Dynamic Reacquisition for Respiratory Gated, Constant TR 2D multi-slice MRI

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Target Audience: Preclinical MRI Community.

Purpose: Constant T_1 weighting is difficult to achieve in 2D multi-slice MRI when used in conjunction with respiratory gating or triggering as the cycles of each are asynchronous, and the respiratory cycle is particularly erratic. Long term averaging and retrospective gating have been used to ameliorate this, but at the expense of a significantly extended scan time. This report describes Slice-Projection Loop Index Counter Enabled Reacquisition (SPLICER), a new technique that allows respiratory-gated 2D multi-slice MRI to operate at a constant, short TR (TR<3T_1) and with the minimum scan time possible for the chosen TR. Each slice has its own projection (phase encode) loop index counter that is updated on-the-fly during a scan. When motion corruption is not detected for any given slice the associated slice-projection loop index counter is incremented, as is customary, to advance acquisition. When motion corruption is detected for any given slice the associated slice-projection loop index counter is held constant and the same projection is reacquired one TR period later. This approach enables maximum scan efficiency as data are acquired throughout the entire respiratory interval and are discarded only when motions are present, making repeated acquisitions of the same uncorrupted projections unnecessary. SPLICER is self-compensating in the event of erratic breaths and changes or drifts in respiratory rates. As such, the method enables robust motion insensitive imaging that operates reliably with only a minimum level of operator intervention. Furthermore, the method is compatible with the addition of cardiac triggering for TR>5T_1. We demonstrate the use of SPLICER in the mouse abdomen.

Methods: MRI was performed at 7.0 T (Varian VNMRS) using a 40 mm ID birdcage coil (Rapid Biomedical). A 2D multi-slice spin echo scan was used (TE 7 ms, TR 400 ms, 32×1 mm sagittal slices, 192(RO)×96(PE) points giving an in-plane resolution of 313 μm). Respiration was monitored using an induction loop and the analogue signal was digitized to generate a TTL gating control signal, the state of which was evaluated by the scanner immediately prior to acquisition of data for each slice. If the TTL signal was high, then respiratory motion was absent, data were considered acceptable, and the slice-projection loop index counter of the slice was incremented. If not, then motion was inferred, the slice-projection loop index counter was held at its current value, and data were reacquired one TR period later. Threshold-based detection of the breath implies that data are already somewhat corrupted by motion. To overcome this, data acquired during a user defined period before the detection of the breath (typically 50-200 ms) were also reacquired to minimize motion artefacts. The respiratory gating signal and the TR were asynchronous so each slice had its own rate of progress throughout the scan. Simulations were run to estimate the time required for each slice to complete and to confirm that the full scan would terminate correctly and efficiently. For *in vivo* experiments, anaesthesia was induced and maintained with Isoflurane in 30% oxygen in air to give a respiration rate of ca. 60 breaths per minute. Approximately 60% of the breath is available for motion-free imaging. Three control mice were scanned with and without SPLICER in order to demonstrate the improvement in performance. Four KPC mice featuring small pancreatic tumours were scanned as above but with TE 20 ms, TR > 4000 ms, and cardiac triggering, to demonstrate that SPLICER is able to detect the abdominal tumours reliably and rapidly.

Results and Discussion: For 100 repeats of the simulation with 60% respiratory duty cycle and the imaging parameters described above, the mean efficiency with which the first and last slice acquisitions terminated were 68±2 % and 52±2 %, respectively. Repeats of the simulation showed that the efficiency was purely dependent upon the respiratory duty cycle and not upon the imaging parameters. Images acquired with and without SPLICER are presented for a single slice (of 32) from 3 mice in Fig 1. The scan times for T_1 weighted respiratory gated SPLICER were 61, 68 and 64 s respectively, whilst the un-gated scans all took 40 s. It is quite clear that multi-slice T_1 weighted imaging with SPLICER is remarkably free of motion artefact and can be performed rapidly with the predicted scan time. Fig 2 shows pancreatic tumours from 4 mice, each from a 32 slice set acquired in approximately 12 minutes. The same tumours were readily identified in 3 separate, consecutive imaging sessions.

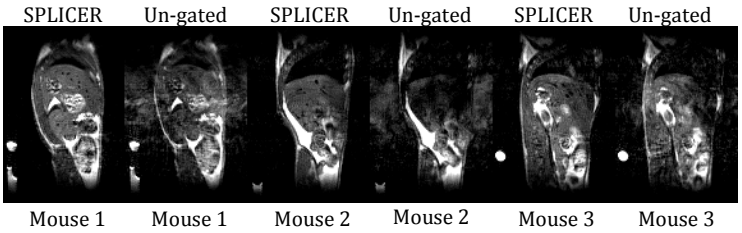

Fig. 1. Comparison of multi-slice respiratory gated T_1 weighted imaging with and without SPLICER.

SPLICER should enable short TR respiratory gated diffusion weighted imaging of the brain enabling either a significant reduction in scan time for a fixed number of diffusion encodings, or significantly more diffusion encodings in the time available. Furthermore, the use of constant TR, as enabled by SPLICER, should improve the homogeneity and efficacy of fat suppression. These applications are currently under investigation.

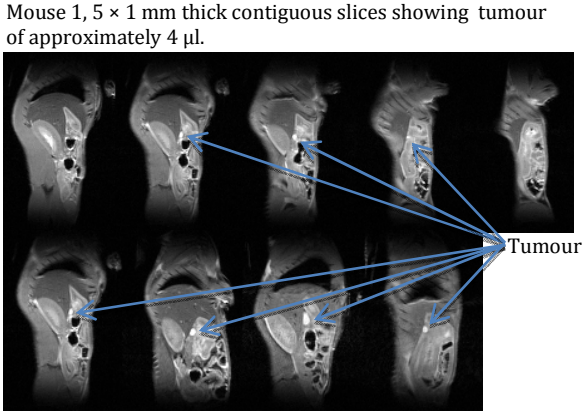

Fig. 2. Cardiac triggered SPLICER in KPC mice featuring small pancreatic tumours.

Conclusion: SPLICER allows maximally efficient capture of uncorrupted data and allows robust high quality multi-slice respiratory gated T_1 weighted imaging to be performed in the abdomen. With the addition of cardiac synchronization, SPLICER allows small pancreatic tumours to be readily identified with a short scan time.