Impact of reduced k-Space acquisition on the Visibility of Moving Puncture Needles - A Phantom Study

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Introduction: Magnetic resonance (MR) guided interventions gained more and more importance over the last few years [1-2]. Since MRI is still a comparatively slow imaging technique, several methods to improve the imaging rate have been proposed [3]. Using keyhole imaging for MR-guided interventions is often related with a loss of signal-to-noise-ratio (SNR) and spatial resolution [4]. Aim of this study was to evaluate the effect of decreasing the keyhole rate of the outer k-space on the visibility and the artifacts of a moving needle in a phantom model.

Material and Methods: All measurements were performed in an 1.0 T open MRI (Panorama, Philips, Netherlands). As interventional sequence we used a gradient echo sequence (flip angle = 15°; TR/TE=6/3 ms; voxel size=1.4x1.4x8 mm; FOV=350x260 mm; acquisition time ta=1.4s). To simulate the typical needle movement of a common intervention reproducibly, a custom made puncture simulator was constructed with a MR-compatible 15.5 cm long 20 gauge needle (Somatex) fixed at the tip of a transducer rod (see figure 1). The puncture simulator was driven pneumatically and the circular motion of the drive was turned into an ovoid motion of the needle tip by a gearing mechanism (figure 2). Due to gravitational forces, the velocity in the forward direction of the rotation was faster (0.17 Hz) than in the backward movement (0.05 Hz) (figure 3, right). We measured the influence of the k-space update on the artifact width, CNR, spatial accuracy and sharpness of the artifact edges correlated with the longitudinal and transversal velocity of the needle tip. The sharpness was determined by the root-mean-square (RMS) of the needle tip. The maximal velocities of the needle tip were 0.06 m/s parallel and 0.03 m/s perpendicular to the needle direction. The mean longitudinal error along the needle direction was 3 mm and 0.9 mm perpendicular to the needle. Neither a correlation of the CNR, RMS nor the width of the needle was found (see figure 4).

Results: The experimentally determined position of the needle tip followed the theoretical values with good agreement (see figure 3). The maximal velocities of the needle tip were 0.06 m/s parallel and 0.03 m/s perpendicular to the needle direction. The mean longitudinal error along the needle direction was 3 mm and 0.9 mm perpendicular to the needle. Neither a correlation of the CNR, RMS nor the width of the needle was found (see figure 4).

Conclusions: Even keyhole imaging with low update rates allows a sufficient visualization of the needle tip in musculoskeletal MR-guided interventions. The gain in temporal resolution was neither correlated with a significant loss of spatial resolution nor CNR.

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