Metal-induced artifacts in computed tomography and magnetic resonance imaging: comparison of biodegradable magnesium alloy versus titanium and stainless steel control

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Background: Metal artifact arising from orthopedic hardware can present a major obstacle to computed tomography (CT) and magnetic resonance (MR) imaging of bone and soft tissues and may preclude its use in postoperative patients. Factors influencing the amount of metal artifacts include the size and orientation of orthopedic hardware, as well as the composition of the metallic object. Most frequently used standard materials for implants, screws, and pins are titanium and stainless steel. Recently, biodegradable magnesium alloys – a new class of degradable biomaterials - have been introduced and rapidly gained much interest[1]. However, so far, there is limited knowledge about these materials with regard to metal-induced artifacts at CT and MR imaging.

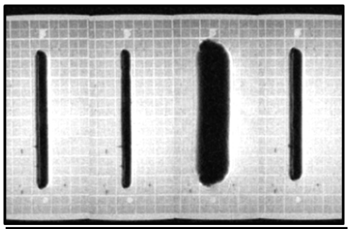

Figure: FFE MR image of 4 different pins made from biodegradable magnesium alloys with 2.4 and 1.6 mm diameter, stainless steel (2mm) and titanium (2mm) (from left to right) illustrates extension of metal artifacts.

Purpose: Our aim was to evaluate metal artifacts induced by biodegradable magnesium alloys at CT and MR imaging at 1.5T in comparison to standard titanium and stainless steel controls.

Methods and Materials: Four different pins made from stainless steel (diameter, 2mm), titanium (diameter, 2mm), and biodegradable magnesium alloys (two pins with 1.6 and 2.4mm diameter, respectively) were scanned using a 2nd generation Dual Energy multidectector CT scanner (Somatom Flash, Siemens, Forchheim, Germany) and a 1.5T MR system (Achieva, Philips Healthcare, Best, the Netherlands). For CT, pins were positioned parallel and orthogonal to the z-direction and scanned using the following protocol: (1) pins embedded in agar-agar; 80kV and 140kV, mAs adapted automatically); (2) pins laid on air; 120kV; four different mAs settings (25, 50, 100 and 200mAs). For MR imaging, pins were placed in a tank filled with 8l of $CuSO_4$ solution (1g $CuSO_4$ per liter distilled water) aligned and orthogonal to the main magnetic field. Fast field echo (FFE) (TR/TE, 100/15ms; flip angle 15°, bandwidth 125Hz) and spin echo (TR/TE, 500/20ms; 70°; 125Hz) MR sequences as described in ASTM 21194[1] were used. Artifacts at CT were quantitatively assessed by calculating the standard deviation of the mean Hounsfield Unit (HU) value of three standardized ROI's placed around the pins. Artifacts at MR imaging were determined by calculating the maximum artifact diameter.

Results: Artifacts at CT and MR imaging were most pronounced for stainless steel, followed by titanium and biodegradable magnesium alloys (***Table 1*** and ***Table 2***). Titanium showed slightly larger artifacts than biodegradable magnesium alloys in both, CT and MR imaging.

Table 1. CT imaging Standard deviation of Hounsfield (HU) units	80 kV 37 mAs	140 kV 18 mAs	120 kV 25 mAS	120 kV 50 mAS	120 kV 100 mAS	120 kV 200 mAS
Stainless steel	99 / 126 *	19 / 40	28 / 131	11 / 109	10 / 155	7 / 154
Titanium	17 / 62	6 / 26	7 / 42	4 / 37	2 / 36	1 / 26
Magnesium (1.6mm)	3 / 24	1 / 13	1 / 3	2 / 4	2 / 5	1 / 7
Magnesium (2.4mm)	2 / 42	3 / 13	3 / 19	1 / 21	1 / 13	1/ 14

*** CT data are reported for pin position parallel and orthogonal to the z-direction, respectively.**

Table 2. MR imaging Artifact diameter [mm]	FFE parallel to B0	SE parallel to B0	FFE orthogonal to B0	SE orthogonal to B0
Stainless steel	30	28	48	37
Titanium	11	10	20	17
Magnesium (1.6mm)	8	8	14	13
Magnesium (2.4mm)	10	9	16	13

Conclusion: In comparison to standard titanium and stainless steel controls, biodegradable magnesium alloys show less metal induced artifacts at CT and MR imaging at 1.5T. Our results indicate that imaging examination of postoperative patients in whom biodegradable magnesium alloys were used for orthopedic hardware would be less hampered by metal induced artifacts compared to titanium or stainless steel hardware. Further clinical studies are recommended to evaluate these new degradable biomaterials in patients, and to optimize parameters for clinical CT and MR imaging protocols.

References: [1] Castellani C et al. Bone-implant interface strength and osseointegration: Biodegradable magnesium alloy versus titanium control. Acta Biomater 2011;7:432-440 [2] ASTM F2119-07. Standard Test Method for Evaluation of MR Image Artifacts from Passive Implants: ASTM; 2007.