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# Manometry studies in children: minimum standards for procedures

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## OVERVIEW

Over the past decade, there has been a tremendous increase in our knowledge of normal and abnormal gastric, intestinal and colonic motility in paediatrics. Manometry tests are beginning to be used with increasing frequency in children of all ages. The equipment and study protocols utilized to test adults in most cases cannot be applied successfully to the investigation of children. This article reviews the factors to consider in performing motility studies in children. Minimum standards to be used in performing oesophageal, antroduodenal, colonic, and anorectal manometry are suggested.

## APPROACH TO THE PAEDIATRIC PATIENT

Manometry tests may produce worthless results if not tailored to paediatric patients. Infants and toddlers rarely cooperate with medical testing. It may be better to adapt the study to the patient rather than expect the patient to adapt to the specific study. Manometric patterns are difficult to interpret when crying and movement artefacts overlap and obscure intraluminal pressure changes. Threats ('if you don't do this, I'll have to do that') often worsen the situation. Instead, the examiner should attempt to calm the patient with entertainment appropriate to the patient's developmental stage. Crying infants can suck on a pacifier, nurse or drink from a bottle, or be comforted with rocking and swaddling. For long studies, parents may bring the child's favourite quiet-time activities and encourage happy play. Older children may benefit from slow, deep-breathing exercises, which focus the patient on the task of breathing and away from the noxious event.

In most cases, it is advisable to have the parents be present during testing. Parents give the child a sense of security and familiarity, and they provide the child with a model of cooperative behaviour with the examiner. 'Parentectomy' is counterproductive with the preschool child, unless the parent is histrionic and not behaving in the child's best interests. Most parents are happy to provide information about their child's coping methods and strategies that have worked in the past. They are willing to accept guidance on how best to support their child during the test session. With the parents present, the examiner can get an idea of child–parent interaction: is the parent comforting, neutral, or anxiety-provoking? Sometimes a toddler has a temper tantrum with the parents present, but promptly calms when they leave the room. Observing a disturbed caretaker–child interaction in conjunction with normal motility studies should lead to a careful examination of behavioural and mental health issues in concert with the medical evaluation.

Motility testing in the paediatric patient requires an examiner familiar with developmental and behavioural paediatrics as well as gastrointestinal motility. The examiner must attend to the procedure, but also to the child. It takes practice to gain the spontaneity and creativity to achieve the optimal outcome in both data

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acquisition and child comfort. These two outcomes are closely linked! The adult gastroenterologist without such practice may choose to collaborate with a paediatrician, child mental health professional, or child life specialist during test sessions.

### Sedation

When sedation is necessary, it is advisable to wait for the child to have recovered completely from the effects of the drugs before starting the motility tests. However, when anorectal manometry is performed to rule out a nonrelaxing internal anal sphincter, the test may be performed under sedation. Sedation with barbiturates, benzodiazepines, chloral hydrate, and ketamine does not affect the recto-anal inhibitory reflex. Narcotics should be avoided. Any drug with a known effect on gastrointestinal motility should be discontinued before testing.

### Equipment

There are two main methods to perform manometry studies in children. One requires the use of water perfusion with low compliance systems, and the other uses miniature strain-gauge pressure transducers mounted within thin catheters. Commercially available or custom-made catheters can be used and should be tailored to the child's size and the required test. Most laboratories use low-compliance capillary tubing perfused with a pneumohydraulic pump. The hydraulic capillary infusion system achieves high-fidelity recording of intraluminal pressure at infusion rates from 0.1 to 0.4 mL $min^{-1}$ of water per port. Such set up may provide an unacceptable amount of water to small babies or premature infants. During prolonged tests, such as antroduodenal and colonic manometry, even toddlers and young children are at risk for water intoxication. Successful adaptations to decrease the perfusion rate have been developed and perfusion rates as low as 0.02 mL $min^{-1}$ may be needed. One may also consider infusing balanced saline solutions instead of free water during prolonged studies.

The solid-state catheters have strain-gauge pressure transducers incorporated into specially designed catheters. The use of a microtransducer is convenient, the set-up and calibration are easy, and the pressures are recorded directly from the area and not transmitted through a water column. Stimulation artefacts are minimal. They can be used in an ambulatory setting for prolonged studies. Limitations of solid-state catheters include the high cost and the size; too large to be used in premature and full-term babies. There is very little experience with the use of solid-state catheters in children. Another disadvantage related to the use of ambulatory recording of antroduodenal and colonic motility is that on-line display is not available in some cases, and therefore it may not be detected that a catheter has migrated out of his original location until the study is completed and fluoroscopy is done or the data are downloaded.

## OESOPHAGEAL MANOMETRY[1–5]

### Indications

1 To diagnose achalasia and other primary motility disorders, such as diffuse oesophageal spasm and nutcracker oesophagus (Figs 1,2).
2 To assess oesophageal motor function in children and adolescents with dysphagia, odynophagia, and chest pain of noncardiac origin.
3 To assess the appropriate location at which a pH electrode for the recording of gastroesophageal reflux activity should be positioned, in particular when there is an anatomical malformation (i.e. hiatal hernia).
4 To evaluate the effect of pharmacologic or surgical treatment.
5 To aid in the diagnosis of diseases that may be associated with oesophageal dysmotility, like systemic sclerosis, polymyositis/dermatomyositis, or chronic intestinal pseudo-obstruction.

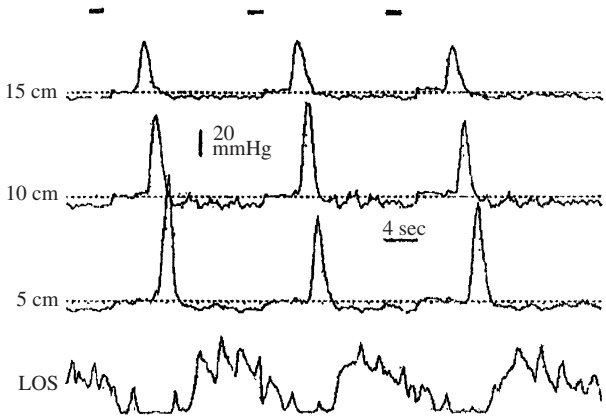


**Figure 1** Normal oesophageal manometry. There is a decrease in pressure of the LOS when the child swallows (–). There are normal amplitude peristaltic oesophageal contractions. Distance above LOS is indicated in cm.

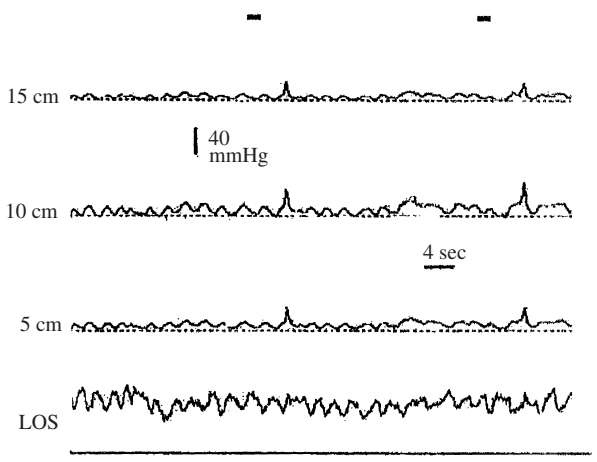


**Figure 2** Oesophageal manometry of a child with achalasia. There is a high LOS pressure, and there is absent peristalsis and lack of LOS relaxation after wet swallows (–). Distance above LOS is indicated in cm.

### Equipment

Water perfused and solid-state catheters should have at least three recording sites. Catheters should be tailored to the size of the child (recording sites 1 cm apart in premature babies, 3 cm apart in toddlers and children, 5 cm apart in adolescents).

### Performance of the test

Nasal placement in children > 4 months old, oral placement in younger infants. The fasting time depends on the age of the child (3 h in newborns, > 4 h in children).

Standard protocol:

- Station (slow) pull-through from stomach into oesophagus.
- 'Wet' swallows (1 mL in infants and 3–5 mL in older children) with one recording port in the lower oesophageal sphincter (LOS) and the remaining ports in the oesophageal body until LOS function is satisfactorily assessed.
- Peristalsis in the whole oesophageal body is then assessed.

### Parameters that should be measured

**1** Measurement of LOS pressure, which is performed relative to intragastric pressure.
**2** LOS relaxation upon swallowing.
**3** Oesophageal peristalsis with wet swallows.
**4** Unclear value of upper oesophageal sphincter measurements with standard catheters.
**5** Similar normal values in preterm babies, newborns, and older children.

### Components of the report

**1** General information (this section applies to the other tests as well)
- Patient identifiers.
- Date and time of the procedure.
- Referring physician.
- Medication used during the test.
- Person performing the study.
- Catheter used.
- Indications for the study.

**2** LOS
- Distance from mouth or nares to upper border of LOS.
- LOS pressure.
- LOS relaxation upon swallowing.

**3** Oesophageal body
- Characteristics of swallow-induced and non-swallow-induced contraction waves,including propagation, amplitude and duration of contractions.

**4** Comments.
**5** Interpretation.

## ANTRODUODENAL MANOMETRY[6–14]

### Indications

**1** To assess antroduodenal motility in children with chronic intestinal pseudo-obstruction (Figs 3–5).
**2** To assess antroduodenal motility when colectomy is considered for intractable constipation.
**3** To distinguish between rumination and vomiting.
**4** To assess antroduodenal motility in children with unexplained symptoms that might be related to motility problems.

### Equipment

Water-perfused catheters are preferred in view of the increased size and stiffness, and higher cost of the solid-state catheters. Virtually all paediatric data published in the literature regarding antroduodenal manometry have been obtained using water-perfused catheters. Catheters should be tailored to patient size and information needed (minimum one antral and three small bowel recording sites).

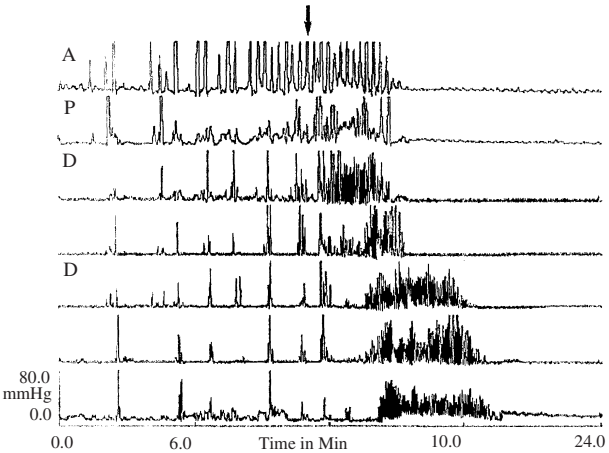


**Figure 3** Example of normal antroduodenal manometry. The arrow indicates a phase 3 of the motor migrating complex originating in the antrum and migrating distally. The phase 3 is followed by phase 1, characterized by motor quiescence, and is preceded by phase 2, with random contractions of varied amplitude. A, antrum; P, pylorus; D, duodenum.

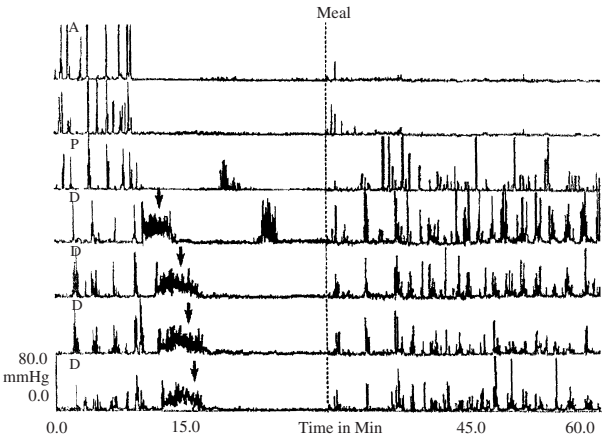


**Figure 4** Abnormal antroduodenal manometry. Example of postprandial antral hypomotility. There are no antral contractions after ingestion of a meal. The arrows indicate a phase 3 of the motor migrating complex during fasting A, antrum; P, pylorus; D, duodenum.

## Performance of the test

As an elective study, the test should be performed in the absence of intercurrent illnesses. A physician or a trained observer should stay with patient and family during the entire study. It is important to perform careful catheter taping to the child. When sedation is used for placement of the catheter, the test should wait for complete recovery from sedation. Recording

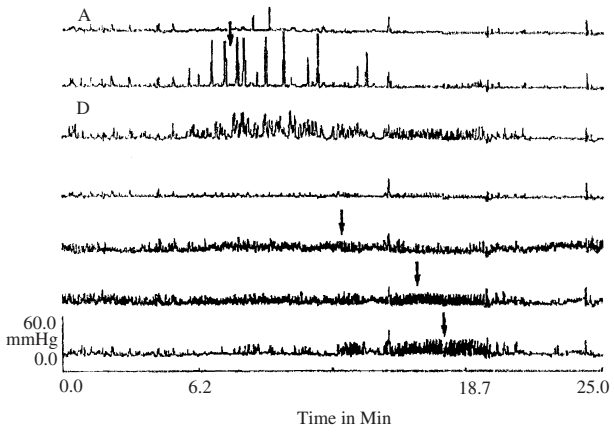


**Figure 5** Abnormal antroduodenal manometry. Example of myopathic form of pseudo-obstruction. There are very low amplitude contractions both in the stomach and duodenum. The arrows indicate a phase 3 of the motor migrating complex during fasting A, antrum; P, pylorus; D, duodenum.

should be extended over at least 3 h of fasting (or two migrating motor complexes [MMCs]) and at least 1 postprandial hour. The type and size of meal should be adjusted according to patients' age and preference (at least 10 kcal $kg^{-1}$ or 400 kcal; > 30% kcal from lipids). The meal should be administered by mouth or into the stomach if possible. Drug stimulation with intravenous erythromycin (1 mg $kg^{-1}$ over 30 min) should be given if no MMC is recorded during fasting.

## Components of the report

**1** General information
- Same as oesophageal manometry.

**2** Fasting period
- Maximal frequency and amplitude of gastric antral and duodenal contractions.
- Description of the duration and propagation of phase 3 if present, and absence of phase 3 if it does not appear.
- Abnormal patterns.
- Explanation of symptoms during the test, and any correlation with manometric events or with the environment.
- Test drug if given (motility response and symptoms).

**3** Postprandial period
- Nature of the meal and route of delivery.
- Start and end of the meal should be stated.
- Manometric patterns and symptoms.

**4** Interpretation.

## COLONIC MANOMETRY[15–18]

### Indications

1 To assess colonic motor activity in patients with persistent constipation unresponsive to conventional treatment and of uncertain cause (Figs 6–8).
2 To assess the presence or absence of colonic involvement in children with chronic intestinal pseudo-obstruction and to characterize the relationship between motor abnormalities and symptoms.
3 To determine the relationship between motor activity and persistent symptoms following surgery for Hirschsprung's disease or other colorectal problems.
4 To assess colonic motor activity prior to intestinal transplantation in order to find out whether or not the colon should be kept at the time of transplant.

### Patient preparation

The patient should be cleansed with colonic lavage solutions, avoiding enemas. Catheter placement should take place under endoscopic guidance. When sedation is used for catheter placement, complete recovery from sedation should occur before starting the test.

### Equipment

The catheter should be placed with the tip proximal to the splenic flexure, preferably throughout the colon. A perfused catheter with at least four recording sites is preferred. The number of and distance between recording sites depends on the length of the colon and where the catheter is placed. In most cases 10–15 cm distance between recording ports is adequate.

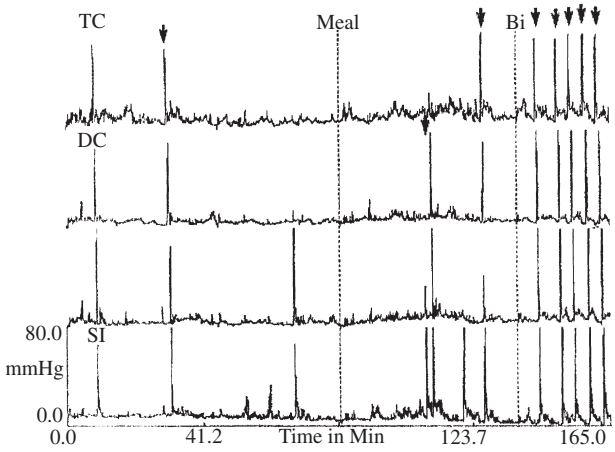


**Figure 6** Normal colonic manometry. There are high amplitude propagated contractions (arrows) before and after the meal and after intracolonic administration of bisacodyl. There is an increase in colonic motility in the postprandial period. TC, transverse colon; DC, descending colon; SI, sigmoid colon; Bi, bisacodyl.

### Performance of the test

A physician or trained observer should remain with the child and their family during the entire study. It is important to perform careful catheter taping. At least 1 h fasting and 1 h postprandial recording should be carried out. The type and size of meal should be adjusted according to patient's age and preference (at least 20 kcal $kg^{-1}$ or 1000 kcal; > 30% kcal from lipids). Drug stimulation with bisacodyl 0.2 mg $kg^{-1}$ with maximum of 5 mg should be administered if no high-amplitude propagated contractions (HAPCs) are observed during fasting or after ingestion of the meal. It is important to check the catheter placement before and after the test.

This study lends itself to both qualitative and quantitative interpretation.

### Components of the report

1 General information
- Same as oesophageal manometry.

2 Fasting period
- Quantity and characteristics of contractile activity.

3 Postprandial period
- Size and type of meal, route of administration.
- Presence of gastrocolonic response (increase of motility index).
- Presence of HAPCs and patient's behaviour during HAPCs.
- Other manometric patterns and symptoms.
- Test drug given (motility response and symptoms).

4 Interpretation.

## ANORECTAL MANOMETRY[19–27]

### Indications

1 To diagnose a nonrelaxing internal anal sphincter.
2 To assess anorectal motility in children with faecal incontinence due to suspected anatomical or organic disease.
3 To assess anorectal motility in patients having been operated on for Hirschsprung's disease who have obstructive symptoms or faecal incontinence, and to evaluate the effect of botulinum toxin injection into the anal sphincter.

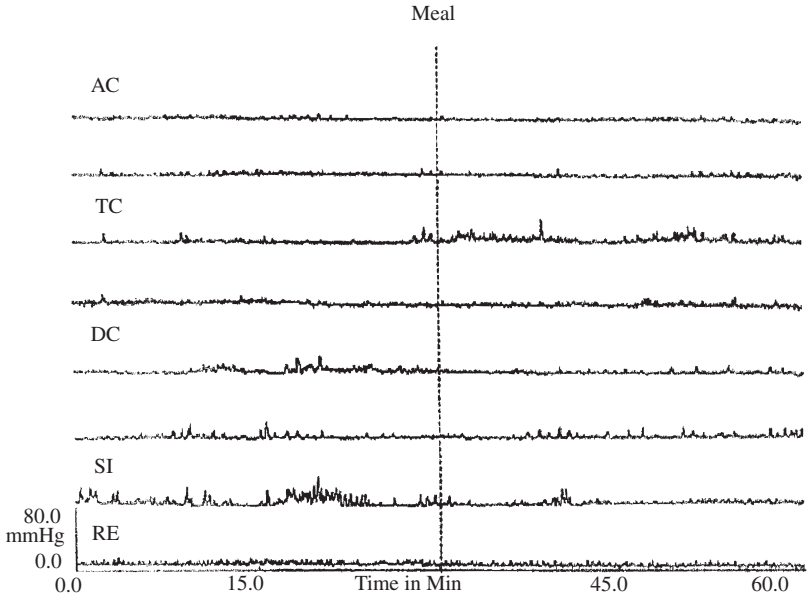


**Figure 7** Abnormal colonic manometry. There is paucity of colonic contractions during fasting and no increase in colonic motility after ingestion of a meal, indicating an abnormal gastrocolonic reflex. AC, ascending colon; TC, transverse colon; DC, descending colon; SI, sigmoid colon; RE, rectum.

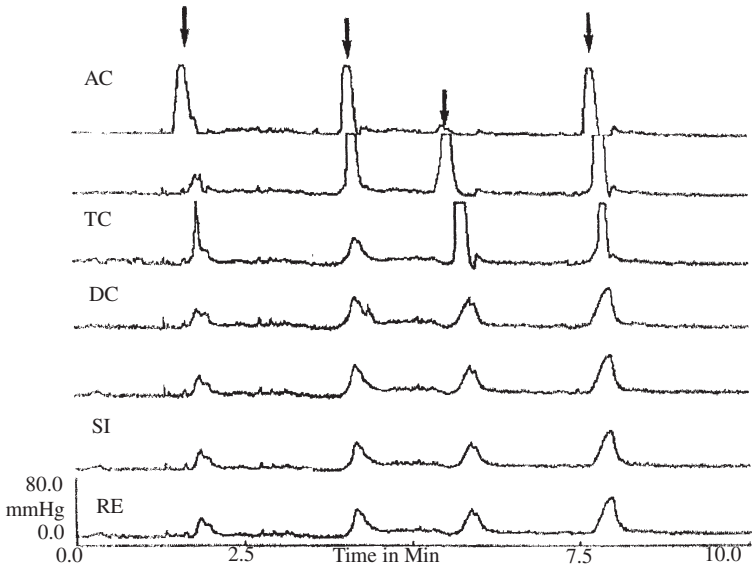


**Figure 8** Abnormal colonic manometry. There are high amplitude contractions (arrows) originating from the ascending colon and migrating only to the transverse colon. Contractions in the descending and sigmoid colon and rectum are low amplitude and simultaneous. AC, ascending colon; TC, transverse colon; DC, descending colon; SI, sigmoid colon; RE, rectum.

**4** To evaluate postoperative patients after imperforate anus repair.
**5** Used during biofeedback therapy in children with faecal incontinence.

## Patient preparation

No bowel preparation is needed in newborns or breast-fed infants. Clearance of stool from the rectum in older children should be performed**.** Sedation of an uncooperative child is occasionally necessary.

## Equipment

**1** Motility catheters
- Catheters: minimum 2 recording ports, one in the rectum and one in the anal canal.
- Newborns: the first sidehole is 10 mm below the tip, the next sidehole 20 mm below the first sidehole. A small 1 cm × 1 cm latex balloon is inserted as far up into the rectum as possible to be sure that the balloon is not lying inside the anal canal. Children: at least three recording ports separated by 10 mm, radially

orientated. A balloon can be attached to the perfused catheter or to the end of a thin polyethylene tube and tied to the motility probe.

2 Balloon (caution should be exercised regarding latex allergy).
   • Newborns: Balloon is $1 \times 1$ cm when deflated. Toddlers and older children: balloon is usually $3 \times 5$ cm when deflated, placed into the rectum above the perfused catheter or firmly attached to the catheter.

## Parameters that should be measured

1 Anal resting pressure, squeeze pressure, and anal canal length
2 Effect of rectal distension on anal resting pressure and rectal sensation
   • Rectosphincteric reflex (RSR) or rectoanal inhibitory reflex (RAIR).
   • Transient rectal sensation, defined as the smallest volume of balloon distension that the patients perceives in 2/3 trials.
   • Initial urge to defecate.
   • Sensation of a lasting/strong urge to defecate (critical volume).
3 Defecation dynamics
   • Evaluation of the external anal sphincter and pelvic floor during straining for defecation.

## Performance of the test

1 Newborns with suspected Hirschsprung's disease: anal resting pressure and the rectosphincteric reflex are evaluated.
2 Infants and toddlers: the rectosphincteric reflex, anal resting pressure, and the effect of rectal distension on the urge to defecate or withholding manoeuvre are evaluated.
3 Children $\geq 5$ years of age with chronic constipation with or without encopresis or with faecal incontinence due to underlying organic or neurological disease, and children who have undergone surgery to repair an anorectal malformation or Hirschsprung's disease should have all parameters assessed.

## Anal resting pressure, squeeze pressure, and anal canal length

1 Anal resting pressure
   • Anal resting pressure is defined as the pressure in mmHg at the troughs of the waxing and waning pressures and is highest 1–1.5 cm above the anal verge in children.
   • Maximal squeeze pressure (Fig. 9). The maximal squeeze pressure in mmHg is measured either as the maximal highest pressure increase above anal resting pressure or as the average of the three highest squeezes.
   • Anal canal length (Fig. 10). The anal canal is defined as the region with resting pressure at least 5 mmHg higher than the pressure in the rectum. The length of the anal canal is determined by the distance of this pressure increase from the anal verge.
2 Effect of rectal distension on anal relaxation and rectal sensitivity
   • The size and the type of the balloon and the location of the balloon in the lower bowel affect the results of all parameters measured with balloon distension, so normal values vary from laboratory to laboratory.

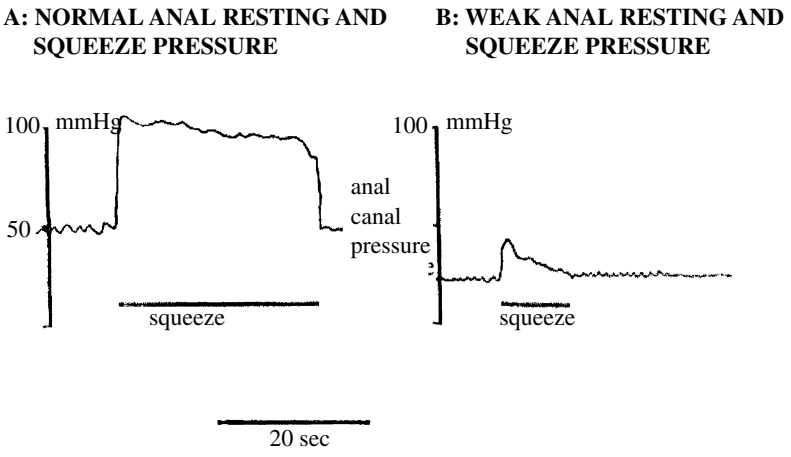


**Figure 9** Pressure recordings from the anal canal. (A) A healthy child with normal anal resting pressure, who can squeeze the external anal sphincter; (B) a child who had previous surgery for anal atresia with low anal resting pressure and a weak and short voluntary squeeze.

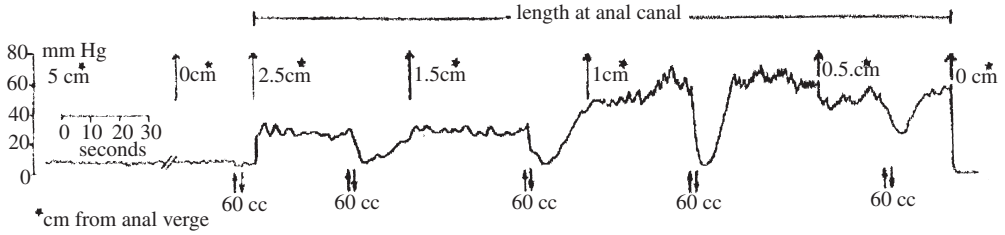


**Figure 10** Pressure recording from the lower rectum and anal canal. As the recording transducer is retracted stepwise at intervals of 0.5 cm from the rectum into the anal canal, a sharp rise in pressure indicates the entering of the anal canal, 2.5 cm from the anal verge. The high pressure in the anal canal is maintained throughout the length of the anal canal. The highest anal pressure is recorded 1 cm above the anal verge. The intervals of withdrawal are marked by the vertical arrows (↑). The anal canal exhibits reflex relaxation in response to rectal distension. Transient rectal balloon distension with 60 mL air is marked with double arrows (↑).

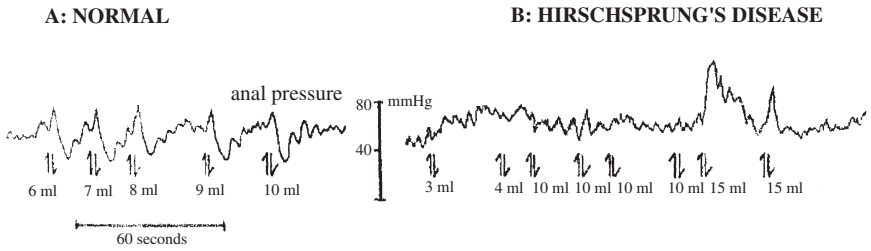


**Figure 11** Examples of anorectal manometry in a normal newborn and in a newborn with Hirschsprung's disease. The arrows indicate air distension of a rectal balloon for 1 second. (A) Rectal balloon distension produced an immediate relaxation of the internal anal sphincter seen as a decrease in anal pressure. The presence of the rectosphincteric reflex rules out Hirschsprung's disease as a cause of this newborn's symptoms. (B) Distension of a rectal balloon produces no decrease in anal pressure. The absent rectosphincteric reflex suggested Hirschsprung's disease in this newborn, which was later confirmed by the absence of ganglion cells in the rectal biopsy.

- The rectosphincteric reflex (RSR) also called the rectoanal inhibitory reflex (RAIR) (Fig. 11). The minimal amount of air in ml required to elicit the threshold of the RSR/RAIR (≥ 5 mmHg relaxation of anal pressure) is evaluated by rapidly inflating the balloon with air in random order, starting each time at 0 mL.
- Newborns: distension volumes up to 15 mL are used. Infants: distension volumes up to 30 mL, occasionally up to 60 mL, are used. Older children: distension volumes up to 60 mL. Occasionally, if reflex is not demonstrated, the balloon is further inflated until the patient reports sensation, or resistance to distension is perceived.
- Threshold of transient rectal sensation. The amount of air required to produce a transient rectal sensation is determined by inflating the rectal balloon two to three times transiently with volumes up to 60 mL in random order, starting each time at 0 mL. The threshold of transient rectal sensation represents the smallest volume required to perceive the distension.
- Initial urge to defecate. The minimal amount of air required to produce a sensation of an initial urge to defecate is determined by stepwise adding initially 10 mL air up to 60 mL and then 30 mL each 10–15 s into the rectal balloon.
- Lasting/strong urge to defecate/critical volume. The minimal amount of air required to produce a sensation of a lasting urge to defecate (critical volume) is determined by stepwise adding initially 10 mL air up to 60 mL and then 30 mL each 10–15 s into the rectal balloon.

**3** Evaluation of the defecation dynamics

- Studies of the external anal sphincter and pelvic floor during straining for defecation (Fig. 12). The child is asked to strain down as if defecating and to squeeze (tighten up) at least three times each in random order. During a squeeze, the anal pressure increases and rectal pressure remains stable. During a normal defecation attempt, the anal pressure decreases and rectal pressure increases. During an abnormal defecation attempt anal pressure and rectal pressure increase.

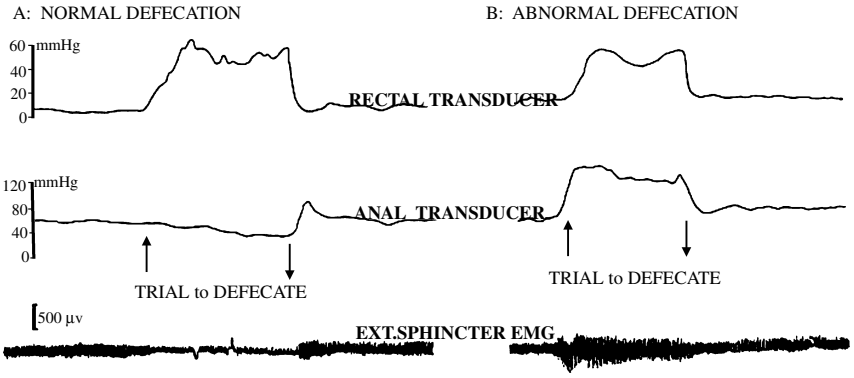


**Figure 12** The tracings show the pressure changes in the rectum and anal canal and the electromyographic changes of the external anal sphincter during trials to defecate. The duration of the defecation trial is indicated by the arrows. (A) Normal defecation consists of increased rectal (intra-abdominal) pressure, decreased anal pressure, and decreased external anal sphincter EMG activity. (B) Abnormal defecation consists of increased rectal (intra-abdominal) pressure, increased anal pressure, and increased external anal sphincter EMG activity.

## Components of the report

**1** General information
Same as oesophageal manometry
**2** Anal measurements:
- Anal resting pressure (mmHg) measured with slow pullthrough
- Squeeze pressure: maximal or average of 3 highest squeezes (mmHg)
- Anal canal length (cm)

**3** Balloon measurements
- Indicate the presence or absence of the recto-sphincteric or rectoanal inhibitory reflex
- Threshold of the rectosphincteric or rectoanal inhibitory reflex (ml)
- Threshold of transient rectal sensation (ml)
- Initial urge to defecate (ml)
- Sensation of a lasting urge to defecate/critical volume (ml)

**4** Defecation test
- Indicate the presence or absence of anal sphincter dyssynergia

**5** Interpretation

## ACKNOWLEDGMENT

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