Optimization and validation of small bowel water content estimation using MRI

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Introduction:

Small bowel water content (SBWC) is a novel way of assessing the response to feeding which is abnormal in some pathological conditions such as coeliac disease. Recent developments have allowed non-invasive, patient-acceptable monitoring of SBWC, using an MRCP MRI sequence[1]. This method assumes that in MRCP images, any pixel in the peritoneal cavity, with a signal intensity above a given threshold is filled with free water. Since SAR and imaging time constraints preclude the use of quantitative imaging (e.g. T_2) the threshold must be chosen to normalize for intra- and inter-subject variations in signal due to scanner instabilities, subject repositioning etc. The methods of choosing this threshold and the accuracy of this technique have not been tested to date. The aim of this study was to address this, using naso-duodenal bolus infusions in healthy volunteers.

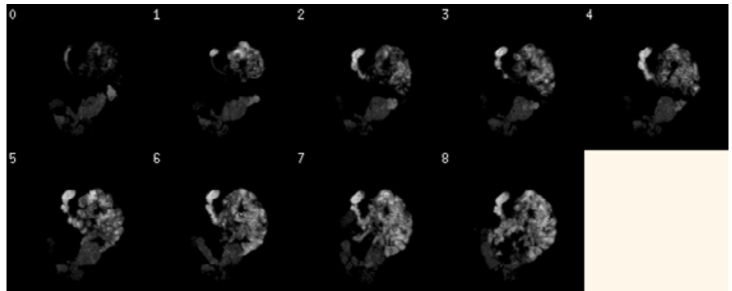

Figure 1: Coronal MIPs of small bowel water above threshold level set. Image 0 shows the baseline and subsequent images the progressive infusion of 40ml boluses of liquid. (Stomach volumes are not shown in these MIPs for clarity of small bowel data)

Methods:

The study was approved by the local ethics committee and all volunteers gave written informed consent. 13 healthy volunteers (7 male, 6 female) were intubated using a naso-duodenal tube (14 Ch (4.7mm)). Tube position in the duodenum was confirmed by MRI using the MRCP sequence described below. A baseline data set was acquired and then eight 40ml boluses of a test solution (145 mM/L NaCl and 15 mM/L Mannitol) were infused into the small bowel (320ml total infusion), in less than 15 mins. This solution causes no net fluid flux across the bowel wall when infused into the small bowel[2]. Immediately after each bolus infusion, MRI data were acquired on a 1.5 T Philips Achieva scanner using a coronal TSE (MRCP) (TE_{eff}=320 ms, TR=8000 ms, 24 slices, SL= 7mm, FOV=400mm, reconstructed matrix = 512x512). Volumes of fluid in the bowel were calculated for the baseline scan and after each 40ml bolus by integrating the volume of all image pixels above a threshold (see below), after exclusion of signal from the kidneys, gallbladder, bladder and visible blood vessels.

Preliminary studies showed that the CSF signal provided the most stable basis for setting the threshold. Therefore to optimize the choice of threshold the first 6 volunteers' data (4 male, 2 female) were used as 'training data sets'. CSF histograms were used to set an initial CSF 'intensity level' and the threshold for the SBWC was set as a % of CSF signal. The CSF 'intensity level' was calculated from smoothed normalised histogram data of the CSF and closely surrounding tissue. The second differential was calculated numerically and when this difference remained below 10 it was assumed that the data was arising from the CSF and had excluded background tissue signal. The intensity level for this point was used for the CSF value. Graphs of the estimated versus infused volumes (with baseline subtracted) were plotted for a large range of test threshold levels (using different % CSF intensity levels) and the test threshold levels giving results closest to identity across all subjects was determined and the corresponding % CSF level used to calculate all thresholds in future studies. To validate the technique this threshold was applied to the 'study data' of the remaining 7 volunteers.

Results:

Figure 1 shows a set of Maximum Intensity Projections (MIPs) for a single volunteer at baseline and after each 40 ml bolus, clearly showing the small bowel water content increasing. Stomach volumes were also included in the measurements of the volumes as it was clear on some data sets that some infused fluid was in the stomach. Figure 2 shows a validation curve for the 'study data'. A linear regression fit of the data gave a gradient of 1.06 and intercept of 7.29 ml (R^2=0.93, p<0.001). The average percentage difference between infused and measured volumes was 20%, corresponding to an average error of 8ml in every 40ml bolus.

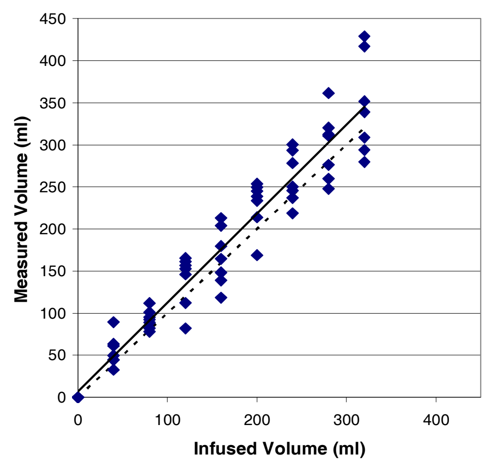

Figure 2: Graph of infused volume versus measured volume for the 'study data' subjects. Identity line – dashed, fitted line - solid

Conclusion:

This study has shown that using a threshold chosen as described above, it is possible to estimate small bowel water content volumes with a reasonable degree of accuracy.

References:

1. Marciani L, *et al.* Gastrointestinal Effects of Bran: A MRI Study. Proc. Int. Soc. Mag. Reson. Med. 14, 2006, p840

2. Spiller RC, *et al.* Inhibition of jejunal water and electrolyte absorption by therapeutic doses of clindamycin in man. Clin. Sci. 1984; 67; 117-120