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Introduction (max 600 character)

MRI with hyperpolarized tracers has enabled new diagnostic applications, e.g. metabolic imaging in cancer research. However, the acquisition of the transient, hyperpolarized signal with spatial and frequency resolution requires dedicated imaging methods. Here, we compare three promising candidates for 2D MR spectroscopic imaging (MRSI): (i) multi-echo balanced steady-state free precession (me-*b*SSFP),[1,2] (ii) echo planar spectroscopic imaging (EPSI) sequence and (iii) phase-encoded, pulse-acquisition chemical-shift imaging (CSI).

Methods (max 800 character)

All sequences were implemented on a clinical 3T PET/MR system (Siemens) equipped with a ^{1}H-^{13}C birdcage coil (Rapid Biomedical). A multi-compartment container filled with Gd-doped (c=0.23%v/v) aqueous model solutions of 1.0 M ^{13}C-bicarbonate (bi), ^{13}C-urea (ur) and [1-^{13}C]-acetate (ac) was used for imaging.

For better comparison, field of view (FOV), voxel size and scan time was identical for all methods. Faster methods were repeated until one acquisition of the CSI was completed resulting in 1, 16 or 670 averages for CSI, EPSI or me-*b*SSFP (Tab. 1).

Chemical shift (CS) maps were calculated with dedicated methods for each sequence, signal-to-noise (SNR) ratios were obtained by dividing the mean signal of a region of interest (ROI) by the mean signal of an ROI, where no ^{13}C-signal is expected.

	me-*b*SSFP	CSI	EPSI
Flip angle (°)	30 / 60	90	90
TR (ms)	23.9	1000	1000
Acquired data points in time domain	5	512	128
Dwell time (ms)	1.14	0.2	2
Spectral resolution	175 Hz	10 Hz	8 Hz
Spectral bandwidth	709 Hz	5000 Hz	500 Hz
Averages (NA)	**670**	**1**	**16**
Single scan duration	380 ms	4 min, 16 s	16 s
Total acquisition time	4 min, 16 s		
FOV (mm^3)	100 x 100 x 100		
Matrix size	16 x 16 x 1		
Voxel size (mm^3)	6.3 x 6.3 x 100		
Zero-filling (x)	2		
Final resolution (mm^3)	3.15 x 3.15 x 100		
^{13}C-SNR (ac / bi / ur)	146 / 123 / 125	62 / 105 / 35	47 / 66 / 31

Table 1: Acquisition parameters for ^{13}C MRSI. Metabolic maps (for ac: +328 Hz, ur: -252 Hz, bi: -328 Hz) were obtained by using a Dixon based IDEAL[3,4] for me-*b*SSFP and peak amplitude per voxel reconstruction for CSI and EPSI. SNR was calculated for ROIs (ac, bi, ur), manually segmented based on ^{1}H MRI (Figure 1, B.).

Results/Discussion (max 1000 character)

Non-localized ^{13}C spectroscopy revealed three peaks for ac (+328 Hz), ur (-252 Hz) and bi (-328 Hz) (Figure 1). In a single ^{13}C MRSI acquisition, CSI provided most SNR. Over the entire scan time, me-*b*SSFP yielded more SNR (max. 146, NA=670) than CSI (max. 105, NA=1) and EPSI (max. 66, NA=16). The direct comparison of the SNR is possibly inaccurate (due to the different number of averages, signal evolution and the reconstruction algorithms), but a similar trend is expected using HP tracers in vivo.

With respect to the max. signal, me-*b*SSFP revealed the smallest artifacts (which are not apparent on a linear scale, Figure 1, C.1-3).The logarithmic scale (C.4-6) reveals two kinds of artifacts for all methods: localized signal-leakage (e.g. signal at the position of ur in the bi image), as well as signal banding.

The SNR and image quality provided by me-*b*SSFP may allow shortening the acquisition time further. Simulation of signal evolution may also help understanding the observed results.

Conclusion (max 600 character)

We presented and compared ^{13}C MRSI of thermally polarized model solutions using the methods me-*b*SSFP, CSI and EPSI. For a given time, imaging volume and resolution, me-*b*SSFP results in highest SNR at the reconstructed metabolite maps and least artefacts (with lowest flip angle and shortest scan time per average).

These results make me-*b*SSFP a suitable candidate for 3D MRSI of large FOVs. Metabolite separation and robustness appears to be sufficient *in vivo*, too, as is indicated by first results of a different study that is ongoing.

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Figures (max 2) Table is 1 figure

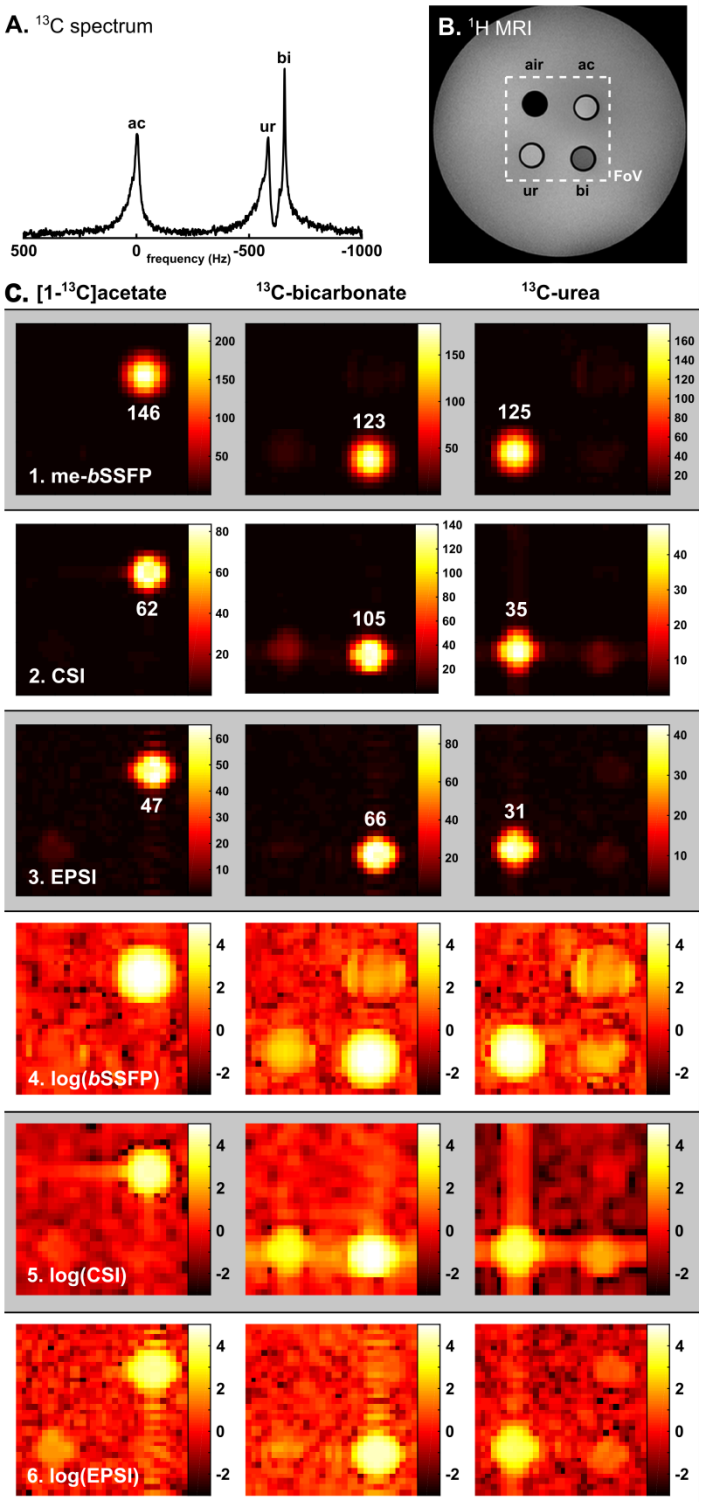

Figure 1: ^{13}C MR-spectrum (A.), ^{1}H MRI (B.) and ^{13}C MRSI (C., linear 1-3 & logarithmic 4-6 scale) of acetate, bicarbonate and urea using me-*b*SSFP, CSI and EPSI. Spatial localization, metabolite separation as well as high SNR (white numbers) was achieved with each method, with me-bSSFP giving highest SNR. Note that some signal leaking is apparent in all logarithmic images. Due to small chemical shifts the reconstructed metabolite maps can have artifacts at the corresponding positions.