Advanced Neuroimaging 1: Brain & Spinal Cord; 7 T / Diffusion Imaging of Cervical Cord

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- A range of RF engineering approaches have been explored for 7 T spinal cord MRI
- 7 T anatomical imaging with customized coils reveals unprecedented resolution
- 7 T functional contrasts (diffusion, spectroscopy) are also beginning to see benefits

I. Target Audience: Scientists / clinicians interested in cervical cord MRI at ultra-high field

II. Purpose: Technological advances in concert with guidance from clinical needs have continually improved diagnostic performance of clinical spine radiology. One route to improvement is increasing the static magnetic field strength (B_0), such as the recent generation of full-body 7.0 T scanners [1]. This survey will focus on this "ultra-high" field in the zone of the spinal cord. Since the submillimeter features of the cord require high spatial resolution, the enhanced signal-to-noise ratio (SNR) at high field enables dramatic advances in morphological spinal cord imaging.

III. Methods: Various approaches for high field spine MRI have been demonstrated. Some achieve full spine coverage (cervical, thoracic, and lumbar) with large multi-element arrays or multiple acquisitions with a movable one. Many designs have used arrays of rectangular loop coils of varying length (4 [2-5], 6 [2], or 8 [6] rostral-caudal stations) and width (1 [2], 2 [4-6] or 3 [3] left-right stations). Some rectangular arrays used the same elements for transmission / reception [2,4,5] while others used separate groups [3,6]. Localized cervical imaging studies have used a loop transmit/butterfly receive composite coil [7], a 4-ch transmit-receive cervical cradle array [8], or a 19-ch receive + 4-ch transmit composite array [9,10].

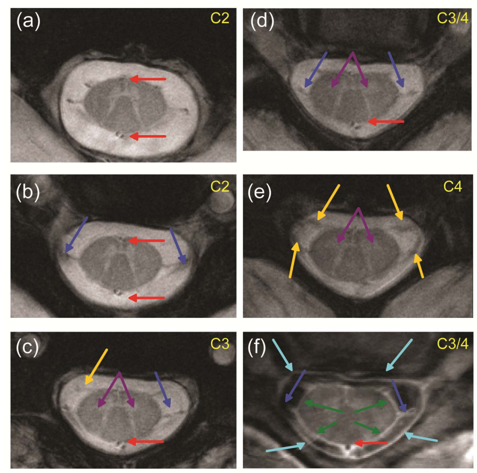

Fig. 1: C-spine MRI at 7 T. (a)-(e) GRE and (f) TSE sequence. Labels: dorsal/ventral nerve roots (yellow), gray matter anterior horn (purple), denticulate ligament (blue), dorsal/ventral blood vessels (red), dura mater (cyan), pia mater (green). (Ref. 8)

IV. Results Recent studies [7-9] have employed high resolution cervical spine imaging at 7 T to resolve gray and white matter parenchyma, which is rarely visualized at lower field. Cross-sectional white and gray matter area fractions agreed well with histological reference. Surrounding structures are also delineated with the resolution achievable at 7 T (0.2 mm, Figure 1): denticulate ligaments, nerve roots, rostral-caudal blood vessels, dura mater, and pia mater [8]. A high resolution 7 T cord study also revealed localized hemosiderin and Wallerian degeneration features that would escape detection at lower field. Other features in the thoracolumbosacral spine (posterior longitudinal ligament, cauda equina nerve fibers, blood vessels, common iliac artery, foramen venae basivertebralis) have also been resolved [4,6]. Functional contrasts (diffusion, spectroscopy) are beginning to benefit at the clinical level from enhanced SNR and/or chemical shifts, and these areas continue to grow [10-14].

V. Discussion / Conclusions: Several pilot studies have shown that the anatomy of the spine be visualized at unprecedented levels of detail at 7 T. As always, technical and clinical sectors of the imaging community should continue to share and cross-fertilize ideas to ensure the highest degree of innovation and effective clinical application of the high field imaging platform.

VI. References 1. Moser E, NMR Biomed 2012;25(5):695-716. 2. Wu B, IEEE Trans Biomed Engin 2010;57(2):397-403. 3. Duan Q, ISMRM 2010 p 324. 4. Kraff O, Invest Radiol 2009;44(11):734-740. 5. Grams AE, Skeletal Radiol 2012;41(5):509-514. 6. Vossen M, J Magn Reson 2011;208(2):291-297. 7. Bae K, ISMRM 2009 p 632. 8. Sigmund EE, NMR Biomed 2012;25(7):891-899. 9. Cohen-Adad J, Neurology 2012;79(22):2217. 10. Zhao W. ISMRM 2012 p 431 11. Kogan F ISMRM. 2012 p 737. 12. Polders D ISMRM 2012 p 1804. 13. Henning A ISMRM 2012 p. 711. 14. Dula AN. ISMRM 2012 p 3371.