Introduction: Early detection of metastatic disease is critical for optimal treatment but whole-body MRI screening remains technically challenging. Recent developments in whole-body MRI have included diffusion-weighted imaging (DWI) with projection of axial 2D stacks to generate large field-of-view coronal images with reversed ‘PET-like’ contrast for rapid screening [1]. Slice thickness is limited for these techniques and therefore the resulting volumetric datasets provide relatively poor spatial resolution along the cranial-to-caudal orientation potentially limiting capabilities for detecting small metastases. The purpose of our study was to investigate the feasibility of using super-resolution (SR) techniques to improve through-plane spatial resolution during multi-slice whole-body DW-MRI. We demonstrate that SR improves through-plane spatial resolution in phantoms and animal models of liver cancer.

Materials and Methods: All studies were performed using a 1.5T clinical MRI scanner (Siemens Magnetom Sonata). For DWI we used a single-shot spin-echo EPI sequence with the following parameters: TR/TE = 3000/80ms, BW=1.5kHz, and 72 × 128mm² FOV. In-plane voxel size = 1 × 1 mm². For animal studies ‘PET-like’ contrast was produced by reversing gray scale signal intensity values.

Phantom Studies: Six multi-slice stacks with relatively low through-plane spatial resolution were acquired in an orientation orthogonal to the resolution markers of a Siemens Multipurpose MRI Phantom. Each stack consisted of 15 slices with 6mm thickness. To permit super-resolution reconstruction, each of the 6 image stacks were acquired with serial 1mm through-plane shifts from the previous image set. For comparison purposes a high through-plane spatial resolution data set was acquired with 2mm slice thickness.

Animal Studies: Animal experiments were performed in 4 VX2 liver tumor rabbits. Data sets were acquired according to the procedures discussed in the phantom study with 2D imaging stacks positioned in an axial orientation.

Super-Resolution Reconstruction: The data model to be considered is: \[ g = Df \] where \( g \) is the low resolution data set, \( D \) is the point spread function (PSF), and \( f \) is the high resolution data. High resolution data was iteratively reconstructed: \[ f_{k+1} = D^{-1}128mm² \text{FOV. In-plane voxel size was 1 × 1 mm².} \]

Results: All phantom data sets are displayed using a coronal view with RO and SS directions along the vertical and horizontal dimensions respectively. Multi-slice DW-MRI image volumes reconstructed with zero-padding (ZP), interleaving (IN), and SR at 2mm (Group I) and 1mm (Group II) slice thickness are depicted in Fig. 1. ZP and IN failed to differentiate the 3mm resolution markers depicted with SR reconstruction. SR also clearly improved resolution marker depiction along the SS dimension compared to ZP with 2mm slice-thickness reconstruction, Group II images demonstrated the potential to increase through-plane spatial resolution beyond sequence limitations. MSE between SR and reference converged at ~400 iterations (Fig. 3).

Conclusion: SR techniques can improve through-plane spatial resolution for reversed-contrast ‘PET-like’ DWI. These improvements could potentially increase sensitivity for detecting small metastasis during whole-body screening procedures.

References