The physiological, pathological and pharmacological factors which affect the rate of gastric emptying impinge on anaesthetic practice in a number of ways. Inhalation of gastric contents may be a major cause of morbidity and mortality. Nausea and vomiting are distressing sequelae of anaesthesia. Changes in gastric emptying have important effects on the absorption of orally administered drugs, including premedicant, analgesic and concurrent medication. Improved understanding of these factors depends upon techniques for the practical measurement of gastric emptying. Although a number of methods have been developed, so far none is ideal (that is safe, non-invasive, non-radioactive, applicable to solid or liquid test meals and repeatable).

Scintigraphy using a radiolabelled test meal and a gamma camera is non-invasive, but the use of radioactive isotopes precludes repeated studies in the same patient, and during pregnancy. Gamma cameras are expensive and not readily available for routine clinical or experimental purposes. The images may be subject to errors caused by changes in distance between isotope and camera as the stomach empties as a result of both the inverse square law and tissue attenuation.

Marker dilution is accurate and repeatable, but gastric intubation is unpleasant and may itself affect gastric motility through both mechanical and psychological effects. It is applicable only to liquids and the repeated mixing and aspiration of gastric contents provides a limited number of data points.

Absorption of paracetamol after its administration by mouth is an index of gastric emptying as this drug is absorbed only after it has left the stomach. The technique has been used to demonstrate delayed gastric emptying following opioid analgesia during labour [1] and to demonstrate the intestinal prokinetic action of cisapride after morphine premedication [2]. However, it requires repeated blood samples and is only an indirect measure.

Real-time ultrasound is non-invasive and safe and has been used to measure gastric emptying in volunteers [3]. A series of cross-sectional scans along the long axis of the stomach is obtained and the volume computed using a video cassette recorder and a microcomputer. The accuracy of the method was assessed by scanning balloons filled with known volumes of water: in the hands of an experienced operator the mean error of the computed volumes was 4%. Gastric emptying after a 500-ml orange drink was measured in volunteers and found to be log-linear; the half-life of emptying was reduced in four of the five subjects by i.v. metoclopramide given 10 min before. The method seems to fulfil many of the criteria for an ideal technique, disadvantages being the size and the relative expense of the ultrasound scanner and ancillary equipment and the need for an experienced operator.

The measurement of electrical impedance can provide the basis for measuring gastric emptying if the test meal has electrical conductivity different from that of surrounding tissues. Two techniques have been described recently and offer considerable advantages over the more invasive methods [4-6].

Measurement of epigastric impedance is the simpler technique. Two adhesive electrodes are placed in standard positions on the front of the abdomen and two on the subject's back. A constant 2-mA 100-kHz current is passed across the abdomen through one pair of electrodes and the potential difference measured between the second pair. The output signal is displayed on a chart recorder. The maximum deflection of the
trace after drinking a test meal is designated 100% and the time taken to reduce to 50% (or any other fraction) of the original deflection is measured.

Epigastric impedance has been used to measure gastric emptying in a simultaneous comparison with scintigraphy [4]. There was a significant correlation between the slopes of the declination curves measured by the two methods in six healthy volunteers. The technique has also been shown to give results in accord with simultaneous dye dilution measurements and has demonstrated a faster rate of emptying after i.v. metoclopramide in volunteers [5]. Epigastric impedance used to measure gastric emptying after 500 ml of water or orange drink in obstetric patients demonstrated delayed emptying in the first 1 h after delivery following opioid analgesia during labour. Gastric emptying in women in the third trimester of pregnancy was not different from that in women who were not pregnant.

One major problem encountered was inability to locate the stomach in 14 of the 68 women studied, and this included 10 of the 30 in the third trimester. This was attributed to displacement of the stomach in a manner similar to the rostral rotation of the stomach which occurs in obese subjects. Other problems encountered were vomiting of the test meal by two of the post-partum group and artefact caused by excessive movement in a further two subjects.

A further and more serious difficulty is the relationship between epigastric impedance and the contents of the stomach. Although the decline in the initial deflection of the trace is clearly related to the rate of gastric emptying, the assumed linear relation between the volume of gastric contents and the change in impedance has not been demonstrated. A related problem is the effect of gastric acid on the measured impedance. Repeated aspiration of small volumes during a 20-min period following the ingestion of 600 ml of orange drink showed that pH decreased progressively and the conductivity increased, despite the absence of protein or fat which stimulate the cephalic phase of gastrin-mediated gastric secretion [5]. Impedance is clearly related to the conductivity of the gastric contents and the change in impedance is to increase the apparent rate of emptying indicated by impedance measurements. This is supported by simultaneous comparison of scintigraphy and epigastric impedance: the gastric half-emptying time obtained by the impedance technique was faster than that obtained by scintigraphy in all six subjects [4]. Perhaps an H2-antagonist should be administered before epigastric impedance tests. The relation between volume of gastric contents and the measured impedance has yet to be clarified.

The second technique based on detecting changes in resistivity is that of applied potential tomography (APT), which creates cross-sectional images of the body based on tissue resistivity. The name APT invites comparison with x-ray computed tomography (CT), but the analogy is not an exact one. The images from CT scans are derived from collimated beams of x-rays which are absorbed to a variable extent, whereas the current in APT follows the path of least electrical resistance. Laplace's law describes the voltage distribution within a body as a function of position and conductivity and the problem in impedance imaging is to determine the spatial distribution of resistivity from the measured surface potentials. This inverse solution to Laplace's equation is a complex mathematical problem, but a working device capable of generating images of tissue resistivity is now available [6]. Sixteen electrodes are placed in a ring around the upper abdomen at the level of the stomach. An alternating current of 1 mA at 50 kHz is passed between two adjacent electrodes and the potential differences between the other 13 adjacent electrodes are measured. The process is repeated using each pair of electrodes in turn as the drive electrodes. A computer generates a tomographic image from data from 150 cycles, collected over approximately 30 s to reduce the effect of respiratory movements. Following ingestion of a solid or liquid test meal, the position of the stomach can be outlined using a cursor on the computer-generated image and the change in resistivity within this area is calculated for each subsequent image to yield a profile of gastric emptying. Although the spatial resolution is poorer than CT, with a spatial resolution of approximately 10% of the field diameter, the sensitivity to changes in resistivity is very good: 1% changes can be detected.

A recent study has described the use of APT to measure gastric emptying [7]. The optimum position of the electrodes was determined using scintigraphy: positioning of the electrodes at the level of the eighth costal cartilage was found to coincide with the level of the body or fundus of the stomach in all 19 subjects examined. A linear relationship was demonstrated between the
volume of an intragastric balloon and the APT value up to a volume of 250 ml. The effect of acid secretion was examined by two methods: first, by stimulating secretion with subcutaneous pentagastrin and second, by measuring gastric emptying with and without the prior administration of cimetidine. Acid secretion increased the gastric conductivity as expected and, whereas there was a strong correlation between the gastric half-emptying times obtained in repeated studies on each subject after cimetidine, there was no correlation between the half-emptying times in repeated studies when acid secretion was not inhibited. Cimetidine itself does not affect gastric emptying [8, 9]. APT was compared in simultaneous studies of emptying of liquid meals (with both scintigraphy and dye dilution) and of solid meals (with scintigraphy): in all cases there was good correlation between the gastric half-emptying times obtained with APT and the other methods. Test meals were used which were either more or less conducting than the surrounding tissues and were found to give equally good results.

APT clearly has considerable potential for measuring gastric emptying in a clinical setting. However, unlike ultrasound and epigastric impedance, it has been used only in healthy volunteers. Nevertheless, the availability of techniques for measuring gastric emptying which are non-invasive, non-radioactive, relatively portable and repeatable should provide a stimulus to further research in this important subject.

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REFERENCES