified basal cochlear turns by adapting the planning procedure in the otological software. By increasing the drilling depth, even more extensive ossifications will probably become successfully implantable with this new technique. Unfortunately, we did not perform objective taste tests pre- and postoperatively, but we will include them in future HEARO® procedures. The previously reported duration of robotic CI surgery ranged from 3:15 to 5:00 hours. This case took 6:41 h during which the most time-consuming part was positioning of the patient as his head rotation was severely reduced. A time reduction will be

expected with procedure familiarity and by optimising all safety steps. Stepwise expansion of the robotic surgery to patients with more complex anatomical conditions will further improve this new technique.

PEER REVIEW

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author A.AB.

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