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SCIENTIFIC REVIEW

Complicated Diaphragmatic Hernia in Emergency Surgery: Systematic Review of the Literature

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Abstract

Introduction Complicated diaphragmatic hernia (DH) can be congenital or acquired. Congenital diaphragmatic hernias (CDH) are rare and often can be asymptomatic until adulthood. Traumatic diaphragmatic hernia (TDH) is a complication that occurs in about 1–5% of victims of road accidents and in 10–15% of penetrating traumas of the lower chest. CDH and TDH are potentially life-threatening conditions, and the management in emergency setting still debated. This study aims to evaluate the surgical treatment options in emergency setting.

Methods A bibliographic research reporting the item "emergency surgery" linked with "traumatic diaphragmatic rupture" and "congenital diaphragmatic hernia" was performed. Several parameters were recorded including sex, age, etiology, diagnosis, treatment, site and herniated organs.

Results The research included 146 articles, and 1542 patients were analyzed. Most of the complicated diaphragmatic hernias occurred for a diaphragmatic defect due to trauma, only 7.2% occurred for a congenital diaphragmatic defect. The main diagnostic method used was chest X-ray and CT scan. Laparotomic approach still remains predominant compared to the minimally invasive approach.

Conclusion Surgery is the treatment of choice and is strongly influenced by the preoperative setting, performed mainly with X-ray and CT scan. Minimally invasive approach is safe and feasible but is highly dependent on the surgeon's expertise, especially in emergency setting.

Abbreviations

DH	Diaphragmatic hernia
CDH	Congenital diaphragmatic hernia
ADH	Acquired diaphragmatic hernia
MH	Morgagni's hernia
TDH	Traumatic diaphragmatic hernia

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Introduction

Diaphragmatic hernia (DH) is a defect of the diaphragm which allows the passage of an organ, or part of it, into the thoracic cavity. DH can be congenital or acquired. Congenital diaphragmatic hernias (CDH) are rare. CDH prevalence ranges from 1.7 to 5.7 per 10,000 births [1] with a survival rate of 67% [2]. Normally, during the eighth week of gestation, the diaphragm formation divides the thoracic cavity from the peritoneal one. The premature

bowel returns to the abdomen or the incomplete development of the diaphragm are the etiopathological factors of CDH [3]. Traumatic diaphragmatic hernia (TDH) occurs in about 1–5% of victims of road accidents and in 10–15% of penetrating traumas of the lower chest [4].

Complicated DH is a rare problem encountered by Emergency Department. The diagnosis and management of complicated DH can be a medical issue; the onset of symptoms is subsequent to the traumatic event. Often the symptoms may occur even months or years after the injury [5].

There is no consensus about the indications to surgery and the timing. This study aims to evaluate the surgical treatment options in emergency setting.

Methods

An extensive bibliographic research of literature according to PRISMA criteria was performed (Fig. 1). Medline and PubMed were consulted in order to identify articles reporting the item "emergency surgery" from 1983 up to May 2020, and then, it has been meshed using the Boolean operator "AND" and "OR" with the following mesh terms: "traumatic diaphragmatic rupture" and "congenital diaphragmatic hernia." Additional articles were searched by manual identification from the key articles.

Inclusion criteria articles in English language, reporting "emergency surgery" for diaphragmatic hernia (congenital and traumatic). In case of multiple papers from the same group of authors, an effort was made to identify duplicate paper.

Exclusion criteria non-English papers, patients under 19 years, hiatal or paraesophageal hernias, procedures performed in "elective setting" have been excluded.

Several parameters were recorded and analyzed including: sex, mean age, etiology, diagnosis (chest X-ray, CT scan, barium studies, MRI and others), treatment (laparoscopic, laparotomic, thoracoscopic, thoracotomic, thoracoabdominal, robotic, damage control surgery), use of mesh, site (right or left) and herniated organs.

Results

In the present review, 146 articles were included (Fig. 1, Table 1).

Among the 1542 analyzed patients, 809 (52.4%) were male and 379 (24.5%) were female. In the remaining 354 (22.9%), sex was not specified. The average age was 47.7 (SD ± 18.3) years. Considering the etiology, the cause of hospitalization was trauma in 1261 patients (81.7%) and CDH in 113 (7.2%). Among these, 50 (3.2%) were Bochdalek's hernias (BH) and 54 (3.5%) were Morgagni's hernias (MH). Five patients had previously performed surgery, 5 were pregnant, and in 151 patients the etiological diagnosis was not reported.

Trauma patients were younger than patients who developed symptoms for a congenital diaphragmatic defect (45.1 vs. 53.1 years). Mean age of Bochdalek's hernia patients was 47.2 ± 18.3 years while in patients with Morgagni's hernia was 64.1 ± 19.2 years.

In 709 cases (45.9%), the defect was located on the left side of the diaphragm while in 273 cases (17.7%) on the right one. In only 10 cases (all traumas), the defect was bilateral, and in 550 patients the site of the herniation was not specified (Table 2). The left hemidiaphragm was more involved than the right one: trauma (644 vs. 207), Bochdalek (34 vs. 14), post-surgery DH (4 vs. 1), during pregnancy DH (4 vs. 1). Unlike the others, Morgagni's hernias mainly occur on the right side compared to the left side (45 vs. 9) (Table 3).

Chest X-ray was the most common diagnostic test used in 697 patients (45.2%). CT scan also plays a major role in instrumental diagnostic methods and was used in 315 cases (20.4%). In our analysis, the other methods were much less used: barium studies in 15 cases, US in 15, gastrografin swallow in 5, MRI in 8, EGDS in 5 and manometry in only 1 case. Diagnosis was achieved intraoperatively 6 performed. Diagnostic tests were not performed in 12 patients because they were unstable. Diagnostic methods could not be deduced in 463 patients. Of the 1261 trauma patients, a delayed presentation (> 7 days) has been reported in 297 cases. Surgery was performed the same day of hospital admission in 47 trauma patients (interval time range: 1 to 9 h). Surgery was performed in the first week after trauma in 100 cases. Data about time interval from trauma to surgery have not been reported in 817 patients.

As far as surgical treatment is concerned, the open approach is the one widely used. Laparotomy, thoracotomy and thoracoabdominal approach were used in 907 cases (58.8%), 184 (11.9%) and 42 (2.7%) patients, respectively. Laparoscopic, thoracoscopic and robotic approaches were used in 103 (6.6%), 28 (1.8%) and 3 (0.1%) patients, respectively. A conservative management was chosen in 11 patients for contraindications to surgery or because they were unstable. In 22 patients, along with the repair of the diaphragmatic defect, another associated procedure was performed (mainly splenectomy, gastrectomy and colectomy). Damage control surgery (DCS) was performed in only 12 patients. In one patient, a colopexy was performed to cover, without repairing, a massive diaphragmatic defect.

The use of meshes has been observed only in 55 cases, 17 times with laparotomic approach and 35 times with laparoscopy.

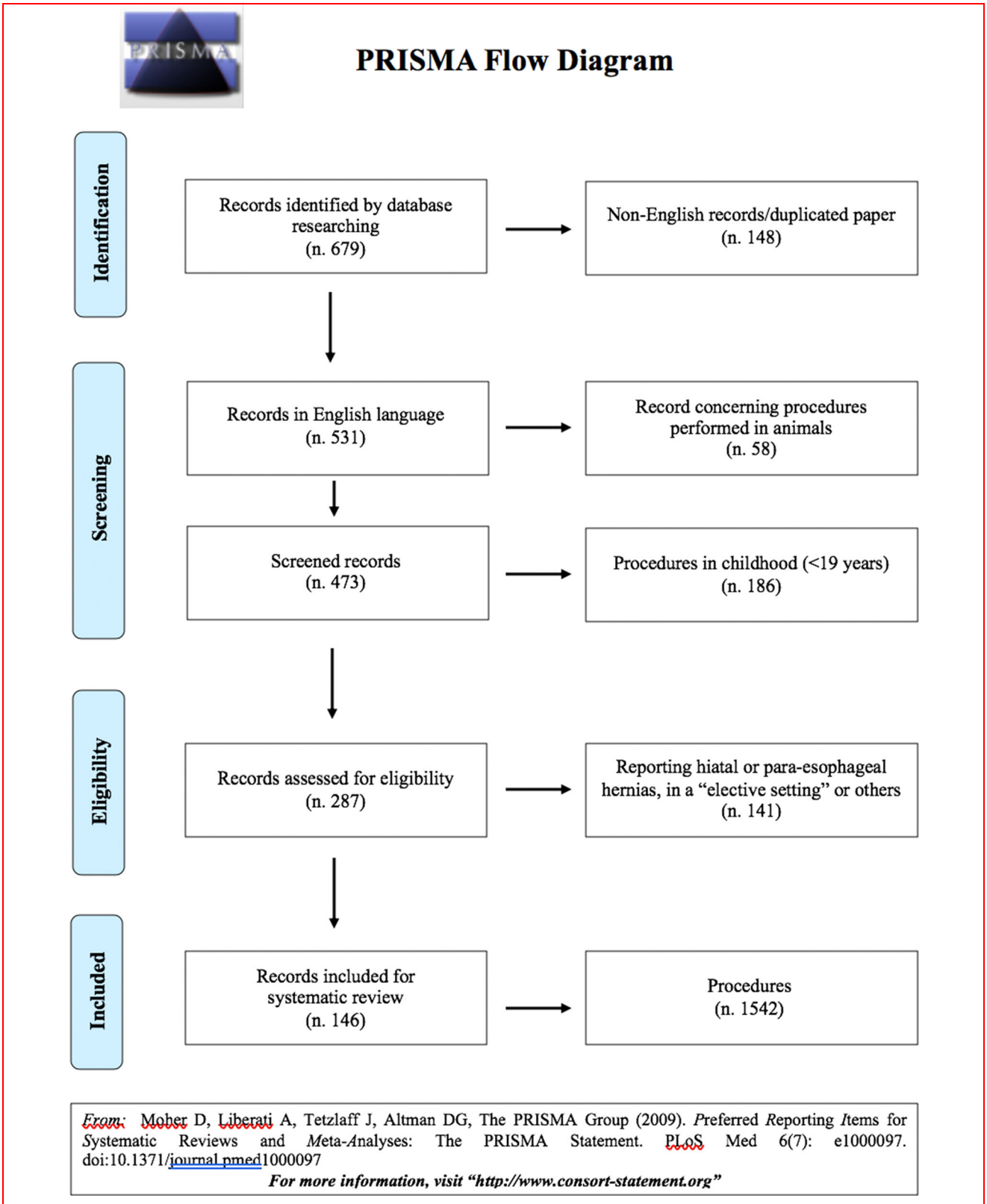

Fig. 1 PRISMA flow diagram

Table 1 Papers included in literature systematic review

References	No. of patients	Sex	Age (years)	Etiology	Diagnosis	Treatment	Site of Hernia	Herniated organs
Mohamed et al. [31]	1	M	29	Morgagni hernia	Chest X-ray, CT scan	Laparoscopic repair with mesh	Right	Transverse colon
Choy and Chiam [30]	1	M	81	Morgagni hernia	Chest X-ray, CT scan	Laparoscopic repair with mesh	Right	Transverse colon
Coolidge et al. [45]	1	M	66	Morgagni + paraesophageal hernias	CT scan	Laparoscopic repair with mesh + laparoscopic reduction and fundoplicatio sec. nissen	Right	Small bowel
Costa Almeida et al. [46]	1	F	77	Morgagni hernia	Chest X-ray, CT scan	Laparoscopic repair with transfascial suture	Left	Transverse colon, omentum
Hunter et al. [42]	2	F (2)	69–48	Bochdalek hernia (2)	CT scan–CT scan	Robotic thoracoscopic with two-layer tension-free primary repair	Right (2)	Omentum–liver
Okyere et al. [28]	2	M (1) F (1)	44–33	Trauma–trauma	EFAST, chest X-ray, CT scan–EFAST, chest X-ray	Thoracotomic suture	Right (2)	Liver (2)
Porojan et al. [47]	15	M (8) F (7)	42 (Mean)	Penetrating trauma (7), blunt trauma (8)	Chest X-ray and CT scan (3 patients), 12 no exams because hemodynamically unstable	Phrenoraphy laparotomy (13), thoracotomy (1), laparotomy + thoracotomy (1)	–	Liver (2), spleen (2), stomach (3), small bowel (1), none (9)
Zanotti et al. [48]	1	F	20	Congenital diaphragmatic hernia	MRI	Laparoscopic repair with mesh	Right	Kidney, right colon, small bowel
Zhao et al. [49]	40	M (24) F (16)	35 (Mean)	Trauma (36)–unknown (4)	Chest X-ray, CT scan	Thoracotomy (38, 4 cases required a subsequent laparotomy), thoracoabdominal Incision (2)	Left (32) Right (8)	–
Al-Thani et al. [50]	52	M (48) F (4)	31 (Mean)	Trauma	–	Laparotomy (33), Laparoscopy (4), thoracoabdominal approach (5), damage control surgery (12)	Left (41) Right (11)	Stomach (13), omentum (1), multiple visceral organs (6)
Arikan et al. [51]	21	M (9) F (12)	63 (Mean)	Morgagni hernia	Chest X-ray (10), CT scan (17)	Laparoscopic repair with mesh (8), laparoscopic suture + mesh (4), laparotomic repair with mesh (3), laparotomic suture (4), laparotomic suture + mesh (2)	Left (2) Right (19)	Omentum (17), transverse colon (16), stomach (4), small bowel (3), cecum (1)
Gao et al. [52]	1	M	44	Trauma	Chest X-ray, CT scan, MRI	Thoracotomic suture	Right	Transverse colon, liver
Gurrado et al. [53]	1	F	64	Congenital diaphragmatic hernia	Chest X-ray, CT scan	Laparotomic subtotal colectomy with ileostomy and splenectomy	Left	Transverse and descending colon

Table 1 continued

References	No. of patients	Sex	Age (years)	Etiology	Diagnosis	Treatment	Site of Hernia	Herniated organs
Jambhekar et al. [41]	1	M	74	Bochdalek hernia	Chest X-ray, CT scan	Robotic suture + right colectomy	Right	Liver, hepatic flexure of the colon
Mittal et al. [29]	1	M	71	Morgagni + paraesophageal hernias	EGDS, chest X-ray, manometry, CT scan	Laparoscopic suture + mesh	Left	Stomach
Rehman et al. [38]	1	F	42	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic repair with mesh + gastric suture	Left	Stomach
Tarcoveanu et al. [54]	8	M (1) F (7)	65.8 (Mean)	Morgagni hernia (8)	–	Laparoscopic suture (2), laparoscopic repair with mesh (2), laparotomic suture (2)	Left (1) Right (7)	Omentum, transverse colon, stomach
Tonini et al. [55]	1	M	27	Bochdalek hernia	Chest X-ray, CT scan	Laparotomic suture	Left	Stomach, spleen, bowel's loops, transverse colon
Ayane et al. [56]	1	F	35	Bochdalek hernia	Chest X-ray	Laparotomic suture	Right	Transverse colon, right colon, appendix, ileum
Manson et al. [57]	1	F	30	Bochdalek hernia	Chest X-ray, CT scan	Laparotomic total gastrectomy + splenectomy	Left	Stomach, spleen
Susmallian and Raziel [40]	1	M	81	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic suture + Mesh	Left	Stomach
Testini et al. [23]	6	M (2) F (4)	58.3 (Mean)	Trauma (2)–trauma (6 years before)–congenital diaphragmatic hernia (3)	Chest X-ray (6), barium studies (3), CT scan (6)	Laparotomic repair with mesh (3), laparoscopic repair with mesh (1), thoracotomic suture (1), thoracoabdominal repair with mesh + colectomy (1)	Left (6)	Stomach (4), colon (4), spleen (3), left lobe of the liver (1)
Abdullah and Stonelake [58]	1	F	65	Trauma	Chest X-ray, CT scan	Emergency laparotomy	Left	Colon (perforated)
Bhatt and McMonagle [59]	1	M	23	Trauma (2 years earlier)	Chest X-ray, CT scan	Laparotomic suture	Left	Small bowel, omentum and colon (obstruction)
De la Cour and Teklay [60]	1	F	27	Bochdalek hernia	Chest X-ray, CT scan	Primary closure	Left	–
Harada et al. [61]	1	M	78	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic suture	Left	Omentum, transverse colon, small bowel
Kumar and Bhandari [62]	1	M	80	Morgagni hernia	CT scan	Laparotomic suture	Left	Stomach (obstruction)
Lu et al. [13]	6	M (5) F (1)	39.1 (Mean)	Trauma (traffic accident) (5)–penetrating injury (1)	Chest X-ray(5), gastrografin swallow (5), barium enema (1), CT scan(1)	Non-operative treatment (3), splenectomy (3)	Left (6)	Stomach (6), omentum (4), splenic flexure of the colon (1), small bowel (1)
Manipadam et al. [63]	1	M	23	Bochdalek hernia	Chest X-ray	Laparotomy + gastric resection	Left	Stomach (volvulus)
Massloom [36]	1	M	50	Bochdalek hernia	CT scan	Thoracoabdominal approach	Left	Small bowel
Razi et al. [64]	1	F	83	Morgagni hernia	Chest X-ray, CT scan	Laparoscopic repair with mesh	Left	Transverse colon, stomach (partial volvulus)
Siow et al. [65]	1	M	32	Trauma (traffic accident)	CT scan	Laparoscopic repair with mesh	Left	–

Table 1 continued

References	No. of patients	Sex	Age (years)	Etiology	Diagnosis	Treatment	Site of Hernia	Herniated organs
Atef and Emna [66]	1	M	56	Bochdalek hernia	Chest X-ray, barium studies, CT scan	Laparotomic suture	Left	Stomach (volvulus)
Haratake et al. [67]	1	F	50	Heterotopic endometriosis	CT scan	Laparotomic suture	Right	Heterotopic endometriosis (chilaiditi syndrome)
Sutedja and Muliani [68]	1	F	51	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic repair with mesh	Left	–
Tokur et al. [69]	1	F	27	Congenital diaphragmatic hernia	Chest X-ray, CT scan	Thoracotomic suture	Left	Tension gastro-thorax
Debergh and Fierens [70]	1	F	34	Bochdalek hernia	None (pregnant)	Laparoscopic suture	Left	Small bowel
Gali et al. [71]	1	M	28	Penetrating Injury (years before)	CT scan	Laparotomic suture	Left	Small bowel
Moussa et al. [72]	1	F	65	Previous history of pericardial effusions and sarcoidosis	Chest X-ray, CT scan	Laparoscopic repair with mesh	Right	Left lobe of liver, stomach, colon
Nakamura et al. [73]	1	M	81	Post-surgery diaphragmatic hernia (hcc treated with radiofrequency ablation)	Chest US, CT scan	Laparotomic suture + small bowel resection	Right	Liver, small bowel (incarcerated)
Newman [74]	1	M	25	Bochdalek hernia	Chest X-ray, CT scan	Laparotomic suture + gastric resection	Left	Stomach, small bowel
Ota et al. [75]	1	M	62	Trauma (fall)	EFAST, chest X-ray, CT scan	Video assisted mini thoracotomy primary suture	Right	Hemothorax
Topuz and Ozek [76]	1	F	55	Trauma (traffic accident)	Chest X-ray, CT scan	Laparotomic suture	Right	Liver (Mechanic Compression on Ventricle)
Tyagi et al. [77]	1	M	36	Morgagni hernia	Chest X-ray, CT scan	Laparoscopy repair with gore-tex fixed with a spiral tacker	Left	Omentum, transverse colon
Wigley et al. [78]	1	F	72	Trauma (traffic accident)	–	–	–	–
Elangovan et al. [79]	1	M	30	Trauma	Chest X-ray, CT scan	Laparoscopy	Left	Stomach
Husain et al. [80]	1	M	20	Bochdalek hernia	Chest X-ray, barium swallow, CT scan	Laparoscopic suture + mesh	Left	Stomach, omentum, splenic flexure of the colon
Kurniawan et al. [24]	1	M	17	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic suture	Left	Stomach, spleen, colon
Patle et al. [81]	1	F	50	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic suture + mesh	Right	Ascending colon, hepatic flexure of the colon, transverse colon, right kidney
Safdar et al. [82]	1	M	60	Trauma (fall)	Chest X-ray, CT scan	Laparoscopy + laparotomy	Left	Stomach, small bowel spleen
Sonthalia et al. [83]	1	F	78	Morgagni hernia	Chest X-ray, barium studies, CT scan	Thoracotomy	Left	Stomach (volvulus)
Vega et al. [84]	1	M	35	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic suture + total gastrectomy	Left	Stomach
John et al. [85]	1	F	57	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic suture	Left	Stomach

Table 1 continued

References	No. of patients	Sex	Age (years)	Etiology	Diagnosis	Treatment	Site of Hernia	Herniated organs
Kuppusamy et al. [86]	1	M	28	Trauma	CT scan	Thoracotomy	Right	Liver
Nayak et al. [87]	1	M	50	Blunt Trauma	EGDS, barium studies, CT scan	Laparoscopic suture	Left	Stomach (volvulus)
Ngai [26]	1	F	31	Bochdalek hernia	MRI	Nasogastric tube	Left	Spleen, small bowel, stomach, pancreas
Toydemir et al. [88]	1	M	77	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic repair with mesh	Left	Transverse colon
Vassileva et al. [89]	1	F	25	Morgagni hernia	Chest X-ray, CT scan	Laparoscopic suture	Right	Omentum
Vernadakis et al. [90]	1	F	46	Liver donor	Chest X-ray, barium studies, CT scan	Laparotomy	Right	Small bowel
Agrafiotis et al. [91]	1	F	52	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic approach, minilaparotomy and mesh	Left	Small bowel, right colon
Baloyiannis et al. [92]	1	M	56	Trauma	Chest X-ray, US, CT scan	Laparotomic suture + mesh	Right	Right hepatic lobe, omentum
Okan et al. [93]	10	M (4) F (6)	44.3 (Mean)	Trauma	CT scan	Laparotomy (7), Thoracotomy (2), Thoracoabdominal Approach (1)	Left (9) Right (1)	Colon (7), stomach (5), omentum (5), spleen (4), small bowel (2), left kidney (1)
Altinkaya et al. [94]	12	M (2) F (10)	60 (Mean)	Morgagni hernia	CT scan	Laparoscopic suture (2), laparotomic repair (4), transthoracic repair (1)	Right (12)	Omentum, Colon
Andreev et al. [95]	2	M (2)	40 – 46	Trauma–post-surgery diaphragmatic hernia	CT scan, chest X-ray	Laparoscopic suture (2)	Left (2)	Omentum, colon (obstruction)–transverse colon
Dente and Bagarani [96]	1	F	86	Bochdalek hernia	Barium Swallow, CT scan	Laparoscopic repair with mesh	Left	Stomach
Hamid et al. [97]	1	F	53	Bochdalek hernia	CT scan	Laparoscopic repair with mesh	Left	Gastric diverticulum
Walchalk and Stanfield [98]	1	F	57	Trauma	Chest X-ray, CT scan	–	Right	Stomach
Akhtar et al. [99]	1	M	27	Bochdalek hernia	Chest X-ray, CT scan, upper GI endoscopy	Laparoscopy repair with gore-tex dual mesh	Left	Small bowel, ascending and transverse colon, spleen
Fraser et al. [100]	1	F	75	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic reduction + thoracoscopy repair with mesh	Right	Hepatic flexure of the colon, small bowel, right kidney
Kavanagh et al. [101]	1	M	76	Bochdalek hernia	Chest X-ray, CT scan	Laparotomic suture	Right	Transverse colon (strangulation)
Laaksonen et al. [102]	1	F	38	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic Reduction + Thoracotomy Repair with Mesh	Right	Right lobe of the liver, hepatic flexure of the colon, omentum
Ouazzani et al. [103]	1	M	24	Trauma	Chest X-ray, CT scan	Laparoscopic repair with mesh	Left	Stomach
Ozpolat et al. [104]	1	M	52	Previous tube thoracostomy	Chest X-ray, MRI	Thoracotomic suture	Left	Omentum

Table 1 continued

References	No. of patients	Sex	Age (years)	Etiology	Diagnosis	Treatment	Site of Hernia	Herniated organs
Peer et al. [105]	29	M (25) F (4)	33.6 (Mean)	Trauma	Chest X-ray (20), CT scan (4), intra-operative diagnosis (5)	Thoracotomy (20), laparotomy (8), thoracoabdominal approach (1)	Left (23) Right (6)	–
Sung et al. [106]	1	F	49	Congenital diaphragmatic hernia	Chest X-ray	Thoracotomy	Left	Stomach, spleen, splenic flexure of the colon, small bowel
Tan et al. [107]	14	M (12) F (2)	38 (Mean)	Trauma	Chest X-ray, CT scan, MRI	Laparotomy, thoracotomy or VATS primary repair (12)	Left (9) Right (5)	–
Boyce et al. [108]	1	F	35	Post-surgery diaphragmatic hernia	CT scan	Laparotomic suture	Left	Bowel loops (ischemic)
Esmer et al. [109]	1	F	42	Bochdalek hernia	Chest X-ray, CT scan	Thoracoscopic suture + laparoscopic colostomy	Left	Left colon, omentum
Gourgiotis et al. [110]	1	M	25	Trauma	Chest X-ray, CT scan	Laparoscopic suture + pfannestiel incision for the bludder	Left	–
Hung et al. [111]	2	M (1) F (1)	74 – 75	Bochdalek hernia (2)	Chest X-ray, CT scan	Laparotomy (1), transthoracic repair (1)	Left (1) Right (1)	Small bowel, colon (obstruction)
Mohammadhosseini and Shirani [112]	1	M	–	Bochdalek hernia	–	–	–	–
Sano et al. [14]	1	F	25	Diaphragmatic hernia during pregnancy	Chest X-ray, CT scan	Emergency caesarean section sutures and a gore-tex sheet	Left	Small bowel
Terzi [113]	1	F	70	Bochdalek hernia	Chest X-ray, CT scan	Thoracoscopic + laparoscopic suture	Right	Colon
Tsuboi et al. [114]	1	M	50	Post-surgery diaphragmatic hernia (16 months later)	CT scan	Laparotomic suture	Left	Stomach
Vogelaar et al. [115]	1	F	37	Post-surgery diaphragmatic hernia (6 months after gastric banding)	CT scan	Laparotomic suture	Left	Stomach
Wu et al. [116]	1	M	74	Blunt trauma (2 months before)	CT scan	Thoracotomic suture	Left	Small bowel
Campbell et al. [117]	1	M	85	Congenital diaphragmatic hernia	Chest X-ray, CT scan	Colopexy (massive defect)	Left	Liver, small bowel
Igai et al. [118]	1	M	48	Trauma	Chest X-ray, CT scan	Laparotomic repair with mesh	Right	Hepatothorax
Rifki et al. [119]	1	F	27	Trauma	Chest X-ray, CT scan	Emergency laparotomy	Left	Stomach, transverse colon and omentum
Rosen et al. [120]	1	M	50	Bochdalek hernia	Chest X-ray, CT scan	Laparoscopic retroperitoneal repair with dual mesh	Right	
Rout et al. [121]	1	F	35	Bochdalek hernia	Chest X-ray, CT scan	Emergency laparotomic suture	Right	Colon
Barbetakis et al. [37]	1	F	31	Bochdalek hernia	Chest X-ray, chest US	Thoracoabdominal approach, primary suture + bowel resection	Left	Right transverse colon, omentum, stomach

Table 1 continued

References	No. of patients	Sex	Age (years)	Etiology	Diagnosis	Treatment	Site of Hernia	Herniated organs
Barrett and Satz [122]	1	M	54	Trauma	CT scan	–	Left	Small bowel
Eglinton et al. [15]	3	F (3)	30.3 (Mean)	Diaphragmatic hernia during pregnancy (28–27–34 week of gestation)	Chest X-ray (3)	Cesarean section + laparotomic suture − laparotomic suture—cesarean section + thoracolaparotomic suture	Left (2) Right (1)	Stomach − stomach + transverse colon + spleen − liver + colon
Iso et al. [123]	1	F	81	Morgagni hernia	Chest X-ray	Primary suture of diaphragm and colic resection	Right	Transverse colon
Luu et al. [16]	1	F	34	Diaphragmatic hernia during pregnancy (33 weeks of gestation)	Chest X-ray, CT scan, barium studies, esophagoscopy	Thoracotomic repair and gastric resection	Left	Stomach (necrotic)
Testini et al. [124]	1	M	51	Post-surgery diaphragmatic hernia (splenopancreasectomy 4 years earlier)	Chest X-ray, CT scan, MRI	Thoracotomic suture	Left	Stomach
Barakat et al. [125]	1	F	43	Congenital diaphragmatic hernia (marfan's syndrome)	Chest X-ray, CT scan	Laparoscopy + laparotomy	Right	Transverse colon, terminal ileum, appendix (perforated)
Chai et al. [126]	1	F	46	Bochdalek hernia	Chest X-ray	Thoracoscopic primary repair with open colectomy	Left	Colon
Gupta et al. [127]	1	M	42	Spontaneous rupture	Chest X-ray, CT scan	Laparotomic suture + bowel resection	Left	Small bowel
Ransom and Cornelius [128]	1	M	21	Trauma	Chest X-ray, chest US, EGDS	Thoracotomy	Left	Stomach, colon
Tiberio et al. [129]	33	–	–	Blunt trauma (22)–penetrating injury (11)	Chest X-ray, CT scan	Direct suture in all cases	–	–
Abboud et al. [130]	1	M	–	Trauma	Chest X-ray	Laparotomic suture	Left	Transverse colon, small bowel
Dalton et al. [131]	1	M	43	Bochdalek hernia	Chest X-ray	Thoracic drainage + diaphragmatic primary suture	Left	Stomach, transverse colon and spleen
Kara et al. [132]	1	M	28	Trauma	Chest X-ray, CT scan	Left thoracotomy + laparotomic repairing with mesh	Left	Stomach
Sirbu et al. [133]	1	M	67	Trauma	Chest X-ray	Laparotomic suture	Left	Stomach, spleen, splenic flexure of the colon
Genc et al. [17]	1	M	29	Bochdalek hernia (29 week of gestation)	Chest X-ray, MRI	Laparotomic suture	Left	Stomach, transverse colon
Niwa et al. [134]	1	F	53	Bochdalek hernia	Chest X-ray, CT scan	Thoracotomic suture + resection of necrotic organs	Left	Stomach, omentum

Table 1 continued

References	No. of patients	Sex	Age (years)	Etiology	Diagnosis	Treatment	Site of Hernia	Herniated organs
Bergeron et al. [20]	160	M (91) F (69)	41 (Mean)	Trauma	Chest X-ray (98), CT scan (8), US (6), upper-GI series (3), fluoroscopy (2), barium enema (1), diagnostic peritoneal lavage (1)	Laparotomy (134), thoracotomy (20), combined (6)	Left (126) Right (31) Bilateral (3)	–
Guven et al. [135]	2	M (1) F (1)	65–67	Morgagni hernia	Chest X-ray, CT scan–barium enema, CT scan	Laparotomic repair with mesh (2)	Right (2)	Small bowel, transverse colon − stomach, transverse colon
Kanazawa et al. [136]	1	F	63	Bochdalek hernia	Chest X-ray, CT scan	Thoracolaparotomy repair	Right	Colon, right kidney
Sato and Kosaka [137]	1	M	57	Trauma	Chest X-ray, CT scan	Thoracotomic suture	Right	Liver
Bujanda et al. [138]	1	M	22	Bochdalek hernia	Chest X-ray, barium meal	Laparotomic suture	Left	Stomach, transverse colon, omentum, small bowel, spleen
Carreño et al. [139]	1	M	52	Bochdalek hernia	–	Laparoscopic suture	–	Stomach (volvulus)
Fisichella et al. [140]	1	F	55	Bochdalek hernia	CT scan	Thoracolaparotomy repair	Right	Liver, small bowel (rotate)
Nursal et al. [35]	26	M (21) F (5)	35 (Mean)	Trauma	Chest X-ray, CT scan	Primary suture (24), synthetic grafts (2)	Left (24) Right (2)	Stomach (31.8%), colon (27.2%), omentum (15.9%), small bowel (13.6%), spleen (6.8%), Liver (4.5%)
Prieto Nieto et al. [141]	1	M	36	Trauma (8 months later)	CT scan	Laparotomic repair and gastric suture	Left	Stomach (incarceration and perforation)
Pross et al. [142]	1	M	20	Trauma	Laparoscopy	Laparoscopic suture	Left	Stomach
Saito et al. [143]	1	M	51		Chest X-ray, CT scan	Thoracoabdominal approach	Left	stomach (gastric ulceration had perforated aorta)
De Waele and Vermassen [144]	1	M	45	Trauma	Chest X-ray, US	Laparotomy + splenectomy	Left	Spleen
Colliver et al. [145]	1	M	80	Trauma	Chest X-ray, CT scan	Laparotomic suture	Left	Stomach
Allen et al. [146]	147	M (93) F (54)	–		–	–	–	Stomach
Zantut et al. [21]	1	M	33	Trauma	Chest X-ray, CT scan, MRI	Laparoscopy	Bilateral	–
Girzadas and Fligner [147]	1	F	71	Trauma	Chest X-ray	–	Pericardial sac	Omentum, transverse colon (herniated into the pericardial space causing cardiac tamponade)
Thomas and Kapur [148]	2	M (2)	38—30	Bochdalek hernia	Chest X-ray	Laparotomic suture (2)	Left (2)	Colon−splenic flexure
Bush and Margulies [149]	2	M (2)	18—64	Trauma	Chest X-ray, barium enema	Laparotomic suture (2)	Left (2)	Omentum

Table 1 continued

References	No. of patients	Sex	Age (years)	Etiology	Diagnosis	Treatment	Site of Hernia	Herniated organs
Chidamdaram et al. [150]	1	M	32	Trauma	Chest X-ray	Thoracotomy	Left	Stomach
Feliciano et al. [151]	16	M (15) F (1)	25 (Mean)	Penetrating trauma (delayed diagnosis)	–	Thoracotomy (6) laparotomy (10)	Left (15) Right (1)	–
Gardezi et al. [152]	2	M (2)	43	Bochdalek hernia	Chest X-ray	Laparotomy (2)	Left (2)	Transverse colon and splenic flexure, stomach
Saber et al. [153]	8	M (8)	33.4 (Mean)	Trauma (delayed presentation)	–	Laparotomy (6), thoracotomy (2)	Left (7) Right (1)	Omentum (5), colon (5), stomach (4), small bowel (2), spleen (1), liver (1), gallbladder (1), appendix (1)
Symbas et al. [154]	194	–	–	Trauma	Chest X-ray, barium studies, laparotomy	Laparotomic primary suture (193), laparotomic repair with mesh (1)	–	–
Brown and Richardson [22]	41	M (31) F (10)	17–72	Trauma	Chest X-ray, peritoneal lavage	Laparotomy (23), thoracotomy (13), combined (5)	Left (27) Right (12) Bilateral (2)	Stomach (24), spleen (16), colon (13), liver (3), small bowel (2), omentum (4)
Clark et al. [155]	10	–	40 (Mean)	Trauma	Chest X-ray	–	–	–
Clarke et al. [156]	54	–	29 (Mean)	Trauma	–	Laparotomy (19), laparoscopy (13), thoracotomy (5), thoracolaparotomy (1), relaparotomy (6), thoracoscopy 2	Left (6) Right (3)	Stomach (10), colon (1), and spleen (2)
Mjoli et al. [157]	55	M (50) F (5)	26.3 (Mean)	Trauma	Chest X-ray	Laparoscopic suture (21),	–	Omentum (26), stomach (26), colon (1)
Bairagi et al. [158]	1	M (1)	40	Trauma	Chest X-ray–CT scan	Laparotomy suture and small bowel resection (1)	Right (1)	Colon (1), liver (1), small bowel (1)
Kwon et al. [159]	60	M (47)	49 (Mean)	Trauma	–	–	Left (29) Right (31)	–
Houston et al. [160]	1	M (1)	50	Trauma	Chest X-ray–CT scan	Laparoscopic suture (1)	Left (1)	Stomach (1)
Powell et al. [161]	23	–	–	Trauma (3 delayed presentation)	CT scan–vats	Thoracoscopy suture (23)	–	–
Shaban et al. [162]	1	M (1)	59	Trauma	Chest X-ray–CT scan	Laparotomic suture (1)	Left (1)	Stomach (1), colon (1)
Chughtai et al. [163]	208	M (134) F (74)	42 (Mean)	Trauma	Ultrasound–CT scan	Laparotomy (194), thoracotomy (3)	Left (135) Right (47) Bilateral (4)	–
Pehar et al. [164]	1	F	61	Spontaneous	Chest X-ray–CT scan	Thoracotomy suture (1)	–	–

Table 1 continued

References	No. of patients	Sex	Age (years)	Etiology	Diagnosis	Treatment	Site of Hernia	Herniated organs
Ercan et al. [165]	1	M	66	Trauma (delayed presentation)	Chest X-ray–CT scan	Laparotomy repair with mesh (1)	Right (1)	Stomach (1), liver (1), gallbladder (2), omentum (1)
Muroni et al. [166]	1	M	59	Trauma (delayed presentation)	Chest X-ray–CT scan	Laparotomy suture (1)	Right (1)	Colon (1), small bowel (1)
Aborajooh and Al-Hamid [167]	1	M	48	Trauma (delayed presentation)	CT scan	Laparoscopic repair with mesh (1)	–	Colon (1), omentum (1)
Vyas et al. [168]	1	M	21	Trauma	Chest X-ray–CT scan	Laparotomy repair with mesh (1)	Left (1)	Stomach (1), spleen (1), colon (1), small bowel (1), omentum (1)
Öz et al. [169]	1	F	77	Trauma	Chest X-ray–CT scan	Thoracotomy suture (1)	Left (1)	–
Lee et al. [170]	1	F	59	Trauma	Chest X-ray–CT scan	Thoracotomy suture (1)	Right (1)	Liver (1)
Kumar et al. [171]	1	M	26	Trauma (delayed presentation)	Chest X-ray–CT scan	Laparotomy suture (1)	Left (1)	Colon (1)
Lim et al. [172]	46	M (37) F (9)	36.5 (Mean)	Trauma	Chest X-ray (21)–CT scan (13)	Laparotomy (17), mesh(1), thoracotomy (3) laparotomy and Thoracotomy (2)	Left (37) Right (9)	–
Gu et al. [173]	69	M (49) F (20)	51 (Mean)	Trauma	Chest X-ray (16)–CT scan (47)–surgery (6)	Thoracotomy (35), laparotomy (22), laparotomy and thoracotomy (10)–suture	Left (50) Right (19)	–
Simpson et al. [174]	16	–	21 (Mean)	Trauma	Chest X-ray (7)–CT scan (1)–ultrasound (2)	Laparotomy (16)	Left (14) Right (2)	Stomach (8), spleen (1), small bowel (2), colon (4)
Ganie et al. [175]	11	–	–	Trauma	–	Suture	Left (9) Right (2)	Stomach (2), spleen (1)
Xenaki et al. [176]	3	M (2) F (1)	44, 62, 53	Trauma	CT scan (3), ultrasound (1)	Laparoscopy (2)	Left (2) Right (1)	Stomach (1), spleen (1), pancreatic tail (1), colon (2), omentum (1)
Davoodabadi et al. [177]	6	M (4) F (2)	41 (Mean)	Trauma	Chest X-ray (6)–CT scan (6)	Thoracotomy repair (6), mesh repair (1)	Left (5) Right (1)	Stomach (4), colon (3), liver (2)
Nain et al. [178]	9	M (9)	30–40	Trauma (3 delayed presentation)	Chest X-ray (4)–CT scan (5)	Laparotomy (6), thoracotomy (3)	Left (9)	Stomach (2), small bowel (2), colon (1), liver (3)

M male, *F* female, *US* ultrasonography, *MRI* magnetic resonance imaging

Table 2 Demographic, and pathological features of the studied population

Parameters	Analyzed variable	No, %	Mean ± SD
Sex	Female	379, 24.5%	
	Male	809, 52.4%	
	Not reported	354, 22.9%	
Mean age (years)	All considered patients		47,7 ± 18.3
	Bochdalek DH		47,2 ± 18.7
	Morgagni DH		64,1 ± 19.2
	Other CDH		48,0 ± 23.9
	Traumatic DH		45,1 ± 14.5
Etiology	Bochdalek DH	50, 3.2%	
	Morgagni DH	54 3.5%	
	Not specified CDH	9, 0.5%	
	Post-surgery DH	5, 0.3%	
	During pregnancy DH	5, 0.3%	
	Traumatic DH	1261, 81.7%	
	Other DH	7, 0.4%	
	Not reported	151, 9.7%	
Side	Left	709, 45.9%	
	Right	273, 17.7%	
	Bilateral	10, 0,6%	
	Not reported	550, 35.6%	

SD standard deviation, *DH* diaphragmatic hernia, *CDH* congenital diaphragmatic hernia

The treatment for each category of diaphragmatic hernias is summarized in Table 4.

The stomach was the most common herniated organ in 176 cases, followed by the colon, in 125 cases, the omentum (90 cases), the small bowel (95 cases) and the spleen (44 cases). Liver and kidney involvement were observed in 32 and 5 patients, respectively. In 68 cases, there was no finding of abdominal organs in the chest, while for 906 patients, this information was not reported.

Discussion

The symptomatology of complicated diaphragmatic hernias can vary greatly depending also on their etiology. In CDH, the symptoms can be varied and occur at different times. Symptomatic CDH in the childhood derives from pulmonary hypoplasia because the herniation of the organs in the chest during prenatal period prevents the development of the lungs [6]. In spite of our series does not suggest it clearly, literature reports BH as the most frequent among the CDH [7, 8]. The MH are rarer. MH have an anterior development and derive from a closure defect of the sternal part of the diaphragm with the seventh chondrocostal arch. They can remain asymptomatic, and often, the diagnosis is an incidental finding during other instrumental test (chest X-ray) [9, 10]. CDH in the adulthood can present with non-specific respiratory and gastrointestinal disorders. Gastrointestinal problems at the diagnosis can be more common in the left-sided hernias, where the absence of the liver allows the migration of the abdominal organs into the thorax, sometimes causing mild (dyspepsia, recurrent or non-specific abdominal pain) or acute (obstructions or flies) abdominal symptoms. In right-side CDH, respiratory symptoms are predominant [11, 12]. TDH presentation symptoms may vary depending on the type of trauma (blunt or penetrating), on the amount of energy absorbed by the body and on the involved side. The most common cause of TDH is a traumatic event that creates an increase gradient between the abdominal and thoracic compartment with a rupture mainly at the level of the embryonic melting points. Penetrating traumas are the most frequent, but the diaphragmatic defects are generally smaller than the blunt ones [13]. Small chronic traumatic events such as coughing or obesity acting over time may cause the exhaustion of already existing hiatuses or the rupture of weaknesses. In fact, in some cases the symptoms may not be present for many months or years after the trauma [5]. Pregnancy also plays a fundamental role in this context; increased abdominal pressure that occurs in this period contributes to

Table 3 Defect's localization in various etiologies

Etiology (No. of patients)	Diaphgram's side			
	Left (No, %*)	Right (No, %*)	Bilateral (No, %*)	NR (No, %*)
Total of hernias (n. 1542)	709, 45.9%	273, 17.7%	10, 0,6%	550, 35.6%
Traumatic DH (n. 1261)	644, 51.0%	207, 16.4%	10, 0.5%	400, 31.7%
Bochdalek DH (n. 50)	34, 68.0%	14, 28.0%	–	2, 4.0%
Morgagni DH (n. 54)	9, 16.7%	45, 83.3%	–	–
Not specified CDH (n. 9)	7, 77.8%	2, 22.8%	–	–
Post-surgery DH (n. 5)	4, 80.0%	1, 20.0%	–	–
During pregnancy DH (n. 5)	4, 80.0%	1, 20.0%	–	–
Other DH (n. 7)	3, 42.8%	3, 42.8%	–	1, 14.4%
Not reported (n. 151)	–	–	–	151, 100.0%

NR not reported, *CDH* congenital diaphragmatic hernia

*Percentage refers to the total of patients for respective etiology

Table 4 Surgical approach: differentiated analysis by etiology

Surgical approach	Etiology			
	Bochdalek DH (50 patients) No, %*	Not-specified CDH (9 patients) No, %*	Morgagni DH (54 patients) No, %*	Traumatic DH (1261 patients) No, %*
Laparoscopic approach	21, 20%	1, 0.9%	31, 29.5%	52, 49.5%
Robotic approach	2, 4%	–	–	–
Thoracoscopic approach	3, 10.7%	–	–	25, 89.3%
Thoracotomy	3, 1.9%	2, 1.2%	2, 1.2%	150, 95.5%
Laparotomic approach	16, 1.7%	6, 0.65%	13, 1.4%	878, 96.1%
Thoracoabdominal approach	4, 5.4%	–	–	35, 94.6%
NOM	–	–	8, 15%	5, 1%
NR	1, 2%	–	–	58, 8%

NOM non-operative management, *NR* not reported

*Percentage refers to the total of patients for respective etiology

the rupture of the diaphragm in its weaknesses point or can unmask congenital diaphragmatic defects. It is a rare situation, and in our series, it occurred in 5 cases (0,5%), but in some cases, it may endanger the life of the fetus; therefore, it must not be ignored [14–17].

CDH have a different rupture site's prevalence depending on the type of considered hernia. BH occur more frequently on the left side (80%), [18] MH mainly develop on the right side, but sometimes it can be bilateral or develops on the left side [3]. Our analysis also follows the

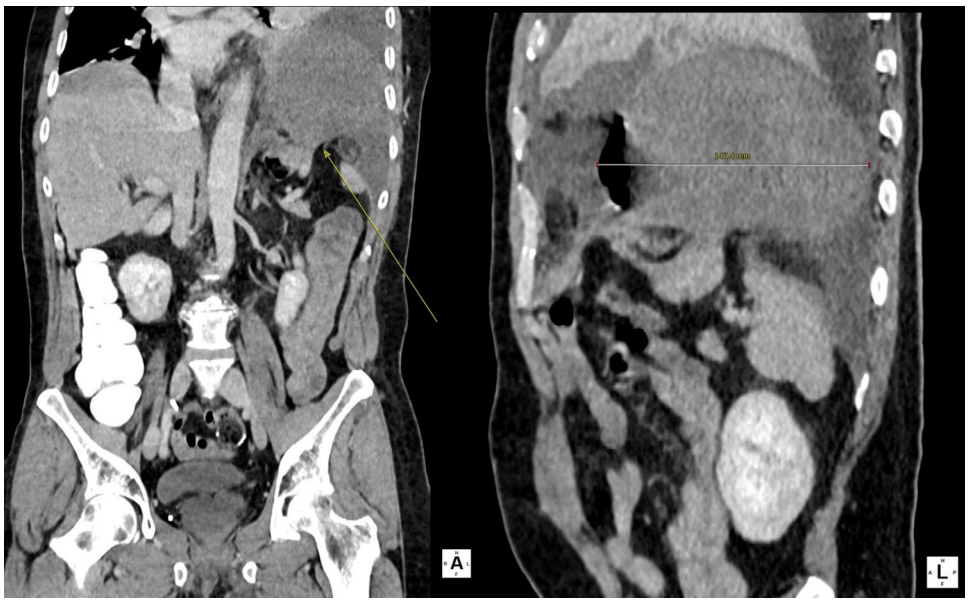

Fig. 2 CT scan shows ischemia signs (the forward displacement of the gastric bubble, the missing of the gastric folds and the absence of gastric walls contrast enhancement)

literature, indeed 68% of BH developed on the left side (34 vs. 14), while almost all MH are on the right one (83%, 45/54). Considering TDH, in our series as well as in literature, the left hemidiaphragm is more commonly involved in blunt or penetrating injuries. This is probably due to the protective effect of the liver for the right hemidiaphragm on the blunt trauma, and the fact that most people use their right hand on the penetrating trauma [19]. The great variability in the etiology of trauma also determines the possibility the defect develops in both hemidiaphragms; in our review, there are only 6 bilateral herniations and all have traumatic origin [20–22].

In a "border" pathology between the thorax and the abdomen, a correct preoperative diagnostic work-up is essential. A precise diagnosis inevitably influences the surgeon in choosing the most correct approach to the patient with complicated diaphragmatic hernia. The most used diagnostic test in both our series and literature is chest X-ray. It allows to show an opaque hemithorax with deviation of the mediastinum and when the nature of the thoracic contents is uncertain, nasogastric tube's course can help in the diagnosis. Soft opacity in the thorax with or without gas can be a sign of hernial sac, and in larger hernias, loops of bowel or the transverse, can also be visualized in the chest [3]. CT scan, with a sensitivity and specificity of 14–82% and 87%, respectively, is considered the diagnostic gold standard [23, 24]. Unlike chest X-ray, which can be normal in case of intermittent herniation, CT scan determines the presence, location and size of the diaphragmatic defect. CT scan can evaluate the intrathoracic herniation of abdominal contents and related complications [25]. Even in one case, in our unit the diagnostic accuracy of CT scan was fundamental to recognize some ischemia signs, such as the forward displacement of the gastric bubble, the missing of the gastric folds and the absence of gastric walls contrast enhancement (Fig. 2). The other diagnostic tests, barium studies, gastrografin swallow, EGDS, US and manometry are much less used in the considered articles. Barium studies can help in revealing barium filling stomach or bowels within the thorax with the strict segment of intestine at hernia site of the diaphragm, while MRI, not performable in emergency, may be used in selected patients (pregnant) [17, 26] in the study of the herniated structures and associated abdominal organ's injuries [3].

Although there is no consensus on the indications and timing of surgery. Surgery seems to be the treatment of choice for complicated diaphragmatic hernia, both congenital and traumatic. Hernias, especially congenital and accidentally diagnosed, should be corrected even if the patient is asymptomatic because the risk of strangulation or incarceration [10, 27]. In case of complications, surgery is mandatory [23]. Smaller diaphragmatic defects can be primarily closed with a non-absorbable suture [28, 29] while for larger defects, where the primary suture would develop excessive tension due to the considerable loss of tissue, or also in order to reinforce the suture, meshes should be used [30, 31]. The biologic mesh represents an alternative to the synthetic one due to its lower rate of hernia recurrence, higher resistance to infections and lower risk of displacement [23, 32, 33]. The surgical approach can be either thoracotomic or laparotomic depending on the diagnostic investigation's result and on the surgeon's preferences and skills. The thoracotomic approach, with

the addition of a separate laparotomy when indicated, can be recommended especially in chronic herniation in order to reduce visceral-pleural adhesions and to avoid intrathoracic visceral perforation [34]. Sometimes, thoracoabdominal approach may be necessary in emergency setting, when it is difficult to identify visceral abdominal lesions or to exclude bilaterality [35–37].

Recently, laparoscopic or thoracoscopic approach is becoming more feasible and safer allowing a lower hospital length stay and a lower morbidity rate [31, 38–40]. Despite this, our analysis reveals that open approaches are still predominant. This could be related to the majority of trauma hernias in which the laparoscopic approach is still very limited. A differentiated analysis of the etiology shows that most of the minimally invasive approaches have been used in repair of complicated CDH, while almost all of the complicated TDH have been approached with laparotomy. A further and even more recent approach is the robotic one, which allows a detailed anatomical visualization and a more precise dissection, but literature findings are poor. In our series, the robotic approach has been used only in 3 patients, [41, 42] and this can be determined by the high costs and the nature of the pathology that often occurs in "emergency setting" compared to "elective setting." Damage control surgery (DCS) can be an advantageous/rescue alternative in emergency management of the patient with complicated DH although there is no general consensus on its use mainly due to the intra-abdominal hypertension and the abdominal compartment syndrome that may result [43]. DCS can be useful especially in complicated TDH. In unstable patients or damaged/bleeding organs, a second look may be required. The re-exploration of the abdomen 24/48 h later can help surgeon in recognizing the vital/non-vital areas of an ischemic organ leading him in resection [44].

Conclusion

Complicated CDH and TDH have different etiology but similar management. Surgery is the treatment of choice and is strongly influenced by the preoperative setting, performed mainly with chest X-ray and CT scan. DCS can be considered especially in traumas and can offer an advantage in management of the compromised patients. Minimally invasive approach is safe and feasible and offers advantages in terms of hospitalization and lower morbidity rate but is highly dependent on the surgeon's expertise, especially in emergency setting.

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