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DIAPHRAGMATIC INJURIES – THERAPY AND DIAGNOSIS

Abstract: Traumatic diaphragmatic injury (DI) is a unique clinical entity that is usually occult and can easily be missed. Their delayed presentation can be due to the delayed rupture of the diaphragm or delayed detection of diaphragmatic rupture, making the accurate diagnosis of DI challenging to the trauma surgeons. Diaphragmatic injury may result within closed, blunt thoracoabdominal trauma or acute, penetrating thoracic, abdominal and thoracoabdominal trauma. Signs and symptoms of diaphragm injury are not specific and often remain undetected due to serious associated injuries, which distract surgeons' attention, complicating the diagnosis. Since it is not that frequent, little attention has been paid. For all above-mentioned, preoperative diagnosis is established with less than 1/2 of patients, with 44% on autopsy or intraoperatively accidentally, and in about 14% it was delayed even for several years. Many authors have tried, and Grimes has succeeded in introducing three phases of diaphragmatic injury describing acceptable system of detecting this organ injury: Acute phase – the diaphragmatic rupture, usually missed, because symptoms of associated injuries of organs prevail; Latent phase – with viscera partially protruding through diaphragmatic opening. It is characterised by mild symptoms of discomfort and uneasiness in hypochondrium and hemithorax of the injured side. Signs of dyspnoea and orthopnoea are moderate, and there might be a radiograph after chest X-ray;

Obstructive phase – where the abdominal organs penetrate into the thorax and symptoms resulting from an obstruction or ischemia occur. It is usually characterised by Borchardt's Triad (strong epigastric pain, vomiting and the inability to pass a nasogastric tube), with X-ray indicating mediastinum shift, with obvious penetration of abdominal organs into the pleural space. Any diaphragmatic injury requires operational treatment, since this organ's injuries cannot spontaneously heal. Even injuries of smaller dimensions must be sutured to prevent outcome such as diaphragmatic hernia and its consequences.

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Introduction

In surgical history, the diaphragmatic injury was early and properly detected, however it has sustained as delayed diagnosis injury with high mortality.

Information about diaphragm injury could be found as early as XVI century (Sennertus and Ambroise Paré). The earliest description of diaphragmatic injury and protrusion of abdominal viscera through diaphragmatic tear was given by Sennertus. He detected the stomach which had protruded into the left hemithorax, when conducting an autopsy of the male who died 7 months after the injury – chest wall stab wound.

In 1575, Ambroise Paré described clinical manifestations of traumatic rupture of diaphragm, and in 1579 he had set up a diagnosis and clinically described strangulated hernia with lethal outcome.

Diaphragmatic injury may result within closed, blunt thoracoabdominal trauma or acute, penetrating thoracic, abdominal and thoracoabdominal trauma.

Diagnosis

Signs and symptoms of diaphragm injury are not specific and often remain undetected due to serious associated injuries, which distract surgeons' attention, complicating the diagnosis. Since it is not that frequent, little attention has been paid [1]. For all above-mentioned, preoperative diagnosis is established with less than 1/2 of patients, with 44% on autopsy or intraoperatively accidentally, and in about 14% it was delayed even for several years.

Many authors have tried, and Grimes has succeeded in introducing three phases of diaphragmatic injury describing acceptable system of detecting this organ injury:

- *Acute phase* – the diaphragmatic rupture, usually missed, because symptoms of associated injuries of organs prevail;
- *Latent phase* – with viscera partially protruding through diaphragmatic opening. It is characterised by mild symptoms of discomfort and uneasiness in hypochondrium and hemithorax of the injured side. Signs of dyspnoea and orthopnoea are moderate, and there might be a radiograph after chest X-ray;
- *Obstructive phase* – where the abdominal organs penetrate into the thorax and symptoms resulting from an obstruction or ischemia occur. It is usually characterised by Borchartd's Triad (strong epigastric pain, vomiting and the inability to pass a nasogastric tube), with X-ray indicating mediastinum shift, with obvious penetration of abdominal organs into the pleural space.

In establishing diagnosis of acute diaphragmatic injury standard diagnostic methods are used:

1. Medical history (*anamnesis morbi*)

Anamnestic or heteroanamnestic data obtained on the severity of accident, as well as the mechanism of injury, will engage clinician's attention to take into consideration this rare injury. The injured patient usually complains of the generalised abdominal pain, and that symptom is not very helpful with the multiple trauma patients. Patient may experience chest pain radiating to left shoulder and to rib cage, dyspnoea, and nausea with or without vomiting. When the injury is associated with other extra-abdominal and intraabdominal injuries, these discomforts can be combined with other and are not particular for diaphragmatic injury.

2. Physical examination

Diagnosing hemodynamically stable patients with injuries caused by *blunt trauma* is carried out by one type of protocol, while the hemodynamically non-stable patients with *penetrating wounds* require urgent surgery after the shortest possible diagnostic procedure.

Inspection – The location of the stab wound of the thorax and abdomen should make us think and inspect if the diaphragm is among the injured organs. Entrance and exit wounds with shooting injuries, as well as imaginary missile trajectory, indicate the possibility of diaphragmatic injury. Front thorax injuries, below the bimammary line, should cause suspicion of this injury. All open abdominal wounds should be explored, and thorough examination of both hemidiaphragms is necessary for wounds located in upper part.

With blunt injuries, the patients could have pulmonary and abdominal contusions. In case of an imprint of the safety belt improperly placed over the belly, the incoming power of the force against the abdomen should be questioned. If there are pelvic fractures, multiple extremities fractures and multiple ribs fracture, one should be highly suspicious of diaphragmatic trauma. Signs of lower thorax injuries, bruises, paradoxical motion, modifications in thorax shape, delay of breath sounds on one side of the chest, dyspnoea, orthopnoea, also boat-shaped abdomen (Gibson's sign) should cause suspicion of the diaphragmatic injury.

Palpation – Palpating the thorax on the side of the injury a light asymmetry may be noted, the ribs fracture and subcutaneous emphysema could be also felt. In palpating abdomen the abdominal guarding might be present. Hedrier sign may be also present: when applying pressure in anteroposterior and laterolateral direction against chest if there is pain in lower chest, without obvious ribs fracture it is a symptom of diaphragmatic lesion.

Percussion – Percussing over lower parts of thorax the dullness of the right hemithorax could be found, due to elevation of the liver dullness zone when this organ herniates or due to signs of pleural effusion. Tympanic sound in left hemithorax could be a consequence of a herniation of a hollow organ.

Auscultation – Quiet breath sounds are heard when auscultating the bases of the lung or there is absence of breath sounds due to hemothorax or pneumothorax. Quite often breath sound is normal. Gastric or bowel peristaltic could be heard in left hemithorax, which is a definitive sign of organs herniating to the chest, yet not a solid sign of diaphragmatic injury. The injury should be confirmed or rejected by additional diagnostic methods. Pericardial herniation could be manifested as a cardiac tamponade.

Any closed thoracoabdominal injury is followed by: *respiratory syndrome; shock syndrome; peritoneal syndrome and bleeding syndrome.*

All syndromes could be present with diaphragmatic injuries with associated thoracoabdominal injuries.

In adjacent ribs fractures or fractures in two places, the phenomenon of flail chest occurs, which causes paradoxical breathing. It will cause weak ventilation, and then hypoxia, hypercapnia and atelectasis. This all leads to acute *respiratory* insufficiency. In case of a diaphragmatic injury the intrapleural pressure will increase, and clinical presentation is even more distinctive if organs have herniated to left hemithorax. It is most usually omentum which pulls the stomach, but it could be even small intestine or colon. Depending of the size and location of diaphragmatic rupture we have following situations:

- Greater curvature enters into the thoracic cavity first and stays at the highest position, when axial volvulus develops;
- If diaphragm rupture is wide, the obstruction will not occur although the stomach is rotated even for 180 degrees. The efferent loop is obstructed, while the afferent loop is functional. Accumulation of air, fluid or food will cause the secondary gastric dilatation. Sudden increase of volume of protruded organs will aggravate respiratory insufficiency since it causes lungs collapse, mediastinum shift to the opposite side (differential diagnosis tension pneumothorax). After the injury, diaphragm loses its role of a respiratory muscle, and phrenic nerve could have been also irritated (hiccup reflex, pain under left shoulder blade).
- If diaphragmatic rupture is small, there is an obstruction of afferent and efferent loop with compromised vascularization, creating necrosis and possible organs perforation.

Circulation and vascularisation are often disrupted due to changes in intrathoracic pressure, which can cause *shock*, and its degree is not measured by the severity of pathoanatomical injuries of intrathoracic organs. Shock comes as a consequence of

cardiovascular system weakness, compression and shift of mediastinum to the opposite side, as well as extreme stimulation of vegetative nerve on serous membranes of open body cavities, as well as shifting and stretching of organs covered with serosa.

Diaphragmatic injury will not cause severe *bleeding*, but associated with parenchymatous organ injuries (liver and spleen), it will indicate the presentation of progressive hypovolemia, with abdominal distension, but also with pleural fluid excessively building-up. Some authors believe that hemothorax is rare with closed diaphragmatic injuries, if lung artery, mammary artery or intercostal artery have not been injured. These authors believe that hemothorax could only be found only the non-injured side of diaphragm, while on the injured diaphragm side, through the diaphragmatic tear, blood fills the visceral cavity excessively, and retains minimally in pleura.

Peritoneal signs depend on the degree of intra-abdominal organ injury. It can be a contusion, laceration, and mesentery and bowels haematoma.

If gastrointestinal viscera have protruded to the chest cavity, bowels passage disruption might occur from paresis to ileus. With the rupture of some hollow organ, the *peritonitis* will occur.

3. Nasogastric suction

A mandatory diagnostic, at the same time therapeutic procedure with polytrauma patients is to administer nasogastric suction right after the admission. It enables preparation for endotracheal anaesthesia, eliminating and controlling the appearance of stomach content, enabling decompression of chest in the event of prolapsed stomach to the chest cavity, preventing the aspiration of stomach content to the respiratory tract, at the same time enabling the diaphragmatic rupture diagnosis.

In the event of gastric volvulus, it might not be possible to place the tube. With hemodynamically stable patients suspected of gastrothorax, the tube is visible in the chest cavity with X-ray.

Additional diagnostic might be to inject contrast to stomach through the tube, when the stomach is visualised above diaphragm, and if the stomach is incarcerated through the diaphragmatic hernia, the contrast is delayed or disabled.

4. Peritoneal lavage

For the last 50 years this potentially might be the best diagnostic method. Although precisely accurate in diagnosing the presence of bleeding, it comes with negative sides too. Peritoneal lavage is not very helpful for the patients with retroperitoneal trauma diagnosis since this region is separated by posterior perineum from peritoneal cavity. Peritoneal lavage could not give precise diagnosis to isolated diaphragmatic injuries, due to absence of excessive bleeding from lesion.

This diagnosis gives falsely negative result with 14-36% patients with blunt, and with 12-40% patients with penetrating diaphragmatic trauma (the book). This diagnostic method is often quite helpful with patients who have chest tube, and the lavage fluid appears in intercostal drain. It witnesses the communication between peritoneal and pleural cavity and confirms the presence of injury. It is a definitive method of choice with hemodynamically non-stable patients, for the quickest orientation if there is hemoperitoneum or not. It is relevant for quick decision on urgent operative treatment.

5. Native X-ray examination

Standard diagnostic method in both acute and latent phase of diaphragmatic injury is chest and abdomen radiography in upright position, and with polytrauma patients in supine position, while lying.



Figure 1. *Diaphragmatic injury X-ray*

Despite technical limitations of chest X-ray, since portable apparatus must be used with patients in supine position, and limited cooperation from polytrauma patients, this is again a very successful method in detection of the rupture and the acute injury [2]. Despite the high precision of this diagnosis, the percentage of correct diagnosis of initial X-ray is not large, and in the reported cases the range is 27–60% with left

side injuries, yet only 17 % for right side injuries. Even liver herniation is missed. Differential diagnosis to be taken into consideration includes: atelectasis, pleural effusion and lungs contusion.

Percentage of predicted diaphragmatic ruptures with X-ray is about 12–66%, with potential risk of late herniation of organs through the defect.

It is important for the patients to get repeated radiographs while monitoring the clinical presentation along with findings of physical exams. Careful interpretation of findings is also important along with X-ray imaging.

The presence of this injury is highly suspected if the following signs occur: absence of diaphragm contour (unclear outline and irregularity of diaphragmatic shadow); shift of mediastinum, heart and trachea to the opposite side; image of abnormal shadows in lower chest field; visceral herniation (presence of stomach and bowels in thorax); elevation of diaphragm; excessive pleural fluid; presence of hollow organ above the liver shadow, at the right; free air under diaphragm with the patients who had chest penetrating wound; coiled nasogastric tube above diaphragm or behind the heart shadow [3–4].

Other non-specific suspicious abnormalities are: adjacent ribs fracture (especially lower), hemothorax, pneumothorax, lungs contusion or extended mediastinum, phrenic nerve paralysis. These signs can also mask and conceal the injury. Positive pressure in artificial ventilation should be taken into consideration since it postpones the organs herniation even when the diaphragmatic defect is bigger.

Repeated X-ray monitoring, in case of gastric dilatation in left hemithorax, will indicate the findings progression with the atelectasis on the same side of the lungs and mediastinum shift to the opposite side. It is especially important to emphasise that profile-view (right and left) radiographs are better than PA-view radiographs, though in acute states of polytrauma patients these cannot be used. Radiological examination with suspicion of old wound can assist the diagnosis, since it can indicate the diaphragm rigidity or paradoxical motion (stomach above diaphragm).

Despite the fact that X-ray diagnostics is currently considered the best diagnostic method in acute injuries, it is far from perfect. The proof of this could be found in the studies with normal X-ray radiographs incidence of 36% with confirmed diaphragmatic injury with penetrating wound (Wise, the book). With associated blunt diaphragmatic injuries only 50% of X-ray radiographs suggested this injury, while 12% of findings did not indicate any pathology. Percentage of predicted diaphragmatic ruptures with X-ray is 12–66%, with potential risk of late herniation of organs through the defect.

6. Ultrasonography

With associated diaphragmatic injury, with signs of other abdominal organs injuries prevailing, the Echo will give us information on the presence of fluid in abdomen

and thorax, but will not give us information on small diaphragmatic injuries, especially without the presence of organs in the thorax. Obvious diaphragmatic injuries with organs prolapse into the thorax, could be view by ultrasonography. In any case, this is a non-invasive method of choice for diagnosing blunt thoracoabdominal injury [5].

7. Contrast radiography

Imaging that is rarely applied with acutely injured, and almost never with hemodynamically instable patients. It is significant as additional diagnostics means with positive suspicion of the injury and already existing herniation of the hollow organs.

Contrast stomach imaging (gastrography) can indicate herniation, volvulus, complete cardia obstruction if the afferent loop is obstructed, gastric retention if the efferent loop is obstructed and extravasation of the contrast if the gastric wall has been perforated. By passage of barium contrast (now usually Gastrografin), the intrathoracic position of stomach and bowels could be identified through gastrointestinalum. By introducing the nasogastric tube, when the stomach has been shifted to thorax, the cardia angulation occurs, so it would be difficult to place the tube to the stomach, yet if it would pass successfully, it would be visible in hemithorax. Small intestines prolapse is identified by the same method but with repeated imaging, and irigography is applied with obstruction of the colon with the suspicion of the prolapse to the chest cavity.

8. Computerised tomography

At the beginning of 90s, the introduction of helical CT and extension of its indications for use, has improved the diagnostic precision of polytrauma patients after blunt trauma.

Previous research indicated that sensitivity of conventional CT is 14–61% and specificity – accurateness 76–99% in diagnosing diaphragmatic rupture. Helical CT has demonstrated the sensitivity of 71% (78% for left side injuries, and 50% for right side), and specificity 100%. If viscera were dislocated along with collar sign, then sensitivity is 63%, and specificity is 100%. Helical CT with addition of image processing techniques is very useful in diagnosing acute closed diaphragmatic injury.

Due to increased incidence of associated closed injuries, hemodynamically stable patients suspected of diaphragmatic injury should be sent for CT in order to exclude or confirm intraabdominal organs injuries.

Signs of hemidiaphragm lesion include the following:

- Direct hemidiaphragm discontinuity. In 71–73%, diaphragm defect is often the most sensitive indication of rupture, which is visible with the conventio-

nal CT with 73% sensitivity and 90% specificity. However, to diagnose the diaphragm rupture one should rely on more than just CT scan,

- Sensitivity is 55%, and specificity is 100% with intrathoracic herniation of abdominal organs. Most usually colon and stomach protrude to the left, and liver to the right hemidiaphragm.
- “Collar sign”, a waist-like constriction of the hollow organs by the diaphragmatic tear, has 36% sensitivity with conventional CT (18), and 63% with helical. The collar sign can appear on the right side only if the liver has indented into the right hemithorax, but it is subtle and can be overlooked. This sign requires detailed analysis of the axial and sagittal and coronal multiplanar reformatted imaging.
- “Dependent viscera sign” is an additional sign observed in Bergin et al study with 90%. With patient lying in supine position for CT, the diaphragm will not be able to support prolapsed viscera, so they would fall posterior and move to the ribs. This sign is present if the upper one-third of the liver abuts the posterior ribs on the right side or if the stomach, spleen, or bowel abuts the posterior ribs on the left side. This sign is rarely isolated, but it indicates the confirmation of the diaphragmatic injury, on axial images, before the herniation could be even diagnosed (sagittal and coronal imaging).

CT advantages – previous studies indicate that accuracy of older CT is limited in diagnosing the diaphragmatic rupture. This limitation was, in part, related to the axial orientation of images paralleling the outline of the diaphragm, to respiratory motion around the diaphragm, and to the generally poor quality of coronal and sagittal reformation images.

Nowadays, helical CT enables smaller cross-sections, eliminating respiratory movability, while providing good quality of sagittal and coronal reformation images. It is therefore desirable for exploring diaphragm and improving the accuracy of CT in diagnosing diaphragmatic rupture.

Multisection CT imaging with increased speed and higher sagittal and longitudinal resolution could facilitate the diagnosis of the injury. Thinner cross section profiles give results even when the injury is on the surface.

Image reformation improves the quality and it can be even more successful with subtle visceral herniation, especially with right-sided injuries. In the study of Killen et al [6], in addition to this, it was demonstrated that the sensitivity for left-sided injuries is not increased if the image reformation is added. The sensitivity has increased from 16.7 to 50% for right hemidiaphragm.

Diaphragmatic ruptures are still rarely isolated; so the speed and quality of new CT generations results is relevant for the treatment of non-stable patients.

Disadvantages of CT – posterolateral defect that is detected by CT in about 6% of adults can mimic the diaphragmatic injury in asymptomatic adults. These defects

occur more often on the left side and represent congenital asymptomatic Bochdalek hernia. These defects are more often with women, older patients, as well as those with emphysema.

In addition to this, diaphragmatic eventration can mimic a rupture. Coronal and sagittal images sections are helpful to avoid false-positive diagnosis of diaphragmatic injury.

Motion artifacts can decrease the quality of images and mimic an injury, especially on the right side with pseudoherniation of the liver. False negative findings occur when the injury is associated with thoracic trauma, with effusion, particularly without visible small tears and in the absence of herniation of intraabdominal viscera.

At the end of the last century, the conventional CT has benefited from two major advances: the introduction of helical CT in the early 1990s and the introduction of multi-detector row CT in 1998. Despite these advantages and progress, the CT results stayed unchanged.

9. Pneumoperitoneum

With the patients who had developed pneumothorax, injecting 300–1000 cc of fresh air in the peritoneal cavity, followed by X-ray of the patient in vertical position could provide a diagnosis. This diagnostic method can be carried out only if the patient does not have a tube drainage. It is a light and quick procedure, but it could be followed by tension pneumothorax and pulmonary embolism. False-negative results occur if the defect is closed by the omentum or intraabdominal organs. Though this method is encouraged by many, more authors do not recommend it due to complications and “lack of accuracy”.

10. Scintigraphy

When X-ray radiography has indicated highly elevated diaphragm in latent or chronic stage, the scintigraphy of the liver could be carried out as the additional diagnostic. Only few cases have been published.

Definitely most precise methods are endoscopic methods, video-assisted thoracoscopy and laparotomy.

11. Thoracoscopy (V.A.T.S. – video-assisted thoracic surgery)

This relatively new method is believed to be very helpful in establishing diagnosis of diaphragmatic trauma. Thoracoscopy proved to be the most efficient if carried out

with the stable patients with penetrating trauma of lower ribs immediately within 24 hours from the moment of injury. After this time, the interpleural adhesions will develop which complicates the diagnosis and increases the number of “inadequate results” [7].

This method is done in operating room, patient is under anaesthesia while sterile paediatric proctoscope is administered via the drain, and the tube is being introduced through stabbing or shot wound. By this procedure entire lungs could be explored and entire pulmonary pleurae. The drain is replaced after the procedure. If the defect in diaphragm has been detected, the patient will undergo the laparotomy and have the abdomen examined.

12. Laparoscopy

Surgeons have dissenting opinions on the importance of this method in diagnosing the diaphragmatic injury. One claim it is exceptional, particularly in diagnosis, even in therapy of acute trauma and diaphragmatic injury, but also for treating diaphragmatic hernia, while others dispute its importance. Others (Adamthwaite, the book) say that application of laparoscopy on the patients within 24 hours from the moment of injury, and with all patients in latent phase, did not provide positive results for the diaphragmatic lesion (due to already formed adhesions). This is not an optimal therapy procedure for patients with acute associated abdominal injuries, so it is converted to medial laparotomy.

13. Magnetic resonance imaging

It is not applied with polytrauma patients, as well as for acute diaphragmatic injuries. It should be reserved for patients in latent phase, especially those with smaller liver herniation into right hemithorax [8]. This method overrides liver scintigraphy.

2.1. Surgical management

Any diaphragmatic injury requires operational treatment, since this organ's injuries cannot spontaneously heal. Even injuries of smaller dimensions must be sutured to prevent outcome such as diaphragmatic hernia and its consequences.

2.1.1. Acute phase

Injured patients treatment requires detailed examination, and all life-threatening injuries require urgent treatment.

Diaphragmatic injury is rarely isolated, priority must be to explore all associated injuries, and the part of mandatory diagnostic procedure is the estimation of the morphological and functional integrity of the diaphragm. Intrabdominal and life-threatening injuries must be treated first, followed by the closure of the diaphragmatic lesion. Rarely, in case of massive obstruction or herniation to the thorax, as well as tamponade or heart torsion, diaphragmatic rupture will get primary treatment, since it might cause disruption in cardiopulmonary functions. If this occurs, herniation is immediately treated, and the heart is restored to its normal anatomical position of diaphragmatic injury.

In deciding which operational procedure is the best as regards the diaphragmatic rupture, there is no real consent. Associated injuries often impose the type of operational procedure in treatment of diaphragm.

Thoracotomy and laparotomy were very useful during many years. Many experienced trauma surgeons prefer abdominal approach with the patients in the acute phase. Associated intraabdominal injuries are present with more than 85% patients. However, during thoracotomy these injuries cannot be explored properly and in detail.

With some authors (Waldschmidt) it is underlined that only 1 in 65 patients had to undergo thoracotomy after laparotomy was administered, while 7 out of 15 patients who had initially undergone thoracotomy had to be treated with laparotomy. Some authors believe that the only way to repair diaphragmatic injury is to perform midline incision and exploratory laparotomy. Following the diagnosis, the additional thoraco-phreno incision could be carried out or even thoracotomy.

Midline incision could be also extended to median sternotomy, if vena cava must be stabilised urgently, the access to the liver injury improved, and the mediastinum structures set under control. With right side diaphragmatic injury, especially posterolateral injuries with liver prolapse, in addition to laparotomy the right thoracotomy is also necessary, in order to repose the liver into the belly without consequences.

With the introduction of new minimally invasive technologies, laparoscopy and thoracoscopy, have been gradually but unquestionably entering all surgical disciplines, and trauma surgery as well. Thoracoscopic approach is relevant for diagnostic and therapy resolution of acute diaphragmatic injury, especially open injuries of lower parts of thorax. There can always be an easy conversion of thoracoscopy into classical thoracotomy. Laparoscopic approach, both diagnostically and therapeutically, received importance in resolving the acute diaphragmatic injury, but also diaphragmatic hernia [9]. Also, there can always be an easy conversion of laparoscopy into laparotomy.

The selection of incision is based on anatomical localisation of the injury and depends of current issues, but it also depends on the surgeon's experience.

Latent and obstructive phase

Both latent phase and developed chronic diaphragmatic hernia with obstruction, which could clinically happen at any time – within few months up to several years (when the initial injury is even forgotten), are operatively managed by thoracotomy due to presence of adhesions with intrathoracic structure. Some authors still give advantage to transabdominal approach, and if needed they will add thoracotomy. Third group of authors believes that thoracotomy and laparotomy are equally important, since there is no injury of intraabdominal viscera, meaning the bleeding.

If the edges of wound are devitalised, they are minimally debrided and refreshed.

Current defect closure can be carried out in several ways depending on the size of wound and surgeon's experience. Surgeons mostly use non-absorbable suture material [10]. Monofilament suture material might get advantage over multifilament suture material with patients who have contaminated content in their abdomen. Techniques of suture use are different. Some surgeons use single layer suture (with small penetrating wounds) or double layer suture, some continuous, and even single-return suture are used [11]. Some authors believe that simple interrupted suture is sufficient, even for bigger defects (Laws). Some surgeons use lock-stitch suture, the one used when managing fascial defects with umbilical hernia (Mayo). Mattress stitches are used for one edge, and simple sutures for the other edge. By tying tensely these sutures, free edge is used for placing second layer of sutures that can be simple interrupted or continuous. It is important to achieve hermetization with sutures so as to prevent discharge of any type of secretion from abdomen into thorax in postoperative period.

Skeletal-diaphragmatic disinsertion is managed by reinsertion for one or two intercostal spaces up above. Then sutures may be placed around the ribs or the mattress stitches are used to fix the intercostal musculature, by using Teflon plates.

Irrelevant of the time when the treatment is managed for the majority of cases the tear can be managed by the direct suture technique. Loss of tissue rarely poses a problem (only with explosive injuries with great damage and complete tissue crushing – *conquassatio*) for primary reconstruction. Synthetic material could be necessary in such cases. Some authors mention they use prosthetics for chronic, old injuries with large defects and established solid fibroses edges of diaphragm, which prevent the primary adaptation and defect closure. Those are usually Dacron® and PTFE nets.

Pleural space should be drained, except with laparoscopic or thoracoscopic procedures when the drain issue does not get consent from everyone [12]. Number of drains – one or two, depends on the surgeon's attitude, though there is very

few theoretical discussions on that matter. Subfrenium should be drained only if the gastrointestinal tract, liver or kidney injury were also involved.

2.2. Complications

Following the initial diagnostics and management, and definite surgical treatment, the injured patient with diaphragmatic rupture and severe thoracic or abdominal trauma is hospitalized in the emergency care unit for the purpose of compensation and monitoring of vital functions. The injured patient is under risk of various complications of pathophysiological disorders, mostly respiration and ventilation.

Pleuroperitoneal pressure gradient of these injuries has an adverse effect, since it affects the herniation of abdominal viscera, because there is aspiration of abdominal content, disturbed chest mobility and impact on cardiocirculatory function. Artificial ventilation excludes this impact, so the abdominal organs prolapse with these patients is manifested and revealed only when they are shifted to spontaneous breathing. With missed injuries, subsequent prolapses of interabdominal viscera are almost regular, and acute incarcerations are present in about 10% of cases. Volume of viscera prolapse depends on pressure differences between abdominal cavity and size of diaphragmatic defects. Later factors which should be included in favour of the extension of the tear are the respirator, laparotomy, strain, cough, increase of intra-abdominal pressure, negative pressure in chest cavity, gaining weight. Three years after trauma, the strangulation will occur in 70–90% cases. Strangulations are more frequent with smaller ruptures.

For the cases which did not include surgical procedure, the posttraumatic diaphragmatic hernia could be formed. These hernias are diagnosed several months after the injury, even 20 years after.

After intervention on the injured diaphragm the following complications occur:

- Early complications: pneumothorax, hemothorax, respiratory insufficiency due to diaphragm paralysis and other, aspirations, atelectasis, pneumonia, ARDS, acute renal insufficiency, fat or air embolism;
- Late complications: dehiscence of diaphragmatic suture (rarely described), wound infections, pleural empyema, subfrenic abscess, ileus, strangulation and/or stomach or colon perforation, recurrent bowel obstruction, urinary infection and stress ulcers' bleeding, uncontrolled or recurrent bleeding of liver or spleen, and complications of intercerebral trauma, as well as any other complications frequent with polytrauma patients;
- Evolving injury: diaphragmatic hernia that could be taken as a complication of the undetected acute injury or a part of its natural course.

According to the literature data, the lethality is about 15 to 30% and it is mostly related to severe associated injuries and their complications [13].

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