



Magnetic resonance imaging after cochlear implants

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ABSTRACT

Introduction: Most cochlear implants are currently compatible with magnetic resonance imaging (MRI) up to 3 T. Nevertheless, this does not completely eliminate the risk of serious accidents. Implant displacements and other adverse events with compatible implants have been reported in the literature.

Case reports: Among the six patients who had MRI after receiving implants at our center, we report three cases with adverse events related to the examination. The first case was complicated by magnet displacement with partial demagnetization. The second case showed total demagnetization, which necessitated removal and re-implantation of the implant. The third case involved severe pain sensation which disrupted the MRI scan. The smallest artifact was found with 3D MRI angiography, and largest artifact was found with diffusion and T2 FLASH.

Discussion: Moving the patient into the MRI apparatus must be supervised by an otorhinolaryngology specialist or an experienced radiologist. It is important to consider the magnetic field directions, so that angle between the implant magnetic fields and the MRI B0 always remains less than or equal to 90°. In addition, we recommend the use of an “arrow drawing” to facilitate the orientation of the magnetic field directions. Furthermore, to prevent magnet displacement, we recommend systematic use of a protective splint in addition to bandaging.

1. Introduction

In January 2015, 4101 patients in France fitted with cochlear implants were recorded on the national register. Many of these patients may need magnetic resonance imaging (MRI) during the course of their lives, since this technology is indicated for diagnosis of a large range of pathologies (Dubrulle et al., 2011).

Cochlear implants include a speech processor, an external antenna, an internal receiver and a stimulator. The external antenna and the internal receiver are coupled by transcutaneous magnets. The internal implant components are a magnet and a non-ferromagnetic electrode array. MRI imaging after cochlear implantation was initially contraindicated. However, following extensive work to measure torque, demagnetization, force and induced heating, both in vitro and in vivo, MRI has been authorized since 1995 under strict conditions, initially for 0.2 T MRI and then progressively up to 3 T currently (Deneuve et al., 2008). The aim of this article is to present our experience and review the literature on instructions, safety and risks following MRI post cochlear implantation, to further improve our understanding of this uncommon situation in daily clinical practice.

2. Case reports

Between 2008 and 2015, among 151 patients receiving cochlear implants in our center, six patients (ages 7–60 years) had MRI after cochlear implantation. Of these six patients, we provide a detailed report of three cases of serious complications from MRI.

Case 1: a 28-year-old patient who had been fitted with an implant because of progressive congenital deafness (cochlear model CI422). A brain MRI was requested in 2012, eight months after implantation, due to a progressive neurological illness that was difficult to diagnose, associated with progressive blindness and an ataxia of the cerebellum. A 1.5 T Siemens MRI with sagittal FLAIR sequences and axial T1, T2 and FLAIR sequences was carried out, strictly following the updated recommendations at that time, with the head wrapped. The patient experienced pain during the MRI and clinical examination showed clear evidence of magnet migration, with the magnet rotated 90° from its initial position under the skin. An emergency cerebral CT scan was performed, confirming magnet rotation without total implant displacement within the cochlea (Fig. 1). Emergency surgical intervention was organized, but shortly before entering the operating theatre,

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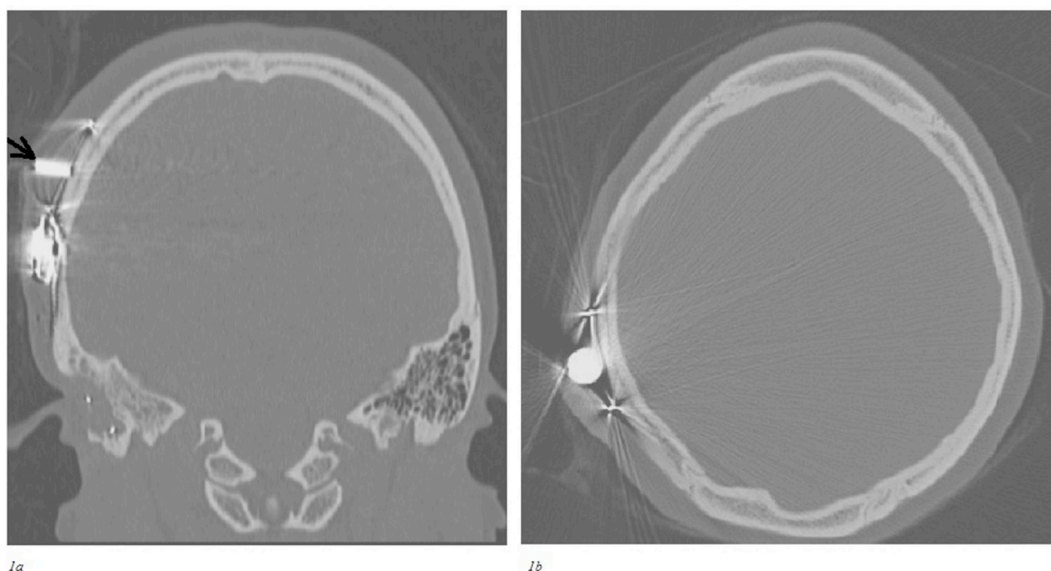


Fig. 1. (a, b). Patient 1, CT scan of cranium: magnet rotation is visible, perpendicular to its housing (arrow).

examination showed that the magnet had reverted spontaneously to the correct position and orientation. However, there was a slight loss of magnetism which made it necessary to increase the external magnet power. Auditory performance remained stable after MRI.

Case 2: a 68-year-old patient who had been wearing a cochlear implant for three years and for whom an MRI of the internal auditory canal was indicated to check on contralateral schwannoma. He had his first cerebral Siemens MRI at 1.5 T two years after implantation, which was carried out without incident. The patient had a follow-up MRI in 2009 (three years after implantation) with his head wrapped, erroneously carried out via 3 T Siemens Avanto MRI. He did not suffer any pain, but immediately following examination the external component could not be attached. On palpation, no edema or palpable changes were found. The implant magnet had been demagnetized. Since the magnet on this implant model (Digisonic SP) was not removable, this necessitated explantation and reimplantation of a model with a removable magnet (CI24RE). There were no postoperative infectious complications. Regarding audition quality, after reimplantation the patient experienced a slight improvement in his ability to perceive speech and improved comfort from reduced peripheral noise.

Case 3: a brain MRI (Avanto T1.5, Siemens) was performed six weeks after the implantation, for repeated tonic-clonic convulsions in a patient fitted with a cochlear CI24RE implant. A compressive bandage and a splint were used. Examination was stopped during the diffusion sequences when the patient experienced considerable pain at the implant site. There was no complication with the implant afterward.

Cases 4–6: uneventful brain MRI (Avanto T1.5, Siemens) examination using a compressive bandage and splint for cochlear CI24ER implants (all three patients fitted with the same implant model).

Among the six patients, the sequences producing the smallest artifacts were the venous 3D gadolinium MRI angiography sequences. The sequences with the largest artifacts were the diffusion and T2 FLASH sequences. The T1, T2 and T2 FLAIR sequences presented intermediate artifacts (Fig. 2).

3. Discussion

Nowadays, an increasing number of cochlear implants has become MRI compatible. Nevertheless, this compatibility does not eliminate the risk of incidents, despite following rigorous compliance with manufacturers' safety instructions. (Hassepass et al., 2014) The 2011 recommendations for MRI post cochlear implant are: an indisputable

need for the MRI, agreement (among the doctor ordering the MRI, the otolaryngologist, the radiologist and the patient), the manufacturer's authorization, a time interval between device implantation and MRI of at least six months, the systematic removal of the implant's external component and the fitting of an external, close-fitting compressive bandage (Dubrulle et al., 2011). The bandage should be 10 cm wide and should pass around the head in at least two layers (Fig. 3).

Pain and magnet displacement are the most frequently described complications in the literature. To date, 15 cases of magnet displacement and three cases of reversal of the internal magnet's polarity (rotating 180° in place) have been reported (Deneuve et al., 2008; Hassepass, Stabenau, Arndt, Beck, Bulla, Grauvogel, Aschendorff). These complications sometimes need surgical intervention to replace the magnet or to explant and then reimplant the device (Kim et al., 2015). Dotú et al. (Côté et al., 2007) estimated that the risk of infection from reimplantation is the same as for the initial implantation, and in terms of hearing and speech performance, results were reassuring, as Coté et al. demonstrated (Dotú et al., 2010). Another problem posed by MRI post implantation is the artifact generated by either the magnet (if left in place) or the electrode (which contains titanium). Image distortion may spread up to 6 cm around the electrode holder on a 1.5 T MRI and may extend up to 12 cm on a 3 T MRI, when the magnet is left in place (Dotú et al., 2010).

The presence of an experienced physician is important to prevent iatrogenic complications. The angle between the B0 MRI magnetic field and the implant's internal magnet (B1) must remain less than 90° to eliminate risk of implant magnet demagnetization. The critical zone of the magnetic field starts 30 cm from the MRI entrance tunnel (Vincent et al., 2008). A supine position with head straight (no inclination or deviation) will ensure the perpendicularity of the magnetic fields, with negligible risk of demagnetization (Vincent et al., 2008). Nevertheless, the orientation of the magnetic fields, the compatibility of the implant, the need for removal of the internal magnet and the need for application of other special instructions must be verified by consulting the manufacturer. We propose the use of an arrow drawing to be held by the patient, indicating the implant's B1 magnetic field orientation, to minimize error. In addition, we recommend the use of a protective splint (if there was no protective material provided by the manufacturer) with a bandage, regardless of implant brand. This could help in minimizing the risk of magnet displacement and pain (Fig. 3). The splint may be a piece of A4 paper folded into five lengthwise or a plastic card.

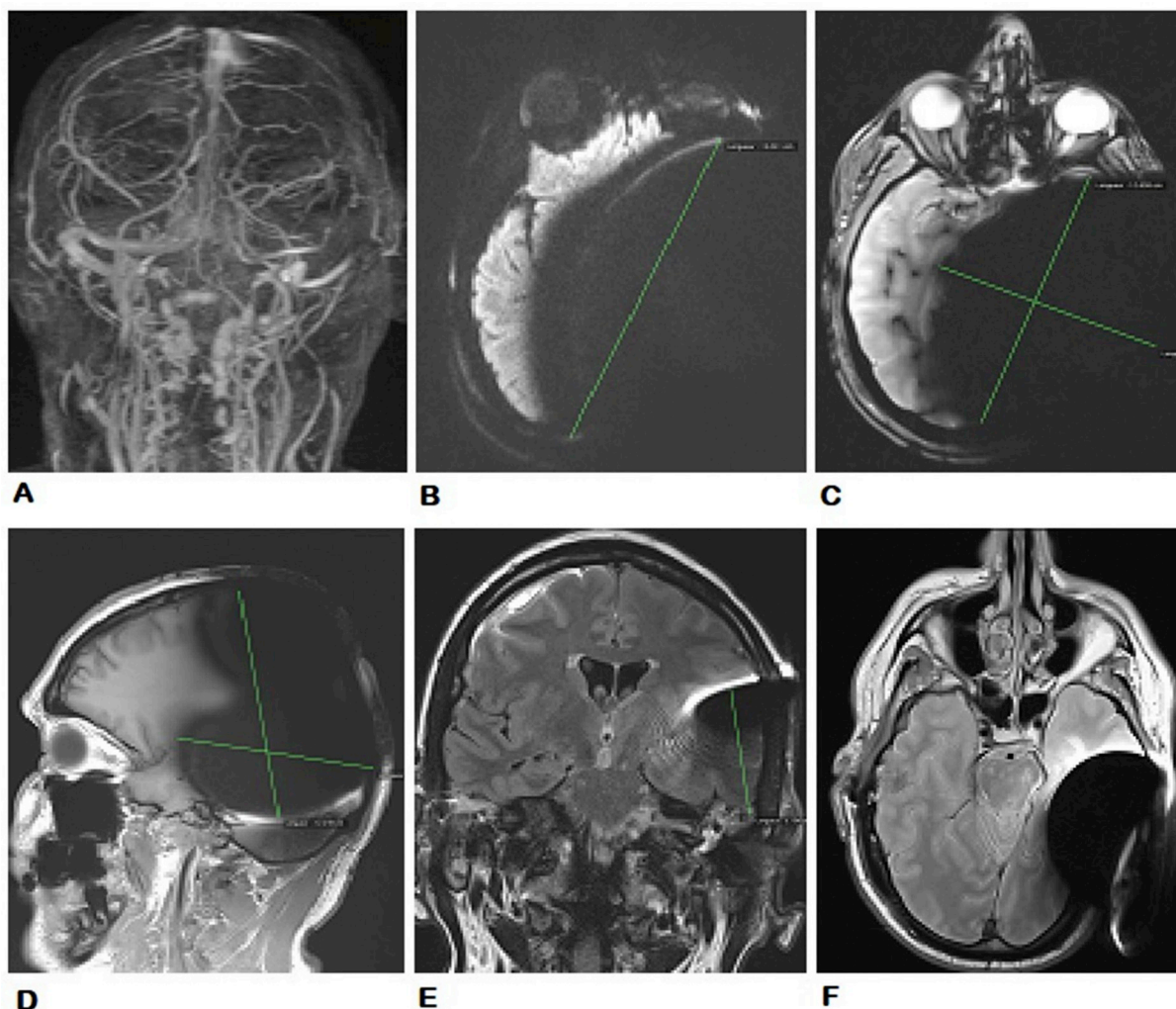


Fig. 2. 3D (1.5 T) MRI Angiography (a), Diffusion sequence (b) and T2 FLASH sequence (c), T2 Flair sequence (d) and T1 (e), T2 Sequence (f). The green lines correspond to the longest in-axis diameter.

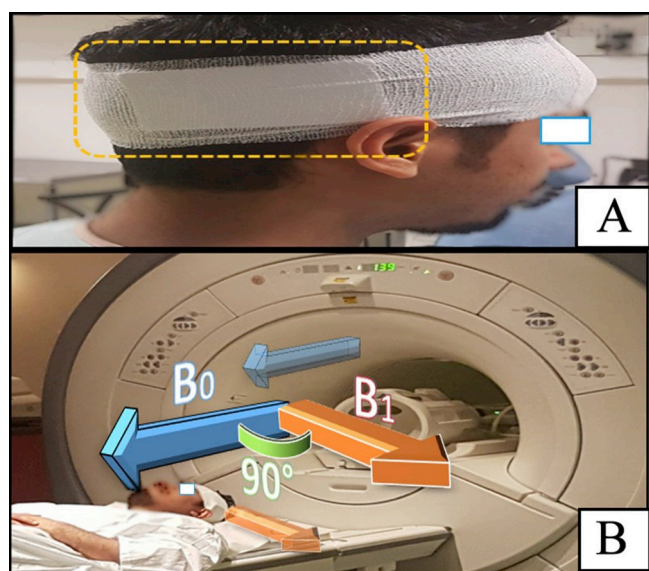


Fig. 3. (A) Application of the plastic splint on the implant site. (B) Demonstration of the B0 MRI and the B1 implant magnetic fields orientation that need to be respected.

Oral sedation had been proposed to the patient before MRI, to increase tolerance of the pain and pressure that could be felt during the examination (Crane et al., 2010). Additional artifacts in the images can result from pain leading to slight movements of the patient's head. The pain experienced by our patient could be explained by the diffusion sequence, which includes twelve directions, increasing the amplitude of the gradients and tissue stimulation. Finally, cochlear implant companies have started to tackle this problem. For example, MED-EL introduced a new model in the first quarter of 2018 (SYNCHRONY) that is completely MRI-safe at 0.2 up to 3 T, without even the need to apply a head bandage or splint kits, as it has a rotatable self-aligning magnet that reduces torque and ensures patient comfort. There is no recommendation from the manufacturer regarding MRI machines operating at more than 3 T, as they are limited in standard clinical practice nowadays.

4. Conclusion

Adverse events related to MRI may include pain, magnet displacement, polarity reversal or demagnetization. MRI indication must be indisputable, and the patient must be clearly informed about the risks of MRI. Supervision by an experienced person and careful consideration of the angle between the MRI B0 magnetic field and that of the implant's internal magnet must be strictly observed. A compression bandage and a protective splint are recommended.

Disclosure of benefit

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.joto.2018.11.001>.

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