In-Vivo Flow-Artifact Suppression Using Parallel Spatially Selective Excitation

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Introduction: In-vivo MR imaging on humans and animals is often affected by flow and motion of nuclear spins causing blurring and ghosting artifacts [1]. If these moving spins are not of direct investigational interest their effects need to be suppressed or compensated efficiently. For this purpose a variety of techniques has been developed, like preparation modules with saturation pulses, triggering or adapted sequence and reconstruction designs. In this study a novel approach using parallel spatially selective excitation (parallel SSE) / TransmitSENSE [2,3] and inner volume imaging [4] has been taken for this end and it could be demonstrated in an in-vivo experiment that this technique is suitable for achieving effective suppression of pulsatile flow artifacts in rat-head imaging.

Theoretical background: While gradients are applied during an imaging sequence, moving spins accumulate phases which are unintended with respect to phase encoding. Thus, signals originating from such spins may be assigned to wrong positions showing up as ghosts superimposed on the reconstructed image. E.g. periodic motion, like pulsatile flow, produces ghosting artifacts along the phase direction [1]. SSE, achieved by playing out multi-dimensional RF pulses, i.e. RF pulses simultaneously with gradient waveforms, offers the possibility to generate transverse magnetization confined in predefined regions of interest. If these regions are defined in such a way that all potential sources of motion artifacts are located outside, this technique will prevent signals from moving spins to be included in the image reconstruction. In case of in-vivo imaging, SSE significantly benefits from parallel excitation with multiple transmit coils [2,3,5], because it allows shortening the RF pulse duration which results in an improved spatial excitation quality due to reduction of B_0 inhomogeneity effects [4].

Materials and Methods: The experiments were carried out on an 8-TX-channel 9.4 T, 30 cm bore BioSpec system (Bruker BioSpin MRI GmbH, Ettlingen, Germany) in combination with an 8-element TX/RX volume array. In-vivo images of a complete slice through the head of an anesthetized rat were acquired with a conventional 2D RARE method. To accentuate flow and pulsation artifacts, the repetition time was reduced to TR=500 ms, the echo time prolonged to TE= 15 ms and the array was driven in a mode similar to a birdcage coil to achieve homogeneous excitation.
With the same parameters a second image was acquired in which only the rat's brain was excited. For this purpose the excitation module in the RARE sequence was substituted by a parallel 2D SSE pulse with a constant density, constant angular velocity spiral as gradient trajectory. The spatially selective RF-pulse was calculated by the conjugate gradient method described by Graesslin et al [6]. An acceleration-factor of 2 for pulses and trajectory was used resulting in pulse durations of 8.5 ms.

Results and Discussion: Excitation of the whole slice with the conventional RARE sequence resulted in the image shown in Fig. 1a: Very strong signals from the vessels showed up (arrow 1, Fig. 1a) due to the inflow of unsaturated spins into the imaging slice. Caused by periodic pulsatile flow with slightly varying pulsation frequencies, the phase encoding of the vessels signal was disturbed resulting in ghosts of the vessels appearing along the phase encoding direction (arrows 2+3, Fig. 1a). Assuming the rat brain to be the region of interest, images of this target volume were highly disturbed by the ghosting artifacts, which originatied from the left carotid and appeared on top of the brain image (arrow 3, Fig. 1a). After masking the brain as region of interest and calculating a parallel SSE pulse accordingly, the excitation was very effectively restricted to this region (Fig. 1b). Since in this case almost no signal was generated by the vessels, the brain could be imaged without loss of quality and no ghosting artifacts were apparent.
A great advantage of this technique over MRI sequence preparation modules with slice selective saturation is, that multiple saturation pulses with additional SAR contributions are no longer required. As another significant benefit, the possibility to define arbitrarily shaped patterns for the regions to be excited allows very flexible adaptations of these regions to the imaged object's particular geometry e.g. anatomical structures.
After selectively exciting the given region of interest, there is a further possibility for artifact reduction, namely by reducing the imaging FOV to the excited region as shown in Fig. 2. Keeping the spatial resolution constant results in fewer phase encoding steps and therefore in reduced measurement and readout time. Since especially effects of global object movement are accumulated during the whole scan time a reduced measurement as well as readout duration will consequently reduce such artifacts.

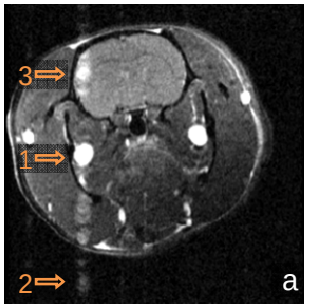

Fig. 1: *Artifact suppression in RARE images of the rat head: TE=15 ms; TR=500ms; res.=(0.15x0.15x2.0)mm^3; RARE-factor=4, averages=2.* ***a)*** *excitation of a complete slice with conventional pulses shows strong vessel signal (arrow 1) which results in ghost artifacts along phase direction (arrow 2,3). Especially the brain region is disturbed by this artifact (arrow 3).* ***b)*** *parallel spatially selective excitation restricted to the brain region generates no signal from the vessels resulting in an artifact free brain image.*

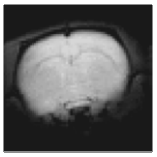

Fig. 2: *Inner volume imaging: parallel spatially selective excitation of the brain region with FOV reduction from 3.8 cm^2 to 1.9 cm^2. Keeping the spatial resolution constant means a reduction of phase encoding steps and measurement time by a factor of 2.*

Conclusion: Parallel SSE has proven to be a very effective means for in-vivo MRI to restrict signal generation and acquisition to arbitrarily shaped regions of interest and to exclude signals originating from outside. In particular, if moving spins, which cause image artifacts in conventional imaging, are excluded from the excited volume such artifacts can be avoided. Furthermore, inner volume imaging with reduced FOVs offers the possibility to reduce the measurement and readout time, while keeping the spatial resolution constant, which results in reduced motion artifacts. This will be beneficial for many applications in small animal MRI, e.g. the suppression of ghosts from vessels or eye movement, reduction of distortions through the spine caused by breathing and mitigation of artifacts from heart motion in thorax images. Therefore the technique of parallel spatially selective excitation provides a great potential for improvements of image quality.

References: 1. Wood ML, Henkelman RM (1985) Med Phys 12:143 // **2.** Katscher U et al. (2003) MRM 49:144 // **3.** Ullmann P et al. (2005) MRM 54:994 // **4.** Feinberg DA et al., (1985) Radiology 156:743 // **5.** Zhu Y (2004) MRM 51:775 // **6.** Graesslin I. et al. (2006) Proc. ISMRM 2006:2470

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