Imaging procedures after bone-anchored hearing aid implantation

Susan Arndt, Jan Kromeier, Ansgar Berlis, Wolfgang Maier, Roland Laszig, Antje Aschendorff

Angaben zur Veröffentlichung / Publication details:

Arndt, Susan, Jan Kromeier, Ansgar Berlis, Wolfgang Maier, Roland Laszig, and Antje Aschendorff. 2007. "Imaging procedures after bone-anchored hearing aid implantation." The Laryngoscope 117 (10): 1815–18. https://doi.org/10.1097/mlg.0b013e3180f62b5e.

Imaging Procedures After Bone-Anchored Hearing Aid Implantation

Susan Arndt, MD; Jan Kromeier, MD; Ansgar Berlis, MD; Wolfgang Maier, MD; Roland Laszig, MD; Antje Aschendorff, MD

INTRODUCTION

After more than 25 years of clinical experience, the bone-anchored hearing aid (BAHA) system is a well-established method of treatment for hearing impaired patients with conductive or mixed hearing loss (HL).[1] Since 2003, a new indication for BAHA implantation has been established in the case of patients with single-sided deafness of various causes, for instance, after acoustic neuroma surgery, bacterial meningitis, sudden sensorineural HL, or stapes or middle ear surgery.[1–4] In patients with single-sided deafness, the BAHA is placed near the deaf ear and works as a transcranial contralateral-routing-of-signal device. The BAHA system is an osseointegrated bone conduction implant system that uses direct bone conduction by a 3 or 4 mm titanium-based countersunk head screw with premounted abutment that is implanted into a tapped hole in the temporal bone behind the ear. A tight coupling between the BAHA and the skull is essential for efficient vibration conduction.

The purpose of this study was to evaluate the feasibility and usability of different radiologic methods such as computed tomography (CT), magnetic resonance imaging (MRI), and rotational tomography (RT) for assessment of the position of the implanted screw after placement into the temporal bone. Another aspect of the study was to determine the method with the smallest possible artifacts and its influence on the postoperative imaging procedure control, after for instance, acoustic neuroma surgery.

From the Departments of Oto-Rhino-Laryngology, Head and Neck Surgery (S.A., W.M., R.L., A.A.), Radiology (J.K.), and Neuroradiology (A.B.), University Medical Center Freiburg, Freiburg, Germany.

Editor's Note: This Manuscript was accepted for publication May 11, 2007.

Send correspondence Dr. Susan Arndt, Department of Oto-Rhino-Laryngology, Head and Neck Surgery, University Medical Center Freiburg, Killianstrasse 5, D-79106 Freiburg, Germany. E-mail: arndt@hno.ukl.uni-freiburg.de

MATERIALS AND METHODS

A formalin-fixed cadaver head was implanted with a fixture, 4 mm long and titanium based, self-tapping, and premounted (Cochlear GmbH, Hannover, Germany). Screw dimensions, together with the abutment, are 5.35 mm in length and 5.5 mm in diameter at the top of the abutment (Fig. 1). The screw was implanted obliquely to determine the best method for detecting the angle. Furthermore, we did not perform a disposal well for determining the distance of the abutment from the temporal bone.

The head was imaged with CT, MRI, and RT. Navigated CT scans were performed with a 16-slice scanner (Somatom Sensation 16, Siemens Co, Erlangen, Germany), with a slice thickness of 1 mm.

The technique of RT is based on three-dimensional (3D) digital radiography with a DynaCT-capable angiography unit. DynaCT enables selected systems of the Axiom Artis family to create images that are similar to a CT scan. We used DynaCT with an Axiom Artis dTA (Siemens Co., Erlangen, Germany) equipped with a digital flat-panel detector. Maximum field of view was a volume scan of 18 cm height and a slice size of 24×24 cm. Minimal slice thickness and voxel size were 0.4 mm. DynaCT uses the images of single Dynavision rotational radiography.[5,6]

The head then underwent examination in a 3 Tesla MRI scanner (Siemens Trio Tim, Siemens Co., Erlangen, Germany). We obtained a T1-weighted 3D data set with 1 mm slice thickness (isotrope data set) and an axial T2-weighted data set with 4 mm slice thickness. Differences of artifacts, visibility of the screw, and size of artifacts were compared among the CT, MRI, and RT scans.

RESULTS

CT and RT procedures allowed identification of the screw that was positioned inside the temporal bone. The CT scan showed small, metallic artifacts but still showed

Fig. 1. (A) Four millimeter titanium-based countersunk head screw with premounted abutment. (B) Engineering detail drawing of 4 mm flange fixture (Cochlear GmbH, Germany).

partial volume effects. The drill hole, penetrating the entire temporal bone diameter, could also be seen, but the exact length of the screw in the bone was difficult to quantify because of the artifacts (Fig. 2). RT allowed identification of the accurate position of the screw (Fig. 3). The metallic artifacts caused by the implanted screw were negligible. The exact angle between the screw and skull surface could be identified accurately with RT imaging (Fig. 4). Furthermore, RT clearly depicted the length of the screw in the bone and the distance to the dura (Fig. 3).

In the MRI scans, the screw was not visible, but the location of the screw hole in the temporal bone could be identified because of the artifact. The artifact was 15.1 to 17.4 mm (Fig. 5), and therefore evaluation of the screw or possible injury to the dura was not available.

We also wanted to determine the possibilities and limitations in identifying the brainstem and the internal

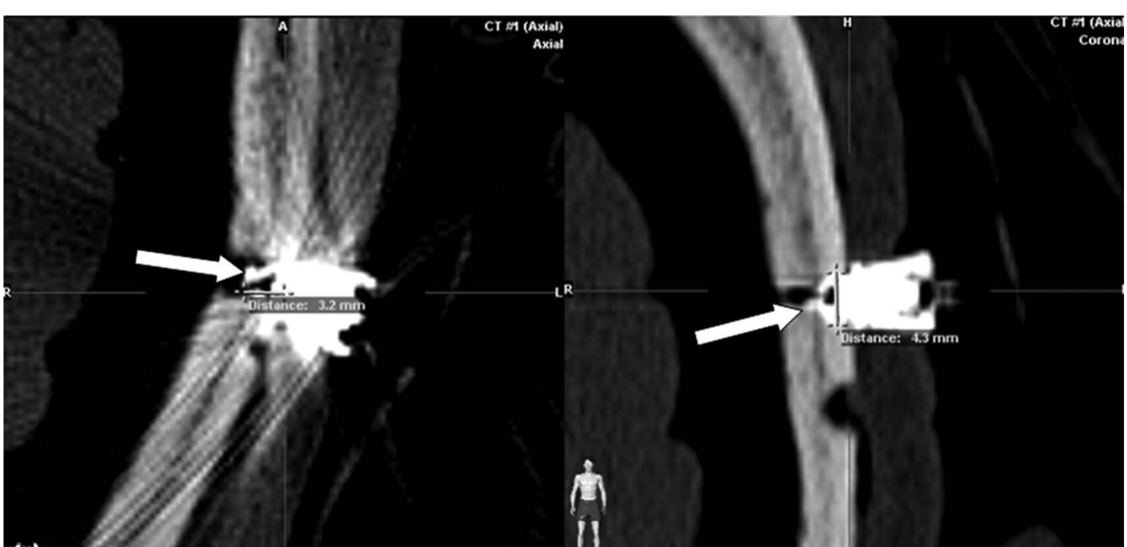

Fig. 2. Multislice computed tomography imaging (left, axial; right, coronal) in human temporal bone after screw implantation. Arrows indicate artifacts that do not allow definition of exact end of screw.

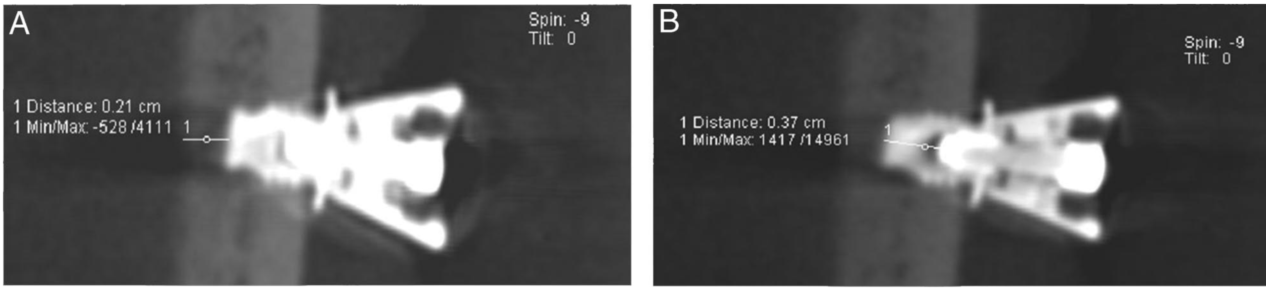

Fig. 3. Rotational tomography shows accurate position of the implanted screw and distance to dura. (A and B) sagittal.

auditory canal with CT or MRI after BAHA implantation. This might be of clinical interest after acoustic neuroma surgery in combination with BAHA implantation. In both CT and MRI (T1- and T2-weighted) scans, the internal auditory canal and brainstem were clearly visible, and there were no limitations resulting from the artifacts of the screw.

DISCUSSION

Because of the relatively new indication for BAHA implantation in patients with single-sided deafness of various causes, especially after acoustic neuroma surgery, postoperative quality control by suitable imaging methods is desirable. In cases of surgical complications, a possible dislocation of the implanted screw or an injury of the dura must be visible. Also, evaluation of the internal auditory canal and brainstem has to remain possible after the implantation to exclude recurrent neuroma.

Our results demonstrate that multislice CT scans show only small artifacts but are not useful for differentiating the screw position. The depth of the screw within the bone could not be measured accurately. The artifacts in MRI resemble oblong "black holes" that blot out the underlying image and sometimes distort nearby structures.[7] The distortion of the image is related to the degree of deflection of the object in a magnetic field caused by its ferromagnetism.[8] In our study, the screw produced a "black hole" type artifact even larger than the actual drill hole or screw. In addition, the artifacts included the imaging of the dura, so any injury to the dura could not be evaluated sufficiently. We performed the CT and MRI with 1 mm slice thickness and the RT with 0.5 mm slice thickness. According to our results, this difference of 0.5 mm has no influence. It might be possible to reconstruct the CT and MRI scans at 0.5 mm, but the results would be the same.

For definite interpretation of screw position in the temporal bone, only RT appears to be a suitable imaging tool, it being minimally impaired by metallic artifacts. This new imaging technique offers the same fast performance as CT scans. RT also results in lower radiation exposure, between a third and half the dose needed for CT.[9] Furthermore, RT allows an excellent isovolumetric resolution in three dimensions, which, at the present time, cannot be realized by CT scans.

In MRI as well as CT, there was no effect by the implanted screw on the evaluation of the internal auditory canal and the brainstem. With RT, the internal auditory canal can be evaluated, whereas an evaluation of the brainstem is not possible because of RT's lack of contrast resolution.

In comparing the three methods, RT appears to offer new possibilities for postoperative evaluation after BAHA surgery. Our study results can be summarized as follows:

First, in clinical cases of insufficient implant placement with subsequent implant loosening or even injury to the dura or sigmoidal sinus, RT enables the otosurgeon to determine whether a displacement of the implant has occurred, providing him or her with immediate feedback about surgical procedures. At this time, there is clinical evidence of RT feasibility in cochlear implant patients.[5]

Second, there are no restrictions of CT or MRI in terms of the image quality of the internal auditory canal and the brainstem, which is useful to exclude recurrent acoustic neuroma, but these techniques do not allow precise evaluation of the BAHA screws. Further examinations on the safety of MRI, especially as concerns temperature, are essential.

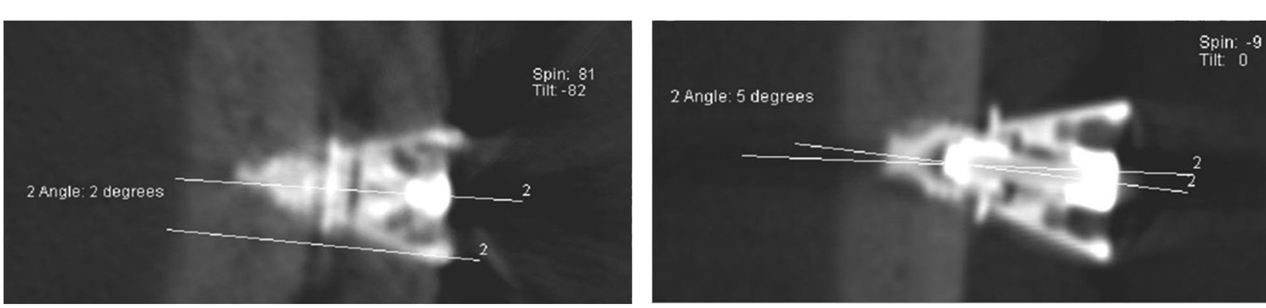

Fig. 4. Angle between screw and skull surface is clearly visible in rotational tomography imaging. (A) axial; (B) sagittal.

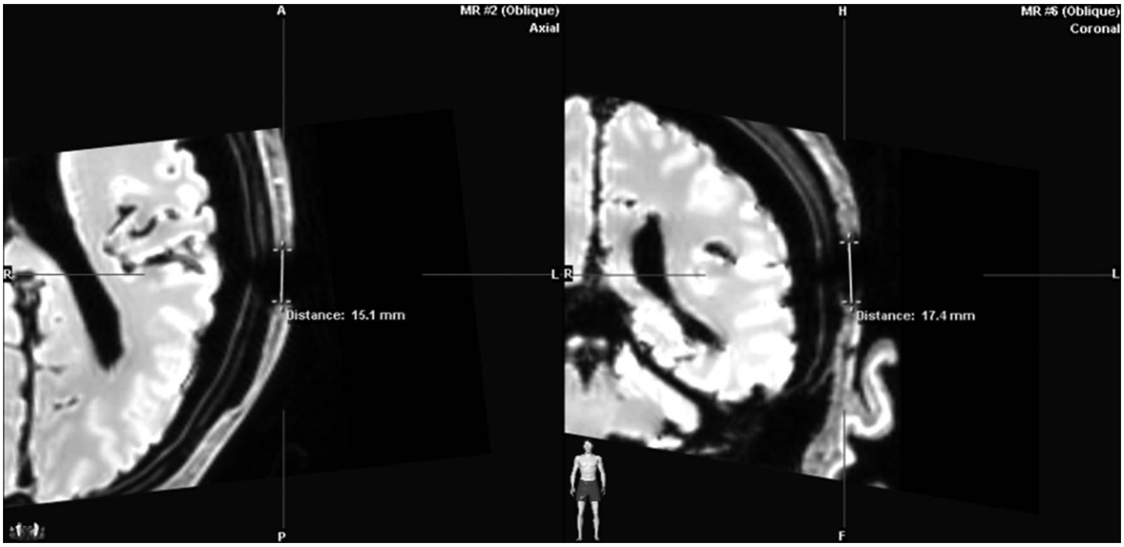

Fig. 5. "Black hole" type artifact in magnetic resonance imaging including the dura (left, axial; right, coronal).

BIBLIOGRAPHY

1. Snik AF, Mylanus EA, Proops DW, et al. Consensus statements on the BAHA system: where do we stand at present? *Ann Otol Rhinol Laryngol Suppl* 2005;195:2–12.
2. Wazen JJ, Spitzer JB, Ghossaini SN, et al. Transcranial contralateral cochlear stimulation in unilateral deafness. *Otolaryngol Head Neck Surg* 2003;129:248–254.
3. Niparko JK, Cox KM, Lustig LR. Comparison of the bone anchored hearing aid implantable hearing device with contralateral routing of offside signal amplification in the rehabilitation of unilateral deafness. *Otol Neurotol* 2003;24:73–78.
4. Hol MK, Bosman AJ, Snik AF, Mylanus EA, Cremers CW. Bone-anchored hearing aids in unilateral inner ear deafness: an evaluation of audiometric and patient outcome measurements. *Otol Neurotol* 2005;26:999–1006.
5. Aschendorff A, Kubalek R, Turowski B, et al. Quality control after cochlear implant surgery by means of rotational tomography. *Otol Neurotol* 2005;26:34–37.
6. Offergeld C, Kromeier J, Aschendorff A, et al. Rotational tomography of the normal and reconstructed middle ear in temporal bones: an experimental study. *Eur Arch Otorhinolaryngol* 2007;264:345–351.
7. Teitelbaum GP, Bradly WG, Klein BD. MR imaging artifacts, ferromagnetism, and magnetic torque of intravascular filters, stents and coils. *Radiology* 1988;147:139.
8. Sullivan PK, Smith JF, Rozzelle AA. Cranio-orbital reconstruction: safety and image quality of metallic implants on CT and MRI scanning. *Plast Reconstr Surg* 1994;94:589–596.
9. Aschendorff A, Kubalek R, Hochmuth A, et al. Imaging procedures in cochlear implant patients–evaluation of different radiological techniques. *Acta Otolaryngol Suppl* 2004;:46–49.