Spectral-Spatial-Spiral MRSI: Fast prostate MR spectroscopic imaging with low SAR on 7T

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Target Audience: Spectroscopists, prostate cancer clinicians

Purpose: Proton Magnetic Resonance Spectroscopic Imaging (MRSI) of the prostate can be used to discriminate cancer from non-cancer tissue and to assess the aggressiveness of prostate cancer [1, 2]. 7T offers two major advantages for MRSI (increased signal to noise ratio (SNR) and chemical shift dispersion), but also poses several technical challenges. One of the solutions to these issues is to use an external coil array and RF shimming to create a high and homogenous transmit field locally in the prostate, and to receive signals locally with an endorectal coil [3,4]. In combination with the increased chemical shift dispersion on 7T the homogenous transmit field enables the use of conventional RF pulses that are simultaneously spectrally and spatially selective. Without use of SAR intensive methods, such as outer volume suppression or adiabatic pulses, repetition times can be made short, enabling efficient MRSI. We propose to combine this technique with a spiral MRSI acquisition to optimally use the SNR gain on 7T and increase spatial resolution while maintaining feasible acquisition times.

Methods: 8 patients with prostate cancer were scanned with a multi-parametric prostate MRI protocol [5]. Measurements were performed on a 7T whole-body MR system (MAGNETOM, Siemens Healthcare, Erlangen, Germany) with use of butylscopolamine and glucagon to reduce bowel movements. An 8-channel multi transmit proton body array coil was used for B0 and B1 shimming of the prostate [6]. After localized calibration of RF power the MR signal was received with an endorectal receive coil modified from a 3T endorectal balloon (MEDRAD, Pittsburgh, PA). After T2w MRI, we used a PRESS-like volume selection with one excitation pulse (bandwidth 1200 Hz) for axial slice selection followed by two VERSE-modulated spectral-spatial refocusing pulses [7] (duration of 35.22 ms, spectral passband from 2.4 to 3.4 ppm and subpulse bandwidth of 4.1 kHz) in anterio-posterior and right-left directions for volume and frequency selection (Fig. 1). No additional water or lipid suppression was used. Acquisition was performed using spiral MRSI with a constant density spiral [8]. The echo time and repetition time were 135 ms and 1 second, respectively. The spiral acquisition was performed with a FOV of 120x120x72 mm^3 (full prostate coverage in all cases), matrix of 20x20x12, 2 time interleaves, 5 spiral interleaves, three averages and acquisition time of 7:15 min. As a comparison 4 patients were also measured using the same sequence with a conventional elliptical phase encoding acquisition (FOV of 80x80x67 mm^3, matrix of 12x12x10, one average and acquisition time of 6:59 min). A 3-dimensional 50% hamming k-space filter was used in both acquisition methods, resulting in true voxel sizes of 0.48 cc for spiral and 1.1 cc for elliptical acquisitions (the true voxel size was determined by integrating the normalized point spread function).

Results: Spectral maps in axial direction for one of the patient measurements that was performed with both the spiral and the elliptical acquisition showed similar spectra at corresponding locations with sufficient SNR and almost no water residual (Fig. 2). In some parts of the prostate, lipid contamination was present. The red and blue circles represent the voxelsize for the respective measurements. Spectra from the same location (but different voxel size) with both acquisition methods were similar, although the lower right voxel indicated in Fig.2A and D contains less lipids in the spiral acquisition due to less partial volume effect (higher resolution). Spermine signals with this sequence are generally high, because the spectral-spatial RF pulses refocus the J-coupling between the 1.8 ppm and 3.2 ppm resonances.

In the apex of the prostate of another patient with a Gleason 3+4 tumor in the left dorsolateral peripheral zone, local spectral differences were present (Fig. 3) in the group of resonances around 3.1 ppm (choline, spermine and creatine). The red voxel (B), located in this area, shows a choline peak that is clearly separable from the high spermine peak. In the voxel indicated in blue (C), on the contralateral side of the prostate, choline only appears as a slight shoulder on the spermine signal, featuring a substantially lower choline over spermine ratio. Residual lipid signals were present in the apex.

Discussion and Conclusion: Using spectral-spatial RF pulses in combination with a spiral acquisition, prostate MRSI can be performed at 7 Tesla without running into SAR limits and with high flexibility in matching SNR, FOV, resolution and acquisition time. Although the method still suffers from some lipid contamination, it offers possibilities to explore the limits of SNR and spatial resolution in 7T MRSI of the prostate. In addition, it would be a suitable method to assess the role of spermine in prostate MRSI.

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References: [1] Scheenen T; Invest. Radiol. 2011; 46(1):25-33; [2] Kobus T; Radiology. 2012; [3] Metzger; MRM 64:625–1639, 2010; 265(2):457-67; [4] Lagemaat et al. ISMRM 2014; abstract 4113; [5] Maas et al. ISMRM 2014 abstract 0964; [6] Maas et al MRM 71:1711-1719 (2014) [7] Kerr AB, Pauly JM. In: Proceedings of the 16th Annual Meeting of ISMRM. Toronto, Canada; 2008; [8] Andronesi O; Radiol. 2012;262:647-661;

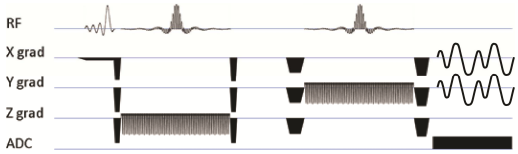

Figure 1: The spectral-spatial-spiral sequence.

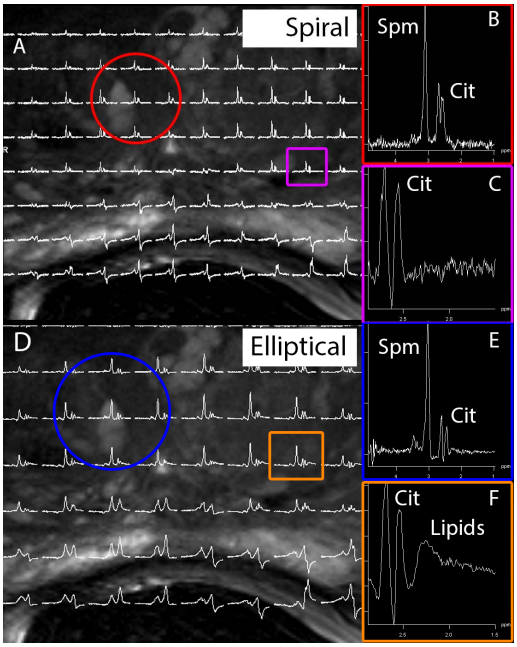

Figure 2: Spectal maps superimposed on a T2W image, of a patient measurement with a spiral (A) and an elliptical acquisition (D). B, C, E and F are spectra from correspondingly colored voxels from these measurements. B and E, and C and F are voxels from corresponding locations within the prostate.

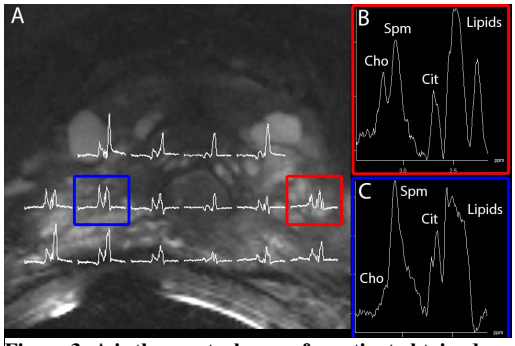

Figure 3: A is the spectral map of a patient obtained with spiral acquisition. Prostate cancer is present in the left dorsolateral peripheral zone. B is a voxel located in the tumor area. C is a voxel on the contralateral side. (This particular spiral acquisition was performed with a FOV of 160x160x70 and matrix size of 23x23x10; true voxel size: 0.77 cc, acquisition time: 6:44 min)