ACUTE TRACHEAL INJURY

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Abstract
The article presents the definition of the concept of various types of damage to the respiratory tract, the mechanisms of their development, the principles of first aid and the choice of surgical treatment tactics, taking into account the nature of the injury and its localization. The technique of surgical restoration of the integrity of the breathing tube, the features of anesthetic and endoscopic support are described. Only timely diagnosis, adequate surgical and anesthetic care can ensure a favorable outcome in the treatment of this contingent of seriously ill patients.

INTRODUCTION

Damage to the trachea refers to extremely dangerous injuries, when procrastination can have a fatal outcome. In case of a combined injury, respiratory recovery takes priority in the algorithm of assistance, even ahead of other dangerous manifestations, such as bleeding, perforation of other organs. The frequency of tracheal injuries with a closed chest injury remains small, but this damage is extremely dangerous [5,13,15]. Thus, Madden B. (2020) found that 42 patients (1.8%) had a tracheal rupture among the 2115 cases of closed chest injury that ended fatally [11]. Chu C. (2002) calls tracheal rupture the cause of death of 5 (1.4%), out of 350 deaths from a closed chest injury [5]. The trachea is damaged 2 times less often than large bronchi with a closed chest injury. Localization and frequency of airway ruptures are important for determining treatment tactics and emergency care [8,14].

According to the mechanism of occurrence, there are closed and open tracheal trauma. By localization, it is divided into damage to the cervical, thoracic parts, tracheal bifurcation. There are longitudinal and transverse damages, partial and complete. Multifocal trauma is isolated when the process is localized in several parts of the respiratory tract. The cervical part of the trachea appears to be less protected, where its damage occurs more often (Table 1).

Table 1.

Type and localization of tracheal and bronchial trauma (Welter S., 2021).

	Closed		Open		Total	
	abc	%	abc	%	abc	%
Cervical spine	65	28	161	77	226	51
Thoracic department	62	27	36	17	98	22
Bronchi	105	45	12	6	117	27
Total	232	100	209	100	441	100

However, an injury to the thoracic trachea is more dangerous and cupping it can be much more difficult. With a closed injury, damage to the main bronchi is much more common than with an open one. This is due to the protection of the bronchi in the depth of the chest from the penetrating damaging agent.

Open injury. With an open injury, damage occurs more often in the cervical trachea, because it is most accessible to the damaging agent. Isolated damage to the trachea in this case is quite rare. Usually the injury is of a combined and combined nature. The proximity to the trachea of large venous and arterial vessels, the esophagus causes simultaneous damage to these structures, which significantly aggravates the situation. Usually the injury is accompanied by blood loss. Asphyxia often occurs as a result of aspiration of blood into the respiratory tract.

When providing first aid, it is necessary to isolate the tracheobronchial tree from the source of bleeding, restore ventilation of the lungs. Bleeding is stopped according to the standard principles of vascular surgery. Unfortunately, there are serious shortcomings in providing emergency care to patients with open injuries of the cervical trachea. Usually the operation is limited to tracheostomy. As a rule, attempts are not made to restore the integrity of the respiratory tract with a primary suture. This leads to a loss of time, the development of an inflammatory process in this area. Under such conditions, reconstructive surgery is impossible. In the future, these patients are doomed to complex, often multi-stage reconstructive operations.

Closed injury. The mechanism of obtaining a closed tracheal injury can have many options. The main cause of tracheal ruptures is a transport injury. Most often, this occurs as a result of chest impact on the steering wheel of a car due to a car accident, neck impact on the back of the front seat, on the seat belt,

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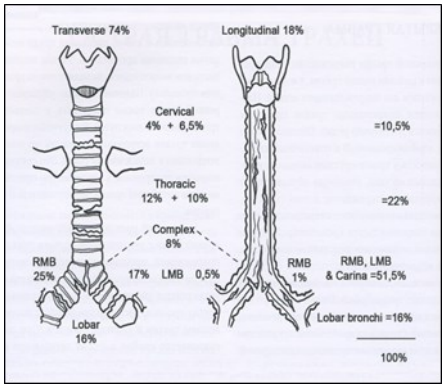
when hitting a pedestrian with the victim's car pressed against the wall, chest compression between two hard objects, hitting a motorcyclist or cyclist on a wire stretched at neck level. Falling from a height, strangulation with a rope can also lead to a closed injury of the respiratory tract. Iatrogenic damage to the trachea is common, but tends to steadily increase. This is due to the widespread introduction of tracheal intubation and endotracheal surgery methods into clinical practice.

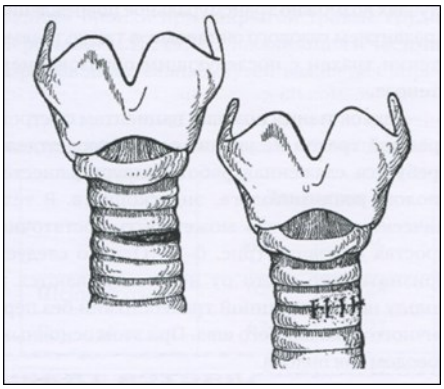
Every year, an increase in road traffic injuries with an increase in cases of severe injuries, industrial injuries with an increase in energy-intensive production cause an increase, along with injuries to other organs, in the number of victims with damage to the trachea and main bronchi. At the same time, an extremely high mortality rate remains immediately at the time of injury and at the stage of medical care. The spectrum of damage to the airways is quite variable (picture 1).



Picture 1. Scheme of localization and frequency of ruptures of the trachea and large bronchi.

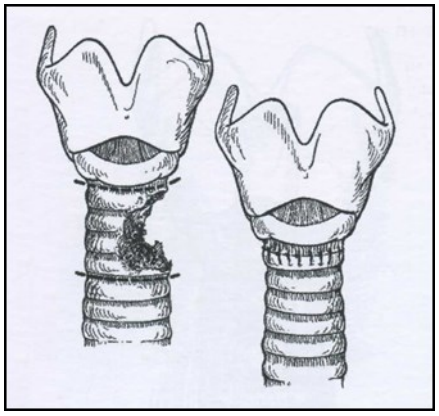
Separately, in a closed injury, iatrogenic damage to the trachea is isolated during intubation, tracheostomy or operations on adjacent organs. In these cases, transmural damage with the development of gas syndrome is possible, as well as trauma to the tracheal wall with the subsequent formation of stenosis. When providing assistance to patients with acute tracheal trauma at the level of its cervical department, the coordinated work of a surgeon, an anesthesiologist, an intensive care specialist, and an endoscopist is required. Technically, this can be a fairly simple operation (picture 2). However, it should be recognized that it is often abandoned in favor of an unreasonable tracheostomy without a primary tracheal suture. At the same time, the main reason for such a refusal is the severe and unstable general condition of the injured patient.

However, it should be recognized that such an injury is rare. More often it is necessary to perform more complex reconstructive operations that require appropriate professional training in reconstructive tracheal



Picture 2. Diagram of the rupture of the trachea and the primary tracheal suture.

surgery from the operating team. In these cases, the operation of choice may be resection of the injured tracheal segment with anastomosis (picture 3).



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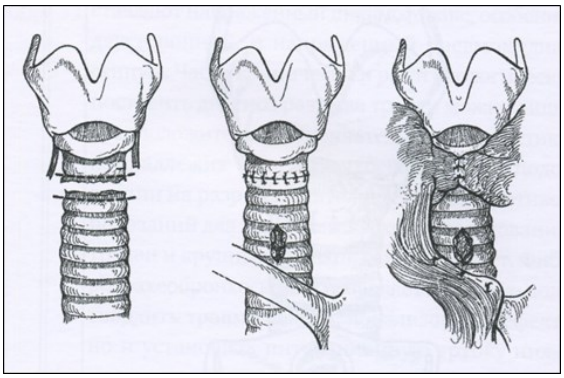

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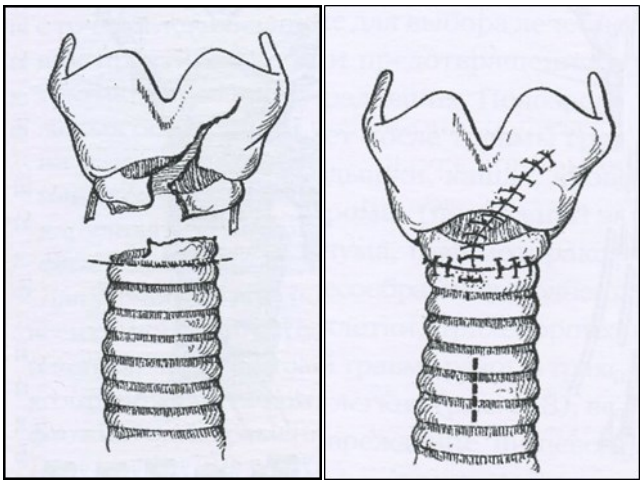
Picture 3. Diagrams of tracheal ruptures and subsequent reconstructive operations. Extensive trauma to the left lateral wall of the trachea (a), which required circular resection and anastomosis. Transverse rupture with restoration of tracheal integrity by circular anastomosis and "safety" tracheostomy (b). Isolation of tracheal sutures by the thyroid gland, and from the brachiocephalic arterial trunk by a muscle flap.

In addition to possible respiratory disorders due to edema, arrosive bleeding from large vessels of the neck and mediastinum re-mains a serious postoperative complication. This is especially important, because the operation is performed in an infected wound. The use of the entire complex of prevention of erosive bleeding (covering the anastomosis line with surrounding tissues, isolation of vessels from tracheal

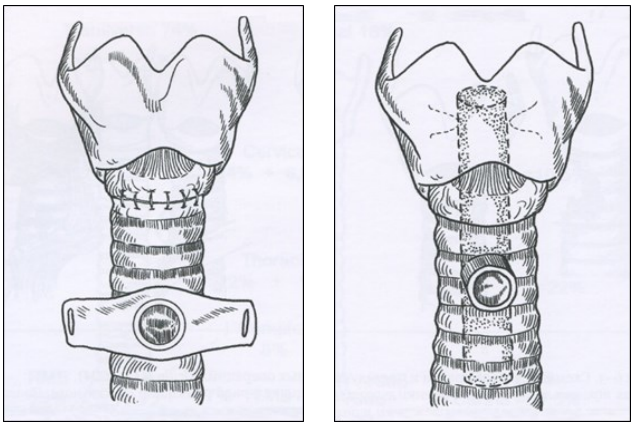
sutures with muscle flaps), which is used in tracheal surgery, is absolutely shown.

A closed injury of the cervical trachea is often accompanied by damage to the larynx at different levels (picture 4).



Picture 4. Diagram of one of the possible variants of tracheal and laryngeal trauma. It is advisable to end the operation with a "safety" tracheostomy (indicated by the dotted line).

There can be a lot of damage options and a good knowledge of not only anatomy, but also physiology, primarily of the larynx, is required for adequate restoration of the respiratory tract. Operations on the upper respiratory tract are often accompanied by the development of edema, especially the subclavian larynx, and respiratory disorders. In this regard, it is advisable to perform a "safety" tracheostomy for the period of relief of inflammation and edema. In cases of alleged prolonged cannulation, the introduction of a T-shaped silicone tube may be more physiological, because at the same time it is possible to restore breathing through the nose with the outer knee of the tube closed (picture 5).



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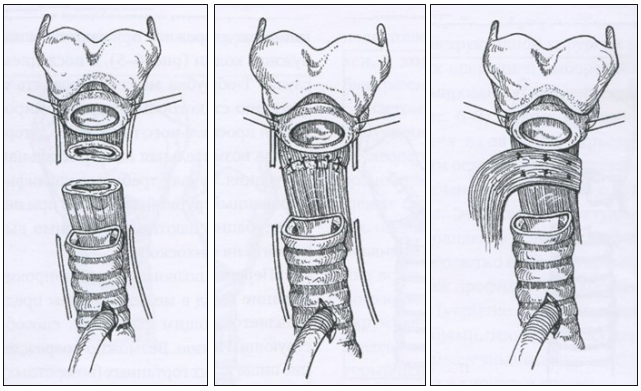
Picture 5. Scheme of "safety" tracheostomy with the introduction of a standard tracheostomy cannula (a), T-shaped tube (b).

In the latter case, the T-shaped tube can also function as a wall on which the lumen of the respiratory tract will be formed. As an alternative, prolonged nasotracheal intubation is possible. In these cases, qualified care of the tube is required, especially during reintubation, which is absolutely necessary to perform on a fibrobronchoscope.

Overextension of the spine and tilting of the head back at the moment of injury appears to be an aggravating factor contributing to the damage. Possible damage to the esophagus and lower laryngeal (recurrent) nerves (picture 6).

Trauma of the latter occurs more often with transverse high ruptures of the respiratory tract. Such an injury requires long-term preservation of the tracheostomy and complex reconstructive operations on the larynx. Damage to the thoracic part of the trachea usually does not lead to damage to the recurrent nerves.

Complex reconstructive operations for urgent indications should be completed with prevention of arrosive bleeding.



a b c

Picture 6. Diagram of the rupture of the trachea, esophagus and lower laryngeal nerves (a). Restoration of the esophagus (b), strengthening of the esophageal suture with a muscle flap (c).

Timely recognition of a tracheal rupture with accurate localization of the defect site is of great practical importance for the choice of therapeutic tactics, saving lives and preventing severe complications in victims. Suspicion of a tracheal rupture occurs after a chest or neck injury with the appearance of shortness of breath, cough, hemoptysis and "gas syndrome" (subcutaneous emphysema, pneumomediastinum, pneumothorax). To clarify the diagnosis, it is advisable to perform chest X-ray, tracheobronchoscopy. Often, with a closed injury, the rupture of the trachea is accompanied by a contusion of the lungs, simultaneous damage to the esophagus is possible. With small breaks, the general condition of patients does not change significantly.

Clinical manifestations may be delayed. Tense pneumothorax, especially bilateral, and tense pneumomediastinum are particularly dangerous. Often,

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clinically and radiologically, the diagnosis of a tracheal rupture can only be assumed. The final diagnosis belongs to tracheobronchoscopy. If there is a suspected rupture of the respiratory tract, there can be no contraindications for endoscopic examination of the trachea and large bronchi. Fibrotracheobronchoscopy allows not only to confirm the trauma of the trachea, localize the defect, but also to install an intubation tube below the rupture site, thereby saving the patient. The question of the time of the endoscopic examination should be decided individually. Severe chest injury with rib damage, lung tissue may be accompanied by signs of respiratory failure, "gas syndrome". In these cases, it is very controversial that fibrotracheobronchoscopy can worsen the patient's condition. In addition, in case of rupture of the respiratory tract, blind intubation is dangerous by the occurrence of dislocation of the tube into the paratracheal space with subsequent asphyxia, and additional trauma to the tube with an increase in the size of the defect is also possible. Even a successful blind intubation can have negative long-term consequences. Artificial ventilation of the lungs for several days through an intubation tube, the caudal end of which may be located below the rupture site, thereby creating an impression of well-being, causes late diagnosis of tracheal damage. Restoration of the integrity of the respiratory tract after 3-4 days is unfavorable due to the development of an inflammatory process in the tracheal wall and paratracheal space.

Thus, in case of blunt trauma of the chest with suspected rupture of the trachea, with "gas syndrome", diagnostic laryngotracheobronchoscopy is indicated, which allows to exclude injury of the respiratory tract, and, if necessary, to perform safe intubation of the trachea and sanitation of the tracheobronchial tree from blood, stomach contents, etc., as well as to determine indications for timely surgery.

Fi-brotracheobronchoscopy allows you to determine the location of the rupture of the wall of the damaged trachea, which is important for the choice of subsequent surgical access. Treatment of small ruptures can be conservative. The patient should be carefully monitored in order to quickly recognize possible complications. Nasotracheal intubation with the location of the end of the intubation tube caudal to the rupture is shown. At the same time, the patient can be on his own breathing and not require sedation and relaxation. Small tears, especially non-transmural ones, heal safely within 3-7 days. Basically, this refers to ruptures of the membranous wall of the trachea. In addition to endoscopic treatment, in the presence of "gas syndrome", appropriate drainage of the pleural cavity, mediastinum is indicated.

With large ruptures of the trachea, especially its thoracic part, surgical intervention is necessary to save the life of the victim. Conservative treatment can only have a temporary effect. Even the seemingly achieved well-being can be deceptive due to purulent-inflammatory complications, often complicated by arrosive bleeding from large mediastinal vessels into the tracheobronchial tree [1]. Despite other severe injuries, surgery is indicated, be-cause without it is often impossible to eliminate a strained pneumothorax, pneumomediastinum, violation of the patency of the respiratory tract.

Indications for emergency surgery with a closed injury of the trachea and main bronchi should be considered: complete transverse rupture of the trachea with diastasis of its ends; multiple ruptures of the trachea, its bifurcation, the main bronchi; progression of the "gas syndrome"; inability to restore airway patency by endoscopic methods; continued bleeding into the tracheobronchial tree; simultaneous damage to the esophagus, mediastinal vessels, and heart.

Due to the tension of the trachea along its axis in the vertical direction, with a complete transverse rupture, diastasis of its ends occurs. At the same time, it can be significant. Such injuries often lead to the death of patients at the moment of rupture of the trachea. At the stage of first aid, intubation of the caudal segment of the trachea under endoscopic control is indicated. This is not always possible for technical reasons, and the victim often dies from asphyxia directly at the scene. Performing an urgent tracheostomy in these cases may not lead to an effect (it is difficult to blindly intubate the caudal segment of the trachea with a tracheostomy tube through a tracheotomy). In case of ruptures of the trachea that are not associated with diastasis of its ends, operative access is determined depending on the localization of damage according to the principles accepted in tracheal surgery. With complete transverse ruptures with diastasis of the ends of the trachea, cervicotomy with partial sternotomy or lateral right-sided thoracotomy is fundamentally possible.

The tracheal rupture line can have a complex "stellate" character and spread in the cranial and caudal directions with the involvement of the main bronchi (picture 7).

After performing the access, the dislocated ends of the injured trachea are found in the soft tissues of the mediastinum. Perform a thorough revision of the integrity of the trachea and the main bronchi throughout. The first stage provides safe ventilation of the underlying tracheobronchial tree using the "shunt-breathing" system through the surgical wound (picture

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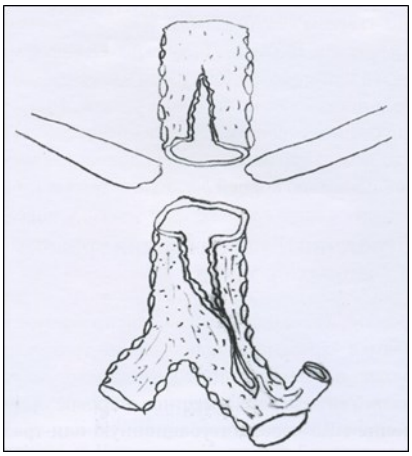
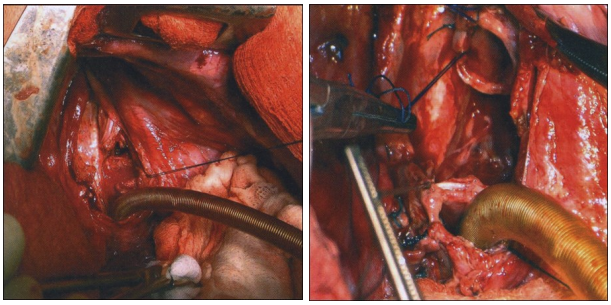


Picture 7. Diagram of the rupture of the thoracic trachea and the right main bronchus (rear view). A "stellate" rupture is determined: a complete transverse rupture of the thoracic trachea, a longitudinal rupture of the membranous part with a spread to the right main bronchus.



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Picture 8. Photo of the stage of the operation – restoration of the integrity of the thoracic trachea after its transverse rupture with a rupture of the right main bronchus. The bifurcation of the trachea with a longitudinal defect of its membranous part and the spread of the rupture to the right main bronchus is determined. An intubation tube for ventilation of the "shunt-breathing" type was introduced into the latter (a). The defect in the membranous part of the cranial end of the trachea is sutured, the trachea is pulled up to its caudal end, in which the defect of the membranous wall is also sutured (b).

First, the ruptures of the bronchi are sutured after their additional mobilization. Then the membranous part of the trachea is sutured. The final stage is tracheal anastomosis "end to end". As a rule, extensive resection is not required. It is possible to "smooth out" the edges of the injured trachea with excision at its ends of non-viable tissues, fragmented cartilage. There is no tension, which makes it possible not to perform additional mobilization of the roots of the lungs, larynx, etc.

Iatrogenic injuries of the trachea and main bronchi. A special, but increasingly urgent problem is iatrogenic damage to the trachea during various manipulations of medical personnel. Given the widespread use of ventilators through an intubation or tracheostomy tube, the widespread use of endoscopic methods of treatment, one should not expect a decrease in the number of such complications. Unlike traumatic non-iatrogenic injury, there is very little information in the available literature about the frequency of iatrogenic tracheal injuries. The available publications reflect re-ports of isolated cases and rarely – more than ten observations [9,11,12]. Perhaps iatrogenic isolated tracheal damage occurs more often than it seems at first glance. Small ruptures heal well enough on the intubation tube, and suturing timely diagnosed tracheal wall injuries during esophagectomy or strumectomy also leads to recovery of most patients without any complications and an increase in the length of hospital stay. In addition, a subjective factor plays a certain role – the authors' unwillingness to point out such an unpleasant iatrogenic complication. Currently, there is no universally recognized tactic for the treatment of isolated tracheal ruptures of iatrogenic nature. Some authors point to the need for urgent surgery [4,6,11], others [3,7,10] – for a favorable outcome after conservative treatment without any longterm complications.

Active surgical tactics in isolated postintubation ruptures of the trachea should be treated with restraint. Unlike the trauma of bifurcation of the trachea and the main bronchi, this pathology is a resuscitation and anesthesiological problem. Properly performed intubation of the trachea with isolation of the rupture site from the paratracheal space, adequate drainage of the corresponding pleural cavity, if necessary, antibacterial and anti-inflammatory therapy, normalization of gas exchange and acid-base state can successfully cope with this serious complication without major surgery. Conservative therapy is possible when the patient is well examined, and the rupture of the respiratory tract can be controlled endoscopically. In general, specialists who know both surgical and conservative methods of treatment should determine the tactics of treatment.

From a surgical point of view, suturing postintubation ruptures of the trachea is quite favorable. In the remote period, the place of the former rupture is practically not determined.

Surgery for iatrogenic rupture of the trachea is indicated when blood vessels are damaged and the clinic continues bleeding into the tracheobronchial tree, it is impossible to isolate the tracheal defect from the pleural cavity and paratracheal space using an intubation tube, the rupture spreads to the bifurcation and main bronchi, when a refractory pneumothorax with a collapsed lung persists, hypoxemia increases. Also, a tracheal defect should be sutured in the case when there is already access to it, and a thoracotomy is performed for another disease. A relative indication for active surgical tactics is a large rupture of the trachea with gaping edges, when there is an interposition between the edges of the soft tissue defect of the paratracheal space. In these cases, one should not expect such a rapid healing.

Endoscopic methods of destruction of intraluminal

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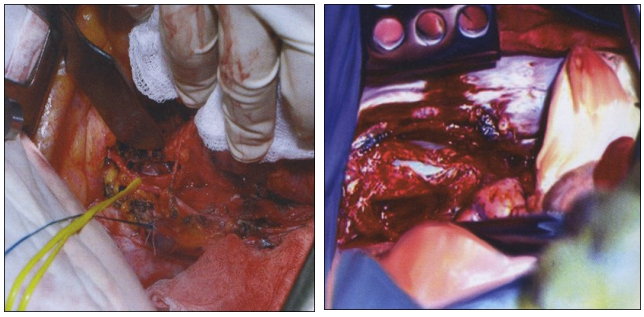
pathological tissues make it possible to cope with this complication, but require multistage and longterm treatment.

When choosing surgical access, you should adhere to the routine principles used in tracheal surgery. If the cervical region is damaged, cervicotomy is indicated, upper thoracic – cervicotomy with partial sternotomy, middle and lower thoracic, as well as tracheal bifurcation - thoracotomy.

After thoracotomy, pneumomediastinum is diagnosed, the severity of which depends on the integrity of the mediastinal pleura.

After dissection of the mediastinal pleura, ligation and crossing of the unpaired vein, the trachea is isolated with its subsequent rotation along the axis for visualization of the membranous part (picture 9). It should be borne in mind that the gap may be multiple in nature.



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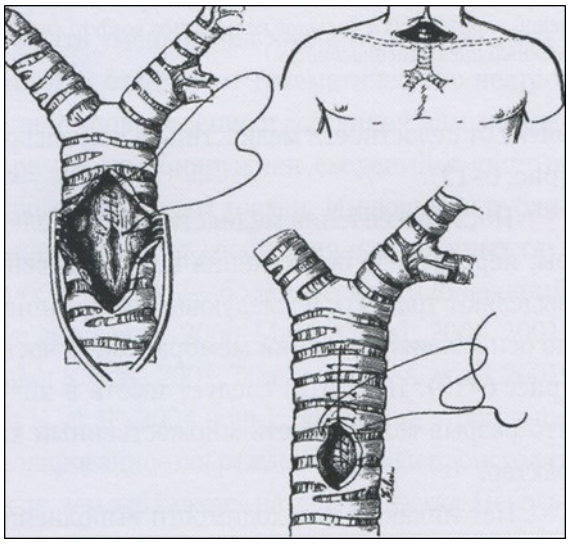
Picture 9. Intraoperative photo. Lateral thoracotomy. The mediastinal pleura was opened. The membranous wall of the thoracic trachea was isolated, in which a longitudinal defect (a) is visible. Two longitudinal ruptures of the membranous part of the trachea are determined, through which the intubation tube (b) is visible.

There is no need to perform the proposed Altinok T. (2014) and Aouad R. (2007) additional longitudinal tracheotomy in the cartilaginous part to reach the membranous wall [1,2] (picture 10). These authors believe that dissection of the intact part of the trachea can also be performed to prevent damage to the recurrent laryngeal nerves when the posterolateral trachea is isolated. We believe that the indications for such an operation should be limited. It leads to additional trauma to the respiratory tract. Perhaps this manipulation is justified when a sternotomy has already been performed for another disease and a rupture of the membranous wall has been detected, and it is not possible to rotate the trachea for some reason.

The vagus nerve is isolated throughout and diverted to the side. Sutures on the trachea are applied longitudinally using Vicryl type threads on a 3-0 or 4-0 atraumatic needle. The operation is completed by checking the aerostasis under the fluid level, sanitizing the tracheobronchial tree and installing an intubation tube above the tracheal suture under endoscopic control. The presence of a cannula and, especially, a swollen cuff at the seams is unfavorable for the healing of the anastomosis.



Picture 10. The cartilaginous part of the trachea is dissected longitudinally and the defect of its membranous wall is sutured from the side of the airway lumen, followed by restoration of the integrity of the cartilaginous part [1].

There is no need for a "safety" tracheostomy, defended by some authors [13]. It causes unnecessary trauma to the respiratory tract and creates an additional source of infection, which is unfavorable for the healing of the anastomosis.

CONCLUSIONS

The tracheal injury refers to extremely severe injuries, proper surgical tactics, timely surgery can achieve a good result. Success is largely determined by the quality of first aid, anesthesiological and endoscopic treatment of such patients.

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