The diaphragm: Normal anatomy and pathology

Poster No.: C-0989
Congress: ECR 2010
Type: Educational Exhibit
Topic: Chest
Authors: J. C. Quintero¹, F. Cembellin¹, I. Guasch², S. Mourelo², C. Pérez¹, A. Soboh¹; ¹Ourense/ES, ²Badalona/ES
Keywords: Diaphragm, Normal anatomy, Peridiaphragmatic, and transdiaphragmatic process
DOI: 10.1594/ecr2010/C-0989

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Learning objectives

To describe the normal anatomy, variants of normality and pathology of the diaphragm and peridiaphragmatic structures, emphasizing CT.

To illustrate the importance and advantages of the multidetector CT and magnetic resonance imaging reconstructions from evaluate the diaphragm.

Background

The diaphragm is generally regarded as a structure intrathoracic albeit for their integration across the diaphragmatic crura also be regarded as a structure intraabdominal.

The diaphragm is often considered to be an intrathoracic structure because its major function is to alter the intrathoracic pressure and volume. However, since its long crural pillars arise from the mid lumbar spine, the diaphragm is a leat partly an intraabdominal structure. Covered by pleura on its cephalic aspect and by peritoneum on its caudal aspect, the diaphragm might better be considered to lie in the extrapleural/extraperitoneal space.

Become familiar with the embryological development of the diaphragm will facilitate know the anatomy, pathology and periphragmatic processes.

Imaging findings OR Procedure details

Embryology of the diaphragm

The diaphragm develops from four structures:

- The horizontal septum transversum forms the central tendon that partially separate the pleuropericardial and abdominal cavities
- The bilateral pleuroperitoneal membranes fuse with the posterior aspect of the septum transversum and the dorsal mesentery of the esophagus to complete the separation between the thoracic and abdominal cavities.

- The dorsal mesentery of the esophagus forms the median portion of the diaphragm, fusing with the septum transversum and pleuroperitoneal membranes. The crura develop within this structure.

- The body wall contributes muscular fibers to the peripheral aspect of the diaphragm at the costophrenic sulci.

NORMAL ANATOMY

The mature diaphragm consists of peripheral muscle fibers that converge onto the boomerang-shaped central tendon (Figures 1 to 4). The muscle fibers are longest posteriorly (Figures 5, and 6). The middle leaflet of the central tendon fuses with the caudal aspect of the pericardium; the right and left lateral leaflets of the central tendon from the domes of the hemidiaphragms.

The diaphragm is covered by parietal pleural and peritoneum except for the bare area of the liver. The right and left phrenic nerves arise from the C-3 to C-5 nerve roots and descend through the mediastinum to innervate the diaphragm. Blood is supplied by the phrenic artery and vein, which travel with the phrenic nerve and insert lateral to the pericardium.

The overall configuration and position of the diaphragm is influenced by the mass effect exerted by adjacent intrathoracic and subdiaphragmatic abdominal contents, as well as by the person's body habitus and position. The diaphragm is higher when a person is supine than when he is standing.

Normal openings in the diaphragm

Aortic hiatus

At the level of T12, transmits the aorta, thoracic duct, and the azygos and hemiazygos veins. Because the hiatus is actually an osseoaponeurotic opening located behind the diaphragm, these transmitted structures pass posterior to the diaphragm rather than through it.
Esophageal hiatus

At the level of T10, is formed by decussation of the medial fibers of the right crura. It transmits the esophagus, vagus and sympathetic nerves, and esophageal branches of the left gastric vessels.

Inferior vena caval hiatus

At the level of T8-T9, is located in the central tendon. It transmits the inferior vena cava and branches of the right phrenic nerve.

Attachments of the diaphragm

Anterior attachments

The sternocostal portion or the diaphragm is a muscular band that attaches by muscular slips to the xiphoid and the lower six ribs and cartilages.

The most cephalic attachment of the diaphragm is to the xiphoid. This gives an inverted U-shaped configuration to the anterior diaphragm. The appearance of the anterior diaphragm on transaxial images is influenced by the position of the middle leaflet of the central tendon relative to that of the xiphoid.

Posterior attachments

Crura

Each of the two crura is a musculotendinous pillar that attaches to the anterolateral surfaces of the lumbar vertebral bodies and discs (L1-L3 on the right, L1-L2 on the left). The most cephalic extent of each crus is a level of the esophageal hiatus.

The two crura are connected in front of the aorta just above the celiac trunk by the fibrous median arcuate ligament.

The crura form the anterior and lateral borders of the retrucrural spaces, which contain fat, the aorta, the azygos and hemiazygos veins, nerves, the thoracic duct, other lymphatics, and lymph nodes (Figures 7, and 8).

Medial arcuate ligament
The medial arcuate ligament (or medial lumbocostal arch) is a tendinous arch in the fascia that covers the upper, anterior part of each psoas muscle.

This thin ligament blends with the crus and extends from the L1 or L2 vertebral body to the transverse process of L1.

**Lateral arcuate ligament**

The lateral arcuate ligament (or lateral lumbocostal arch) is a thickened band of fascia covering each quadrates lumborum muscle anteriorly.

This ligament extends from the transverse process of L1 to the midpoint of the 12th rib (*Figure 9*). on page 20

**Ligaments attaching to the diaphragm**

**Inferior pulmonary ligament**

The inferior pulmonary ligament is a double layered extension of pleura that connects the visceral pleural on the lower medial aspect of the lung to the parietal pleural on the mediastinum.

It courses caudally for a variable distance from its origin at the inferior pulmonary veins; it may terminate above the diaphragm, or it may reflect posterolaterally onto the diaphragm to create a bare area on the dome.

The right ligament is located near the inferior vena cava or azygos vein, and the left ligament, nears the esophagus or descending aorta.

**Phrenoesophageal ligament**

The phrenoesophageal ligament (or membrane) is a connective tissue layer arising from the undersurface of the diaphragm and from the diaphragmatic reflection of the endothoracic fascial.

The two main components of this ligament attach to the lower esophagus and tether it, thereby normally limiting esophageal movement relative to the diaphragm.

**Falciform ligament**
The falciform ligament consists of two layers of peritoneum arising from the anterior abdominal wall and anterior-inferior surface of the diaphragm. These layers subsequently diverge onto the liver surface to form the right coronary and left triangular ligament.

The ligamentum teres or round ligament courses from the umbilicus to the anterior surface of the liver in the free edge of the falciform ligament.

The superior and inferior layers of the right coronary ligament fuse laterally to form the right triangular ligament. The bare area of the liver, located between the superior and inferior layers of the coronary ligament, is devoid of peritoneal covering and is in direct contact with the diaphragm posteriorly.

The left triangular ligament extends from the superoposterior surface of the lobe of the liver to the diaphragm, thereby separating the left subphrenic space from the lesser sac.

**Phrenicocollic ligament**

The phrenicocolic ligament connects the splenic flexure of the colon to the diaphragm at the level of the 11th rib. This small but important ligament tends to prevent left paracolic gutter fluid from entering the perisplenic space.

**Ligament of Treitz**

The ligament of Treitz (or suspensory muscle of duodenum) arises from the right crus of the diaphragm and extends obliquely to the duodenojejunal junction. This ligament is rarely visible on CT images.

**Normal diaphragmatic attachments and slips simulating disease**

The median arcuate ligament may extrinsically compress the cephalic aspect of the celiac trunk in some individuals. This compression is most obvious during expiration and may simulate a stenosis at angiography.

Rarely, the diaphragmatic crus may similarly compress a renal artery and, thereby, produce renovascular hypertension. During deep inspiration, the crus markedly thickened.

Diaphragmatic slips may simulate diaphragmatic masses or lymphadenopathy on CT. Multiple diaphragmatic slips appears as parallel structures, which coursed obliquely from anterolaterally to medioposteriorly in the right hemidiaphragm. Diafrraphragmatic slips
appeared as either wedge-shaped, round, oval lobulated, or irregularly shaped structures 1-1.5 cm in transverse diameter (*Figure 10*).

**PERIDIAPHRAGMATIC PATHOLOGY**

**Fluid**

On key to localizing peridiaphragmatic collections is the identification of the diaphragm, most often by sonography or CT (*Figure 11*).

The location of fluid relative to the diaphragm is usually obvious on ultrasound by virtue of the sharp contrast between the echogenic diaphragm and hypoechoic fluid.

On CT images, fluid located peripheral to the diaphragmatic outline usually is in the thorax (*Figure 12*), and fluid located central to it is in the abdomen (*Figure 13*).

It is not always possible on CT scans to identify the diaphragmatic outline with confidence, particularly in patients with little retroperitoneum fat.

**Cardiophrenic nodes**

Enlarged lymph nodes in the cardiophrenic space can be distinguished from pleural abnormalities by a low-attenuation plane between the nodular and the diaphragmatic contour. Similarly, such nodules can be distinguished from exophytic lesions of the upper abdominal viscera by a low-attenuation plane between the nodular and adjacent organs.

We encountered lymph nodes in anterior cardiophrenic in lymphoma (*Figure 14 on page 25*), breast carcinoma, lung carcinoma, and colo-rectal carcinoma.

**Portosystemic shunts** (*Figures 15, and 16*)

**Retrocrus masses**

Enlarged lymph nodes
TRANSDIAPHRAGMATIC PROCESS

Normal diaphragmatic defects and transdiaphragmatic lymphatics

Fluid or cells, or both, can pass from the peritoneal cavity into the pleural space by two routes: microscopic or macroscopic holes in the diaphragm, or transdiaphragmatic lymphatic vessels that connect the peritoneal and pleural spaces.

Flow appears to be exclusively unidirectional, from abdomen to chest, presumably because of the normal abdominothoracic pressure gradient.

Various intraabdominal inflammatory processes (subphrenic abscess, pancreatitis), and no inflammatory conditions (Meigs syndrome, cirrhosis) produce fluid on both sides of the diaphragm.

Abnormalities of the lung bases

An intrapulmonary mass at the lung base abutting the diaphragm often can be distinguished from a pleural or diaphragmatic abnormality on axial images alone. When the origin of such masses cannot be determined on axial images, multiplanar reformations can clarify anatomic relationship.

An intrathoracic origin of the mass can be suggested by depiction of a low-attenuation plane between the mass and intraabdominal organs on reformatted images, or irregular margins with adjacent lung and by acute angles between the mass and the diaphragm.

Focal atelectasis or scarring can be suggested by a flat, smooth interface with the pleural surface or by focal volume loss, as evidenced by vessels and bronchi curving into the mass.
**Abnormalities of the pleura**

A pleural origin of the lesion is suggested by obtuse angles between the lesion and the diaphragm or chest wall, or more specifically, by a contour that follows the course of the pleural surface.

**Abnormalities of the liver and peritoneal/retroperitoneal spaces**

Pyogenic abscess liver  *(Figures 18, and 19)*

Amebian abscess liver  *(Figures 20, and 21)*

Subphrenic abscess  *(Figures 22 to 25)*

Hydatid cyst

Hematoma *(Figure 26) on page 37*

Iatrogenic

**DIAPHRAGMATIC DEFECTS**

**Bochdalek hernia**

Bochdaleck's hernia is a common type of congenital diaphragmatic hernia that usually occurs in the left posterolateral part of the pleuroperitoneal canal by maldevelopment or defective fusion of the pleuroperitoneal membranes during development.

CT shows a discontinuity of the posterolateral part or the diaphragm and a continuous mass above and below the diaphragm *(Figure 27) on page 38*. Stomach, bowel, and even spleen or kidney may herniated into the left hemithorax; on the right, part of the liver may be found above the diaphragm.

Bochdalek hernias as have been reported to occur in 1/2200-1/12500 live births  *(Figures 28, and 29)* with a left to right ratio of 9:1. With the advent of CT, however, many small, asymptomatic defects are being detected: a 6% prevalence of fat filled Bochdalek hernias with a left to right ratio of 2:1 on CT was reported recently.
**Morgagni hernia**

The Morgagni hernia is a rare congenital defect of the anteromedial diaphragm that results from maldevelopment of the septum transversum. It is caused by a weakness in the triangular parasternal space bounded medially by muscle fibers from the xiphoid process and laterally by fibers from the costal cartilages.

Because this retrosternal defect often is associated with a pericardial deficiency, abdominal viscera or fat may herniated into the pericardial sac, or the heart may herniated into the upper abdomen *(Figure 30).* on page 41

**Hiatal hernia**

A weakened or torn phrenoesophageal membrane causes the common sliding hiatal hernia *(Figures 31, and 32)* and the less common paraesophageal hernia. In a sliding hernia, the gastroesophageal junction is above the esophageal hiatus of the diaphragm *(Figure 33).* on page 44

In a paraesophageal hernia, all or portions of the stomach herniated into the chest, but the gastroesophageal junction is below the diaphragm *(Figure 34)* on page 46.

Although esophagography is the best way to show a hiatal hernia, CT also can be used *(Figure 35)* on page 46

A possible complication is the intrathoracic gastric volvulus *(Figures 36, and 37)*

**Partial eventration**

Partial eventration of the diaphragm was thought to be of congenital origin due to lack of muscle in an area where the diaphragm becomes very thin, consisting of only pleural and peritoneum. The area is usually located in the anterior aspect of the right hemidiaphragm.

Although the most common type of eventration did occur in the anterior aspect of the right hemidiaphragm, thinning of the involved part of the diaphragm was not observed. It is possible; therefore, that partial eventration may also be caused by focal dyskinesia or focal weakness of the diaphragmatic muscle, or traumatic antecedent *(Figures 38, and 39).*
DIAPHRAGMATIC TUMORS

There are very rare Malignant tumors: sarcoma, metastasis, and fibrous tumors
Benign tumors: lipoma, neurofibroma, mesotelial cyst

DIAPHRAGMATIC ELEVATION (Figures 40, and 41)

DIAPHRAGMATIC RUPTURE

Epidemiology

Diaphragmatic rupture may result from a penetrating injury (usually a knife or gunshot wound) or from blunt trauma. Since knife injuries are commonly caused by an upward thrust, the external entry point is often abdominal and not thoracic. Injuries to the left hemidiaphragm occur three times more frequently than injuries to the right side following blunt trauma possibly due to a buffering effect of the liver on the right hemidiaphragm.

In patients with multiple injuries following blunt trauma, the incidence of diaphragmatic rupture is about 5%. 90% of ruptures in patients who survive their initial injuries occur in the left hemidiaphragm. Most recognized diaphragmatic tears exceed 10 cm in length. Traumatic diaphragmatic injury is generally suggested on chest radiographs but is often diagnosed incidentally at surgery.

The "interval" phase of herniation, defined as occult diaphragmatic herniation, is often asymptomatic or manifests as vague dyspeptic symptoms or upper abdominal discomfort. In approximately 85% of cases that culminate in organ strangulation, the strangulation occurs within 3 years.

The diagnosis of diaphragmatic rupture is frequently delayed from months or years, often to the detriment of the patient who may present with a catastrophic complication such as bowel strangulation.
Chest radiography

Plain radiographic findings of diaphragmatic injury include hemothorax, basal lung opacity, herniation of a hollow viscous into the chest, contralateral shift of the mediastinum, apparent elevation of a hemidiaphragm, or abnormal contour of the hemidiaphragm.

Specific diagnostic findings include: intrathoracic herniation of a hollow viscus with or without focal constriction of the viscus at the site of the tear (collar sign), and visualization of a nasogastric tube above the hemidiaphragm on the left side.

Computed Tomography

Discontinuity of the diaphragmatic outline rarely is identified on CT studies in cases of diaphragmatic rupture. Unfortunately, the scans of severely injured patients are often suboptimal owing to poor bowel opacification and patient motion, and the diaphragmatic tear may be parallel to the plane of section. Use of helical CT and sagittal reformation may improve the sensitivity.

Findings suggestive of hemidiaphragmatic tears include: direct discontinuity of the hemidiaphragm (Figure 42), intrathoracic herniation of abdominal contents (stomach, colon, and liver), the collar sign, and a waistline constriction of the herniating hollow viscus ate the site of diaphragmatic tear, and dependent viscera sign.

Other imaging findings

Direct coronal and sagittal MR imaging with respiratory and cardiac gating may allow confirmation or exclusion of the diagnosis. Interruption of the diaphragmatic signal due to the laceration may confirm a traumatic diaphragmatic injury.

Barium studies allow confirmation of herniated intestine or stomach but are limited to evaluation of hollow viscera.

Fluoroscopy demonstration of severely decreased diaphragmatic motion, which resembles paresis, is highly suggestive but no diagnostic of traumatic diaphragmatic injury.
Images for this section:

**Fig. 1:** Figure 1. Normal anatomy of diaphragm. Coronal CT reconstruction
Fig. 2: Figure 2. Normal anatomy of diaphragm. Coronal CT reconstruction
**Fig. 3:** Figure 3. Normal anatomy of diaphragm. Coronal CT reconstruction
**Fig. 4:** Figure 4. Normal anatomy of diaphragm. Coronal CT reconstruction
**Fig. 5:** Figure 5. Normal anatomy of diaphragm. Sagittal CT reconstruction
Fig. 6: Figure 6. Normal anatomy of diaphragm. Sagittal CT reconstruction
Fig. 7: Figure 7. Coronal CT reconstructions. The crura are well delineated when in contact with fat
Fig. 8: Figure 8. Crura detail. Axial CT images in three cases
**Fig. 9:** Figure 9. The lateral arcuate ligament may be visible on CT scans as they course toward the 12th ribs. The ligaments should not be mistaken for fascial thickening or tumor deposits. Oblique-sagittal, axial, and coronal reconstructions
**Fig. 10:** Figure 10. Prominent diaphragmatic slips are smoothly indenting the dome of the liver. The periodicity of the indentations is a clue to their nature. The slips themselves are not individually visible because of the paucity of fat. Diaphragmatic slips may simulate diaphragmatic masses or lymphadenopathy on CT.
**Fig. 11:** Figure 11. Pleural effusion is separate of abdominal cavity from right diaphragm. Note brachiocefalic vein thrombosis.
Fig. 12: Figure 12. Left pleural effusion separate with abdominal cavity from left diaphragm
Fig. 13: Figure 13. Fluid peritoneal in child A cirrhosis. Relation with right diaphragm
Fig. 14: Figure 14. Enlarged lymph nodes in anterior cardiophrenic right in a patient affect of lymphoma
Fig. 15: Figure 15. Venous tortuous in anterior cardiophrenic right in a patient with cirrhosis (Child C)
Fig. 16: Figure 16. Contrast-enhanced axial CT shows esophageal varices, which are difficult to see because they are embedded in the esophageal wall.
Fig. 17: Polysplenia, and inferior vena cava agenesis. Enlarged azygos vein in right retrocrural space
**Fig. 18:** Figure 18. Contrast-enhanced CT show a large well defined and hypoattenuation, and multilocular lesion with smooth margins or complex with internal septa and an irregular contour
**Fig. 19:** Figure 19. Five days after the pyogenic liver abscess progress to pleural cavity
**Fig. 20:** Figure 20. Amebian liver abscess with thoracic extension. Ultrasound images
Fig. 21: Figure 21. Amebian liver abscess with continuity into right pleural space. CT findings
Fig. 22: Figure 22. Left subphrenic abscess and effusion pleural associated after distal pancreatectomy by adenocarcinoma of the pancreas. Coronal CT image
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**Fig. 24:** Figure 24. Right subphrenic abscess in a patient with AIDS. Ultrasound detected extension into the pleural cavity
Fig. 25: Figure 25. Right subphrenic abscess in a patient with AIDS. Axial CT images shows the relation with right pleural space
Fig. 26: Figure 26. Spontaneous retroperitoneal hematoma in a 67-years-old patient. Coronal and axial CT images
Fig. 27: Figure 27. CT scan show discontinuity of left posterolateral part of diaphragm contain stomach and tissue pancreatic
Fig. 28: Figure 28. Diaphragmatic congenital hernia. Posterolaterally radiographs
**Fig. 29:** Figure 29. Diaphragmatic congenital hernia. Laterally radiographs
**Fig. 30:** Figure 30. MR images show a large Morgagni hernia containing colon. No diaphragm could be identified cephalic to the mass.
**Fig. 31:** Figure 31. Axial CT images in a sliding hernia
Fig. 32: Figure 32. Coronal and sagittal reconstructions. Sliding hernia
Fig. 33: Figure 33. Spot radiograph of the proximal stomach obtained with the patient supine shows the gastric fundus (*) lying above the diaphragm.
Fig. 34: Figure 34. Paraesophageal hernia. Esophagography
Fig. 35: Figure 35. Diagram of sliding and para-esophageal hernias

Fig. 36: Figure 36. Intrathoracic gastric volvulus. Esophagogastroduodenal barium serie
Fig. 37: Figure 37. Intrathoracic gastric volvulus. Coronal, sagittal and axial reconstructions
**Fig. 38:** Figure 38. Focal eventration in a patient with diaphragm metastasis from kidney tumor six years ago.
Fig. 39: Figure 39. A 67-years-old women with history of coloplastia ten years ago from caustic voluntary ingestion. No repaired sliding hernia. Recurrente hernia demonstrated with esophagography and axial CT images.
Fig. 40: Figure 40. Left diaphragm elevation. Coronal CT reconstruction
**Fig. 41:** Figure 41. Left diaphragm elevation. Axial CT image in a patient with bronchogenic carcinoma
**Fig. 42:** Figure 42. Left diaphragmatic tear in a 35-year-old patient after blunt trauma. CT scan shows intrathoracic herniation of the stomach and colon owing to left diaphragmatic rupture, and a pleural effusion
Conclusion

Given the shape and thinness of the diaphragm is difficult to visualize a structure in its entirety. For its structural complexity anatomical structures with multiple ligaments and connections to the chest and abdomen is more than just a border between the two cavities.

Technological advances with team's multidetector CT with multiplanar reconstructions have improved markedly display normal diaphragm and the pathology of the area and diaphragmatic peridiaphragmatic.

Presently, helical CT enables acquisition of volumetric data, eliminating respiratory motion while providing good-quality sagittal and coronal reformation images. Consequently, it is well suited to evaluation of the diaphragm and improves the accuracy of CT in diagnosis of diaphragmatic injuries.

Personal Information

Juan Carlos Quintero Rivera
Complexo Hospitalario de Ourense
Department of Radiology
Rúa Ramón Puga, 52-54
32005 Ourense

juan.carlos.quintero.rivera@sergas.es
Images for this section:

Fig. 1: Figure 1. Uxia, Andrea, and Uxia. My daughters and niece
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