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Original Article

# Intraindividual Comparison of Image Artifacts of Two Generations of Rotatable Cochlear Implant Magnets

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**BACKGROUND:** In cochlear implant recipients, the diagnostic value of magnetic resonance imaging (MRI) scans is reduced by image artifacts. The static magnetic field of a 3.0T scanner is associated with the risk of implant demagnetization. The development of rotatable implant magnets aimed to support the advancement of 3.0T MRI scanners and eliminate the risk of demagnetization of cochlear implant magnets. This study aimed to compare the image artifacts caused by first-[t] and second-generation rotatable cochlear implant magnets in 3.0T MRI.

**METHODS:** Three Tesla MRI T2W TSE sequences were performed on 3 subjects with first- and second-generation rotatable cochlear implant magnets. The cochlear implant was fixed to the head at the implantation position by a swim cap. The size of the image artifact was determined in the transverse plane.

**RESULTS:** Intraindividual comparative analyses showed that within the margin of combined uncertainty of 5 mm at a resolution of 2 mm, the cochlear implant-induced image artifacts in all subjects showed for both (first- and second-generation rotatable cochlear implant magnets), the same maximum image artifact dimension of 125 mm.

**CONCLUSION:** We could show that no difference in image artifact size was detected within the margin of error determined by resolution, localized induced shift of the scan, and reproducibility of the tilt angle of the head relative to the chest in a living subject. Assumed improved magnet attachment can be reached without compromising of the magnet artifact size.

**KEYWORDS:** 3T, cochlear implant, magnetic resonance imaging, image artifact

## INTRODUCTION

Cochlear implants (CI) have been established as a possible treatment option for hearing rehabilitation after unilateral hearing loss caused by vestibular schwannoma (VS) or intralabyrinthine schwannoma (ILS).[1-3] Magnetic resonance imaging (MRI) has been demonstrated as a valuable tool for regular tumor follow-up for cases of VS or ILS resection even after cochlear implantation,[4] with a proper MRI sequence and CI implant position at the head.[5-7] As shown by Ay et al[8] in an intraindividual comparative study, the image artifact position can be further optimized by the choice of head position.

The first generation of diametrically magnetized CI magnets allowed pain-free MRI scans at 3T even without headband deployment and removal of the magnet.[9] The second generation of removable cochlear implant magnets (e.g., Sonata 2 & Synchrony 2, Medel, Austria, Innsbruck) aims to achieve increased magnetic retention force by a positional change of the dipole in the implant magnet housing. Retention force is highly important since off-the-ear audioprocessors (OTE) are associated with increased weight compared to a regular audioprocessor coil. This increased weight can lead to problems of the attachment of OTE in terms of skin irritation or loss of the OTE.[10,11]

The present study aimed to compare first- and second-generation rotatable implant magnet artifacts at 3T MRI.

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## MATERIAL AND METHODS

The ex vivo measurements of 3T MRI artifacts with CI systems containing first- and second-generation removable rotatable magnets were performed in the radiology department. For the intraindividual comparison of the image artifact size, the implants (SYNCHONY vs. SYNCHRONY 2 (S-Vector), MED-EL, Innsbruck, Austria) were fixed with a silicone swim cap to the head of volunteers (2 males and 1 female adults) (Figure 1) with regular anatomy of the head and neck region without any pathology. The S-Vector implant magnet is a further development of the SYNCHRONY implant magnet with better utilization of the space inside the hermetically sealed magnet housing and with a new diametrically magnetized magnet where the magnetic dipole is shifted in parallel and closer toward the skin. The magnet is particularly suitable for use with MED-EL's single-unit processors.

Direct quantitative comparison of MR image artifact size caused by 2 different internal magnets is only feasible by surgical replacement of the internal magnet in situ—provided both internal magnets share the same mechanical interface—or by placing the magnet in the same position of the same volunteer head ex situ and holding a comparable regular position inside the scanner. For this study, the latter method was achieved using a silicone swim cap.[12] Figure 1 shows the swim cap used to reproducibly position the cochlear implant on the subject's head at the same position and orientation by permanently marking the initial circumference of the cochlear implants. The imaging was performed with a 3.0T MRI (Achieva, Philips, Best, NL) with T2-weighted turbo spin echo (TSE) sequences: TSE T2 2D: TR: 3000 ms, TE 120 ms, slice thickness 2 mm, voxel size 0.449 mm, and FOV 230 × 199.35 slices.

All participants gave their written informed consent. Procedures conformed to the World Medical Association's Declaration of Helsinki and were approved by the Ethical Committee of University Münster/Bielefeld University (Approval Number: 135-f-S; Date: August 20, 2019).

**Figure 1.** Silicone swim cap with the circumference of the implant being marked for reproducible positioning of the implant.

## RESULTS

Figure 2 shows an intraindividual comparison of maximum image artifact size in 3T MRI T2W TSE images for all 3 subjects with cochlear implants with both first- and second-generation rotatable implant magnets. The image artifact caused by the 3 cochlear implants during 3T MRI T2W TSE imaging for both the first- and second-generation internal magnets can be circumscribed by a circle of 125 mm in diameter within the margin of a combined uncertainty of 5 mm at a resolution of 2 mm (Figure 2).

Intra personally no difference in artifact size could be observed. Although a swim cap was used to achieve optimized comparability and the volunteers were asked to hold a "regular" position, it was still difficult to achieve an equivalent position for the artifact (Figures 3 and 4).

## DISCUSSION

Magnetic resonance imaging behavior of implantable (especially magnetic) devices is of high importance for their daily use compatibility.

For cochlear implantees, the rate of MRI scans in a lifetime can be assumed to be similar to that of the regular population. Therefore, strategies to allow problem-free MRI scans are important. Through the development of rotatable cochlear implant magnets (Synchrony, Medel, Innsbruck), and special attention to implant position on the

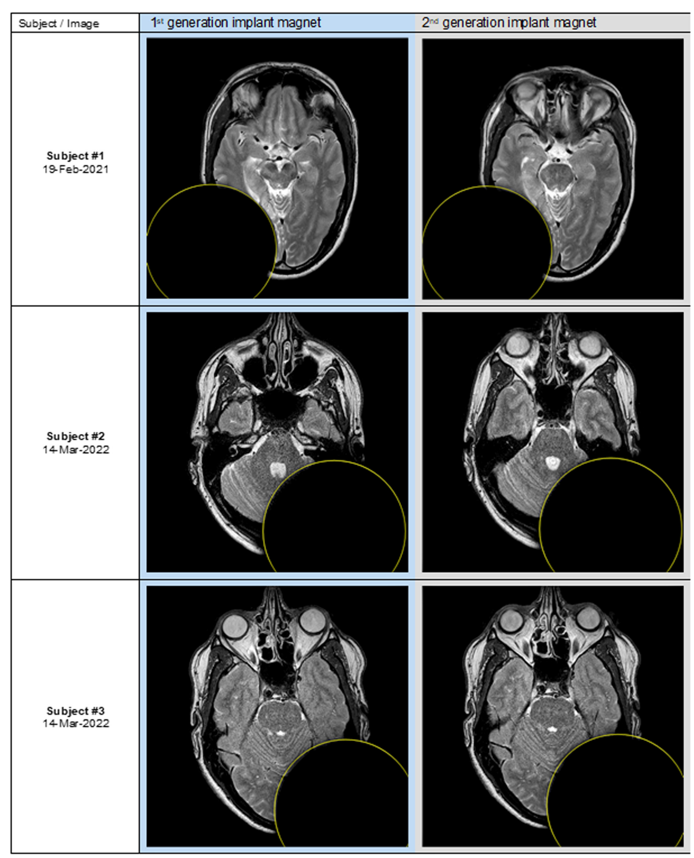


**Figure 2.** Intraindividual comparison of maximum image artifact size in 3T MRI T2W TSE images for 3 subjects with cochlear implants with both first- and second-generation implant magnets fully circumscribed by a circle of 125 mm in diameter.

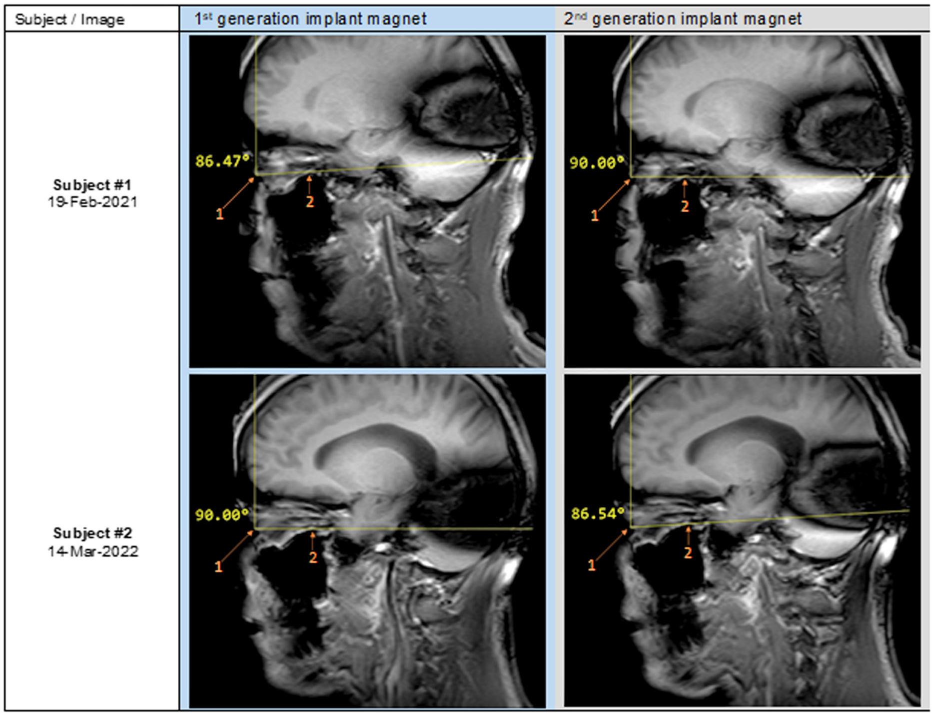


**Figure 3.** In subjects 1 and 2, the head inclination changed by 3.5° between the SYNCHRONY and S-Vector scans at an estimated measurement error for the angle of 0.5°. The reference plane extends over the bridge of the nose (point "1") and the upper side of the maxillary sinus (point "2").

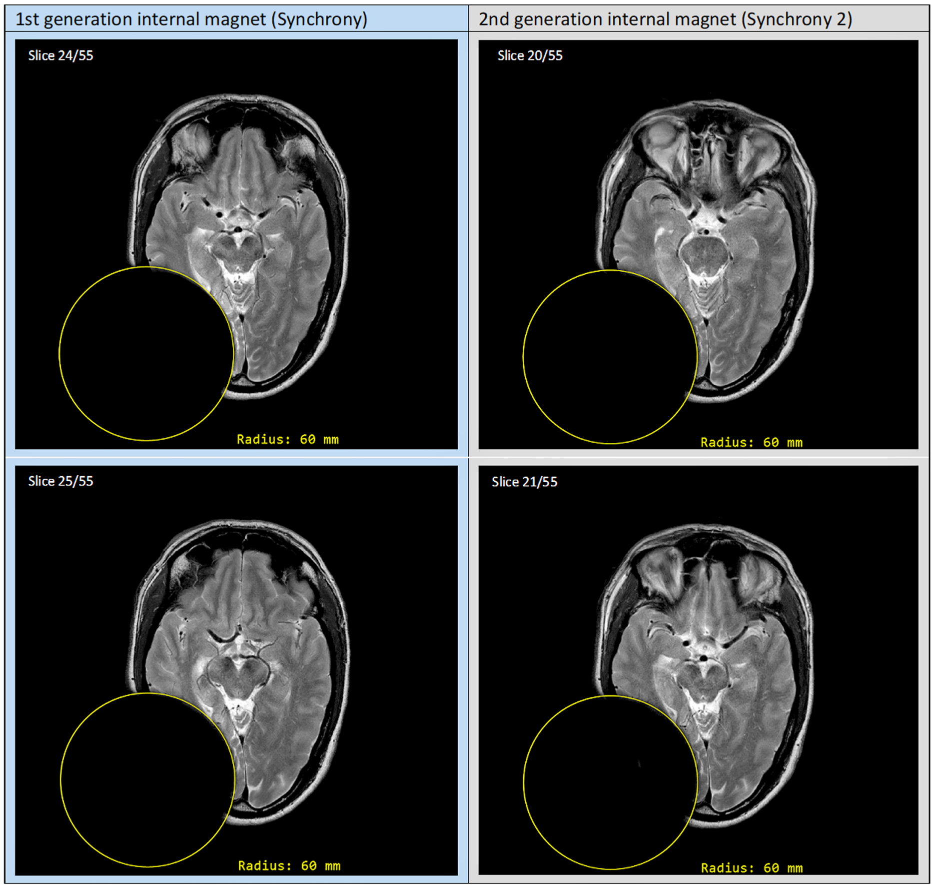


**Figure 4.** Comparison of the maximum artifact size of the first- and second-generation diametrical internal magnet study: Both 3T MRI T2W TSE image artifacts extend over a circular area with the same radius of 60 mm.

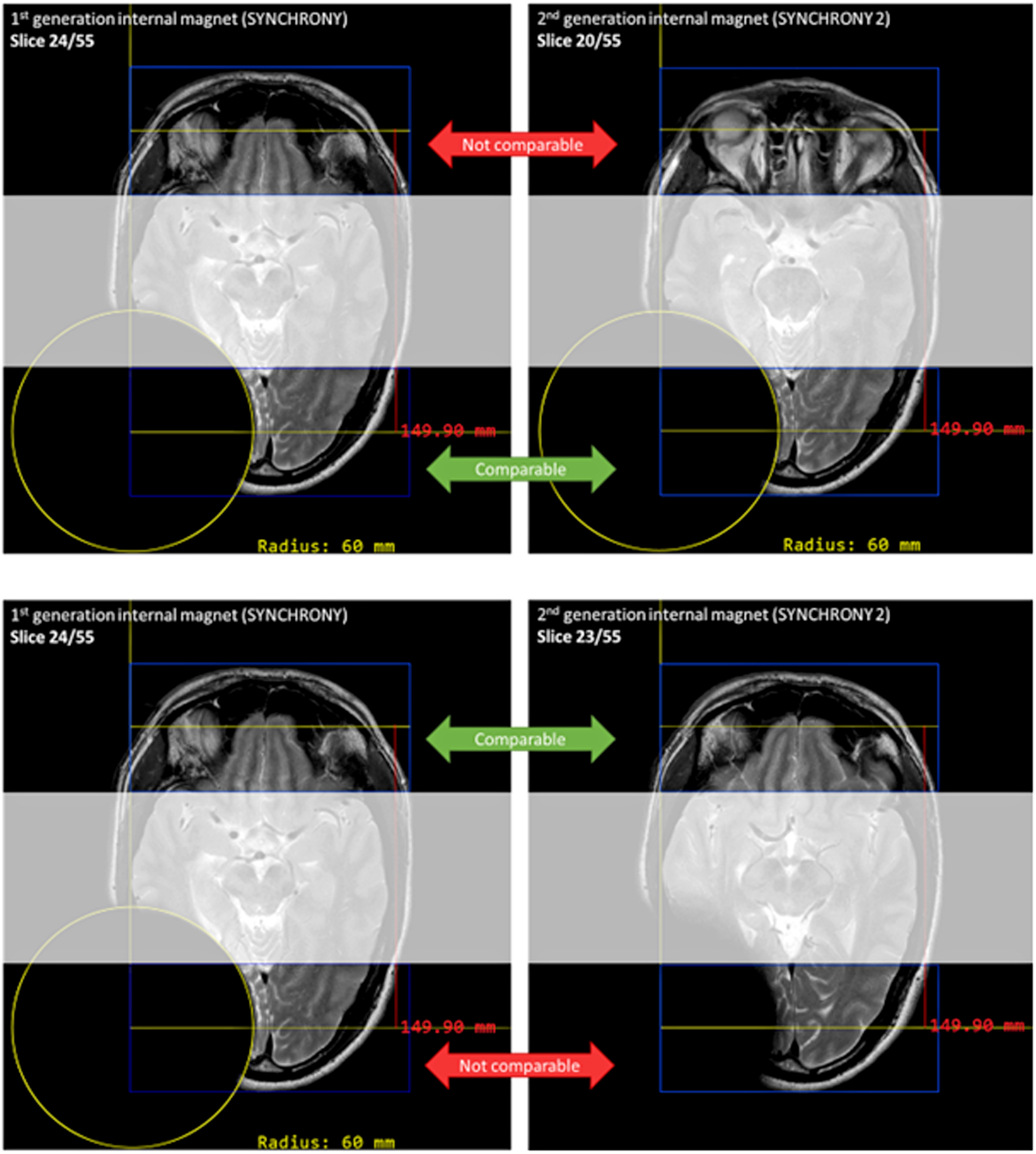


**Figure 5.** Comparison of the anterior–posterior areas in the transverse scans with maximum artifact size. While the anatomical structures in the posterior area of the first-generation internal magnet image 24/55 and the second-generation internal magnet image 20/55 are the same, they differ significantly in the anterior area. The anterior area of the first-generation internal magnet picture 24/55 is comparable to that of the second-generation internal magnet picture 23/55. This confirms the relative head inclination of 3.5°, which results in a shift of the anterior area by 3 layers (= 9 mm) along the longitudinal axis of the body.

head,[8] in the scanner,[7] and then MRI sequences,[13,14] problems like pain, demagnetization, and visualization of the internal auditory canal and cochlea can be resolved for most cases.

The introduction of OTE audio processors has once again focused special attention on the magnet. The increased weight in comparison to the regular coil demands an increased retention force of the internal magnet to allow a balancing out of the OTE magnet. Problems with magnets and OTE are well known with an association rate of up to 31%.[10] The change of the magnet design from a regular rotatable to a rotatable with increased retention force (S–S-Vector) itself led again to the question of how it is affecting the artifact size. Our results were able to show that the new design of the Vector does not affect the artifact size. Still, the results underline again the importance of the head position inside the scanner and the effect of minor head movements inside the scanner on the artifact position (Figures 2-4).

Accurate reproduction of the scan position concerning anatomical structures of the head is crucial when aiming for a quantitative comparison of the image artifact size. Direct intrapersonal comparison has to overcome the obstacle of different head positions and orientations even when taking extreme precautions to place the cochlear implant in the same position on the subject's head. While a variation in head position is compensated fully by the MRI operator by choosing the field of view based on the localizer scans, the following paragraphs describe how to compensate for differences in anteflexion and head tilt angle when determining image artifact size.

Comparison of the localizer images in the sagittal plane showed that for both subjects 1 and 2 the anteflexion angle of the head differs between the first- and second-generation implant magnet scan (Figure 3).

A reference line is drawn from the bridge of the nose (point "1") to the upper side of the maxillary sinus (point "2"). The head inclination angle is enclosed between the reference plane and the transverse plane.

Figure 3 shows a direct comparison of the first- to second-generation implant magnet scan in the sagittal localizer scans. For subject 1, in the first-generation implant magnet scan, an angle of 86.50° is enclosed between the reference plane and transverse plane. In the second-generation implant magnet scan, the reference and transverse plane are rectangular (90°), resulting in a difference in the head anteflexion angles of 3.5° between both scans of the same subject. While the head of subject 1 was tilted by about 3.5° more toward the chest, the situation was reversed for subject 2.

Figure 4 gives the slice number of the transversal image slices with the maximum radius of the circle circumscribed around the image artifact recorded for subjects 1 and 2 for first-[t] and second-generation implant magnets, respectively. The different head tilt angles are noticeable when comparing the anterior–posterior areas in the transverse slices.

However, the measured image artifact size in the transverse plane can be corrected for the head tilt angle. This will be explained in the following example of subject 1. Figure 5 shows that although for subject 1 the anatomical structures match in the posterior area, the first- and second-generation implant magnet imaging slices 24/55 and 20/55, respectively, differ significantly in the anterior area. However, the anterior area of the images is comparable for the first- and second-generation implant magnet imaging slice 24/55 and 23/55, respectively. Hence, the maximum artifact size of 120 mm has to be corrected for the head tilt angle of 3.5° confirmed by the analysis of the sagittal localizer images shown in Figure 3. As a result, the head tilt corrected maximum dimension of the image artifact has to be adjusted between 7 mm to 10 mm for subject 1, lying between 127 mm and 130 mm.

One limitation of our study is the use of only one MRI sequence. The effect of different MRI sequences on MRI artifact size is well known; therefore, our comparison of the magnets is limited.[13,14]

A simple ex vivo method for direct quantitative intrapersonal comparison of MR image artifacts induced by different cochlear implants is demonstrated by first- and second-generation 3T MRI-approved internal magnets. It shows that no difference in image artifact size can be detected within the margin of error determined by resolution, localized induced shift of the scan, and reproducibility of the tilt angle of the head relative to the chest in a living subject. The proposed improved magnet attachment can be reached without compromising the magnet artifact size.

**Ethics Committee Approval:** This study was approved by the Ethics Committee of University Münster/ Bielefeld University (Approval Number: 135-f-S; Date: August 20, 2019).

**Informed Consent:** Informed consent was obtained from the participants who agreed to take part in the study.

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**Declaration of Interests:** The authors have no conflicts of interest to declare.

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