Sonographic evaluation of proximal gastric accommodation in patients with functional dyspepsia

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Supported by A Grant from the Scientific Research Foundation for the Returned Overseas Chinese Scholars, State Education Ministry of China, No. [2008] 101

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Received: May 1, 2013 Revised: July 3, 2013
Accepted: July 17, 2013
Published online: August 7, 2013

Abstract

AIM: To assess the value of ultrasonography (US) in evaluation of proximal gastric accommodation disorder in patients with functional dyspepsia (FD).

METHODS: Between April 2011 and March 2012, 45 patients with FD and 27 healthy volunteers were enrolled in this study. Two-dimensional ultrasound (2DUS) and 3-dimensional ultrasound (3DUS) were performed sequentially to measure proximal gastric area (PGA), maximal proximal gastric diameter (MPGD), and proximal gastric volume (PGV). These values were measured separately in the two groups every other 5 min for a duration of 25 min after the beginning of ingestion of a test meal. Air pocket grading was done separately for images of 2DUS and blocks of 3DUS obtained at five scanning time points.

RESULTS: Both PGA and PGV of patients were significantly smaller than healthy controls (P = 0.000 and 0.002, respectively). Comparing the two parameters between the groups at each time point, the differences were also statistically significant (P = 0.000-0.013), except at 10 min for the PGV (P = 0.077). However, no overall difference was found between the groups in the MPGD measurements (P = 0.114), though it was statistically significant at a 20-minute examination point (P = 0.026). A total of 360 sets or blocks of images were obtained for both 2DUS and 3DUS. For the images analyzed by 2DUS, none were excluded because of gastric gas, and 50 (13.9%) and 310 (86.1%) sets were determined as air pockets grades 1 and 2, respectively. For the images analyzed by 3DUS, 23 (6.4%) blocks were excluded from the measurement due to presence of a large fundus air pocket (grade 3); fifty (13.9%) and 287 (79.7%) blocks were also graded as 1 and 2, respectively.

CONCLUSION: Measurement of both PGA and PGV by 2DUS and 3DUS could be useful for assessment of the proximal gastric accommodation.

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Key words: Functional dyspepsia; Gastric accommodation; Ultrasonography; Diagnosis; 2-dimensional ultrasound; 3-dimensional ultrasound

Core tip: We adopted 2-dimensional and 3-dimensional ultrasonography to measure area and volume of the proximal stomach in patients with functional dyspepsia; a condition whereby patients can experience impaired gastric accommodation. Area and volume could be used to assess accommodation impairment, because both area and volume of the patients were smaller than the controls (P < 0.05). Therefore, the ultrasound measurement of gastric area and volume could help predict the functional dyspepsia.

Fan XP, Wang L, Zhu Q, Ma T, Xia CX, Zhou YJ. Sonographic evaluation of proximal gastric accommodation in patients with functional dyspepsia.
INTRODUCTION

Functional dyspepsia (FD) is the presence of symptoms thought to originate from the gastro-duodenal region, in the absence of organic, systemic, or metabolic disease that is likely to explain the symptoms\(^1\). The prevalence of FD is 24.4% in Australia and 23.5% in China, based on the Rome II criteria\(^2\). The pathogenesis of FD is still unknown, but several studies have indicated that the proximal stomach, which includes the fundus and the proximal one-third of the body, is the site of an accommodation disorder that is likely to substantially contribute to the pathogenesis of FD\(^3\). Cannon et al\(^4\) first described gastric accommodation in 1911. It is thought to be a vagally mediated reflex that occurs postprandially and results in reduction of tone, providing a reservoir for the meal\(^5\). In patients with impaired gastric accommodation, the proximal stomach cannot relax and change its volume to the content following meal ingestion, and the subsequent increase of intragastric pressure contributes to postprandial discomfort\(^6\). The impairment of proximal gastric accommodation has been found in 40% of patients with FD\(^7\). Hence, it is likely that FD can be diagnosed through the recognition of impaired gastric accommodation.

There are two methods to measure proximal gastric accommodation. One method is the intragastric barostat technique, in which a polyethylene bag is directly placed into the proximal stomach via oral intubation. The intragastric barostat bag technique is regarded as the gold standard because it allows simultaneous acquisition of volume, pressure, and tone, and makes the user correlate these variables to sensory parameters\(^8\). The disadvantages of the method are its interventional and time-consuming nature, leading to discomfort of patients\(^9\), and a likely interference with gastric physiology due to pressure caused by the bag\(^10\). The second method is imaging, such as magnetic resonance (MR) imaging, single photon emission computed tomography (SPECT), and ultrasonography (US). MR imaging and SPECT can estimate volumetric change of the stomach directly and accurately\(^11\), but the equipment is not widely available and is costly, and the natural state of the stomach impacted by gravity is also neglected owing to the flat position of the examination. In addition, there is a problem of SPECT-associated radiation exposure\(^12\).

US is widely available, inexpensive, non-radioactive, and can be performed repeatedly, even at the bedside, making it a much more attractive option for the measurement of proximal gastric accommodation. Moreover, because gravity plays a role in the propulsion of gastric contents, accommodation should be measured in a sitting or standing position that can be easily accomplished during the US examination\(^13\). However, published studies reviewing the feasibility of this method are limited, presumably due to the complex procedure of scanning the stomach with US. Therefore, the aim of the current study was to investigate the usefulness of US, including 2-dimensional US imaging (2DUS) and 3-dimensional US imaging (3DUS), in the measurement of proximal gastric accommodation disorders in patients with FD compared to healthy controls.

MATERIALS AND METHODS

Subject characteristics

Between April 2011 and March 2012, 46 consecutive patients with FD underwent US scanning. One patient was excluded from the study because of nephroptosis, which obscured the left kidney as a landmark in obtaining a sagittal plane of the proximal stomach. Thus, 45 enrolled patients consisted of 17 men and 28 women, with an age range of 19-64 years (mean: 33.70 ± 9.86 years) and a body mass index (BMI) of 16.33-25.95 kg/m\(^2\) (mean: 20.67 ± 2.34 kg/m\(^2\)). None of the patients had a history of other abdominal diseases, abnormal hepatic function tests, organic changes on gastroendoscopy, and positive findings on routine abdominal US scanning.

The Rome III classification system was the basis for the diagnostic criteria for inclusion of patients with FD\(^3\). According to these criteria, the patient must have one or more of the following symptoms: bothersome postprandial fullness, early satiation, epigastric pain, or epigastric burning. Further, the patient could have no evidence of structural gastrointestinal diseases on upper endoscopy likely to explain the symptoms, and the symptoms must have occurred 6 mo prior to diagnosis and be active for the last 3 mo. Of the 45 patients, 33 (73.3%), 20 (44.4%), 19 (42.2%), and 14 (31.1%) presented with postprandial fullness, epigastric pain, early satiation, and epigastric burning, respectively.

Twenty-seven healthy volunteers were examined by US. This sample included 14 men and 13 women with an age range of 19-75 years (mean: 38.07 ± 14.55 years) and a BMI of 18.02-24.21 kg/m\(^2\) (mean: 21.10 ± 1.74 kg/m\(^2\)). Healthy controls had no symptoms and physical signs of gastrointestinal diseases in the past six months, history of other abdominal diseases, abnormal hepatic function tests, and positive findings on routine abdominal US examination.

There were no statistically significant differences between the patients with FD and control groups with respect to age and BMI. Informed consent was obtained from all of the subjects.

Test meal

A 500 mL esculent liquid was used as the test meal, and was prepared by mixing 200 mL of nutrient emulsion (Enteral Nutritional Emulsion; Sino-Swed Pharmaceutical
Corp, Beijing, China) with 300 mL of warm water. The emulsion contained 15 g of protein, 11.6 g of fat, and 34 g of carbohydrate (300 kcal). To decrease the presence of small bubbles in the nutridrink, the meal was allowed to sit stationary on a table for approximately 10 min before consumption.

**US equipment**
A Voluson 730 expert system with a RAB 2-5 type probe with 3DUS imaging function was employed (GE Medical Systems, Milwaukee, WI, United States).

**Examination protocol**
To avoid inrescent gas within the stomach, the examination was performed before 10:00 am after an overnight fasting of > 8 h. Administration of medication affecting gastrointestinal motility was discontinued for at least 48 h prior to US. Smoking was not allowed on the day of examination. All the patients were examined within 7 d following gastric endoscopy.

The subjects were scanned in a half-sitting position, leaning back at an angle of approximately 80° on an examining couch. The antrum was observed 2-3 min before nutridrink ingestion to avoid antral contractions and emptying into duodenum, in which the elevation of proximal stomach tone is induced by an enterogastric reflex occurring in phase III of the migrating motor complex. Thereafter, in the other phases without the contraction, a 500 mL meal was ingested with a straw within 4 min. The proximal stomach of each subject was scanned every other 5 min during 25 min after beginning ingestion.

**Air pocket grading**
To assess image quality, a grading system based on the amount of air pockets in the proximal stomach was established as follows: grade 1 (absence of visible air within the stomach); grade 2 (some air within the stomach, but the following measurements still being able to be proceeded); and grade 3 (a great amount of gastric air so that the image would be excluded from the measurement). Grading was done separately using 2DUS and 3DUS using five examinations for each subject.

**US scanning and measurement**
Subjects were instructed not to move and to hold their breath at the end of expiration to permit diaphragmatic rising and restoration of the gastric configuration.

For 2DUS imaging, a scanning probe was placed longitudinally under the left subcostal margin and tilted cranially in the long axial direction to show the top of the gastric fundus. In this way, a sagittal section of the proximal stomach was visualized, in which the left renal sinus, the left lobe of the liver, and the tail of the pancreas served as anatomic landmarks (Figure 1). Then, the probe was rotated 90° and tilted cranially in the short axial direction to obtain a maximal transverse section of the proximal stomach, in which the left diaphragm and the left liver were landmarks (Figure 2). Image post-processing was done using image-processing software (4D View, version 5.0; GE Medical Systems). On the sagittal section, the proximal gastric area (PGA) was outlined by tracing along the luminal echogenic surface corresponding to the interface between the liquid and mucosa of the gastric wall, from the top margin of the fundus to 7 cm level inferiorly (Figure 1). On the transverse section, a maximal proximal gastric diameter (MPGD) was measured between the inner echogenic surfaces of the lesser and greater curvatures (Figure 2).

For 3DUS analysis, volumetric image data was acquired immediately following 2DUS using similar placement of the probe to that of the above sagittal section. A sweeping angle of 85° was set. The proximal stomach was scanned via automated sweeping between the curvatures over 5-10 s. The block cut at a distance of 7 cm inferior to the top of the fundus was saved for further processing on the workstation. Using a virtual organ computer-aided analysis (VOCAL) technique of the 4D View, six sections of one block were separately outlined manually along the echoic inner surface of the fundus to 7 cm level inferiorly (between cursors). Grading was done separately using 2DUS and 3DUS using five examinations for each subject.

**Figure 1  Sagittal section of the proximal stomach.** A: To obtain the section, a probe is placed longitudinally under the left subcostal margin and tilted cranially in the long axial direction of proximal stomach (PS) to show the top of gastric fundus, in which left renal sinus (LRS), left liver (LL), and pancreatic tail (PT) are simultaneously displayed; B: Proximal gastric area (PGA) is measured by means of outlining along the echogenic mucosa surface of PS in the distance between the echoic inner surface of the fundus top down to 7 cm level (between cursors).
respectively). When the two parameters were compared at each time point separately, the differences were also statistically significant between the two groups ($P = 0.000-0.013$), except at 10 min of the PGV.

The patients with FD revealed shorter MPGD than healthy controls postprandially; however, it was not statistically significant in the two groups, and the difference was significant ($P = 0.026$) only at 20 min when comparing each time point (Table 1).

**DISCUSSION**

Based on the theory that the impairment of proximal gastric accommodation is likely to lead to the pathogenesis of FD, both 2DUS and 3DUS imaging were utilized to measure the size of the proximal stomach. The data indicated that both PGA and PGV could help assess the proximal gastric accommodation.

US can provide an indirect evaluation of stomach relaxation and intragastric pressure by measuring the size of the stomach [17]. The 2DUS method of assessing gastric accommodation was developed first by Gilja et al [18]. According to their study, 2DUS could offer a geometric estimation of proximal gastric size by measuring PGA and MPGD. They also found that the patients with FD exhibited a smaller PGA and MPGD than controls ($P = 0.018$ and $0.046$, respectively) [19]. Having adopted a similar method, our study showed that the PGA was significantly different between FD patients and healthy controls, but the MPGD was not different overall, being significant only at 20 min ($P = 0.026$) only at 20 min when comparing each time point (Table 1).

**RESULTS**

**Air pocket grading**

Three-hundred-and-sixty sets of 2DUS images (one sagittal and one transverse section), and the same number of 3DUS blocks, were graded. Of these, 225 were obtained from patients and 135 from controls in five time examinations. The 2DUS imaging revealed 50 (13.9%) and 310 (86.1%) sets of the image were determined as grades 1 and 2, respectively, and none were excluded due to grade 3. In 3DUS, 50 (13.9%) and 287 (79.7%) blocks were graded as 1 and 2, and the other 23 (6.4%) were grade 3 and in turn excluded from the measurement. Of these excluded blocks, 13 (56.5%) appeared at 10 min, and the remaining four (17.4%), three (13.0%), one (4.3%) and two (8.7%) occurred at 5, 15, 20 and 25 min after the meal, respectively.

**PGA, MPGD and PGV measurements**

The PGA and PGV of patients were significantly smaller than those of healthy controls ($P = 0.000$ and $0.002$, respectively). When the two parameters were compared at each time point separately, the differences were also statistically significant between the two groups ($P = 0.000-0.013$), except at 10 min of the PGV.

The patients with FD revealed shorter MPGD than healthy controls postprandially; however, it was not statistically significant in the two groups, and the difference was significant ($P = 0.026$) only at 20 min when comparing each time point (Table 1).
Table 1  Ultrasonography measurement of postprandial size of proximal stomach (mean ± SD)

| Time in min | Patients (n = 45) | Controls (n = 27) | t    | P     |
|-------------|------------------|------------------|------|-------|
| PGA in cm²  |                  |                  |      |       |
| 5           | 22.78 ± 6.59     | 30.68 ± 6.97     | 4.819| 0.000 |
| 10          | 25.13 ± 6.39     | 29.52 ± 7.46     | 3.853| 0.000 |
| 15          | 22.32 ± 5.93     | 27.51 ± 7.13     | 3.332| 0.001 |
| 20          | 21.34 ± 6.34     | 28.25 ± 7.76     | 4.110| 0.000 |
| 25          | 21.51 ± 6.02     | 26.35 ± 7.23     | 3.062| 0.003 |
| MPGD in cm  |                  |                  |      |       |
| 5           | 6.77 ± 1.34      | 7.08 ± 1.10      | 1.035| 0.304 |
| 10          | 6.92 ± 1.31      | 7.27 ± 1.00      | 1.185| 0.240 |
| 15          | 6.66 ± 1.43      | 7.11 ± 1.03      | 1.432| 0.157 |
| 20          | 6.33 ± 1.29      | 7.00 ± 1.06      | 2.275| 0.026 |
| 25          | 6.31 ± 1.50      | 6.66 ± 1.24      | 1.032| 0.305 |
| PGV in cm²  |                  |                  |      |       |
| 5           | 145.75 ± 60.40   | 185.08 ± 60.81   | 2.645| 0.010 |
| 10          | 152.91 ± 52.10   | 177.13 ± 59.10   | 1.797| 0.077 |
| 15          | 142.46 ± 49.50   | 184.16 ± 52.28   | 3.358| 0.001 |
| 20          | 132.45 ± 46.70   | 169.12 ± 48.64   | 3.147| 0.002 |
| 25          | 126.15 ± 50.23   | 157.46 ± 49.97   | 2.544| 0.013 |
| F = 17.499, P = 0.000 |            |                  |      |       |
| F = 2.562, P = 0.114 |            |                  |      |       |
| F = 10.319, P = 0.002 |            |                  |      |       |

PGA: Proximal gastric area; MPG: Maximal proximal gastric diameter; PGV: Proximal gastric volume.

The feasibility of assessing the proximal gastric accommodation with PGA on 2DUS images has been confirmed by several studies\cite{21-24}. The measuring of PGA was simple, with only one section being outlined in this process. It was less likely to be affected by gastric air, which was verified since no subject was excluded for this factor. However, it was difficult to find the landmarks in subjects with obese body types, nephroptosis, or renal ectopy. The volumetric estimation that was based on values of 2DUS, i.e., \( V = PGA \times MPG \), and adopted by other studies before the advent of 3DUS could to some extent bring an error because of the irregular-shaped stomach\cite{25}.

In general, 3DUS has advantages over 2DUS, which can measure a volume directly and needs no landmarks. Using this technique, Gilja et al\cite{25} obtained a good correlation (\( r = 0.997, P < 0.05 \)) between the estimated volume of porcine stomach filled with water \textit{in vitro} and the actual quantity of water injected. Another study demonstrated that 3DUS had a moderate correlation (\( r = 0.55, P = 0.002 \)) with the barostat in measurement of proximal gastric volumes\cite{26}. However, there were some drawbacks of the freehand 3DUS technique used in these studies\cite{21,24,25,26}.
limited sample size did not allow us to divide patients into two subgroups of postprandial distress syndrome and epigastric pain syndrome according to the Rome III criteria[8]. After fasting overnight, ingesting a 500 mL test meal in a short time would make subjects uncomfortable, and consequently the smaller amount of the meal should be tested. The observation duration of 25 min might not be enough to investigate into the gastric accommodation, which lasts in the entire process of postprandial digestion[39]. Because no reference method as the barostat procedure or SPECT was adopted in our study, the comparative study of 2DUS and 3DUS imaging could not be carried out to find out which one was more accurate.

In conclusion, we show that the impaired gastric accommodation to a test meal was present in patients with FD. Two parameters of PGA and PGV on 2DUS and 3DUS images could be used for assessing the proximal gastric accommodation in which 2DUS was simpler in manipulation and less likely to be degraded by gastric gas, and 3DUS had the merit of measuring volume directly, providing less gastric gas.

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