Effect of intragastric barostat bag on proximal and distal gastric accommodation in response to liquid meal

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Mundt, M. W., T. Hausken, and M. Samsom. Effect of intragastric barostat bag on proximal and distal gastric accommodation in response to liquid meal. Am J Physiol Gastrointest Liver Physiol 283: G681–G686, 2002. First published May 10, 2002; 10.1152/ajpgi.00499.2001.—The barostat is the gold standard for measurement of proximal gastric accommodation. Ultrasonography can be used to measure gastric volume. The aim was to investigate the effects of the barostat bag on gastric accommodation and transpyloric flow. Accommodation after a liquid meal (300 ml, 450 kcal) was measured twice at random in eight healthy volunteers. Proximal accommodation was measured once using barostat and once using ultrasound (US). Antrum accommodation was measured using US. Bag volume (BV), antral area (AA), proximal gastric area, and proximal gastric diameter (PGD) data were assessed before and 1, 5, 15, 30, 40, 50, and 60 min postprandially. Transpyloric flow was measured using Doppler 1–5 min postprandially. Fasted, AA size was not affected by the barostat bag (1 mmHg > minimal distension pressure; 2.7 ± 0.5 vs. 2.6 ± 0.3 cm²). Postprandially, AAs were larger with the bag present (ANOVA, P < 0.04). Maximum AA was reached with the bag in 5 min, without the bag in 1 min postprandially (15.1 ± 2.3 vs. 9.4 ± 1.5 cm²; P < 0.03). Furthermore, AAs were related to BVs (r = 0.57; P < 0.01). After bag deflation, AA decreased (11.9 ± 1.8 to 7.0 ± 0.9 cm²; P = 0.02) and was comparable with the 60-min AA size without the bag (7.1 ± 1.2 cm²; P = 0.76) present. Proximal gastric radius calculated from the BVs and PGDs was larger with the bag present (ANOVA, P < 0.001). No effect on early gastric emptying was observed. Postprandially, the barostat bag causes dilatation of the antrum due to meal displacement without influencing early gastric emptying. This antral dilatation is likely to induce exaggerated proximal gastric relaxation observed in studies using the barostat to evaluate fundic accommodation.

THE ACCOMMODATION RESPONSE to meal ingestion is a reflex, which facilitates the ingestion of solids or liquids without inducing dyspeptic symptoms.

Recent studies have shown that impaired accommodation of the stomach, especially reduced fundus relaxation, is one of the pathophysiological mechanisms in functional dyspepsia (19, 21, 24), postfundoplication dyspepsia (28), rumination syndrome (23), postvagotomy/gastric surgery (2), and diabetes mellitus (20, 25). The reduced fundus accommodation response in these conditions appears to contribute to dyspeptic symptoms, especially early satiety and weight loss (21).

At present, the gold standard for the measurement of accommodation involves placement of a polyethylene bag into the stomach and linking it to a barostat device (2) to measure intragastric volumes at a low constant “operating” pressure in fasting and postprandial periods. The presence of a bag in the proximal stomach has been shown to affect the rate of gastric emptying (18). The intragastric bag may also influence the accommodation response after meal ingestion by displacement of the ingested meal. To date, this has not been investigated. Recently, several studies reported the use of a noninvasive technique, such as magnetic resonance imaging (16), single-photon-emission computed tomography (13, 14), and ultrasonography to measure gastric volumes (6–8, 26). Volume measurements performed with ultrasonographic techniques produce accurate estimations of actual volumes of both solid organs and hollow organs such as the stomach (12, 22). With the use of this technique, the gastric fundus relaxation was shown to be impaired, although less in magnitude, in a subset of patients with diabetes mellitus and functional dyspepsia (8, 25, 27). The aim of the present study was to investigate the effects of an intragastric bag on the accommodation response of the gastric fundus and antrum and on early gastric emptying in healthy human.

MATERIALS AND METHODS

Subjects

Eight healthy volunteers (3 males and 5 females; mean age 23; age range 18–25 yr; mean weight 68 kg) without any gastrointestinal symptoms or previous gastrointestinal surgery or disease were included in the study after giving writ-
ten informed consent. The protocol was approved by the ethics committee of the University Medical Center Utrecht.

**Test Meal**

The meal used was a 300-ml liquid nutridrink (1.5 kcal/ml; Nutridrink, Nutricia, Zoetermeer, Holland) that contained 10.0 g protein, 13.0 g fat, and 29.0 g carbohydrate.

**Experimental Design**

All subjects were studied twice on 2 separate days in random order. On 1 study day, proximal gastric accommodation was studied using the barostat bag and distal gastric accommodation using ultrasound (US). On the other study day, accommodation of the proximal and distal stomach was studied using US only. Studies were performed at 9:00 AM after an overnight fasting. The subjects were placed in a sitting position leaning slightly backward (at a 120° angle).

**Measurement of Gastric Accommodation**

With barostat bag present in stomach. A polyethylene bag with a maximum capacity of 1,000 ml attached to a double lumen tube (Ventrol, 6 mm × 120 cm) was introduced into the proximal stomach transorally. After the bag was introduced, it was unfolded by manual inflation of 200 ml air and, thereafter, completely deflated. The tube was then connected to the barostat device. After a 15-min resting period, minimal distension pressure (MDP) was determined by increasing the pressure of the barostat in 1-mmHg increments. MDP was defined as the lowest pressure level that provided a mean intrabag volume of 30 ml (2, 18). Then, pressure was increased 1 mmHg above MDP for the remainder of the study.

A 15-min equilibration period was followed by a baseline recording of 15 min and ingestion of the liquid meal within 2 min. Barostat bag volumes were monitored at MDP + 1 mmHg for another 60 min. All volume and pressure recordings were stored in the personal computer. After 60 min, the bag was deflated and removed. During the barostat procedure, antral area (AA) was measured before the bag introduction, before the meal, and at 1, 5, 15, 30, 40, 50, and 60 min after the meal. For this, a standard duplex US scanner (Esaote AUS, Pie Medical, Maastricht, The Netherlands) with a 5-MHz probe was used. The AA was measured in a standardized sagittal section in which the antrum, the superior mesenteric vein, the liver, and the aorta were visualized simultaneously (27). The outer profile of the muscularis propria was outlined, and the area was calculated automatically using the built-in caliper and calculation program of the US scanner. Data were expressed in square centimeters. All US measurements were carried out by one investigator, and each US measurement at each time point was performed twice. The mean of the two measurements was used for further analysis.

Without barostat bag in the stomach. The proximal stomach relaxation was assessed by US using two ultrasonographic sections, the proximal gastric area (PGA) and the proximal gastric diameter (PGD). PGA and PGD data were acquired at 1, 5, 10, 15, 30, 40, 50, and 60 min postprandially. The PGA was measured in a sagittal plane, with the left renal pelvis in a longitudinal projection and the left liver lobe and the pancreas tail as landmarks (7, 8). The PGA was outlined by tracing from the top margin of the fundus and 7 cm downward along the axis of the stomach (27) and automatically calculated by the scanner and expressed in square centimeters. (7) Then, the transducer was rotated 90° clockwise to obtain an oblique frontal section, where the left hemidiaphragm, the top margin of the fundus, and the liver parenchyma served as landmarks. In this view, the PGD was calculated (kept within 7 cm along the axis of the proximal stomach) (7, 27). AA was measured at the same time points as used in the study with the barostat bag present in the stomach.

**Transpyloric Flow**

In both studies, transpyloric flow was measured using Doppler 1 to 5 min after finishing the meal. The first minute after the meal was used for the ultrasonographic AA, PGA, and PGD measurements. Transpyloric flow was studied with the US probe positioned at the level of the transpyloric plane, with the antrum, the pylorus, and the proximal duodenum visualized simultaneously (10, 11). The sample volume of the pulsed Doppler was positioned across the pylorus, and the angle between the Doppler beam and the transpyloric direction of flow was almost <60°. The following variables were measured: 1) time to first gastric emptying: the first occurrence of gastric emptying (GE) after the start of drinking the liquid nutrient. An episode of GE is defined as flow across the pylorus with a mean velocity of >10 cm/s lasting >1 s (20, 21). 2) Number of GE episodes: the total number of GE occurring in the 5-min period. 3) Duration: total duration of one GE episode.

**Data Analysis**

Data are presented as mean values ± SE. Accommodation variables were compared using a parametric paired test. A multivariate ANOVA method was used to evaluate the effect of the repeated measurements over time, the effect of the barostat bag, and the interaction between them. Correlation coefficient was calculated using the bivariate correlation method to express relationship. Significance was accepted at the 5% level. For comparison of both types of proximal accommodation data (bag volumes (ml) and PGD (mm)), a calculation of fundal radius was performed. Radius data of bag volumes were calculated using the formula V = 4/3πr³, whereas r = 0.5d was used for radius calculation of the PGD assessed by US. All statistical analysis was performed with SPSS 8.0 for Microsoft Windows.

**RESULTS**

Both procedures were well tolerated by the healthy volunteers, and all eight volunteers completed both studies.

**AA**

Figure 1 shows a typical example of the maximum AA in a volunteer with and without the barostat bag in the proximal stomach. In the fasting state, the AA was not affected by the presence of an intragastric bag at a pressure of MDP + 1 mmHg (US + barostat bag: 2.7 ± 0.5 vs. US − barostat bag: 2.6 ± 0.3 cm²; P = 0.68). In contrast, after ingestion of the meal, the presence of the barostat bag increased the AA significantly (ANOVA, P < 0.04; Fig. 2). This increase was observed immediately after meal ingestion (5 min postprandial) and lasted throughout the entire study period. Maximum AA with the barostat bag present (15.1 ± 2.3 cm²) was reached 5 min postprandially, whereas maximum AA without the barostat (9.4 ± 1.5 cm²) was reached 1 min after finishing the meal. After 60 min, the bag was...
deflated, which resulted in a significant decrease in AA from 11.9 ± 1.8 to 7.0 ± 0.9 cm² ($P = 0.02$). This was comparable with the AA size at 60 min in the study without the intragastric bag present in the proximal stomach (7.1 ± 1.2 cm²; $P = 0.76$).

**Proximal Gastric Accommodation**

Proximal gastric relaxation was observed in all subjects by the barostat. The mean MDP was 6.8 ± 0.5 mmHg. The mean maximum volume of the bag was 637.8 ± 67.7 ml and was observed 30 min after meal ingestion (Fig. 3A). The ultrasonographically acquired PGA and PGD increased in size after ingestion of the liquid nutrient, indicating a relaxation of the proximal stomach. This relaxation remained constant over the 60-min period (Fig. 3B). Comparing proximal accommodation with and without the barostat bag present by calculating mean radius from both studies resulted in a significantly larger radius in the study with the barostat bag in the gastric fundus (ANOVA, $P < 0.001$; Fig. 4). This more than twofold size difference was observed throughout the entire study period. A significant correlation could be observed between AA and barostat bag volume ($r = 0.57; P < 0.01$); however, a very weak but significant negative correlation could be observed between AA and PGD ($r = -0.28; P = 0.04$).

**Transpyloric Flow**

Doppler tracings from 1–5 min after the meal were analyzed on the three parameters mentioned above. No differences were observed within a subject, and also no difference could be observed between the two studies (with and without barostat bag) in time to first gastric emptying (68.3 ± 22 vs. 141.4 ± 62 s; $P = 0.25$), number of gastric emptying episodes (3.75 ± 0.8 vs. 3.69 ± 0.9; $P = 0.92$), and duration (4.8 ± 0.6 vs. 4.6 ± 0.3 s; $P = 0.77$) during the first 5 min after the meal.

**DISCUSSION**

In the present study, we showed that the gastric antrum and proximal stomach are larger in size after ingestion of a liquid meal when a barostat bag is present in the gastric fundus, whereas no effect of the barostat bag on AA was observed in fasting state. In contrast, to the effect of the intragastric bag on antral size in the postprandial state, no effect was observed on early GE.

In this study, as in others, a pressure of 1 mmHg above MDP in the intragastric bag induced a relaxation of the proximal stomach to accommodate a volume of ~140 ml in the intragastric bag. At this MDP + 1 mmHg pressure level, the intragastric bag had no...
Fig. 3. Proximal gastric relaxation: A: intragastric bag volume change measured by the barostat. B: ultrasonographic-measured proximal gastric diameter (*) and proximal gastric area (○).

Fig. 4. Results of radius calculations. The filled bars show the radius of the proximal stomach calculated from the proximal gastric diameter, whereas the open bars show the radius derived from barostat bag volumes.
effect on antral size. In contrast, after ingestion of the liquid nutrient AA was found to be almost doubled compared with the situation without the bag present in the gastric fundus.

In contrast to the observations by Ropert et al. (18), the intragastric barostat bag did not affect early GE, suggesting that the increased AA is attributable to gastric, as opposed to duodenal mechanisms. Indeed it is conceivable that the pressure exerted by the barostat bag on the proximal stomach induced redistribution of the meal, thereby distending the gastric antrum.

Supporting this explanation is the observation that AA declined after the barostat bag was deflated.

Typically, placement of a barostat bag in the stomach results in an overrelaxation of the proximal stomach. In our study, ingestion of 300 ml liquid nutrient resulted in a maximal relaxation of the proximal stomach of ~640 ml. Relaxation of the proximal stomach can be the result of activation of mechanoreceptors in both the fundal (19) as well as the antral (4) regions of the stomach. Activation of these receptors has been shown to induce local or vagally mediated reflex pathways resulting in adaptive relaxation of the stomach (1, 29). In addition, relaxation of the proximal stomach may result from activation of mechanono- and chemoreceptors at the level of the duodenum (3). Chemoreceptors are activated by a variety of substances such as acid, fat, and glucose (5, 15). In contrast to our observations, Ropert et al. (18) reported faster GE in barostat studies, which favors activation of duodenogastric pathways as a possible explanation for the increased relaxatory response in barostat studies. However, our results show that transpyloric flow was not affected by the barostat bag in the early GE period, which suggests that this mechanism is less important in the initial phase of the stomach relaxation observed during barostat studies. Ongoing activation of fundal mechanoreceptors as an explanation for the observed relaxation is also unlikely, because the volume in the barostat bag was constant at a pressure level of 1 mmHg above MDP in the fasting state, which was similar to the pressure level of the postprandial period. In our opinion, the most likely explanation for the overrelaxation of the proximal stomach is displacement of the meal toward the distal stomach causing antral size to double, thereby activating antral mechano-receptors.

Intragastric air can potentially limit visualization of gastric outline by US. However, our studies, using the technique described by Gilja et al. (6–8), in a seated position were not limited by air-fluid interfaces. These findings are in concordance with the results presented by Gilja et al. and encourage the use of two- and three-dimensional ultrasonography in studies of the stomach. Future studies using these techniques might clear up some questions relating functional gastric disorders.

Several studies reported a larger AA in a subgroup of patients with functional dyspepsia (9, 17). Those findings, together with our observations, suggest that the gastric antrum plays an important role in both symptom generation and impaired relaxation of the proximal stomach in patients with functional dyspepsia. In conclusion, the intragastric barostat bag effects the normal accommodation response. These findings suggest that the results from studies investigating proximal gastric accommodation using the barostat technique may need to be reevaluated.

Dr. M. Samsom is a fellow of the Royal Netherlands Academy of Arts and Sciences.

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