Strategies for Fast 3D Volumetric Coverage using Spatiotemporally-Encoded MRI

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Introduction

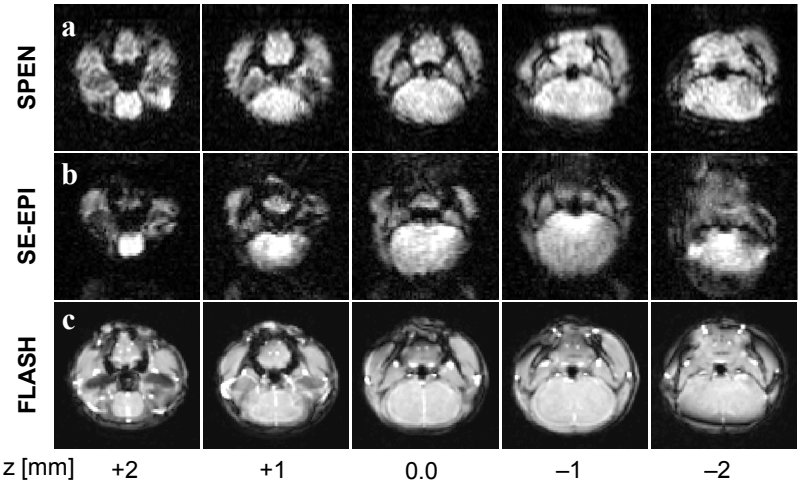
The generation of MR images in a single-shot is essential for a variety of applications. Most applications, however, require covering 3D volumes of interest, while keeping the overall scanning as short as possible. Two practical approaches for this type of imaging are to "tailor" multiple consecutive slices with a minimal gap, or to implement pure 3D acquisition by phase-encoding the 3rd dimension. The most common sequence for producing the underlying 2D single-scan images is Echo Planar Imaging (**EPI**). Notwithstanding its proven success, EPI is highly challenged by the existence of B_0 heterogeneities and/or multiple chemical sites, which lead to image distortions that increase with the B_0 field strength. Recent work [1-4] explored a new single-shot imaging scheme that is based on combining spatiotemporal-encoding (**SPEN**) with super-resolution (**SR**) reconstruction algorithms, and which has high immunity to artifacts of this kind. Generalizations of this approach to multi-slice and 3D sequences were developed and are demonstrated on in-vivo samples.

Methods

Experimental data were acquired on a Varian Inova 7T vertical imaging unit. In-vivo multi-slice and 3D mouse brain images were collected for 5 slices covering a FOV of 20x20x5 mm^3. Multi-slice Spin-Echo (**SE**) EPI was evaluated vis-à-vis two SPEN based MRI sequences: one employing a 2D slice-selective and spatiotemporal-encoding excitation pulse and the other employing a 180^0 spatiotemporal-encoding pulse (panel (b) in the attached Figure). Matching FLASH images were also collected as a reference. Imaging parameters were: SE-EPI [slice thickness = 1.0 mm, gap = 0 mm, matrix size = 70x70, TE = 21 ms, TR = 100 ms, overall acq time = 0.6 sec]; SPEN MRI [180^0 pulse sweep rate = 40 kHz/ms, slice thickness = 0.75 mm, gap = 0.25 mm, matrix size = 70x70, TE = 21 ms, TR = 100 ms, overall acq. time = 0.6 sec]; FLASH [TE = 2.56ms, TR =100 ms, matrix size = 128x128, slice thickness = 1 mm, overall acq. time = 51 sec].

Results

The attached Figure shows the quality enhancement afforded by using SPEN for an in-vivo multi-slice mouse brain MRI. (**a**) A Multi-slice Hybrid SPEN sequence employing 180^0 spatiotemporal-encoding pulse (horizontal x-axis is frequency-encoded and the vertical y-axis is spatiotemporally-encoded), (**b**) Multi-slice SE-EPI (**c**) FLASH. Different panels correspond to different z-axis values.



Discussion

Integration of SPEN into multi-slice sequences enhances the quality of 3D coverage, as compared to the fully frequency-encoded SE-EPI. The apparent difference between sets (**a**) and (**b**) is attributed to the inherent robustness of the spatiotemporal-encoding approach to field inhomogeneities [3]. This property is even more evident when addressing z-values far from the scanner isocenter, characterized by poorer shimming conditions. Another added value originates from the incorporation of a super-resolution processing algorithm, which not only matches the resolution provided by EPI, but also reduces the relatively high SAR which characterizes SPEN MRI [4]. Further utilization of the SPEN pertaining to B_1 inhomogeneities, is currently being developed. By incorporating the B_1 spatial response into the spatiotemporal-encoding pulse design (either the 2D or 180^0 pulse variants) one might be able to compensate for its non-uniformities, thereby optimizing the performance of excitation, inversion or refocusing pulses.

References

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