Antroduodenal Manometry

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Introduction

Antroduodenal manometry (ADM) is a diagnostic tool that provides both a qualitative and quantitative assessment of the foregut motor function by recording intraluminal pressure changes within the gastric antrum and the proximal small intestine. Specifically, such pressure readings provide a measure of coordination and contractile activity of the foregut. Since first manometric recordings, methodological improvements have steadily occurred, progressing ADM manometry from a purely research technique to an investigation commonly performed in adults and children for definitive clinical purposes. A substantial development has been the ability of the recording equipment to digitize online manometric recordings so that the latter can be easily analyzed by computer programs. Although the test is still performed in highly specialized motility centers, ADM has provided an improved understanding of the pathophysiology of neuromuscular disorder of the stomach and small intestine.

Normal Motility

In healthy individuals, the primary function of the small intestine is the absorption of nutrients, and the motor pattern is programmed to promote this function by assuring timely propulsion of luminal contents and avoiding stasis or, conversely, rapid transit of luminal contents. Under physiologic conditions, the motor activity of the antrum and the small intestine is characterized by patterns of organized motor activity in the fasting and postprandial periods [1].

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Fasting or interdigestive gastrointestinal motility comprises a sequence of three main components or phases with a combined total average duration of about 100 min (50–180 min), which together constitute the so-called migrating motor complex (MMC) (Fig. 11.1) [2, 3]. Phase III of the MMC, the most distinctive and well-studied pattern of gastrointestinal motor activity, is a characteristic burst of high-amplitude rhythmic contractions of at least 2 min duration occurring at the maximum frequency allowed by the underlying myoelectrical rhythm for a given segment of the gastrointestinal tract [4]. For instance, in the antrum the contractions occur at a rate of 2–3 per minute, whereas in the proximal small bowel this increases to 10–14 per minute. In children, phase III may begin anywhere from the stomach to the ileum, but in about 70% it starts in the gastric antrum, 18% in the proximal duodenum, 10% in the distal duodenum, and 1% in the proximal jejunum [2, 3]. Migration is a basic requisite of phase III activity, which usually propagates aborally over various lengths of the small intestine; however, only 50% of these propagate beyond the middle jejunum, and only 10% reach the distal ileum [5]. The duration of phase III progressively increases in the aboral direction ranging between 2 and 5 min in the duodenum and 10–20 min the distal ileum [2, 6–8]. Conversely, the propagation velocity of phase III decreases from 5–10 cm/min in the proximal small bowel to about 0.5–1 cm/min in the distal ileum [1, 2, 7]. The average amplitude of single contractions is at least 40 mm Hg in the antrum and 20 mm Hg in the small intestine. Finally, the mean interval between episodes of phase III varies with age. It ranges between 25 and 45 min in newborn, approximately 60 min in children less than 2 years, and 85–110 min in adolescent and adults [3, 8–12]. However, significant variation between subjects and within the same individuals may be seen [2, 13, 14]. Phase III activity is usually followed by quiescence or phase I, which is defined as less than three pressure waves every 10 min [15]. Phase I is followed by a period (Phase II) of irregular contractions (more than 3 pressure waves every 10 min), which represent in the small intestine about 70–80% of the whole cycle.

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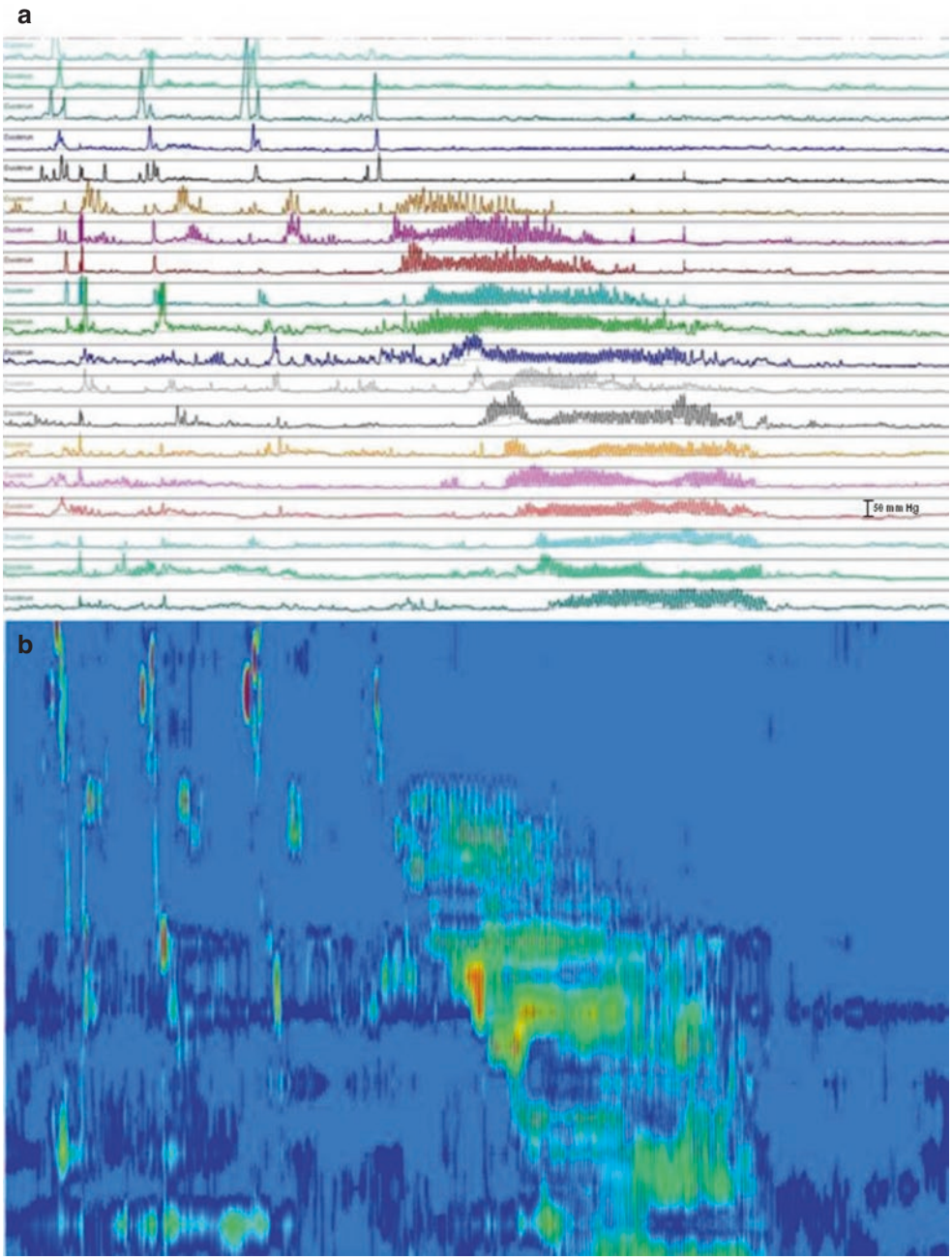

Fig. 11.1 Examples of conventional (**a**) and spatiotemporal plot (**b**) of normal migrating motor complex (MMC) recorded in a child with recurrent vomiting. All three phase (phase I, phase II, and phase III) are well represented. The phase III is seen starting in the duodenum and migrating aborally toward the proximal jejunum. A period of quiescence (phase I) follows phase III; the latter is preceded by intermittent phasic activity (phase II). Phase III is readily recognized by using spatiotemporal plots. The recording has been performed with a 20-channnel manometric catheter (side holes 2.5 cm apart)

Phases I and III of the MMC require an intact enteric nervous system (ENS) with modulation by the central nervous system (CNS) and gastrointestinal regulatory peptides [5, 16, 17]. For instance, endogenous motilin blood concentration peaks during late phase II and phase III of the MMC cycle [18, 19]. However, motilin is not required for initiation or aboral migration of Phase III in the small bowel but seems to be involved in the antral participation of phase III [20, 21]. Conversely, phase II activity seems to rely more on extrinsic modulation of CNS, given it is suppressed during sleep and abolished after vagotomy [5, 16]. The importance of MMC is highlighted by the fact that its absence is associated with bacterial overgrowth [1]. Indeed, the pulsatile flow ahead of phase III is of paramount clinical importance for clearing secretion, debris, and microbes during the interdigestive period, whereas colonization of the foregut with gram-negative bacteria is observed when phase III is impaired or absent [22]. For this reason, phase III has been termed as the "gastrointestinal housekeeper." MMC cycles do not occur in the intestine of premature infants aged less than 34 weeks, which instead show a pattern of clustered phasic contractions lasting between 1 and 20 min and occurring every 4–35 min. As post-conceptional age increases, this activity becomes longer and the frequency of occurrences decreases. By term,

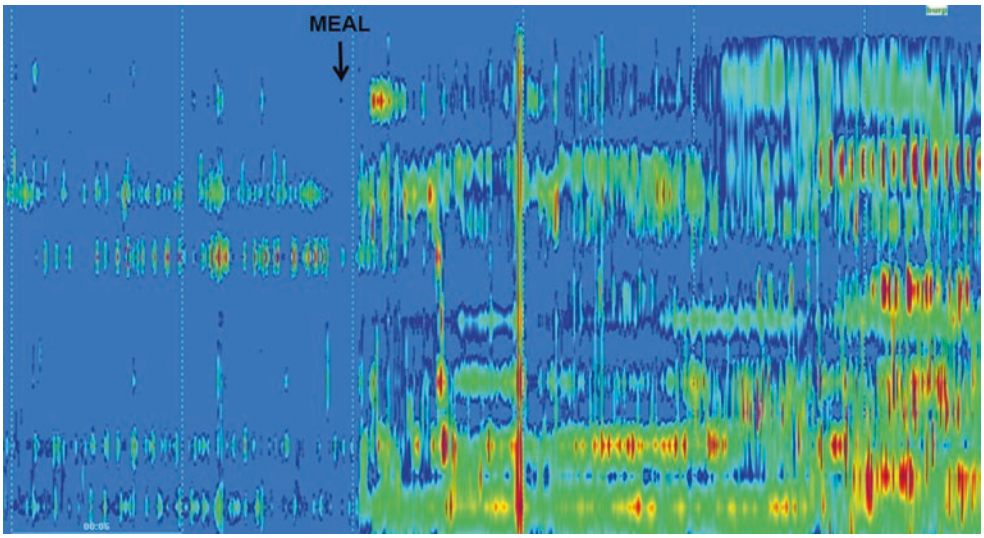

Fig. 11.2 Examples of spatiotemporal plot of normal postprandial activity characterized by irregular but persistent phasic activity. Temporal and pressure resolution easily recognize the increase in motility index. The recording has been performed with a 20-channnel manometric catheter (side holes 2.5 cm apart)

well-defined cyclical fasting motor activity is present with distinct phase I, II, and III activities, with the latter showing less variability in term of length and intervals [11, 23].

Following the ingestion of food, the MMC cycle is interrupted and replaced by a pattern of regular antral contractions associated with apparently uncoordinated contractions of variable amplitude in the small intestine, termed "postprandial" or "fed" pattern (Fig. 11.2) [5, 16, 24]. These phasic contractions also show variable frequency and propagation. Typical postprandial contractions usually propagate over a shorter distance than those of phase III, and almost 80% of them propagate less than 2 cm [24]. This minute movement of postprandial contractions is devoted to mixing and grinding of the nutrient chyme, stirring, spreading, and exposing the intestinal contents to a larger surface, and thus promoting its optimal absorption. Moreover, minute aboral transport is also sufficient in preventing bacterial colonization. Thus, normal postprandial motor activity is a compromise between optimal absorption and adequate clearance. The postprandial period lasts from the time of the evident increase in frequency and/or amplitude of contractions occurring after the introduction of a meal to the onset of the following phase III and is affected by the amount of calories as well as by the composition of the meal [25]. For instance, fats induce a more prolonged fed pattern than protein and carbohydrates. Extrinsic neural control is a prerequisite for a normal postprandial pattern, since persisting MMC activity after meal intake has been reported after vagal cooling [26, 27]. Neural reflexes, endocrine, and paracrine mechanisms also play a key role [17]. In small infants aged less than 32 week's post-conceptional age, who usually receive only small volumes of enteral feeding, the fasting pattern is not disrupted by either the bolus or continuous feeding. Between 31 and 35 week's post-conceptional age, the larger volumes of enteral feeding induce a degree of postprandial activity, but it is only over 35 week's post-conceptional age that a disruption of cyclical activity can be seen with feeds [10].

The presence of other distinct motility patterns has been identified in both healthy individual and patients. *Discrete clustered contractions (DCCs)* or *cluster of contractions (CCs)* are defined as the presence of 3–10 pressure waves of slow frequency, each having a significantly higher amplitude and duration compared to isolated individual contractions [15, 28]. They propagate aborally for less than 30 cm at rate of 1–2 cm sec^{-1} and usually show a rhythmic pattern with regular intervals of quiescence lasting at least 30 sec (Fig. 11.3) [3]. DCC are usually recorded during phase II, although they are occasionally seen during the postprandial period (phase III-like activity) [3, 14, 28, 29]. Postprandially, clusters of contractions seem to occur in association with mechanical obstruction or intestinal pseudo-obstruction, and they are characteristically non-propagated [30]. *Bursts of contractions* are defined as sequences of intense irregular pressure waves, which do not correspond to the definition for phase III or for DCC. They can be clearly distinguished from background pressure wave activity during both phase II and the postprandial period. Short bursts of propagating contractions have been described in healthy individuals, whereas sustained bursts of contractions confined to one limited segment (non-propagated) lasting for a period of >30 min and associated with tonic intermittent baseline pressure elevation are considered an abnormal neuropathic pattern [21, 31, 32]. *Giant migrating contractions* or *prolonged intestinal contractions* are pressure waves of prolonged duration (>20 s) and high amplitude more than 30 mm Hg. In healthy individuals they occur primarily in the distal ileum and propagate uninterruptedly and rapidly with highly propulsive force over long distance in aborad direction in the small intestine and colon [33, 34].

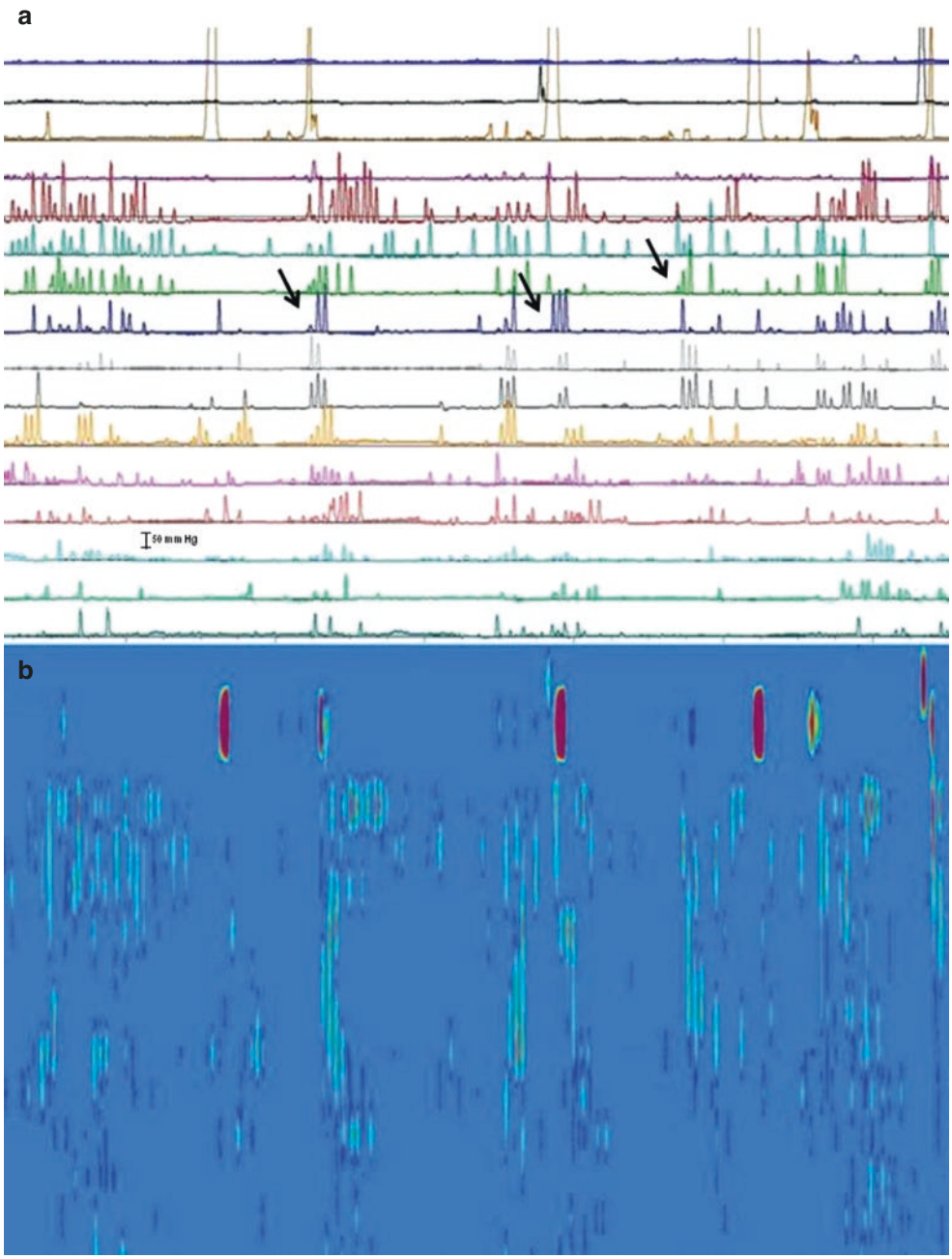

Fig. 11.3 Examples of conventional (**a**) and spatiotemporal plot (**b**) of short burst of contractions (arrow) recorded in the duodenum during phase II lasting more than 2 min. They can be clearly distinguished from background pressure wave activity during phase II. The third channel is localized in the antrum. The recording has been performed with a 20-channnel manometric catheter (side holes 2.5 cm apart)

Technical Aspects

Manometry is by nature a highly technical evaluation. When knowledgeably used, manometric examination provides an accurate description of intestinal neuromuscular function, but only if physical principles and equipment characteristics are respected [35]. In general, manometric data are reliable only if the methodology used to acquire them is accurate.

A manometric apparatus setup consists of a pressure sensor and transducer combination that detects the gastric and small intestine pressure complex and transduces it into an electrical signal, and a recording device to amplify, record, and store that electrical signal. The pressure sensor/transducer components of a manometric assembly function as a matched pair and are available in two general designs: either water perfused catheters connected to a pneumohydraulic perfusion pump and to volume displacement transducers or strain gauge transducers with solid state circuitry [35, 36].

Low Compliance Perfused Manometric System

The water infusion system includes a catheter composed of small capillary tubes, a low compliance hydraulic capillary infusion pump, and external transducers. In adults, the small capillary tubes usually have an internal diameter of approximately 0.4–0.8 mm and an opening or port at a known point along the length of the catheter. In adults, the most used catheters have an overall diameter of 4.5 mm [35]. In children in order to reduce the diameter of the catheter smaller capillary tubes (with internal diameters of 0.35 mm) are utilized; moreover, the study is performed at lower infusion rates [36, 37]. The manometric probes are usually tailored to the child's size, and the distance between the recording ports should be decided based on the purpose of the investigation [35, 36]. Since one antral recording site is insufficient to provide an accurate recording of antral motor activity due to its continuous forward and backward movement, the manometric catheter should have at least five recording ports with the two most proximal side holes spaced 0.5–1.5 cm apart positioned 1 cm proximal to the pylorus to provide measurements of antral activity, while the remaining side holes positioned in the small intestine and spaced 2.5–5 cm apart in infants and toddlers and 5–10 cm apart in children and adolescents [35–37]. Each capillary tube is connected to an external transducer. The infusion pump, a simple and essential device for stationary manometry, perfuses the capillary tubes providing a constant flow rate without increasing the compliance of the manometric system. When a catheter port is occluded (e.g., by a muscular contraction), there is a pressure rise in the water filled tubes that is transmitted to the external transducers. High-fidelity recordings of intraluminal pressure are achieved by infusion rates from 0.1 to 0.4 mL min^{-1}, even if they may provide an unacceptable amount of water to small babies or premature infants. To overcome this problem, perfusion rates as low as 0.02 mL min^{-1} have been successfully used [38]. Furthermore, for prolonged studies, the use of a balanced saline solution should be considered.

A device activating the pressure transducers, storing their signals, and displaying the latter in such a way to allow immediate interpretation and analysis is needed. The personal computer has become the heart of any manometry system. It interfaces with purposed-designed electronic modules that activate and receive signals from pressure transducers, while commercially available software programs are essential for acquiring, displaying, and storing pressure recording data. The technical adequacy of different commercially available device recording systems is quite comparable. Probably the dominant consideration that should determine the choice of a system is the level of technical assistance and the training available locally to support the user.

The required characteristics of the manometric recording apparatus is defined by the magnitude of the pressure to be recorded and the frequency content and waveform of foregut contractile waves. It has been shown that the frequency response of manometric systems required to reproduce foregut pressure waves with 98% accuracy is of 0–4 Hz (maximal recordable dP/dt: 300 mm Hg/s). Most of commercially available manometric systems can provide a pressure rise rate of 300–400 mm Hg/s, which is adequate for faithful recordings in the gastric antrum and small intestine.

Solid-State Manometric System

The main alternative to the water-perfused manometric system is a manometric assembly incorporating strain gauge sensors and solid-state electronic elements [39]. In this system, the manometric probe contains miniature strain gauge pressure transducers built into the catheter at a fixed location along its length, so that pressure changes directly influence the transducers to generate electrical output signals. The probe can be plugged into a small box containing the electronics, which is then connected to the recording device and to a personal computer. In the ambulatory system, the recording devices are blind and need to be connected to a personal computer with the appropriate software to display and analyze the recording. The main advantage of using solid-state catheters is that the pressures are recorded directly from the area and are unrelated to the relative position of the subject; therefore, manometric studies may also be performed with the subjects in the upright position. This, and the fact that it does not require water perfusion, makes solid-state catheters suitable for long-term ambulatory monitoring of the intraluminal pressure [40]. It has been calculated that for a given number of pressure-recording points on a recording assembly, solid-state catheters are 20 times more expensive than a perfused manometric assembly. In the last years, the improvement in miniaturizing transducers has allowed the production of solid-state catheter with up to 36 recording channels with an external diameter comparable to that of the water perfused manometric catheter used in small infants and children. However, there is still a very little experience in pediatric patients.

High-Resolution Manometry

Manometric techniques have improved in a stepwise fashion from few pressure recording channels to the development of high-resolution manometry (HRM), which is a relatively recent technique that enables more detailed definition, both in term of space and time, of pressure profiles along segments of the gut [41]. This has been achieved by a combination of new manometric assemblies allowing intraluminal pressure to be recorded from up to 72 pressure sensors

spaced less than 2 cm. At the same time, advances in computer processing allow pressure data to be presented in real time as a compact, visually intuitive "spatiotemporal plot" of gastric and small intestine pressure activity. HRM recordings may reveal the complex functional anatomy of the foregut, and recent studies suggest that spatiotemporal plots may provide objective measurements of the intraluminal pressure profile in the small intestine and improve the sensitivity and specificity of manometric recording by removing much of the ambiguity usually encountered using line plot analysis [42]. However, further efforts to define the role of HRM in the diagnosis and management of neuromuscular disorders are needed.

Methodological Aspects

Preparation of the Patient

Before starting the ADM manometric recording , it is important to assess patient information regarding medical history, symptoms, medication, and allergies. Any drug with a known effect on gastrointestinal motility should be discontinued at least 72 h before the study.

It is important to emphasize that ADM manometry in children is performed in a different fashion to that in adults due to differences in size, cooperation, and neurological and developmental maturation. Performing manometric studies in children require great patience from the operator. The parents should be present during the testing in order to settle the child and provide the child with a model of cooperative behavior with the physician. The cooperation can also be improved by using age-appropriate relaxation techniques. For example, infants may relax with swaddling and the use of a pacifier. Having a favorite toy can comfort toddlers. School age and older children benefit when equipment is shown and explained prior to the procedure. ADM manometry is best performed without sedation [37]. However, in many children sedation is necessary, and midazolam has been shown to be effective with no or minimal influence on pressure measurement [43]. It is advisable to wait for complete child recovery from any drug effect before starting the motility tests. Finally, before starting the procedure it is important to obtain and verify a signed informed consent and it is also necessary to check that the fasting period has been of adequate duration. In healthy children an overnight fast is enough, whereas in infants at least 4 h are necessary to eliminate nausea, vomiting, and aspiration. In children on parenteral nutrition, it should be stopped 12 h prior to the study, because of the effect of nutrients on hormones, which may affect the intestinal motility [17]. Similarly, blood glucose levels should be carefully assessed since hyperglycemia inhibits gastric emptying and reduce the occurrence of phase III [44, 45].

Study Procedure

The manometric catheter can be placed either nasally or orally, but there is broad consensus that studies are better tolerated when the catheter is introduced through the nose. The catheter can also be placed through an existing gastrostomy, or jejunostomy. The manometric probe should be positioned deep enough in the small intestine in order to prevent its falling back into the stomach as a consequence of postprandial gastric distension or duodenal contraction (Fig. 11.4). The tube placement can be performed either fluoroscopically or endoscopically [37, 46]. Under fluoroscopy, the probe placement usually requires high skill to pass the pyloric region, which may be easier with a firm probe rather than a soft, flexible one. The former, however, is more difficult to advance beyond the duodenal bulb due to its acute angle. Moreover, a hard probe may cause greater discomfort during the recording time especially in young children. The addition of a weighted probe tip may facilitate the placement as it utilizes the advantage of gravity. The probe can be also advanced through the pylorus using an endoscope and biopsy forceps, taking care to use as little air as possible to insufflate the bowel, given that over-inflation may affect gastrointestinal motility and provoke a backward movement of the manometric probe. In some centers the manometric recording is performed the day after the tube placement with additional radiology confirmation to ascertain appropriate catheter position, allowing for correction if necessary.

During the manometric recording using a water-perfused system, the patients usually maintain the same position

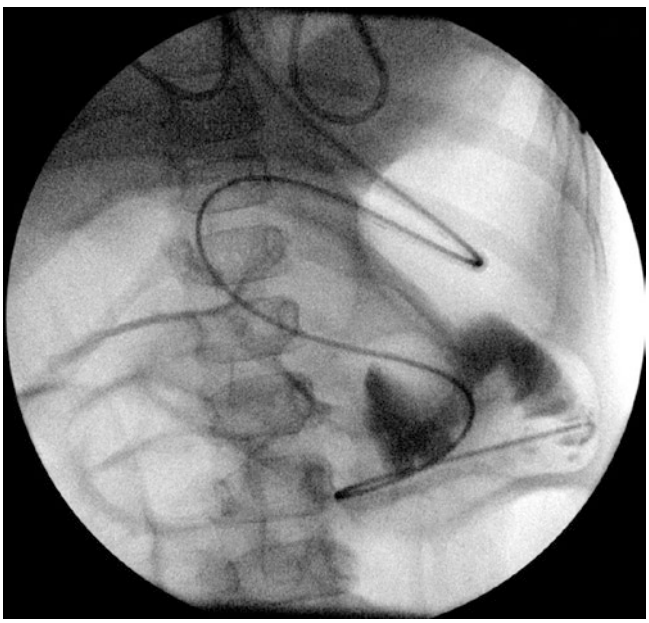

Fig. 11.4 Fluoroscopic placement of ADM catheter. Note the position of the tip is in the distal duodenum at level of the ligament of Treitz

(supine), whereas when using portable solid-state equipment the patients are encouraged to perform daily activities when possible [36, 37]. When using water-perfused system, patients require regular (4–6 hourly) electrolytes monitoring due to potential water toxicity [47].

Ambulatory manometry is usually performed for 24 h, whereas for stationary manometry, recording must be carried out until a phase III and/or clear-cut abnormalities are recorded. However, it is generally advisable to perform a fasting recording for at least 6 h (or two MMCs), and postprandial recording for at least 90 minutes [36, 37]. There is single study in children showing that ADM recording can be affected by the anesthetic drugs on the day of the catheter placement, suggestive of the need to perform extended recording on the following day, in selected patients [48].

The type and the size of meal should be adjusted according to patient's age and preference. In older children the test meal should be of at least 400 kcal, in order to ensure an adequate postprandial response in the small intestine lasting for at least 90–120 min [25, 36, 37]. In younger children the test meal should provide at least 10 kcal kg^{-1}. The meal should be balanced with at least 30% of calories provided as fat content. However, in some cases it is impossible to provide a predetermined volume to a patient, for example, one with severe gastrointestinal dysmotility and inability to tolerate oral or enteral feeding. Finally, if no phase III is recorded during fasting, a drug stimulation test should be performed using iv erythromycin (1 mg kg^{-1} over a period of 30 min), which is able to induce a gastric phase III and allows assessment of its migration in the small intestine [49, 50]. Other agents such as azithromycin, octreotide [51] amoxicillin/clavulanate, ghrelin, and neostigmine were also found to induce phase III activity, increase amplitude and duration of MMC; however, there is still a lack of adequate clinical experience in the use of these agents to allow for a general recommendation [49, 52–56].

Analysis of Manometric Recording

Both qualitative and quantitative analysis of the ADM tracings should be performed. Qualitative analysis includes the recognition of specific motor patterns as well as the overall characteristics of the fasting period (typical cyclical pattern of the MMC, characteristics of phase III activity including the total number of phase III occurrences, migration pattern, mean amplitude, mean peak velocity, and intervals) and fed period (presence of change in motility after test meal). Quantitative analysis includes the calculation of distal antral and duodenal motility indices (MI), expressing the contractile activity as the natural logarithm of the area under the manometric pressure peaks above a threshold pressure. Computerized data evaluation, including wave identification algorithms, artifact removal, and algorithms for detection of propagated activity offer an improved degree of objectivity in the analysis of pressure tracing and can facilitate the quantitative analysis of relevant parameters [57].

Table 11.1 Manometric features associated with gastrointestinal motility disorders

Interdigestive or fasting period
• Absence of phase III
• Short intervals between phase III
• Abnormal phase III
– Stationary
– Retrograde
• Non migrating burst of contraction
• Sustained simultaneous cluster of contractions
• Low amplitude contraction
Postprandial or fed period
• Failure to switch to postprandial period
• Postprandial hypomotility
– Low frequency of contraction
– Low amplitude of contraction
• Non migrating cluster of contraction

A normal motility pattern is defined as the presence of at least one MMC per 24 h of recording (it has been shown that almost 95% of normal children have phase III within 4 h fasting study), conversion to the fed pattern without return of MMC for at least 2 h after a 400-kcal meal, distal postprandial contractility (MI per 2 h >13.67), small intestinal contraction >20 mm Hg, and absence of abnormal findings described in Table 11.1 [58]. Therefore, the presence and characteristics of the MMC and its response to nutrients is used as a marker of enteric neuromuscular function.

Based on the findings of abnormal manometric features, various clinical/pathophysiological categories of abnormalities can be recognized [36, 37, 58]. In patients with *enteric neuropathy,* the motor activity is typically disorganized and/or uncoordinated. The most compelling finding is represented by the absence of a MMC during a sufficient recording time (ideally 24 h); however, this scenario is a rare event in patients with enteric neuropathy. More common findings include the presence of retrograde or uncoordinated phase III activity (Fig. 11.5), increased frequency of phase III (in adults and older children >1 MMC cycle per hour) (Fig. 11.6), presence of non-propagated bursts and sustained uncoordinated phasic activity, antral hypomotility, inability to establish a fed pattern after a test meal, and presence of phase III-like activity in the fed period. In patients with *enteric myopathy* the normal manometric patterns are usually preserved, but the amplitude of contractions in both preprandial and postprandial periods do not exceed 20 mm Hg (Fig. 11.7); however, low amplitude contractions may also represent a consequence of gut dilatation proximal to an obstructive segment. For this reason, the absence of dilated loops is a prerequisite for a diagnosis of enteric myopathy.

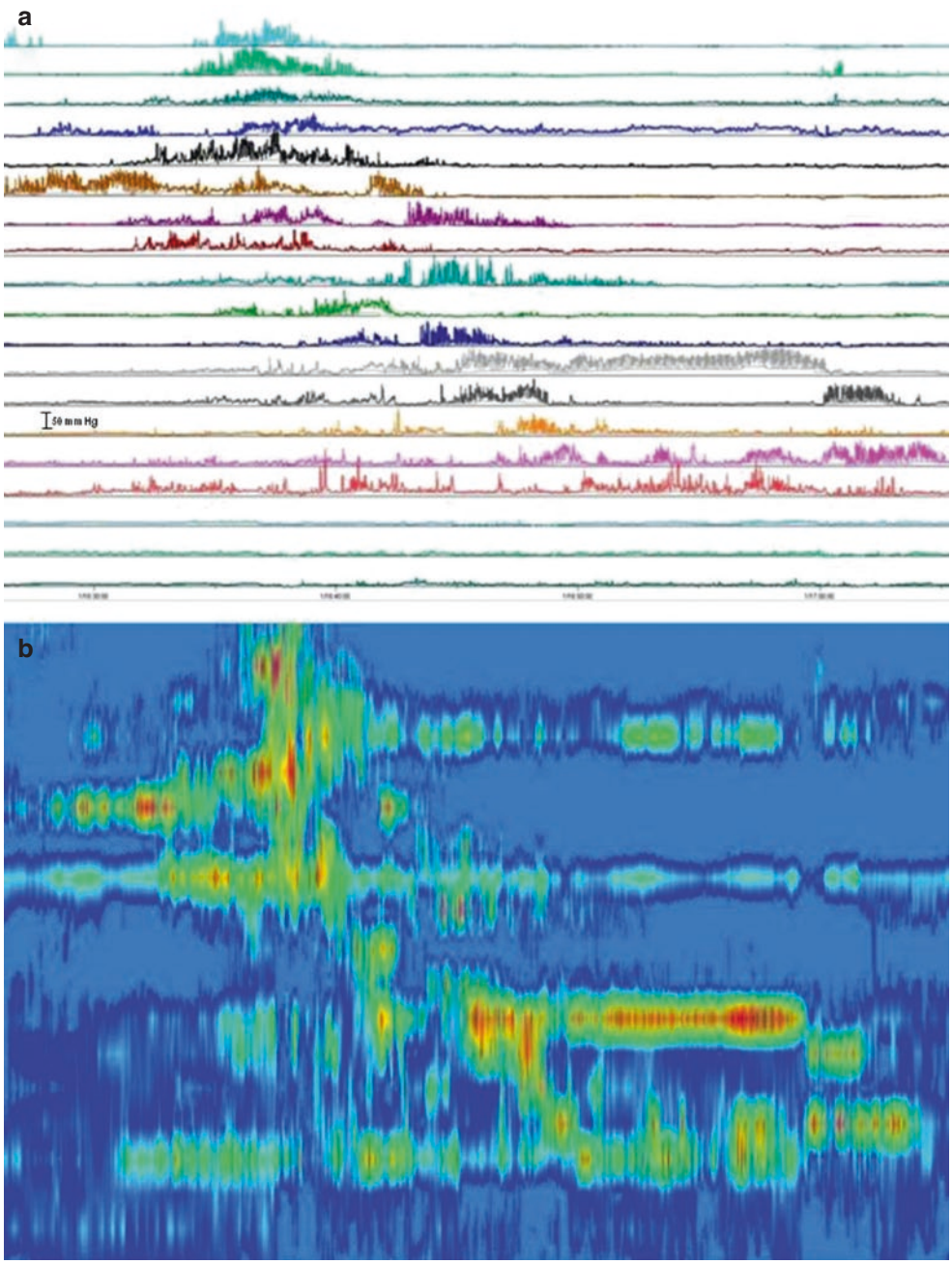

Fig. 11.5 Examples of conventional (**a**) and spatiotemporal plot (**b**) of an abnormal propagation of phase III in a child with neuropathic pediatric chronic intestinal pseudo-obstruction (PIPO). The fifth channel is localized in the antrum. The recording has been performed with a 20-channnel manometric catheter (side holes 2.5 cm apart)

Recently, the protocol for enhanced analysis of ADM contractile patterns, including a scoring system, was published [59]. The scoring system was able to discriminate between PIPO and non-PIPO patients, but also between distinct histopathological pathologies. However, further studies are needed on larger population to validate these results.

In patients with *mechanical obstruction,* multiple simultaneous giant contractions as well as the presence of simultaneous DCCs in the postprandial period are frequently reported. In neonates, the presence of high-amplitude retropropagated contractions should raise the suspicion of mechanical obstruction. In children with *CNS abnormalities,* it has been shown an abnormal frequency and propagation of phase III, increase proportion of nonpropagated DCCs, antral hypomotility, abnormal proportion between periods of phase I and II activity, and altered postprandial pattern duration with the presence of phase III-like activity [60]. Finally, in adult patients with *postvagotomy syndrome,* the most common manometric findings are an increased frequency of MMC, the absence of antral phase III and the presence of antral hypomotility after test meal, and altered postprandial pattern duration with a rapid return of MMC activity. An example of the different parameters that should be included in a manometric report is shown in Table 11.2.

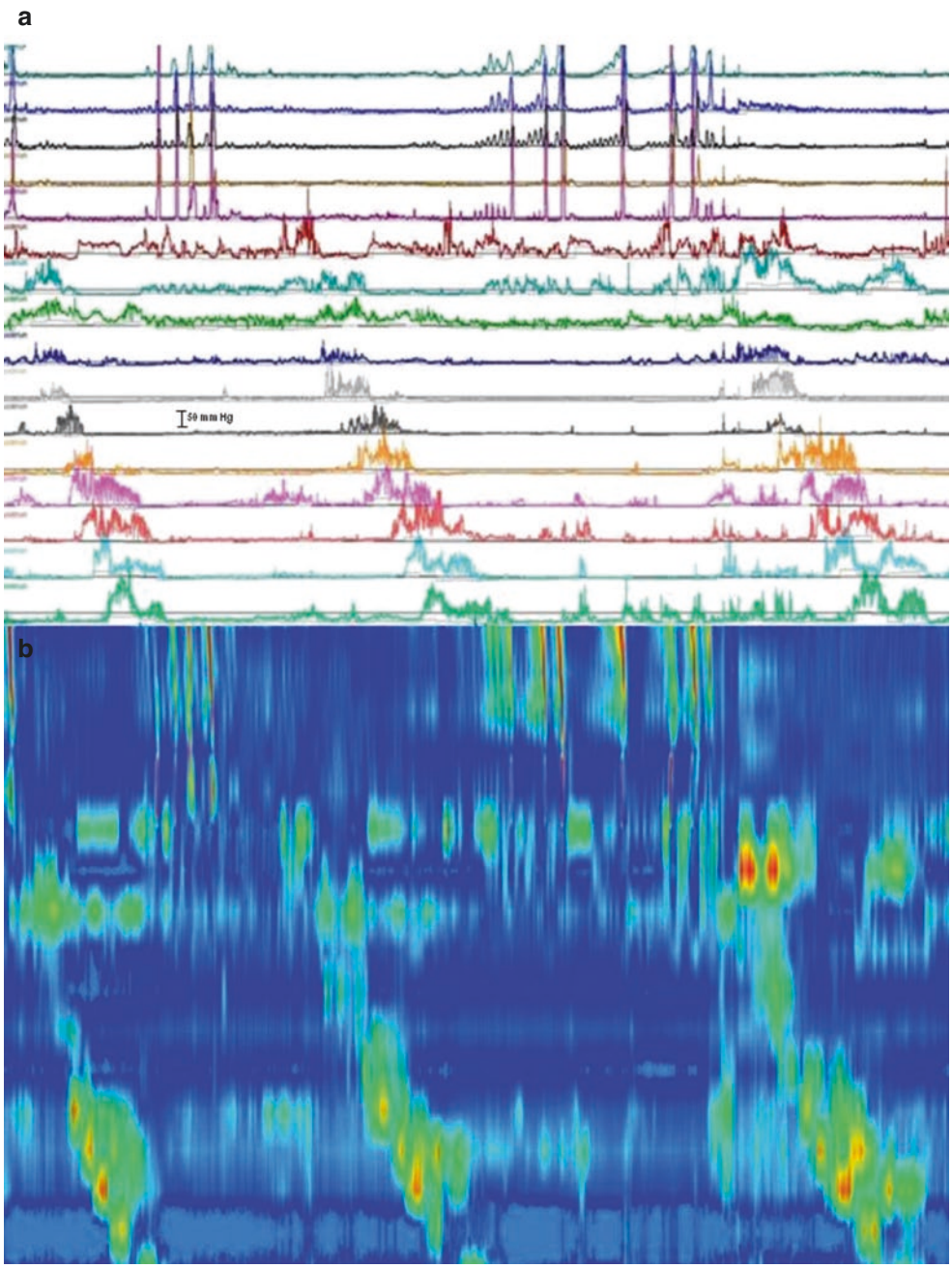

Fig. 11.6 Examples of conventional (**a**) and spatiotemporal plot (**b**) of short intervals of phase III child with chronic intestinal pseudo-obstruction. The phase III occurred separated by interval of 10–15 min. Note also the tonic component within phases III, which are defined as an elevation of the baseline more than 10 mm Hg for longer than 1 min. The recording has been performed with a 20-channnel manometric catheter (side holes 2.5 cm apart)

Reference Values

Prior to interpreting the recorded data and deciding whether abnormalities of gastric and small intestinal motor activity are present, it is of pivotal importance to define the spectrum of normality. Unfortunately, the lack of normal controls is an important limiting factor for the establishment of normal motility patterns, making the interpretation of manometric recording data difficult and subjective and occasionally leading to over-interpretation. However, some normal values have been published (Table 11.3). Although each center performing ADM should have an own set of normal values, it is suggested that "normal" ranges proposed by one group could be used by another if the investigation is performed and interpreted in the same way.

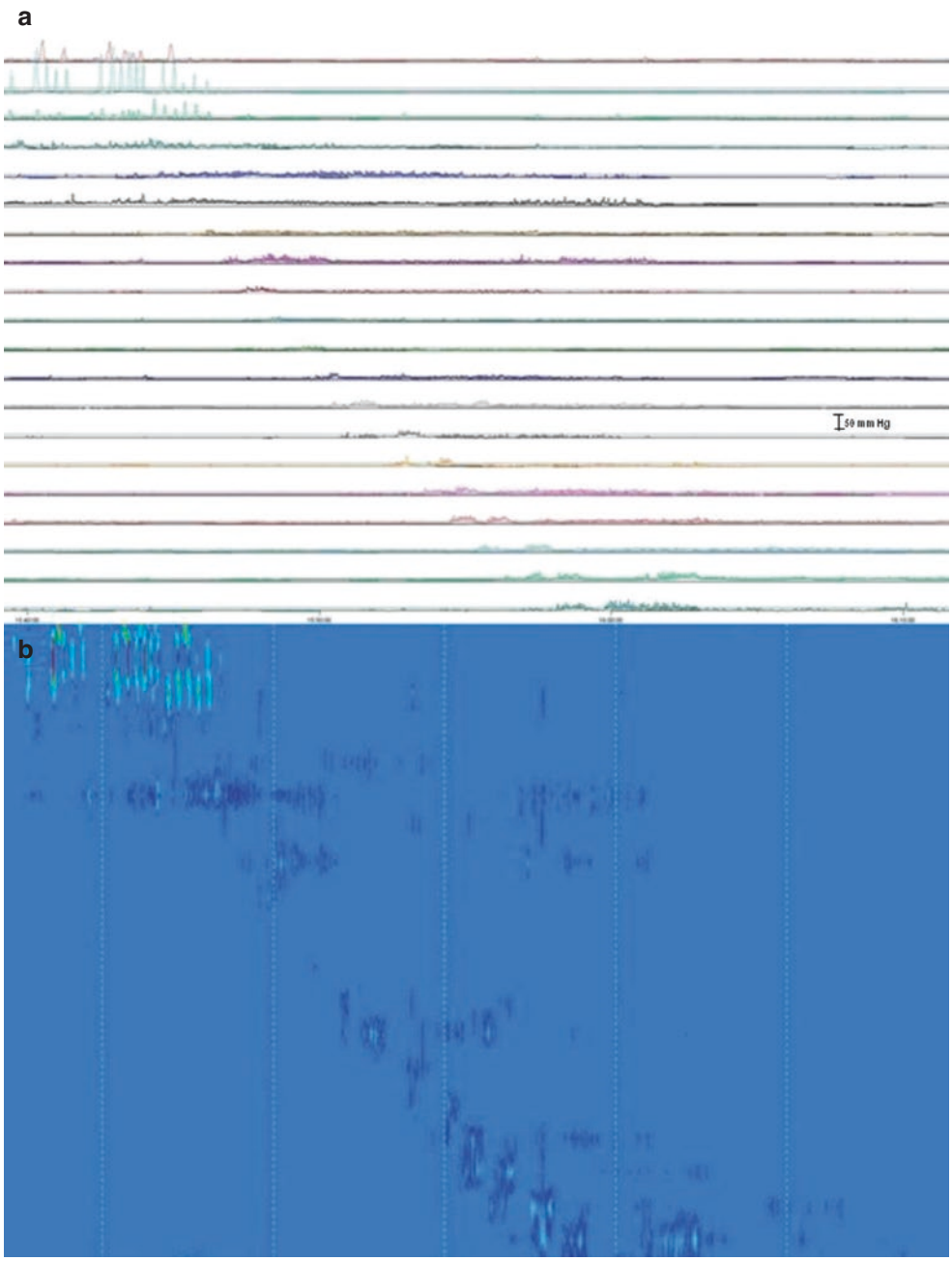

Fig. 11.7 Manometric tracing in a child with myopathy pediatric chronic intestinal pseudo-obstruction (PIPO). Note the low amplitude but normal propagation of the phase III and the paucity of other contractile activity in the small intestine in both conventional (**a**) and spatiotemporal plot (**b**). The recording has been performed with a 20-channnel manometric catheter (side holes 2.5 cm apart)

Table 11.2 Components of the report

General information
1. Patient ID
2. Date and time of the procedure
3. Referring physician
4. Medication used during the test
5. Person performing the study
6. Type of catheter used
7. Indications for the study
8. Study duration
9. Test meal (y/n); route of delivery; calories eaten
10. Catheter placement (nostrils/gastrostomy)
11. Position of the catheter tip (?Beyond DJ flexure)
12. Any significant symptoms reported
Fasting period: Analysis of 3 distinct phases of MMC (presence, propagation and duration):
1. Number and duration of cycles of all 3 phases
2. Phase III
– Highest contraction frequency of duodenum
– Highest contraction frequency of duodenum
– Highest contraction frequency of antral activity (normal 3 cpm)
– Highest amplitude (normal >20 mm hg)
– Presence of phase III
– Duration of phase III (normal 3–4 min)
– Number of phase III during the study
– Propagation of phase III (normal/abnormal)
3. Phase I
– Duration (normal 40–50 min)
4. Phase II
– Frequency
– Presence of discrete clusters of contractions
– Presence of single bursts of contractions (single, propagated, simultaneous)
5. Presence of symptoms
6. Drug stimulation
Postprandial
1. Start and end of the meal should be stated.
2. Presence of postprandial contraction pattern (fed-response)
3. Duration of postprandial phase (normal at least 2 h after meal ingestion)
4. Pre- and postprandial motility index (MI) calculated 30 min before and 30 min after test meal.
5. MI ratio (ratio between postprandial and preprandial motility index)
6. Amplitude ratio (ratio between postprandial and preprandial amplitude)
Interpretation

Table 11.3 Normal values for preprandial motor activity (mean and ranges) [8, 9, 12, 23]

Parameter	Infants	Children	Adolescents
Duration of phase 1—Small intestine (min)		12	
Duration of phase 2—Small intestine (min)		40	
Duration of phase 3 (min)			
• Antrum	3.5 (3–4)		
• Small intestine	3.5 (3–7)	4.4	5.0
Amplitude of phase 3 contractions (mm hg)			
• Antrum		131.8	
• Small intestine	20 (15–30)	55.3	35 (30–40)
Frequency of phase 3 contractions (contr./min)			
• Antrum	3.3 (3–3.5)		3 (2.5–3.5)
• Duodenum	12 (11–12.5)		11.3 (10.8–11.6)
Migration velocity of phase 3 (cm/min)			
• Stomach to duodenum	2 (1–4)		12 (7–30)
• Duodenum/jejunum	2.5 (1–5)		9 (3–15)
Interval of phase 3 (min)		103.9	100 (40–240)

Adapted from Tomomasa T. Antroduodenal manometry p 195–214. In Pediatric Gastrointestinal Motility Disorders. Hyman PE ed. Academy Professional Information Service

Indications

Although ADM is indicated in patients with otherwise undiagnosed gut motility disorders unresponsive to conventional therapies and whose quality of life is substantially impaired (by symptom severity and the diagnostic uncertainty), it is a rather cumbersome procedure to perform, not always easy to interpret, and practically useful in the clinical management of only a minority of patients. For instance, it has been shown in children that there is an excellent interobserver agreement for the number of fasting phase III and their measurement, whereas the interobserver agreement for the detection of other motor abnormalities, such as sustained phasic contraction and postprandial simultaneous clusters, is significantly low [61]. Therefore, given that the small bowel manometry requires expertise and dedicated equipment and personnel, it should be ideally performed in a limited number of referral centers with a specific interest in the field.

Table 11.4 Clinical indications for antroduodenal manometry

1. Clarify the diagnosis in patients with unexplained nausea, vomiting or symptoms suggestive of upper gastrointestinal dysmotility
2. Differentiate between neuropathic vs myopathic gastric or small bowel dysfunction in patients with chronic intestinal pseudo-obstruction.
3. Identify generalized dysmotility in patients with colonic dysmotility (e.g., chronic constipation), particularly prior to subtotal colectomy
4. Confirm diagnosis in suspected chronic intestinal pseudoobstruction syndromes when the diagnosis is unclear on clinical or radiological grounds
5. Assess for possible mechanical obstruction when clinical features suggest, but radiological studies do not reveal, obstruction
6. Determine which organs need to be transplanted (isolated vs multi-visceral transplantation) in patients with chronic intestinal pseudo-obstruction being considered for intestinal transplantation
7. Confirm a diagnosis of rumination syndrome

ADM serves to clarify a clinical diagnosis of abnormal motility or exclude a gastrointestinal (GI) motility disorder. There are only a few indications for the test (Table 11.4). Manometry is indicated in children with suspected chronic intestinal pseudo-obstruction in order to verify the diagnosis, clarify the pathogenesis, and optimize clinical management [62]. For instance, the presence of a myopathic pattern is an indicator of a poor response to enteral feeding, whereas the presence of MMC predicts clinical response to prokinetics therapy and success of enteral feeding [25, 63]. Manometric assessment may allow determination of the extent of disease (localized or diffuse) and the optimal route for nutritional support (gastric, enteric, or parenteral). ADM may be useful in guiding the intestinal transplantation strategy in children with chronic intestinal pseudo-obstruction by identifying the extent of GI dysmotility [25]. Severe gastric or duodenal motor abnormalities seem to compromise the postoperative course of the intestinal graft recipient. In patients with intractable constipation, ADM manometry should be performed if surgery is being considered, given that patients with small bowel dysmotility have generally a poor outcome after the surgery. ADM is also indicated in patients with recurrent subocclusive episodes, in order to differentiate a pseudo-obstructive syndrome from a mechanical obstruction, which may sometimes be overlooked even by an experienced radiologist [64]. Manometry is indicated in the investigation of children with severe unexplained gastrointestinal symptoms, such as vomiting, nausea, abdominal distension, and abdominal pain who fail to respond to an appropriate therapy, and in this context the test helps to differentiate between vomiting and rumination [65, 66]. For instance, in children with suspected rumination syndrome, the ADM is useful in confirming the diagnosis by showing a characteristic motor pattern, characterized by postprandial simultaneous pressure increases at all recording sites [65]. This is covered elsewhere in the book. There is evidence of the utility of ADM in investigating patients with orthostatic intolerance with associated GI symptoms, like nausea, vomiting, and abdominal pain [67, 68]. Finally, an entirely normal study in children clinically suspected of having a severe dysmotility syndrome may help to redirect the diagnostic effort, and may result in the consideration of other diagnoses such as fabricated or induced illness (formerly Munchausen's by proxy syndrome) [69, 70].

In adults, ambulatory ADM is often performed. It is a safe and useful tool and the most common indications for ambulatory ADM are chronic abdominal pain, slow-transit constipation, refractory gastroparesis, chronic diarrhea, recurrent episodes of subocclusion, postsurgical evaluation, suspicion of gut involvement in systemic disease, and unexplained nausea [71].

Conclusion

Antroduodenal manometry provides relevant physiological information on the neuromuscular activity of the foregut and is useful in diagnosing and guiding the management of enteric neuromuscular disorders. Because of the complexity in performing and analyzing ADM, it requires considerable experience and skills that may only be available in referral centers with a specific interest in the field of GI motility. The development of recording equipment and advanced computer analysis that are in progress appear to have the potential to substantially improve our understanding of normal and abnormal foregut neuromuscular function.

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