Electric Properties Tomography (EPT) of the Liver in a Single Breathhold Using SSFP

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Introduction

MR-based Electric Properties Tomography (EPT) provides a noninvasive means to assess electric tissue properties, such as conductivity and permittivity, and provides a framework for an accurate determination of local SAR [1]. Furthermore, it may provide a diagnostic parameter in oncology and cardiology. Recently, simplified EPT reconstruction methods based on the pure image phase information were introduced [2,3]. In these studies, spin echo (SE) sequences were employed due to their low susceptibility to B0 variations, or fast field echo (FFE) sequences in concert with B0 mapping were performed. However, these scans are prohibitively long for applications which require breath-holding. In the present study, we have employed a fast balanced SSFP sequence, which has similar properties as SE in terms of B0-independend phase accuracy, but provides increased imaging speed and allows for abdominal imaging in a single breathhold. Phantom experiments and first *in vivo* conductivity scans in the liver of healthy adults are shown.

Methods

Phantom and *in vivo* experiments were conducted on a clinical 1.5T scanner (Achieva, Philips Healthcare) using a 16-element torso coil. A volumetric SSFP acquisition (FOV = 300 x 280 x 90mm³, isotropic resolution 2.5 x 2.6 x 2.5mm³, 36 transversal slices, α=35°, TR/TE = 2.5 / 1.25 ms) with 6 averages was performed. An SSFP pre-scan was performed with a constant gradient to provoke banding artefacts and to interrogate the SSFP offresonance frequency response. Furthermore, a 3D spin echo (SE) scan as described in [2] was performed to provide a reference. Two cylindrical phantoms (water, 2-Propanol, Magnevist, and NaCl) with known conductivity (410 mS/m and 1480 mS/m at 64MHz) were used in the phantom study. *In vivo* abdominal scans were performed in 10 healthy adults during inspiration and expiration for comparison. The breath hold duration was 26s. A reconstruction method based on the image phase [2,3] was employed.

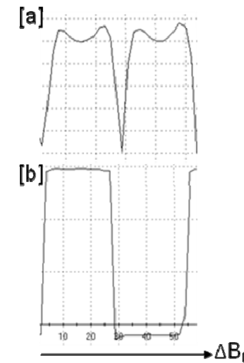

Fig. 1 SSFP frequency response in the presence of a linear gradient ([a] magnitude, [b] phase). The phase plateaus between the periodic wraps.

Results and Discussion

The SSFP frequency response (measured profile across the water phantom in the presence of a linear gradient) is shown in Fig. 1. While the magnitude plot shows a residual dip over the SSFP passband, the phase plot perfectly plateaus between the periodic wraps. Color-coded conductivity maps of the cylindrical phantoms acquired with SE and SSFP are shown in Fig. 2 [a] and [b], respectively. A good agreement between the conductivity values obtained with SE, SSFP, and the expected value was observed. Selected *in vivo* conductivity maps of the liver (anatomy, conductivity map, and fusion image) are shown in Fig. 3[a]-[c], respectively. The resulting conductivity values (mean ± standard deviation) are summarized for all volunteers in table 1.

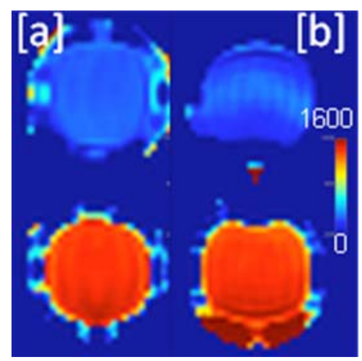

Fig. 2 Conductivity maps ([a] SE, [b] SSFP) in phantoms with known electrical properties (σ=410mS/m and 1480mS/m at 64MHz). Excellent agreement between the two scans and the reference was found.

Conclusion

The low susceptibility of the image phase to B0 variations (within the bandwidth 1/TR) makes SSFP particularly useful for phase based EPT mapping. SSFP overcomes the need to employ time-consuming spin echo sequences, or B0 mapping. This facilitates abdominal conductivity mapping, e.g. in the liver, during a single breath hold. The phantom study yielded excellent agreement between SSFP and previously employed SE sequences for conductivity imaging in phantoms. The *in vivo* liver conductivity could be measured in a reproducible manner in all subjects, and it is in good agreement with previously published values [4]. However, the conductivity maps were heterogeneous, particularly near large vessels. This may be attributed to flow and perfusion effects. Furthermore, maps acquired in inspiration were consistently better than those acquired in expiration (not shown), which requires further investigation. A possible explanation is reduced cardiac-related abdominal motion during inspiration, which will be addressed in future studies.

References:

[1] Katscher U. et al, IEEE Trans Med Imag. 28(9):1365-74 (2009)
[2] Voigt T. et al, Proc. Intl. Soc. Mag. Reson. Med. 18 (2010), p2865
[3] van Lier AL. et al, Proc. Intl. Soc. Mag Reson. Med. 18 (2010), p2864
[4] Gabriel C, U.S. Air Force Report AFOSR-TR-96

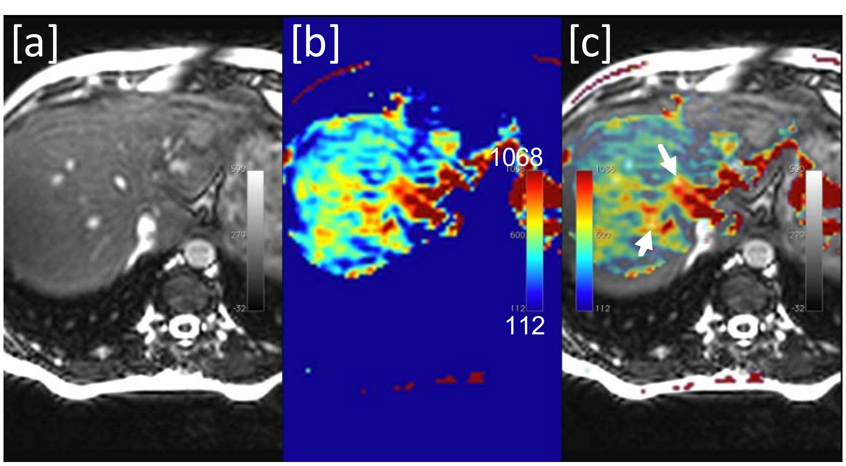

Fig. 3 Abdominal SSFP scan [a], reconstructed conductivity map [b] and fusion image [c]. The reconstructed values are in good agreement with the literature except in the vicinity of large vessels (solid arrows).

Table 1 Measured liver conductivity in 9 volunteers versus ref [4].

vol #	mean ± std dev	
1	419 ± 150	mS/m
2	400 ± 181	mS/m
3	434 ± 129	mS/m
4	498 ± 153	mS/m
5	470 ± 177	mS/m
6	474 ± 125	mS/m
7	488 ± 235	mS/m
8	446 ± 116	mS/m
9	458 ± 176	mS/m
10	472 ± 45	mS/m
mean	456 ± 31	mS/m
ref [4]	448	mS/m