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# Management of complicated diaphragmatic hernia in the acute setting: a WSES position paper

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## Abstract

**Background** Diaphragmatic hernia (DH) presenting acutely can be a potentially life-threatening condition. Its management continues to be debatable.

**Methods** A bibliographic search using major databases was performed using the terms “emergency surgery”, “diaphragmatic hernia”, “traumatic diaphragmatic rupture” and “congenital diaphragmatic hernia.” GRADE methodology was used to evaluate the evidence and give recommendations.

**Results** CT scan of the chest and abdomen is the diagnostic gold standard to evaluate complicated DH. Appropriate preoperative assessment and prompt surgical intervention are important for a clinical success. Complicated DH repair is best performed via the use of biological and bioabsorbable meshes which have proven to reduce recurrence. The laparoscopic approach is the preferred technique in hemodynamically stable patients without significant comorbidities because it facilitates early diagnosis of small diaphragmatic injuries from traumatic wounds in the thoraco-abdominal area and reduces postoperative complications. Open surgery should be reserved for situations when skills and equipment for laparoscopy are not available, where exploratory laparotomy is needed, or if the patient is hemodynamically unstable. Damage Control Surgery is an option in the management of critical and unstable patients.

**Conclusions** Complicated diaphragmatic hernia is a rare life-threatening condition. CT scan of the chest and abdomen is the gold standard for diagnosing the diaphragmatic hernia. Laparoscopic repair is the best treatment option for stable patients with complicated diaphragmatic hernias. Open repair is considered necessary in majority of unstable patients in whom Damage Control Surgery can be life-saving.

**Keywords** Diaphragm hernia, Emergency surgery, Guidelines, Rupture, Trauma, Congenital

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## Background

Complicated diaphragmatic hernia (DH) is a rare life-threatening condition. It is a defect in the diaphragm or its attachments having the risk of the protrusion of the abdominal contents into the thoracic cavity. It can be congenital or acquired. Acquired DH usually occurs following trauma. It occurs in 1–5% of victims of vehicle crashes and in 10–15% of penetrating injuries of the lower chest. Complicated congenital diaphragmatic hernias are less frequent [1–4].

Complicated DH can be associated with large herniation of intra-abdominal organs that may cause incarceration, perforation or strangulation of the organs. The herniation of the abdominal contents into the chest may compress the lungs causing respiratory failure or compressing the heart causing cardiac tamponade. However, the diagnosis of a diaphragmatic hernia can be difficult and delayed. It can be easily missed in the acute setting due to its rarity, nonspecific findings and not being thought of. There is a paucity of clinical guidelines to help the acute care physicians to diagnose and manage this condition. This is the first position paper on this topic aiming to guide clinicians to diagnose and manage diaphragmatic hernias in the emergency setting [5–7].

## Methods

The present paper has been developed according to the GRADE methodology [8, 9].

An extensive bibliographic search of the literature was performed including Medline, EMBASE and PubMed in order to identify articles on complicated diaphragmatic hernias covering the period of January 1983 up to December 2022. The search strategy was conducted identifying articles reporting the item “diaphragmatic hernia,” and then, it has been meshed using the Boolean operator “AND” and “OR” with the following mesh terms: “traumatic diaphragmatic rupture,” “congenital diaphragmatic hernia,” “acquired diaphragmatic hernia,” “trauma,” “lesion,” “rupture” and “emergency surgery.” Additional articles were searched by manual identification from the

key articles. No other search restrictions were imposed except the studied period. This allowed identification of published abstracts of clinical trials, comparative studies, congresses, guidelines, government publications, multicenter studies, systematic reviews, meta-analysis, case series, original articles, randomized controlled trials and case reports.

Two researchers (M.G. and G.P) coordinated by a central coordinator (F.C) developed the questions and assembled the different answers to cover the field of this pathology.

Leading specialists in the field then were asked to revise the manuscript. Through subsequent rounds, the expert’s opinions were included in the manuscript. Expert group discussed the definitive version. The final version after agreement was reached resulted in the present manuscript.

## Classification of diaphragmatic hernia

DH is typically classified into congenital diaphragmatic hernias (CDHs) or acquired diaphragmatic hernias (ADHs) Table 1.

### Congenital diaphragmatic hernia in adults

CDHs are rare and usually occur on the left side (80%) of the diaphragm. Normally, the diaphragm forms and divides the thoracic cavity from the abdominal cavity during the eighth week of gestation. CDH occurs from incomplete development of the diaphragm. CDH in childhood becomes symptomatic when there is pulmonary hypoplasia. This is caused by the presence of the abdominal organs in the chest cavity during the prenatal period which prevents or delays the lung development. [10–12]

*Bochdalek hernia (BH)* is the most common CDH (95%), occurring more commonly on the posterior left side of the diaphragm (85%, versus right side 15%) [13]. BH in the adult patient has an incidence of 0.17% presenting at an average age of 40 years. Its diagnosis is difficult because of its rarity and its wide range of presenting

**Table 1** Diaphragmatic hernia classification

Congenital diaphragmatic hernia (CDH)	
Bochdalek hernias:	posterior left side of diaphragm, 85% of the cases
Morgagni hernia:	anterior, retrosternal or parasternal defect of the diaphragm
Diaphragmatic eventration:	anteromedial portion of the right hemidiaphragm
Central tendon defects	
Acquired diaphragmatic hernia (ADH)	
Hiatal hernia:	types I–IV, sliding (90%) or paraesophageal hernias (10%)
Traumatic:	Blunt or penetrating
iatrogenic	

symptoms. Failure to promptly diagnose and treat a symptomatic BH may lead to complicated BH in up to 25% of cases [10, 14–16]. *Morgagni hernia* (MH) was first described by Morgagni in 1769 as an anterior, retrosternal or parasternal defect of the diaphragm [17] which develops from failure of the complete migration of muscle fibers to cover the triangular space located between the sternum and the bilateral costal margins (foramina of Morgagni). It accounts for approximately 2% of all CDH. MH can remain asymptomatic, and therefore, its diagnosis is often incidental [18, 19]. In a retrospective study, it was diagnosed at an average age of 42 years. Complicated MH can occur in up to 10% of cases [20]. *Diaphragmatic eventration* occurs in the anteromedial portion of the right hemidiaphragm because of incomplete muscularization of the diaphragm which is replaced by a thin membranous sheet [21]. *Central tendon defects* of the diaphragm are extremely rare and are usually associated with significant pericardial effusion and lung hypoplasia [22].

#### Acquired diaphragmatic hernia

ADH occurs usually in adulthood. ADH can be categorized into 3 types: (1) hiatal, (2) traumatic and (3) iatrogenic hernias.

#### Hiatal hernia

Hiatal hernias are included into acquired diaphragmatic hernias classification, but they are not real diaphragmatic hernia. They can be classified into four main types (1) Type I is a sliding hiatal hernia. It is the most common type (90%) and occurs when the esophageal hiatus is widened enough to allow herniation of the gastric cardia resulting in the migration of the gastroesophageal junction to be above the diaphragm [23], (2) Type II is a paraesophageal hiatal hernia and accounts of 10% of the hiatal hernias. The defect is in the phrenoesophageal membrane that allows the herniation of the gastric fundus, while preserving the gastroesophageal junction in a normal position [24], (3) Type III is the combination of a Type I and Type II hiatal hernias; it is a paraesophageal hiatal hernia with superiorly displaced gastroesophageal junction [23] and (4) Type IV is a significantly large diaphragmatic hernia that can accommodate the herniation of additional viscera including the stomach, colon and spleen.

#### Traumatic diaphragmatic hernia

Traumatic diaphragmatic hernias (TDHs) are caused by a traumatic incident that creates a defect in the diaphragm as a result of a sudden increase of intra-abdominal pressure or a penetrating injury. This will cause a tear in the diaphragm and may be associated with migration of

abdominal contents from the abdomen to the thoracic cavity. Diaphragmatic rupture occurs in 2.1% of blunt trauma and 3.5% of penetrating trauma [24, 25]. Overall, diaphragmatic rupture (DR) is infrequent and may reach up to 5% of trauma patients depending on the injury severity and mechanism of injury [26].

The mechanism of rupture diaphragm will vary between different countries depending on the prevalence of certain mechanisms. Penetrating trauma is the most frequent mechanism of TDH (65%), but their defects are generally smaller than those following blunt trauma. Currently, the most frequent penetrating thoracic trauma are caused by knife wounds. Blunt trauma accounts for approximately 3–8% of all TDH [27, 28]. The most common cause of blunt diaphragmatic rupture is road traffic collisions. High risk of associated intra-abdominal injuries must be considered in determining the optimal surgical approach requiring an open or laparoscopic approach to evaluate the entire abdomen.

Left-sided injuries are more common after blunt and penetrating trauma in those treated at the hospital due to the protective effect of the bare area of the liver in contact with the diaphragm on the right side, reducing the traumatic force [29]. Those patients will have a better chance of survival. The distribution of DH after blunt trauma is as follows: 50–80% affect the left hemidiaphragm, 12–40% affect the right side, while 1–9% are bilateral [26]. In contrast autopsied victims display predominance on the right side. Aun et al. observed a significantly higher incidence of diaphragmatic lacerations on the right side in an autopsy group (49.6% of 146 cases identified in 12,276 autopsies) compared with the hospitalized group (14.4% of 97 operated cases). However, depending on the mechanism of trauma, both diaphragms can be injured [30–33].

It is important to distinguish between an acute isolated diaphragmatic injury and the potential presence of other associated injuries. Trauma may cause a tiny rupture of the diaphragm, which will remain asymptomatic or may cause delayed complications. This accounts for the typical delayed onset of symptoms of diaphragmatic hernias, few years post-injury [7].

AAST grading of traumatic hernia is reported on Table 2 [34].

#### Clinical presentation

Symptoms of DH will depend on their etiology and can be very insidious. Delayed diagnosis of DH was reported in 5–45% of all CDH [19]. CDH in the adulthood can present with nonspecific respiratory and gastrointestinal symptoms and signs. Severe symptoms have been reported in 46% of CDH [35]. In left-sided CDH, gastrointestinal symptoms including intestinal obstruction are

**Table 2** AAST diaphragm injury scale

Grade*	Description of injury
I	Contusion
II	Laceration < 2 cm
III	Laceration 2–10 cm
IV	Laceration > 10 cm with tissue loss (< 25 cm <sup>2</sup> )
V	Laceration with tissue loss > 25 cm <sup>2</sup>

\*Advance one grade for bilateral injuries up to grade III

more common, while right-sided CDH predominantly have respiratory symptoms. Mild chronic symptoms (dyspepsia, recurrent or nonspecific abdominal pain) may occur. Occasionally, acute abdominal symptoms caused by bowel obstruction, ischemia, or perforation can cause cardio-respiratory failure [19, 36, 37].

Patients with BH typically develop gastrointestinal (GI) symptoms. These hernias can subsequently be complicated with gastric obstruction, strangulation, volvulus, incarceration, dysphagia, bleeding and respiratory symptoms [38]. Conversely, GI and respiratory symptoms are both common in symptomatic MH in adults. MH has a lower incidence of bowel incarceration or strangulation compared with BH [15].

The symptoms of TDH will depend on the involved side, the severity of the trauma, the type of trauma (blunt or penetrating) and on the amount of energy transferred to the body [39]. The effects of the diaphragmatic rupture are primarily on the circulation and respiration resulting in a 25–50% decrease in the pulmonary function. The most common symptoms are dyspnea (86%) and abdominal pain (17%) [40, 41].

The natural history of traumatic diaphragmatic injury with hernia formation has been described to have three phases (the Carter's scheme): the acute phase, the latent phase, and the obstructive phase [20]. In the acute phase, between 33 and 66% of TDH are missed [42] because TDHs are often associated with other thoraco-abdominal, cerebral, or musculoskeletal injuries. The associated injuries are responsible for the poor prognosis and not the TDH [42]. In the latent phase, there are nonspecific GI and respiratory symptoms caused by the herniation (sometimes intermittent) of the intra-abdominal viscera into the thoracic cavity [43]. In the obstructive phase, visceral obstruction may progress to ischemia of the herniated organs.

Delayed presentation of DH is common. DH can be asymptomatic for decades before becoming symptomatic in later stages. This occurs either because the hernia becomes huge, or it has already caused secondary visceral complications [44]. Nonspecific presentation may lead to misdiagnosis and inappropriate management.

Antecedent viral illness with subsequent respiratory distress may lead to the misdiagnosis of pneumonia or bronchiolitis. As the diameter of the diaphragmatic injury increases over time, herniation of the abdominal organs and subsequent worsening clinical symptoms occur [45, 46].

Undetected DH may cause strangulation of the bowel and subsequent perforation causing severe peritonitis, sepsis and multi-organ failure which is a surgical emergency having a high mortality. Commonly, patients with delayed diagnosis have right-sided diaphragmatic ruptures (50%) [48]. In a series of 980 cases, the diagnosis of DH was made preoperatively in 43.5% of the patients, the diagnosis of 41.3% of the patients was reached during autopsy or surgical exploration, and in the remaining 14.6% of the patients, the diagnosis was delayed until the clinical condition worsened [42].

### What is the best way to diagnose DH in the emergency setting?

In patients without a history of trauma and with respiratory symptoms, a chest X-ray both anteroposterior and lateral is recommended as the first diagnostic study (Strong recommendation based on low-quality evidence, 1C).

In stable trauma patients with suspected DH (nonspecific symptoms and chest X-ray), CT scan with contrast enhancement of the chest and abdomen is recommended (Strong recommendation based on moderate-quality evidence, 1B).

In stable trauma patients with lower chest penetrating wounds and suspected DH (nonspecific symptoms and chest X-ray), diagnostic laparoscopy is recommended (Weak recommendation based on low-quality evidence, 1C).

Endoscopy is not recommended in traumatic hernias (Weak recommendation based on low-quality evidence, 2C).

In pregnant patients with suspected non-traumatic DH, ultrasonography is suggested as the first diagnostic study (Weak recommendation based on very low-quality evidence, 2D).

In stable pregnant patients with suspected non-traumatic DH, MRI is suggested after ultrasonography (Weak recommendation based on very low-quality evidence, 2D).

The most commonly used diagnostic test for DH in the literature, but not necessarily the most accurate, is the chest X-ray. However, initial radiographic findings can be misinterpreted in around 25% of the cases [4]. Normal chest radiographs have been reported to range from 11 to

62% in diaphragmatic injuries or in uncomplicated diaphragmatic hernias [40, 49, 50]. Suspicious chest X-ray findings in DH include an abnormal bowel gas pattern, an air-fluid level, an abnormal lucency or soft tissue opacity with deviation of the mediastinum, or hemidiaphragm elevation. Larger hernias may show loops of small or large bowel. When the nature of the thoracic contents is uncertain, a nasogastric tube located inside the herniated stomach can be diagnostic [3]. The chest X-ray has a sensitivity of 2–60% for diagnosing the left-sided hernia and 17–33% for right-sided hernia [51]. Despite advances in imaging methods, the chest X-ray is still useful. It is easy, inexpensive, has low radiation, and universally available. In cases of persistent clinical suspicion, a CT scan should be performed to confirm or refute the diagnosis [52].

CT scan is the gold standard for diagnosing the diaphragmatic hernia. It has a sensitivity and specificity of 14–82% and 87%, respectively [35, 53]. Nevertheless, it may miss small tears of penetrating injuries like stab wounds, when no hernia has yet occurred. Unlike the chest X-ray, which can be normal in intermittent herniation, CT scan is more accurate in determining the presence, location and size of the diaphragmatic defect. Chest and abdominal CT scan can evaluate the intrathoracic complications of the herniated abdominal organs [54]. The various radiological findings which have been described in the literature include: diaphragmatic discontinuity, segmental non-recognition of the diaphragm, “Dangling diaphragm” sign (visualization of the free edge of the ruptured diaphragm curling toward the center of the abdomen away from the chest wall) [55], “Dependent viscera” sign [56] (no space between the liver, bowel or stomach and the chest wall, described as abutted), intrathoracic herniation of abdominal contents, “Collar sign” (constriction of the herniating abdominal organ at the level of the rupture) [57], contiguous injuries of both sides of the diaphragm, elevated abdominal organs, thickened diaphragm, thoracic fluid, abutting intra-abdominal viscera, hypo-attenuated hemidiaphragm and associated fractured ribs [28, 58–60]. CT scan findings of ischemia include forward displacement of the gastric bubble, the missing of the gastric folds, the absence of gastric walls contrast enhancement, intestinal wall thickening with target enhancement, spontaneous hyper-density of the intestinal wall, lack of enhancement after injection of iodinated contrast agent, and parietal pneumatosis with portal and mesenteric venous gas [53, 61].

Laparoscopy and thoracoscopy can be useful in stable patients with a thoraco-abdominal penetrating wound. Small diaphragmatic defects may be not detected by both chest X-ray and CT scan [62–64].

Other diagnostic tests such as esophagogastroduodenoscopy, ultrasound and barium studies have been used in

the diagnosis of complicated DH. Endoscopy is useful in stable patients to assess the presence of erosive esophagitis or gastroesophageal reflux especially in patients with hiatal hernia.

Endoscopy can determine the size and type of hernia and evaluate the gastric viability. However, the role of endoscopy in the diagnosis of diaphragmatic hernia, especially in emergency setting, is underreported. Endoscopy must be avoided especially in acute trauma patients. When used, performing endoscopy using CO<sub>2</sub> instead of air, is less dangerous in cases of existing or suspected perforations [26, 35, 65].

Nevertheless, ultrasound has not been routinely used in evaluating the diaphragm during the primary and secondary survey in unstable multiple trauma patients. A recent systematic review in children showed that it has a very low sensitivity of 25% (5/20) [66]. It is a tedious study and takes time and possibly it may be useful in tertiary survey when a more detailed study can be done. The distended stomach may hinder its evaluation during the acute setting.

During pregnancy, ultrasound has been reported to be useful for evaluating a suspected DH [67–71]. In pregnant stable patients, MRI should be always performed instead of a CT scan to avoid radiation exposure when a DH is suspected. MRI in pregnant women may be performed on a 1.5 T or 3 T MRI scanner without the administration of an intravenous gadolinium-based contrast agent. In complicated DH, a high signal on T1W, T2W, and T1W fat-saturated sequences indicates ischemic infarction, especially in the strangulated herniated viscera with obstruction or ischemia. DWI may be useful for describing early ischemia [3, 53, 72, 73].

### **What is the best treatment for patients with traumatic diaphragmatic hernia?**

Surgery is recommended in stable patients with traumatic DH, preferably with a laparoscopic approach (Strong recommendation based on moderate-quality evidence, 1B)

In unstable TDH patients, a laparotomy approach is suggested (Weak recommendation based on low-quality evidence, 2C)

### **Technical issues**

Sac excision is not suggested (Weak recommendation based on very low-quality evidence, 2D)

Defect repair using non-absorbable sutures is suggested (Weak recommendation based on low-quality evidence, 2C)

Mesh use is suggested for defects that cannot be closed with direct suture (Weak recommendation based on low-quality evidence, 2C)

Biosynthetic, biologic or composite meshes are suggested due to the lower rate of hernia recurrence, higher resistance to infections and lower risk of displacement\* (Weak recommendation based on low-quality evidence, 2C)

Percutaneous endoscopic gastrostomy (PEG), gastrostomy or jejunostomy are suggested in patients with oral intake difficulties (Weak recommendation based on low-quality evidence, 2C)

Preemptive anti-reflux surgery is not suggested in the emergency traumatic DH setting or complicated hernia (Weak recommendation based on very low-quality evidence, 2D)

Damage Control Surgery (DCS) is recommended in case of patients with intraoperative instability, hypothermia, coagulopathy, significant acidosis or impossibility to close the diaphragm [74] (Strong recommendation based on low-quality evidence, 1B)

Although there is no consensus or randomized trials on the management and treatment of complicated DH, surgery is the treatment of choice for this pathology [18, 26, 75]. Several studies (meta-analysis, reviews and case series) propose primary repair for the diaphragmatic defects with non-absorbable sutures. This should always be attempted when possible. This is classically done in two layers using interrupted non-absorbable mattress suture. Majority of surgeons still prefer using interrupted non-absorbable 2-0 or 1-0 monofilament or braided sutures in two layers [76–85].

Suturing defects has the benefit of providing a flat surface for placement of the mesh, preventing mesh extrusion through the defect. In a DH with larger defects (>3 cm), an attempt to primary repair the defect could lead to excessive tension due to the considerable loss of tissue. A very high recurrence rate of 42% has been reported after primary DH repair. In order to reinforce the suture repair, a mesh should be used [83, 86–89].

Excision of the hernial sac is controversial. In most studies, retention of the sac had no obvious complications. In other studies, sac excision occasionally led to pneumomediastinum, damage to pericardium or mediastinal structures. In other studies, sac excision reduced tissue trauma, fluid collection and recurrence, especially in cases where the colon or stomach was contained within the sac because in these cases only the sac was manipulated (rather than its contents) which reduces the possibility of transmural visceral injury or neurovascular injury. This reduced the chance for symptomatic fluid collection since the serous lining membrane was

removed. Sac excision also negates the possibility for the remaining sac to act as a lead point for recurrent herniation [90, 91].

Larger defects that cannot be closed primarily should be bridged with a mesh and/or reattach the diaphragm to the ribs by encircling the ribs for fixation, even at a higher rib level than the anatomical one if needed. It was recommended not to perform primary closure of the diaphragm if the distance between the edge of the remaining part of the diaphragm and the chest wall is more than 3–4 cm. Primary diaphragmatic suture or mesh reconstruction can seal the chest cavity without paradoxical chest movement or increase in mortality. Many different materials can be used for the reconstruction, mostly favored by the surgeon's experience, attitude and preference. The reconstruction is typically performed with synthetic meshes. They are well tolerated, can be bio-prosthetic materials or entirely artificial mesh, either absorbable or non-absorbable [92, 93].

Many reviews have evaluated the role of different meshes in DH repair. A mesh should be used for larger defects. Biological meshes have lower rate of hernia recurrence, higher resistance to infections and lower risk of displacement compared with synthetic meshes [26, 94, 95]. An alternative to biological meshes for the repair, particularly of the clean-contaminated and contaminated diaphragmatic hernia repair, is an absorbable synthetic mesh. Absorbable synthetic mesh has the prospective advantages of reduced cost and minimal constraints in manufacturing alternative sizes. Because of its strength and impermeability, polytetrafluoroethylene (PTFE Gore-Tex™, Gore&Assoc, Arizona, USA) is one of the most common meshes recommended for diaphragmatic reconstruction. It has an advantage of not adhering to the bowel with reduced risk of bowel fistulation [86, 93]. Despite several advantages of using absorbable synthetic mesh, data on diaphragmatic hernia repair in the emergency setting are not available and further studies are warranted [97, 98].

The decision about the best surgical approach in the treatment of diaphragmatic hernias, thoracic or abdominal, depends primarily on the chronicity of the condition, the surgeon's preferences and skills, and the local resources. Complicated diaphragmatic hernias in unstable patients or those who have signs of strangulation or perforation should be primarily approached through the abdomen, reserving the thoracic approach as a complementary access. Thoracotomy or thoracoscopy may be used, especially in chronic herniation because of the presence of visceropleural adhesions and the higher risk of intrathoracic visceral perforation [99–102]. Rarely, a thoraco-abdominal approach for complicated DH has been utilized. This approach can be useful when

it is difficult to identify all abdominal injuries or when it is needed to exclude bilateral cavity complications [103–105].

Laparoscopic or thoracoscopic approaches have become the most used approaches to manage complicated DH. Minimally invasive surgery, if properly indicated, is now more feasible, safer, has shorter length of hospital stay, and less morbidity compared with open surgery [89, 106–110]. Robotic surgery of complicated DH repair has been reported only in few cases [111, 112].

Data about robotic DH repair are poor. According to the 2021 WSES position paper on robotic surgery in emergency setting, the potential use of robotic DH repair should be considered by experienced surgical and nursing team in clinically stable patients [113].

Gastrostomy and PEG have added advantage for patients who have difficulties in oral intake. Gastrostomy and PEG are both used to provide fixation of the anterior stomach to the abdominal wall [114–116]. The use of PEG or combined PEG/laparoscopy in the treatment of DH is successful in relieving symptoms, preventing recurrence, stopping progression of complications (such as gastric ischemia), has very low morbidity, and is well tolerated, especially in high-risk elderly patients who are otherwise unsuitable candidates for a definitive surgical repair [117, 118].

Literature data about anti-reflux procedures combined with TDH repair are poorly reported. Anti-reflux procedure, due to the fixation of the organ in the abdominal cavity, may be performed successfully in traumatic diaphragmatic hernia patients with history of gastroesophageal reflux and the need to repair a large defect [26, 109].

In critical patients, Damage Control Surgery (DCS) can be life-saving. In unstable patients with severely injured abdominal organs, a second look may be needed to re-evaluate an ischemic bowel. Furthermore, leaving the abdomen open may prevent abdominal compartment syndrome. Furthermore, DCS should be considered when the diaphragm cannot be closed [119, 120].

### **What is the best treatment for patients with non-traumatic diaphragmatic hernia?**

Surgery is recommended in complicated non-traumatic DH (Strong recommendation based on moderate-quality evidence, 2C)

In unstable non-traumatic complicated DH patients, a laparotomy approach is suggested (Weak recommendation based on low-quality evidence, 2C)

In stable patients with complicated non-traumatic DH, minimally invasive approach is suggested (Weak recommendation based on very low-quality evidence, 2D)

Sac excision is not suggested (Weak recommendation based on very low-quality evidence, 2D)

Defect repair using non-absorbable sutures is suggested (Weak recommendation based on low-quality evidence, 2C)

Mesh use is suggested especially for larger defects that cannot be closed (Weak recommendation based on low-quality evidence, 2C)

Biosynthetic, biologic or composite meshes are suggested due to the lower hernia recurrence, higher resistance to infections and lower risk of displacement (Weak recommendation based on low-quality evidence, 2C)

Gastropexy is suggested in patients with gastric volvulus in order to prevent recurrence (Weak recommendation based on moderate-quality evidence, 2B)

Percutaneous endoscopic gastrostomy (PEG), gastrostomy or jejunostomy are suggested in patients with preexisting oral intake difficulties (Weak recommendation based on low-quality evidence, 2C)

Gastrostomy and PEG are suggested to provide fixation of the anterior stomach to the abdominal wall in patients unsuitable or high-risk candidates for a definitive surgical procedure, only in case of non-ischemic stomach (Weak recommendation based on low-quality evidence, 2C)

Anti-reflux surgery is recommended especially in congenital diaphragmatic hernia repair and in patients with gastroesophageal reflux (Weak recommendation based on low-quality evidence, 2C)

Toupet or Nissen fundoplication is suggested in case of gastroesophageal disease. (Weak recommendation based on low-quality evidence, 2C)

Thoracoscopy combined with laparoscopy is suggested especially in complicated DH with history of chronic herniation in order to reduce visceral-pleural adhesions and to avoid intrathoracic visceral perforation (Weak recommendation based on very low-quality evidence, 2D)

The treatment of non-traumatic diaphragmatic hernia is similar to traumatic diaphragmatic hernia.

Surgery is the treatment of choice for this condition. [78, 82].

Primary repair for the diaphragmatic defects with non-absorbable sutures should always be attempted when possible [76–85, 121].

However, the treatment of TDH surgeons is reluctant in the use of mesh in the emergency setting due to the risk of infectious complications. In clean-contaminated and contaminated diaphragmatic hernia repair, biologic or most recent biosynthetic meshes can be safely used [94, 96–98].



Several papers advise that the mesh overlaps the defect edge by 1.5–2.5 cm. When tension-free primary closures are difficult, for defects larger than 8 cm or an area of more than 20 cm<sup>2</sup>, the interposition of a graft can be used successfully. Mesh can be fixed using tackers or transfascial sutures. Tackers should be avoided in proximity of the pericardium because of the risk of cardiac complications [109, 122–126].

Minimally invasive abdominal approach can be performed with an excellent safety profile and a reported overall in-hospital mortality rate of 0.14%. Several studies showed similar outcomes in terms of perioperative morbidity and mortality in both laparotomy and minimally invasive approach. In right diaphragmatic hernia, due to the presence of the liver, the diaphragmatic repair can be difficult and a combined or a thoracic approach may be necessary [100, 127–130].

The incidence of gastroesophageal reflux after repair of congenital diaphragmatic hernia is high reaching up to 62%. Accordingly, fundoplication should be performed during congenital hernia [131, 132]. Several studies have reported the role of fundoplication during repair of a sliding hiatal hernia but not for diaphragmatic hernias to manage the associated gastroesophageal reflux. Factors affecting the surgical procedure selection include the history of gastroesophageal reflux, the need to repair a large defect repair, a paraesophageal hernia, or a congenital hernia [133, 134]. In case of gastric volvulus with diaphragmatic hernia gastropexy after detorsion of the volvulus, reduction of herniated structures and repair of the diaphragmatic defect has been successful [136–139].

A Collis procedure or gastric resection is required in selected cases, determined by the gastric condition and should be tailored case by case [100]. Nissen fundoplication is the most common technique performed. Nissen fundoplication and Toupet fundoplication have similar effects on restoration of the mechanical gastroesophageal barrier against gastric reflux. Few papers reported that recurrence rate in Toupet fundoplication is lower compared with Nissen fundoplication [140–145].

### Clinical outcomes

Clinical outcomes following the management of complicated DH are poorly reported in the literature. A wide range of complications are reported with rates varying from 11 to 62.9% [12].

Postoperative pulmonary complications including atelectasis are common following surgery for TDH. Other complications include surgical infection, bleeding, respiratory failure, ileus, gastroesophageal reflux, chronic pain, hernia recurrence, and cardiac injury.

The high morbidity is related to the surgical approach used. In complicated BH, laparoscopic repair has a lower

morbidity (6%) compared with the open approach (18%) [14]. The laparoscopic approach of MH repair has similar morbidity rate compared with BH. Laparoscopy approach of MH has a lower morbidity rate (5%) compared with the open approach (17%) [107]. The survival rate in adults presenting with delayed complicated CDH varies between 97 and 100% [146, 147]. The mortality rate in complicated TDH ranges from 14.3 to 20%. [47, 148–150].

The current data regarding recurrence are poor. Hanna et al. reported recurrence in only two cases out of 76 cases after primary repair but only 13 (17.1%) could be followed up [95]. The recurrence of a diaphragmatic hernia may be due to the use of absorbable sutures for the primary repair, suture tension, improper fixation of the prosthetic material to the defect edges with a minimal overlap, increased intra-abdominal pressure due to a prolonged ileus, poor chest toileting and an intra-abdominal sepsis causing tension, disruption of tissue and sutures, leading to mesh displacement or re-opening of the defect. Recurrence is largely due to failure of the host-prosthesis interface, while the synthetic patch integrity is usually maintained [109, 125, 128, 132, 135].

### Conclusions

Complicated diaphragmatic hernia is a rare life-threatening condition. CT scan of the chest and abdomen is the gold standard for diagnosing the diaphragmatic hernia. Laparoscopic repair seems to be the best treatment option for stable patients with complicated diaphragmatic hernias. Open repair is considered necessary in majority of unstable patients in whom Damage Control Surgery can be life-saving.

### Abbreviations

DH	Diaphragmatic hernia
CDH	Congenital diaphragmatic hernia
ADH	Acquired diaphragmatic hernia
BH	Bochdalek hernias
MH	Morgagni's hernia
TDH	Traumatic diaphragmatic hernia
DR	Diaphragmatic rupture

### Author contributions

MG and GP conducted the systematic review of the literature and wrote the first draft of the manuscript. All authors were involved in the statement evaluation and consensus process. All authors critically reviewed the manuscript and approved the final version. All authors read and approved the final manuscript.

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### Availability of data and materials

The original dataset generated during the current study is available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

Not applicable.

### Consent for publication

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### Competing interests

The author declares no competing interests.

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