

Estimation of gastric secretions after a nutrient test meal using T₁ mapping MRI.

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Target audience: Monitoring the amount of gastric secretions generated after ingestion of a meal is important for gastroenterologists managing the symptoms of patients who have abnormal stomach function (e.g. functional dyspepsia and acid reflux).

Introduction: Naso-gastric studies which sample the contents of the stomach during gastric emptying may alter the mechanics of emptying [1] and cannot determine the intra-gastric distribution of meal and secretions [2]. MRI provides a non-invasive method of determining the distribution of gastric secretions within the stomach [3]. **Aim:** to estimate the volume and distribution of gastric secretions generated after ingestion of a nutrient test meal using MRI.

Methods: This study was approved by the local ethics committee and all subjects gave written informed consent. 24 healthy volunteers (HVs) (13 male, mean age 48 yrs) and 7 functional dyspepsia patients (FD) (1 male, mean age 38 years) attended after an overnight fast. The nutrient test meal (200 ml Fortisip Vanilla (Nutricia Clinical) with 200 ml water) was doped with 0.5 mmol/l Gd-DOTA (Dotarem®, Guerbet, France) to improve image segmentation and allow dilution effects to be studied. To mimic the solid phase of a meal 12 agar beads (11 mm diameter) were also ingested with the liquid meal. A 1.5 T Philips Achieva scanner with a 16-element SENSE XL torso coil was used for image acquisition. The gastric volume was scanned before and 0, 5, 10, 15, 30, 45, 60, 75, 90 and 120 mins after meal consumption using bTFE (TrueFISP) [4]. Dilution measurements were made at the 15 and 75 minute time points. Dilution of the meal was estimated from T₁ maps generated from respiratory triggered transverse, inversion recovery echo planar images (IR-EPI) acquired in the main body of the stomach (voxel resolution 3 x 3 x 8 mm³, FOV 324x324 mm², 5mm slice gap, minimum TR 3000ms, TE 31 ms, SENSE 2.0, 13 different TIs from 50 to 1000 ms). An in-vitro dilution experiment was used to calibrate the T₁ data by measuring the T₁ of the 400ml Fortisip meal sequentially diluted with simulated gastric secretions [5] at 37 °C.

Data Analysis: Stomach content (meal + secretions) volumes were measured using customized software [4] and the resulting volume data for the first 60 minutes of emptying was fitted to a 3 parameter model [4] of gastric emptying. The κ term in the model describes the early volume changes, with a rise in volume due to secretion initially exceeding emptying resulting in $\kappa > 1$ (Fig 1C). T₁ maps were generated by fitting the IR-EPI data voxel by voxel using a 3 parameter fit. The in-vitro dilution calibration curve of meal with gastric secretions was fitted to the equation: $\frac{1}{T_1} = \frac{1}{aC_{gd} + T_{1GS}} + (cC_{gd} + d)C_{gd}$ (Eqn 1)

where C_{gd} is the absolute amount of Gd-DOTA within a 400ml volume of diluted solution and T_{1GS} the estimated T₁ of pure gastric secretion [3]. This equation describes mixing of 2 systems with very different T₁ values resulting in a non-linear relationship between C_{gd} and $1/T_1$. A line profile was drawn through the T₁ map of the stomach (Fig 1A) to characterise any secretion layer. Histograms were generated of the T₁ values within the stomach (Fig 1B) and the T₁ value for each histogram bin was converted to percentage of secretion using the in-vitro calibration data. The results were used to estimate dilution and hence meal and secretion volumes assuming that the distribution within a single slice was a good representation of the distribution across the whole gastric lumen. Estimated secretion volume and secretion layer were compared to κ value determined from the fit to gastric volumes using the Pearson Correlation co-efficient (PCC) (SPSS 20.0) for HV data [6].

Results: The in vitro calibration curve data fitted to equation 1 with the following values $a = -0.07$, $T_{1GS} = 3830$ ms, $c = 0.00524$, $d = 0.0084$. T₁ data from 3 HVs and 1 FD could not be analysed for technical reasons. All subjects except 2 HVs and 2 FDs data showed distinct layering of secretions. Data is presented for the 15 minute time point only as by the 75 minute time point more than half the meal had emptied from the stomach. Figure 2A shows the correlation between estimated secretion volume and secretion layer (PCC = 0.753, $p < 0.001$, N=19) for HVs. Figure 2B shows the secretion layer is positively correlated with κ from the gastric emptying data (PCC = 0.702, $p = 0.001$, N=19). A similar positive correlation was obtained between secretion volume and κ (PCC = 0.578, $p < 0.006$, N=21, not shown). For the FD patient data the κ value did not correlate with the secretion layer, with a lower κ occurring for no change in secretion layer thickness compared to HV (Fig 2B).

Discussion and Conclusions: This is the first time that an estimation of total gastric secretion volume has been made from T₁ maps which include secretions that have diluted the ingested meal. The κ value from the fit to the gastric emptying data correlated well with the secretion layer thickness and, to a lesser extent, with estimated secretion volumes in healthy volunteers. Some subjects did not show a layering of secretions which may give an insight into the mixing action of the stomach. κ was lower in FD patients compared to HVs with similar secretion layer thickness and volume. This shows that the change in κ is due to impaired accommodation in this group rather than reduced secretion rate. Future work will (i) determine which biomarker (secretion volume or layer for secretion rate or mixing) is best for assessment of abnormal gastric function, (ii) increase volume coverage of the T₁ measurements to take account of any inhomogeneous mixing (iii) determine whether this technique can be used to study the impact of secretion volume on symptoms in FD and reflux disease.

References [1] Read et al. Gastroenterol 1983;84:1568-1572. [2] Goetze et al. Neurogastroenterol Motil 2009;21:725-742 [3] Trier et al. JMRI. 2008;28:96-102. [4] Hoard et al. ISMRM 2012:1279. [5] Rayment et al. Food Hydrocol 2009;23:816-822 [6] Fruehauf H. et al. Neurogastroenterol Motil 2011;23:854-861.

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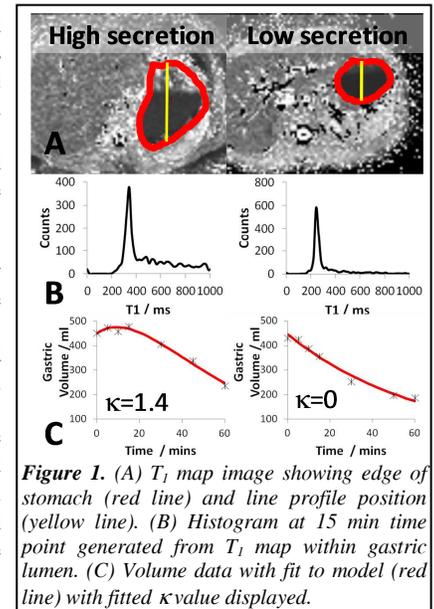


Figure 1. (A) T₁ map image showing edge of stomach (red line) and line profile position (yellow line). (B) Histogram at 15 min time point generated from T₁ map within gastric lumen. (C) Volume data with fit to model (red line) with fitted κ value displayed.

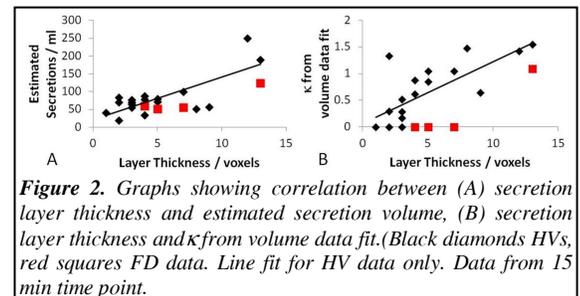


Figure 2. Graphs showing correlation between (A) secretion layer thickness and estimated secretion volume, (B) secretion layer thickness and κ from volume data fit. (Black diamonds HVs, red squares FD data. Line fit for HV data only. Data from 15 min time point.