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CELLULAR AND MOLECULAR GASTROENTEROLOGY AND HEPATOLOGY

REVIEW

Measurement of Gastrointestinal and Colonic Motor Functions in Humans and Animals

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SUMMARY

Accurately measuring the complex motor behaviors of the gastrointestinal tract has tremendous value for the understanding, diagnosis, and treatment of digestive diseases. This review synthesizes the literature regarding current tests that are used in both human beings and animals. Further opportunity remains to enhance such tests, especially when such tests are able to provide value in both the preclinical and the clinical settings.

The ability to assess the complex motor functions of the gastrointestinal tract accurately has been of tremendous value to understanding and treating digestive diseases. Unlike other smooth or cardiac muscle organ systems with relatively more rhythmic and patterned motor behavior, the complexity of the diverse motor behaviors of the alimentary canal have made the development and use of clinical and preclinical tests of gastrointestinal motor function a great challenge. It is perhaps this complexity, as well as the importance of gastrointestinal function to overall health and well-being, that have fascinated early physiologists and continue to push modern physiologists and clinical diagnosticians to develop new and more accurate measurements of motility. It is also because of this complexity that the standardization of these measures presents hurdles to broad adoption and that the measurements of the more complex motility functions remain restricted mainly to tertiary referral centers. *(Cell Mol Gastroenterol Hepatol 2016;2:412–428; http://dx.doi.org/10.1016/j.jcmgh.2016.04.003)*

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Assessing motility in human beings has 3 obvious values. First, standardized clinical tests have diagnostic value in stratifying patients who present with a relatively limited repertoire of symptoms in the complex multifactorial digestive diseases into more manageable subsets and in the identification of underlying pathophysiology. Second, these clinical tests provide measures that can be used to objectively determine the efficacy of therapies for digestive diseases in the clinic and during drug and device development in clinical trials. Third, motility measurements in human beings have value in broadening our understanding of the physiology and pathophysiology of the gastrointestinal tract to generate new hypotheses and new drug targets to understand and treat digestive diseases.

Motility tests in nonhuman animals also have value that parallels the value of tests for human beings. First, animals serving as companions, or in labor, sports, and food production industries, benefit from the diagnostic value of accurate motility tests in veterinary medicine. Second, motility tests provide the basis for objective measures to assess the efficacy and dosing guidelines of new therapies in preclinical drug and device development. Third, animal models provide the basis for understanding the physiology and pathophysiology of the gastrointestinal tract. This latter value historically has been greater in nonhuman animals because of the ability to conduct terminal or ex vivo experiments followed by anatomic or biochemical assessments that are not possible in human beings.

The purpose of this review is to critically assess the current state of motility tests (listed in Table 1, and examples given in Figure 1), based on these values in both human beings and non–human beings. It is organized by region of the alimentary canal in an oral to anal direction, followed by measures of whole-gut transit. The hope is that such juxtaposition of human and nonhuman tests will enlighten both the benefit and deficiencies in each to aid in the de novo or cross-development of new motility tests.

In the interest of brevity, we will not describe tests of esophageal motility here. High-resolution manometry has become the diagnostic tool of choice, about which many recent reviews have been published.[1–3]

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Abbreviations used in this paper: AC, ascending colon; CF6, filling the colon at 6 hours; CT, computed tomography; GEBT, gastric emptying breath test; HDAM, high-definition anorectal pressure manometry/topography; HRAM, high-resolution anorectal manometry; HT, hydroxytryptophan; IQR, interquartile range; MMC, migrating motor complex; MRI, magnetic resonance imaging; ^{99m}Tc, technetium-99m; SPECT, single-photon emission computed tomography; ^{13}C, carbon-13; 3-D, 3-dimensional; WMC, wireless motility capsule.

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Table 1. Tests Currently Available for Measuring Gastrointestinal and Colonic Motility

Function	Tests available
Gastric capacity or accommodation	Barostat balloon measurements Nutrient drink test *SPECT* Ultrasonography MRI High-resolution intragastric manometry
Gastric emptying	*Scintigraphy* Wireless pH and motility capsule Stable isotope breath tests
Gastric transit in preclinical studies	Analysis of gastric contents *Stable isotope breath tests* Scintigraphy
Small-bowel transit	Breath hydrogen tests Stable isotope breath tests Scintigraphy Wireless pH and motility capsule
Whole-gut transit in preclinical studies	Nonabsorbable marker such as carmine red Scintigraphy using steel beads and barium in mice
Colonic transit	*Radiopaque markers* *Scintigraphy* Wireless pH and motility capsule
Gastrointestinal, colonic, and anorectal contractility	*Antropyloroduodenal manometry* Wireless pH and motility capsule *Colonic* phasic contractility (including high-resolution manometry) and tone *Anorectal manometry*
Colonic motility and transit in preclinical studies	Bead expulsion Colonic manometry (including high-resolution manometry) Scintigraphy
New MRI applications	All the earlier-described functions as well as anorectal and pelvic floor motion and anatomic integrity

NOTE. Tests with the strongest validation or most widely available and used are indicated in italics.

Tests to Evaluate Gastric Capacity and Accommodation

One of the principal functions of the proximal stomach is the storage of ingested food. The gastric fundus and body are able to accommodate large volume changes, while maintaining a relatively low intragastric pressure. Altered gastric tone and distensibility may occur in several disease states, including tumor infiltration, vagal dysfunction, and post–gastric surgery status, and in up to 40% of patients with functional dyspepsia.[4]

Barostat Balloon Measurements

The gold standard for the measurement of tone in hollow organs was the barostat,[5] which estimates changes in tone by the change of volume of air in an infinitely (typically polyethylene) compliant balloon maintained at a constant pressure to maintain the balloon in apposition with the stomach lining. The barostat maintains the constant pressure by infusion or aspiration of air in response to relaxation or contraction of stomach tone. This method is not used extensively in clinical practice because it requires intubation and results in stress and discomfort during the tests, which may last 3 hours or longer.[6]

Development and validation studies of the barostat to measure compliance, tone, and postprandial accommodation in the dog were performed by Azpiroz and Malagelada.[5] Since then, the barostat has been used extensively in animals including cats,[7] rabbits,[8] pigs,[9] horses,[10] rats,[8,11] and mice.[12]

Satiation or Nutrient Drink Test

The nutrient drink test has been proposed as a surrogate method for estimating gastric volumes. In this test, a standardized liquid nutrient drink, such as Ensure (1 kcal/mL; Ross Products, Division of Abbott Laboratories, Columbus, OH), is ingested at a standard rate of 30 mL/min, and the volume to normal fullness and the maximum tolerated volume are recorded as measures of satiation. Postprandial symptoms of nausea, fullness, bloating, and pain are measured 30 minutes after the meal.[13] Tack et al[14] suggested that a high-caloric, slowly administered drinking test compared favorably with the barostat in predicting impaired gastric accommodation, especially in patients with a maximum tolerated volume less than 750 kcal. Because of the obvious limitations of feedback regarding sensory experiences, there are no reports of the use of nutrient drink tests in nonhuman animals.