Feasibility of small bowel flow rate measurement with MRI – a volunteer study

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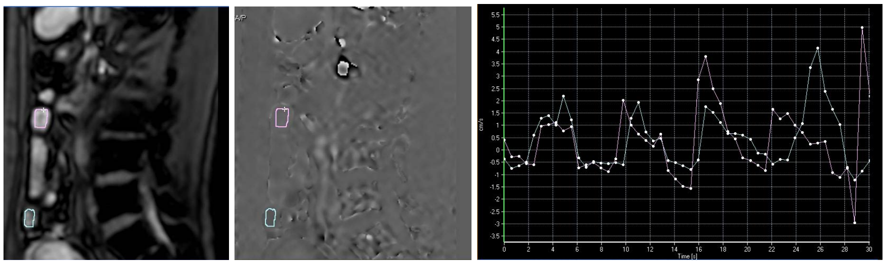
Introduction: Disturbances of the small bowel may lead to nausea, vomiting, diarrhea and pain causing various clinical syndromes (dysmotility, slow transit, obstipation, irritable bowel syndrome, obstruction). To date, the response of symptoms to treatments targeting motility for these conditions has remained disappointing. From the functional perspective it might be important to understand better the relationship between small bowel peristalsis and intraluminal flow. Until now it has only been possible to measure small bowel flow using invasive methods. Motility of the small bowel wall with its contractions has been examined with MRI [1,2], while there are no studies investigating the small bowel flow in humans. Thus, the aim of our prospective volunteer study was to develop and validate a new MR technique based on phase-contrast pulse sequences to measure intraluminal flux of the gastrointestinal content in single segments of the small bowel.

Fig. 1 a,b,c: Sagital modulus (a) and PC flow measurement (b) for two ROIs depicted on the two figures on the left. The two curves (Fig 1c - right) represent a typical propulsive back and forth flow type.



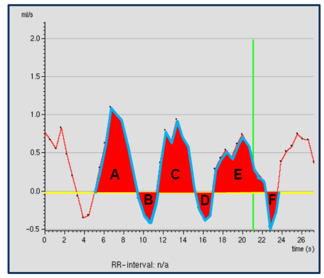


Fig 2 (left): Typical small bowel flux curve for one of the volunteers measured with phase-contrast MRI: Evaluation of the net-flux measuring entire amplitudes (here 3) corresponding to = A + C + E – B – D – F. Calculations yield the net flux over time.

Material and Methods: With institutional review board approval and informed consent a total of 10 volunteers (mean age: 34yrs; range 27-57yrs; 1f; 9m) were included. One hour prior to MRI they ingested at regular intervals 1600ml of water spiked with totally 20ml Gd-DOTA (gadoterate, Dotarem®, Guerbet) and 23.2g Metamucil® mite (ispaghula). Volunteers were placed feet-first and prone into the 1.5T scanner (Gyroscan Intera, Philips Medical) with a 4-channel phased-array body coil. A 3D T1-weighted coronal overview of the entire abdomen was used to identify well-distended segments. On each of these selected planes flow velocity-sensitive 2D PC pulse sequences were acquired in apnea (30-45sec) with a high temporal resolution (1.1sec) using the following parameters: TR 7.8ms; TE 5.8ms; FA 15; TFE-factor 32; voxel-size 4mmx4mmx10mm; velocity encoding Venc=7cm/sec. In a phantom study consisting of a high-precision pump and tubing system, various flow-rates from 0.077ml/sec up to 3.10ml/sec were correlated with PC measurements. Flow velocity measurements of single intestinal segments were performed using the cardiac software provided on an EWS workstation (Advanced viewing 2.6.3, Philips) allowing to automatically process the phase-contrast MR velocity images.

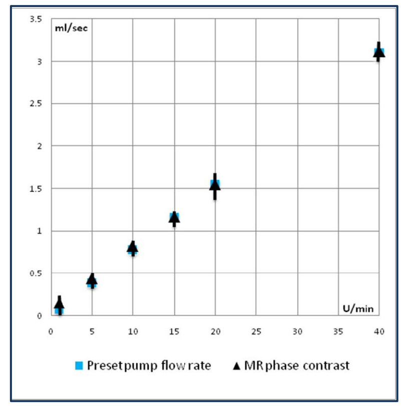


Fig 3 (right side): Rotational speed of the high-precision pump was entered on the x axis and the corresponding flow rates in ml/sec on the y axis. The graph illustrates the high degree of accuracy (correlation R= 0.999) with which contrast enhanced phase contrast MRI allows measuring flux within a tube-like structure here in orthogonal direction (90°) to flow. Flux is depicted with standard deviations.

Results: Flow velocities of the bowel content were measurable in all volunteers (Fig. 1c, 2) for single well distended small bowel segments. The intestinal flux analyses plotted over time showed that the curves featured all similar patterns corresponding to rhythmic flow (Fig. 1c,2). Altogether, 24 measurements were included in the statistical analysis yielding flux in ml/sec. Overall, an average flow rate with a mean of 0.188 ml/sec (range: 0.027-0.516 ml/sec) with a standard deviation of 0.144 ml/sec and a mean velocity of 0.129 cm/sec (±STD=0.131) resulted. This reflects the high intra- and interindividual differences of the small bowel flux and velocity measurements. The phantom measurements resulted in an excellent correlation between the preset pump values and the phase-contrast measured flow rates (R=0.999) for all flow-rates ranging from 0.08-3.1ml/sec (Fig. 3). Standard deviations of flux rise at lower flow rates up to 7% at 0.39ml/sec and 15.8% at 0.08 ml/sec.

Conclusion: Time-resolved measurement of segmental small bowel flux is feasible using a phase-contrast MR technique with low amounts of gadolinium. After validation of our technique using a phantom we were able to visualize and quantify location-dependent small bowel flux in 10 healthy volunteers. The mean flow-rate of 0.188 ml/sec corroborates with transit-time extrapolations for the entire small intestine, but presents high inter- and intraindividual variabilities. This new method provides a first insight into the physiology of small bowel peristalsis and propagation of food on a segmental level. Motility does not seem to be the sole factor providing flux of the intraluminal content in the small bowel.

References: 1. Froehlich JM, Patak MA, von Weymarn C et al: Small bowel motility assessment with magnetic resonance imaging. JMRI 2005; 21:370-375.
2. Patak MA, Froehlich JM, von Weymarn C et al.: Non-invasive measurement of small-bowel motility by MRI after abdominal surgery. Gut 2007; 56:1023-1025.