Invited Review

Gastrointestinal Motility Study in Human

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Abstract

Gastrointestinal motility study is now enabled to use a variety of techniques including the more advanced technology. Gastrointestinal motor function can be assessed by measurement of the gastroduodenal wall motion, relaxation, contraction and the change in myoelectrical activity. Besides ultrasonography, radioisotopic breath test and magnetic resonance imaging, scintigraphy is the gold standard for measurement of the gastric emptying (gastric wall motion), due to its accuracy, ease of quantification, reasonable cost and noninvasiveness. While barostat is the only method for assessing proximal gastric relaxation, manometry is the method to evaluate the lumen occlusive contraction of the tubular gut. Impedancometry is a new technique that may be more sensitive than manometry in providing the information on gastroduodenal motor function alterations, including the flow events along the gut lumen.

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Forty years ago, the esophagus was the only area actively studied by motility techniques, and certainly the only area in which studies had clinical significance. Since then, major technological advances have occurred in the measurement of motility, not only in the esophagus, but also in some other areas of the tubular gut. This paper focuses on assessment of gastroduodenal motility.

Gastroduodenal motor function in humans can be assessed by four categories of techniques: (i) measurement of gastric wall motion; (ii) measurement of gastric relaxation; (iii) measurement of intraluminal pressures or contractions; and (iv) measurement of gastric myoelectrical activity. In research studies, a number of techniques are frequently used concurrently.

Measurement of gastric wall motion

Scintigraphy, ultrasonograhy, radioisotopic breath test, and magnetic resonance imaging (MRI) are employed to evaluate gastric wall motion. MRI has been used to quantify contractile activity in different regions of the stomach;[1,2] however, due to the high costs and limited accessibility, it is unlikely that MRI will be used clinically for this purpose in the foreseeable future.

Scintigraphy

Scintigraphy has become the "gold standard" for measuring gastric emptying due to the accuracy, ease of quantification, and non-invasiveness. For gastric emptying evaluation, radionuclide markers are incorporated into liquid, solid, or mixed liquid/solid meals. All tests assume that the gastric emptying of the radionuclide adequately represents the behavior of the test meal. Because the liquid and solid phases of a mixed liquid/solid meal may empty at different rates, the precise identification of each phase is necessary for accurate definition of the emptying of either phase, or of the total meal.[3] The isotope used in the studies is ^{99m}Technetium. ^{99m}Tc is favored due to its short half-life (6 hr), relatively low cost and wide availability. In all studies radio-isotopic data are acquired in 1 min frames for the first 60 min and in 3 min frames thereafter. Data are corrected for subject movement, radionuclide decay and, where appropriate, gamma ray attenuation Compton Scatter. A region-of-interest is drawn for the total stomach, which is subsequently divided into proximal and distal regions. The proximal region represented the fundus and proximal corpus, and the distal corpus and antrum are represented by the distal region.[3] Total, proximal and distal regions bring about gastric emptying curves which are expressed as percent retention over time.

Ultrasonography

The use of ultrasonography provides a noninvasive method for the study of gastric function in real time and potentially in three dimensions without radiation exposure. Gastric emptying can be measured with ultrasound using a variety of techniques.[4,5] The most common of these is to image a standardized parasagittal area in the antrum with both the aorta and the superior mesenteric vein in the field of view.[6] Using a built-in measurement program, included on all modern ultrasound machines, the circumference of the antrum can be outlined and the area then

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calculated. The area recorded during the fasting state is subtracted from the subsequent measurements made after a meal. Gastric emptying is expressed at any time as

$A_{C(t)} = 100-((A_{(t)}/A_{max})\times 100)$;

where $A_{C(t)}$ = corrected antral area at a time point;
$A_{(t)}$ = area measured at a given time; and
A_{max} = maximum antral area recorded after meal ingestion.[7]

The technique is operator dependent, and can only be used to measure meals of specific composition, mainly liquids. Measurement of gastric emptying of liquids by ultrasonography in this way has been shown to correlate closely with scintigraphic assessment.[8] More recently, three-dimensional ultrasonography imaging, both of the proximal and distal stomach, has been used to quantify gastric emptying.[9,10]

Radioisotopic breath test

Based on the principle that gastric emptying is the rate-limiting step in the absorption of ^{13}C-octanoate from the small intestine and its metabolism to $^{13}CO_2$, isotopic breath tests is used to evaluate gastric emptying.[11,12] A major advantage of breath tests is their relatively low cost, simplicity and noninvasive nature (with the use of stable isotopes). Moreover, there is a good correlation between scintigraphic and breath test measurements of gastric emptying in healthy subjects.[13] Breath samples are analyzed for $^{13}CO_2$ concentration using an isotope ratio mass spectrometer. The $^{13}CO_2$ concentration of each sample is expressed relative to the international standard (PDB Limestone), which has the highest natural enrichment of ^{13}C. The values obtained are converted to the percent dose recovery (PDR) per hour from the baseline and used to determine the cumulative percent dose recovery (cPDR) per hour during the 6-hr period following administration.[14]

Measurement of gastric relaxation

Barostat is the only technique that can quantify relaxation of the proximal stomach. It consists of a pressure transducer linked by an electronic relay to an air injection system. A compliant bag, positioned in the proximal stomach, is connected via a double-lumen tube to the barostat. Once a pressure is set in the system, frequently 2 mmHg above basal intragastric pressure, the barostat is capable of indirectly measuring gastric relaxation by monitoring changes in intragastric bag volume at a set pressure. Thus, when the stomach relaxes, air is injected into the gastric bag to maintain the pressure, and when the stomach contracts, air is withdrawn. The uncomfortableness felt by the subject is the significant limitation of this technique and the presence of the air-filled bag in the proximal stomach also affects gastric emptying, and other normal physiology.[15,16] More recently, other techniques, including single photon emission computed tomography (SPECT) imaging,[17,18] 3D ultrasound[19-21] and MRI[2,22,23] have been used to quantify proximal gastric motility in research studies. All of these techniques may potentially be employed to evaluate the relaxation of the distal stomach. Attempts have been made to use the barostat for this purpose,[24] but positioning of a barostat balloon in the distal stomach poses substantial logistical difficulties.

Measurement of intraluminal pressures or contractions

Intraluminal pressures or contractions can be measured by manometry. The use of perfusion manometry to measure intraluminal pressures provides an accurate assessment of antral, pyloric and duodenal pressures.[25-27] Transducers linked to a manometric catheter allow the concurrent recording of luminal pressures at multiple points along the gastrointestinal tract. Intraluminal pressures exhibit significant variation even over short distances, therefore, closely spaced (1.5 cm apart) pressure sensors are essential.[25,28] The pylorus has a narrow contractile zone (~2 mm), hence optimal measurement of pyloric motility requires the incorporation of a sleeve sensor (usually 4.5 cm) into the design of the catheter.[29] The development of the pyloric sleeve sensor is an adaptation of the sensor developed originally for lower esophageal sphincter manometry.[30] The position of the catheter is monitored by continuous measurement of the antroduodenal transmucosal potential difference (TMPD) gradient.[31] This is essential to correct for antegrade and retrograde movement of the catheter. The secretions of the stomach (primarily hydrochloric acid) and proximal duodenum (bicarbonate ions) produce electrically negative and electrically neutral charges, respectively, when compared to the reference point (the forearm). Using TMPD recordings, measured via voltage transducers connected to these two channels, the position of the sleeve sensor across the pylorus can be maintained. The TMPD between the stomach and duodenum is measured using side-holes located at the oral and orad margins of the sleeve sensor (i.e. the most distal antral side-hole and the most proximal duodenal side-hole). The channels corresponding to these side-holes are perfused independently of each other and the other pressure channels, with 0.9% degassed saline; 2.2 M potassium chloride electrodes[31,32] connected each of these side-holes to calomel half-cells.

A common reference electrode (a sterile saline-filled 21G cannula placed subcutaneously in the forearm, also connected to a calomel half-cell), established an electric circuit enabling continuous measurement of TMPD across the stomach and small intestine.[28] Data are subsequently only analyzed when TMPD measurements indicate correct positioning across the pylorus. The criteria used for this are that the antral TMPD potential is < -20mV and the duodenal TMPD potential is > -15mV.[31] Studies involving manometry used either 4 mm (outer diameter), or 4.5 mm, silicone rubber manometric assemblies which incorporate 2-4 antral side-holes, a pyloric sleeve and between 3-7 duodenal side-holes. All side-holes are perfused at a rate of 0.15 ml/min the TMPD side-holes with degassed 0.9% saline and the manometric side-holes with degassed distilled water.[33] After an overnight fast (12 hr for solids and 10 hr for liquids) the manometric assembly is inserted via an anaesthetized nostril into the stomach, and allowed to pass by peristalsis into the duodenum; this took between 20-150 min.

Manometric pressures are recorded on a computer-based system with commercially available software and then stored for later analysis. Antropyloroduodenal pressures are analyzed using the software. Parameters assessed include isolated waves in the antrum, pylorus and duodenum, isolated antral, pyloric waves and duodenal waves with an amplitude ≥ 10 mmHg are analyzed.[34] Pressure wave sequences which is defined as two or more temporally-related pressure waves and basal pyloric pressure are also assessed. Pressure waves in adjacent channels are regarded as temporally related if they have onsets within ± 3 s (in the duodenum) or 5 s (in the antrum) of each other.[34] In addition, isolated waves are characterized by their amplitudes, and pressure wave sequences by the distance travelled. Basal pyloric pressure ('tone') is calculated for each minute by subtracting the mean basal pressure (excluding phasic pressures) recorded at the most distal antral side-hole from the mean basal pressure recorded at the sleeve,[31] using custom written software.

More recently, high-resolution manometry has been used to evaluate intraluminal pressures or contractions. The systems detect pressures by using pressure transduction technology.[35] The pressures are converted to an electrical signal by pressure transducers that either contain or are connected to the catheter. The electrical signal will be amplified, filtered, and digitized to a personal computer which can be displayed in the computer screen during the study and is recorded to a storage device for analysis.

Measurement of gastric myoelectrical activity

Gastric electrical activity can be measured using surface electrodes attached to the skin, providing insight into the function of the gastric pacemaker.[36] The pacemaker generates the slow wave (electrical control activity), which determines the contraction frequency of the stomach musculature distal to it. This electrogastrography (EGG) is only capable of measuring the electrical control activity and not the actual occurrence of contractions. Currently its application remains limited to the research sphere.

Impedancometry: A New Technique

Intraluminal impedance recording is the method that can detect flow events by monitoring changes in electrical impedance between pairs of electrodes positioned within the gut lumen, while manometry technique can only detect the lumen occlusive contractions. The electrical conductivity of the luminal contents and the cross-sectional area is inversely proportional to the intraluminal electrical impedance between two electrodes. Air which has a lower electrical conductivity leads to an increase in impedance when compared with the muscular wall. In contrast, fluid which has a higher conductivity decreases the impedance at the corresponding measurement segments. The sequential electrode pairs can monitor the transit of the bolus along a gut segment. Impedance monitoring has now been used widely to evaluate esophageal motility.[37] A recent study reported concurrent manometric and impedance recordings to evaluate the effects of hyoscine on motility and flow events, glucose absorption and incretin hormone release in human.[38]

The assembly incorporated an impedance catheter with six electrode pairs spaced at 3 cm intervals (external diameter 2 mm) (Sandhill Scientific, Highlands Ranch, Colorado, USA) in parallel with a multilumen silicone manometry catheter (external diameter 4 mm) (Dentsleeve, Wayville, Australia) with 6 duodenal side-holes spaced at 3-cm intervals. The location of the manometric side-holes corresponded to the midpoint of each electrode pair, therefore this can evaluate duodenal pressure waves, propagated pressure sequences and flow events concurrently. The sampling rate of 30 Hz (Insight stationary system, Sandhill Scientific, Highlands Ranch, Colorado, USA) was used to record the manometric and impedance signals before storing on a hard disk for subsequent analysis. Impedance recordings were analyzed by two independent observers, who were blinded to the study conditions. A flow event was defined as a transient decrease in impedance ≥ of 12% from baseline[39] in at least three sequential electrode pairs (i.e ≥ 6 cm)[40] either antegrade or retrograde.[39,40]

This technique provides the insight into duodenal motor functions and the information of how flow patterns of glucose within the small intestine affect both rate of glucose absorption and incretin hormone. The intraluminal impedance measurement may be more sensitive than manometry in demonstrating alterations in duodenal motor function.

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Conflict of Interest

None.

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