# Digestive Tract

6

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## 6.1 Gastroesophageal Reflux Scintigraphy ("MILK SCAN")

### Clinical Indications [1, 2]

GER scintigraphy, is a sensitive, noninvasive, physiologic, direct technique indicated to detect GER and possible pulmonary aspiration in children with:

- Signs and symptoms suggesting gastroesophageal reflux disease (GERD).
- Recurrent lower respiratory tract infections.
- Recurrent vomiting.
- Failure to thrive.
- Apparent life-threatening events (ALTE).

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### Pre-Exam Information

- Feeding route: Orally, through nasogastric (NG) or permanent gastric tube.
- Volume and composition of a regular meal.
- Does the child have a milk allergy?
- Barium study performed in the previous 48 h?

**Study Protocol for GER Test ("Milk Scan") [3]**

**Patient Preparation:**

- Older children: 4–6 h fast
- Young infants: The study should be scheduled to replace a normal feeding, assuming the infant is fed every 3–4 h.
- Bring a feeding bottle with the child's regular meal such as cow milk, expressed breast milk, milk-based formula, and an additional empty bottle.
- Children allergic or intolerant to milk: orange juice or other liquid meal substitutes can be used.

**Radiopharmaceutical, Administered Activity, Mode of Delivery**

*Radiopharmaceutical:*

- [$^{99m}$Tc]sulfur colloid (SC)—is recommended.
- Alternative: [$^{99m}$Tc]Sn colloid, [$^{99m}$Tc] phytate.


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*Activity:*
- A fixed dose of 9.25 MBq (0.25 mCi) for SC is recommended by the SNMMI. The EANM pediatric dose card uses patient weight to calculate the dose.
- Refer to the EANM pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

  Reference to national regulation guidelines, if available, should be considered.

*Mode of Delivery—Feeding the Child:*
- Added to 1/3–1/2 of the normal milk or formula feeding volume.
- Introduce this labelled portion to the stomach by oral feeding or, in children with feeding difficulties, through a NG tube (to be removed after feeding) or through an existing gastric tube.
- Continue feeding from a separate bottle containing the remaining non-labelled portion of the meal.
- The total meal volume should be similar to the volume the child is given for regular meals.
- Ideally, feeding should be completed within 10–15 mins.
- When possible, young infants should be burped before imaging.
- Placing disposable absorbent sheets lined on one side with plastic material over the neck, chest, and abdomen can contain potential contamination.

**Acquisition Protocol:**
- Position: Supine.
- Posterior views with the detector behind the patient.
- Field-of-view (FOV): Chest and upper abdomen.
- *Acquisition parameters:*
  - Posterior dynamic images for 60 mins, 10–30 s/frame, matrix 128 × 128.
  - 1-h static anterior and posterior views of the chest, immediately after dynamic study, for an acquisition time of 3–5 mins, matrix 256 × 256.
  - 2–4 h static anterior and posterior views of the chest, after completion of the meal, for an acquisition time of 3–5 mins, matrix 256 × 256.
  - 24-h static images can be obtained as well.
  - Markers placed over suprasternal notch and xiphoid and/or $^{57}$Co transmission image of the thorax can be used to improve orientation and help determine the reflux level and to adequately localize ectopic activity over the chest.

## Study Interpretation

- New appearance of tracer activity in the esophagus indicates an episode of GER.
- If reflux is detected the following parameters should be recorded:
  - Number of episodes.
  - Level of reflux: proximal or distal esophagus, oropharynx.
  - Intensity of reflux: mild, moderate, severe.
  - Volume of reflux: can be calculated by drawing a region-of-interest (ROI) over the activity in the esophagus and over the activity in the esophagus and stomach.
- Estimate the residence time of the GER by dividing the number of frames showing tracer activity in the esophagus by the total number of frames.

- Tracer localization in the tracheobronchial tree or in the lung parenchyma can be suggestive of pulmonary aspiration.
- Including the stomach in the FOV allows calculation of "milk based" gastric emptying (GE) rates.
- Visual inspection can be aided by creating a time-activity curve (TAC) from a ROI placed over the esophagus.

## Correlative Tests and Imaging

- Extended esophageal pH monitoring:
  - Requires placement of a transnasal pH catheter into the esophagus to measure the pH over 24 h.
  - Extended monitoring provides an accurate estimation of the residence time of gastric content in the esophagus.
  - A drop in esophageal pH below 4 is suggestive of an acid reflux episode.
  - Limitations: invasive nature; inability to detect episodes of nonacidic reflux which have been associated with several pulmonary manifestations of GERD.
  - Intraluminal esophageal electrical impedance electrodes placed on a NG tube detect both acidic and nonacidic retrograde flow in the esophagus and are often coupled with esophageal pH monitoring thus increasing the sensitivity of the study.
- Barium contrast radiography:
  - It is less sensitive in detecting reflux episodes and pulmonary aspiration.
  - It can show anatomical conditions that produce symptoms similar to GERD (pyloric stenosis, malrotation, etc.).
  - It can assess GER complications such as esophagitis and esophageal strictures.

### Red Flags

- Extra care should be taken to avoid external contamination due to spillage of labelled milk during feeding or due to vomiting or regurgitation.
- The continuation of feeding with the non-labelled portion of the meal plays an important role by clearing residual tracers from the oropharynx and esophagus prior to imaging.
- A child with feeding difficulties should be fed using a NG tube.
- If the child is fed through a naso-jejunal tube this should be replaced by a NG tube prior to the study.
- Posterior views with the detector behind the patient are less intimidating to the children, allowing them to comfortably communicate with their parent/caregiver or staff during acquisition.
- Reflux episodes appear as sharp peaks. Patient motion can introduce significant errors in this analysis.
- This study has a low detection yield for the detection of aspiration. Contamination artifacts over the lungs can be erroneously interpreted as pulmonary aspiration or prevent detection of such aspiration.
- GER scintigraphy can also diagnose gastric dysmotility providing the stomach is included in the FOV.

## Take Home Messages

- GER scintigraphy is a low dose, simple, sensitive, and physiologic study that can diagnose all three related conditions: GER, pulmonary aspiration, and gastric dysmotility.
- SC is not absorbed by the GI or pulmonary mucosa and remains stable in the acidic medium of the stomach.
- Scintigraphy, with its long imaging time, can help diagnose GER, an intermittent phenomenon.
- Static images performed at 1 and 2 h, and potentially 24 h after administration of the radioactive meal aim to detect subtle pulmonary aspiration that was not evident in the early, dynamic images.

## Representative Case Examples

### Case 6.1. Severe Gastroesophageal Reflux Disease (Fig. 6.1)

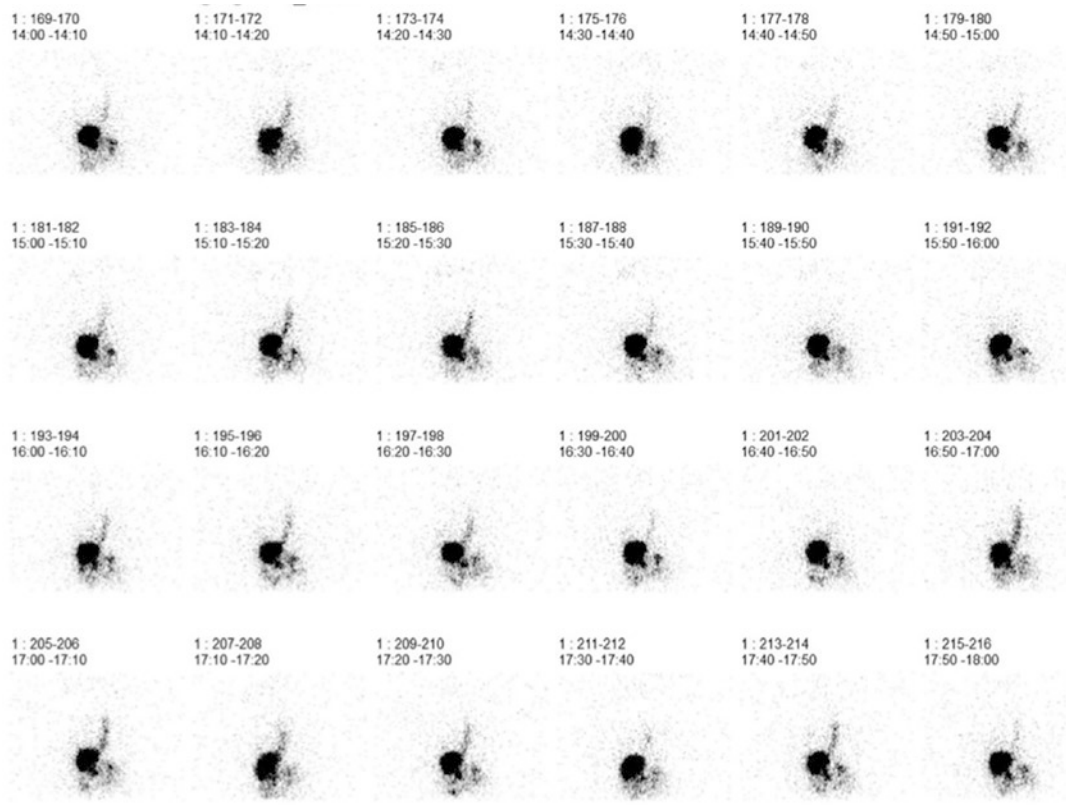


**Fig. 6.1** History: An 8-year-old child with Trisomy 21 and Moya-Moya disease. Aspiration was noted on a recently modified barium swallow test. A milk scan was performed to assess for GER after administration of 18 MBq [Tc]Sn colloid in a volume of feed of 230 ml given through a nasogastric tube which was removed before the reflux search. Study report (only the frames recorded from 14 to 18 mins are shown): Reflux reaching the proximal esophagus is seen on most of the 360 frames recorded during the observation period. The longest reflux lasts 170 s. The refluxes contain up to 9 and 11% of total activity. Impression: The findings are consistent with very severe GER

## Case 6.2. Pulmonary Aspiration (Fig. 6.2)

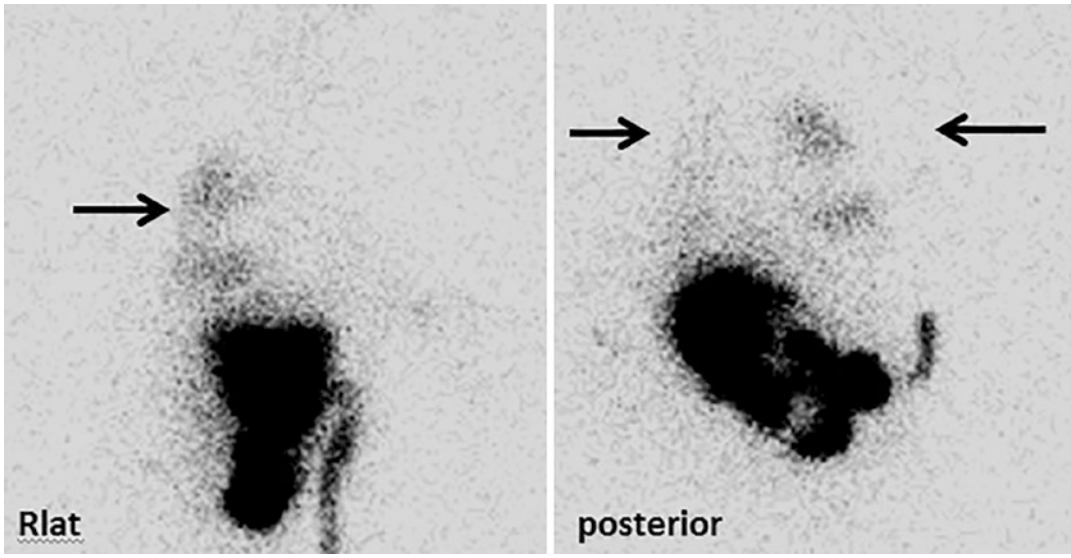


**Fig. 6.2** History: A 12-year-old boy with spastic cerebral palsy and failure to thrive presented with swallowing difficulties. A GER study was performed to assess if GERD was the cause for his failure to thrive. The tracer and a milk-based meal were given orally. Study report: Multiple refluxes were observed during the GER study that frequently reach buccal level (not shown). Posterior static images recorded at the end of the reflux search (left) and at 2 h after tracer administration (right), demonstrate a large amount of tracer activity in the bronchial tree (arrows), more on the right. Impression: The findings are consistent with pulmonary aspiration

## 6.2 Gastric Emptying

### Clinical Indications [4]

- Determination of the gastric emptying rate in children with suspected gastric dysmotility:
  - Solid GE is considered more reliable and is the preferred study in older children and adolescents.
  - Liquid GE (better referred to as a semisolid meal), mostly milk based, is the only study that can be performed in infants and young children.

### Pre-Exam Information

- History of food allergies, especially to milk or eggs.
- Feeding route: orally, NG tube, permanent gastric tube.
- Medications: some drugs such as proton pump inhibitors can affect GE.
- The referring physician should be consulted on whether the gastric motility should be assessed with or without medication intake.

**Study Protocol for Liquid Gastric Emptying Test [1, 4, 5]**

**Patient Preparation:**

- Older children: 4–6 h fast.
- Infants and young children:
  - Plan the study to replace scheduled feeding (assuming the infant is fed every 3–4 h).
  - Bring the child's regular meal (cow milk, human milk, milk-based formula) in his/her regular feeding bottle and an additional empty bottle.

**Radiopharmaceutical, Administered Activity, Mode of Delivery**

*Radiopharmaceutical:*

- [$^{99m}$Tc]sulfur colloid (SC)—is recommended.
- Alternative: [$^{99m}$Tc]Sn colloid, [$^{99m}$Tc] phytate.

*Activity:*

- A fixed dose of 9.25 MBq (0.25 mCi) for SC is recommended by the SNMMI. The EANM pediatric dose card uses patient weight to calculate the dose.
- Refer to the pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

  Reference to national regulation guidelines, if available, should be considered.

*Mode of Delivery:*

- Added to 1/3–1/2 of the normal milk or formula feeding volume.
- Introduce this labelled portion to the stomach by oral feeding or, in children with feeding difficulties, through a NG tube (to be removed after feeding) or through an existing gastric tube.
- Continue feeding from a separate bottle containing the remaining non-labelled portion of the meal.
- The total meal volume should be similar to the volume the child is given for regular meals.
- Ideally, feeding should be completed within 10–15 mins.
- When possible, young infants should be burped before imaging.
- Placing disposable absorbent sheets lined on one side with plastic material over the neck, chest, and abdomen can contain potential contamination.
- Older children allergic or intolerant to milk: orange juice or other liquid meal substitutes can be used.

**Acquisition Protocol:**

*Liquid gastric emptying*—GE with milk or formula is often performed simultaneously with evaluation of GER.

**Acquisition Parameters:**

- Position: supine, secured to the imaging bed.
- FOV: should include the abdomen. If possible, the chest should be in the FOV when the study is also performed to evaluate GER.
- Acquisition parameters:
- Posterior view.
- Dynamic images for 60 mins, 10–30 s/frame, matrix 128 × 128.
- Static images at 1 and 3 h, matrix 256 × 256.
- Older children: anterior and posterior 1-, 2-, and 4-h static images of the stomach and chest over 3–5 mins, matrix 256 × 256.
- Infants: posterior images only at 1 and 3 h.

## Study Processing and Interpretation [6–8]

- Percent GE values are calculated by placing separate ROIs over the stomach and bowel activity and further dividing the bowel counts by the sum of the gastric and bowel counts.
- Normal reference values for liquid GE in infants and young children up to 5 years old are not defined but "pseudo"-normal values derived retrospectively from a large study group of children are currently used [8].
- Normal liquid GE was defined retrospectively as >50% at 1 h and > 80% at 3 h post-feeding.

### Study Protocol for Solid Gastric Emptying Test [1, 4, 5]

**Patient Preparation:**

- Older children: 4–6 h fast.
- Young children: plan the study to replace scheduled feeding (assuming the infant is fed every 3–4 h).

**Radiopharmaceutical, Administered Activity, Mode of Delivery**

*Radiopharmaceutical:*

- [$^{99m}$Tc]sulfur colloid (SC)—is recommended.
- Alternative: [$^{99m}$Tc]Sn colloid, [$^{99m}$Tc] phytate.

*Activity:*

- A fixed dose of 9.25 MBq (0.25 mCi) for SC is recommended by the SNMMI. The EANM pediatric dose card uses patient weight to calculate the dose.

  Refer to the pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

  Reference to national regulation guidelines, if available, should be considered.

*Mode of Delivery:*

- The standard meal used for adults can be adapted for pediatric studies:
  - 120 grams of egg white
  - 2 toasted slices of white bread
  - 30 grams of strawberry jam
  - 120 ml of water
- Alternative (in cases of egg allergy or intolerance): meal based on bran, pudding, chocolate crispy cake, yogurt, cheddar cheese.

**Acquisition Protocol:**
- The adult protocol for solid gastric emptying should be used when possible.
- Static upright anterior and posterior views of the upper abdomen are acquired for 1 min at: time 0 (immediately) and at 1, 2, 3, and 4 h after meal ingestion.

## Study Processing and Interpretation [6–8]

- GE measurements are based on gastric counts derived from the geometric mean of anterior and posterior 1 min static images in the upright position.
- Normal values of residual stomach activity at 1, 2, 3, and 4 h with a standard solid meal are available for adults. These values were validated in a large group of pediatric patients, and it has been shown that these criteria can be applied to pediatric patients.
- These values are:
  - 37–90% at 1 h
  - 30–60% at 2 h
  - Less than 30% at 3 h.
  - Less than 10% at 4 h.

## Correlative Imaging

- GE scintigraphy is the gold standard for the assessment of functional abnormalities in gastric motility.
- Upper GI endoscopy can assist in excluding other causes of motility disorders such as esophagitis, gastritis, or masses.
- Conventional radiologic imaging techniques are used for the evaluation of anatomical malformations that cause motility disorders.
- Barium contrast radiography specifically is used to exclude anatomical abnormalities which could mimic functional abnormalities such as malrotation, stenoses, etc.

## Red Flags

- Meal standardization is essential for the scintigraphic evaluation of GE as well as for any meaningful comparison of follow-up studies.
- The most stable label is achieved by cooking the radiopharmaceutical with egg whites. Cooking with whole egg results in lower labelling stability.
- Alternative meals given to children with egg allergy or intolerance are less standardized and the labelling stability may be significantly lower.
- If vomiting occurs during the study, the calculated gastric residuals may be inaccurate.
- In infants posterior views are sufficient because of the small body habitus. They are more comfortable and allow easy access to technologists and caregivers.
- In older children, acquisition of both anterior and posterior views allows for a more precise assessment of gastric activity from the geometric mean of counts obtained in both images.
- The images should be scrutinized for patient motion. If present, the gastric ROI may be inaccurate and include activity originating from adjacent bowel loops. Applying motion correction can resolve this issue. For static images, it is advised to draw a separate gastric ROI for each image.

## Take Home Messages

- GE with milk or formula is often performed simultaneously with an evaluation of GER.
- Meal standardization is essential.
- The most commonly used quantitative value is the gastric residual activity which can be easily calculated by dividing the decay corrected counts within a gastric ROI at specific time points by the initial gastric counts at the start of the acquisition.
- Solid GE is more standardized and reliable and should be used when possible.

- "Pseudo" normal reference values for liquid gastric emptying in children younger than 5 years were recently established, derived retrospectively from a selected group of over 2000 children without risk factors for gastric dysmotility who underwent GER scintigraphy.

## Representative Case Examples

### Case 6.3. Delayed Gastric Emptying (Fig. 6.3)

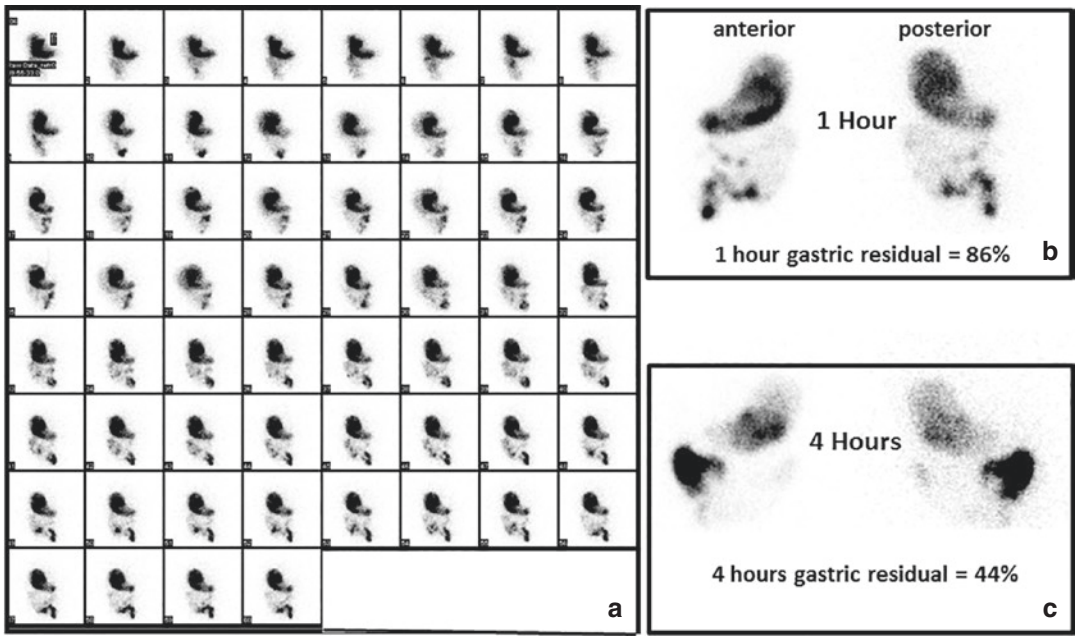


**Fig. 6.3** History: A 22-month-old girl with repeat episodes of regurgitation and vomiting was referred for evaluation. The patient was fed orally with 230 cc of milk formula labelled with Tc-sulfur colloid. Study report: Posterior view dynamic images obtained for 60 mins (**a**) demonstrate marked retention of tracer in the stomach. Static images obtained at 1 h (**b**) and 4 h (**c**) after completion of feeding show significant gastric residual activity. The gastric residue from the initial gastric activity was 86% at 60 mins and 44% at 4 h. Impression: These findings suggest delayed gastric emptying

## 6.3 Esophageal Transit Studies

### Clinical Indications

Visual detection and quantitative evaluation of esophageal transit abnormalities.

**Study Protocol for Esophageal Transit Studies [1]**

**Patient Preparation:**

- Plan the study to replace scheduled feeding (assuming the infant is fed every 3–4 h).
- Bring the child's regular meal (cow milk, human milk, milk-based formula) in his/her regular feeding bottle and an additional empty bottle.

**Radiopharmaceutical, Administered Activity, Mode of Delivery**

*Radiopharmaceutical:*

- [$^{99m}$Tc]Sn-colloid or [$^{99m}$Tc]sulfur colloid.

*Activity:*

- A fixed dose of 9.25 MBq (0.25 mCi) for SC is recommended by the SNMMI. The EANM pediatric dose card uses patient weight to calculate the dose.

  Refer to the pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

  Reference to national regulation guidelines, if available, should be considered.

*Delivery:*

- A small volume (2.5–5 ml) of the feed is labelled and given to the patient with a syringe.

**Acquisition Protocol:**

- The study is performed with the detector upright.
- The child drinks the activity on the parent's/caregiver's lap with the back against the camera, so the esophagus is viewed from the left posterior oblique position.
- Acquisition parameters: dynamic study, 0.5 s/frame, 120 frames, matrix 128 × 128.
- Take care to keep the child still during the acquisition.

### Study Interpretation

- Review the raw data in planar and cine format.
- The raw data is then converted to a condensed image (Fig. 6.4).

**Normal Transit Study**

- The normal transit time of activity through the entire esophagus is less than 3 s.
- With most swallows, there is a transient hold-up of activity at the level of the gastroesophageal junction (GEJ) which should decrease from a maximum of 4 s for swallow initiated during the first 4 s of the study to less than 0.5 s after 12 s.
- A hold-up of less than 2 s is considered normal.

**Common Pathological Patterns**

- Hold-up in the proximal esophagus, at the cricopharyngeal level, with prolonged initiation of swallowing: can be found in children with neurological abnormalities.
- Hold-up high in the esophagus with slower transit distal to the stricture: can indicate esophagitis due to causes other than GER or to the presence of anatomical abnormalities (e.g., aberrant pulmonary artery, repaired tracheoesophageal fistula, esophageal stricture).

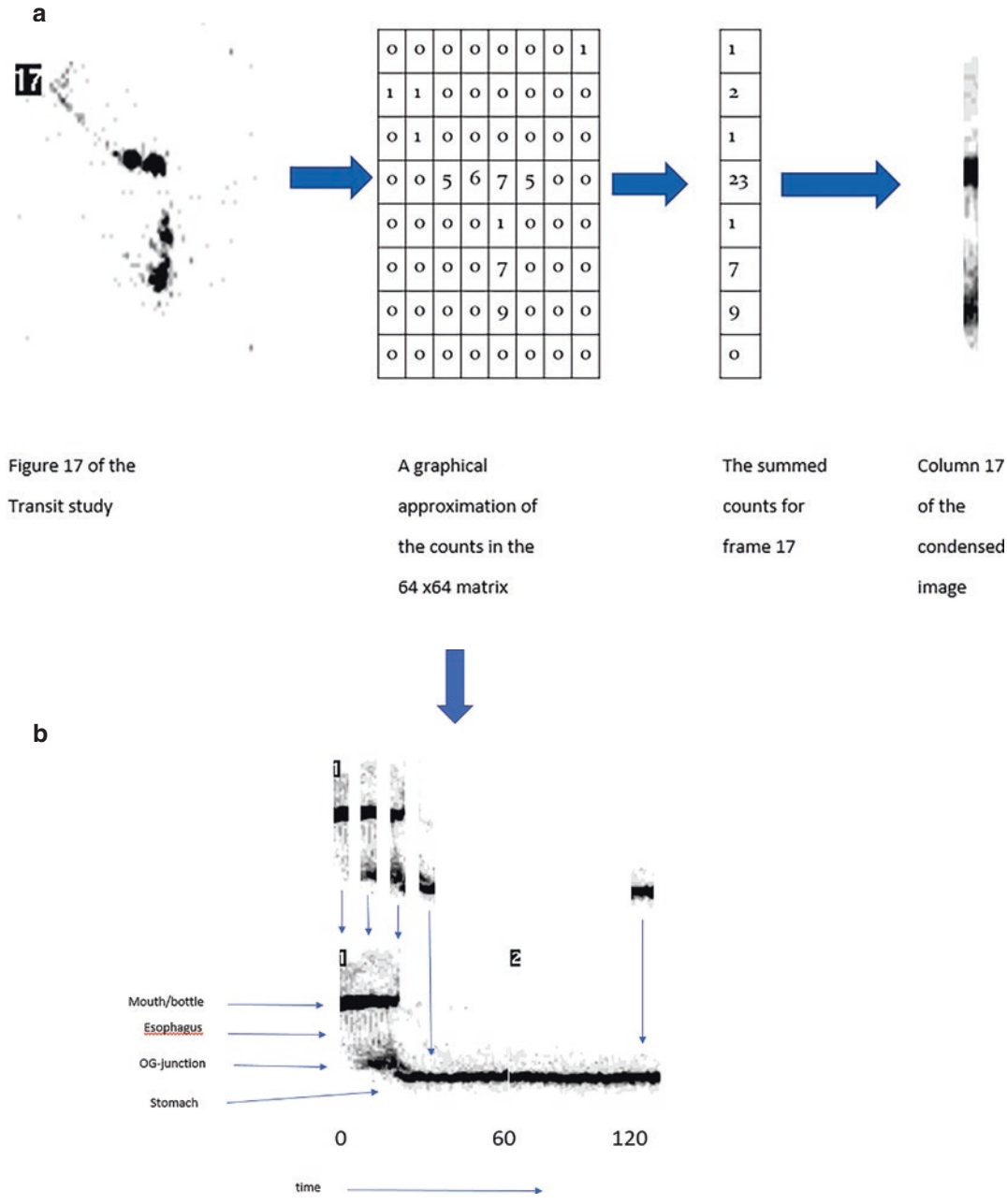


**Fig. 6.4** Condensed image in a study with normal esophageal transit. Image (**a**) illustrates how the raw data of a single image of the dynamic series are compressed into a single column of the condensed image. Image (**b**) illustrates how the summed columns of each of the dynamic image frames are arranged sequentially to form the condensed image. The condensed image makes it easier to assess the transit of activity through the esophagus from the mouth to the stomach

- Hold-up at more distal esophageal levels with succeeding swallows or slowing of each successive swallow may be seen in:
- Prematurity.
- Transient over the first 3 months.
- In children who are developing cerebral palsy or those with low muscle tone such as in case of Trisomy 21 or myopathy.
- Severe "general" illnesses such as malnutrition, cardiac diseases with poor stamina, and respiratory distress.
- Hold-up at the same level with multiple swallows proximal to the GEJ: may be consistent with esophageal spasm secondary to reflux esophagitis.

## Correlative Imaging

- Modified Barium swallow if available may provide useful additional information on the different phases of swallowing.

### Red Flags

- Residual buccal activity in a child with a poor sucking reflex can make interpretation of a transit study very difficult.
- Contamination frequently occurs since children spit out the activity or drool during the study. Placing paper towels under the child's chin allows the technologist to quickly remove contamination during study acquisition.
- Identifying contamination is crucial as it can be mistaken for "hold-up," particularly on the condensed image.
- To prevent artifacts on the condensed image the technologist should ensure that the activity in the bottle/ syringe does not move in front of or below the child's mouth or anterior to the patient's neck or chest. Always move the activity vertically down to and up from the mouth.

## Take Home Message

- The clinical differential diagnosis between a severe esophageal transit abnormality and GER is difficult.
- Esophageal transit studies are easy to perform and give valuable information regarding possible esophageal dysmotility or GER.
- If a child has been fed via a NG tube for a prolonged period, a transit study should be avoided, and the child should rather be given the feed for the reflux study via the NG tube.

## Representative Case Examples

### Case 6.4. Normal Esophageal Transit Study (Fig. 6.5)

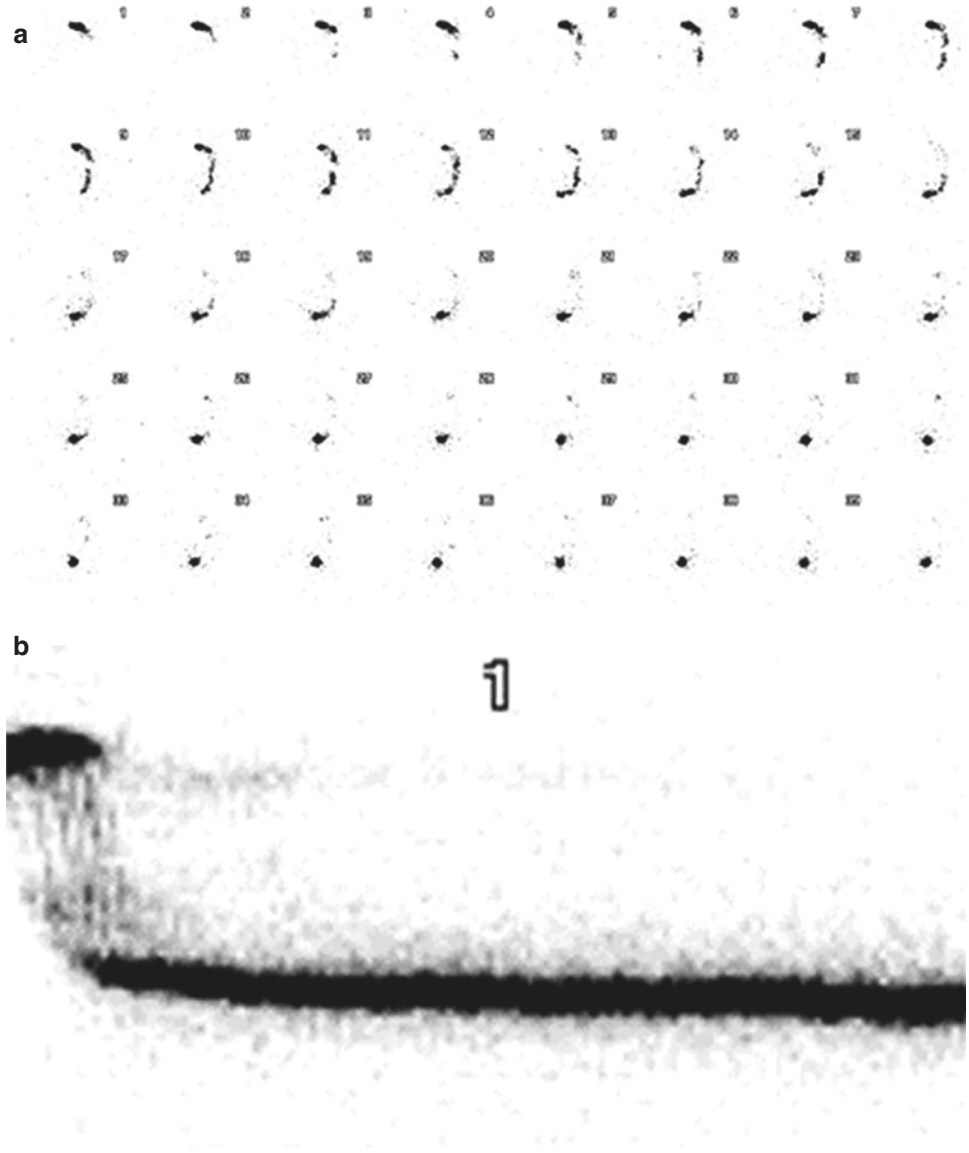


**Fig. 6.5** History: A 9-month-old baby was repeatedly admitted to the hospital with recurrent chest infections and pneumonia over the last 5 months. The transit study was performed as a precursor to the GER study. Study report: There is rapid progression of tracer activity from the mouth to the stomach with all observed swallows (**a**). In condensed image (**b**), the black horizontal line at the top of the image represents the mouth and bottle, which both clear of activity after the first few frames. The horizontal line at the bottom of the image represents activity in the stomach and only appears after a few frames. The vertical lines between the two horizontal lines are the swallows, each line corresponding to a single swallow. These lines are nearly vertical as you would expect in a patient with rapid transit of activity through the esophagus. The angle of the near vertical lines is influenced by the position of the child and the frame rate. The angle between the vertical line and the line showing the passage of activity down the esophagus is wider if the child is supine or the frame rate is increased. Impression: Normal pattern of esophageal transit

## Case 6.5. Impaired Initiation of Swallowing (Fig. 6.6)

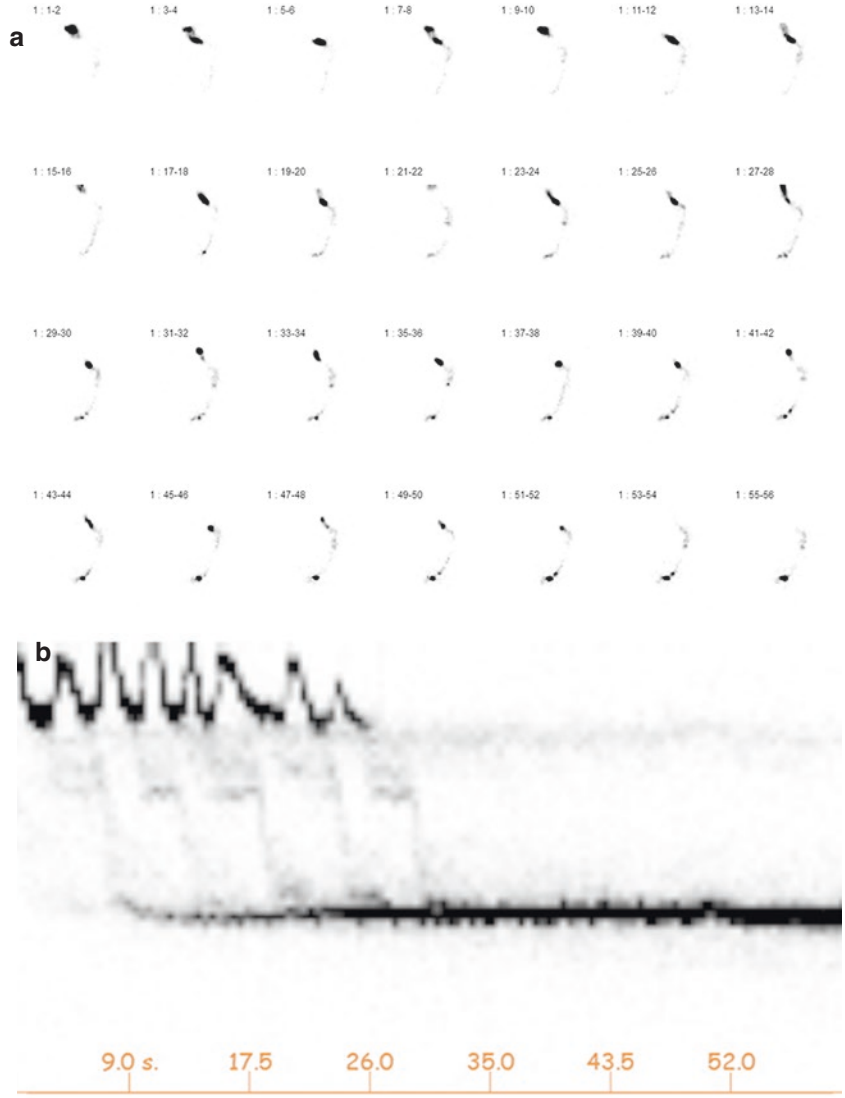


**Fig. 6.6** History: A 16-month-old boy presented with feeding difficulties and symptoms of GER following an intraventricular bleed. Study report: There is a hold-up in the proximal third of the esophagus in several swallows (**a**). During the 1-min transit study 10 swallows were observed. In condensed image (**b**), the swallows have a repeat pattern of occurring in pairs, with the first swallow of each pair showing prolonged hold-up in the proximal third of the esophagus. The hold-up persists at this level until the second swallow reaches this level, the activity then moves as a bolus to the distal esophagus. Impresison: This pattern suggests impaired initiation of swallowing seen in patients with neurological abnormalities

## 6.4 Salivagram

### Clinical Indications

- Detection of saliva aspiration in:
  - Children with neurological impairment, recurrent lung infections, and suspected pulmonary aspiration.
  - Children with normal neurological development presenting with recurrent lung infections or unexplained chronic lung disease.

**Study Protocol for Radionuclide Salivagram [9, 10]**

**Patient Preparation:**
There is no special patient preparation for this test. Ideally, the test should be done between feeds.

**Radiopharmaceutical, Administered Activity, Mode of Delivery**

*Radiopharmaceutical:*
- [$^{99m}$Tc]Sn-colloid or [$^{99m}$Tc]sulfur colloid.

*Activity:*
- 10–15 MBq (0.25–0.4 mCi) in small, approx. 0.1 ml, volume.

  Refer to the pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.

  Reference to national regulation guidelines, if available, should be considered.

*Delivery:*
- The radiotracer is placed under the patient's tongue.

**Study Protocol:**
- Collimator: low energy all purpose.
- Position: supine, posterior view images (standard).
  - On dual head camera: optional simultaneous posterior and lateral acquisitions (detectors in "L" shape).
  - If the patient is neurologically impaired with ongoing salivation it is useful to place linen savers under the head and over the chest. They can be replaced during the study if contamination occurs.

**Acquisition Parameters:**
- Dynamic study: 5–30 s/frame for 60 mins, matrix 128 × 128, size-appropriate zoom.
- Static images at the end of the dynamic study: anterior, posterior, lateral views, 2–5 mins/view, matrix 256 × 256, appropriate zoom.
- Markers and/or transmission images may improve localization of activity.
- If there is residual activity in the mouth at the end of the dynamic acquisition a late static image at 2 h from the beginning of the study is recommended.

### Study Interpretation [11]

- Tracer visualizing the tracheobronchial tree or in the lung should be interpreted as aspiration.

### Correlative Imaging

- Barium esophagogram study may show incidental aspiration.
- Modified Barium swallow can be performed in the presence of a speech or occupational therapist and videotaped, using multiple food types and consistencies and various delivery methods depending on age (e.g., different nipple types for infant feeding, feeding by cup, spoon, and straw), can detect and/or document aspiration and swallowing triggers.

### Red Flags
- It is essential that the activity is given in a small bolus since it mimics native saliva transit.
- Dynamic images can be stopped earlier than 60 mins if all activity has cleared from the mouth or if clear aspiration is seen.

- If there is no clearance of buccal activity after 15 mins a small amount of water (about 0.25 ml) can be placed under the tongue.

## Take Home Messages

- Salivagram is currently the only imaging study to directly demonstrate saliva aspiration.

- A normal study shows prompt clearance of activity from the mouth to the stomach and no activity in the lungs.

## Representative Case Examples

**Case 6.6. Normal Salivagram (Fig. 6.7)**

**Case 6.7. Tracheobronchial Aspiration (Fig. 6.8)**

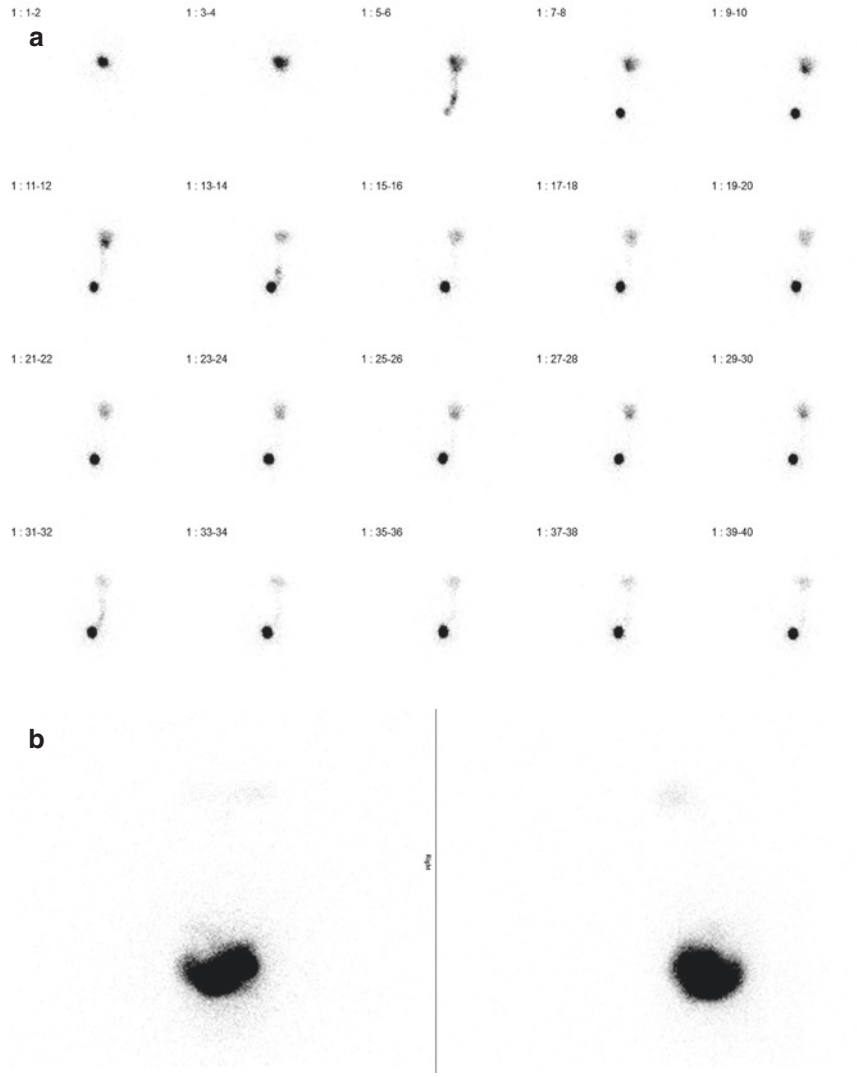


**Fig. 6.7** History: A 6-month-old girl born prematurely developed nosocomial infections early during hospitalization. She had been admitted to the intensive care unit on four occasions with pneumonia and developed cystic lung disease. Study report: Early posterior images summed for display at 10 s/frame (**a**) demonstrate prompt clearance of activity from the mouth to the stomach. No aspiration is detected. Planar images obtained after 1 h (**b**) show no evidence of tracer activity in the lungs. Impression: Normal salivagram. No evidence of pulmonary aspiration

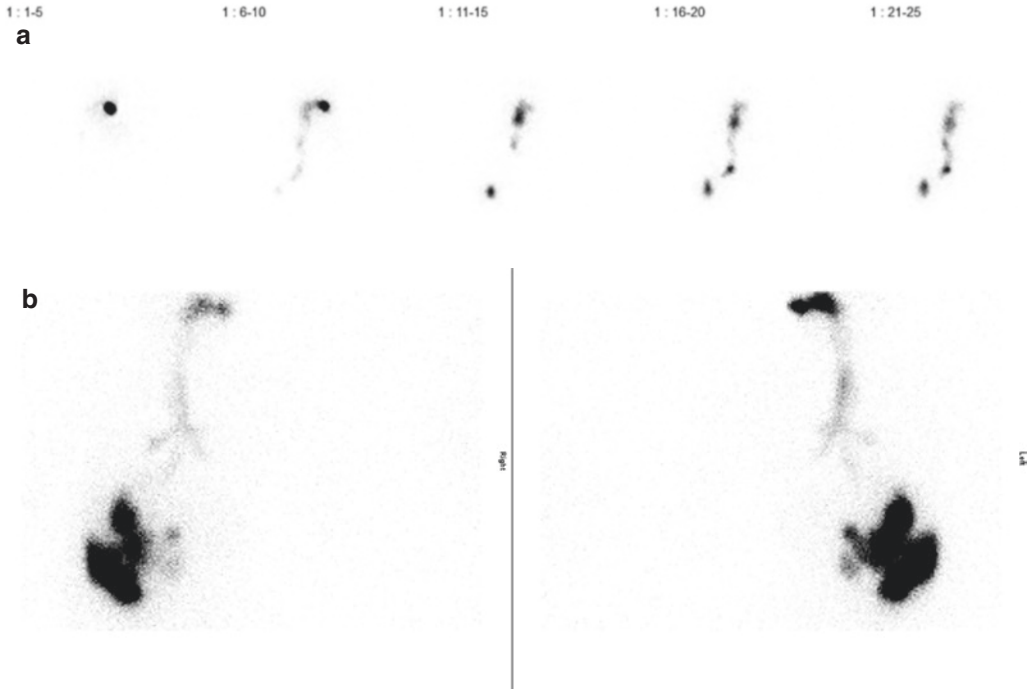


**Fig. 6.8** History: A 13-year-old spastic quadriplegic patient with cerebral palsy presented with recurrent pneumonias. Study report: Early posterior images summed at 30 s/frame for display (**a**) show tracer activity entering the trachea and stomach. Planar images obtained after 1 h (**b**) show tracer activity in the bronchi, bilaterally. Impression: Tracheobronchial aspiration

## 6.5 Gastrointestinal Bleeding

### Ectopic Gastric Mucosa (Meckel's Diverticulum Scan)

#### Clinical Indications [12, 13]

- Detection of ectopic gastric mucosa in a Meckel's diverticulum or, rarely, in a duplication cyst as a source of painless lower GIB.
- Detection of a Meckel's diverticulum in rare cases of abdominal pain, due to diverticulitis, or, less common, due to recurrent intussusception.
- Unexplained anemia.

#### Pre-Exam Information

- Number and timing of bleeding episodes. Performing the study during active bleeding may reduce its sensitivity.
- Was premedication taken as instructed?
- Is a Barium study planned within 3 days prior to the Meckel's scan?

**Study Protocol for Meckel's Scan [13, 14]**

**Patient Preparation:**

- Fast: 3–4 h, can improve the sensitivity for detection of ectopic gastric mucosa.
- Premedication options to increase the study sensitivity for detection of ectopic gastric mucosa:
  - Histamine H2 receptor antagonists reduce tracer release from the gastric mucosal cells. These drugs are most commonly used due to their availability, low cost, and infrequent side effects.
  - Cimetidine.
    Orally (PO) for 1–3 days: 20 mg/kg/day. In neonates 10–20 mg/kg/day.
    Intravenous (IV) 1 h before the scanning procedure: 300 mg in 100 mL of 5% dextrose over 20 min.
  - Famotidine.
    PO: 0.5 mg/kg/day.
    IV 1 h before the scanning procedure: 0.25 mg/kg.
  - Recently, proton pump inhibitors have been used to control acid secretion in children and some institutions may use this drug as a premedication. Currently, there are no fixed recommendations for the dose or the duration of this premedication.

**Radiopharmaceutical, Administered Activity, Mode of Delivery**

*Radiopharmaceutical:*

- [$^{99m}$Tc]pertechnetate (Pertechnetate).

*Activity:*

- 1.85 MBq/Kg (0.05 mCi/Kg), minimum dose 9.25 MBq (0.25 mCi).
  Refer to the pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective EANM and SNMMI and image gently web sites.
  Reference to national regulation guidelines, if available, should be considered.

**Acquisition Protocol [15]:**

- Collimator: low energy, high- or ultra-high resolution collimator.
- Position: tracer is injected with the patient lying supine.
- FOV: entire abdomen and pelvis to ensure the entire bladder is in the field of view.

*Acquisition Parameters:*

- Step 1: Dynamic study for 60 s: 1–5 s/frame, matrix 128 × 128. Aiming to look for vascular blush from arteriovenous (AV) malformation or to localize a site of rapid bleeding.
- Anterior and posterior dynamic study step 2 for 30–60 mins: 30–60 s/frame, matrix 128 × 128.
- Static images of the abdomen (upon completion of the dynamic part): anterior, RAO, and/or right lateral; 300 Kcounts, matrix 256 × 256, appropriate zoom.
  - Post-void images are mandatory when there is significant bladder activity that can obscure focal uptake from an adjacent diverticulum.
  - Posterior and lateral views can help delineate renal uptake.
  - Standing/sitting views may be needed to differentiate normal tracer transit in the duodenum from uptake in ectopic gastric mucosa.
  - Additional views after diuretic administration may also be required.

- SPECT (if performed, should be done after the dynamic phase): 60–120 projections, 10–20 s/projection, matrix 128 × 128.
- SPECT/CT including a pediatric low-dose CT with a FOV limited to the abdomen and pelvis (when available).

## Study Interpretation [16]

**Interpretation criteria for ectopic gastric mucosa:**

- Focal tracer uptake appears at the same time as the activity in the normal gastric mucosa, and persists or increases in intensity over time.
- Typical location: right lower quadrant.
  - Other abdominal locations are occasionally seen.
  - The location of the focus may change during the study due to peristalsis.

**False positives: physiologic abdominal tracer biodistribution.**

- Focal tracer activity in the urinary tract:
  Renal or extra-renal pelvis, dilated ureter, bladder diverticulum, vesicoureteral reflux (VUR), ectopic kidney. Urinary tract activity is occasionally seen but it clears during the dynamic acquisition, unlike focal uptake in a Meckel's diverticulum.
- Physiologic tracer transit in the small bowel:
  - Diffuse, usually in the left upper quadrant, or focal, commonly in the duodenal bulb.
  - Appears later in the study than uptake in ectopic gastric mucosa.
  - Cinematic display can identify normal tracer movement from the stomach to the duodenum and small bowel loops.
- Uterine blush.
- Hemangioma or AV malformation. The latter is usually prominent during the initial angiographic phase of the study.
- Ectopic gastric mucosa present in enteric duplication cysts.

**False negatives:**

- Barium fluoroscopy a few days prior to scintigraphy. Barium can attenuate faint activity in ectopic gastric mucosa.
- Perchlorate administration inhibits Pertechnetate uptake by gastric mucosa.
- Physiologic low Pertechnetate uptake in neonates.
- Scarring, necrosis, or ischemia within the diverticulum.
- A very small focus on ectopic mucosa.

## Correlative Imaging

- Upper GI and follow-through contrast examination to detect duplication cyst.
- Contrast enema to detect duplication cyst.
- US of the abdomen may incidentally identify a cystic structure.
- Cross-sectional CT or MRI imaging may identify a mass or cyst in the bowel.

## Red Flags

- The study cannot demonstrate Meckel's diverticula that do not contain ectopic gastric mucosa. It will only detect diverticula containing ectopic gastric mucosa (20–50% of cases).
- Potential pitfalls can include:
  - Very small lesions that may first appear a bit later than the stomach.
  - Uptake suspected to be in the excretory system. In doubtful cases, upright, postvoid, or repeat images after administration of furosemide may clear the urinary tract activity.
  - In patients who have acute GI bleeding with a significant drop in hemoglobin, the study may be falsely negative due to failure to deliver the tracer to the ectopic mucosa. This may necessitate a repeat scan 10–14 days later.
  - Active bleeding during imaging can dilute and shift tracer activity away from the diverticulum.
- A Meckel's scan should not be performed within several days after a bleeding study that

employed in vivo labelling of red blood cells (RBCs). Small amounts of persisting circulating Sn-pyrophosphate from the prior study, will cause Pertechnetate, injected for the Meckel's scan, to label RBCs and thus no uptake will be found in the gastric mucosa. This is not the case if in vitro labelling of the RBCs; then a Meckel's scan can be performed without interference.

## Take Home Messages

- Interpreting physicians should be familiar with the characteristic pattern of uptake in ectopic gastric mucosa, with conditions that can potentially result in erroneous interpretations and with the various techniques that can be used to increase the diagnostic certainty in doubtful cases.
- Pertechnetate is taken up by the mucin-producing cells of the gastric mucosa and excreted later on into the gut lumen. This feature makes a Meckel's scan the study of choice for the detection of ectopic gastric mucosa.
- Pertechnetate scintigraphy is the only direct study to demonstrate the presence of ectopic gastric mucosa within a Meckel's diverticulum. When adequately performed, it is reported to have a sensitivity of 94%, and a specificity of 97%.
- This examination is seldom of value in children with no history of rectal bleeding.
- SPECT/CT increases the diagnostic confidence:
  - In small diverticula with low uptake.
  - For precise preoperative localization.
  - To identify ectopic gastric mucosa foci obscured by the bladder.
- When studies are negative or equivocal and the clinical suspicion is high, repeat studies should be considered as they may present with more definite findings and help in establishing or refuting the diagnosis.
- Ectopic gastric mucosa present in symptomatic enteric duplication cysts often require surgical resection similar to symptomatic Meckel's diverticula.
- US of the abdomen should not be used as a screening test.

## Representative Case Examples

**Case 6.8. Meckel's Diverticulum (Fig. 6.9)**

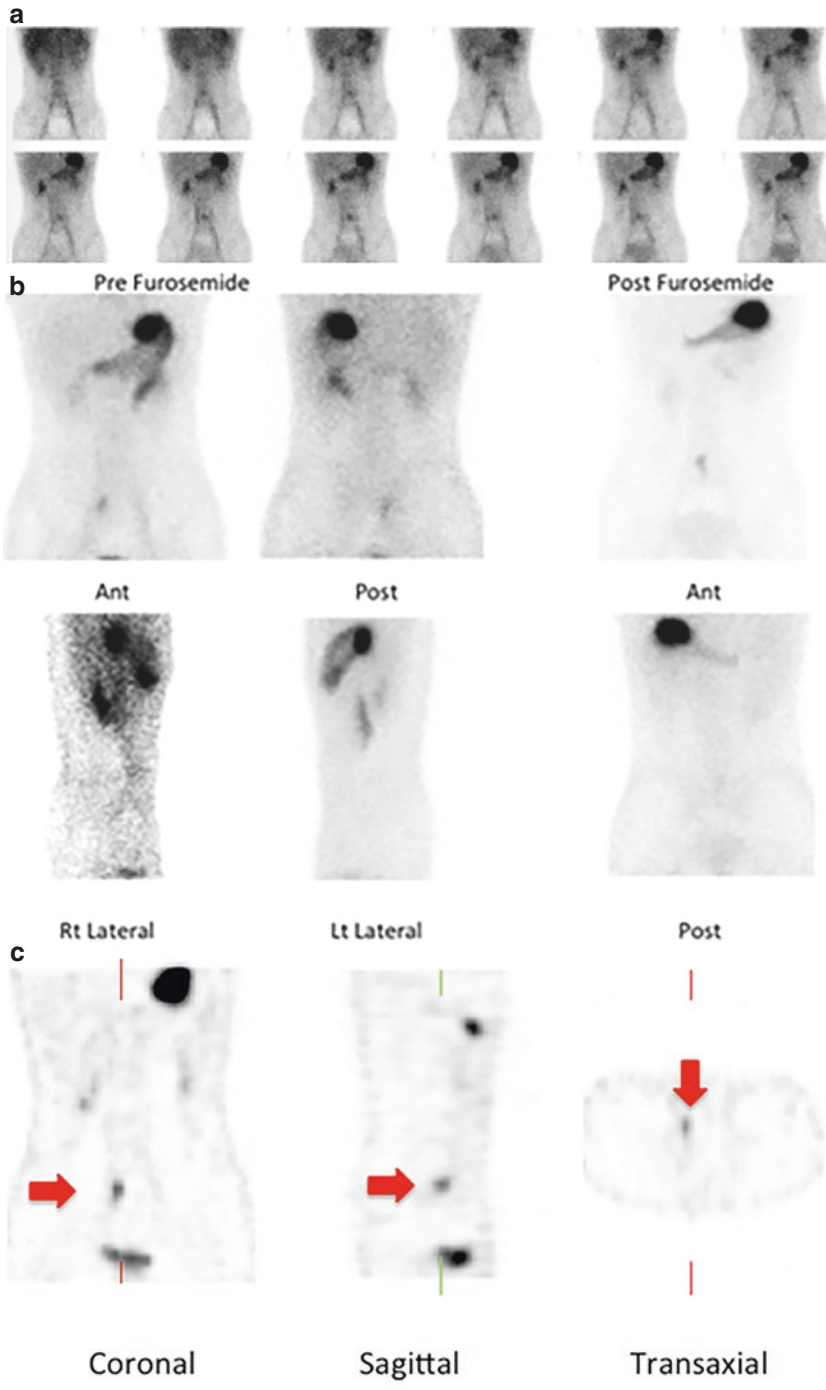


**Fig. 6.9** History: A 12-year-old boy presented with significant painless melena and a drop in hemoglobin. Study report: Following oral premedication with H2 blocker 6 h previously, Pertechnetate was injected, and dynamic flow images were obtained over 2 mins (not shown), followed by 15 mins of dynamic imaging of the abdomen and pelvis (**a**) Subsequently, static images were obtained at 20 mins (**b**). There is some activity in right and left kidney areas seen on the initial dynamic and static imaging that drained after the administration of 20 mg furosemide IV. There is a focal area of increased activity in the lower abdomen. SPECT of the abdomen and pelvis (**c**) identifies a focus of activity in the lower mid-abdomen (arrows). Impression: The findings are consistent with an area of ectopic gastric mucosa in a Meckel's diverticulum

## Case 6.9. Meckel's Diverticulum (Fig. 6.10)

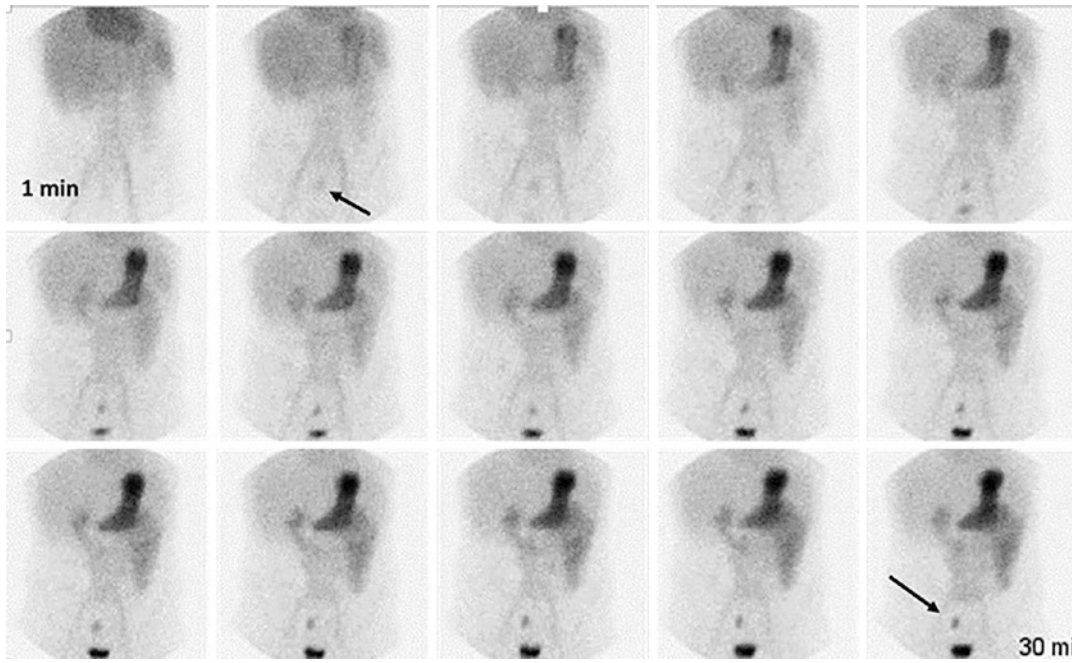


**Fig. 6.10** History: An 11-year-old boy presented with recurrent abdominal pain and anemia. The study was requested in search of a possible Meckel's diverticulum with ectopic gastric mucosa as a cause of diverticulitis and was performed after premedication with ranitidine. Study report: Dynamic images obtained for 30 mins after administration of Pertechnetate show a focal uptake (arrow) in the lower pelvis, above the urinary bladder. This focus appeared simultaneously with the physiological uptake in the gastric mucosa and increased in intensity over time. Impression: The findings are consistent with the diagnosis of ectopic gastric mucosa. On surgery an inflamed Meckel's diverticulum located proximal to the ileo-caecal valve was resected. Typically, a Meckel's diverticulum manifests as painless rectal bleeding in a young child, in most cases under 2 years of age. This case illustrates that occasionally less common presentations may be encountered, especially in older children, like in the present case in whom the child suffered from "Meckel's diverticulitis" with recurrent abdominal pain and chronic blood loss

## Blood Pool Scintigraphy

### Clinical Indications

- Detection of GIB.

### Pre-Exam Information

- Are there signs of active bleeding just prior to the study?
- Hemoglobin levels and administration of blood transfusions should be known.
- Hemodynamic status of the patient and the need for supportive therapy and monitoring.

**Study Protocol for GI Bleeding Scan [14, 17]**

**Patient Preparation:**

- No preparation is required.

**Radiopharmaceutical, Administered Activity, Mode of Delivery**

*Radiopharmaceutical:*

- [$^{99m}$Tc]Tc-RBCs [18] In vitro labelling is the method of choice and should be employed when an adequate facility and proper radiopharmacy practices are available 1–3 ml of the patient's blood are drawn anticoagulated with heparin or acid citrate dextrose (ACD).
- RBC are labelled with a commercially available preparation according to the manufacturer's instructions.
- In vivo labelling:
  - $^{+2}$Sn pyrophosphate is injected in appropriate, weight-based amounts obtained from the package insert of the commercial cold kit.
  - Administration of Pertechnetate follows 20 mins later.

*Activity (Pertechnetate):*

- 74 MBq/Kg (2 mCi/Kg), minimum dose 74 MBq (2 mCi).

  Refer to the EANM pediatric dosage card and to the North American consensus guidelines on radiopharmaceutical administration in children in the respective European Association of Nuclear Medicine (EANM) and Society of Nuclear Medicine and Molecular Imaging (SNMMI) and image gently web sites.

  Reference to national regulation guidelines, if available, should be considered.

*Delivery:*

- For in vitro labelled RBCs: the labelled blood should be slowly reinjected IV into the patient from whom it was drawn.

**Acquisition Protocol:**

- Collimator: low energy, general purpose, or high resolution.
- Position: supine, anterior view.
- FOV: entire abdomen.

*Acquisition Parameters:*

- Dynamic study, Step 1: immediately following tracer injection, 60 × 1–5 s/frame, matrix 128 × 128, size-appropriate zoom.
- Dynamic study Step 2: immediately following step 1, with 30 s/frame for 60–90 mins.
- Additional delayed sequences of dynamic imaging can be performed up to 24 h if no bleeding is noted.
- SPECT or SPECT/CT, when available, can be used to clarify foci of uncertain origin.

### Study Interpretation

- A new, focal tracer accumulation in the abdomen or pelvis should be considered to represent a bleeding site.
- This focus typically increases in intensity and travels through the bowel lumen from the original bleeding site in an antegrade or retrograde fashion.

- Focal or diffuse sites of tracer accumulation that do not change their location throughout the study are unlikely to represent bleeding sites.
- Bleeding is often intermittent. Abnormal uptake first detected on late images indicates that bleeding has occurred in the time that elapsed from the prior imaging sequence but does not necessarily reveal the original bleeding site because of the movement of labelled blood in the intestinal lumen due to peristalsis.
- Physiologic tracer activity accumulation can be seen in:
- The blood pool of the kidneys or occasionally in the renal pelvis or ureter and in the bladder.
- In the blood pool of the large abdominal blood vessels and the liver and spleen.
- Uptake in the thyroid gland and gastric mucosa is due to free circulating Pertechnetate and suggests inadequate RBC labelling.

## Correlative Imaging

- Angiography can be used both for detection of the GIB as well as for therapeutic purposes but requires larger bleeding volumes than scintigraphy.

## Red Flags

- General blood manipulation and handling precautions have to be always implemented.
- Injection of in vitro labelled blood requires extreme caution to ensure that the blood is injected into the patient from whom it was drawn. To reduce the chance of misadministration it is advised to avoid booking more than one in vitro labelled RBC study per session.
- Referring physicians should be advised when ordering a GIB study that this investigation can only detect active bleeding that occurs at the time of imaging and grossly localize the bleeding source to one of the four abdominal quadrants.
- Distinctions between small and large bowel bleeding can sometimes be made. The etiology of bleeding such as ectopic gastric mucosa, erosion, AV malformation, and tumor cannot be determined.
- When there is a high clinical suspicion for a Meckel's diverticulum as the bleeding site, a Meckel's scan should be performed instead of a labelled RBC bleeding study.
- Uptake in organs and sites suggesting free Pertechnetate is more commonly encountered with in vivo labelling which is not advised for GIB investigations.

## Take Home Messages

- RBC scintigraphy is a sensitive and specific study for the detection of GIB. The long scanning duration increases the likelihood of detecting intermittent bleeding episodes.
- The study can detect smaller bleeding volumes than angiography, 0.1–0.4 ml/min.
- In vitro RBC labelling is the method of choice because of significantly higher labelling efficiency and a lower likelihood of artifacts related to free Pertechnetate.
- The migration of the focus of abnormal activity both ante- and retrograde occurs because blood irritates the bowel mucosa and induces peristalsis. When sufficient labelled blood accumulates in the lumen the outline of the bowels may be recognized allowing distinction between the small and large intestines.

**Fig. 6.11** History: A 3-year-old girl undergoing chemotherapy for leukemia experienced repeat episodes of melena and bright red blood rectal bleeding. Angiography failed to detect the bleeding source. Study report: Following reinjection of autologous Tc-labelled RBCs dynamic images of the abdomen acquired in the anterior view show abnormal tracer accumulation in the upper left quadrant (arrow). The uptake increases in intensity and changes in shape and location over time. Impression: These findings suggest active gastrointestinal bleeding, most probably from the small intestines in the left upper quadrant

### Representative Case Examples

### Case 6.10. Left Upper Quadrant Gastrointestinal Bleeding (Fig. 6.11)

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