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Otology

3T MRI-based estimation of scalar cochlear implant electrode position

Valutazione con RMN 3-T della posizione degli elettrodi degli impianti cocleari nella scala cocleare

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SUMMARY

Common techniques to evaluate intracochlear electrode position include ionised radiation by multi-slice computer tomography, digital volume tomography (MSCT, DVT) and flat panel tomography (FPT). Recent advances in the knowledge about handling MRI artefacts and the pain-free performance of MRI scans in cochlear implantees showed that estimation of the intracochlear electrode position is possible at 1.5 T with perimodiolar or midmodiolar arrays. The aim of the present study is to evaluate the assessment of the ipsilateral scalar position of a cochlear implant lateral wall electrode by MRI sequences at 3T. In a prospective study we evaluated 10 patients implanted with a diametrically bipolar implant magnet system with a lateral wall electrode in the intrascalar electrode position in an axial and coronal position and a T2 weighted sequence at 3T and a resolution of 0.8 mm. We compared the intracochlear position with routine postoperative DVT scan. In all cases, the MRT-estimated scalar position corresponded with that estimated by DVT scan. In all cases, a scala tympani position was present. While the position in the basal turn is reliably localisable, the first-turn visual assessment is difficult. Estimation of the intracochlear position of lateral wall cochlear implant electrodes by 3T MRI is possible for the basal turn. Electrode design plays a major role in visual assessment.

KEY WORDS: MRI • Cochlear implant • Electrode position

RIASSUNTO

La valutazione del posizionamento dell'elettrodo di un impianto cocleare avviene generalmente mediante tecniche che utilizzano radiazioni ionizzanti come la tomografia computerizzata multi-slice (MSCT), la tomografia a volume digitale (DVT) o la tomografia flat-panel (FPT). Recenti sviluppi nella gestione degli artefatti in risonanza magnetica (MRI) e la possibilità di eseguire MRI senza arrecare comorbidità al paziente impiantato, hanno dimostrato che l'applicazione della MRI a 1,5 T è possibile per stimare il posizionamento dell'elettrodo di un impianto cocleare. Lo scopo dello studio è indagare il posizionamento scalare di un elettrodo a parete per mezzo di MRI a 3 T. In questo studio prospettico sono stati arruolati 10 pazienti sottoposti ad impianto cocleare dotato di magnete bipolare, con elettrodo posizionato a livello intrascalare a parete. I pazienti sono stati valutati con MRI a 3 T, in sequenze T2-pesate con risoluzione di 0,8 mm, assiali e coronali. La posizione intracocleare dell'elettrodo osservata nelle sequenze MRI è stata comparata con quella ottenuta in DVT, eseguita routinariamente nel periodo postoperatorio. In tutti i casi la posizione scalare dell'elettrodo stimata in MRI era sovrapponibile a quella evidenziata in DVT. In tutti i casi è l'elettrodo è stato osservato nella scala timpanica. La posizione dell'elettrodo è stata valutata in modo affidabile a livello del giro basale della coclea, al contrario, la visualizzazione dell'elettrodo nei giri cocleari successivi è risultata difficoltosa. La valutazione con tecniche di MRI a 3 T del posizionamento dell'elettrodo a parete è possibile per il giro basale della coclea. La tipologia di elettrodo gioca un ruolo fondamentale nella stima visiva.

PAROLE CHIAVE: *MRI • Impianto cocleare • Posizionamento dell'elettrodo*

Introduction

Estimation of intracochlear electrode position after CI electrode insertion is of high importance for audiological outcomes [1]. Radiological tools associated with ionised radiation (CT, DVT, FPT) are mainly used to clarify this important question for the surgeon, technician and audiologist. Recent observations show of the possibility to perform radiation-free positional estimations of electrode position. One option is positional estimation based on intraoperative electrophysiological measurements [2], with limitations in terms of the electrodes used and brand-specific intraoperative electrophysiological measurement abilities.

Another option is the use of MRI scans to clarify this

clinically important question. Due to the internal magnet, MRI scans can be associated with complications such as pain or magnet dislodgements [3 4] at 1.5T, and scans cannot be performed without removal of the magnet at 3T (current implant series, Cochlear Company, Sydney, Australia). This observation limits the utility of MRI scans.
New studies show that the specific positioning of the implant magnet allow MRI-based visual assessment of the internal auditory canal and the cochlea-even after the implantation is performed [5 6]. Recently, it was shown that estimation of the electrode position at 1.5T for perimodiolar or midmodiolar electrodes is possible [7].
3T scanning is known to provide increased visual resolution. Diametrically bipolar internal magnet systems containing CI systems offer the opportunity of 3T MRI scanning without complications [8]. This system contains an electrode that is positioned at the lateral wall of the cochlea. Lateral wall electrodes are known for their less effective visual localisation abilities in the CT, DVT and FTP in comparison to perimodiolar or midmodiolar electrodes, due to their generally higher lateral position in the scala tympani.
The aim of the present study was to evaluate assessment of the ipsilateral scalar position of cochlear implant lateral wall electrodes by MRI sequences at 3T.

Materials and Methods

The study was approved by the institutional review board of Klinikum Bielefeld, Germany (IRB-klibi-HNO-2017/05). Patients gave written informed consent for use of clinical records.
In this prospective study, 10 patients underwent 3T MRI scanning in a tertial referral centre. Between May 2017 and December 2017, all patients were implanted with a MED-EL SYNCHRONY implant (MED-EL, Innsbruck, Austria) with a diametrically magnetised internal magnet. In all cases, the implant magnet was intraoperatively determined and positioned 7-9 cm behind the external auditory canal.
All examinations were performed in a 3T MR imaging unit (Achieva, Philips Medical Systems, Best, NL) without a headband on the first postoperative day. Additionally, cone beam CT (NEW TOM VGI, Verona, Italy) was performed.
MRI scanning parameters:
TSE T2 2D: TR: 3000ms, TE 120ms, slice thickness 0.8 mm, voxel size 0.449 mm, F0V 230×199; 35 slices.
CBCT parameters:
FOV 15x15 cm, 10,48 mAS-20,52 mAS, KV 110, 360° followed by 2D and 3D reconstruction at an external workstation (NNT, main station).

Results

In all patients MRI scanning was performed without any pain or discomfort. Related to a scanning slice thickness of 0.8 mm, 7 to 8 pictures of the electrode inserted in the cochlea in the axial view were visible. In all scala tympani-positioned cases, visualisation of the basal turn was possible with a diminished signal of the scala tympani and a persistent signal in the scala vestibuli (Fig. 2a). During the first turn, the signal at the axial overview was visible with improved quality compared to a previous study [7]. The comparison between the regular axial view without an electrode (Fig. 1a,b) and the inserted electrode (Fig. 2b) allowed for estimation of the inserted electrode in the first turn. A diminishing signal, which allows a differentiation between a scala tympani or a scala vestibuli position of the electrode, was difficult since in this series a CT-based scala vestibuli position is missing. The coronal view shows diminishing of the fluid signal of the electrode (Fig. 4a,b) in comparison to the non-inserted cochlea (Fig. 3a,b). Coronal differentiation with a resolution of 0.8 mm between the scala tympani and scala vestibuli was difficult. A simultaneous DVT scan allowed for determination of the observed MRI-based position.

Discussion

The scalar position of the cochlear implant electrode is of high clinical importance, as it significantly influences the understanding of speech [1 9]. Therefore, post- or intraoperative estimation acts as a quality control for the surgery and is influenced by anatomy, electrode design and the surgeon's expertise.
The techniques used thus far for visual electrode assessment include the disadvantage of ionised radiation. The initial electrophysiological-based assessments of electrode position seem to be successful under acute and long-term conditions, but are electrode-dependent [2] and influenced by the brand-specific properties for intracochlear electrophysiological measurement.
MRI observations on cochlear implantees have been shown to be possible for all implant systems-with restrictions in terms of the field strength of the scanner and the need for a headband [10 11]. However, a persistent risk of magnet dislocation and a high rate of pain are known obstacles for some of the implant systems [3 4].
The introduction of a diametrically bipolar internal magnet solved the problem of magnet dislocation and pain [8]. Additionally, the observation of implant position-dependent artefact removal out of the cochlear and internal auditory canal area [5 6] allowed postoperative visual assessment of these otologically important regions.

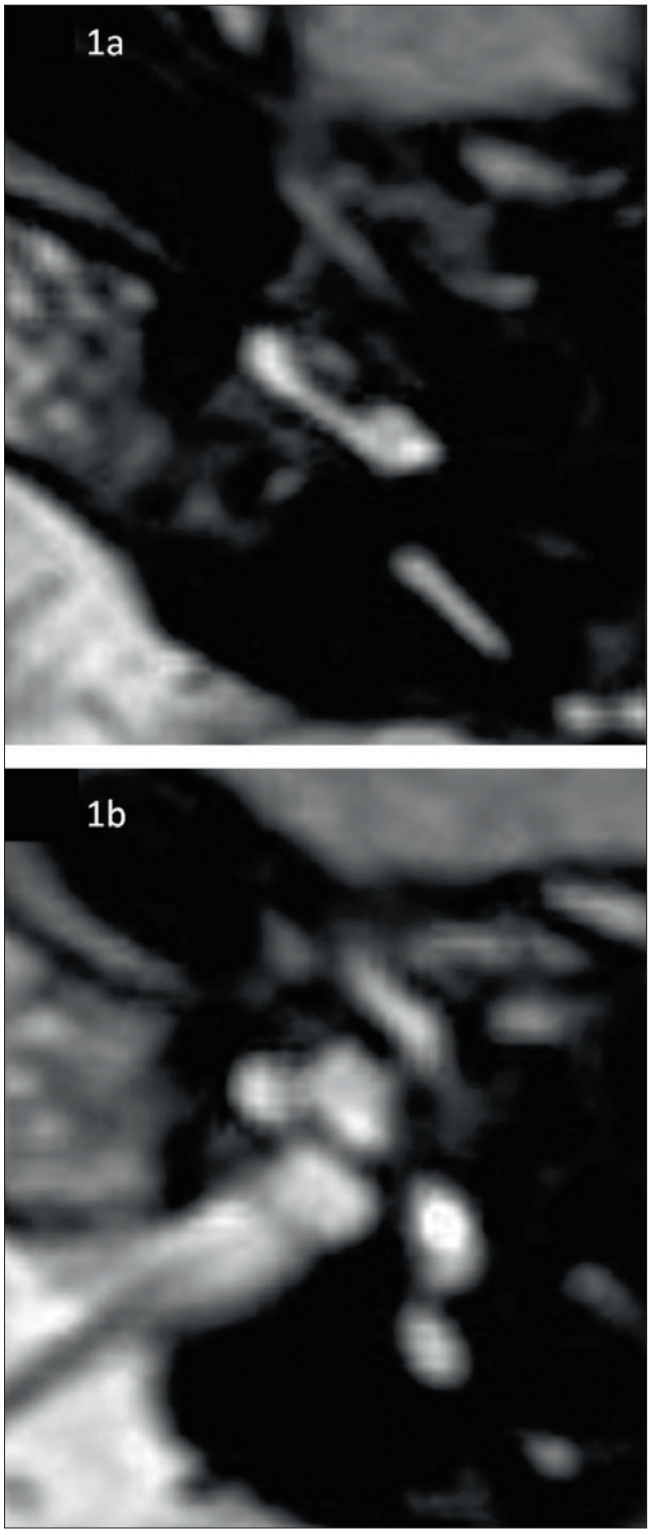

Fig. 1. 3T TSE t2 0.8 mm axial cochlea: a) basal turn, b) first turn.

In a previous study, it was shown that at 1.5T estimation of the electrode position by MRI is possible [7]. However, the electrodes used in this study were non-lateral wall

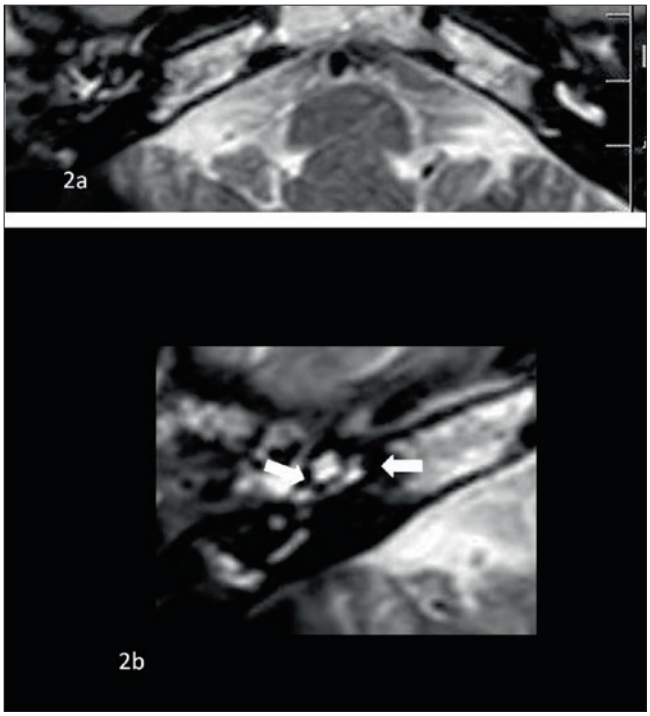

Fig. 2. 3T TSE t2 0.8 mm axial cochlea: a) basal turn inserted and not inserted, b) first turn with inserted electrode. Arrow indicates electrode-related signal diminishing.

electrodes. It is more difficult to visually assess the intracochlear position of lateral wall electrodes in DVT and FPT due to their high lateral position in the cochlear scala. In our study, we observed a positive correlation between CT-estimated positions and MRI observations. In all cases, we observed a scala tympani position in the basal turn. Compared to the previous 1.5 T study, the assessment in our study is characterised by higher visual resolution. This is related to the higher resolution of scans at 3T.

A difference between the fluid diminishing of the lateral wall electrode in this study and the perimodiolar/midmodiolar electrodes of the 1.5 T study was observed. While in both studies basal turn estimation of the electrode is easily possible, the more difficult assessment in the first turn is influenced by two factors: the scanner specific field strength and associated resolution abilities, and the electrode itself. Because the estimation of the electrode in the first turn is difficult in our 3T study and possible in the 1.5T study, electrode design thus seems to play a central role. Two points might explain the disadvantage of the lateral wall electrode used in terms of visual assessment. The first point is explained by a lower electrode volume of the lateral wall electrode in the first turn and therefore a lower fluid diminishing signal than a perimodiolar/midmodiolar electrode in this region.

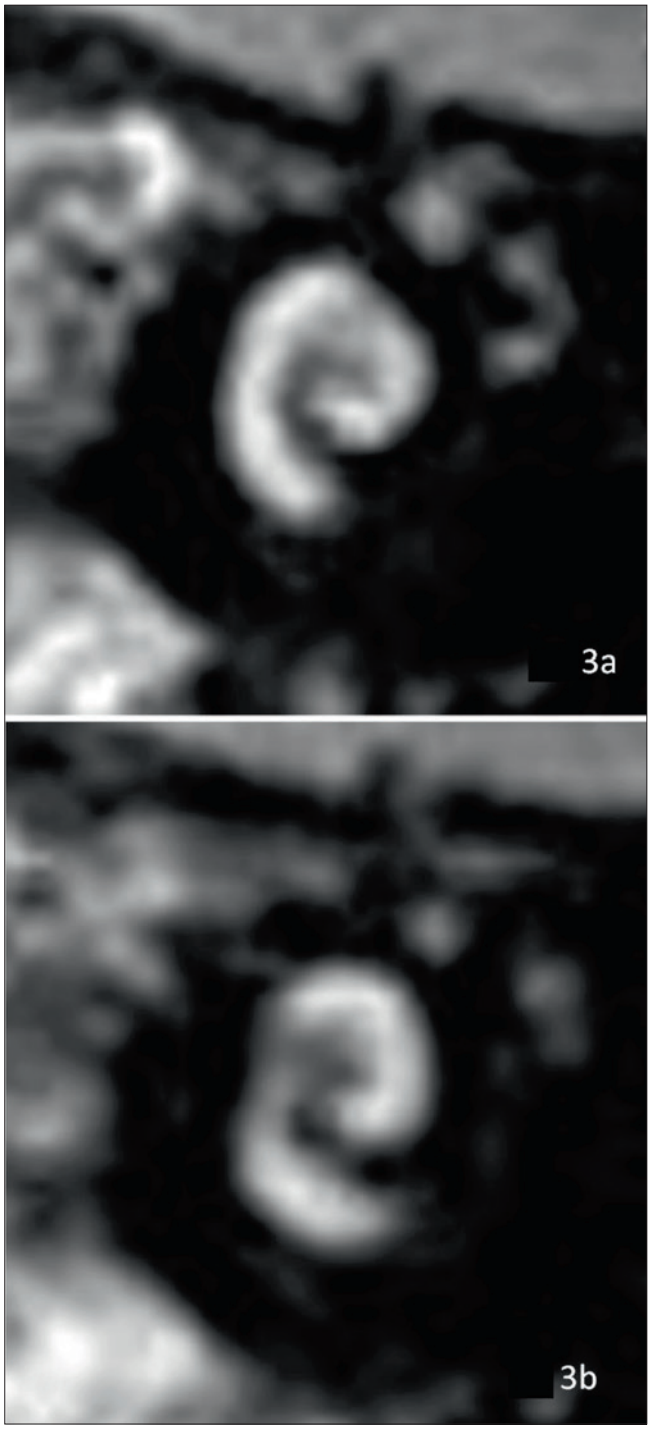

Fig. 3. 3T TSE t2 0.8 mm coronal cochlea: a) basal turn 1, b) basal turn 2.

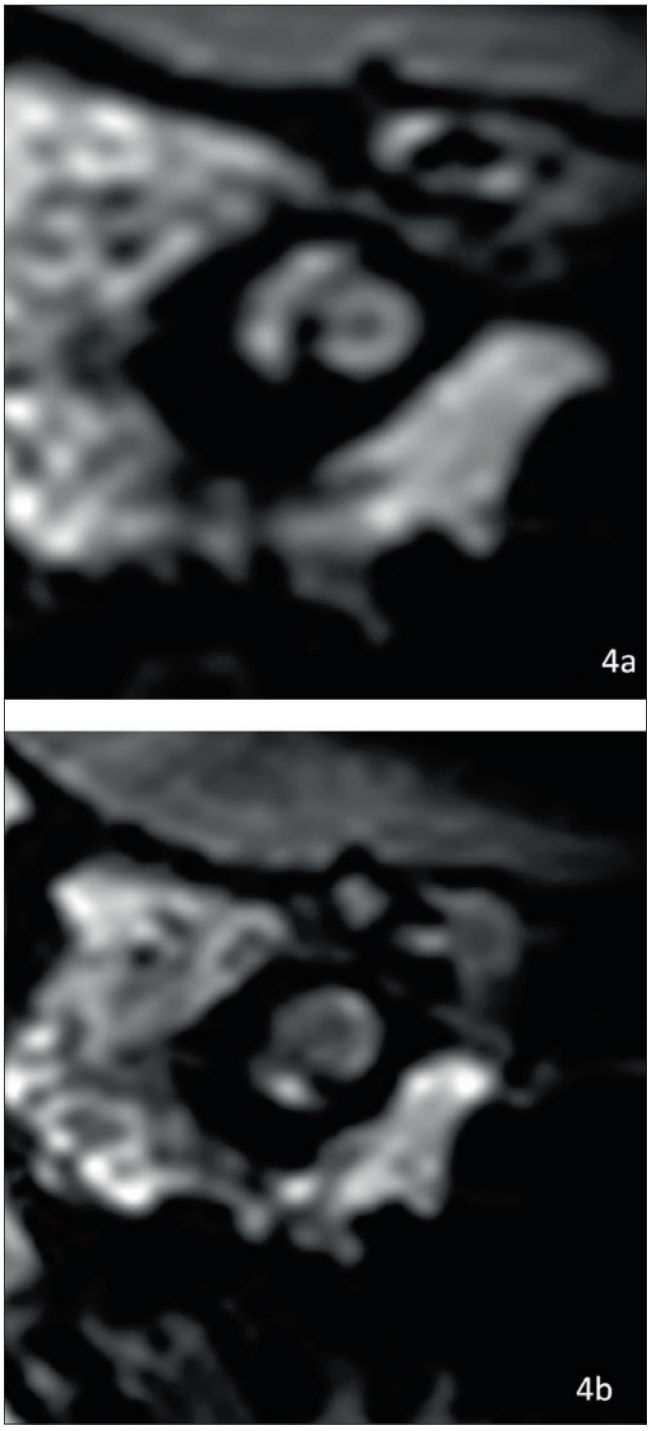

Fig. 4. 3T TSE t2 0.8 mm coronal cochlea: a) basal turn 1, b) basal turn 2 with inserted electrode.

The second point has to do with the lateral position of the electrode in the scala itself.

A limitation of the study is that a clear scala tympani to scala vestibuli translocation as a counterpart pattern for the scala tympani position was not observed. This is related to the lower translocation rate of lateral wall electrodes [12]. On the other hand, it is a disadvantage to the previously published 1.5T MRI study with a clear FTP and MRI-estimated visual translocation pattern of a perimodiolar electrode [7].

It can be assumed that with refined scanning protocols and prolonged scanning times better resolution will be possible.

Heating has a negative effect on neural structures when the temperature is increased to 43°C for more than 30 min [13]. The temperature increase of CI electrodes by a 3T scan is less than 3°C for 15 min scans. Usually the peak of temperature increase is reached during the first 3-5 min (personal communication, MEDEL, Innsbruck, Austria).

The postoperative MRI scanning at 3T allows high-resolution assessment of the internal auditory canal and the cochlea, if implanted with a diametrically bipolar internal magnet system. Ionised-free electrode assessment by MRI allows scanning in children. This opportunity is of reasonable clinical importance, even if it can be assumed that in a group of 400,000 CI-implanted patients, some developed a vestibular schwannoma after implantation. Another important reason for MRI scans in this patient group is the need for clarification of vertigo (e.g., infarction).

Therefore, the importance of postoperative MRI in the group of cochlear implantees with an otological and neurotological indication should not be underestimated.

Conclusions

Estimation of intracochlear position of a lateral wall cochlear implant electrodes by 3T MRI is possible for the basal turn. Electrode design plays a major role for visual assessment.

Acknowledgements

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Conflict of interest statement

None declared.

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