Contrast-Enhanced High Resolution MR Angiography of the Rat Spinal Region

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Introduction: High-field MR imaging has become a standard tool for use in small animal imaging. The large signal-to-noise ratio enables acquisition of images with high quality. However the ability to perform contrast-enhanced 3D high resolution vascular imaging is hampered by the inherent long image acquisition times and the rapidly diffusive nature of small molecule contrast agents. In this study, high resolution vascular imaging of the spine region is demonstrated in a rat model using a liposomal blood pool contrast agent.

Materials and Methods: Liposomal contrast agent was prepared by ethanolic hydration of a lipid mixture consisting of 1,2-Dipalmitoyl-sn-glycero-3-phosphocholine (DPPC) , Cholesterol and 1,2-distearoyl-sn-glycero-3-phosphoethanolamine-N-[methoxy(poly(ethylene glycol))-2000] (mPEG2000-DSPE) in 0.5 M gadodiamide (Omniscan®) solution. The resulting solution was sequentially extruded through a Lipex Thermoline extruder with five passes through 0.2 μm membrane and eight passes through 0.1 μm membrane. The external phase was then cleaned and the liposomes simultaneously concentrated by diafiltration process. For in-vivo imaging, five Sprague–Dawley rats weighting between 350-390 g were used. The left jugular vein was cannulated for intravenous delivery of the contrast agent, as described previously (1). A rectangular coil (11 x 35 mm) was implanted in the back of the animal and centered at the T7 level and inductively coupled to an external surface coil (30 x 40 mm) for improved image quality (2). Imaging was performed on a 7 Tesla Bruker scanner, 70/30 URS using a 116-mm shielded gradient insert that is capable of producing maximum gradient amplitude of 400 mT/m with 80-μs rise time. Vascular imaging was performed using a flow compensated fast 3D gradient-echo sequence with the following parameters: TR/TE = 18.3/2.8 ms, flip angle = 30 degrees, image matrix = 256× 256 × 256, FOV = 41 mm × 28 mm × 25 mm, bandwidth = 200 KHz, and number of averages = 3. With these parameters, the voxel size was 160 μm. × 109 μm.× 98 μm. The total scan time was 60 minutes. Signal from the surrounding tissue was reduced by incorporating a 1 ms long magnetization transfer pulse with a frequency offset of 1500 Hz. Post-contrast images were acquired following the injection of 0.1 mmol/kg of liposomal Gd through the jugular vein using the previously implanted catheter.

Results: The liposomal contrast agent enabled visualization of several small blood vessels in the vicinity of the spinal cord. In addition to the thoracic structures such as the Aorta (AO) and Pulmonary Artery (PA), the post-contrast image shows the venous plexus (VP) surrounding the spinal cord and the posterior spinal vein (PSV) running along the dorsal side of the spinal cord. Improved visualization of the Intercostal Arteries (IA) is observed in the post-contrast images.

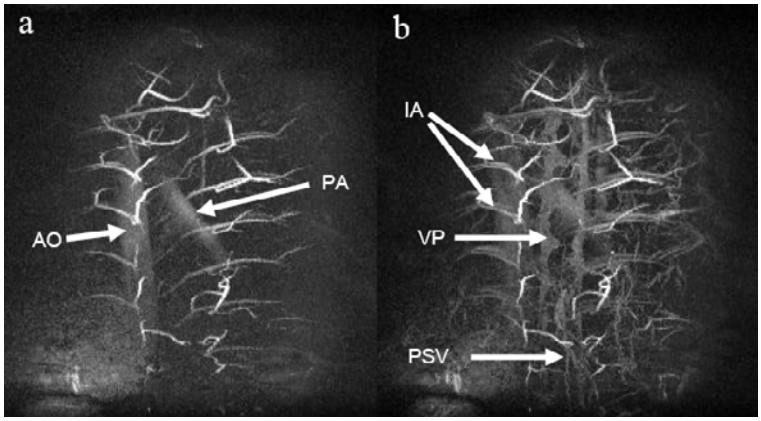

Figure 1 : Coronal MIP images of the spine region acquired before (a) and after (b) administration of liposomal contrast agent. The descending aorta (AO) and pulmonary artery (PA) are visible in both the pre- and post-contrast images. More details about the intercostal arteries (IA) are visible in the post-contrast image. The venous plexus (VP) surrounding the spinal cord is also seen in the post-contrast image. The posterior spinal vein (PSV) running along the dorsal side of the spinal cord is also visible in the post-contrast image.

Conclusion: The current study demonstrates the ability to perform contrast-enhanced high resolution vascular imaging in small animals. Several important vascular features were visible in the post-contrast scans. The liposomal contrast agent enabled acquisition of 3D angiograms with high image quality, thus demonstrating the potential as a blood pool agent for use in small animal imaging.

References:

1) Bilgen M et al., Abbe R, Narayana PA. Dynamic contrast-enhanced MRI of experimental spinal cord injury: in vivo serial studies. Magn Reson Med 2001;45(4):614-622.
2) Bilgen M, Elshafiey I, Narayana P A. In vivo magnetic resonance microscopy of rat spinal cord at 7 T using implantable RF coils. Magn Reson Med 2001;46(6):1250-1253.