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# MRI Artifacts and Cochlear Implant Positioning at 3 T In Vivo

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**Hypothesis:** To evaluate the assessment of the internal auditory canal and the labyrinth in relation to different CI magnet positions and MRI sequences at 3 T.
**Background:** The indication criteria for cochlear implantation have been changed over the years and the growing number of implantations in patients after acoustic neuroma resections underline the importance of a postoperative MR imaging to assess the internal auditory canal (IAC) and the labyrinth. The MRI artifact induced by the cochlear implant magnet is a known problem that should be further observed by this investigation.
**Methods:** We compared the artifacts of Cochlear 512 magnets at different head positions in vivo at 3 T. The observed positions varied with a nasion-external ear canal angle of 90, 120, and 160 degrees and a variable distance of 5, 7, and 9 cm in relation to the external ear canal and different MRI sequences.
**Results:** The complete assessment of the internal auditory canal and labyrinth was possible with a magnet positioned at 90 degrees and 9 cm and 160 degrees and 9 cm. Evaluation of the IAC alone was possible with magnet positions at 90 degrees and 7 cm and 9 cm, 120 degrees and 9 cm, and 160 degrees and 7 cm and 9 cm. A high-resolution 3D T2w Drive sequence decreased the visibility of the structures significantly. A high-resolution TSE 2D T2w sequence together with one of the above-described positions allowed sufficient visualization of the structures.
**Conclusion:** The position of the implant and the MRI sequence used determine the assessment of the IAC and the labyrinth at 3 T MRI. A position of the implant magnet at a nasion-external auditory canal angle which is more horizontal and posterior than so far commonly used allows a better visualization of the IAC and the labyrinth at 3 T. **Key Words:** 3 T—Cochlear implant—Implant positioning—MRI.

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Magnetic resonance imaging is the standard diagnostic radiologic tool for different brain diseases and neurologic lesions. It is also part of the preoperative test battery for cochlear implant candidates. With a number of about 320,000 implantees worldwide, the probability of a postoperative MRI scan for medical reason is quite high (1). The current rate of MRIs performed in the group of cochlear implantees in Western countries is about 10% (2). The number of high-field scanners (3 T and above) with improved image quality has continuously increased and led to a decline of MRI applications with a lower magnetic field strength. This trend underlines the need for further studies that investigate the application of 3 T MRI in cochlear implants.

The indication for cochlear implantation has developed from single-sided implantation to bilateral ones, from old-aged with single-sided deafness to those with residual hearing. This widening of the indication range increases the probability of the need to scan the labyrinth and the internal auditory canal on the implanted side postoperatively for different medical reasons.

Expanding the indications led to the implantation of patients with vestibular or intracochlear schwannomas (neuromas) removed and subsequently implanted as a single-step (3,4) or two-step procedure with a controlled time frame to decrease the probability of tumor reoccurrence (5).

To date, MRI artifacts at 3 T as induced by the cochlear implant hardware have been reported to make it highly difficult to realistically assess audiovestibular structures (6) with a CI magnet in place. Retrospective analyses of implantees undergoing a 1.5-T scan showed a relationship between the used MRI sequence and the assessment of the ipsilateral internal auditory canal (7). Cochlear implant manufacturers made different attempts to enable scanning procedures at 3 T. Cochlear (Sydney, Australia), with a 3-T-approved device (8), offers the removal of the magnet as solution to decrease MRI-related artifacts.

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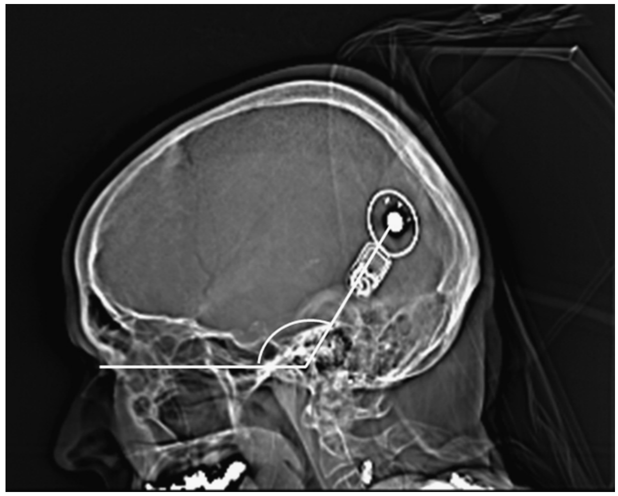

**FIG. 1.** Estimation of the implant position. Nasion/outer ear canal angle and magnet distance position.

A similar solution is offered by Advanced Bionics (Stäfa, Switzerland), with the approval of up to 1.5 T. Med-El (Innsbruck, Austria) recently introduced a device with approval for 3 T with a magnet which makes a removal not necessary. Neurelec's device (Oticon Medical, Askim, Sweden) is approved for up to 1.5 T in a ceramic housing, even with a non-removable magnet, but no solution with respect to the artifacts.

The aim of the present study was to observe differences in the magnet artifacts in terms of magnet position and MRI sequences under the visual assessment of internal auditory canal (IAC) and the labyrinth at 3 T MRI.

## MATERIALS AND METHODS

For the investigation of magnet artifacts in vivo, the magnet was placed in a silicon implant (Cochlear 512 dummy) and fixed onto the head of a volunteer with a tight dressing and a polyethylene block on the magnet to prevent any displacement. The magnet was placed in nine different positions defined by a nasion-outer ear canal angle. The used angles were 90, 120, and 160 degrees. The distance of the magnet from the outer ear canal was 5, 7, and 9 cm (Fig. 1). The volunteer was 45 years old, male, and had a regular anatomy of the head and neck region without any pathology. The study was evaluated and accepted by the IRB.

For these nine different positions, the head was scanned with different MRI sequences. The internal auditory canal and labyrinth were evaluated by an experienced neuroradiologist.

The imaging was performed with a 3-T MR imaging unit (Philips Achieva; Philips Medical Systems, Best, Netherlands) using an eight-channel array head coil.

We evaluated the inner ear structures, the internal auditory meatus and canal, and the cerebellopontine angles ipsi- and contralaterally with T2- and T1-weighted sequences at different positions.

Detailed MRI scanning parameters:

1. TSE T2 DRIVE 3 D MR cisternography: TR: 2,000 ms, TE 200 ms, flip angle of 90 degrees, and a refocusing angle of 120 degrees. The thickness was 0.5 mm and reconstruction resolution was $0.29 \times 0.29 \times 0.5$ mm, F0V $150 \times 150$, 55 slices, matrix size: $300 \times 297$, and scan time of 6:38 minutes.
2. TSE T2 2 D: TR: 3,106 ms, TE 120 ms, slice thickness 3 mm, reconstruction resolution of $0.23 \times 0.23 \times 3$ mm, F0V $120 \times 120$, 20 slices, matrix size: $400 \times 293$, and scan time of 3:00 minutes.
3. TSE T1 2 D: TR: 550 ms, TE 20 ms, slice thickness 3 mm, reconstruction resolution of $0.23 \times 0.23 \times 3$ mm, F0V $120 \times 120$, 20 slices, matrix size: $400 \times 318$, and scan time of 2:50 minutes.

## RESULTS

Comparing the different positions of the magnet, we could differentiate the labyrinth and the internal auditory canal in relation to the magnet artifact by evaluating the scans (Fig. 2). Although a visualization of the IAC was possible at 90 degrees (7 cm and 9 cm distances), 120 degrees (9 cm distance), and 160 degrees (7 cm and 9 cm distances), the evaluation of the labyrinth was even possible at 160 degrees (9 cm distance) and partially at 90 degrees (7 cm and 9 cm distances).

Performing a reconstructive high-resolution 3D T2w Drive sequence decreases the visualization of those structures significantly (Fig. 3) so that they could not more be evaluated.

Subjectively, the displacement of the magnet in the silicon housing of the magnet led to a painful pressure on the skin. In one case, the magnet became dislodged from the housing.

## DISCUSSION

MRI scanning with any hearing implant in place is a highly relevant issue which is recognized by the manufacturers, the clinicians, and the patients as well (9). The scanning at 1.5 or 3 T for cochlear implants causes artifacts with large areas of non-assessment. Some companies tried

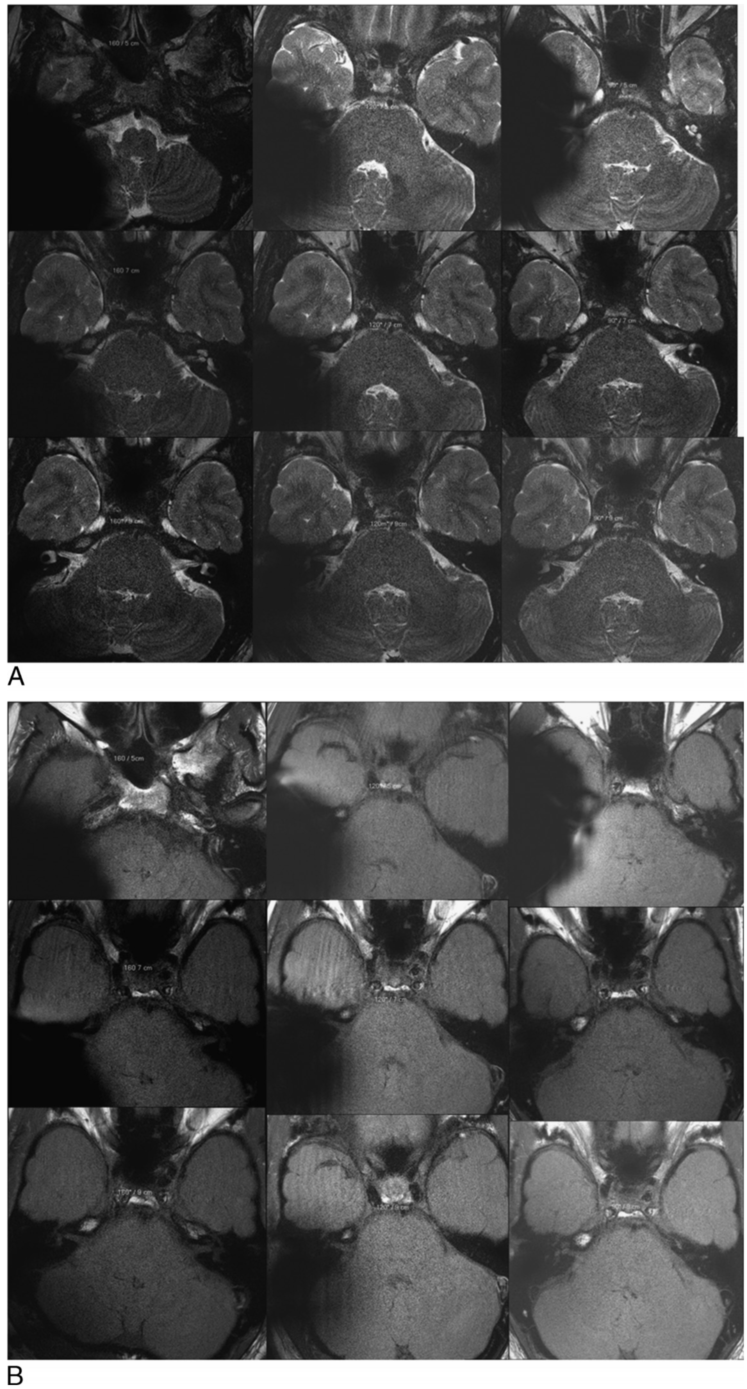


**FIG. 2.** Artifact of T2 (*A*) and T1 (*B*) scans at the different magnet positions, which are included in the figure.

to solve this issue with removable magnets. However, this approach bears the risk of an infection or subsequently even loss of the implant. Therefore, it is not a preferred solution by surgeons.

With evolving indications for cochlear implantation including patients after the removal of a vestibular schwannoma, the postoperative visualization of the IAC and the labyrinth by MRI is of high importance for the follow-up of patients (10). The growing number of 3 T MRI scanners in clinically routine use underlines the relevance of this topic.

The literature describes no significant temperature increases or technical defects of or around the CI as related to 3 T scans (6). Demagnetization is a potential problem which depends on the position of the magnet in relation to the magnetic field of the scanner (11). Implant displacement

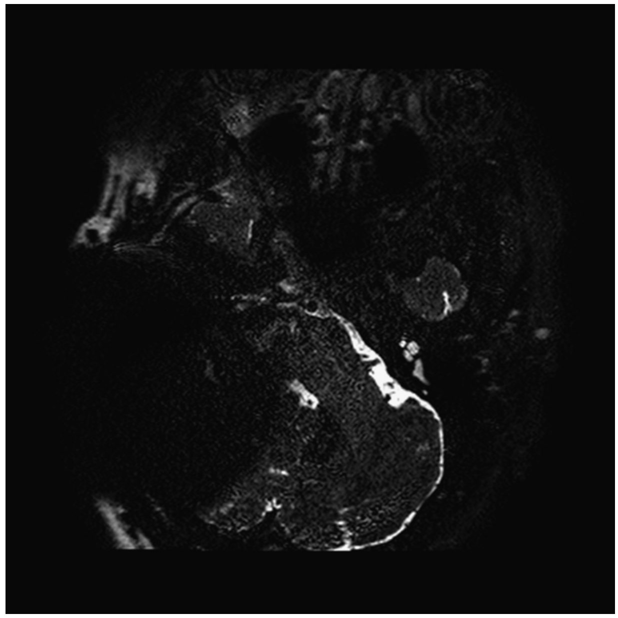

**FIG. 3.** Artifact of a T2 Drive sequence scan at a 90-degree, 9-cm magnet position.

has not been discussed in the literature because the majority of the studies were centered around the lack of visualization of the IAC and the inner ear because of the artifacts as induced by the scanning (6).

In our series, two specific magnet positions allowed a good visualization of those structures in a 3 T scanning mode. At 90 degrees/9 cm and at 160 degrees/9 cm, a good visual assessment of the structures became feasible. At 160 degrees/9 cm, the center of the artifact is calculated to be behind (more towards the brain) the IAC, and at 90 degrees/9 cm, the center is above the IAC. Taking the external position of the magnet on the surface of the skin and a scalp thickness of about 6 mm into account, this should not have a significant impact on the visibility of the important structures in comparison to an implanted magnet. Additionally, it has to be considered that the study was performed in an adult. Children might pose a slightly different head. However, this should not be an obstacle that cannot be overturned by simply adapting the specific positions of the magnet as suggested by our investigation.

Additionally, we found that the artifacts are highly dependent on the technical scanning sequence used. A 3D Drive sequence (Philips, Netherlands), which is comparable to a 3D CISS sequence (Siemens, Erlangen, Germany), enlarges the artifact to an extent that makes it difficult to visualize the IAC and the labyrinth. Therefore, our study used sequences allowing an improved visual assessment of the IAC, but we also had to find out that there are certain limitations in visualization with a subsequent 3D reconstruction. However, the MRI scans with the specific magnet position are suited to exclude the reoccurrence of a vestibular schwannoma (neuroma) within the inner ear or the IAC. We assume that certain artifact-reduction algorithms increase greater tolerance limits in angle and absolute distance of the implant in place.

The finding of our study at 3 T, that an assessment and visualization of the IAC and the labyrinth are possible, even with a regular high-resolution T2w sequence, is in line with Walton et al. (7), who analyzed retrospectively 1.5 T scanning sequences in neurofibromatosis type II patients and also reported a possible visualization of residual tumor tissue. In line with others (12), we found one dislocation of a magnet. This clinically unsolved problem is related to the removable magnet construction. This is based on the clinical need to fully visualize the complete neurocranium with MRI scanning (e.g., trauma, tumors apart from the IAC, labyrinth). As yet, no technical solution is in sight to overcome this problem (e.g., screw in magnets, moveable multipolar magnets). The observed regional pain reaction was induced by the magnet movement under the tight head dressing.

The clinical and surgical consequences of our study are as follows:

- Based on our findings, a more horizontal and posterior position of the magnet is recommended in terms of an improved MRI visualization. Even a 90-degree position of the implant body could become an obstacle when wearing caps, helmets, and head bands.
- The possibility of a medically required postoperative follow-up by MRI scanning in any tumors/neoplasms in or around the CPA allows the development of different treatment pathways for those patients, particularly in auditory rehabilitation.
- Magnet dislocation is an unsolved problem yet.
- Pain is an unsolved problem yet.

The position of the implant magnet and the MRI sequence used determine the size and location of the magnet artifact. For a diagnostic visual assessment of the IAC and the labyrinth at 3 T, a position for the implant magnet should be at a more horizontal and posterior position than so far common nasion-ear angle.

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