Dynamic imaging of the stomach by real-time ultrasound—a method for the study of gastric motility

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SUMMARY The use of real-time ultrasonic imaging of the stomach for the study of gastric contractions in response to a liquid test meal is described. Gastric contractions in the pyloric antrum and distal body of the stomach were observed on closed circuit television, recorded on to cassette tape and also imaged on polaroid and ciné film. Gastric contractions were recorded from the pyloric antrum by longitudinal scanning in the lower epigastrium and reproducible motility tracings were obtained on a fiberoptic chart recorder. Intravenous metoclopramide enhanced the magnitude and frequency of antral movement, which was abolished by intravenous propantheline. Real-time ultrasonic imaging permits the non-invasive study of gastric contractions. It is safe, may be repeated as required, and provides a method for the study of the effect of drugs and disease states on gastric motility.

Most current techniques for the study of gastric motility require intubation of the stomach or exposure of the subject to ionising radiation.¹⁻³ Gastric intubation is often disliked by volunteers and patients and may itself induce anxiety or nausea which may be sufficient to disturb normal gastric motility. Contrast radiography or scintigraphic scanning techniques, used to determine gastric emptying rate, are unsuitable for repeated studies on the same individual because of radiation hazards and are best avoided in the premenopausal female.

To overcome these disadvantages of existing methods for the study of gastric motility, we have used real-time ultrasonic scanning⁴ to obtain dynamic images of the stomach. Abdominal ultrasound has hitherto been used mainly to study organs other than the stomach or intestines, principally because gas in the gastrointestinal lumen disrupts the ultrasonic beam. An abnormally thickened or food-filled stomach produces a recognisable echographic image.⁵⁻⁸ Gastric intercontraction times have been recorded using a B-scan plus time-motion (T-M) scan technique.⁹ Real-time ultrasonic imaging has a number of advantages resulting from visualisation of the motion of the selected section while the time-motion record is being produced.

In this study we describe the use of a real-time ultrasonic scanner for dynamic imaging of the stomach and the recording of gastric contractions after a liquid test meal.

Method

The stomach was visualised in 10 healthy male subjects using a real-time ultrasonic scanner of the rotating transducer type.^{10,11} In this scanner four transducers of 2.5 MHz are mounted on a wheel which rotates in an oil-filled plastic cylinder. The beam of ultrasound from each transducer is directed radially from the centre of the wheel. A 90° sector image is produced with four crystals in operation and a 180° sector image with two crystals. A hand-held version of the scanner was employed for searching the upper abdomen and short duration studies. For continuous observation or recording, a small tubular version was strapped to the abdomen (Fig. 1).

After an overnight fast each subject drank 500 ml of orange juice at 37°C. The fundus, body, and antrum of the stomach were located in the upper abdomen by systematically altering the plane of scan, starting with a transverse scan of the epigastrium (Fig. 2). Scanning was also performed in five subjects at intervals up to three hours after a variety of solid and liquid meals and on other occasions attempts were made to visualise the fasting stomach.

The antrum was visualised most frequently using a

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Fig. 1 Tubular version of the rotating transducer real-time scanner strapped to the abdomen for continuous recording.

Fig. 2 Transverse ultrasonic scan in the upper epigastrium.

longitudinal plane of scan in the lower epigastrium approximately 3 cm above the umbilicus. All scans were performed with the subject standing or seated upright. This position avoided strong reflection and scattering of the ultrasonic beam by stomach gas which collects in the fundus with the patient erect. Contrary to the problems of gas in the stomach and bowel which often render ultrasonic techniques ineffective, it was found that, with this technique, the stomach was easily imaged as a clear liquid-filled structure in all subjects.

After location of the area of interest in the distal stomach, the transducer was fixed in position on the abdominal wall using a belt. Real-time ultrasonic images were obtained by a closed circuit television system, in which the camera viewed the display screen of the scanner, and recorded on to a video cassette, allowing detailed study and reappraisal of the stomach movement. Permanent photographic records were obtained by direct photography of the television screen using a Polaroid or a ciné-film camera. To record gastric contractions on a chart, the pyloric antrum in the lower epigastrium was

visualised by scanning in a longitudinal plane and simultaneously a T-M mode trace was generated by electronically selecting echo signals which corresponded to one ultrasonic beam direction through the antrum. Movement of the gastric contents often interfered with the T-M trace. To overcome this problem and record total movement of the antrum, a fibreoptic chart recorder was used which is able to handle complex echo patterns without the need to gate out electronically signals from specific tissue boundaries.

Repeated studies were performed in three subjects to assess reproducibility of recordings and to observe the effect of pharmacological modification of gastric motility after the intravenous administration of metoclopramide (10 mg) and propantheline (30 mg).

Although the real-time scanning instruments described here were made by the authors, gastric motility has also been studied using a linear array real-time scanner which was manufactured by a commercial company. The contractions can be studied by virtually all real-time scanners, which are becoming readily available in hospitals.

Fig. 3 Ultrasonic scan across the body of stomach shows (a) stomach filled with fluid and some food particles, (b) multiple echoes from stream of gas bubbles in stomach during drinking.

Results

Transverse scanning in the midline, 4 cm below the xiphisternum allowed the visualisation of the proximal part of the body of stomach and liquid contents. Multiple echoes were apparent during drinking or belching due to bubbles of moving gas within the stomach and, after solid meals, food particles were seen churning through the body of the stomach (Fig. 3). These findings were also demonstrated by oblique scanning in the left hypochondrium, across the distended stomach. The dynamic images facilitated rapid spatial orientation while scanning the left quadrant of the abdomen. Showers of echoes, seen after drinking, cleared within three minutes, with the result that the stomach appeared as a homogeneous cystic structure. The distended liquid-filled stomach provided an echo-free zone through which the contents of the stomach bed could easily be identified. Scanning with the patient in the erect position frequently showed the stomach as a vertical tubular structure. The lower border of

the distal body of the liquid-filled stomach often descended to a level at or below the umbilical plane. Scanning with the patient supine resulted in movement downwards of the fundal air collection with the result that the stomach image became indistinct because of gaseous disruption of the ultrasonic beam. The fasting stomach could not be reproducibly imaged with clarity.

Longitudinal scanning in the lower epigastrium after the ingestion of 500 ml orange juice at 37°C by fasting subjects allowed the antrum to be visualised as a rounded clear zone (transonic zone) in the resting state (Fig. 4a). After the liquid meal, contraction of the antrum was absent or weak for up to five minutes but was followed by regular contractions occurring with a frequency of 3 per minute (Fig. 4b). Reproducible motility tracings of antral movement obtained on a fibreoptic chart recorder are shown in Fig. 4c. Intravenous metoclopramide (10 mg) enhanced the magnitude and frequency of the antral movement, which was abolished by intravenous propantheline (30 mg). For up to 30

Fig. 4 Longitudinal ultrasonic scan in the lower epigastrium showing (a) pyloric antrum open, (b) pyloric antrum closed, (c) T-M mode trace corresponding to the ultrasound beam direction indicated by the white line in (a) and (b).

minutes after drinking there was no marked change in the diameter of the resting pyloric antrum.

Discussion

We have recorded contractions and peristaltic waves in the distal portion of the body and pyloric antrum of the stomach in response to liquid and solid test meals using real-time ultrasonic scanning. Our findings accord with previous ultrasonic measurements of antral wall movement, Bateman and his colleagues,⁹ using T-M mode recordings, reported a 'biphasic response' to drinking liquids. In our study, an initial paucity of antral contractions was followed often by regular contractions occurring approximately every 20 seconds. The technique of real-time imaging has a number of advantages over T-M mode scanning. During mixing and emptying of gastric contents, a selected section of the stomach may be displayed as a dynamic image providing information on spatial relationships in the area of the distal stomach under investigation. In addition, artefacts that may be produced by transmitted movements of the patient or movement of stomach contents can be easily identified. A time-motion mode trace can be generated simultaneously with the presentation of the real-time image. Furthermore, investigators may find that the images produced by real-time techniques are easier to recognise, as they bear a close resemblance to images obtained during barium screening studies of the upper gastrointestinal tract. However, ultrasonic imaging is not suitable for the study of an empty stomach and scanning of the stomach may be difficult in obese subjects.

Real-time ultrasonic scanning of the stomach permits the non-invasive recording of gastric contractions. It produces dynamic images which allow rapid orientation during scanning of the left upper quadrant of the abdomen. The method is safe,

readily acceptable to patients or volunteers, and may be repeated as required. As real-time ultrasonic imaging equipment becomes increasingly available, it will provide a useful technique for the study of the effect of drugs and disease states on gastric contraction.

References

- ¹Sheiner HJ. Gastric emptying tests in man. *Gut* 1975; **16**: 235-47.
- ²Cooperman AM, Cook SA. Gastric emptying—physiology and measurements. *Surg Clin North Am* 1976; **56**: 1277-87.
- ³Eisner M. Effect of metoclopramide on gastrointestinal motility in man. *Am J Dig Dis* 1971; **16**: 409-19.
- ⁴McDicken WN. *Diagnostic ultrasonics—principles and use of instruments*. London: Crosby Lockwood Staples, 1976.
- ⁵Lutz HT, Petzoldt R. Ultrasonic patterns of space occupying lesions of the stomach and intestine. *Ultrasound Med Biol* 1976; **2**: 129-32.
- ⁶Holt S, Samuel E. Multiple concentric ring sign in the ultrasonographic diagnosis of intussusception. *Gastrointest Radiol* 1978; **3**: 307-9.
- ⁷Holt S, Samuel E. Grey scale ultrasound in Crohn's disease. 1979; **20**: 590-5.
- ⁸Warren PS, Garrett WJ, Kossoff G. The liquid-filled stomach—an ultrasonic window to the upper abdomen. *JCU* 1978; **6**: 315-20.
- ⁹Bateman DN, Leeman S, Metreweli C, Willson K. A non-invasive technique for gastric motility measurement. *Br J Radiol* 1977; **50**: 526-7.
- ¹⁰Bow CR, McDicken WN, Anderson T, Scorgie RE, Muir AL. A rotating transducer real-time scanner for ultrasonic examination of the heart and abdomen. *Br J Radiol* 1979; **52**: 29-33.
- ¹¹McDicken WN, Anderson T, McHugh R, Bow CR, Boddy K, Cole R. An ultrasonic real-time scanner with pulsed Doppler and T-M facilities for foetal breathing and other obstetrical studies. *Ultrasound Med Biol* 1979; **5**: 333-9.