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Diaphragmatic hernias: classifications and spectrum of presentations in computed tomography, magnetic resonance and plain radiography

Hernias diafragmáticas: clasificaciones y espectro de presentaciones en tomografía computarizada, resonancia magnética y radiografía simple

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Abstract

Diaphragmatic hernias represent a frequent pathology in radiological practice. A congenital or acquired defect in the diaphragm facilitates the passage of abdominal structures into the thoracic cavity. Their clinical relevance varies widely from benign and incidental findings (mostly), to potentially life threatening. The objective of this work is to review the range of findings in computed tomography of diaphragmatic defects in adult patients, categorized according to location and origin, as well as their possible complications. We include a brief description of the embryological development and normal anatomy of the diaphragm, to understand this entity.

Keywords: *Diaphragmatic hernias. Congenital diaphragmatic hernias. Multislice computed tomography. Magnetic resonance.*

Resumen

Las hernias diafragmáticas representan una patología frecuente en la práctica radiológica. Un defecto congénito o adquirido en el diafragma facilita el paso de estructuras abdominales hacia la cavidad torácica. Su relevancia clínica varía ampliamente desde hallazgos benignos e incidentales (en su mayoría), hasta potencialmente mortales. El objetivo del presente trabajo es realizar una revisión de la gama de hallazgos en tomografía computarizada de los defectos diafragmáticos en pacientes adultos, categorizados según localización y origen, además de sus eventuales complicaciones. Incluimos una breve descripción del desarrollo embriológico y anatomía normal del diafragma, para comprender esta entidad.

Palabras clave: *Hernias diafragmáticas. Hernias diafragmáticas congénitas. Tomografía computarizada multicorte. Resonancia magnética.*

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Introduction

Diaphragmatic hernias represent a frequent pathology in radiological practice. They consist of the ascent of abdominal structures towards the thoracic cavity through a defect in the diaphragm[1]. These defects may be congenital or acquired. In turn, congenital hernias are subdivided into posterior (Bochdalek) (about 80%) or anterior (Morgagni); there are also diaphragmatic eventrations that, although they are not hernias through defects between diaphragmatic muscle groups, occur during development due to aplasia of a region of the diaphragm[2]. On the other hand, acquired hernias can be classified according to their etiology as traumatic (closed, penetrating or iatrogenic trauma) or non-traumatic (hiatal hernias or posterior diaphragmatic defect) (Fig. 1).

The clinical importance varies widely from benign and incidental findings for the most part, to potentially fatal. Given its ability to perform fine slices and multiplanar reconstructions, multidetector computed tomography (MDCT) plays a fundamental role in the adequate characterization of the diaphragmatic defect and its possible complications, which makes it an essential tool to guide treatment.

The objective of this work is to review the range of imaging findings of diaphragmatic defects in adult patients, categorized according to location and origin, as well as their possible complications. We include a brief description of the embryological development and normal anatomy of the diaphragm, to understand this pathology.

Embryology and anatomy

The diaphragm is a dome-shaped muscle-tendon structure that delimits the peritoneal and pleural cavities. During its development, three main muscular components are formed that converge towards a central tendon: the *pars lumbaris* (posterior), the *pars costalis* (middle) and the *pars sternalis* (anterior). The spaces formed between the three muscle groups are covered only by pleura, peritoneum and two fascias (transversalis and phrenicopleural) and represent points of potential weakness through which abdominal contents can protrude. Dorsally, the defect between the *pars costalis* and the *pars lumbaris* is called the Bochdalek space. Ventrally, the defect between the *pars costalis* and the *pars sternalis* is called the Morgagni space on the right and the Larrey space on the left, however, any ventral herniation is called a Morgagni hernia.

Transphrenic communications linking the thoracic and abdominal cavities (allowing passage of vital structures and bidirectional migration of pathological processes) are the esophageal, aortic and Morgagni hiatus and potentially the lumbocostal triangle, the vena cava foramen, phrenic lymphatic vessels and potential small diaphragmatic defects (in the porous diaphragm syndrome)[3]. The vena cava foramen is located in the central tendon and its adherence to the vein wall does not allow passage of other structures. The esophageal and aortic hiatuses are located between the medial, intermediate and lateral arms of the *pars lumbaris*. The esophageal-diaphragmatic membrane connects the esophagus to the diaphragm and seals the potential pleuroperitoneal communication in this area (Fig. 2)[1,4].

Bochdalek hernia or posterior (dorsal) diaphragmatic defect

Bochdalek hernias are known as posterolateral diaphragmatic defects present from birth (congenital hernia) and posterior diaphragmatic defects (acquired hernia) are those that appear after the eighth week from birth. The Bochdalek hernia represents about 80% of congenital hernias and was first described in 1848 by Vincent Bochdalek[5]. It consists of a developmental defect of the pleuroperitoneal folds or failure in the fusion between these and the transverse septum, with the intercostal muscles, between the fourth and tenth week of gestation; depending on the size of the hernia, it can prevent normal lung development (Figs. 3 and 4)[1].

It has been most frequently described between the neonatal and preschool periods, and presents with respiratory symptoms secondary to pulmonary hypoplasia; it is associated with other congenital anomalies in 25 to 50% of cases, the most frequent being congenital heart disease[5]. The prevalence of posterior diaphragmatic defects in the adult population varies between 0.17 and 6%, being more frequent in patients with pulmonary emphysema and in the female gender, probably secondary to a congenital weakness in the region of the pleuroperitoneal membranes[1,6]. They correspond to incidental findings in 75% of cases or are presented with nonspecific gastrointestinal symptoms.

The typical imaging appearance is a posterior or posteromedial diaphragmatic discontinuity, with variable abdominal content (Fig. 5)[5]. The size of the diaphragmatic defect does not necessarily correlate with the size of the hernial sac. Although traditionally it has been described that these hernias predominate on the

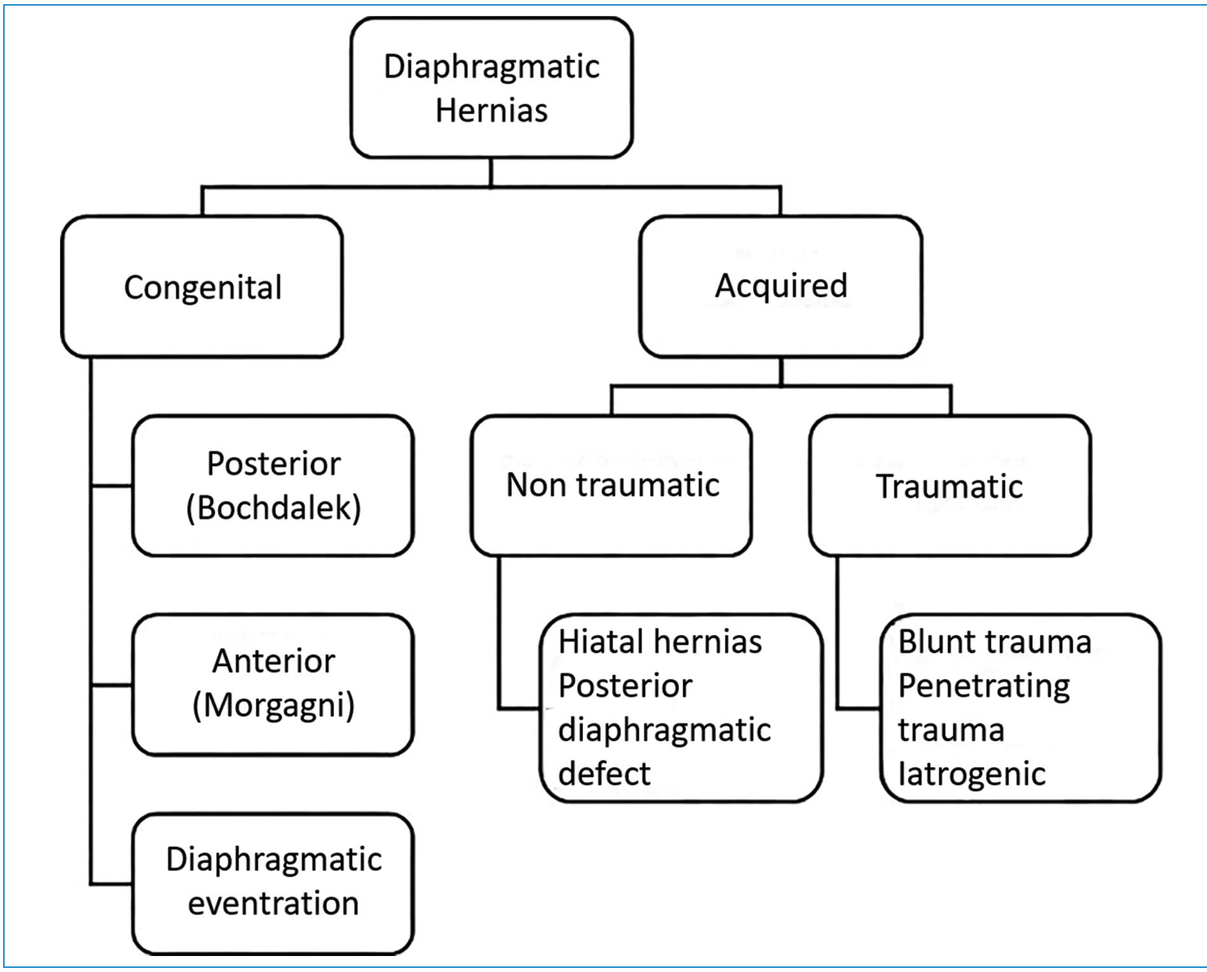

Figure 1. Classification of diaphragmatic hernias according to origin.

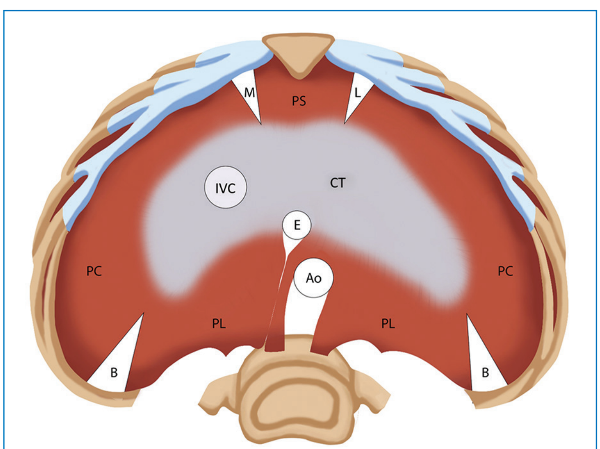

Figure 2. Anatomical drawing of the diaphragm, axial view from caudal. Potential weak points of the diaphragm.
Ao: aortic hiatus; B: Bochdalek; E: esophageal hiatus; L: Larrey; M: Morgagni; PC: *pars costalis*; PL: *pars lumbaris*; PS: *pars esternalis*; TC: central tendon; IVC: inferior vena cava.

left side (70-90%), some case series report a right-sided predominance[1,6].

When the diaphragmatic defect is on the left side, the hernia content may include the colon, stomach, spleen, small intestine loops, omentum, pancreas, and the ipsilateral adrenal gland; while, if the defect is on the right side, it may contain the liver, gallbladder, ipsilateral kidney, and omentum[5].

Morgagni's hernia

Morgagni's hernia corresponds to a rare type of congenital hernia (less than 10%) first described in 1769 by Morgagni as a ventrolateral diaphragmatic defect, based on autopsy findings[1,7].

They are caused by an alteration in the fusion of the transverse septum with the lateral muscular wall, that defines a ventral opening of triangular morphology between the muscle fibers of the diaphragm, which

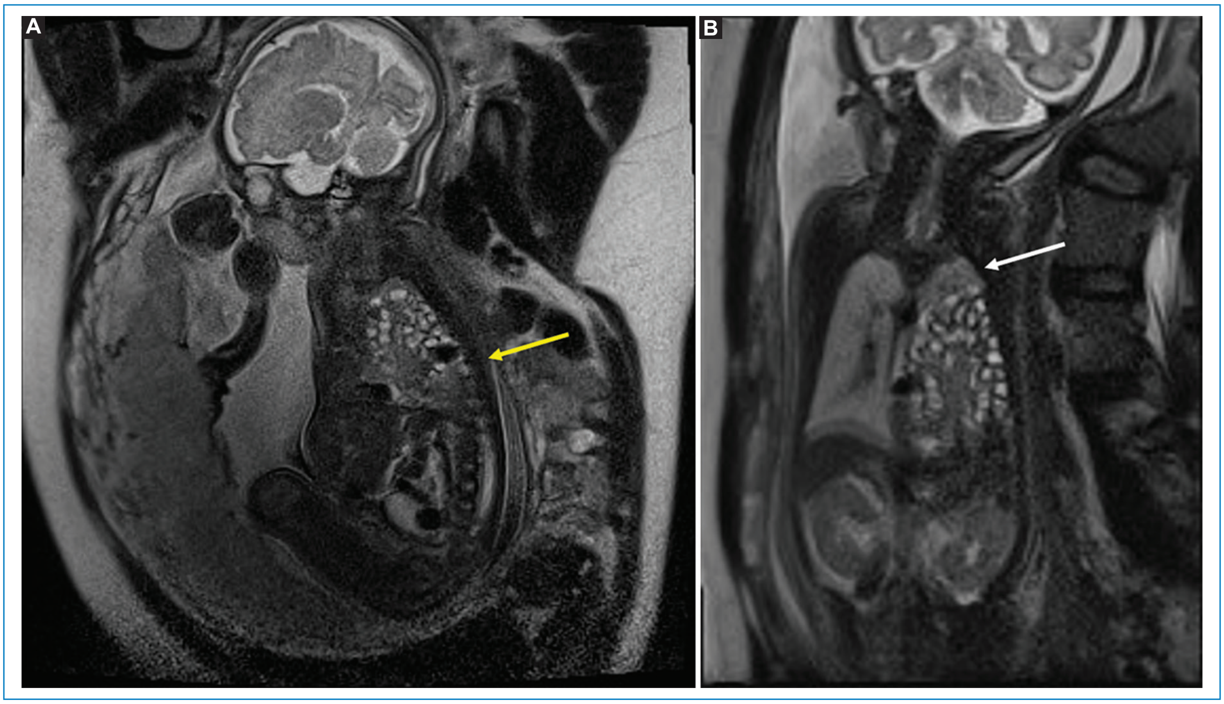

Figure 3. Bochdalek hernia. Selected fetal magnetic resonance images on sagittal (**A**) and coronal (**B**) T2-weighted planes. A left dorsal diaphragmatic defect is observed (yellow arrow) with ascent of multiple intestinal loops to the thoracic cavity and ipsilateral pulmonary hypoplasia (white arrow).

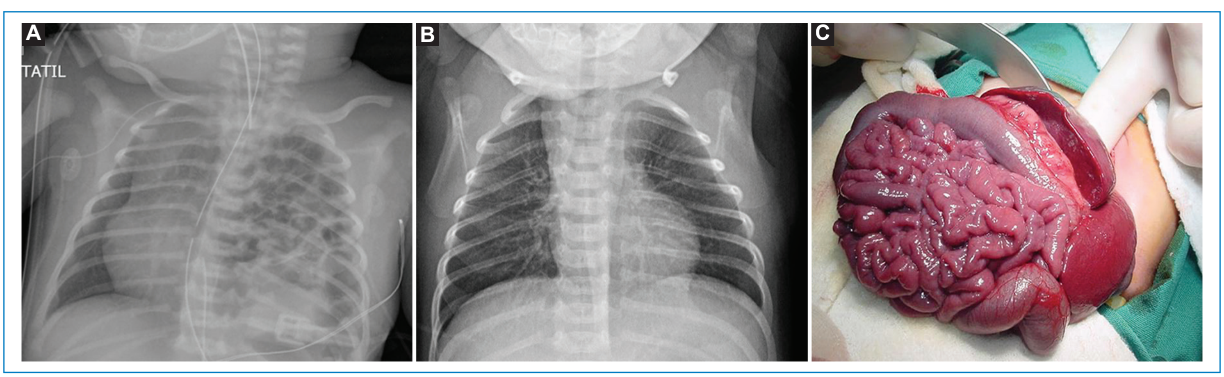

Figure 4. Evolution of Bochdalek hernia. **A**: postnatal control x-ray, ascent of multiple intestinal loops is observed towards the left pulmonary field, with contralateral displacement of the cardiothymic silhouette. **B**: late postoperative control X-ray, showing adequate insufflation and symmetrical lung fields, continuous diaphragms and a normally positioned cardiothymic silhouette. **C**: intraoperative image.

originate in the xiphoid process medially and the eighth rib laterally, called the foramen of Morgagni; the increased intra-abdominal pressure secondary to various causes determines the migration of abdominal contents towards the thorax[8,9].

They are generally unilateral, affecting the right side 90% of the time. The most frequent contents are the colon (54 to 72%) and the omentum (65%), but loops of the small intestine, stomach or liver may also protrude[7].

They are usually diagnosed in adults or older children, with a predominance in the female gender (61%). Most are asymptomatic, however some cases may manifest as recurrent lung infections or gastrointestinal obstruction[7,9]. When diagnosed in young children, it is associated with other congenital abnormalities in

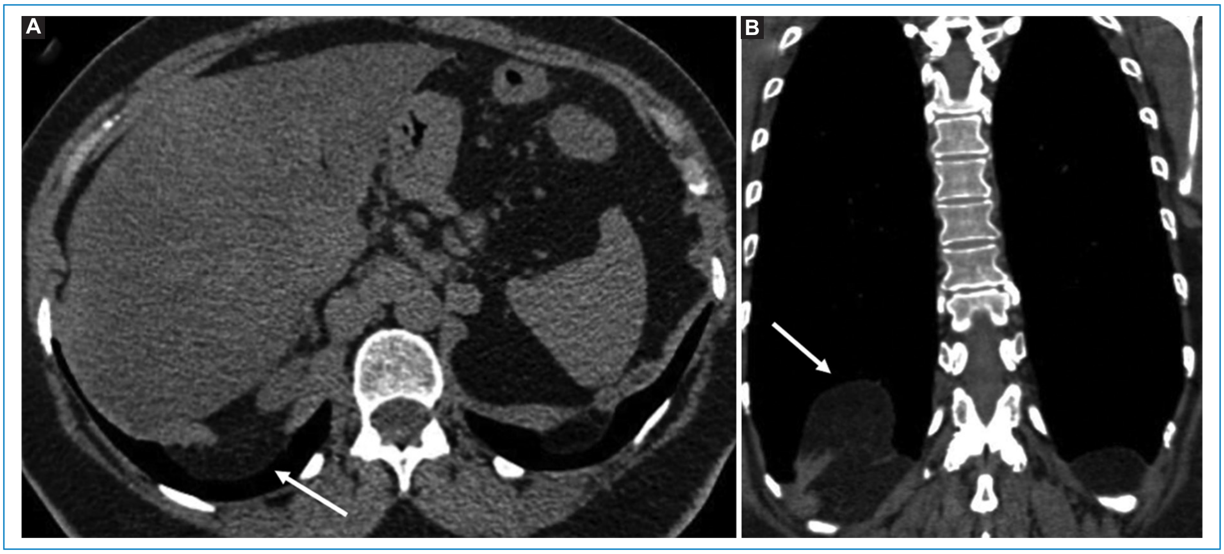

Figure 5. Posterior diaphragmatic defect. Selected images of axial non-contrast multidetector computed tomography of the chest (**A**) and coronal reconstruction (**B**), showing a right posterior discontinuity of the diaphragm with ascent of abdominal adipose tissue (white arrows).

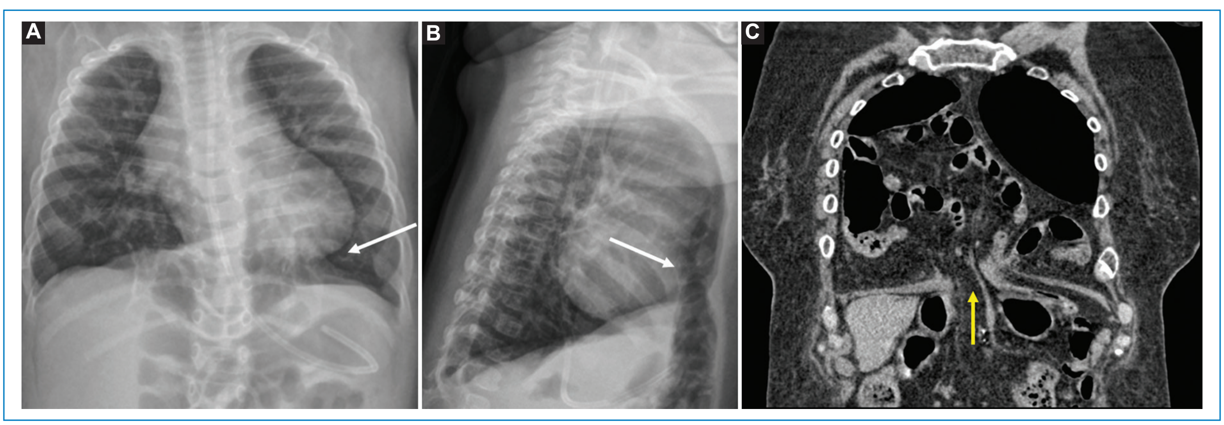

Figure 6. Morgagni hernia. Frontal (**A**) and lateral (**B**) chest X-ray, showing a retrosternal diaphragmatic defect with midline hydro-air images in continuity with the intra-abdominal intestinal loops (white arrows). Coronal reconstruction (**C**) of multidetector computed tomography of the chest showing an anterior diaphragmatic defect with ascent of intestinal loops and adipose tissue (yellow arrow).

34 to 50% of the cases, the most frequent being congenital heart disease (25 to 60%) and Trisomy 21 (15 to 71%)[7].

MDCT is the best diagnostic tool, as it allows characterization of the diaphragmatic defect and the herniated content, and shows a well-circumscribed retrosternal mass with smooth edges, with variable content depending on the herniated abdominal structure (Fig. 6). In addition, it allows the diagnosis of possible complications, such as incarcerated or strangulated hernias (Fig. 7).

Hiatal hernia

The esophageal hiatus is an elliptical opening in the muscular portion of the diaphragm, on the left ventrolateral aspect of the spine, at the level of the tenth thoracic vertebra; its edges are formed by the diaphragmatic crura and it is separated from the aortic hiatus by the decussation of the right crus. The esophagus is joined to the diaphragm through the phrenico-esophagael ligament (PEL) or Laimer Bertelli membrane, which obliterates the potential space between the diaphragm

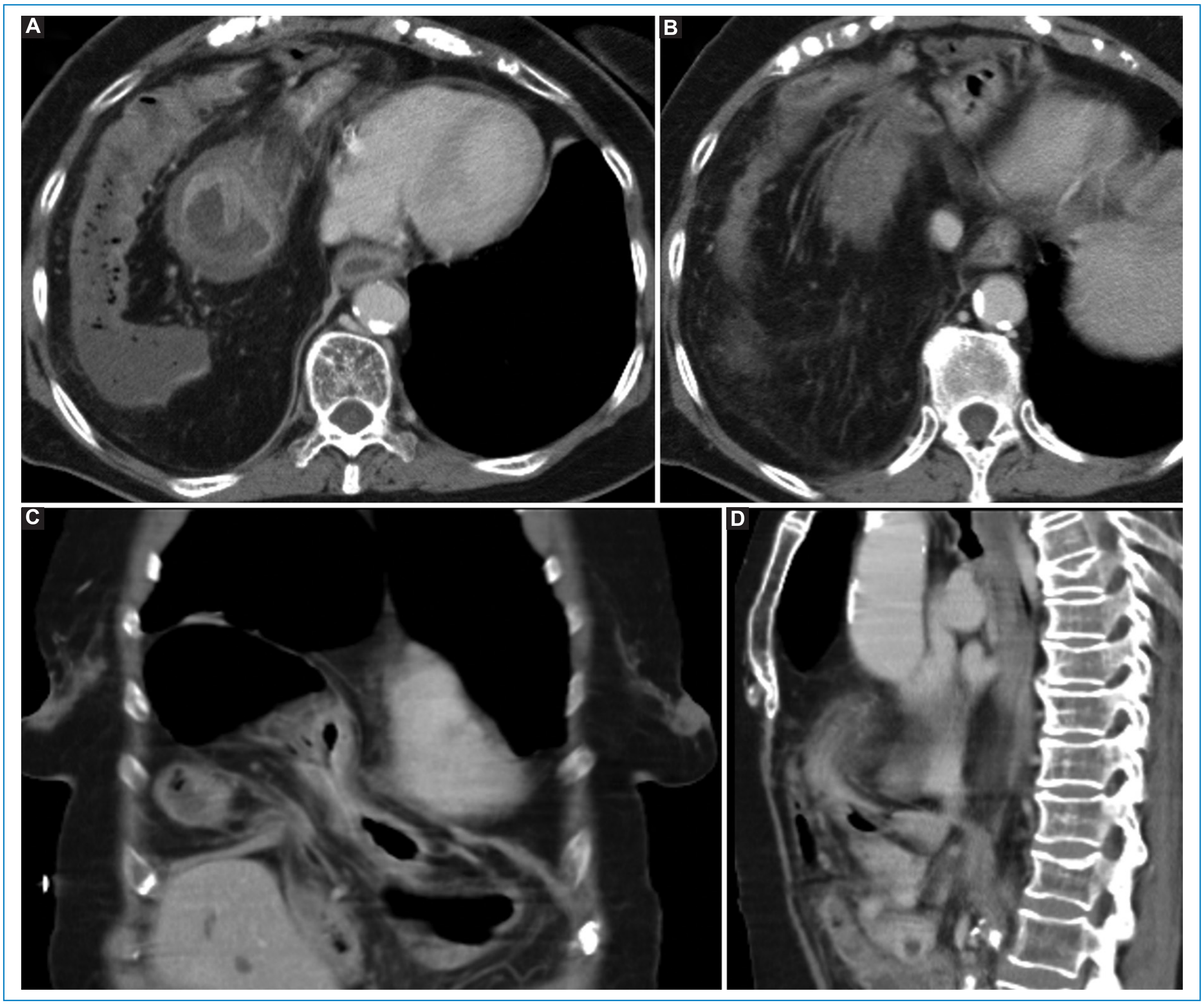

Figure 7. Complicated Morgagni hernia. Selected axial multidetector computed tomography images (**A** and **B**) and sagittal (**C**) and coronal (**D**) reconstruction.

and the esophagus. This ligament contains elastic fibers that allow, but at the same time limit, the sliding of the esophagus during swallowing and breathing. In the hiatal hernia, the ligament is significantly thinned and its elasticity is reduced, which determines that the esophagus becomes more mobile[1,6].

The prevalence of hiatal hernias increases with age and shows a slight predominance in the female gender[10].

Four subtypes are described (Fig. 8):

– Type I (sliding hiatal hernia) is the most common, around 90-95% of all hiatal hernias. It occurs when the gastroesophageal junction ascends with the cardia towards the mediastinum, due to weakness or elongation of the PEL[6]. The cardia is usually displaced more than 2 cm above the esophageal hiatus, which is frequently widened (3-4 cm), the gastric fundus may also be displaced above the diaphragm; it presents as a retrocardiac mass with an air-fluid level on chest x-ray (Figs. 9 and 10). Most patients are asymptomatic; the symptoms are usually secondary to gastroesophageal reflux.

– Type II (paraesophageal hernia) occurs when the gastroesophageal junction remains in its normal intra-abdominal position and the gastric fundus ascends through the hiatus (Fig. 11), secondary to a focal defect in the ventrolateral region of the PEL. The main complication is incarceration and ischemia.

– Type III (mixed hiatal hernia) consists of the ascent of both the gastroesophageal junction and the stomach, they are usually large in size and are associated with gastric malrotation (Fig. 12). It is the most frequent presentation of paraesophageal hernias and combines characteristics of type I and II hernias[10].

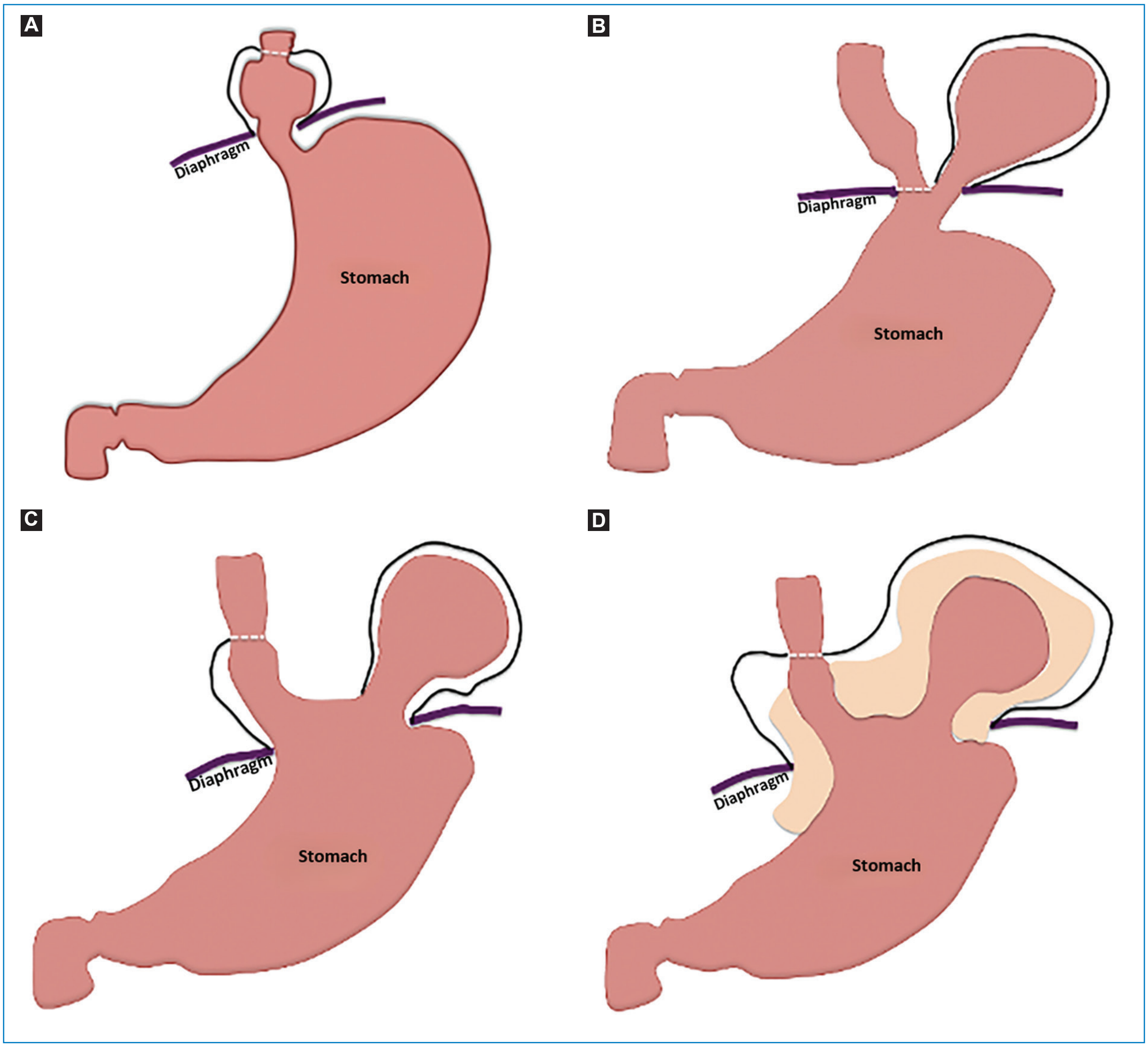

Figure 8. Diagram of the types of hiatal hernias: type I (**A**), type II (**B**), type III (**C**) and type IV (**D**).

There is a combination of diffuse weakness and elongation of the PEL, in addition to a focal ventrolateral defect.

– Type IV hernias (mixed hernias) are associated with herniation of the omentum, intestinal loops, pancreas, liver or other abdominal organ; although the colon is usually the most frequent finding in the hernial sac (Fig. 13).

– Type III and IV hernias are associated with gastric malrotation, which in turn can be complicated by gastric volvulus.

The most common gastric rotation is the organ-axial, along its longitudinal axis, so the position of the greater and lesser curvatures is reversed (the greater curvature moves towards the cephalad and medial and vice versa)[6]. Mesenteric-axial rotation occurs when the stomach rotates perpendicular to its longitudinal axis, the pylorus ascends and moves anteriorly.

The term gastric volvulus is applied when the gastric rotation is at least 180º and is associated with intestinal obstruction. Organo-axial volvulus is more frequent in adults (60%), while mesenteric-axial volvulus predominates in pediatrics.

Diaphragmatic eventration

Although they do not represent a diaphragmatic hernia in their classic definition, diaphragmatic eventrations are produced by an area of diaphragmatic muscle aplasia that allows the protrusion of abdominal

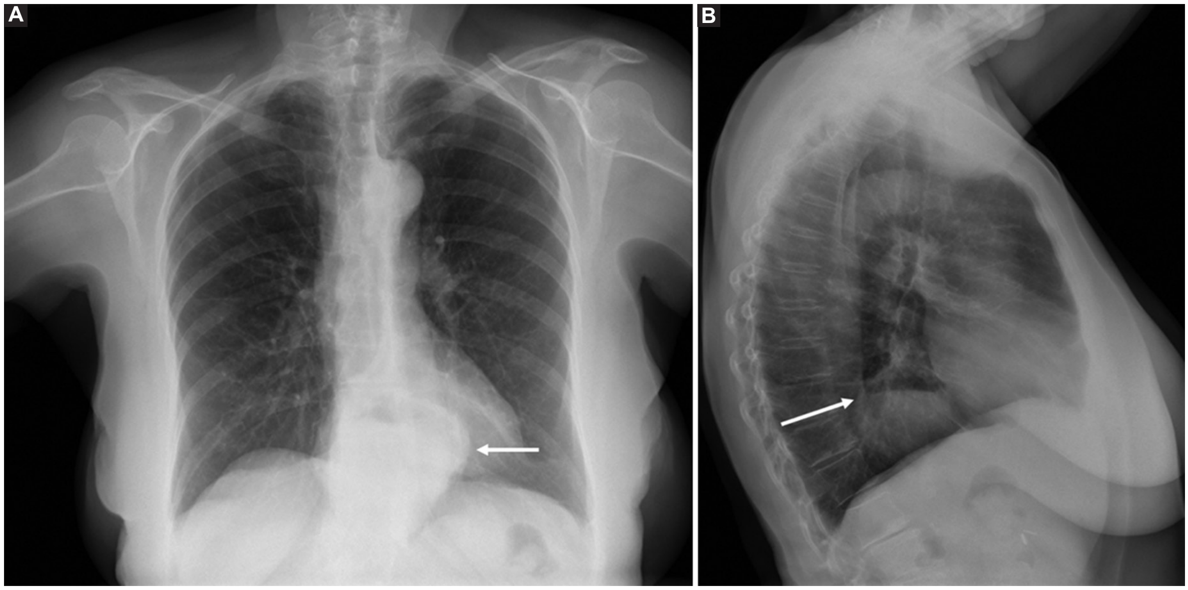

Figure 9. Sliding hiatal hernia. Frontal (**A**) and lateral (**B**) chest X-ray. In the retrocardiac region, a rounded opacity with well-defined edges is observed, with an air-fluid level inside (white arrows in **A** and **B**).

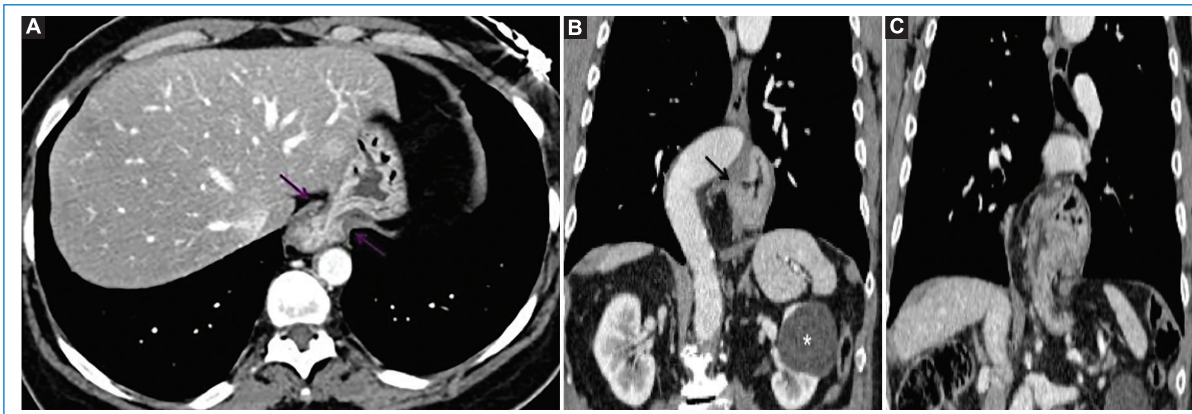

Figure 10. A: type I hiatal hernia. Selected MDCT axial slice, showing the ascent of the gastroesophageal junction through the diaphragmatic crura (arrows), determining a dilatation of the esophageal hiatus. **B** and **C**: type I hiatal hernia. Coronal (**B**) and oblique coronal (**C**) reconstruction of MDCT with intravenous contrast. There is evidence of the gastroesophageal junction ascending into the mediastinum (arrow), with displacement of the descending thoracic aorta to the right, secondary to mass effect. Incidentally, a simple cyst is observed in the left kidney (asterisk).
MDCT: multidetector computed tomography.

structures towards the thorax. This is possible because an area of weakness is produced where only peritoneum, diaphragmatic tendon and pleura are interposed between the thoracic and abdominal spaces (Fig. 14)[1]. Typically, they represent an incidental finding, however associations with congenital cardiac alterations, pulmonary hypoplasia and tracheomalacia, among others, have been described. Usually asymptomatic, they may require surgical intervention when they produce tachycardia, dyspnea or recurrent pneumonia[11].

The typical radiological appearance is the protrusion of a portion of the hemidiaphragm with a thin membrane separating the peritoneal and pleural cavities, which can generate a mass effect and contralateral

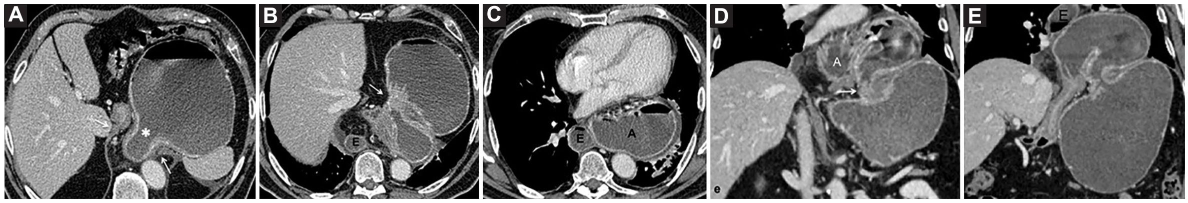

Figure 11. Type II hiatal hernia. Axial slices (**A-C**) and coronal reconstructions (**D** and **E**), identifying intrathoracic protrusion of part of the fundus, body and gastric antrum, the gastroesophageal junction remains in its normal intra-abdominal position (asterisk). Organo-axial gastric rotation (arrows) of chronic appearance is also observed, with dilatation of the esophagus (**E**) and intra-abdominal stomach (**A**).

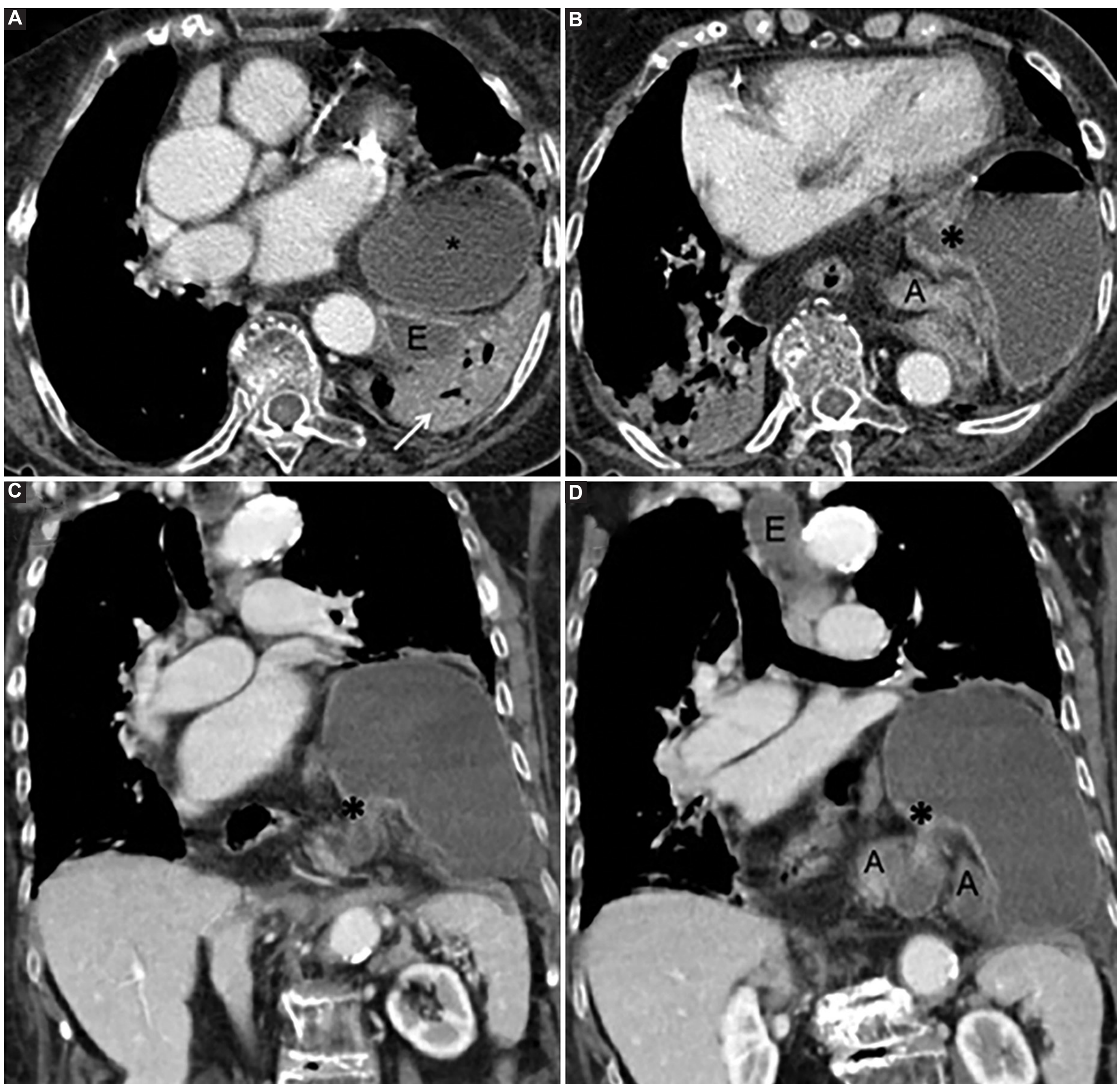

Figure 12. Type III hiatal hernia. Axial slices (**A** and **B**) and coronal reconstructions (**C** and **D**) of a computed tomography of the thorax, abdomen and pelvis. There is evidence of the gastroesophageal junction (asterisks) and the gastric chamber, which is slightly rotated, ascending into the thoracic cavity, with no evidence of complications. There is also secondary dilatation of the esophagus (E) and a focus of aspiration etiology condensation in the left lung base (arrow). *A: antrum.*

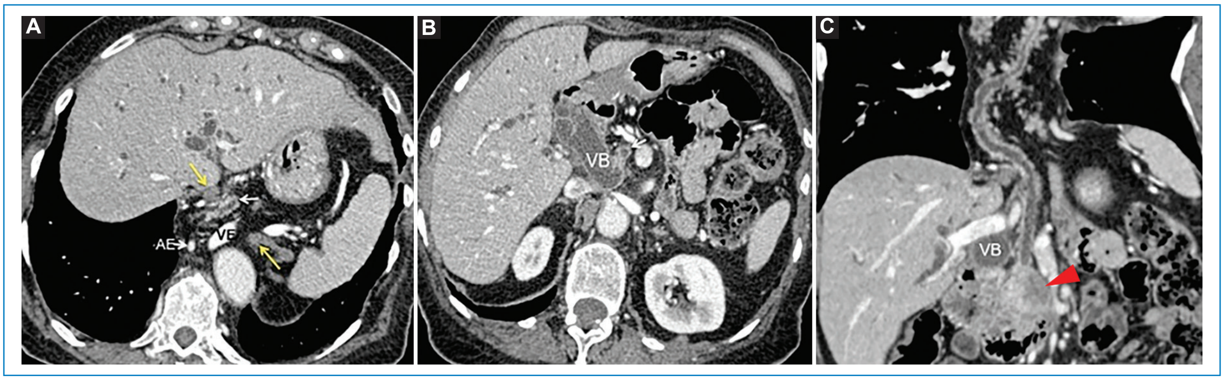

Figure 13. Type IV hiatal hernia. Axial slices (**A** and **B**) and coronal reconstruction (**C**) of a multidetector computed tomography of the thorax, abdomen and pelvis. Dilatation of the esophageal hiatus (yellow arrows) is observed with the gastroesophageal junction, stomach, pancreas (white arrows) and splenic vessels ascending into the thoracic cavity. The pancreas is seen to be atrophic in its ascending course through the esophageal hiatus, with dilatation of the main pancreatic duct secondary to the presence of a hypovascular mass in the head of the pancreas (red arrowhead) which also causes dilatation of the bile duct (**B** and **C**).
AE: splenic artery, VB: bile duct; VE: splenic vein.

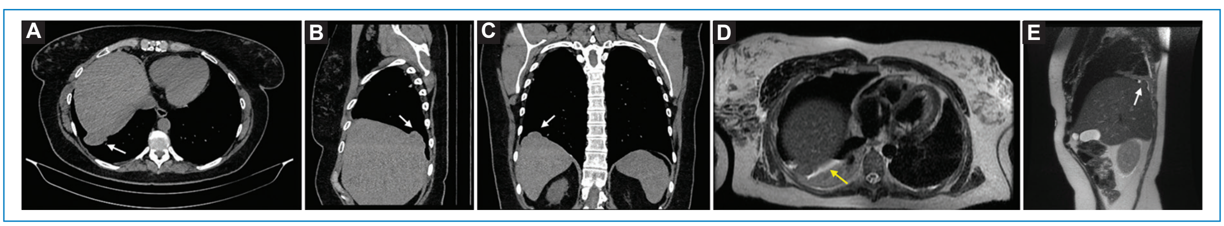

Figure 14. Diaphragmatic eventration. Multidetector computed tomography, axial slice (**A**), sagittal (**B**) and coronal (**C**) reconstruction. Axial T2 (**D**) and sagittal T2 (**E**) magnetic resonance. Focal weakness of the right diaphragm is observed through which the liver parenchyma protrudes (white arrows). It is associated with mild pleural effusion (yellow arrow in **D**).

mediastinal displacement, which allows a potential differentiation with diaphragmatic paralysis[11].

Traumatic hernias

Traumatic hernias, also called traumatic diaphragmatic ruptures, occur in about 75% of cases in relation to blunt trauma and in the remaining 25% in penetrating trauma close to the diaphragm region[12]. Due to the nature of the high-energy blunt trauma, these lesions may go unnoticed due to their diagnostic difficulty or diminished in the presence of other serious traumatic injuries (frequent in this scenario), since it is believed that their incidence is significantly underestimated. They rarely occur due to iatrogenic causes due to surgery near the diaphragm or due to hyperpressure during pregnancy[1].

There is controversy regarding the most frequent location of blunt traumatic hernias, with a certain preference for the location on the left side, with a ratio of approximately 3:1, which could be due to a combination of multiple factors, including the protective effect of the liver or a congenital weakness in the dorsolateral aspect of the left hemidiaphragm[12].

Blunt mechanism traumatic hernias are usually larger than those from a penetrating cause, frequently greater than 10 cm[13].

The findings on the plain radiograph are nonspecific and include ascent of the diaphragmatic dome, presence of opacity with soft tissue density or hydro-air in the lower chest, visualization of an enteral tube with an abnormal U-shaped path that ascends towards the chest after crossing the diaphragmatic level and contralateral displacement of the mediastinum or concurrent ipsilateral traumatic injuries.

On the MDCT, it is occasionally possible to visualize diaphragmatic discontinuity with a focal defect,

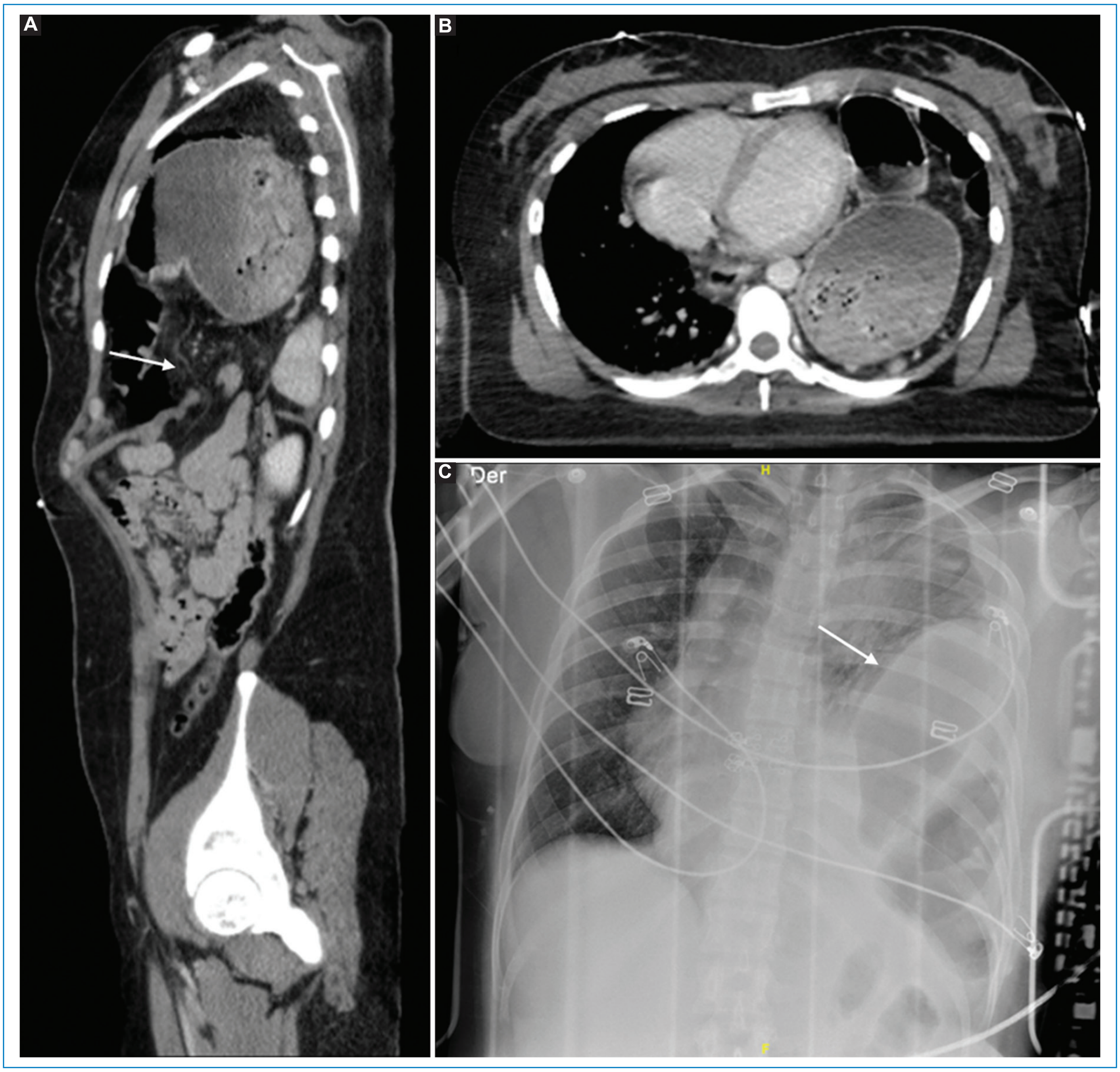

Figure 15. Blunt mechanism traumatic hernia. Sagittal reconstruction (**A**), axial slice (**B**) and portable chest X-ray (**C**). Diaphragmatic discontinuity with ascent of abdominal contents into the thoracic cavity and the "hourglass" sign can be seen on the sagittal reconstruction (white arrows).

visualization of the "hanging diaphragm" representing the partially retracted free edge of the rupture, herniation of abdominal contents through a diaphragmatic defect with or without a "waist" or "hourglass" morphology that represents a stenosis of the herniated structures through the hernial ring (Fig. 15).

It is relevant to mention that continuous negative pleural pressure can produce herniation of abdominal contents for years after the original trauma, which makes its diagnosis even more difficult. In about 80% of cases, herniation of contents into the thorax occurs in the first three years after the trauma has occurred.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical considerations

Protection of people and animals. The authors declare that no experiments have been performed on humans or animals for this research.

Confidentiality, informed consent and ethical approval. The authors have followed the confidentiality protocols of their institution, have obtained informed consent from the patients, and have the approval of the Ethics Committee. The recommendations of the SAGER guidelines have been followed, according to the nature of the study.

Declaration on the use of artificial intelligence. The authors declare that they did not use any type of generative artificial intelligence for the writing of this manuscript.

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