Correction of Subject Motion in Quantitative T2*-Mapping

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Introduction: Several applications for quantitative mapping of the effective transverse relaxation time *T2** have been described, such as the investigation of tumor vascularization [1], the determination of cerebral oxygen extraction [2], and the mapping of iron enriched structures [3,4]. However, *T2** mapping is particularly prone to artifacts induced by subject motion as it requires the acquisition of gradient echo (GE) images at relatively long echo times (*TE*), so superposition of image and motion artifact leads to deviations of the signal-time curve $S(TE)$ from an ideal exponential behavior, resulting in erroneous *T2** values upon exponential fitting. Purpose of this study was (1) to show that even minor sparse subject movement affecting a small portion of k-space may lead to severe errors in *T2** determination, and (2) to propose a suitable correction method. This method is based on scan repetition with reduced spatial resolution in phase encoding direction and weighted averaging of both raw data sets, choosing the weighting factor individually for each k-space line in a way that motion affected data are suppressed.

Theory: In multiple GE imaging, subject motion distorts locally the exponential signal decay. As a consequence, fitted *T2** values will be erroneous and the correlation coefficient *r* between measured and exponentially fitted data will be reduced. For the method proposed here, the acquisition is performed twice: (1) with full spatial resolution, yielding the k-space data set $F(k_x,k_y,TE)$, (2) with reduced spatial resolution in phase encoding direction (k_y), yielding $F_L(k_x,k_y,TE)$. Both data sets may be corrupted by motion. A combined data set F_C is created from $F_C=w(k_y)\cdot F+[1-w(k_y)]\cdot F_L$, choosing the weighting $w(k_y)$ individually for each k-space line to suppress motion corrupted data, i.e. in a way that the image data based on F_C yield maximum *r*-values in all pixels.

Materials and Methods: *T2** mapping was performed on a 3 Tesla whole body scanner (Siemens Magnetom Trio) on five healthy volunteers, using a multiple GE sequence with FoV: 200x160 mm^2, matrix size: 160x128, in-plane resolution: 1.25 mm, *TR*=3000ms, *FA*=30°, 50 axial slices with 2 mm thickness, eight GE per excitation, *TE*=[10/16/22/28/34/40/46/52] ms, duration 6 min 24 s. The scan with reduced spatial resolution comprised 64 phase encoding steps (duration 3 min 30 s). Two ear plugs were attached to the head coil, each of which touched the subject's nose in one of two different head positions (A, B) for guidance, a change in position corresponding to head translations and rotations by 1-2 mm and 2-3°, respectively. The subjects were asked to remain in position A, but to change to position B for 6 s during the full resolution scan after 2min54s of scanning, i.e. during the acquisition of k-space lines 59 and 60. Subjects did not move during the low resolution scan. For reference, the full resolution scan was repeated without head movement. For each subject, three *T2** maps were calculated per slice, based on: (1) full resolution scan without movement (for reference), (2) full resolution scan with head movement, no motion correction, (3) full resolution scan with head movement, motion corrected.

Results: Figure 1 shows *T2** maps for a single slice in a representative subject for the reference data (left), and the motion affected data before (centre) and after (right) motion correction. Although motion was relatively minor and affected a small part of k-space only, there are severe errors in the uncorrected *T2** map. After correction, results correspond to the reference values. For the same subject and slice, Figure 2 shows the weighting factors *w* (green line): the affected k-space lines are reliably detected and suppressed. In contrast, application of the algorithm on the data unaffected by movement leads to approximately equal weighting of all lines (black line). Figure 3 shows histograms of whole brain white matter *T2** values pooled across all subjects for reference data (black), uncorrected data (red) and corrected data (green). Correction clearly reduces the variance and corrected results match the reference values.

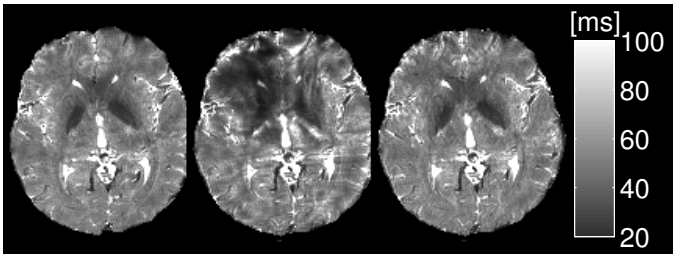

Figure 1: T2 maps (single slice in a representative subject) for the reference data (left) and the motion affected data before (centre) and after (right) motion correction.*

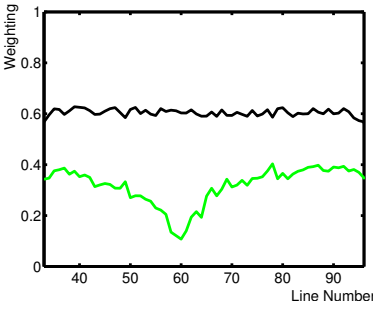

Figure 2: Weighting factors for reference (black) and motion corrupted data (green)

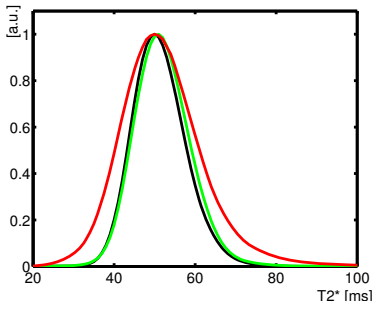

Figure 3: T2 in white matter for reference (black), uncorrected (red) and corrected data (green).*

Discussion and Conclusion

The results presented here show that even minor subject motion can have deleterious effects on the accuracy of quantitative *T2** maps. The method proposed corrects for sparse motion affecting single lines in k-space. Motion of this kind may occur as chorea, dystonia and myoclonus in Chorea Huntington. The technique can be easily implemented on clinical scanners, the only requirement being a multiple GE imaging method with modulus and phase data export.

References

[1] Dennie J et al. 1998, MRM **40:** 793-799. **[2]** An HY and Lin WL 2002, MRM **47:** 958-966. **[3]** Aquino D et al. 2009, Radiology **252:** 165-172. **[4]** Baudrexel S et al. 2010, NeuroImage **51:** 512-520.