

# Manometry of the Gastrointestinal Tract: Toy or Tool?

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Smout AJPM. Manometry of the gastrointestinal tract: toy or tool? *Scand J Gastroenterol* 2001;36 Suppl 234:22–28.

In the eyes of scientific researchers, there are various manometric techniques that are useful tools for studying the motility of the gastrointestinal tract. Clinicians, however, regard most of these techniques as toys, either because they do not lead to clinically relevant results, or because they are too cumbersome in clinical practice. Nevertheless, a number of manometric techniques have reached the status of clinically relevant diagnostic procedure in gastroenterology. Among these, oesophageal manometry is the most important. Not only has conventional oesophageal manometry been added to the diagnostic armamentarium of many hospitals, but also prolonged ambulatory recording of oesophageal pressures (usually combined with pH monitoring). Small intestinal manometry has also gained the status of a diagnostic tool, in particular in patients in whom the existence of pseudo-obstruction syndrome is suspected and in patients in whom total colectomy is considered because of intractable constipation. Sphincter of Oddi manometry is another example of a clinically relevant manometric technique to be used in particular in patients with suspected dyskinesia of the sphincter of Oddi. The value of anorectal manometry may have been overestimated in the past. The most important indication is the exclusion of Hirschsprung disease. The contribution of anorectal manometry to the diagnosis of anismus and to the work-up of patients with faecal incontinence is limited.

**Key words:** Anismus; Hirschsprung disease; manometry; oesophageal motor disorders; pseudo-obstruction syndrome; sphincter of Oddi dyskinesia

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The motor functions of the human gastrointestinal (GI) tract can be studied in many ways. Among these, recording of the intraluminal pressure (manometry) is one of the most informative and popular techniques. Whereas most of the manometric techniques currently available are useful tools for studying the (patho)physiology of the GI tract and the effects of drugs, only a subset of these have proven to be clinically useful. In this paper, the presently available manometric techniques are reviewed and their present status in the research and clinical domains assessed.

## Manometric Techniques

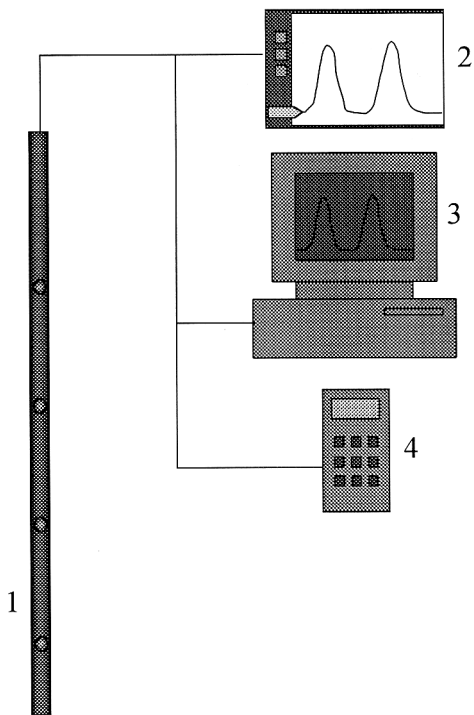
Recording of manometric signals from the GI tract requires conversion of the intraluminal pressure into an electrical signal. The latter can then be recorded, either directly on a chart recorder or after digitization on a digital storage medium such as a magnetic disk or a portable data recorder.

The conversion of the pressure signal into an electrical signal can take place either inside or outside the body. In the former case, a catheter equipped with miniature pressure transducers is used ('solid-state manometry') (Fig. 1A). Advantages of solid-state manometry are their good high-frequency response and the possibility to record in ambulatory subjects. The alternative method uses a water-perfused

catheter and external pressure transducers (Fig. 1B). Recently, it has become possible to manufacture perfusion catheters that combine a small outer diameter (less than 3 mm) and a high number of perfusion channels (up to 21) (1). The advantages of water-perfused catheters are that they are robust and relatively cheap and allow the recording of multiple pressure channels from one small-diameter catheter. Their disadvantage is that their frequency response is limited. For most applications in the GI tract this is not a problem, but for adequate recording of intraluminal pressures in those parts of the tract that contain striated muscle, such as the upper oesophageal sphincter (UES), a solid-state catheter is preferable. Water-perfused manometry needs to be carried out with a special water pump, because adequate pressure recording requires a minimally compliant perfusion system. This is achieved by applying high pressure to a water-filled chamber connected to pressure-reducing narrow tubes (resistors). In systems like these, pressure changes at the catheter outflow opening will only minimally affect the flow rate of the water in the perfusion channel (2).

Nowadays, it is also possible to perform prolonged pressure monitoring in ambulatory subjects with a perfused catheter. This requires an ambulatory perfusion pump and an ambulatory transducer assembly. Obviously, this is a research technique that has not yet found its way into clinical practice.

## A. Solid-state manometry



## B. Perfused manometry

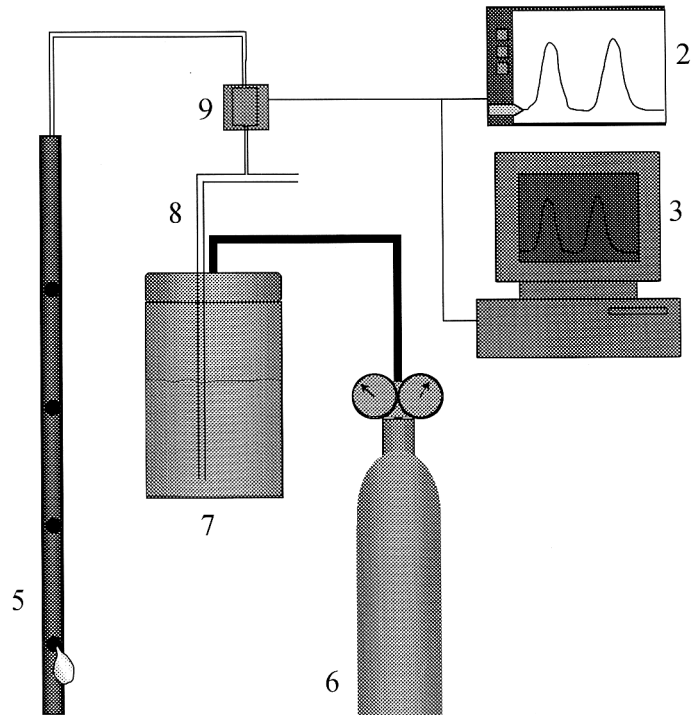


Fig. 1. Schematic representation of equipment used in solid-state and water-perfused manometry of the GI tract. 1. Solid-state catheter with microtransducers; 2. penwriter; 3. computer with software designed to plot and analyse manometric signals; 4. portable digital data recorder; 5. water-perfused manometry catheter; 6. gas cylinder; 7. high-pressure water chamber; 8. resistor tube; 9. external pressure transducer.

### Manometry of the UES

For adequate recording of the pressures in the hypopharynx, UES and proximal part of the oesophageal body, a solid-state catheter is required. One of the best validated techniques uses a catheter with pressure sensors at 3-cm intervals (3). During swallowing, a pressure sensor located in the LES will fall distally (i.e. in the oesophageal body). In order to avoid this problem, one of the sensors is placed slightly proximal to the sphincter. During deglutition, a relaxation of the UES in precise coordination with the hypopharyngeal contraction can be observed.

In experienced hands, manometry of the UES is a clinically useful diagnostic tool in patients with unexplained oropharyngeal dysphagia. In these patients, manometry may show hypoperistalsis of the pharynx and/or discoordination of the UES opening, the most frequent findings in these patients. The latter abnormality in particular points to a centrally located neurological abnormality, for instance a lesion of the nucleus tractus solitarius or the nucleus ambiguus in the brainstem (4). Manometry can be combined with videofluoroscopy, which permits correlation of pressure changes and movements of anatomical structures (5). However, this specialized technique is available in a few centres only.

In patients with globus sensation, an increased UES

pressure (>118 mmHg) is found more frequently than in patients without this symptom (6), but the diagnostic and therapeutic complications of this finding are unclear.

### Manometry of the Oesophagus

Manometric recording of oesophageal motility and lower oesophageal sphincter (LES) function has found widespread clinical application (7). For conventional oesophageal manometry, a water-perfused or solid-state catheter is introduced through the nose and advanced until one or more pressure measuring sites are in the stomach. Thereafter, a so-called stationary pull-through manoeuvre is carried out, usually with a withdrawal of the catheter every 30 s over a distance of 1 cm. During this procedure, the lower and upper borders of the LES are localized, as well as the so-called pressure inversion point (PIP). The latter is the site at which the respiratory-induced variations in LES pressure change in polarity; distal to the PIP, inspiration causes an upward deflection and, proximal to the PIP, inspiration is associated with a negative deflection. Mean LES pressure can be measured at the end-expiratory points, at the mid-expiratory points or at the end-inspiratory points. The end-expiratory LES pressure provides the most accurate reflection of the smooth muscle tone in the sphincteric segment, mid-

expiratory LES pressure has been reported to correlate better with the severity of gastroesophageal reflux disease (8).

Classically, oesophageal manometry is carried out with the patient in a (semi-)recumbent position and includes recording of response of the oesophageal body and the LES to 10 wet swallows (5–10 mL of water). Whereas the normal motor response of the oesophageal body to swallowing consists of a peristaltic contraction that propagates from the proximal to the distal oesophagus and is associated with the relaxation of the LES, simultaneous pressure waves and incomplete or failed peristalsis are also seen occasionally in healthy volunteers.

Recently, techniques for more detailed analysis of oesophageal peristalsis have been described. Using a catheter with 21 channels, computerized data acquisition and topographic plotting of the pressure data, Clouse and co-workers have been able to distinguish more subtle abnormalities of oesophageal function (9).

The primary motor abnormalities of the oesophagus are achalasia, nutcracker oesophagus, diffuse oesophageal spasm and hypertensive LES.

The manometric hallmarks of achalasia are absence of normal oesophageal peristalsis, an incompletely relaxing LES and usually an increased resting pressure of the LES. These findings are characteristic of achalasia, but do not rule out the presence of a distal oesophageal tumour or cardia carcinoma as the cause of the symptoms (pseudo-achalasia). In nutcracker oesophagus the amplitude of the normally propagating oesophageal contractions is increased. Usually sphincter relaxation is normal.

In diffuse oesophageal spasm there is intermittent occurrence of simultaneous pressure waves, which may be repetitive, of prolonged duration or of increased amplitude. Again the function of the LES is normal.

The key symptoms of oesophageal motor abnormalities are dysphagia and non-cardiac chest pain. In patients who present with these symptoms, oesophageal manometry should be carried out when other relevant tests do not provide an adequate explanation for them. Some clinicians would argue that they can recognize achalasia by the typical X-ray appearance or by typical endoscopic signs. However, in the early stages of the disease barium swallows may be normal and endoscopy may reveal no abnormalities. In other words, normal results of oesophageal imaging tests do not exclude the diagnosis of achalasia. In patients with unexplained dysphagia, manometry must be carried out, because an early diagnosis of achalasia saves the patient considerable discomfort and distress. The same applies, albeit to a lesser extent, to patients with non-cardiac chest pain. It has been reported that many clinicians have become disillusioned with the poor specificity of manometry in chest pain (10). However, an early diagnosis of an oesophageal cause of chest pain by itself improves the quality of life of the patient (11).

Since the motor abnormalities leading to angina-like chest

pain are often intermittent in nature, the diagnostic work-up of patients with non-cardiac chest pain is improved by performing a 24-h oesophageal manometry study (combined with pH monitoring). When one or more symptom episodes occur during such a study, the occurrence of abnormally strong or long-lasting contractions in the 2-min periods preceding the symptom episodes provides evidence that the symptoms are dysmotility-related (12). Other indications for ambulatory 24-h pH and pressure monitoring of the oesophagus are nocturnal coughing spells (the pressure recordings enable accurate detection of the cough periods) and suspicion of rumination syndrome. For the latter indication, at least one pressure electrode is placed in the stomach. This allows the characteristic pattern of the rumination syndrome to be observed, i.e. abdominal pressure peaks that precede the episodes of gastro-oesophageal reflux (13).

Some centres perform peroperative manometry during Heller myotomy to detect any residual high pressure at the myotomized area. If such a residual high pressure zone is found, the surgeon is prompted to cut residual muscle fibres (14). After any type of treatment for achalasia, LES pressure appears to be an indicator of therapeutic effectiveness (15).

Secondary oesophageal motor abnormalities may be found in systemic diseases such as systemic sclerosis and related disorders. Usually, in these diseases oesophageal manometry is used as an indicator of gastrointestinal tract involvement. In chronic idiopathic intestinal pseudo-obstruction, oesophageal manometry can be used as a screening test, since in the majority of cases oesophageal manometry will show either a myopathic or neuropathic motility disorder.

Measurement of LES pressure in the work-up of patients with reflux disease is not helpful. Whereas it has been shown that basal LES pressure is decreased in reflux disease and that the severity of the reflux disease correlates with the decrease in LES pressure, the overlap in LES pressure between patients with and without gastro-oesophageal reflux disease is considerable. In other words, oesophageal manometry is not a diagnostic tool for reflux disease. This is largely due to the fact that spontaneous transient LES relaxations play an important part in the pathophysiology of the disease (16). Since TLESRs occur infrequently (i.e. only a few times per hour) a short, conventional manometric study will not reveal their presence. For adequate recording of TLESRs a prolonged recording using a perfused Dent sleeve device is necessary. This is only feasible in the context of scientific research. Solid-state sphinctometers have been found to have inferior performances than the perfused Dent sleeve (17, 18). The Dent sleeve has also been found useful in clinical manometry (19). A four-quadrant sleeve catheter can be used to record LES pressure from four difficult quadrants of the LES (20).

However, oesophageal manometry in patients with reflux disease is felt to be useful before antireflux surgery is considered. Although some studies have shown that impaired oesophageal motility in itself is not a contra-indication against

surgery (21), we and others have seen patients with poor peristalsis preoperatively in whom severe dysphagia and dilatation of the oesophagus occurred after fundoplication.

### Manometry of the Stomach

With conventional manometric techniques, no reliable information about the motility of the proximal stomach can be obtained as a consequence of the large diameter of this part of the GI tract. The phasic contractions of the antrum and the motility of the pylorus can be studied with perfused or solid-state catheters, but accurate pressure measurement requires continuous monitoring of the position of the catheter with respect to the pylorus. The reason for this is that relatively small movements of the catheter with respect to the pylorus have a great impact on the amplitude of the antral contractions that are being measured. Monitoring of the position of the catheter can be carried out by means of measurement of the transmucosal potential difference (TMPD). Usually, the lumen of the gastric antrum is more than 20 mV more negative than the lumen of the proximal duodenum (22). TMPD monitoring requires perfusion of a distal antral and proximal duodenal side-hole with saline solution from two separate perfusion pumps. If required, pressure can be measured simultaneously from the same two sites. This technique necessitates constant supervision by a trained technician who relatively frequently has to reposition the catheter based on the TMPD readings.

Using antral manometry, information can be obtained about the motor activity of the distal stomach. In patients with functional dyspepsia and with diabetic gastric paresis, postprandial hypocontractility of the antrum has been observed (23, 24). It is not impossible, however, that the observed decreased amplitude and incidence of antral contractions may be partly due to the widened antrum that is present in these conditions.

Pyloric motor function can be studied with a pyloric sleeve device, but again this technique requires TMPD monitoring (25). Since no disease-specific pyloric motor abnormalities have been described thus far, pyloric pressure monitoring has no clinical relevance.

For studies of the motor function of the proximal stomach, a specialized piece of equipment, called the 'barostat', has been developed (26). With this technique, a non-compliant plastic bag is introduced into the proximal stomach and filled with air until the bag is in contact with the gastric wall. The pressure in the bag is then kept constant by means of an electronically driven pump. The amount of air in the intragastric bag is measured constantly. Intrabag volume is a measure of gastric tone. Important new pathophysiological insights have been obtained with this technique. For example, it has been found that basal tone of the proximal stomach in patients with functional dyspepsia is generally normal, but the postprandial relaxation of the proximal stomach is impaired in these patients (27). The barostat technique can also be used to

examine the sensitivity of the proximal stomach to distention. For this application of the technique, the intrabag pressure is gradually increased and the patient's sensations (bloating, fullness, pain) are scored. It has been shown that about 50% of the patients with functional dyspepsia have an increased perception of distension of the stomach (28). Barostat measurements have not yet been included in the routine diagnostic armamentarium of most motility laboratories.

### Manometry of the Small Intestine

In the small intestine (as well as in the stomach) two distinct motor patterns can be distinguished: a fasting and a postprandial pattern. The fasting or interdigestive pattern has more characteristic features than the fasting motor pattern, and therefore the former is far more important clinically than the latter. The typical interdigestive motor pattern consists of a cyclic recurrence of a period of intense motor activity (phase III), followed by a period of motor quiescence (phase I). Between phase I and phase III an intermediate activity is seen (phase II). The interdigestive motor complex (IMC) propagates from the gastric antrum to the terminal ileum. The repetition frequency of the cycle is approximately 90 min, but the interindividual and even intra-individual variation is considerable.

Since most clinically relevant motor abnormalities in the small intestine are found in the interdigestive state and the IMC cycle interval is 1.5 h, a meaningful manometric study of the small intestine requires prolonged recording. Preferably, small intestinal manometry is carried out over a period of 24 h, including a sufficiently long fasting period (e.g. during the night). Small intestinal manometry can either be performed with a water-perfused system or with a solid-state catheter with multiple pressure sensors, allowing an ambulatory study.

The main indication for small intestinal manometry is intestinal pseudo-obstruction or the suspicion thereof (29–31). For this indication, small-bowel manometry is complementary to radiographic examination of the small intestine (32). Using manometry, two types of pathophysiological mechanisms can be distinguished. In myogenic pseudo-obstruction (caused by degeneration of smooth muscle in the gut wall) the characteristic interdigestive motor patterns are still recognizable, but the amplitude of the individual pressure waves is diminished. In neurogenic pseudo-obstruction (caused by degeneration of intrinsic or extrinsic neuronal elements) the amplitude of the individual contractions is normal, but the interdigestive motor complex is either absent or disturbed. In particular, abnormal propagation of interdigestive complexes is a feature of neurogenic pseudo-obstruction.

Currently, small intestinal manometry cannot yet be recommended as a tool for the diagnosis of functional disorders such as functional dyspepsia and irritable bowel syndrome. Although it has been shown that patients with these disorders, when compared to healthy controls, show

abnormalities in small intestinal motility, these are non-specific, and the overlap between health and disease is considerable. In patients with diabetes mellitus, especially in those with autonomic neuropathy, several abnormalities of intestinal motility have been found with intestinal manometry. However, the demonstration of these abnormalities usually serves no clinical purpose.

Recent information suggests that small intestinal manometry may be of clinical value in patients with severe constipation in whom colectomy is considered. Several types of motor abnormalities have been described (33) and it has been shown that patients with an abnormal small-bowel manometry preoperatively have a significantly poorer outcome than those who have a normal preoperative manometry.

### Manometry of the Colon

Manometric catheters can be placed in the colon via the anus, using a colonoscope, or be advanced via the nose through the proximal GI tract. Both approaches are cumbersome, which limits the application of these techniques. Catheters inserted into the colon tend to be expelled easily. When inserted by means of colonoscopy, the catheter can be attached to the colonic mucosa by clips.

Studies using colonic manometry have made clear that basically two types of contractions prevail in the colon. The most common type is that of phasic pressure waves that are thought to represent the mixing, haustrating movements of the colon. In the human colon these contractions appear to have no dominant rhythm or propagation. They may, however, serve to propel colonic contents over short distances (34). The other type consists of high-amplitude waves that are propagated over a considerable distance. These waves have been labelled high-amplitude peristaltic contractions (HAPCs). They occur infrequently (6–10 times per day), with a strong tendency for the early morning, shortly after wakening. In patients with idiopathic constipation the amplitude and incidence of phasic pressure waves is decreased (35) and the incidence of HAPCs is diminished.

Colonic manometry clearly is a research technique. It is unlikely that it will soon become a clinically relevant test.

The barostat technique has also been used to study colonic motility. A lower postprandial tone was found in patients with slow transit constipation and outlet obstruction.

### Manometry of the Anorectum

Anorectal manometry is a widely available manometric technique. It is used frequently in the work-up of patients with faecal incontinence and in patients with (severe) constipation. It is doubtful, however, whether this widespread application of anorectal manometry is as justified as believed by its proponents.

During anorectal manometry, a manometric profile of the sphincteric complex can be recorded. The sphincteric com-

plex consists of the internal anal sphincter (IAS), which is composed of smooth muscle, and an external anal sphincter (EAS), composed of striated muscle and under voluntary control. Because of the concentric, overlapping anatomic positions of the internal and external anal sphincters, manometry will always record the pressure resulting from the activity of two sphincters. Without concurrent electromyography of the EAS it is difficult to distinguish the contribution of each of these two sphincters individually to the recorded pressure. However, one can be sure that the increase in basal sphincter pressure that occurs upon squeezing is caused by contraction of the EAS and that the decrease in sphincter pressure observed during distension of the rectum is the result of IAS relaxation.

Basal 'sphincter' pressure is, on average, decreased in patients with faecal incontinence. However, the overlap between healthy subjects and incontinent patients is considerable, limiting the clinical value of anorectal manometry in the work-up of patients with faecal incontinence.

In patients with constipation the most meaningful use of anorectal manometry is to exclude the possibility of Hirschsprung disease. In Hirschsprung disease, resting anal pressure is high and the recto-anal inhibition reflex (relaxation of the external anal sphincter upon balloon distension of the rectum) is absent. Absence of the reflex does not provide evidence that Hirschsprung disease is present, since a widened rectum (megarectum) may prohibit elicitation of the reflex.

Anismus is a condition in which the patient does not relax the EAS and pelvic floor muscles during attempts to defaecate (36). This behavioural abnormality can be treated with biofeedback (37). In the diagnosis of anismus, anorectal manometry alone is of limited value (38). If a clear-cut pressure decrease during bearing down as to defaecate is observed, the diagnosis of anismus is unlikely. However, false-negative findings may be caused by displacement of the catheter, and false-positive findings are frequently caused by embarrassment of the patient. The diagnostic value of anorectal manometry for the diagnosis of anismus can be increased by concurrent electromyography of the EAS, but still embarrassment is an important factor using ambulatory EAS electromyography. It has been shown that 80% of patients who have signs of anismus in the laboratory have a normal EAS relaxation at home (39).

Anorectal manometry can also be used to measure rectal compliance, i.e. the volume-pressure relationship ( $dV/dP$ ) within the rectal balloon. For this purpose, the pressure in the balloon must be measured. Rectal compliance is increased in (a subset of) patients with irritable bowel syndrome and decreased in patients with megarectum. Owing to a considerable overlap between the various groups, however, the diagnostic value of compliance measurement is limited.

In most laboratories, anorectal manometry will usually be combined with measurement of rectal sensitivity. The balloon volumes at which first sensation and the desire to defaecate occur are determined, as well as the maximum volume that

Table I. Clinically useful applications of manometry of the GI tract

Conventional oesophageal manometry
Unexplained dysphagia
Non-cardiac chest pain
Positioning of pH probe
Ambulatory 24-h oesophageal manometry
Non-cardiac chest pain
Rumination syndrome
Unexplained (nocturnal) coughing
Small intestinal manometry
(Suspicion of) pseudo-obstruction
Before colectomy because of intractable constipation
Anorectal manometry
Exclusion of Hirschsprung disease
Sphincter of Oddi manometry
Unexplained biliary-type pain

can be tolerated. It should be emphasized that normal values for these parameters are dependent on size, shape and material of the balloon and on the rate of inflation.

Decreased sensitivity (caused by neuronal damage) can play a role in the pathogenesis of both incontinence and constipation.

### Manometry of the Sphincter of Oddi

The distal end of the common bile duct and the pancreatic duct are surrounded by concentric smooth muscle structures which act as a sphincter. The anatomy of this sphincter is complex: separate pancreatic and common bile duct sphincters ending in a common sphincter have been described.

The function of the sphincter of Oddi can be assessed by means of endoscopical manometry. A small-diameter manometric catheter is positioned in the sphincteric complex with its proximal end either in the common bile duct or in the pancreatic duct. The catheter is then slowly withdrawn until all pressure measuring sites are in the duodenum. The basal sphincter pressure is the most important diagnostic parameter, values above 40 mmHg are abnormal. Since pressures recorded from the pancreatic and biliary segments of the sphincter of Oddi show a low concordance, it has been recommended to measure both (dual-duct manometry) (40, 41). It has been shown that patients with biliary-like episodic pain in whom the basal sphincter pressure is over 40 mmHg respond better to sphincterotomy than those in whom basal pressure in the sphincter of Oddi is normal (42).

The technique of sphincter of Oddi manometry is relatively difficult because of the small size of the sphincter and the constant movements of the sphincter with respect to the catheter. It requires a trained endoscopist and a trained manometrist.

Sphincter of Oddi manometry is associated with a greater risk of pancreatitis than a diagnostic ERCP (43, 44). The reasons for this are unclear. If sphincter of Oddi manometry is combined with diagnostic ERCP the risk of pancreatitis is higher (26.1%) than when sphincter of Oddi manometry is the

sole procedure (9.3%). Sphincterotomy carried out during the same procedure carries no additional risk. Pancreatic stenting decreases the risk of pancreatitis after biliary sphincterotomy for sphincter of Oddi dysfunction (45).

### Conclusion

Whereas most of the manometric techniques designed for the study of gastrointestinal motility are research techniques, a number of manometric tests have proved to be of value in clinical gastroenterology. The latter group of manometric tests is listed in Table I.

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