Scintigraphy and imaging of the oesophagus in children

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Summary

There are different type of abnormalities in the esophagus ranging from congenital to acquired lesions. UGI series continue to be the most common radiologic method for evaluating esophagus.

A. Methods of examination

SCINTIGRAPHY

Introduction

Imaging and scintigraphy are of great interest in the exploration of the esophagus. The choice of the technics must be adapted according to age, the patient behavior but also to the type of pathology. It has to be integrate to clinical examination and to the follow up of certain conditions.

1. The gastroesophageal reflux scintigraphy

The gastroesophageal reflux scintigraphy ("milk scan") is a sensitive, non invasive, physiological, and direct technique to demonstrate the presence of GER [1]. It is easy to perform, is well tolerated and requires minimum patient cooperation. It is also entails a low radiation burden.

Patient preparation

Children should fast for at least 4 hours prior to the exam. Young infants should replace a normal scheduled feeding with the radioactive milk.

Methods

There is no single universally accepted protocol for this study.
Technetium-99m (99mTC)-sulfur colloid is the radiopharmaceutical of choice for the study. The dose is 0.55MBq/kg. It is added to a portion of the patient's feeding (one third or one half of the normal milk). This mixture of milk or milk formula is introduced into the stomach by oral feeding, gastric tube or gastrostomy tube (when used for routine feeding). The volume is similar to the volume the patient is given for regular meals.
After feeding, the patient is placed supine on the imaging bed. Restrains may be used to prevent motion. Dynamic images are carried out during 60 minutes.

Interpretation

New appearance of tracer in the esophagus indicates a reflux episode. Interpretation can be enhanced by generating time activity curves from regions of interest (ROIs) placed over the esophagus. Reflux episodes are seen as sharp spikes in the curves. The number of reflux episodes and the level of the reflux should be documented. In the same time, the gastric emptying could be evaluated. According to most of studies, the sensibility for detection of GER ranges from 60% to 90% [2,3]. The specificity is over 90%.

Contraindications and precautions

None.

2. Esophageal transit scintigraphy

INDICATION
Esophageal scintigraphy provides imaging and quantitative data on the transit of labeled bolus through the esophagus. This study could help for the diagnosis of esophageal motor disorders. In children and adolescents, these troubles can be primary (achalasia) or secondary to other conditions (esophagitis, surgery, tracheoesophageal fistula, esophageal strictures, injury from ingestion of caustic materials, etc.)

Patient preparation

Children should fast for at least 4 hours prior to the exam. Young infants should replace a normal scheduled feeding with the study.

Methods

Technetium-99m (99mTC)-sulfur colloid is mixed with 30 ml of liquid (milk or 5% dextrose water). The dose range is 7.4 to 37MBq. Infants can lie directly on the slightly inclined collimator. Older children can sit up with their back to the collimator. The children can be fed with a bottle or through a straw. Imaging begins at the onset of swallowing.

Interpretation

Oral or pharyngeal retention, esophageal retention, bolus fragmentation, premature swallows, tracheobronchial aspiration and GER can be identified by visual inspection. Slow progression or even stopping of the bolus with the craniocaudal direction maintained can be seen in scleroderma or achalasia. Esophageal transit can be measured quantitatively with time and retention parameters in adult practice. Unfortunately, standardization of the normal quantitative parameters in children has not been established.

Contraindications and precautions

None

IMAGING

Number of conditions may alter esophagus function or structure in children, including congenital anomalies such as atresia, or acquired disorders such as, esophageal reflux esophagitis. Imaging methods allowing a proper diagnosis of these conditions are reviewed in this article

1. The upper gastro-intestinal series (UGI)

Upper gastro-intestinal (UGI) series remains the most common imaging method to evaluate both esophageal structure and function [4].

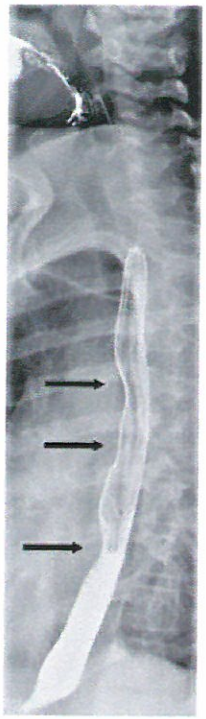


Figure 1. Normal lateral view oesophagogram. Note anterior impressions caused craniocaudaly by : aorta, left main bronchus and left atrium (arrows).

A contrast agent is used to evaluate the esophagus. Barium is often the contrast agent, but in conditions with strong likelihood of aspiration or leak, water-soluble contrast agents are preferred.
The contrast agent is instilled during voluntary swallowing, through an enteric tube placed in the mouth or in the esophagus, or carefully injected between the cheek and the lateral aspect of teeth.
Infants and small children require immobilization without the need for any sedation. Radiation related to UGI series has been dramatically reduced by the advent of several technological improvements including digitization, increase of panel detector's sensitivity, pulsed fluoroscopy and last image hold on fluoroscopic monitor.

During UGI series, children are imaged from level of the palate to the duodenal –jejunal junction to evaluate swallowing, the esophagograms, gastric emptying and small bowel topography. The normal caliber of the esophagus varies with the peristalsis and slightly narrows at both ends. Normal extrinsic compressions on the esophagus are caused by aorta, the left main bronchus and the left atrium (fig.1).

2. Ultrasound (US)

The lower esophagus and the gastroesophageal junction can be assessed via trans-abdominal ultrasound (US). The main indication for this examination is to provide non invasive and radiation-free alternative in cases of gastroesophageal reflux (GER). After ingestion of an amount of liquid equal to a normal feeding volume, the gastroesophageal junction is continuously examined in a longitudinal plane in supine position. monitoring bubbles and fluid passing from the stomach into the esophagus (fig. 2a). US allows therefore to detect GER, appreciate its duration, and frequency. Additionally, the esophageal length can be evaluated. This parameter is of importance, since a decreased length has been correlated with frequency of GER [5,6]. US is highly correlated to pH measurements and allows continuous monitoring of both the gastroesophageal and the of the distal esophagus thickness, contrary to spot fluoroscopy (fig. 2b). Nevertheless, US demands large amounts of the radiologists' or radiographers' time, to sample appropriately the reflux episodes. As other disadvantages, esophagitis, proximal esophageal segment and peristalsis are poorly evaluated by US.
Intraluminal US may have the advantage of evaluating the whole esophagus, but is invasive and has only few indications in infants.

Figure 2.
a. Longitudinal sonogram shows abdominal part of esophagus and gastroesophageal junction.

Figure 2.
b. Wide opening of the esophagus during reflux episode.
☆= Stomach,
⇨= Aorta,
⇕= esophageal lumen,
○= liver

3. Computed tomography and magnetic resonance imaging

Sectional imaging by either computed tomography (CT) or magnetic resonance imaging (MRI) is useful for both evaluation of the local extent of esophageal pathological processes, and the assessment of intrinsic abnormality of the esophagus [7]. Both CT and MRI provide static but multiplanar views of esophagus.
They allow visualization of the relationships between the esophagus and adjacent structures in the mediastinum (thyroid, trachea, vessels, glands, and aorta). The gastroesophageal junction can be visualized on thoracic or upper abdominal imaging. Due to the peristalsis, it is often difficult to visualize the whole esophagus in distension. When the esophagus is optimally distended, its wall thickness should not exceed 5 mm. Cross-sectional imaging can be used to evaluate, extrinsic esophageal compression, vascular rings - slings, duplications or tumors, and the choice between CT and MRI should be made with regard to the availability the indication and their intrinsic properties. CT has a good spatial resolution, and sedation is less frequently required than with MRI. On the other hand, MRI has an excellent soft tissue contrast and requires no ionizing radiation.
In cases of suspected esophageal atresia, on prenatal US –on which the main finding is the absence of stomach in US test [8] – prenatal MRI may advantageously complete the assessment, especially when polyhydramnios or dilation of esophageal pouch are present (fig. 3).

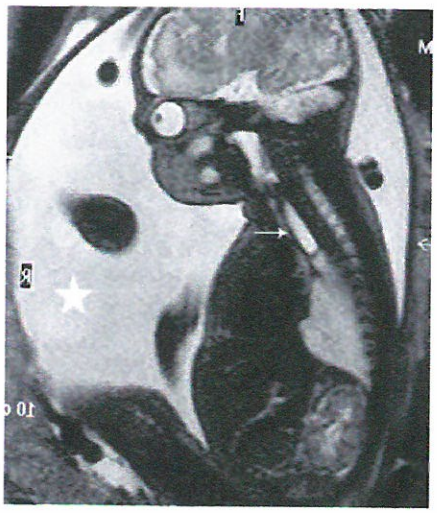


Figure 3.
Fetal MRI demonstrates polyhydramnios (star) with proximal dilatation of the esophagus (arrow) (Courtesy of Dr L Rausin, CHR, Liège).

B. Contributions of imagery in various pathologies of the esophagus

CONGENITAL MALFORMATIONS

1. Esophageal atresia (EA)

The different varieties of EA / TEF are shown in Figure 4. At imaging, plain radiography (some times with air instillation into the enteric tube) exhibits distension of the esophageal pouch. Liquid contrast is not usually used because the potential risk of aspiration. Neonates with TEF connecting distal esophagus with the airway may have air in the gastrointestinal tract (fig. 5). Those with isolated EA or EA with proximal TEF have a gasless abdomen (fig. 6).

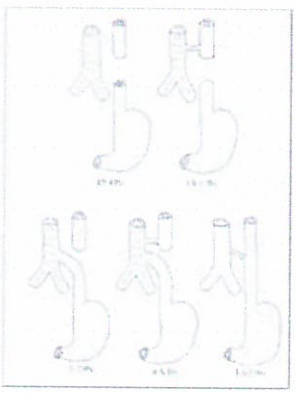


Figure 4.
Morphologic varieties of esophageal atresia.

Figure 5.
Esophageal atresia and tracheo-esophageal fistula: the enteric tube lie in the proximal distended pouch (asterisk). Presence of air seen in the stomach and bowel indicates distal fistula.

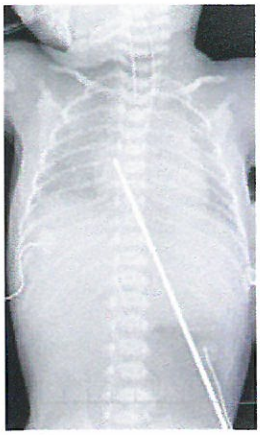
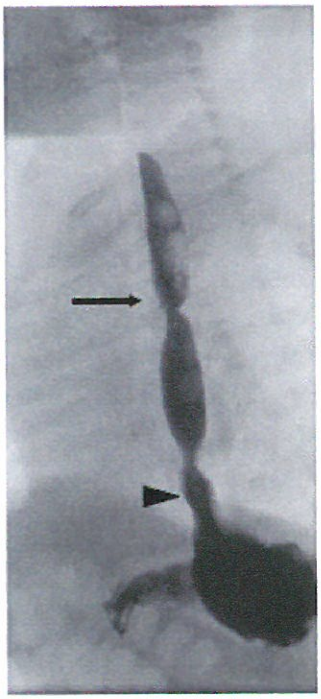


Figure 6.
Neonate with isolated esophageal atresia has gastrostomy before esophageal lengthening procedures.
a. Intraoperative spot film demonstrates NGT in the proximal and metallic tube in the distal segment of esophagus. Note gasless gastrointestinal tract.

Figure 8.
H-Type tracheo-esophageal fistula (black arrow) seen at the level of the thoracic inlet. Contrast media opacifying enteric tube (white arrow) and the respiratory tract (☆).



After surgical repair UGI series help to evaluate potential leaks (18%), strictures, recurrent fistulas, or associated congenital distal stenosis. Long term stenosis (fig. 7) present in 40% of cases can be treated with balloon dilatation. Other long term complications include distal esophageal dysmotility, peptic stricture, recurrent anastomotic stricture, tracheomalacia, rib fusion, and scoliosis. In these patients, gastro-oesophageal reflux (GER) with brachy esophagus is a very common condition 40-70% [9].
When there remains a risk for fistula, other imaging strategies have been proposed and include three-dimensional CT, MRI even radioisotopic imaging [7].

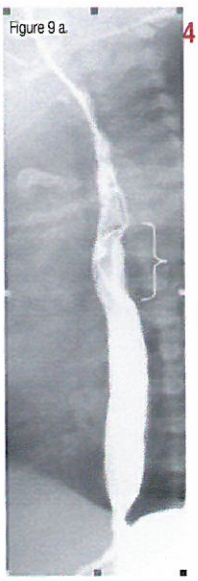
Figure 7.
Esophageal atresia.
Early post operative stenosis (arrow) associated to hiatus hernia (arrowhead).

2. Isolated TEF (H-type or N-type Tracheo-Esophageal Fistula)

Commonly, fistulas are small and inconstantly patent. They may therefore be identified only after repeated examinations if the index of suspicion is high [10].
Examination should be performed following passage of a nasogastric tube (NGT), with the child positioned laterally on the fluoroscopy table (fig. 8). Under fluoroscopic guidance, the NGT is pulled back into the lower third of the esophagus and taped at the nose. The fluoroscopy table may be tilted slightly head down to reduce the risk of aspiration into the lower respiratory tract. 10-20 ml of high-density water-soluble contrast is rapidly injected down the NGT to distend the lower part of the esophagus. The NGT is then adjusted to lie in the mid-esophagus and then the upper esophagus and the procedure repeated. It is important to examine the cervical esophageal segment because many fistulas occur at this level.
Bronchoscopy and imaging are complementary [4], as bronchoscopy may help detecting fistula missed at imaging and vice-versa.

3. Esophageal duplication cysts

Antenatal US rarely demonstrate duplication as a round liquid mass [8]. After birth, plain radiographs may demonstrate a sharply demarcated posterior mediastinal masses or congenital vertebral anomalies. On UGI series, duplication cysts are extrinsic filling defects with smooth margins (fig. 9a). Although communicating cysts has been reported, most do not communicate with the esophagus.
When performed, US, CT (fig. 9b) and MRI can all be helpful for the differential diagnosis (table 1), by demonstrating the cystic nature of the abnormality and assessing its position relative to other structures can. Cyst fluid is typically anechoic at US, has attenuation of water on CT and signal characteristics of water (low signal on T1- and high signal on T2- weighted images) on MRI.



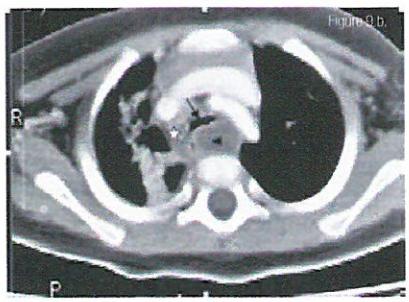


Figure 9.
Esophageal duplication cyst.
a. UGI series demonstrates a filling defect along the posterior wall of the esophagus (accolade).
b. CT obtained after intravenous contrast reveals an homogenous low density round structure (arrowhead). Note tracheal compression (arrow) and esophageal displacement (☆).

Table 1

Differential diagnosis of esophageal duplication cysts
Bronchogenic cyst
Neurogenic tumors
Hiatus hernia
Aortic arch congenital anomaly
Aortic aneurysm

Vascular rings and slings

Anomalies of the great vessels are frequently incidental findings, although some lesions tend to produce significant signs from tracheal, bronchial, or esophageal compression. A variety of different malformations can create extrinsic compression on the esophagus, leading to dysphagia. They are frequently identified on plain films and esophagograms.

The lateral esophagogram is used to evaluate both the airway and the esophagus and differentiate three types of vascular impressions.
An anterior compression of the trachea with a posterior impression on the esophagus is a vascular ring, most often caused by an aberrant subclavian artery. Other causes of vascular ring include double aortic arch (fig. 10a), right aortic arch with aberrant left subclavian artery and ductus arteriosus remnant.
A vessel coursing between the trachea and esophagus is a vascular sling. A pulmonary sling is a left pulmonary artery that arises from the right pulmonary artery and crosses between the esophagus and trachea to pass back to the left lung. This vessel might only be demonstrated intermittently on repeated swallows during UGI series.
Cross-sectional imaging with CT and MR imaging is used to further define the anatomy of the complete vascular rings and/or when typical symptoms are present (fig. 10b).

Figure 10.
Neonate with stridor. Double arch aortic

a. Esophagogram demonstrates stenosis of esophagus with bouble impression in The anterior and posterior wall.

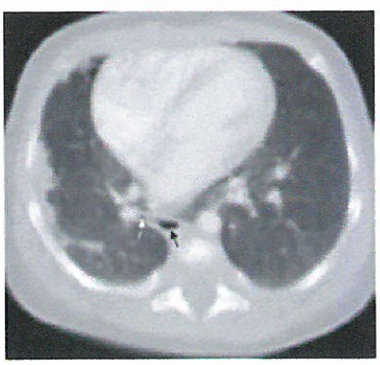
b. Contrast enhanced CT demonstrates double arch encircling trachea and esophagus.

5. Other congenital malformations

Congenital esophageal stenosis occur in 1/25000-50000 live births [11] and may be associated to EA. It is usually present in the distal third of the esophagus and most commonly secondary to tracheal bronchial tissue and cartilage. In the mid thoracic segment stenosis are likely fibromuscular in origin. Peptic stricture is to be differentiated from this congenital condition.
UGI series and esophagoscopy may evaluate the stenosis. Endoscopic ultrasound has been proposed for stenosis differentiation. Unlike others the fibromuscular type responds well to balloon dilatation [11].
Diverticula of the esophagus is rare in children (fig. 11) diverticula is a herniation of mucosa or submucosa through congenital wall weakness, usually above the clavicles. Other anomalies can be seen including esophageal webs, aberrant gastric mucosa, paraesophageal hernia, short esophagus, or esophageal bronchus (fig. 12) [11].

Figure 11.
Congenital diverticula seen as a large additive pouch above the clavicles on esophagogram.

Figure 12.
Esophageal bronchus.
Right lower lobe bronchus (white arrow) arising from the esophagus (black arrow).



ACQUIRED ESOPHAGEAL LESIONS

1. Gastroesophageal reflux

UGI series and radionuclide reflux examinations are not physiologic [11], neither pH monitoring which is nevertheless considered as the standard of reference for the diagnosis of GER. Each of the imaging techniques has it own advantages and disadvantages. US is more sensitive than UGI series, and may identify GER with a sensitivity of 100% and specificity of 87, 5% compared with pH monitoring and/or manometry [12]. US does not allows assessment of the severity of reflux, and its main role is to evaluate for potential obstruction to the gastric emptying, such as pyloric stenosis, antro-pyloric dyskinesia or malrotation, via a detailed study of the stomach's anatomy and dynamics.
In practice the indications for imaging depends on the clinical presentation [11] :
UGI series are useful for anatomic abnormalities (Vascular ring, or swallowing disorders), and for preoperative assessment. Radionuclide is indicated to evaluate lung contamination

2. Achalasia

Upright chest plain film may show air-filled esophagus, often with an air-fluid level (fig 13a). UGI series may show either normal peristalsis or vigorous but uncoordinated peristaltic activity in the esophagus. The beaking of the distal esophagus above the gastroesophageal junction is a characteristic finding (fig. 13b). On late stages, the esophagus becomes completely atonic and dilated.
There is no esophageal wall thickening in achalasia, on cross-sectional imaging techniques. The definitive diagnosis is made by manometry.

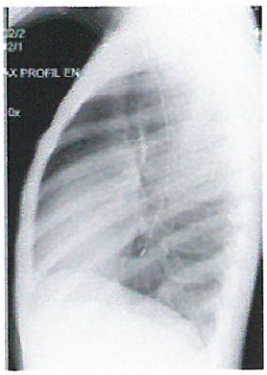


Figure 13 a. Achalasia.

Lateral chest radiograph demonstrates air-fluid level in the dilated esophagus pointed by the tip of the probe.

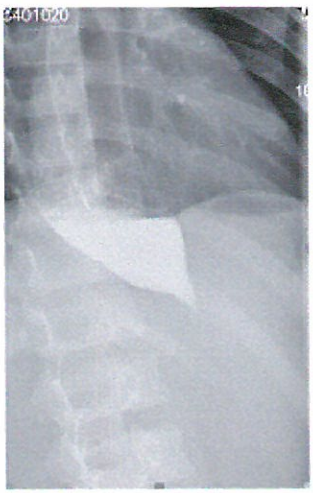


Figure 13b. Achalasia.

Esophagogram demonstrates marked dilatation with abrupt narrowing, the so-called "beak", at the gastroesophageal junction.

3. Foreign bodies

Radioopaque foreign bodies are easily identified on plain radiographs. They represent approximately 60% of all esophageal foreign bodies and most are coins. Coins stop at the areas of narrowing, mainly at the thoracic inlet, and less commonly at the aortic arch or the left main stem bronchus, or just above the gastroesophageal junction. If coins are seen at other levels, underling esophageal anomalies should be considered. Two-view radiographs allow differentiation between foreign bodies in the airway and in the esophagus (fig. 14).
Esophagogram may be useful if there is concern about edema, stricture, or perforation [12]. Nonopaque foreign bodies require esophagogram with small amount of low-osmolarity contrast media.
Sharp objects may be present at any esophageal level if they penetrate mucosa. Long standing foreign bodies may perforate the esophagus leading to pneumomediastinum, and mediatinitis.

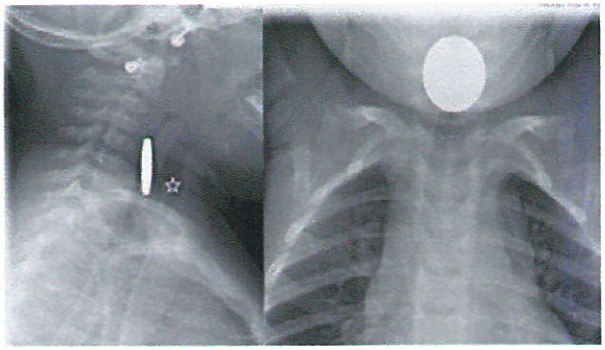


Figure 14. Ingested foreign body.
Frontal and lateral radiographs show a coin lodged above the thoracic inlet (☆ = Trachea).

4. Trauma

The most common cause of esophageal laceration is iatrogenic. The malposition of an enteric tube may perforate pharynx or esophagus, causing esophageal pseudodiverticulum or stricture.
Esophageal laceration secondary to vomiting (Mallory-Weiss syndrome) is quite rare in children but has been reported. Esophageal involvement from blunt or penetrating trauma is anecdotic.

5. Esophagitis

Caustic

Initial chest radiographs or CT may reveal evidence of mediastinitis with a dilated esophagus.
The initial esophagogram is preferably performed with low-osmolar, nonionic contrast material. If no perforation or fistula is seen, barium will provide better coating for thorough evaluation of the mucosa. Early findings include epiglottic swelling, mucosal irregularity, esophageal dysmotility, and ulceration. Inflammation of the pharynx may cause swallowing impairment and aspiration.
Follow-up studies may demonstrate one or several strictures (fig. 15).

Figure 15.
Long term Caustic stenosis of the esophagus

Infectious

Barium esophagogram demonstrates linear or irregular defects separated by normal mucosa. Nevertheless, these children are often treated based on oropharynx findings without any further imaging [11].
Cytomegalovirus and Herpes are other frequents causes of infections esophagitis in immunocompromised patients.

Eosinophilic

Eosinophilic esophagitis is an atopic condition. In such circumstances, the esophagogram shows a narrowed esophageal lumen, caused by thickened wall, a feature also well demonstrated on CT [13,14].

6. Tumours

Esophageal tumours are extraordinarily rare in children and are usually benign. Leiomyoma is the most common benign tumor of the esophagus. It causes leiomyomatous thickening of all or a portion of the esophagus [15].
Barium esophagogram frequently demonstrate smooth, tapered narrowing of the distal esophagus with diminished peristalsis. Esophageal wall thickening may be evidenced. CT is helpful in differentiating this entity from other conditions (90%) and assessing the degree of esophageal wall thickening (fig. 16 a,b,c).
Rare carcinomas has been reported in children with achalasia and following caustic esophagitis [12].

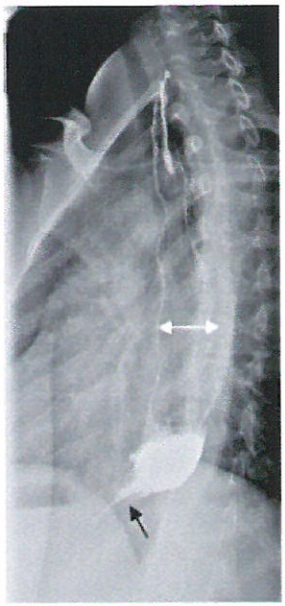
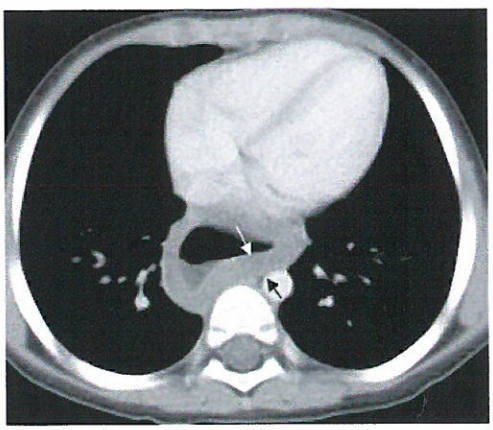


Figure 16. Diffuse esophageal leiomyomatosis.

a. Esophagogram (a) shows esophageal dilatation (double-headed arrow) with distal stenosis (black arrow).

b. Muscular layer thickening demonstrated by US (between calipers)

c. Muscular layer thickening i demonstrated by CT (arrows).



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