Simultaneous assessment of gastric secretion, mixing and emptying during free breathing

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Introduction:
Gastric emptying, distention and intragastric secretion and mixing are important factors in pathogenesis of gastro-intestinal diseases such as gastro-esophageal reflux disease (GERD). Recently a noninvasive method for quantification of gastric secretion was proposed based on combined T1 and B1 mapping (T1B1) [1]. The main drawbacks of this method are motion and flow sensitivity which require multiple, 15–20 s long breath hold cycles. Conventional radial acquisitions are known to be unsusceptible to breathing motion as well as flow artifacts [2]. The aim of this study was to simultaneously assess intragastric secretion, mixing and gastric emptying using an optimized Look-Locker based radial sampling sequence with golden angle profile view order (GOLD). This method was optimized and validated for abdominal imaging during free breathing and compared to the T1B1 mapping method.

Methods:
The previously described GOLD based T1 mapping sequence [2] was expanded for multi-slice acquisition in order to cover the complete stomach volume. To achieve this, a slice selective adiabatic inversion pre-pulse was incorporated. GOLD sequence parameters: single shot T1 weighted TFE with slice selective 180° adiabatic inversion pulse, 12 slices, 8 s inversion time, TR=12 ms, flip angle=6°, 668 radial profiles with golden angle view order, reconstruction matrix 256x256. Image reconstruction was optimized with respect to the applied k-space contrast enhancing filter, number and duration of Look-Locker phases and gridding. GOLD T1 values, from an in vitro experiment using samples with gadolinium labeled agar gels [3], were validated against T1 values from spectroscopic measurements and the previously validated T1B1 mapping method. The feasibility of GOLD T1 mapping during free breathing was tested in a "semi in-vivo" experiment. To this end, a small balloon attached to a nasogastric tube was positioned within the stomach of a volunteer and filled with different homogeneous viscous liquids of predefined T1 values (simulating mixing of a meal with acid secretion). Multi-slice GOLD T1 mapping was performed during free breathing and, for comparison, T1 maps were acquired using T1B1 mapping during four breath holds. The optimized and validated method was applied to assess secretion layer and mixing as well as gastric emptying over 2 hours after the ingestion of a secretion stimulating meal. Furthermore, at several imaging time points of this in vivo pilot study, the sliding window like image-reconstruction procedure was performed to detect gastrointestinal contractility. Standard balanced SSFP volume scans were done interleaved to compare the accuracy of GOLD for gastric volume detection.

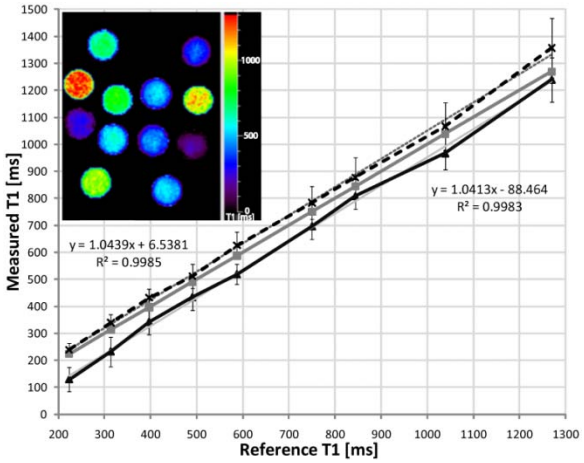

Figure 1: In vitro T1 relaxation times with standard deviation measured in samples with gadolinium labeled agar gels. Black line: GOLD, gray line: reference spectroscopic values, black dashed line: T1B1 reference values. Color image shows the T1 map of the samples.

Results:
Similar to T1B1, in-vitro GOLD T1 relaxation times show a constant offset with respect to spectroscopic reference values [Figure1]. Standard deviation however, was lower in GOLD compared to T1B1. "Semi-in-vivo" experiment showed that free breathing GOLD T1 mapping allowed robust detection of T1 values with a comparable offset to T1B1 as observed in vitro [Figure2]. Secretion layer and intragastric mixing were successfully detected in the gastric emptying experiment and the GOLD derived gastric emptying curve had similar amplitude and dynamic as the control emptying curve [Figure3].

Discussion:
Several important parameters of gastric physiology can be assessed during a single free breathing period of 100 to 120 s using the proposed GOLD method. The offsets in T1 values arise from the k-space contrast enhancing filter and through plane motion due to free breathing. These drawbacks can be addressed by choosing a sagittal or coronal plane for imaging where the in plane movement has less pronounced influence on T1 values or using self-gating methods [4].

References:
[1] Treier R. et al. MRM 57:568-576 (2007); [2] Winkelmann S. et al. IEEE Trans Biomed Eng 26:68-76 (2006); [3] Christoffersson J.O. Acta Radiol 32:426-431 (1991); [4] Lin W. MRM 60:1135-1146 (2008).

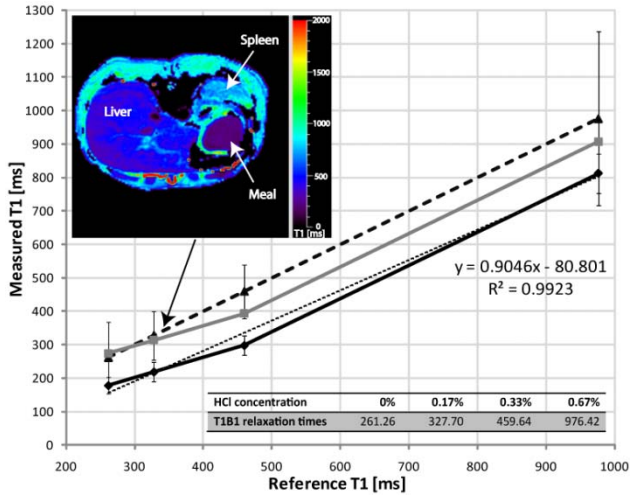

Figure 2: "Semi-in-vivo" T1 relaxation times with standard deviation measured in an intubated balloon filled with a liquid meal mixed with different HCl concentrations. Black line: GOLD, black dashed line: reference T1B1. Gray line represents "corrected" GOLD T1 values with the average offset calculated from in vitro experiment. Color image shows the T1 map of the abdomen and the intubated balloon for the 0.17% HCl concentration.

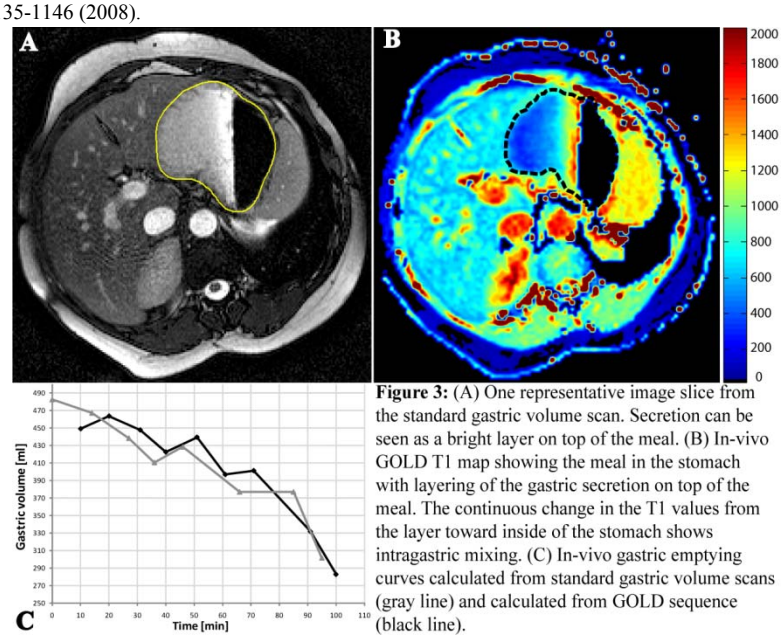

Figure 3: (A) One representative image slice from the standard gastric volume scan. Secretion can be seen as a bright layer on top of the meal. (B) In-vivo GOLD T1 map showing the meal in the stomach with layering of the gastric secretion on top of the meal. The continuous change in the T1 values from the layer toward inside of the stomach shows intragastric mixing. (C) In-vivo gastric emptying curves calculated from standard gastric volume scans (gray line) and calculated from GOLD sequence (black line).