Assessment and Minimization of Susceptibility Artifacts from Different Surgical Talus Screws

Rudolf STOLLBERGER1, Franz Seibert2, Johann Raith3, Franz Ebner4

1University of Graz, Magnetresonanz (MR), Graz, Austria; 2Department of Trauma-Surgery; 3Department for Radiology; 4Magnetic Resonance Institut, University of Graz, Auenbuggerplatz 9, Graz;

Introduction
Surgical fixation screws, even made from a titanium alloy, represent a major problem for the interpretation of MR-images due to susceptibility artifacts. This is of particular importance for the diagnosis of avascular necrosis after surgery using screws. Also this is a common problem and the MRI theory of susceptibility artifacts is well established (1), no study was found, which compared the images of biomechanical similar screws and optimized MR scanning for this application. This study investigates and quantifies extent and configuration of susceptibility artifacts by various talus screws using well-established Spin Echo and Gradient Echo sequences. 3D-Turbo Spin Echo imaging was studied for artifact minimization.

Methods
Eleven screws were investigated (diameter=3.5-4.5 mm, length=48-50mm, 5 steel, 6 titanium alloy (5: Ti-6Al-4V, 1Ti-6Al-4Ni)). For artifacts quantification the screws were scanned within a phantom (container 20*15*25 cm) filled with Gd-doped Water and equipped with a special screw holder. The later enables the exact alignment of the screws in parallel and perpendicular to the main magnetic field. This is of importance because these two orientations produce either the minimal or the maximal artifact. Typical GE and a SE sequences from a “joint protocol” were taken for this investigation (SE: TE=15/70, Voxel Size 0.89*0.89*3 mm, Bandwidth per Pixel (BWpix) = 111 Hz, GE: TE= 4.7/18, Voxel Size 0.86*0.86*4 mm, BWpix = 189 Hz). For artifact minimization the influence of scan technique, echo time, voxel size and acquisition bandwidth. The investigation was performed on a 1.5T System (Philips, ACS-NT) with self-shield gradients (23 mT/m). The shape and extend of the artifact within SE images follows exactly a “joint protocol” with a direct relation to the frequency encoding direction within a slice. A signal change grater then ±15% of the homogeneous phantom was considered as “artifact”. Smaller signal changes were judged tolerable. For phantom investigations the head coil was taken, in vivo a four-channel synergy coil was applied. Dedicated software was written in IDL (RSI, Boulder Colorado) for artifact quantification. It calculates the artifact area and the maximal extend in frequency and phase encoding direction within a slice. A signal change grater then ±15% of the homogenous phantom was considered as “artifact”. Smaller signal changes were judged tolerable. The influence of the coil sensitivity in coronal and sagittal slices was corrected with a special algorithm.

Results
As expected, the artifact area of steel screws were approximately the ten-fold of titanium. So, they will not be analyzed in detail further on. The shape and extend of the artifact within SE images follows exactly the description in (1) with a direct relation to the frequency encoding gradient (BWpix =0.5...3.3). No influence is given by the used echo time (15/70). For GE imaging the strength of the frequency encoding (BWpix =0.5..3.3). No influence is given by the used echo time, voxel size and acquisition bandwidth. The investigation shows that for artifact minimization the best sequence is the 3D TSE sequence, which compensates the increase of noise due to the high acquisition bandwidth using 3D scanning. The favorable properties of TSE imaging in area of metallic artifacts is in accordance with the literature (2), although 3D-imaging is not mentioned. The most surprising aspect was that GE sequences with a short TE have a smaller artifact area then comparable SE sequence, which map the refocused signal to a wrong position. So, GE sequences can also be used if the tissue closely surrounding the screw is not of any diagnostic importance. The screw orientation in parallel to B0 gives distinctive fewer artifacts; in particular on the shaft the artifact is reduced to the screw diameter. Partly threaded screws produce fewer artifacts then full treading one. Cannulated screws may be used whenever needed, because there is no difference concerning artifacts to full-metal screws.

Discussion
The investigation shows that for artifact minimization the best sequence is the 3D TSE sequence, which compensates the increase of noise due to the high acquisition bandwidth using 3D scanning. The favorable properties of TSE imaging in area of metallic artifacts is in accordance with the literature (2), although 3D-imaging is not mentioned. The most surprising aspect was that GE sequences with a short TE have a smaller artifact area then comparable SE sequence, which map the refocused signal to a wrong position. So, GE sequences can be used in particular on the shaft the artifact is reduced to the screw diameter. Partly threaded screws produce fewer artifacts then full treading one. Cannulated screws may be used whenever needed, because there is no difference concerning artifacts to full-metal screws.

Fig. 1. Determined artifact area and extent in a coronal SE (a) and GE (b) image of a titanium screw perpendicular to B0.

References