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

J. C. Rump[1], M. Jonczyk[1], C. J. Seebauer[1], F. Güttler[1], U. Teichgräber[1], and B. Hamm[1]
[1]Radiology, Charité-University Medicine, Berlin, Germany

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.

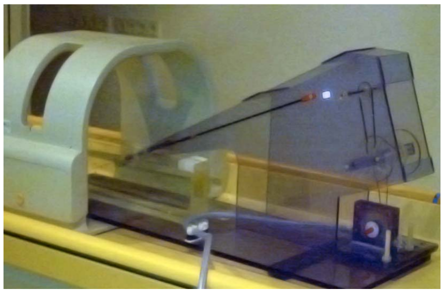

Figure 1: *Set-up at the Panorama open high-field MRI. Shown is the pneumatic driven puncture simulator placed in A abdominal coil.*

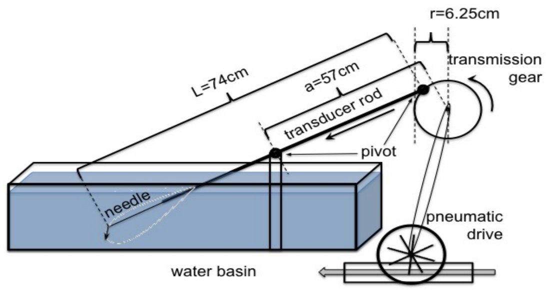

Figure 2: *Schematic representation of the puncture simulator. The needle tip was performing an ovoid movement with oscillating longitudinal and transversal velocities.*

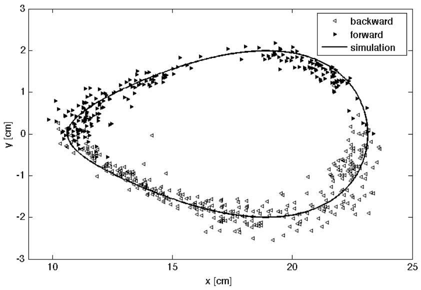

Figure 3: *Plot of the experimentally measured (markers) and theoretical positions (solid line) of the needle tip.*

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, spacial 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 modulation transfer function compared to an ideal needle profile of 2 zeroed pixels.Variable update rates from 100% to 15% in steps of 10% were analyzed. For the statistical analysis, the correlation coefficients and associated significances according to the Pearson test were determined by SPSS.

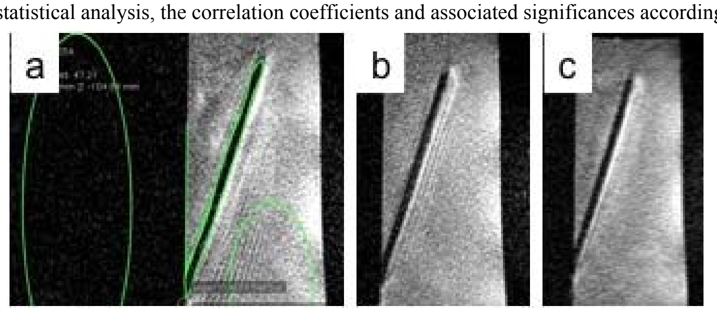

Figure 3: *MR-images of the needle with an update rate of the k-space of 100% (a), 50% (b) and 15% (c). The ROIs marked with the green lines were used to calculate the CNR of the needle.*

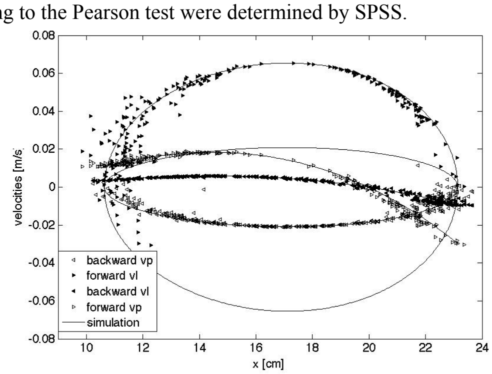

Figure 4: *Plot of the measured (markers) and theoretical velocities (solid lines). The theoretical values resulted from the equations of motions based on the geometrical conditions of the simulator and the rotation frequency of the transmission gear.*

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).

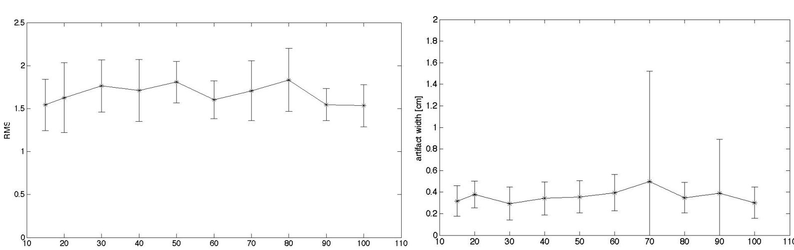

Figure 5: *Plots of the sharpness of the arfifact edges represented by the RMS value (left), artifact width (middle) and CNR values (right) vs the update rates of the k-space.*

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

References:

[1] *Carrino et al.: Magnetic resonance imaging-guided percutaneous biopsy of musculoskeletal lesions. J Bone Joint Surg Am 89 (2007), Nr. 10, 2179-2187.*

[2] *Smith; Carrino: MRI-guided interventions of the musculoskeletal system. J Magn Reson Imaging 27 (2008), Feb, Nr. 2, 339-346.*

[3] *Busch et al.: Fast "real time" imaging with different k-space update strategies for interventional procedures. J Magn Reson Imaging (1998) Nr8, 944-954.*

[4] *Duerk et al.: Application of keyhole imaging to interventional MRI: a simulation study to predict sequence requirements. J Magn Reson Imaging (1996) Nr.6,918-924.*