The Optimizations of SEMAC-VAT Technique for Magnetic Resonance Imaging of Total Knee Prosthesis: Comparison of 1.5T and 3T for Different Metal Materials

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Introduction

Slice encoding for metal artifact correction (SEMAC) technique has preliminarily shown tremendous potential to correct metal induced artifacts in patients with metal based knee replacements, allowing for post-surgical complications to be evaluated more accurately.[1,2] When using SEMAC-VAT, SEMAC-encoding steps determine the degree of metal artifact correction. An increase in the number of steps typically reduces metal artifact further but also increases acquisition time substantially. In addition, the degree of metal artifact is related to the types of metal materials and field strengths of the MRI. In this study, SEMAC-VAT imaging was performed at 1.5T and 3T with varied SEMAC-encoding steps with the use of 3 different types of metal components commonly used in total knee prosthesis.

Materials and Methods:

Phantom evaluation was performed at both 1.5T (Siemens, Espree) and 3T (Siemens, Skyra) equipped with 15-channel knee coils. Three standard metal materials were imaged including two femoral components (Cobalt Chromium [CoCr] and Oxidized Zirconium [ZIR]) and one tibial component (Titanium [TI]). All phantoms were then scanned using SEMAC-VAT (with multiple SEMAC-encoded steps of 1, 5, 10, 15, 20, 25 and 30, BW=781Hz/pixel or 100kHz), high bandwidth (high BW, BW=501Hz/pixel or 64kHz) and conventional TSE sequence (BW= 241Hz/pixel or 31kHz) with proton-weighted imaging (PDWI). The artifact area for each slice was measured using an adaptation of the referenced subtraction method. A plot of artifact area to slice number was obtained. Total artifact volume for the whole image stack was measured by calculating the area under curve (AUC). The efficacy of metal artifact reduction was compared across the varied SEMAC-encoding steps as described above.

Results and Discussion

The area measurements and associated statistical analyses demonstrated that the metal artifact was significantly reduced by high BW, VAT and SEMAC-VAT sequences for all evaluated metal components at both 1.5T and 3T (Figure 1). Improved artifact correction was achieved by increasing SEMAC-encoding steps. However, a relative plateau phase of artifact correction reached with increasing SEMAC, which varies from 1.5T to 3T as well as with different types of metal materials. Considering the increase in acquisition time (about 1min per step), the optimal number of SEMAC-encoding step was around 15 at 1.5T and 20 at 3T for the CoCr. Meanwhile, the optimal number of SEMAC-encoding steps is reduced when imaging metal implants made of ZIR or TI materials (5 to 10 steps for both 1.5T and 3T). These results provide an optimal trade-off between acquisition time and artifact correction especially when there is knowledge of the types of metal materials used in a specific patient or the acquisition of a distortion scout prior to the diagnostic image scan. In addition, much more artifact was seen with all metals at 3T than at 1.5T, in particular when CoCr was the material of interest. The use of SEMAC-VAT with higher encoding steps recovered the symmetric appearance of the metal components very well at 1.5T ("M" shape for femoral components and "Λ" shape for tibial component from sagittal images). Additionally, residual artifact in the middle portion of the images made an irregular "∩" shape for the curves of CoCr and ZIR at 3T, even with increased SEMAC-encoding steps. The performance of SEMAC-VAT on TI component was very similar at both 1.5T and 3T (Figure 2). Compared to conventional 2D sequence, the volume of metal artifact (AUC) was remarkably reduced by high BW, VAT and SEMAC-VAT sequences: 22.4-71.9% at 1.5T and 28.8-59.6% at 3T for CoCr; 12.4-38.0% at 1.5T and 21.6-37.9% at 3T for ZIR; 19.9-47.3% at 1.5T and 12.9-55.9% at 3T for the TI, which further confirmed the results from the area measurements.

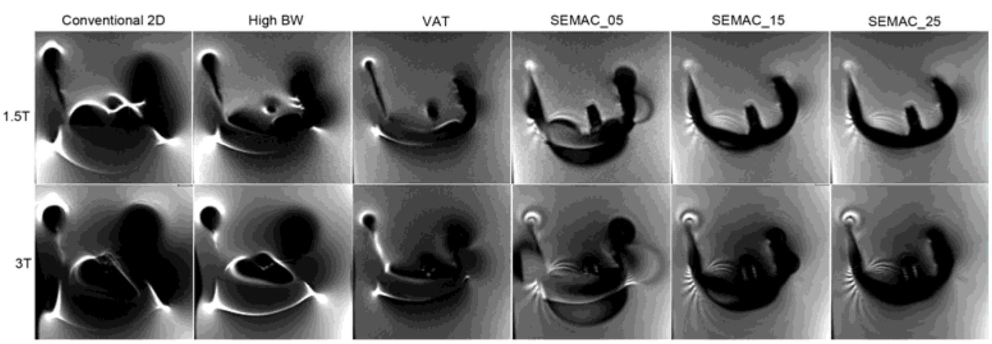

Figure 1: MR imaging of Cobalt Chromium femoral component with different imaging techniques at both 1.5T and 3T. SEMAC-VAT, VAT and high BW significantly reduced metal artifact as compared to conventional 2D sequence.Improved artifact reduction and distortion correction were achieved by increasing SEMAC-encoded steps. Imaging with 3T produced more metal artifact and residual artifact compared to the corresponding imaging sequence at 1.5T.

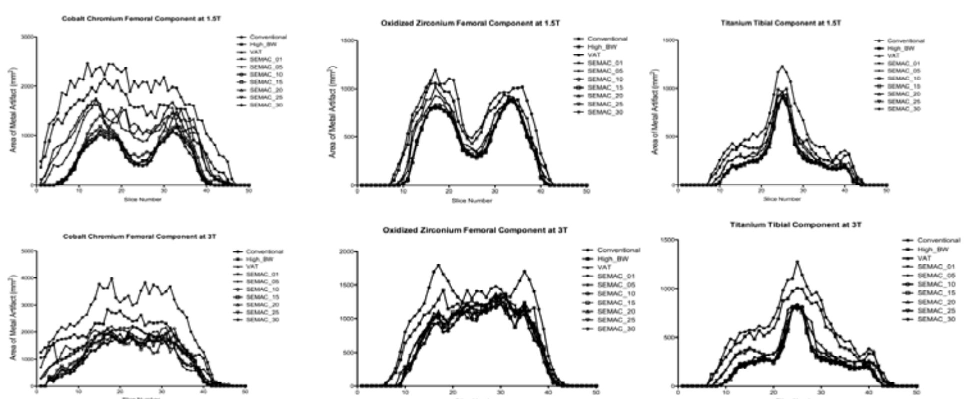

Figure 2: The curves of artifact area to slice number. The artifact area was measured on each slice acuqired by different imaging sequence. The metal artifact was significantly reduced by different sequence techniques, in particular by SEMAC-VAT with increasing SEMAC-encoded steps. The performace of SEMAC-VAT was much better at 1.5T than 3T by recovering the actual apperance of the metal component itself. Titanium component produced very similar curve profiles at both 1.5T and 3T by different sequences.

Conclusions

SEMAC-VAT, VAT and high BW can be successfully used for reduction of metal artifact in the imaging of total knee prosthesis at both 1.5T and 3T. The optimal SEMAC-encoding should be chosen according to the different types of metal material and field strengths, with respect to the optimization of both faster acquisition and better artifact correction.

References:

1. Chen CA, Chen W, Goodman SB, Hargreaves BA, Koch KM, Lu W, Brau AC, Draper CE, Delp SL, Gold GE. New MR imaging methods for metallic implants in the knee: artifact correction and clinical impact. *J Magn Reson Imaging.* May 2011;33(5):1121-1127.

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