In vivo trans-pyloric mass movement dynamics measured by means of phase-contrast MRI

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Introduction: Detailed understanding of the process of digestion and absorption of nutrients is crucial for explaining how abnormal function of the gastrointestinal (GI) tract causes abdominal symptoms. Irregular nutrient absorption can significantly impair the efficiency of medication in the treatment of diseases, e.g. in diabetes and Parkinson's disease (LIT). Gastric function has been studied by means of manometry, scintigraphy, electrogastrography, ultrasonography and recently by MRI, quantifying gastric volume, GI peristaltic frequency and antral flow[1]. Flow measurements by means of phase contrast (PC) MRI are a standard procedure in cardiac imaging and angiography which are characterized by periodic flow patterns and strong phase contrast effects. Flow measurements in the GI tract by means of PC MRI might likewise provide a valuable tool for detecting abnormal GI function. However, expected irregular flow patterns and velocities below 10cm/s [2] in the GI tract make it difficult to use phase-contrast MRI in this region, given that long phase encode gradients for low flow velocities further decrease the already low temporal resolution of this technique. The main goal of this work was therefore to study the feasibility of fast EPI readouts in PC imaging for measuring mass movement dynamics in the GI tract. Presumably, flow patterns are best defined and directed near the pylorus that regulates the flow of nutrients into the intestines. In this pilot study we aimed at detecting gastroduodenal out- and backflow dynamic using EPI PC MRI.

Methods and Materials: All experiments were performed on a 3T whole-body MR system (Philips Healthcare, Best, The Netherlands). *Phantom studies*: The sequences used in vivo were tested in vitro using a TX151-filled phantom (25*13*40cm^3) with immersed PVC tubes of inner diameter of 15mm that simulated the small intestine. Measurements were performed with constant flow in forward and backward direction through the phantom tubes. A reference velocity value was determined by measuring the outflow volume over time. *In vivo studies*: Measurements were performed in a healthy volunteer after four hours of fasting in right decubitus position, assuring fluid inside the gastroduodenal region. Shortly before measurements, the volunteer was given 250ml of green tea. Emptying was observed with simple survey scans and additional liquid was administered according to stomach emptying. In a second scan, the volunteer received additional Gadolinium contrast agent (DOTAREM, 1mmol/ml). Dynamic phase contrast velocity mapping was performed behind the pylorus in an oblique coronal slice (see Figure 1 "S") using either multi-shot FFE EPI (EPI-factor 5), and a temporal resolution of 2.75s or single-shot EPI yielding a temporal resolution of 1.20s. Sequence parameters were as follows: 40 dynamics, FOV 150*182 mm^2, slice thickness 5mm, Matrix 100*122 (multi-shot EPI), Matrix 100*123 (single-shot EPI). The slice was positioned approximately 1cm behind the pylorus to ensure that the pylorus did not move into the slice during peristaltic movement. Pylorus (P) and duodenum (D) were clearly recognizable (see Figure 1). Multi-shot EPI scans were performed at shallow breathing, allowing for long scans (>1min), and breath-hold scans were performed using single-shot EPI. Data was analyzed using MATLAB (The MathWorks, USA). Velocity encoding was performed through-plane and the in-plane shift was accounted for by drawing individual regions of interest (ROI) for all dynamic scans. A backflow percentage estimate was calculated as the share of phase contrast images with negative mean velocity in the ROI relative to the total number of dynamics.

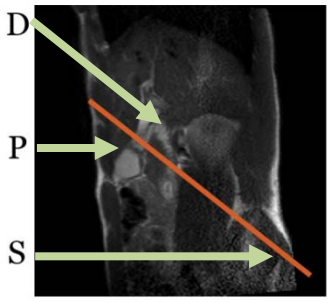

Figure 1 Planscan

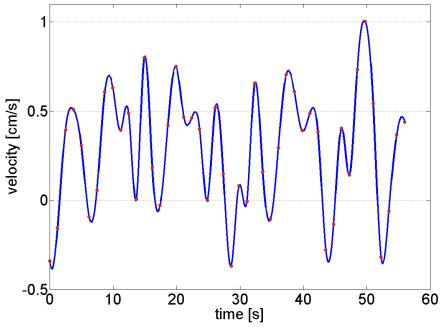

Figure 2 Flow time course

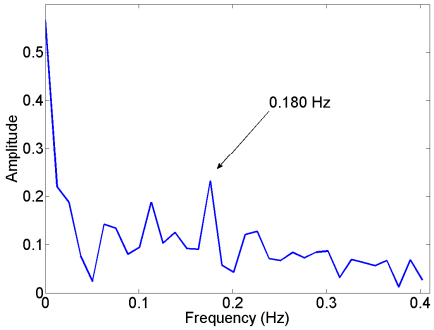

Figure 3 Flow spectrum

Results: Measured unwrapped velocities (Reference, Forward and Backward) in the phantom are shown in Table 1. A reference measurement at zero flow was performed in addition, using single-shot EPI, yielding (0.03±0.04) cm/s. Single-shot EPI scans showed geometric in-plane distortions of up to 23 pixels. For shallow breathing, the mean spatial through-plane shift was quantified as 1.2mm/s, max. 2.4mm/s. Backflow percentage in single-shot EPI was calculated to 0.26. The volumetric flow rate was estimated from the velocity data shown in Figure 2, assuming a mean pyloric diameter of 12mm [3], yielding a mean flow rate of 0.06 ml/s. Finally, a spectral analysis on the velocity time courses (Figure 2) was performed, revealing a prominent peak at 0.180 Hz (Figure 3).

	R [cm/s]	F [cm/s]	B [cm/s]
Multi-shot EPI	±6.6	6.0±0.7	-6.8±1.1
Single-shot EPI	±7.5	6.2±0.5	-7.2±1.7

Discussion: Velocity mapping based on phase-contrast images was successfully performed in the GI tract and showed good agreement with literature data. The velocities measured in vitro are in good agreement with the reference mean velocities and show acceptable standard deviations. For in vivo measurements, the estimated backflow percentage is in agreement with other measurements [4]. The measured velocities are likewise in the expected range, yielding a volume outflow of 250ml in approximately 14 min. The spectral peak coincides very well with the mean duodenal contraction frequency of 0.183 measured by Froehlich et al[1] indicating that mass movements behind the pylorus are primarily governed by duodenal contraction waves. The increase in temporal resolution using single-shot EPI compared to multi-shot EPI is therefore crucial for determining these high frequency movements. Administration of contrast agents was found to be essential in order to unambiguously identify the regions of interest containing the fluid with high signal intensity, considering possible image distortions arising in fast single-shot EPI scan. We considered the measured motion shift non negligible, performing breath-hold for the later single-shot EPI scans. The effect of shallow breathing on flow measurements needs to be further analyzed and a scan protocol with slice tracking is recommended. The described preliminary results show high potential for fast PC MRI as being a valuable tool in characterizing intraluminal fluid movement. Further measurements using duodenal tube feeding as an in vivo velocity reference will have to be performed along with studies on different viscous liquid meals.

References: [1] Schwizer et al. Scand J Gastroenterol 1-16 (2006) [2] Pal et al. P R Soc B 271:2587-94 (2004) ; [2] Froehlich et al. JMRI 21:370-5 (2005); [3] Coupe et al. Pharmaceut Res 8 :360-64 (1990) ; [4] Pallotta et al. Am J Gastroenterol 93:2513-22 (1998)