

# Quantitative Evaluation of Metal Artifact with New Turbo Spin Echo Imaging Techniques

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## Introduction

Metal hardware used in orthopedic surgery often produces severe artifacts on MRI. Turbo Spin Echo (TSE) pulse sequences with high receiver bandwidth (RBW), short echo spacing, and small voxel size have been shown to reduce the appearance of metal related artifacts [1-2]. Recently, new TSE techniques such as BLADE/PROPELLER [3] and 3D acquisitions with variable refocusing flip angles [4] have become clinically available. These advances may influence the characteristics of metal induced susceptibility artifacts and ought to be considered when imaging patients with hardware.

## Methods

To qualitatively evaluate metal artifacts, phantom experiments were performed on a 3.0T scanner (Siemens TIM Trio) to compare the properties of artifacts for 2D and 3D TSE sequences. A phantom was constructed by suspending a titanium alloy screw (Stryker) used for orthopedic surgery in a 0.5 mM gadolinium-saline mixture. The long axis of the screw was in the horizontal (X) direction and was perpendicular to the main magnetic field ( $B_0$ ) in the Z direction. 2D images with 1mmx1mm resolution and 5mm slice thickness were acquired using 2D TSE sequences with TE/RBW/ETL = 151ms/781Hz-per-pixel/32 and refocusing flip angle (RFA) of 150°. Different  $k$ -space sampling strategies, i.e. Cartesian and BLADE, were applied. The slice orientation was tilted from the vertical (Y-Z) to the horizontal (X-Z) plane with 15° increments to vary  $B_0$  inhomogeneity. 3D datasets of 1mmx1mmx1mm resolution were acquired using a 3D TSE (SPACE) sequence with TE/RBW = 149ms/781Hz-per-pixel. Constant refocusing flip angles (CRFA) of 150° and variable refocusing flip angles optimized for T2 contrast (T2-Var) were employed. The ETL was 257 and 65 for two CRFA acquisitions and 65 for T2-Var. From the 3D dataset, multi-planar reformatted images (MPR) matching the slice thickness and orientation of the 2D acquisitions were generated. Pixels in the uniform portion of the phantom with signal intensity difference greater than 20% of the nominal intensity were considered to be distorted by the metal. These pixels were identified with appropriate thresholds and summed to estimate the size of the artifact.

## Results

Although the size of metal artifacts with Cartesian and BLADE  $k$ -space sampling are very similar, their appearance is different. On the other hand, the artifacts in the reformatted images acquired with CRFA and T2-Var have similar shape but difference sizes (Fig. 1). The extent of artifact in the MPR is less than the 2D acquisition. For 3D SPACE, the artifact is almost identical for CRFAs with ETL of 257 and 65, but significantly less for T2-Var with ETL of 65. Figure 2 also illustrates the difference of the artifact size between five acquisition schemes and various slice orientations.

## Discussion and Conclusions

The artifact with BLADE appears to be a blend of artifacts with Cartesian sampling of different encoding directions (Fig. 1A). When  $B_0$  inhomogeneity distribution is asymmetric, such as the case when the slice orientation is tilted 45°, the appearance of the artifact is dominated by the  $B_0$  inhomogeneity rather than the encoding direction and the artifact becomes similar for Cartesian and BLADE (Fig. 1B). There is no significant reduction in metal artifacts with BLADE. Using 3D TSE and MPR, the size of metal artifact is significantly reduced because of the small acquisition voxel size. The artifact also depends on the refocusing flip angle schedule, as T2\_Var reduces blurring, but not significantly on ETL.

## References

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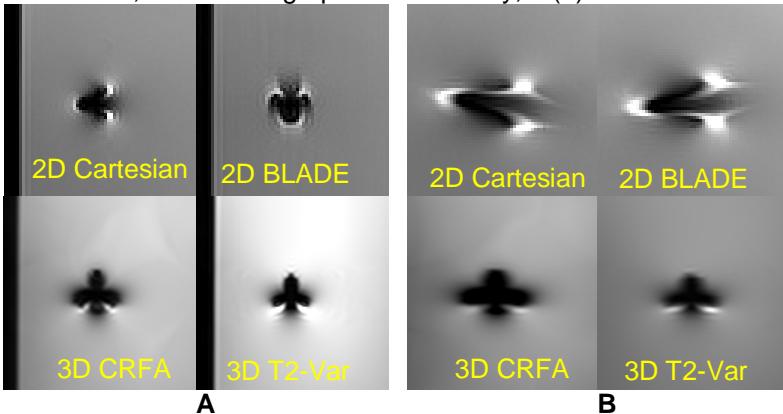


Figure 1. Metal artifacts with different TSE acquisitions and MPR with 0° tilt (A) and 45° tilt of imaging plane.

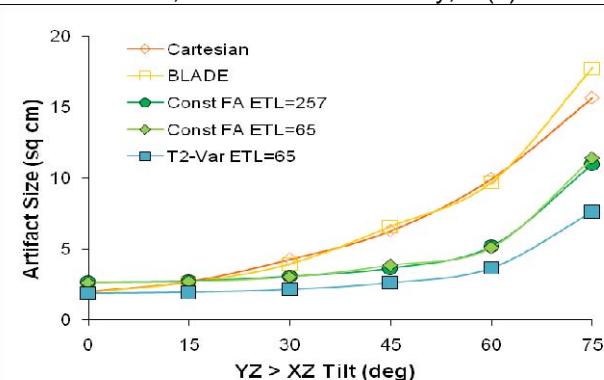


Figure 2. The variation of metal artifact size with slice orientation