Early Postoperative Complications of Thoracic Esophageal Diverticula: A Review of 10 Cases from “Saint Mary” Hospital, Bucharest, Romania

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Rezumat

Complicații postoperatorii precoce ale diverticulilor esofagieni toracici: un studiu pe 10 cazuri din Clinica de Chirurgie Generală și Esofagiană a Spitalului Clinic “Sf. Maria”, București, Romania

Introducere: Diverticulul esofagian toracic reprezintă o patologie rară, frecvent asociată cu tulburări de motilitate esofagiană. Chirurgia reprezintă singura opțiune terapeutică la pacienții cu simptome severe.

Metodă: Studiu retrospectiv pe un lot de 10 pacienți ce au suferit diverticulectomie pentru simptomatologia provocată de diverticuli epifrenici sau medio-toracici. Au fost înregistrate principalele simptome preoperatorii, analizele de sânge uzuale, tranzitul baritat, endoscopia superioară și manometria esofagiană. Am analizat complicațiile postoperatorii, durata de spitalizare și perioada petrecută la terapie intensivă.

Rezultate: Majoritatea pacienților au prezentat regurgitații, disfagie sau ambele. Abordul chirurgical a fost prin toracotomie stângă sau pe cale abdominală pentru diverticuli epifrenici și prin toracotomie dreaptă sau toracoscopie pentru diverticuli medio-toracici. 4 pacienți au prezentat complicații severe: 3 fistule majore (un deces) și un chilotorax.

Discuții: Chirurgia diverticulilor toracici este asociată cu rate mari de morbiditate și mortalitate. Fistula produsă la nivelul liniei de sutură este cea mai frecventă complicație, spre deosebire de chilotorax ce survine mai rar.

Concluzii: Diverticulul esofagian toracic voluminos este o patologie benignă cu complicații “maligne”. O evaluare preoperatorie

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aprofundată este obligatorie în vederea alegerii tehnicii chirurgicale adecvate. Utilizarea mai multor cartușe de sutura mecanică crește riscul de fistulă, iar sutura manuală de întărire diminuează acest risc.

Cuvinte cheie: diverticul esofagian toracic, diverticulectomie, fistulă, chilotorax

Abstract

Introduction: Thoracic esophageal diverticulum is a rare pathology frequently associated with esophageal motility disorders. Surgery is the only option in patients with severe symptoms.

Method: This is a retrospective case series study of 10 patients who underwent diverticulectomy for thoracic (epiphrenic or mid-esophageal) diverticula. It was recorded: main preoperative symptoms, usual blood tests, barium swallow, upper endoscopy and esophageal manometry. We analyzed the postoperative complications, length of stay in hospital and intensive care unit.

Results: Most patients presented with regurgitation and/or dysphagia. The surgical approach was through left thoracotomy or abdominal for epiphrenic diverticula and through right thoracotomy or thoracoscopy for mid-esophageal diverticula. 4 patients had severe complications: 3 had major leaks (one death) and one had chylothorax.

Discussions: Surgery for thoracic diverticula is associated with high mortality and morbidity rates. Leak from the suture line is the most common complication, unlike chylothorax which is a rare complication.

Conclusions: Thoracic diverticula represent a benign pathology which can have „malignant” post-operative complications. A thorough preoperative work-up is mandatory for choosing the appropriate surgical technique. Use of multiple cartridges for stapling suture increase the risk of leakage, but oversewing the suture may diminish it.

Key words: thoracic esophageal diverticulum, diverticulectomy, leakage, chylothorax

Introduction

Thoracic esophageal pulsion diverticulum are rare pathological entities characterized by herniation of the esophageal mucosa through the fibers of the muscular layer, most frequently at the level of 10 cm distal thoracic esophagus (1).

Studies have established that 75-100% of the patients may have associated esophageal motility disorders, especially achalasia and diffuse esophageal spasm (2-5). Histological abnormalities of the myenteric plexus up to 80% were described even in the case of patients with esophageal diverticula with no associated specific esophageal motility disorders (23).

The presence of the epiphrenic diverticular pouch and, the aforementioned pathological

association indicate a disorder of esophageal motility of unclear etiology (6, 7).

Evaluation of esophageal motility is the only way to quantify the etiopathogeny substrate of diverticular pouch development and to decide the therapeutic protocol (8, 9).

Although most patients with esophageal diverticula are asymptomatic, for those who describe symptoms considered specific to this condition (dysphagia, regurgitation), is difficult to establish the etiological substrate of the clinical condition. This may be due to the presence of the diverticulum pouch, by retention, extrinsic compression or associated esophageal motility disorders (10-12).

In patients with severe symptoms due to esophageal diverticula (dysphagia, regurgitation, aspiration pneumonia), medical or endoscopic

treatment is ineffective, therefore surgical treatment remains the only solution (13, 14).

Diverticulectomy associated with sub-diverticular myotomy and possibly gastric fundoplication represent the current standard surgical treatment for these patients (15). The technique can be performed by thoracic approach (thoracotomy or thoracoscopy) or by abdominal approach through laparoscop, as the optimal pathway for the epiphrenic diverticula remains a controversy.

Although surgical treatment is effective in treating symptomatic esophageal diverticula, it is accompanied by a high morbidity rate, up to 75%, including esophageal suture fistula (up to 33%), and a mortality rate up to 11% (16-20).

These results have not been modified despite the introduction of minimally invasive techniques and mechanical suture devices (21, 22).

Objectives

The aim of this review is to identify early, major postoperative complications of thoracic esophageal diverticula, in order to find the best way to avoid and manage them. Also, we look at the impact on the length of stay in hospital and intensive care unit, and mortality risk.

Method

This is a retrospective case series study of 10 patients who underwent surgery for symptomatic thoracic esophageal diverticula between 2012 – 2017 at the „Saint Mary” Hospital, Bucharest, Romania.

The preoperative symptoms were recorded, as well as the usual blood tests (complete blood cell count, chemistry, and iron studies) and other preoperative investigations: barium swallow study, upper endoscopy, perfused esophageal manometry. The barium swallow studies and upper endoscopy were performed in all patients in order to identify the size, the shape, the neck and the location of the esophageal diverticula (defined as distance from the gastroesophageal junction). Through

all these investigations an underlying malignancy was excluded.

All patients underwent diverticulectomy which was performed through abdominal approach or through thoracic approach by open thoracotomy or minimally invasive surgery (thoracoscopy). For some of the patients myotomy and/or fundoplication was performed as well. Selective bronchial intubation was used for general anesthesia.

The variables analyzed in the study were: (a) the postoperative complications as per Clavien-Dindo classification (CDC), (b) the length of stay in hospital and in intensive care unit.

The Clavien-Dindo system grades complications by severity proportional to the effort required to treat them: grade I, complication without need for intervention; grade II, complication that requires pharmacologic treatment or minor intervention; grade III, complication that requires surgical, radiologic, endoscopic intervention, or multitherapy, with or without general anesthesia; grade IV, complication requiring intensive care unit management and life support for single or multiorgan dysfunction; and grade V, complication leading to death (24).

Results

Demographics

Over 5 years' time frame (2012-2017), 10 patients had surgery for symptomatic epiphrenic or mid-thoracic esophageal diverticula performed at the Department of Esophageal and General Surgery „Saint Mary” Hospital, Bucharest, Romania. The gender ratio was 1:1 (*Fig. 1*). Their age was between 50 and 76 years old, with average of 64 years old (*Fig. 2*).

Preoperative work-up

Regarding the main symptoms, 7/10 patients presented with regurgitation, 7/10 had dysphagia, 4 patients having both symptoms.

The only blood tests abnormality found was low serum iron level in 4 patients.

All patients underwent barium swallow

Figure 1. Sex-type distribution of patients with thoracic diverticula

Figure 2. Age distribution of patients with thoracic diverticula

Figure 3. Types of thoracic diverticula

Figure 4. Epiphrenic diverticulum (collection of "Saint Mary" Esophageal and General Surgery Department)

studies and upper endoscopy. These studies identified 4 mid-esophageal diverticula and 6 epiphrenic diverticula (Figs. 3, 4, 5)

Perfused esophageal manometry was successfully performed in 6/10 patients (five patients with epiphrenic diverticulum and one with mid-esophageal diverticulum). Sometimes the catheter had to be placed through the gastroesophageal junction either under radiologic or by endoscopic guidance (25). The 5 patients with epiphrenic diverticulum were found with abnormality of esophageal body motility and a weak or inefficient lower esophageal sphincter (LES). The patient with mid-esophageal diverticulum had a normal manometry (Table 1). Although the manometry was attempted for the other patients, it has failed because of difficulty inserting the probe.

Figure 5. Giant mid-esophageal diverticulum

(collection of "Saint Mary" Esophageal and General Surgery Department)

Table 1. Results of manometry

Patient	Type of diverticulum	LES pressure	LES relaxation	Esophageal body motility
Male, 76yo	epiphrenic	10	100%	inefficient
Female, 66yo	epiphrenic	6	100%	normal
Male, 60yo	epiphrenic	6	100%	inefficient
Female, 71yo	epiphrenic	-	-	absent
Female, 59yo	mid-esophageal	13	100%	normal
Male, 55yo	epiphrenic	12	78%	inefficient

Diverticulectomy technique:

Thoracic approach (thoracotomy or thoracoscopy) was used in 9 patients and abdominal approach was used in only 1 patient. Thus, the 5/6 patients with epiphrenic diverticula underwent left thoracotomy through the 8th - 9th intercostal posterolateral space and 1/6 had abdominal approach (*Fig. 6*). Among the 4 patients with mid-esophageal diverticula, 2 underwent right thoracotomy through the 6th - 7th intercostal posterolateral space and the other 2 had thoracoscopy (*Fig. 7*).

Additional Surgical Procedures

The esophageal myotomy contralateral to the diverticulum was performed in 7 patients: 5 patients with epiphrenic diverticulum and 2 with mid-esophageal diverticulum. Fundoplication was performed in 4 of the 5 patients with epiphrenic diverticulum who also had myotomy. Thus, Belsey-Mark IV fundoplication was done for 3 patients who had left thoracotomy, and Dor fundoplication was done for a patient who had surgery through abdominal approach and concomitant achalasia (*Fig. 8*).

Suture Technique

All 4 patients with mid-esophageal diverticula had stapled suture. The stapling line was done with only one cartridge in two patients (one patient with thoracotomy and the other with thoracoscopy) and with two cartridges in the other two (one patient with thoracotomy and the other with thoracoscopy). Two of the 4 patients with mid-thoracic diverticula also had manual

Figure 6. Surgical approach for epiphrenic diverticula **Figure 7.** Surgical approach for mid-esophageal diverticula **Figure 8.** Myotomy and fundoplication

oversewn continuous suture, both of them being operated through thoracotomy. The reinforced suture line was not possible for the other 2 patients operated through thoracoscopy due to the closed proximity of right bronchus. Two out of 6 patients with epiphrenic diverticula had a double layer manual continuous suture. The other 4 patients with epiphrenic diverticula had a stapled suture with one cartridge and 3 of those underwent a supplementary oversewn manual continuous suture (Fig. 9).

Postoperative Complications

6/10 (60%) patients developed postoperative complications as defined by CDC. Four of those had severe complications (Clavien-Dindo grade III – V). One patient died.

- Two patients with grade II - one with minor, radio-logically detectable leak and the other with a wound infection which required readmission. Both with conservative treatment
- Two patients with grade III – one with major leak which required drainage and esophageal stent and the other with chylothorax which required drainage and surgical debridement,
- One patient with grade IV – major leak complicated by sepsis which needed multiple interventions
- One patient with grade V – major leak complicated by sepsis which needed

Figure 9. Types of suture used for thoracic diverticula

multiple interventions, with fatal outcome (Table 2).

Thus, 3 patients had major leaks. Two of them were patients with mid-esophageal diverticulum who had stapled suture with two cartridges, one also having an oversewn continuous suture. The third patient had an epiphrenic diverticulum and underwent a stapled suture with one cartridge, without oversewn suture. The patient with minor leak and the patient chylothorax had manual suture.

Hospitalization/Intensive Care Unit/Mortality

The duration of hospitalization was between 11 days and 58 days, with a mean length of hospitalization of 28,6 days. The stay in intensive care unit was between 1 day and 35 days and the mean of intensive care unit stay was 8,9 days. Our mortality rate was 10%.

Table 2. Postoperative complications as per Clavien-Dindo classification (CDC)

CDC grade	Complication type	Patient	Type of diverticulum	Surgical approach	Type of suture	Management	Length of stay hospital (days)	Outcome
II	Minor leak	Male, 76 yo	Epiphrenic	Left- thoracotomy	Manual	conservative	32	survived
II	Wound infection	Female, 71yo	Epiphrenic	Abdominal	- Stapled (1 cartridge) - Oversewn	conservative	21	survived
III	Major leak	Male, 60 yo	Mid-esophageal	Right-thoracotomy	Stapled (2 cartridges) Oversewn	Drainage; esophageal stent	58	survived
III	Chylothorax	Male, 55 yo	Epiphrenic	Left- thoracotomy	Manual	Drainage; Mini right-thoracotomy	60	survived
IV	Major leak & sepsis	Male, 50 yo	Epiphrenic	Left- thoracotomy	Stapled (1 cartridge)	Multiple surgical interventions	45	Survived
V	Major leak & sepsis	Female, 69 yo	Mid-esophageal	Thoracoscopy	Stapled (2 cartridges)	Multiple surgical interventions	21	Died

The Chylothorax Case

The chylothorax occurred in the first post-operative day in a 55 years old male patient who was admitted in hospital for dysphagia and regurgitation with an Eckardt score of 5. The barium swallow test showed a giant epiphrenic diverticulum localized mostly in the right thorax (Fig. 10).

The upper endoscopy confirmed the presence of a diverticulum, with a large opening and no endoscopic features of malignancy (Fig. 11). The manometry was performed by using a guide wire which was inserted into the stomach using

the endoscope. It detected a non-specific motor disorder characterized by impaired relaxation of LES(78%) and inefficient esophageal body motility despite normal pressure of LES. A left thoracotomy approach through the 8th intercostal posterolateral space was the method of choice for diverticulectomy (Fig. 12). A continuous manual double layer suture was done after resection of the pouch (Fig. 13). An esocardiomyotomy completed the intervention. A tear in the right pleura occurred during the dissection of diverticulum.

A chest radiography done in the first day post surgery showed a pleural effusion in the

Figure 10. Giant epiphrenic diverticulum (barium swallow)

Figure 11. Endoscopic aspect of the epiphrenic diverticulum

Figure 12. Intraoperative aspect of the giant epiphrenic diverticulum

Figure 13. Intraoperative aspect of the manual suture line

lower half of the right thorax (*Fig. 14*). 1400ml of slightly turbid fluid was evacuated through thoracentesis. The fluid analysis showed negative cultures, high level LDH (662u/l), high level albumin (1,65g/dl). The blood tests showed only minor neutrophilic leukocytosis. These results were consistent with chylothorax. A barium swallow study performed in the 7th day post surgery showed no leakage (*Fig.15*), but it showed a recurrent pleural effusion in the lower third of the right thorax (*Fig. 16*). A pleural drainage evacuated 2000ml chyle-type pleural fluid. The fluid analysis showed again negative cultures, high LDH (391.02 u/l) and high triglycerides (297 mg/dl). The diagnosis was of a recurrent chylothorax. The patient had parenteral nutrition and subcutaneous Sandostatin for the next 6 days.

He had a good recovery and the oral intake was reinstalled after 12 days post-surgery. The pleural drainage was discontinued after 7 days. The patient was discharged on the 26th day post-surgery. A follow-up computed tomography done two and a half month later showed a posterior and basal accumulation in the right thorax, without suture leak (*Fig. 17*). The patient was hospitalized a second time and he underwent right mini-thoracotomy through which a jelly-like like semi-solid mass was evacuated and tested: cultures were negative, but the cholesterol level was high (453 mg/dl) (*Fig. 18*). This indicated a chylothorax. The pleural drain was taken off 12th days later and the patient was discharge following day with no radiological sign of recurrence.

Discussions

Diverticulectomy for thoracic diverticula is associated with a mortality rate of 0 to 10 %, and a morbidity rate ranging from 0 to 33 % (26).

Leakage from the Suture Line

Leakage from the suture line is the most common complication. In 5.3-37.5% of cases it can have severe consequences: empyema, abscess and sepsis (27).

In our case series, life-threatening leaks

Figure 14. Chest radiography in the first day post-surgery

Figure 15. Postoperative contrast study confirms no leak and no residual diverticulum

Figure 16. Chest radiography in the 7th day post surgery

Figure 17. Computed tomography aspect of chest accumulation

Figure 18. Intraoperative aspect of the chest accumulation

happened in 30% of the patients, all after stapled suture technique. We noted that major leaks happen in 2 out of 3 patients (66.6%) who had staple sutures without manual oversewing, but in only 1 out of 5 patients (20%) who had staple sutures with reinforced manual oversewing. Moreover, both 2 patients who had staple sutures with 2 cartridges developed major leaks.

Regarding additional myotomy, we did not find a significant difference in the leakage rate between patients who underwent myotomy (28.5% leakage rate) and those without myotomy (33.3% leakage rate).

In contrast, in a series of 21 patients from Mayo Clinic, patients treated for epiphrenic diverticula with diverticulectomy alone suffered from higher leakage and recurrence rates (24% and 19%, respectively) than those who underwent diverticulectomy with myotomy (0% for both leakage and recurrence rates) (28).

The rationale for myotomy is to reduce endoluminal esophageal pressure, but it may be less important in cases where hypotonic motility patterns of the esophageal body and LES are detected by manometry (29). Zaninotto et al consider that myotomy can be avoided in patients with a normal peristalsis in the esophageal body and a normally relaxing lower esophageal sphincter, with no signs of esophageal obstruction (30).

This may explain the fact that in our study

the leakage of the mid-esophageal diverticula was not related to the performance of myotomy, but rather to the type of suture used.

In the group of patients with epiphrenic diverticula, myotomy was performed in 5 cases only one patient did not have myotomy, but he did not develop fistula. For this one, the manometry findings revealed inefficient esophageal body motility, but a weak LES (6 mmHg) so there was no high pressure zone. A minor leakage was noticed on radiological contrast control only in one patient with a manual suture. The patient recovered in about 2 weeks only by restriction of oral intake (nil per os).

The use of 2 or more staples to completely transect the neck of the diverticulum may be one of the main risk factors for leakage, being more common in cases of diverticula with huge necks (30).

Therefore a thoracotomy approach should be considered when planning to treat large diverticula so a TA stapler can be used, because it has a longer jaw and thus enables the use of just one cartridge to suture the diverticulum neck, avoiding extra weak points being created where suture lines cross over (29,31).

In our case series, the abdominal approach was used for only one patient with epiphrenic diverticulum. It allowed a good view for resection of the pouch and an easy way for the treatment of the underlying motility disorder.

The inconvenience of using the transabdominal route can be the distance of the diverticulum from the hiatus, the diverticulum's size, or severe inflammation and adhesions between the wall of the diverticulum and the mediastinal pleura, with the likelihood of pleural tearing during dissection (29).

Even if it takes a long learning curve, minimally invasive approach seems to reduce the incidence rate of acute postoperative complications.

Currently, there are no studies comparing the outcomes of laparoscopic and thoracoscopic approaches, and given the limited number of cases and the variety of surgical techniques and measured outcomes, it is difficult to make a quantitative conclusion about the superiority of one procedure over the other (26).

The largest study of minimally invasive operations published to date encompassed 20 patients. They reported an overall complication rate of 45% including four leakages and one intraoperative perforation (31). Rates for postoperative leakages vary between 0% and 33% (32). Within a total of 10 different retrospective studies covering 92 patients there have been 12 leakages (13.0%) (33).

In our clinic, the management for 3 the patients with major leakage was pleural drainage. In 2 cases the empyema was on the opposite side (right) than the initial surgical approach and in one case the empyema was on the same side and it happen after the intraoperative drainage was removed and solid food intake reinstated. In this last case, an endoscopically esophageal stent was the curative solution. The other two patients needed thoracotomy.

Recently, new treatment methods of esophagopleural fistulas can be used, such as endovac therapy or vascular plug, coils and surgical glue, thus avoiding extensive surgery or covered stent insertion (34).

The Chylothorax Post-Diverticulectomy

Chylotorax is a rare complication after thoracic surgery, occurring in 0.5% to 2% after esophagectomy (35,36) and 1.4% to 2.3% after

lung resection (37,38). Even rare, chylothorax can be a difficult complication leading to immunologic compromise, pneumonias and death in up to 30% of patients (39-42).

Currently, there is no consensus on the optimal management of chylothorax. Conservative therapy with nil per os, total parenteral nutrition, and pleural drainage has demonstrated to be efficient in up to 90% in some studies, but this takes an average of 14 days (38). Surgical duct ligation can be successful in 90% of postoperative cases (43).

Some have advocated the use of octreotide to decrease splanchnic blood flow in order to lower the triglyceride content of chyle and subsequently aid in sealing leaks (44, 45).

Thoracic duct lymphangiography and embolization is a novel, less invasive and potentially equally efficacious treatment method (44,46,47).

Conclusions

Our case series has the limitation of a small number of patients, but it is comparable with other studies, given the rarity of surgical treatment for esophageal diverticula. So, we can state some reliable conclusions about this surgical treatment.

Thoracic diverticula represent a benign pathology, but can have „malignant” complications. A thorough preoperative clinical, imagistic and functional work-up is mandatory for understanding the pathophysiologic mechanisms leading to the development of diverticula and for choosing the appropriate surgical technique in order to minimize the postoperative complications.

We found that using multiple cartridges for stapling suture increases the risk of leakage, hence the need to properly dissect the neck of diverticulum in order to use only one cartridge of appropriate length and depth.

Also, we found that performing reinforced suture over the stapling line diminishes the risk of leakage.

Abdominal approach of epiphrenic diverticula is a less invasive way than left thoracotomy, with a good view for pouch resection and a better way

for the treatment of underlying motility disorder.

Due to the rarity of the disease, esophageal diverticula must be treated in referral centers since even in experienced hands the index of complications is high.

Conflicts of Interest

None.

References

- Soares R, Herbella FA, Prachand VN, Ferguson MK, Patti MG. Epiphrenic diverticulum of the esophagus. From pathophysiology to treatment. *J Gastrointest Surg*. 2010;14(12):2009–15.
- Fernando HC, Luketich JD, Samphire J, Alvelo-Rivera M, Christie NA, Buenaventura PO, et al. Minimally invasive operation for esophageal diverticula. *Ann Thorac Surg*. 2005; 80(6):2076–80.
- Nehra D, Lord RV, DeMeester TR, Theisen J, Peters JH, Crookes PF, et al. Physiologic basis for the treatment of epiphrenic diverticulum. *Ann Surg*. 2002; 235(3):346–54.
- Melman L, Quinlan J, Robertson B, Brunt LM, Halpin VJ, Eagon JC, et al. Esophageal manometric characteristics and outcomes for laparoscopic esophageal diverticulectomy, myotomy, and partial fundoplication for epiphrenic diverticula. *Surg Endosc*. 2009;23(6):1337–41. doi: 10.1007/s00464-008-0165-9. Epub 2008 Sep 24.
- Tedesco P, Fisichella PM, Way LW, Patti MG. Cause and treatment of epiphrenic diverticula. *Am J Surg*. 2005;190(6):891–4.
- Hirano Y, Takeuchi H, Oyama T, Saikawa Y, Niihara M, Sako H, et al. Minimally invasive surgery for esophageal epiphrenic diverticulum: the results of 133 patients in 25 published series and our experience. *Surg Today*. 2013;43(1):1–7. doi: 10.1007/s00595-012-0386-3. Epub 2012 Oct 21.
- Csendes P, Csendes A, Cortes C, Burgos AM. Evolutionary radiological changes of the esophagus in patients with achalasia who did not receive treatment. *Surg Today*. 2007;37(3):183–6. Epub 2007 Mar 9.
- D'Journo XB, Ferraro P, Martin J, Chen LQ, Duranceau A. Lower esophageal sphincter dysfunction is part of the functional abnormality in epiphrenic diverticulum. *Br J Surg*. 2009;96(8):892–900. doi: 10.1002/bjs.6652.
- Rosati R, Fumagalli U, Elmore U, de Pascale S, Massaron S, Peracchia A. Long-term results of minimally invasive surgery for symptomatic epiphrenic diverticulum. *Am J Surg*. 2011;201(1):132–5. doi: 10.1016/j.amjsurg.2010.03.016.
- Uskudar O, Dagli U, Asil M, Yol S, Saşmaz N. Epiphrenic diverticulum with abnormal manometry: a case report. *Turk J Gastroenterol*. 2004; 15(2):108–11.
- Benacci JC, Deschamps C, Trastek VF, Allen MS, Daly RC, Pairolero PC. Epiphrenic diverticulum: results of surgical treatment. *Ann Thorac Surg*. 1993; 55(5):1109–13; discussion 1114.
- Fisichella PM1, Jalilvand A, Dobrowolsky A. Achalasia and epiphrenic diverticulum. *World J Surg*. 2015;39(7):1614–9. doi: 10.1007/s00268-015-2950-7.
- Galea JL1, Manchè A, Goiti JJ. An unusual case of supraventricular arrhythmia. *Eur J Cardiothorac Surg*. 1995;9(4):221–2.
- Constantinoiu S, Constantin A, Achim F. Diverticuli esofagieni. Diagnostic si tratament. In: Constantinoiu S(coord), Cordos I, Ciuce C, Scripcaru V. editors. *Tratat de patologie si chirurgie esofagiana*. Bucuresti: Editura Academiei Romane; 2017. p. 349–381.
- Rossetti G, Fei L, del Genio G, Maffettone V, Bruscianno L, Tolone S, et al. Epiphrenic diverticula mini-invasive surgery: a challenge for expert surgeons-personal experience and review of the literature. *Scand J Surg*. 2013;102(2):129–35.
- Benacci JC, Deschamps C, Trastek VF, Allen MS, Daly RC, Pairolero PC. Epiphrenic diverticulum: results of surgical treatment. *Ann Thorac Surg*. 1993;55(5):1109–13; discussion 1114.
- Fékete F, Vonns C. Surgical management of esophageal thoracic diverticula. *Hepatogastroenterology*. 1992;39(2):97–9.
- Bowman TA, Sadowitz BD, Ross SB, Boland A, Luberic K, Rosemurgy AS. Heller myotomy with esophageal diverticulectomy: an operation in need of improvement. *Surg Endosc*. 2016;30(8):3279–88. doi: 10.1007/s00464-015-4655-2. Epub 2015 Dec 10.
- Gonzalez-Calatayud M, Targarona EM, Balague C, Rodriguez-Luppi C, Martin AB, Trias M. Minimally invasive therapy for epiphrenic diverticula: Systematic review of literature and report of six cases. *J Minim Access Surg*. 2014;10(4):169–74. doi: 10.4103/0972-9941.141498.
- Hauge T, Johnson E, Sandstad O, Johannessen HO, Trondsen E. Surgical treatment of epiphrenic oesophageal diverticulum. *Tidsskr Nor Laegeforen*. 2014;134(10):1047–50. English, Norwegian.
- Fernando HC, Luketich JD, Samphire J, Alvelo-Rivera M, Christie NA, Buenaventura PO, et al. Minimally invasive operation for esophageal diverticula. *Ann Thorac Surg*. 2005;80(6):2076–80.
- Del Genio A, Rossetti G, Maffettone V, Renzi A, Bruscianno L, Limongelli P, et al. Laparoscopic approach in the treatment of epiphrenic diverticula: long-term results. *Surg Endosc*. 2004;18(5):741–5.
- Rice TW, Goldblum JR, Yearsley MM, Shay SS, Reznik SI, Murthy SC, et al. Myenteric plexus abnormalities associated with epiphrenic diverticula. *Eur J Cardiothorac Surg*. 2009;35(1):22–7; discussion 27. doi: 10.1016/j.ejcts.2008.09.025. Epub 2008 Nov 8.
- Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg*. 2004;240(2):205–13.
- Herbella FA1, Patti MG. Achalasia and Epiphrenic Diverticulum. *World J Surg*. 2015;39(7):1620–4. doi: 10.1007/s00268-015-2949-0.
- Williams T, Ferguson MK. Thoracoscopic Treatment of Epiphrenic Diverticula Associated with Achalasia in P.M. Fisichella et al. Achalasia. 2016. p.87–91.
- Zaninotto G, Portale G, Costantini M, Merigliano S, Guirrolli E, Rizzetto C, et al. Long-term outcome of operated and unoperated epiphrenic diverticula. *J Gastrointest Surg*. 2008;12(9):1485–90. doi: 10.1007/s11605-008-0570-3. Epub 2008 Jul 12.
- Allen TH, Clagett OT. Changing concepts in the surgical management of pulsion diverticula of the lower esophagus. *J Thorac Cardiovasc Surg*. 1965;50(4):455–62.
- Zaninotto G, Portale G, Costantini M, Zanatta L, Salvador R, Ruol A. Therapeutic strategies for epiphrenic diverticula: systematic review. *World J Surg*. 2011;35(7):1447–53. doi: 10.1007/s00268-011-1065-z.
- Zaninotto G, Parise P, Salvador R, Costantini M, Zanatta L, Rella A, et al. Laparoscopic repair of epiphrenic diverticulum. *Semin Thorac Cardiovasc Surg*. 2012;24(3):218–22. doi: 10.1053/j.semtcv.2012.10.009.
- Fernando HC, Luketich JD, Samphire J, Alvelo-Rivera M, Christie NA, Buenaventura PO, et al. Minimallyinvasive operation for esophageal diverticula. *Ann Thorac Surg*. 2005;80(6):2076–80.
- Palanivelu C, Rangarajan M, Maheshkumaar GS, Senthilkumar R. Minimally invasive surgery combined with peroperative endoscopy for symptomatic middle and lower esophageal diverticula – a single institute's experience. *Surg laparosc Endosc Percutan tech* 2007; 18:133– 138.
- Kilic A, Schubert MJ, Awais o, Luketich JS, Landreneau RJ. Surgical management of epiphrenic diverticula in the minimally invasive era. *JSLs*. 2009;13(2):160–4.
- Koo JH, Park KB, Choo SW, Kim K, Do YS. Embolization of post-surgical esophagopleural fistula with Amplatzer vascular plug,

- coils, and Histoacryl glue. *J Vasc Interv Radiol.* 2010;(12):1905-10.
35. Sarkaria IS, Finley DJ, Bains MS, Adusumilli PS, Rizk NP, Huang J, Downey RJ, Rusch VW, Jones DR. Chylothorax and recurrent laryngeal nerve injury associated with robotic video-assisted mediastinal lymph node dissection. *Innovations (Phila).* 2015; 10(3):170-3. doi: 10.1097/IMI.0000000000000160.
36. Cerfolio RJ, Allen MS, Deschamps C, Trastek VF, Pairolero PC. Postoperative chylothorax. *J Thorac Cardiovasc Surg.* 1996; 112(5):1361-5; discussion 1365-6.
37. Bryant AS, Minnich DJ, Wei B, Cerfolio RJ. The incidence and management of postoperative chylothorax after pulmonary resection and thoracic mediastinal lymph node dissection. *Ann Thorac Surg.* 2014;98(1):232-5; discussion 235-7. doi: 10.1016/j.athorac-surg.2014.03.003. Epub 2014 May 6.
38. Takuwa T, Yoshida J, Ono S, Hishida T, Nishimura M, Aokage K, et al. Low-fat diet management strategy for chylothorax after pulmonary resection and lymph node dissection for primary lung cancer. *J Thorac Cardiovasc Surg.* 2013;146(3):571-4. doi: 10.1016/j.jtcvs.2013.04.015. Epub 2013 Jun 12.
39. Paes M, Powell H. Chylothorax: an update. *Br J Hosp Med.* 1994; 51(9):482-90.
40. Lagarde SM, Omloo JM, de Jong K, Busch OR, Obertop H, van Lanschot JJ. Incidence and management of chyle leakage after esophagectomy. *Ann Thorac Surg.* 2005; 80(2):449-54.
41. Shah RD, Luketich JD, Schuchert MJ, Christie NA, Pennathur A, Landreneau RJ, et al. Postesophagectomy chylothorax: incidence, risk factors, and outcomes. *Ann Thorac Surg.* 2012; 93(3):897-903; discussion 903-4. doi: 10.1016/j.athoracsur.2011.10.060. Epub 2012 Jan 15.
42. Pillay TG, Singh B. A review of traumatic chylothorax. *Injury.* 2016;47(3):545-50. doi: 10.1016/j.injury.2015.12.015. Epub 2015 Dec 23.
43. Martucci N, Tracey M, Rocco G. Postoperative chylothorax. *Thorac Surg Clin.* 2015;25(4):523-8. doi: 10.1016/j.thorsurg.2015.07.014. Epub 2015 Sep 8.
44. Markham KM, Glover JL, Welsh RJ, Lucas RJ, Bendick PJ. Octreotide in the treatment of thoracic duct injuries. *Am Surg.* 2000;66(12):1165-7.
45. Al-Zubairy SA, Al-Jazairi AS. Octreotide as a therapeutic option for management of chylothorax. *Ann Pharmacother.* 2003;37(5):679-82.
46. Schild HH, Naehle CP, Wilhelm KE, Kuhl CK, Thomas D, Meyer C, et al. Lymphatic interventions for treatment of chylothorax. *Rofo.* 2015;187(7):584-8. doi: 10.1055/s-0034-1399438. Epub 2015 Jun 19.
47. Marthaller KJ, Johnson SP, Pride RM, Ratzer ER, Hollis HW. Percutaneous embolization of thoracic duct injury post-esophagectomy should be considered initial treatment for chylothorax before proceeding with open re-exploration. *Am J Surg.* 2015;209(2):235-9. doi: 10.1016/j.amjsurg.2014.05.031. Epub 2014 Aug 12.