Standard MRI image artifact reduction sequences improve visibility near a Mobi-C® Cervical Disc Prosthesis

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The metallic plates of the Mobi-C Cervical Disc Prosthesis when imaged in an MRI environment can compromise visibility of the prosthesis itself and the surrounding anatomy, including the spinal cord and adjacent vertebrae. This image artifact is a common occurrence with all metallic implantable medical devices and is the result of an interaction between the metallic components of the implant and the magnetic field of the MRI. The magnetic field of the MRI is controlled via sequences that were developed to highlight anatomical structures; common sequences are T1-weighted spin echo (fat), T2-weighted spin echo (fat and water) and gradient spin echo (small lesions). Following suit, MRI manufacturers have also developed MRI imaging parameters specifically designed to reduce the image artifact from metallic implantable medical devices. These MR image artifact reduction sequences yield improved visibility of the anatomy surrounding Mobi-C.

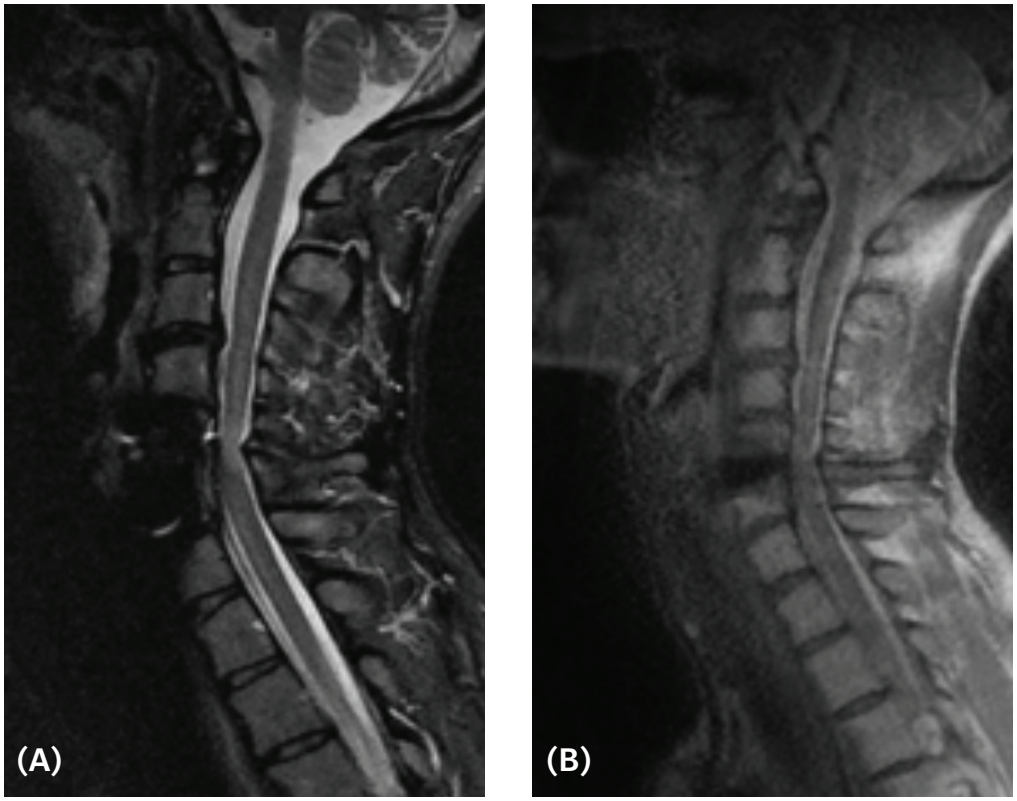

Fig. 1

MR images of the same patient with a Mobi-C prosthesis at C5-C6 acquired with a (A) T2 SE sequence and (B) MAVRIC SL sequence.

Table 1 *Image artifact reduction sequences of most common MRI manufacturers*

Manufacturer	Image Artifact Reduction Sequence	Notes
GE Healthcare	MAVRIC SL	Available on all GE fast spin echo sequences
Siemens Healthineers	WARP	Available on all Siemens turbo spin echo sequences
Philips	Recommend parameters on Philips' website[1]	Refer to Appendix 1 for sequence parameters

1. http://incenter.medical.philips.com/doclib/enc/fetch/2000/4504/577242/577256/588821/5050628/5314862/8360075/US_FS44_p18_Appl_tips_Metal_artifact_reduction.pdf%3fnodeid%3d8360181%26vernum%3d-2

Objective

Given the utility of these MR image artifact reduction sequences, non-clinical testing was performed with Mobi-C to quantify the difference in observed image artifact at 1.5T between each manufacturer's image reduction sequence and each manufacturer's T1-weighted SE and GRE sequences. To facilitate, Mobi-C was placed in three orientations with respect to the static magnetic field (aligned in the axial, coronal and sagittal planes), for each orthogonal direction of the magnetic field (head-to-foot, right-to-left, anterior-to-posterior), and for each sequence (image reduction (WARP/MAVRIC/PHILIPS), T1-weighted SE, GRE). All resulting images were computationally sliced in axial, coronal and sagittal planes, image artifact width (mm) and image artifact surface area (cm2) adjacent to Mobi-C were measured, then the smallest overall and largest overall artifact values among the three orientations of the device were reported for each sequence type for each imaging plane.

Results

The worst-case width and surface area of the image artifact adjacent to Mobi-C was extracted for every orientation of Mobi-C for each MRI sequence performed at 1.5T. Data tabulated in Table 2 and presented graphically in Figures 2-3 detail the minimum and maximum values of the largest (worst-case) observed image artifact among the three orientations of the device.

Table 2 *Minimum and maximum observed image artifacts adjacent to Mobi-C during non-clinical testing at 1.5T*

MRI Sequence	Plane of Observed Atifact	Artifact Width (mm)		Artifact Area (cm²)	
		Min	Max	Min	Max
Gradient Spin Echo	Axial	23.1	29.6	27.9	30.0
	Sagittal	25.4	29.8	22.5	25.6
	Coronal	24.5	28.4	22.7	25.7
T1-Weighted Spin Echo	Axial	14.1	19.0	7.8	11.5
	Sagittal	12.1	20.9	9.1	15.0
	Coronal	12.5	22.5	9.4	15.1
PHILIPS	Axial	9.5	11.3	6.8	6.9
	Sagittal	13.9	15.6	7.0	8.9
	Coronal	11.8	15.0	7.3	8.9
WARP	Axial	4.6	10.9	5.0	5.4
	Sagittal	8.2	12.8	6.0	7.4
	Coronal	7.9	14.3	5.9	7.6
MAVRIC	Axial	8.4	10.6	3.6	3.9
	Sagittal	6.6	9.9	4.1	4.9
	Coronal	5.2	10.6	4.5	4.8

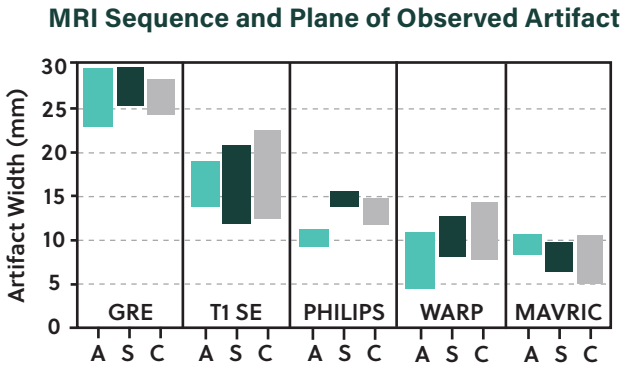

Fig. 2 *Width of image artifact adjacent to Mobi-C at 1.5T observed via non-clinical testing as a function of MRI sequence and imaging plane. A: axial plane; S: sagittal plane; C: coronal plane.*

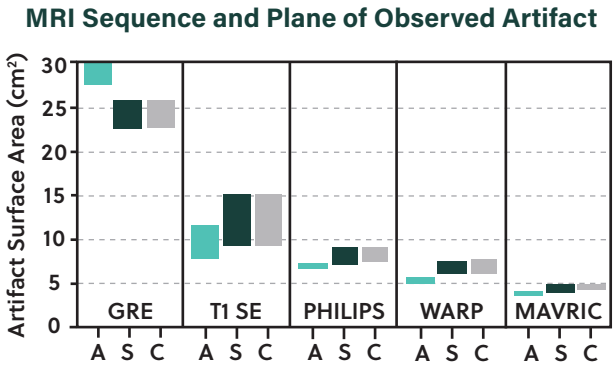

Fig. 3 *Surface area of image artifact adjacent to Mobi-C at 1.5T observed via non-clinical testing as a function of MRI sequence and imaging plane. A: axial plane; S: sagittal plane; C: coronal plane.*

Discussion

Evidence from this non-clinical study supports:

- Mobi-C image artifact at 1.5T is reduced for every device orientation and every image artifact reduction sequence (WARP/MAVERIC/PHILIPS) compared to standard T1-weighted SE and GRE MRI sequences.

Application of image reduction sequences to a clinical setting supports:

- Visibility of vertebrae adjacent to the Mobi-C prosthesis using image artifact reduction sequences at 1.5T as the average cervical spine vertebral body height of C3-C7 in a skeletally mature human is 1.2 cm [1,2].
- Visibility of neurological tissues near the Mobi-C prosthesis of the patient shown in Figure 4 using an image artifact reduction sequences at 1.5T.

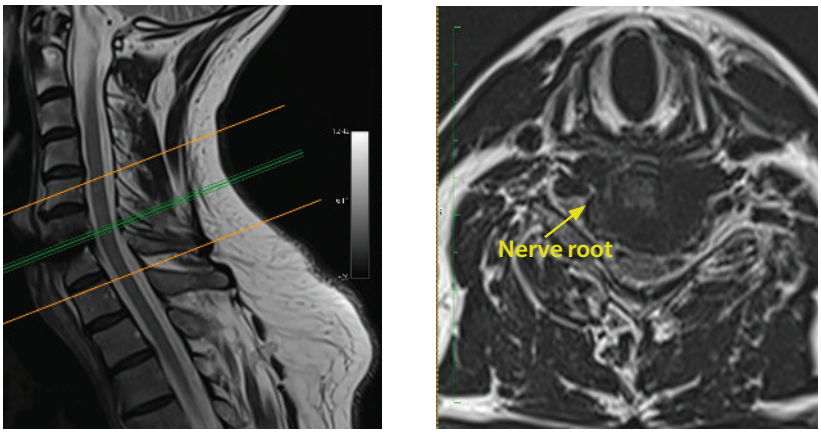

Fig. 4 *MRI scan of a patient with a Mobi-C prosthesis at C6-C7 obtained with WARP sequence. Visibility of the nerve root is maintained on the true axial image (gold arrow).*

CONCLUSION

- Mobi-C image artifact at 1.5T is reduced for every device orientation and every image artifact reduction sequence (WARP/MAVERIC/PHILIPS) compared to standard T1-weighted SE and GRE MRI sequences;
- When presented with the option, we recommend to use first choice WARP or MAVRIC SL sequence with 1.5T MRI which demonstrated better artifact reduction than PHILIPS sequence.
- Though artifact was not evaluated at 3.0T, we speculate trends in the current data collected at 1.5T to align with those at the 3T.

Appendix 1

The metal artifact reduction sequence parameters given by Philips are available on their website[2]. From these recommendations the following sequences were programmed for testing:

Table A1-1 *Philip's sequences applied during non-clinical image artifact evaluation of Mobi-C at 1.5T*

Sequence	Frequency Direction	TR (ms)	TE (ms)	BW (kHz)	Matrix	Echo Train Length	NEX	Flip Angle (°)	Emitting/ Receiving Coil
Fast Spin Echo Axial	RL	3500	30	125	256^2	20	3	180	Body
Fast Spin Echo Axial	AP	3500	30	125	256^2	20	3	180	Body
Fast Spin Echo Coronal	SI	3500	30	125	256^2	20	3	180	Body
Fast Spin Echo Coronal	RL	3500	30	125	256^2	20	3	180	Body
Fast Spin Echo Sagittal	SI	3500	30	125	256^2	20	3	180	Body
Fast Spin Echo Sagittal	AP	3500	30	125	256^2	20	3	180	Body

2. http://incenter.medical.philips.com/doclib/enc/fetch/2000/4504/577242/577256/588821/5050628/5314862/8360075/US_FS44_p18_Appl_tips_Metal_artifact_reduction.pdf%3fnodeid%3d8360181%26vernum%3d-2

Appendix 2

Materials and Method

GE Healthcare Optima MR450w (1.5T) and SIEMENS Healthineers MAGNETOM Aera 1.5T MRI were used to perform tests. The sequence image reduction parameters defined by Philips were applied with the GE system. The largest Mobi-C prosthesis was used for this evaluation, as the largest amount of metallic material will create the worst-case image artifact. All tests were performed according to the principles of ASTM F2119, which defines standardized conditions for evaluating image artifact in an MRI setting.

The implant was suspended by strings to maintain position and immersed in a tank filled with water and a small amount of contrast solution per ASTM F2119. A reference object was placed in the scanner field of view to assess accurately the position of the device and provide a reference for artifact measurement. The Mobi-C prosthesis was tested in three orientations (aligned in the axial, coronal and sagittal planes), for each possible direction of the magnetic field (head-to-foot, right-to-left, anterior-to-posterior), and for each sequence (image reduction (WARP/MAVERIC/PHILIPS), T1-weighted SE, GRE).

For artifact measurement, the Mobi-C implant was superimposed on the artifact and the remaining artifact width and surface area were measured using a computational algorithm. Artifact width and surface area dimensions were translated from pixels to physical units of measure based on the resolution of the MR images.

Description	Value	Unity
Artifact width	7.9	mm
Surface	478	mm^2

Fig A2-1 *Method for Mobi-C artifact measurement, artifact from MAVRIC SL sequence depicted.*

References:

1. P. R. Katz, H. M. Reynolds, D. R. Foust, and J. K. Baum, "Mid-sagittal dimensions of cervical vertebral bodies," Am. J. Phys. Anthropol., vol. 43, no. 3, pp. 319–326, 1975.
2. I. Busscher, J. J. W. Ploegmakers, G. J. Verkerke, and A. G. Veldhuizen, "Comparative anatomical dimensions of the complete human and porcine spine," Eur. Spine J., vol. 19, no. 7, pp. 1104–1114, 2010.

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