Magnetic resonance angiography of rat spinal cord at 9.4 T: a feasibility study

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Introduction

Rat spinal cord injury (SCI) is a commonly-used animal model to mimic the injuries seen in human. This is in part, vascular anatomy of rat spinal cord (SC) exhibits close similarity to that of human (1). Vascular remodeling is known to occur after SCI (2). Traditionally, the arrangement of the vascular structure of rat SC is evaluated using invasive microangiographic and stereomicroscopic techniques (3). Recent advances in imaging modalities offer the possibility of noninvasively visualizing the vascular organization of the rat SC (4). In this paper, we investigate the feasibility of performing three-dimensional (3D), time-of-flight (TOF) magnetic resonance angiography (MRA) for in vivo imaging of the SC arteries of rat. Using a custom designed implantable radio frequency (rf) coil, angiograms are acquired from normal and injured rat SCs, and the potential of the approach is evaluated in terms of monitoring the reorganization of the SC vasculature in longitudinal studies of rat SCI.

Materials and Methods

All MRI scans were performed on a 9.4 T horizontal Varian scanner (Varian Inc., Palo Alto, CA) using a homebuilt inductively coupled coil (5). Under isoflurane anesthesia administrated via a facemask, the coil was implanted subcutaneously in Sprague Dawley rats adjacent to the SC at thoracic level T9. High-resolution axial images were acquired using a standard spin echo (SE) sequence using the parameter values: T_R/T_E = 2000/12 ms, FOV=15 mm, image matrix = 128 X 128, slice thickness = 1 mm and NEX=2. Then, angiograms were acquired using the 3D-TOF technique with T_R/T_E = 45/4 ms and flip angle (FA) = 45^o over a volume of 25x20x20 mm^3. Selective excitation centered on the second phase encode direction was applied over a slab thickness of 16 mm. No triggering by electrocardiogram or respiration was applied. The raw data was sampled at a rate of 128x64x64, where the former represents the readout direction. The data were interpolated to a matrix size of 256x128x128 pixels using the vendor-supplied software (VNMRJ1.1C, Varian Inc. Palo Alto, CA) and maximum intensity projections (MIPs) were generated on the coronal, sagittal and axial planes. The angiograms were volume rendered in 3D using Analyze software (AnalyzeDirect, Inc., Lenexa, KS).

Results

Representative sets of MIPs of rat SCs are shown in Figs. 1 and 2. These sets show the anatomy of arteries supplying blood to the cord at the thoracic level. Figure 1 clearly depicts the posterior intercostal arteries, originating from aorta, and their branching into smaller arteries supplying blood to the anterior part of the cord, as projected onto the coronal plane. The posterior intercostal artery divides into dorsal branches, which further divides into anterior reticular artery. When it reaches the SC, this artery becomes the anterior spinal artery. Experiments with injured rats produced angiogram of the SC shown in Fig. 2, where the injured section of the cord appears brighter than the background.

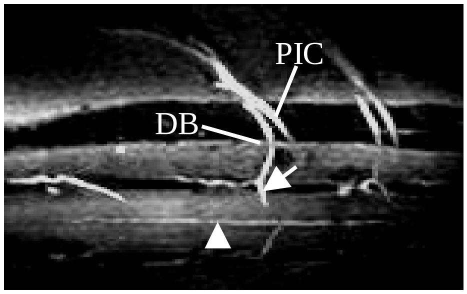

Figure 1. Coronal MIP showing the anatomy of arteries supplying blood to the anterior part of the rat spinal cord. PIC indicates the posterior intercostal artery and DB points to its dorsal branch. Arrow points to the anterior reticular artery and the arrowhead points to anterior spinal artery.

Discussion

Vascular organization of SC consists of a complex network of arteries supplying blood to the cord from multiple directions and multiple levels. The results presented here demonstrate the feasibility of acquiring in vivo MRA data from normal and injured rat SCs. Use of the implantable coil provided certain benefits, such as improved signal-to-noise ratio (SNR) and increased image resolution due to the small FOV selection, enabled by the small footprint of rf excitation. These abilities together facilitated the acquisition of raw MRA data at high-resolution and also from the region of interest only. In conclusion, this methodology should prove useful in studying the vascular reorganization of SC in longitudinal studies of rat SCI.

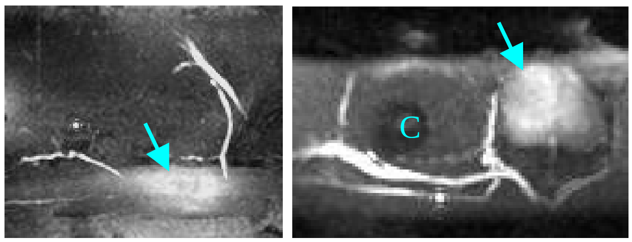

Figure 2. Coronal (left) and axial (right) MIP showing the blood supply to an injured rat spinal cord. Arrows point to the injury. C indicates the implantable coil's side-wire.

References

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