Real-Time Assessment of Gastroduodenal Motility by Ultrasonography

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Key Words

Functional dyspepsia, pathogenesis · Motility · Ultrasonography

Abstract

Functional dyspepsia (FD) is a clinical syndrome involving upper abdominal symptoms, the causes of which cannot be identified by conventional diagnostic evaluation. Many pathophysiological factors, such as gastric acid, gastroduodenal motility, gastric accommodation, sensory disturbance, stress and *Helicobacter pylori* infection, may play a role in the pathogenesis of FD. Dysmotility of the upper gastrointestinal tract has been implicated in the symptoms of FD. In previous studies, antral hypomotility and delayed gastric emptying have been reported as major pathogenetic factors in patients with FD. Although a number of methods have been applied to evaluate gastroduodenal motility in humans, many of them have technical limitations and are too expensive or complex to use in daily clinical practice. Recent technical developments enable one to evaluate gastroduodenal motility by using ultrasonography. Ultrasonography is a simple, noninvasive modality for the assessment of gastric emptying and antral motility in either a liquid or solid meal, along with the examination of duodenogastric reflux.

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Ultrasonography

Real-time ultrasonography does not require intubation and therefore does not interfere with the normal physiologic controls of upper alimentary motility. This technique was first used by Bateman et al. [1] and later Hausken et al. [2], who visualized antroduodenal motility and transpyloric flow simultaneously using pulsed Doppler ultrasonography. More recent studies indicate that accommodation of the proximal stomach can be evaluated by ultrasonography [3]. We have established the method to assess gastroduodenal motility by ultrasonography during the past 15 years [4–7].

Procedures

Liquid Provocation

Gastric emptying rate and antroduodenal motility can be evaluated with real-time ultrasonography. After an overnight fast, the subjects sit in a chair, leaning slightly backwards, and ingest 400 ml of meat soup within 2 min. An ultrasound probe is positioned vertically to permit simultaneous visualization of the antrum, the superior mesenteric artery and the abdominal aorta. At 1 and 16 min after drinking, the antral area is estimated by tracing the mucosal side of the antrum with the built-in caliper. The gastric emptying rate (percent) is expressed as follows: (antral area at 1 min – area at 15 min) × 100/antral area at 1 min. The frequency of antral contractions is defined per 3-min interval for the first 9 min after ingestion. The ampli-

Fig. 1. The upper panel indicates relaxed period at 1 min (left) and 15 min (right) after injection of a liquid meal by vertical ultrasound scan. The middle panel indicates the relaxed period (left) and contracted period (right). The lower panel indicates transpyloric ultrasound scan with simultaneous visualization of the antrum, the pylorus and the duodenal bulb. The blue signal shows normal flow from the antrum to the duodenal bulb and the red signal shows DGR.

tude of antral contractions (percent) is calculated from the maximal reduction of the antral area for each contraction: $(\text{area relaxed} - \text{area contracted}) \times 100 / \text{area relaxed}$. The motility index (MI) is expressed as the multiplication of the mean amplitude and frequency of contractions. To evaluate duodenogastric reflux (DGR) with color Doppler ultrasonography, the probe is positioned at the level of the transpyloric plane to visualize the antrum, the pylorus and the

duodenal bulb simultaneously for 5 min. The color gain, high-pass filter and angle between the ultrasound beam and the transpyloric flow are standardized in all measurements (fig. 1). The frequency of DGR is defined as the number of DGR detected during 5 min and the intensity of DGR as the distance (centimeters) of the color signal from the pylorus. The reflux index is expressed as the multiplication of the frequency and the mean intensity of DGR.

Fig. 2. Vertical ultrasound scan after injection of a solid meal. Relaxed period of the antrum (left) and the corpus (right).

Fig. 3. Gastroduodenal motility evaluated by ultrasonography using a liquid meal in patients with FD and healthy subjects. Gastric emptying rate and MI are significantly lower and DGR is significantly higher in patients with FD than in healthy subjects.

Solid Provocation

As a highly suitable test meal for sonographic observation, commercially prepared egg and chicken soup was mixed with cooking rice and 100 ml of water. The meal (total 380 g) contained 9.7 g of protein, 63.0 g of carbohydrate and 4.3 g of lipid, and the total energy value was 1,775 kJ. After an overnight fast, the subjects sat in a chair and ingested the test meal within 10 min. The gastric residual rate, which was based on ultrasonographic data, was calculated from the cross-sectional area of the antrum and corpus at 5, 15, 30, 45, 60, 90, 120, 180 and 240 min after ingestion (fig. 2). The residual ratio was calculated as follows: area at each time point of observation/area at 5 min $\times$ 100 (%). The antral cross-sectional area was determined with the same scan as that used for the liquid provocation study. The frequency and amplitude

of antral contractions were evaluated in the same fashion as in the liquid provocation test and were measured for 3 min at 5, 15, 30, 45, 60, 90, 120, 180 and 240 min after ingestion of the solid meal. The MI of an antral contraction was also defined by applying the same criteria as in the liquid provocation. The ultrasound instruments used included curved array scanners with 3.75- or 5-MHz transducer (SSA-260A, 270A; Toshiba, Japan).

Antroduodenal Motility Evaluated by Ultrasonographic Method in Patients with Functional Dyspepsia

Our previous study [6] indicates that the gastric emptying rate and MI after the liquid meal are significantly lower and DGR is significantly higher in functional dys-

pepsia (FD) patients than in healthy subjects (fig. 3). After the solid meal, the gastric emptying time, the half-emptying time and the MI are significantly lower in FD patients than in healthy subjects. In addition, at 15 min after ingestion of the solid meal, the MI is significantly lower in FD patients than in healthy subjects. In particular, hypomotility in the early postprandial phase seems to be specific to FD patients.

Advantages and Disadvantages of Ultrasonography

The advantages of ultrasonography include: safety, noninvasiveness, greater acceptability by the test subjects, reproducibility and relative simplicity to perform with appropriate equipment. The results obtained using color Doppler ultrasonography are generally good. Transpyloric reflux can be detected in over 95% of subjects.

Its main advantage is that it allows good quantification of DGR. It is important to evaluate its relevance, as DGR can be detected in approximately two thirds of healthy subjects [4, 6]. Using this method it has been shown that DGR is excessive in patients with FD. Another advantage of color Doppler ultrasonography is that it allows observation of the opening and closing of the pyloric ring, and the occurrence of antral contractions simultaneously with DGR and normal gastroduodenal flow. This enables comprehensive and complete assessment of antroduodenal motility in addition to DGR. Also it permits real-time observation of these events. In addition, several studies [8–10] indicate that ultrasonography is useful in evaluating the accommodation of the proxi-

mal stomach after meals and FD patients have impaired accommodation of the proximal stomach to a meal.

A disadvantage of the technique is that, at present, it can be used to measure DGR and gastroduodenal flow after a liquid meal; measurements during fasting and following a solid meal require further study. Some subjects cannot be evaluated because of image distortions produced by excessive amounts of subcutaneous fat or abdominal gas. Problems can also arise as a result of anatomic variations, which prevent satisfactory visualization of the pyloric channel and proximal duodenum in 1 plane.

Conclusions

Most earlier techniques used to measure gastroduodenal motility are invasive and/or cumbersome. The use of color Doppler ultrasonography represents a significant advance, as this noninvasive technique does not disturb the normal motility of the upper alimentary tract, including the investigation of DGR. Due to its improved accuracy, ease of application and the ability to simultaneously assess antroduodenal motility, the color Doppler technique will provide a means of achieving a greater understanding of the pathophysiology of motility disorders in diseases of the upper alimentary tract.

Disclosure Statement

The authors declare that no financial or other conflict of interest exists in relation to the content of the article.

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