3D EPSI - Exploring the potential of 3D spectroscopic imaging of the prostate at 7 tesla

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Introduction

Prostate cancer is the second most common cancer in men worldwide [1]. Giving the right treatment for each individual prostate cancer patient is still challenging in current medical practice. The diagnosis of indolent tumors by prostate specific antigen (PSA) screening results in overtreatment [2]. In contrary, diagnosis by biopsy results in an underestimation, as significant tumors might be missed [3]. Therefore a better characterization of prostate tumors is needed.

^{1}H MRSI is useful for staging prostate cancer by detection of key metabolites. The main metabolites are choline and citrate, which are respectively increasing and decreasing in tumor tissue. At 3 tesla the resonances choline, polyamines, creatine overlap substantially, limiting prostate cancer grading. With the introduction of high field MR systems (7 tesla and higher), Magnetic Resonance Spectroscopic Imaging (MRSI) obtained great potential to accurately determine different stages of prostate tumor aggressiveness. At high magnetic field, spectral resolution is increased, which allows for separate detection of different prostate tumor markers (choline, polyamines, creatine and citrate).

However, high field ^{1}H MRSI is currently limited to 2D spectroscopic imaging, due to SAR limits. Use of 3D imaging would result in long scan times, which are not desirable for patient care. Nevertheless, 3D MRSI has the potential to obtain a better risk assessment for the whole prostate. Therefore, we studied the use of Echo-Planar Spectroscopic Imaging (EPSI) [4], allowing 3D MRSI at high magnetic field strength, without increasing scan time or energy deposition compared to 2D MRSI.

Methods

A 3D EPSI acquisition and reconstruction method was developed and compared with the current 2D MRSI methods used in our facility.

Acquisition: All measurements were performed on a 7 Tesla Achieva system (Philips, Cleveland, OH, USA). In-vivo measurements were acquired in clinical prostate cancer patients, using a 2-elements endorectal coil (ERC) [5].

The used MR sequences in this study were:

- 2D MRSI (nsLASER [6], TE/TR=56/2150 ms, 24x8x1 matrix, 5x5x5 mm^3 voxel, 12x4x0.5 cm FOV, acquisition time=9.44 min).
- 3D MRSI (nsLASER-EPSI, TE/TR=56/2150 ms, 24x8x47 matrix, 5x5x5.3 mm^3 voxel, 12x4x24 cm FOV, acquisition time=9.44 min).

Both volumes were planned manually in the area suspected for prostate cancer.

Reconstruction: The use of an EPSI gradient brings difficulties for data reconstruction. Gradient imperfections, odd-even gradient combinations and gradient slope sampling issues are generally encountered. Therefore a different way of data reconstruction was developed to process the EPSI data. In this study data signal recorded during the gradient slopes was included in the reconstruction process. The used reconstruction was a *full Fourier transform*, derived from the signal acquisition model (Eq. 1) as followed:

$$S(t) = \iint \rho(\omega, x)\, e^{-i\omega t}\, e^{-ik_x(t)x} \quad \text{with:} \quad k_x(t) = \frac{\gamma}{2\pi} \int_0^t G(\tau)\, d\tau \qquad \text{(Eq. 1)}$$

In matrix form: $S = \rho * E$ (Eq. 2)

Reconstruction: $\rho = E^{-1} * S$ (Eq. 3)

Where S is the acquired signal, G the switching gradient train as designed in the sequence and ρ the actual signal of the prostate metabolites. The pseudo inverse of the signal encoding matrix (E) was calculated and multiplied with the acquired signal. This way the complete kt-space trajectory was incorporated into the reconstruction.

Results

In both the 2D measurement (24x8 voxels) and the 3D EPSI spectroscopy (24x8x47) key metabolites of the prostate are detectable (Figure 1). For comparison between the methods, one voxel (green, healthy) is shown for both methods in the same patient, same slice and same voxel location. The acquired spectra (Figure 1c and 1d) show a similar SNR and spectral resolution. Also a voxel (red, tumorous) from a different slice is shown.

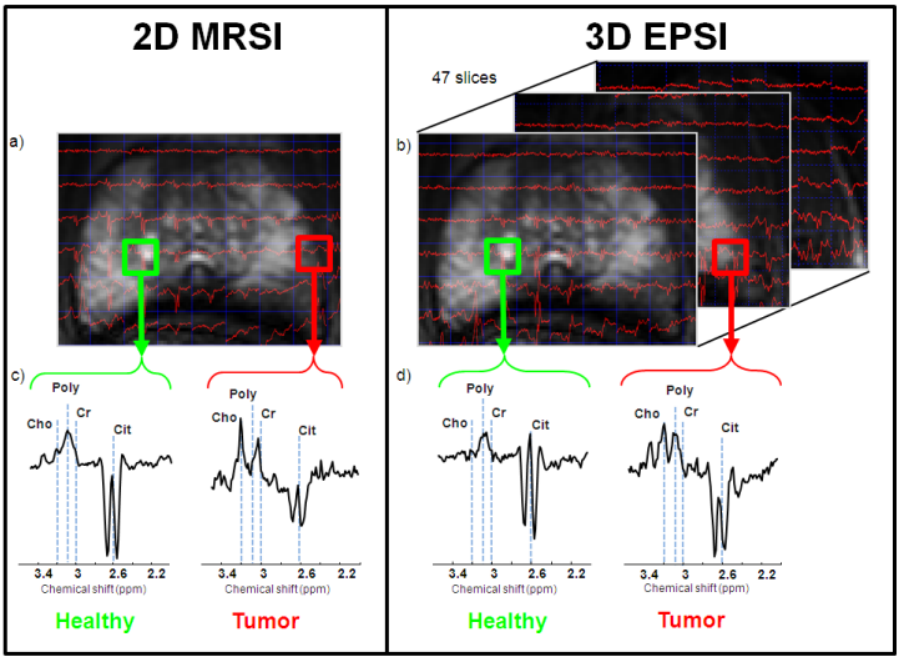

Figure 1: *A transversal slice of a prostate cancer patient (Age: 58, PSA: 7 ng/ml, Gleason score: 6) acquired by 2D MRSI (a) and 3D EPSI (b). 3D EPSI (multi-slice) covers the full prostate, while 2D MRSI covers one slice. For spectral comparison the same slice is selected within the 3D dataset and one (green, healthy) voxel is extracted for display (c,d). Notice how the spectra of the two methods look similar, even though the scan time per voxel is less for the 3D EPSI method.*

Discussion

Both measurements are equal in scan time and energy deposition (SAR). However, when comparing the amount of (potentially cancerous) prostate tissue covered by the two acquisition methods, the 2D MRSI sequence covers one slice, whereas the 3D EPSI sequence covers the full prostate. Because prostate cancer is a multifocal disease, a 3D EPSI method could be of great value to detect all cancerous sites in the prostate.

Even though scan time per voxel decreases for the 3D EPSI method, quality of the spectra appears to be maintained (Figure 1c and 1d). In both measurements choline, polyamine, creatine and citrate peaks are observed.

Conclusions

- Three-dimensional spectroscopic imaging can be performed at high field strength, using an EPSI sequence, avoiding extended scan time.
- Data acquisition during gradient slopes can be used to reconstruct EPSI data to its full potential.

References

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