MRI to assess the contribution of gastric peristaltic activity and tone to the rate of liquid gastric emptying in health

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Introduction: Gastric emptying requires coordinated motor activity of gastric fundus, antrum, pylorus and proximal duodenum. However, the pattern of motor and pressure events, their coordination with pyloric opening, and their relative contributions to gastric emptying is still incompletely understood (1). In this study, effect of gastric tone, antral peristalsis and pyloric contractility on the rate of gastric emptying was studied using concurrent MRI and high-resolution manometry (HRM). Pharmacological relaxation of the fundus was used to clarify whether gastroduodenal pressure differences caused by fundal tonic contractions ("pressure pump") or high antral pressure waves ("peristaltic pump") is the primary force for gastric emptying of liquid. We are presenting the physiological results provided by the placebo group through MRI and HRM.

Methods: Nine healthy subjects underwent a randomized single-blind, placebo controlled study with clonidine (2) (α_2-adrenergic receptor agonist, fundal relaxant that does not affect gastric emptying) and sumatriptan (3,4) (5-HT1-receptor agonist, fundal relaxant that delays gastric emptying). Each volunteer was studied on three separate occasions with randomized drug regimens. Each day a multi-lumen nasogastric tube assembly (Dentsleeve Pty Ltd, Parkside, Australia) was placed across the pylorus and then the subject lied in right decubitus position in the MRI system (1.5T Intera, Philips Medical Systems, Best, The Netherlands). On each study day, participants received either: a) clonidine i.v. and placebo s.c.; b) sumatriptan s.c. or placebo i.v. or c) placebo i.v and s.c. After drug administration, 500 ml 10 % glucose (200 kcal) marked with 500 μM Gd-DOTA (DOTAREM®) was ingested. During concurrent and simultaneous HRM measurements, MRI "volume scans" of the complete gastric region were performed every 5 min after the meal ingestion until 90 min. A steady state free precession (SSFP) sequence with 40 sagittal slices, TR/TE = 4.6/2.3 ms, FOV = 350x205 mm^2, Δz = 10 mm, matrix = 256x164, Tscan = 15 s was used. Each volume scan was followed by a 155s long dynamic scan sequence ("motility scan") using parallel imaging method SENSE to increase image acquisition rate. Three parallel oblique image slices (120 dynamic images each) positioned along the distal gastric antrum were acquired during free breathing using a SSFP sequence (TR/TE = 4.0/1.8 ms, FOV = 350x205 mm^2, Δz = 8 mm, matrix = 256x164, SENSE factor = 1.6). Five rectangular parallel imaging surface coils (h = 20 cm, w = 10 cm) were placed around the abdomen for signal detection. Gastric emptying rates and accommodation were derived from MRI "volume scans" by segmenting stomach and meal volumes. Average peristaltic frequency (f), velocity (v), occlusion amplitude (α) and width (w) of antral contraction waves (ACWs) were derived from detailed analysis of MRI motility scans. F and v were calculated using a manually defined distal gastric axis (Fig. 1). The position of the pylorus was indicated in the images to relate the characteristics of each ACW to the distance from the pylorus (Fig. 2). The propagation of each ACW as detected on MRI was incorporated into the manometry data to assess relationship of ACWs to changes of intragastric pressure and pyloric resistance (Fig. 3). Correlations between the above gastric parameters and gastric emptying rates were assessed to investigate their contribution to the gastric emptying process.

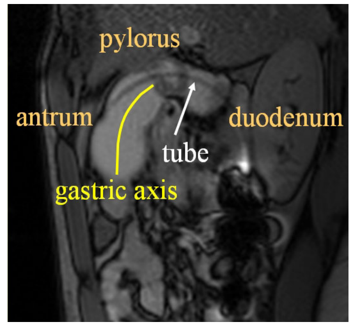

Fig. 1: Sagittal MRI image of the antro-duodenal region. Manometry tube and pylorus are clearly visible. Defined gastric axis is indicated.

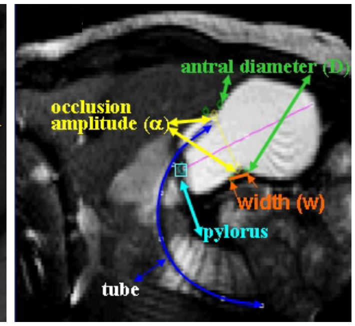

Fig. 2: Enlarged antroduodenal region of a sagittal MRI image. The detection of pylorus and occlusion amplitude and width is depicted.

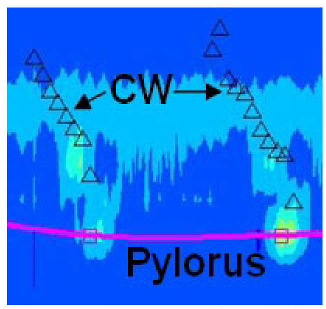

Fig. 3: Manometry recodings (color coded) and ACWs as detected in MRI (balck triangles). Pyloric pressure data are indicated.

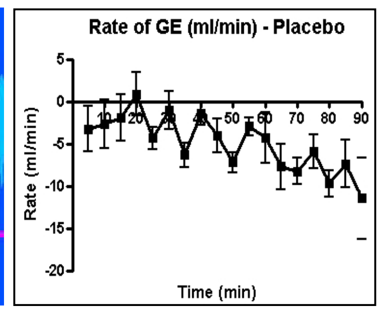

Fig. 4: Rate of gastric emptying over 90 min. Data is given as mean ± SE. The large inter-individual variation led to the variations in the curve.

Results: Stomach and meal volume as well as antral peristaltic activity were detected over the complete study period in all volunteers. Gastric emptying rates showed large variation between individuals and also during the emptying process (Fig. 4). All detected ACWs were non lumen occlusive. 80 % of all contractile events were propagating ACWs of constant speed, which terminated within 1.2 ± 0.6 cm of the pylorus. During first 20 min, f = 1.9/min and v = 2.4 mm/s and thereafter f = 2.6/min and v = 2.9 mm/s. α decreased as ACWs propagated towards the pylorus (Fig. 5). W also decreased as the ACWs approached the pylorus (Fig. 5). No correlation was found between peristaltic frequency, velocity, or occlusion amplitude of ACW and the gastric emptying rate. Greater w was associated with increased gastric emptying rates. Manometry could only detect 31 % of all propagating ACWs detected with MRI. However, pyloric contractile activity could clearly be determined from manometry recordings.

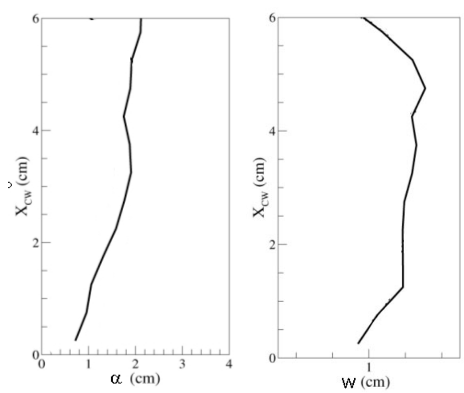

Fig. 5: Average magnitude of occlusion amplitude (α) and width (w) contraction wave plotted over its distance X_{CW} from the pylorus (X_{CW} = 0).

Discussion: This study demonstrates that MRI allows the comprehensive assessment of human gastric motor function. Physiological findings demonstrate that gastric peristalsis does not regulate the rate of gastric emptying of a caloric liquid meal under normal physiological conditions. The use of the SSFP sequence together with multiple abdominal surface coils and parallel imaging technique SENSE, dynamic high-resolution image data sets with excellent quality were acquired, allowing detailed analysis of the characteristics of antral contractility. With the dynamic measurement of three slices at a rate of 2.3 per second the continuous detection of the antral region and the pylorus was assured during free breathing motility scans. Image analysis of motility data was very time consuming, as sophisticated and robust segmentation and feature detection methods for this kind of MRI data are not yet available. A major limitation of MRI for the investigation of gastric function is its inability to quantify the force of intragastric and pyloric pressure events. These are important for understanding physiology of gastric emptying and currently are only obtainable with intraluminal manometry. Hence, concurrent manometry recording, as performed here, complement functional information based on detailed anatomy visible with MRI. Analysis of image and pressure data under influence of fundal relaxants will provide further insight into the interplay between gastric fundus, antrum and pylorus during the emptying process.

References: (1) Indireshkumar K et al, *Am J Physiol Gastrointest Liver Physiol* 278: G604-616, 2000; (2) Thumshirn M. et al, *Gastroenterology* 1999;116; (3) Tack J et al, *Gastroenterology* 1994; 108:A696; (4) Coulie B et al. *Am J Physiol* 1997; 272:G902-908.

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