ENDOSURGICAL TECHNOLOGY FOR CHEST WOUNDS

O.V. Voskresensky, M.M. Abakumov

N.V. Sklifosovsky Research Institute for Emergency Medicine of the Moscow Healthcare Department, Moscow, Russian Federation

Background. Penetrating chest injuries are a common cause of hospitalization for young patients. Various types of thoracotomy prevail over the other surgical approaches performed both under absolute and relative indications, depending on the location of wounds.

Aim of study. To analyze the tactics and evaluate the possibility of thoracoscopy in order to reduce the number of unreasonable thoracotomies and reduce trauma due to surgical intervention.

Material and methods. We studied 596 medical histories of victims who had been operated in 2002-2012. Thoracoscopy was performed in 236 patients, traditional tactics was applied in 360 victims. Wounds in the diaphragmatic area of the chest were in 210 victims, in the "heart" area – in 172 patients, in the intersection of these two zones – 44 cases, in the projection of the lung peripheral part – 49 cases and paravertebral area of the chest – in 52 patients. Typical thoracotomy (TT) was performed in 27% of cases, atypical thoracotomy (AT) – 42.5%, and drainage of the pleural space (DPS) – 30.3% of cases.

Result. Thoracoscopy (TS) could be carried out in 42.2% of patients who had undergone TT, and in 79.4% of patients who had undergone AT. Overall performance of thoracoscopy was possible in 70% of patients with penetrating chest wounds (PCW). Absolute contraindications for thoracoscopy occurred in 29.1% of the victims.

Key words: chest trauma, tactics of threatment, thoracoscopy .

AT – atypical thoracotomy
DCA – diaphragmatic-cardiac area
DPS – drainage of pleural space
ICV – intercostal vessels
ITV – internal thoracic vessels
LSTAI – left-sided thoracoabdominal injury
PAT – penetrating abdominal trauma
PCT – penetrating chest trauma
PWD – primary wound debridement
RSTAI – right-sided thoracoabdominal injury
SD – standard data deviation with normal distribution of variation series
SI – shock index
TAI – thoracoabdominal injury
TT – typical thoracotomy
VATS – video-assisted thoracoscopy

INTRODUCTION

Selection of a type of surgical intervention for a chest injury is based on evaluation of a patient's state severity [1, 2]. The management of shock, associated with massive intrapleural bleeding or cardiac tamponade, has no alternative [3, 4]. Most patients with chest trauma are moderately or mildly injured and have stable hemodynamics. [5] In this group of victims the basic method of treatment is drainage of the pleural space (DPS) [6, 7]. And the tactics for "low" location of wounds is separately discussed as there is difference in management for left-side and right-side injuries [2, 8-11]. Also, methods of management for wounds in the cardiac projection differ [10, 12-19]. The main trend in modern surgery is to reduce the trauma of surgical interventions. This is facilitated by modern endosurgical technologies in hemodynamically stable patients and widening of indications for this intervention [20, 21]. Therefore, the question on the optimal method of surgery, improving the results of treatment for chest wounds, is a relevant challenge.

Aim of study: to assess the traditional tactics in hemodynamically stable victims with wound injuries and retrospectively determine the possibility of endosurgical methods performance depending on the wounds location.

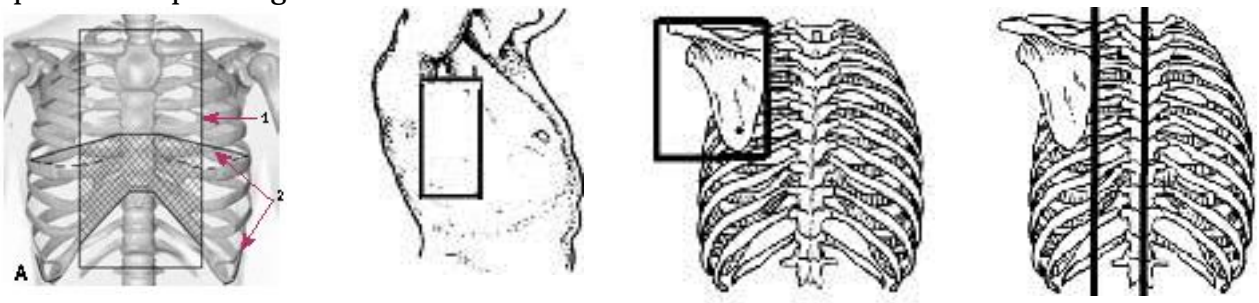
MATERIAL AND METHODS

We studied medical histories of 596 patients with penetrating chest trauma (PCT), operated in the N.V. Sklifosovsky Research Institute for Emergency Medicine in 2002-2012. The main group of patients who underwent thoracoscopy consisted of 236 hemodynamically stable patients with preserved consciousness. The hemodynamic status was evaluated according to the shock index (SI). The criteria for available endosurgical intervention were SI<0.97, and the rate of intrapleural bleeding <250 ml/h, the absence of data on damage, requiring typical thoracotomy and the lack of data for penetrating abdominal trauma (PAT), requiring laparotomy [22, 23]. The average value of physiological disorders severity according to *RTS* (revised trauma score) was 7.823±0.035 (normal value — 7.841), indicating a lack of serious violations. The severity of anatomical failures according to *ISS* (injury severity score) was 8.2±4.6. The average value of SI was 0.78±0.12 (normal value — 0.54). There were 210 (89%) 30-year-old male patients (24; 38). In 228 (96.6%) patients, stab and slash wounds were detected. The single chest wound was revealed in 185 (78.4%) patients, multiple wounds — in 52 (22%) patients. The unilateral injury was observed in 228 (96.6%) patients. Signs of PCT were noted in 194 (82.2%) patients prior to surgery. General anesthesia with one-lung ventilation was performed in 209 (88.6%) patients, general anaesthesia with two-lung ventilation was performed in 24 (10.1%) patients, local anesthesia — in 3 (1.3%) patients.

The control group involved 360 victims, operated with the use of traditional methods, of which 331 (91.9%) were 29-year-old male patients (24; 38). Chest stab and slash wounds were observed in 356 (98.9%) patients, unilateral injuries were observed in 329 (91.4%) patients, multiple chest wounds (2 or more) were in 99 (27.5%) patients. The average value of *RTS* was 7.703±0.249 (normal value — *7.841) (p<0.05)*, which characterized physiological disorders as moderate. The severity of damage according to

ISS was 9.4±5.3 *(p*>0.05). The average value of SI was 0.87±0.23, which generally characterized the group as hemodynamically stable. Ultrasound examination of the chest and abdomen, and chest X-ray were performed before the operation, and confirmed the presence of penetrating trauma in 254 (70.6%) patients. In 244 (67.9%) cases, the operation was initiated under general anesthesia with artificial pulmonary ventilation. DPS and debridement of wounds (PWD) were performed in 109 (30.3%) patients, atypical thoracotomy (AT) — in 153 (42.5%), TT — in 94 (25.7%). Signs of heart injuries and heavy intrapleural bleeding were absolute indications for TT. Indications for AT were chest wounds located in the sixth-eighth intercostal space between the midclavicuar and scapular line mostly on the left side [8]. DPS was performed in hemodynamically stable patients without the threat of heart and diaphragm injuries, and also as the first stage under obvious signs of thoracoabdominal injuries (TAI) before laparotomy [24].

To standardize the results we formed expert groups depending on the location of the chest wound: diaphragmatic, cardiac and adjacent diaphragmatic-cardiac, axillary, scapular, and paravertebral — total 527 (88.4%) patients (Figure 1). Distribution of patients depending on the location of the thoracic wound is shown in Table 1.



A B C D

Fig. 1. The borders of chest areas. *A* — hatching indicates intersection of two areas of the chest: cardiac (upper arrow —1) and diaphragmatic (two lower arrows on the left — 2) forming a cardiac-diaphragmatic adjacent area; *B* — axillary chest area. The superior border — the upper edge of the axillary fossa along II rib; the inferior border — the upper margin of V rib, the anterior border — anterior axillary line, the posterior border — posterior axillary line; *C* — scapular area. The superior border — the margin of the trapezius muscle above the scapular spine, the lateral border — posterior axillary line, the medial border — the medial margin of the scapula, the inferior border — VI rib; *D* — paravertebral area, bounded with a line running along the spinous processes from VII cervical to XI thoracic vertebrae (spinal line), and a vertical line running parallel to the vertebral line along the medial margin of the scapula.

Table 1

Distribution of patients in the main and control group according to the chest wounds location

Group of victims	injured area						
	Diaphragmatic	Cardiac	Diaphragmatic-cardiac	Axillary	Scapular	Paravertebral	Total
Thoracoscopy	81	64	23	11	9	23	211
Traditional tactics	129	108	21	18	11	29	316
Total	210	172	44	29	20	52	527

Identified damages were standardized according to classifications developed in the Clinic of Emergency Thoracoabdominal Surgery of the N.V. Sklifosovsky Research Institute for Emergency Surgery [25, 26]. Conditions of traditional surgery implementation were compared with similar data in victims, who had undergone thoracoscopy. Retrospectively, patients of the control group were evaluated for the ability to undergo thoracoscopy. For statistical data processing we used methods of parametric and nonparametric statistics *(t-test, Mann-Whitney U-test,* median method of *Kruscal-Wallis)*. Data having a normal distribution of variation series, was presented as average value *(M)* and standard deviation *(SD)*. Groups with abnormal distribution of variations were presented as median (upper quartile, lower quartile).

RESULTS AND DISCUSSION

	Areas of chest injuries and the type of surgery								
	Diaphragmatic			Cardiac			Diaphragmatic-cardiac		
	Traditional tactics (129)	Thoracoscopy (81)	*p*	Traditional tactics (94)	Thoracoscopy (64)	*p*	Traditional tactics (27)	Thoracoscopy (23)	*p*
RTS	7.783 ± 0.110	7.841	> 0.05	7.597 ± 0.404	7.841	**<0.05**	7.674 ± 0.297	7.841	> 0.05
Prehospital hypotension (%)	22 (17.1%)	10 (12.3%)		34 (36.2%)	10 (15.6%)	**<0.05**	9 (33.3%)	4(17.4%)	
SI	0.84 ± 0.17	0.79 ± 0.17	> 0.05	0.94 ± 0.45	0.77 ± 0.11	**<0.05**	0.86 ± 0.38	0.76 ± 0.1	> 0.05
Volume of hemothorax (ml)	351 ± 344	377 ± 30 July	> 0.05	596 ± 539	342 ± 260	> 0.05	361 ± 295	262 ± 165	> 0.05
Time gap *injury – surgery* (h)	3.63 ± 1.54	5.39 ± 2.83	**<0.05**	3.77 ± 3.92	7.13 ± 5.54	**<0.05**	3.14 ± 1.18	5.28 ± 1.86	**<0.05**
Bleeding rate (ml/h)	181 ± 183	89 ± 65	**<0.05**	361 ± 346	90 ± 64	**<0.05**	175 ± 176	58 ± 28	> 0.05
ISS	9.6 ± 3.4	8.5 ± 3.1	> 0.05	9.5 ± 4.1	7.8 ± 3.4	> 0.05	9.9 ± 3.8	6.6 ± 2.7	**<0.05**
Bleeding from intercostal vessels/internal thoracic vessels	31/23 (24% / 74.2%)	39/13 (48.1% / 33.3%)	-	33/26 (35.1% / 78.8%)	33/8 (51.6/ 4.2%)	-	11/6 (40.7%/54.5)	9/3 (39.1% / 33.3%)	-
Lung	68 (52.7%)	36 (44.4%)	-	37 (39.4%)	31 (48.4%)	-	5 (18.5%)	8 (34.8%)	-
Diaphragm/thoraco-abdominal injury	47/32 (36.4% / 24.8%)	26/19 (32.1% / 23.5%)	-	4/4 (4.3% / 4.3%)	3/2 (4.7% /%)		13/11 (48.1% /%)	7/2 (30.4% /%)	-
Pericardium /heart	-	1 (1.2%)	-	9/11 (9.6% / 11.7%)	3/6 (4.7%/9.4 %)	-	14/1 (51.9% / 3.7%)	6/0 (26.1%)	-

As shown in Table. 2, when comparing two groups of patients with diaphragmatic injuries in the chest area, they were characterized as hemodynamically

stable. The severity of the anatomical damage and physiological disorders in the main group and the control group did not differ. The frequency of hypotension before hospitalization was low. There was a low average SI. The average volume of hemothorax was in the range of "small-medium" according to P.A. Kupriyanov [27]. The rate on intrapleural bleeding was generally low, although it was higher in the control group due to the higher incidence of damage to blood vessels of the chest wall.

Table 2

Assessment of the severity of physiological disorders and injuries of anatomical damage in patients with injuries of diaphragmatic, cardiac and diaphragmatic-cardiac areas of the chest

Notes: ISS – injury severity score, RTS – revised trauma score, SI – shock index

Thoracoscopy was performed in 81 cases. The diagnosis of PCT prior to surgery was set in 90.1% of victims. The lung took the leading place among injured areas. The average depth of the wound canal in the lung was 1.8±1.4 cm. The moderate bleeding from a wound in the lung occured in 23 (63.9%) patients, discontinued bleeding with symptoms of unstable hemostasis — in 3 (8.3%) patients and in 2 of them the heavy bleeding resumed after the removal of a clot. The closure of wounds during thoracoscopy was performed in 29 (80.6%) patients. Conversion to thoracotomy was required in 7 (19.4%) patients with deep (4.8±1.8 cm) lung wounds.

TAIs were detected in 19 (23.5%) patients with wounds of the "diaphragmatic" chest area (see Table 2). Endosurgical suturing of diaphragmatic wounds was performed in 5 (19.2%) patients of 26, video-assisted thoracotomy — in 5 patients. AT and diaphragmotomy were performed in 2 patients. The stitch was put into the diaphragm during laparotomy in 12 patients.

Blood vessels of the thoracic wall (see Table 2) were the third according to frequency of injury. The heavy bleeding was observed in 5 (12.8%) patients, moderate — in 29 (74.4%) cases. The discontinued bleeding with symptoms of unstable hemostasis occured in 4 (10.3%) patients. Thoracoscopic coagulation of the thoracic wall wounds was performed 23 (59%) victims. Pericostal stitches were put under endoscopic control in 8 (20.5%) patients. Conversion to thoracotomy was performed in 8 (20.5%) patients.

The wound of the pericardium occurred in one victim. The indication for TT was 2,000 ml hemothorax. Pericardiotomy revealed a superficial wound of the heart with hemopericardium 30 ml *(AIS*-3).

Thoracoscopy without conversion was performed in 66 patients 81 (81.5%) with wounds of the diaphragmatic area of the chest.

PCT had been revealed prior to the surgery in 82 (63.6%) cases of 129 victims who were operated using conventional tactics. PAT signs occurred in 18 (14%) victims.

The lung trauma was the most frequent (Table 2). The moderate bleeding from wounds of the lung was found in 22 (32.4%) cases of 68. The average depth of the wound canal in the TT group was greater than in the thoracoscopy group, 3.1±1.4 cm *(p*<0.05). The dissection and inspection of the wound canal were carried out in one

case.

TAIs were revealed in 32 (24.8%) cases (Table. 2). Diaphragmotomy was performed in 13 (27.7%) patients: right-sided TAI (RSTAI) — in 10 victims, left-sided TAI (LSTAI) — in 3 patients. Laparotomy was performed in 19 cases (40.4%): in 13 patients with LSTAI and 6 patients with RSTAI. Laparoscopy was performed in 3 victims. There were no abdominal damages in 9 (28.1%) patients out of 32.

The heave intrapleural bleeding from wounds of the thoracic wall was found in 13 (41.9%) patients out of 31. The moderate bleeding was observed in 10 (32.3%) patients, unstable hemostasis — in 4 (12.9%) patients. One patient had a heavy external bleeding.

Among surgical procedures for diaphragmatic injuries in the chest area, AT was performed in 102 (79.1%) patients. Signs of PCT were in 61 (59.8%) patients and in 41 (40.2%) patients AT was performed after primary surgical debridement of wounds (PWD). The heavy intrapleural bleeding was observed in 8 (7.8%) patients. Obvious signs of PAT were in 11 (10.8%) patients. In 18 patients, perforating diaphragmatic injury was diagnosed in the absence of clinical data for PAT. TT was performed in 9 (7%) patients: under absolute indications — 5, relative indications — 4. DPS and PWD were performed in 18 (14%) victims. In 33.3% of cases, DPS and PWD were performed under obvious signs of TAI, when laparotomy was primarily indicated.

Retrospective analysis showed that thoracoscopy had been possible according to hemodynamic and clinical criteria in 96 (74.4%) patients out of 129 victims with injuries of the diaphragmatic area of the chest (Table. 3). Contraindications for thoracoscopy were detected in 33 (25.6%) cases: in 15 (45.5%) cases due to to the high rate of intrapleural bleeding, and in 18 (54.5%) cases with obvious signs of abdominal injuries requiring urgent laparotomy.

Victims with injuries of the cardiac area were the most serious. They had the greatest physiological disorders. They had prehosital hypotension more often than in the other groups, they also had the highest SI, the highest average hemothorax, and the highest rate of intrapleural bleeding (see. Table. 2).

Upon exploration of lung wounds during thoracoscopy, its average depth was 1.6±1.5 cm. The moderate bleeding from the lung wounds was revealed in 11 (35.5%) patients, and the discontinued bleeding with unstable hemostasis occurred in 3 (9.7%) patients. Sealing of wounds was performed in 22 (71%) victims. Endosurgical suturing was performed in 11 victims, diathermocoagulation was also performed in 11 cases. The average depth of sutured lung wounds was 1.5±0.7 cm. Wounds with the depth of 0.7±0.4 cm were coagulated. In 4 (12.9%) patients, superficial wounds were not debrided. Conversion from thoracoscopy to TT due to lung injury was required in one victim with a deep wound, and a foreign body in the lung.

Of 33 patients with bleeding from the thoracic wall, a vascular injury was revealed in 8 (24.2%) of them: 4 cases of bleeding from internal thoracic vessels (ITV), and 4 cases of bleeding from intercostal vessels (ICV). There was no heavy bleeding. The moderate bleeding was found in 4 cases and the discontinued bleeding with symptoms of unstable hemostasis was aslo observed in 4 cases. In 25 (75.8%) patients, the source of bleeding from the chest wall wound were intercostal muscles. Coagulation was performed in 23 (69.7%) patients, pericostal stiches and clipping of

vessels were performed in 6 (18.2%) patients. Conversion to thoracotomy to stop the resumed heavy bleeding from ICV was required in 1 (3%) case.

Of 3 patients with injuries of the diaphragm, TAIs were in 2 patients (RSTAI — 1, transpericardial LSTAI — one) (see Table 2). Thoracoscopic closure of a diaphragm injury was performed in one victim with RSTAI. A patient with LSTAI underwent thoracotomy and laparotomy. In the third victim, the superficial diaphragmatic wound did not require suturing.

Of 11 (17.2%) patients with injury of organs and structures of the mediastinum, pericardial injury was detected in 3 patients, cardiac injuries were found in 6 cases, and injuries of the superior vena cava were revealed in 2 patients. During diagnostic thoracoscopy we performed pericardiotomy in 2 victims. Conversion from thoracoscopy to TT was performed in all patients.

Thoracoscopic surgery was performed without conversion to TT in 49 (76.6%) patients with wounds in the cardiac area of the chest.

Traditional tactics was used in the treatment of 94 victims (see Table 2). The damage of the chest wall blood vessels was observed in 26 (78.8%) of them: ITV — in 15 victims, ICV — in 11 victims. The heavy bleeding was observed in 11 patients, the moderate bleeding occurred in 7 cases, the discontinued bleeding with signs of unstable haemostasis occurred in 8 patients.

Upon exploration of the lung injury, the average depth of the wound was 4.3±2.6 cm. The heavy bleeding was observed in 5 (13.5%) patients, the moderate bleeding was observed in 15 (40.5%) cases. In one case, there was an intrapulmonary hematoma. Pneumotomy was performed in 7 (18.9%) patients, with an average depth of the wound canal 7±3 cm. Nine (24.3%) patients with lung injuries had absolute indications for TT. In 10 patients, deep lung wounds were combined with trauma of ITV, ICV, heart.

In 4 patients with injuries of the diaphragm RSTAI was diagnosed. In 2 patients, it was combined with ITV trauma, which was an absolute indication for TT.

The pericardial and cardiac trauma was found in 20 (21.3%) cases. Penetrating pericardial injuries were diagnosed in 8 patients out of 9. Hemopericardium of 32±12 ml was diagnosed in 3 of them. In cardiac trauma, 10 patients of 11 victims had an average hemopericardium of 145±78 ml (p<0.05).

DPS and PWD were performed in 25 (26.6%) stable patients (SI — 0.73±0.08) with trauma of the cardiac area of the chest. Of these, DPS and PWD were performed in 7 cases in the absence of obvious signs of PCT according to PWD results, and in 18 cases under prevailing pneumothorax and/or minimum hemothorax. TT was performed in 56 (59.6%) patients. Absolute indications for TT in 31 (55.4%) cases were: a high rate of intrapleural bleeding (22 patients), obvious signs of cardiac trauma (9 patients). The relative indications for TT were observed in 25 (26.6%) patients. The main relative indication for TT was the need to exclude heart wounds in 22 patients. Under this injury, the diagnosis was positive in 6 (27.3%) patients: cardiac trauma was diagnosed in 2 cases, pericardial trauma was diagnosed in 4 cases.

Thoracoscopy could be performed in 38 (40.4%) patients of 94 with trauma of the cardiac area of the chest and signs of PCT (TT — 17, AT — 3, DPS and PWD — 18) (see Table 3). In the absence of evidence of PCT after PWD and confirmation of PCT, thoracoscopy could be carried out in 18 patients. Thoracoscopy was contraindicated in

38 (40.4%) patients. Obvious signs of cardiac injury were observed in 9 affected, heavy intrapleural bleeding — in 29. In these patients, TT was absolutely indicated.

Patients with injuries in the adjacent diaphragmatic-cardiac area of the chest (DCA) were close to the victims with wounds of the cardiac area according to the severity of physiological disorders. Prehospital hypotension occurred more than in a third of cases. There was a small average hemothorax and low rate of intrapleural bleeding (see Table 2).

Under the thoracoscopy, the most common damage was bleeding from wounds of the chest wall (9 cases, 39.1%). The vascular injury of the chest wall (ICV — 2 cases, ITV — 1 case) occurred in 3 patients. The moderate bleeding was observed in 6 affected, and the discontinued bleeding with signs of unstable haemostasis was observed in 3 patients. Coagulation of thoracic wall wounds was performed in 4 patients, the bleeding was stopped with pericostal stitches in 3 patients. To stop bleeding from ITVs, the conversion from thoracoscopy to TT was performed in one case.

The average depth of the wound canal was 1.3±1.1 cm. Endosurgical suturing of wounds was performed in 2 patients, wounds coagulation was performed in 2 patients. In 3 patients, we did not debride superficial wounds. The conversion from thoracoscopy to TT due to adhesions in in the pleural cavity was performed in one patient.

Of 7 (30.4%) diaphragmatic injuries, wounds were perforating in 2 victims (both observations — RSTAI). Endosurgical suturing of the diaphragm was performed in one victim. Superficial wounds were not debrided in 4 patients. In 2 cases, thoracoscopy was converted to video-assisted mini-thoracotomy for wounds, located in the anterior phrenico-costal sinus.

Wounds of the pericardium within the pericardial fat were detected in 4 victims. We also diagnosed one penetrating stab and slash wound and one penetrating gunshot wound with a bullet in the pericardial cavity. Conversion from thoracoscopy to TT was performed in one case in relation to a suspected heart injury. In the 2nd observation, we used video-assisted mini-thoracotomy, which revealed an injury of pericardial fat, not penetrating into the cardiac sac cavity.

In patients who were operated using ***conventional tactics***, pericardial and cardiac injuries occurred almost 2 times more often than under thoracoscopy (see Table 2). Pericardial wounds, penetreating into the cardiac sac cavity, were observed in 5 affected. The average volume of hemopericardium was 62±30 ml. The wound of the right atrium of the heart with hemopericardium of 40 ml occurred in one victim.

LSTAI was diagnosed in 9 patients, RSTAI was diagnosed in 2 patients. A blunt diaphragm injury was observed in 2 patients. Victims with injuries of the diaphragm underwent TT (7), AT (5), and DPS (1).

The heavy bleeding from the chest wall was found in 3 patiemts, the moderate bleeding was observed in 2 patients, the discontinued bleeding with symptoms of unstable hemostasis was observed in 2 patients. ICVs and ITVs were the source of bleeding in 6 affected. AT was performed in 5 victims. This access was performed if wounds were located in the seventh intercostal space. The absolute indication for thoracotomy was the heavy intrapleural bleeding in one patient out of 5. TT was performed in 6 cases.

Lung injuries were diagnosed in 5 (18.5%) patients. The average depth of the

wound canal in the lung was 1 cm. The moderate intake of air and bleeding were detected in 2 cases. We performed 3 TTs for wounds in the sixth intercostal space on the midclavicular and parasternal line and 2 ATs for wounds in the seventh intercostal space. The were no absolute indications for TT due to the lung injury in any case.

TT was performed in 14 (51.9%) affected, AT — in 11. DPS and PWD — 2 victims with TAI as a first stage of operation. Absolute indications for TT were in 5 (18.5%) patients with signs of heavy intrapleural bleeding (1225±811 ml/h).

Retrospective evaluation has shown the ability to perform thoracoscopy in 8 patients with clinical manifestations of PCT. In the absence of clinical manifestations of the PCT in 5 affected, thoracoscopy could be performed after PWD and confirmation of PCT. Thus, thoracoscopy could be possible operation in 13 (48.1%) patients with wounds in the DCA (Table 3). Contraindications for thoracoscopy were observed in 14 (51.9%) patients: with signs of heavy intrapleural bleeding (4 patients), obvious signs of PAT (8 patients), bilateral injury and severe shock (2 patients).

Patients with injuries in the projection of the peripheral part of lungs (in the axillary and scapular area of the chest) were a group with stable hemodynamics, not much differing from patients with injuries in the diaphragmatic area of the chest (see Table 4).

Table 3

Retrospective evaluation of VATS possibility in patients with injuries in the diaphragmatc and diaphragmatic-cardiac area of the chest

Criteria for VATS pssibility	Chest areas								
	Diaphragmatic (*n*=129)			Cardiac (*n*=94)			Diaphragmatic-cardiac (*n*=27)		
	VATS		*p*	VATS		*p*	VATS		*p*
	Yes (*n*=96)	No (*n*= 33)		Yes (n=56)	No (n=38)		Yes (n=13)	No (n=14)	
Shock index	0.76±0.10	1.05±0.34	<0.05	0.74±0.10	1.29±0.48	<0.05	0.76±0.13	0.99±0.38	> 0.05
Hemothorax, ml	193±147	829±673	<0.05	247±188	1196±571	<0.05	225±120	676±484	<0.05
Time, hours	3.95±1.63	2.75±1.10	<0.05	4.62±2.93	2.28±1.04	<0.05	3.17±1.20	3.02±1.15	> 0.05
Bleeding rate, ml/h	79±61	419±333	<0.05	101±93	724±417	<0.05	113±71	556±413	<0.05

Notes: * — *p*>0.05; VATS — vdeo-assisted thoracoscopy

Table 4

Types of intrapleural trauma in patients with injuries in the scapular, axillary and paravertebral area of the chest

Injuries	Area of damage and type of surgery					
	Peripheral			Paravertebral		
	Traditional tactics (*n*=42)	Thoracoscopy (*n*=20)	*p*	Traditional tactics (*n*=30)	Thoracoscopy (*n*=23)	*p*
RTS	7.787±0.102	7.841	>0.05	7.768±0.137	7.841	>0.05
Prehospital hypotension, %	5 (11.9%)	3 (15%)	<0.05	7 (23.3%)	6 (26.1%)	<0.05
SI	0.77±0.1	0.8±0.12	>0.05	0.84±0.20	0.79±0.15	>0.05
Hemothorax, ml	163±167	538±343	<0.05	658±534	434±337	
Time gap *injury-surgery*, h	3.85±1.73	5.75±3.62	<0.05	4.74±2.94	6.59±5.00	>0.05
Bleeding rate, ml/h	93±89	143±102	<0.05	230±183	120±93	>0.05
ISS	6.9±2.5	10.2±4.3	>0.05	8.3±2.2	7.3±3.0	>0.05
Bleeding from ICV/ITV	5 / 2 (11.9% / 40%)	16 / 6 (80% / 37.5%)	–	12 / 12 (40% /100%)	15 / 6 (65.2% / 40%)	–
Lung	14 (33.3%)	4 (20%)	–	17 (56.7%)	11 (47.8%)	–
Diaphragm/TAI	1 / 0	1 / 0	–	–	2 / 1	–
Pericardium/heart	–	1 / 2	–	–	–	–

Notes: ICV — intercostal vessels (*a. et v. intercostalis.*); ITV — internal thoracic vessels (*a. et v. thoracica interna.*); SI — shock index; TAI — thoracoabdominal injury; ISS — injury severity score; RTS — revised trauma score

Table 5

Retrospective evaluation of VATS possibility in patients with injuries in the scapular, axillary and paravertebral area of the chest

Criteris for VATS possibility	Chest area				*p*
	Peripheral (*n*=42)		Paravertebral (*n*=30)		
	VATS		VATS		
	Yes (*n*=39)	No (*n*=3)	Yes (*n*=23)	No (*n*=7)	
Shock index	0.75±0.10	1.71; 1.06; 0.5	0.76±0.12	1.11±0.33	<0.05
Hemothorax, ml	163 ± 94	2500; 50; 600	408±334	1336±273	<0.05
Time, hours	3.94±1.6	3.00;1.66; 2.00	5.17±3.61	3.33±1.03	>0.05
Bleeding rate, ml/h	63±51	800; 47; 300	119±85	503±258	<0.05

Notes: VATS — video-assisted thoracoscopy

Upon thoracoscopy, the heavy bleeding from the chest wall was observed in one patient, the moderate bleeding was observed in 10 patients, and the discontinued bleeding with symptoms of unstable hemostasis was observed in 5 patients. The ITV trauma was revealed in one patient, and the ICV trauma was revealed in 5 patients. Coagulation of wounds was performed in 9 (56.3%) patients, pericostal stitches and vessels clipping were performed in 4 (25%) patients. Conversion from thoracoscopy to TT was required in 3 (18.8%) victims for reasons not related to bleeding from the chest wall.

The average depth of audited lung injury was 1.8±0.8 cm. In 2 victims, the moderate bleeding from the wound was observed and the discontinued bleeding with symptoms of unstable hemostasis was observed in one patient. Endosurgical suturing of lung wounds was performed in 2 patients, coagulation was performed in one patient. Thoracoscopy was converted to TT in one case due to a deep lung wound and injury of segmental vessels.

The wound of the diaphragm, not penetrating into the abdominal cavity, was diagnosed in one victim with an injury in the fourth intercostal space on the anterior axillary line. The wound was sutured during thoracoscopy.

The wound of the pericardial fat occurred in one case. In 2 patients, we diagnosed a wound of the left ventricle (*AIS*-3). Wounds of the chest wall were located in the third, fourth and fifth intercostal space on the anterior axillary line. TT was performed in all cases.

Thoracoscopy was converted to TT in 4 (20%) patients. The reason for that was the cardiac trauma in one patient, bleeding from ITVs, deep lung damage of subsegmental vessels and bronchi, impossibility of one-lung ventilation in the other patient.

Traditional tactics was performed in 42 (11.7%) suffered with injuries in the projection of the peripheral lung area. The wounds in the axillary area of the chest were revealed in 32 cases, in the scapular area — in 10 victims (Table 4).

The heavy bleeding from the chest wall occurred in one victim, the moderate bleeding occurred in 2 cases and signs of unstable hemostasis were in one case. Recent bleedings were revealed in 8 patients, the external bleeding was noted in one patient.

The moderate bleeding was revealed in 2 (14.3%) patients with lung trauma. Deep lung injuries were detected in 2 cases.

There was one blunt diaphragmatic trauma in the fifth intercostal space on the anterior axillary line.

DPS and PWD were performed in 36 (85.7%) patients. AT was performed in one patient with a wound in the fifth intercostal space on the posterior axillary line. TT was performed in 5 patients. An absolute indication for TT was heavy intrapleural bleeding in one patient.

Retrospective evaluation showed that thoracoscopy had been possible in 92.9% of patients with the chest wound in the projection of the peripheral lung area (axillary and scapular area (see Table 5). In 5 of them, thoracoscopy would be possible after PWD. Thoracoscopy was possible, but inadequate in one victim with minimal manifestations of PCT such as tissue emphysema. Thoracoscopy was contraindicated in 3 patients: with heavy intrapleural bleeding, pressure intrapulmonary hematoma and severe bradysystolic atrial fibrillation, and in a patient with a wound that was comparable in its size with the lateral thoracotomy.

Injuries of the chest paravertebral area. These patients more often had prehospital hypotension due to more frequent damage to ICVs and more frequent lung injury (see Table 4).

During thoracoscopy, the heavy bleeding from the wounds of the chest wall were observed in 2 patients, the moderate bleeding was observed in 9 cases, unstable hemostasis was in 4 patients. Coagulation was performed in 12 victims, pericostal stitches were put in 2 patients. Thoracoscopy was converted to TT in one patient.

The average depth of the lung wound was 1.3±1.2 cm. The moderate bleeding was observed in 5 (45.5%) patients. Endosurgical suturing of lung wounds with a depth of 2.1±1.4 cm was performed in 6 affected, coagulation of a wound with a depth of 0.3±0.1 cm was performed in 4 patients. There were no conversions from thoracoscopy to TT.

The wounds of the diaphragm were diagnosed in 2 cases (blunt — 1, penetrating — 1) and were located on its posterior slope. In both of these observations, the wounds were sutured endosurgically.

Conversion from thoracoscopy to TT was performed in 1 (4.3%) affected due to the heavy bleeding from ICSs.

Among patients treated by ***conventional methods***, a lung was damaged most frequently. The bleeding from a lung injury was observed in 5 (16.7%) patients, the heavy bleeding was observed in 1 patient.

The heavy bleeding from the wounds of the chest wall injury was associated with the ICVs trauma in 8 (26.7%) patients. The moderate bleeding was diagnosed in one patient, the discontinued bleeding was diagnosed in 3 patients. ICVs were the only source of bleeding.

DPS and PWD were performed in 19 (63.3%) patients. The AT was performed through the wound canal in 6 (20%) victims. Expansion of the wound in the paravertebral area for exploration and elimination of intrapleural damage are extremely traumatic and ineffective. TT was performed in 5 (16.7%) suffered with the heavy intrapleural bleeding and shock.

Retrospective evaluation showed that the thoracoscopy had been possible in 21 (70%) affected with symptoms of PCT and wounds of the paravertebral area of the chest (Table 5). Thoracoscopy could be performed in a single patient. Thoracoscopy was possible but inadequate in 2 patients with minimal symptoms of PCT and considerable period since the injury (18 and 6 hours). Contraindications for thoracoscopy were observed in 7 (23.3%) patients with the heavy intrapleural bleeding.

Thoracoscopy in "low" injuries to avoid TAI [20] and in wounds in the projection of the heart [28, 17] has been reported more often recently. A significant incidence of intrapleural bleeding associated with wounds of chest wall vessels, lung (in injuries in the paravertebral area of the chest), upper parts of the cardiac area (the second and third intercostal space), female breasts, above the spine of the scapula, suggests a wider use of thoracoscopy. This is supported by data on patients who had underwent TT. Thus, 53.2% of patients had absolute contraindications for it, while thoracoscopy could be performed in 42.2% of patients after TT. Among patients who had underwent TT to exclude TAI, thoracoscopy could be carried out in 79.4% of cases. Retrospective evaluation showed that the overall performance of thoracoscopy had been possible in 70% of patients with PCT. And 29.1% of patients had absolute contraindications for this procedure.

CONCLUSION

Retrospective analysis shows that thoracoscopy is an effective method of surgical treatment of patients with PCT, which may be performed in 70% of patients with chest wounds. Endosurgical technologies are possible for hemodynamically stable patients with chest wounds of different location. Thoracoscopy is most effective for injuries of the diaphragmatic, cardiac, diaphragmatic-cardiac and paravertebral area of the chest, as the traditional tactics in this case implies thoracotomy to diagnose life-threatening injuries that have not yet manifested. Endosurgical technologies help reduce the incidence of thoracotomies performed in relative indications.

RESUME

1. The analysis of the severity of injuries in victims, depending on the location of chest wounds showed that addition of extra topographic anatomical areas of the chest wall to traditionally known, accurately predicts the frequency and type of trauma of organs and anatomical structures.

2. The performed traditional surgeries have shown that thoracoscopy may be reasonably performed in a significant number of patients with chest trauma and stable hemodynamic condition to exclude injury to vital organs and repair damage that does not require thoracotomy.

REFERENCES

1. Demetriades D., Velmahos G.C. Penetrating injuries of the chest: indications for operation. *Scand J Surg*. 2002; 91 (1): 41–45.
2. Renz B.M., Feliciano D.V. Gunshot wounds to the right thoracoabdomen: A prospective study of nonoperative management. *J Trauma*. 1994; 37 (5): 737–744.
3. Reece I.J., Davidson K.G. Emergency surgery for stab wounds to the heart. *Ann R Coll Surg Engl*. 1983; 65 (5): 304–307.
4. Cothren C.C., Moore E.E. Emergency department thoracotomy for the critically injured patient: Objectives, indications, and outcomes. *World J Emerg Surg*. 2006; 1: 4.
5. Sotnichenko B.A., Glushko V.I., Makarov V.I., et al. Taktika khirurga pri otkrytykh sochetannykh povrezhdeniyakh grudi mirnogo vremeni [The tactics of the surgeon at the open combined injuries of chest in peacetime]. *Byulleten' VSNTs SO RAMN*. 2007; 4: 111–114. (In Russian).
6. Ashraf S.S., Volans A.P., Sharif H., et al. The management of stab wounds to the chest: sixteen years' experience. *J R Coll Surg Edinb*. 1996; 41(6): 379–381.
7. Gambazzi F., Schirren J. Thoracic drainage. What is evidence based? *Chirurg*. 2003; 74 (2): 99–107.
8. Abakumov M.M., Isfakhani A.K. Khirurgicheskaya taktika pri nozhevykh levostoronnikh torakoabdominal'nykh raneniyakh [Surgical approach in left-sided thoracoabdominal stab wounds]. *Vestnik khirurgii im II Grekova*. 1997; 156 (1): 86–90. (In Russian).
9. Uribe R.A., Pachon C.E., Frame S.B., et al. A prospective evaluation of thoracoscopy for the diagnosis of penetrating thoracoabdominal trauma. *J Trauma*. 1994; 37 (4): 650–654.
10. Murray J.A., Demetriades D., Cornwell E.E. 3rd, et al. Penetrating left thoracoabdominal trauma: the incidence and clinical presentation of diaphragm injuries. *J Trauma*. 1997; 43 (4): 624–646.
11. Leppaniemi A., Haapiainen R. Occult diaphragmatic injuries caused by stab wounds. *J Trauma*. 2003; 55 (4): 646–650.
12. Kutushev F.Kh., Korolev M.P., Sagatinov R.S., Michurin N.V. Diagnostika i khirurgicheskaya taktika pri raneniyakh serdtsa i perikarda [Diagnostics and surgical tactics in wounds of the heart and pericardium]. *Vestnik khirurgii im II Grekova*. 1995; 1: 72–74.
13. DeGennaro V.A., Bonfils-Roberts E.A., Ching N., Nealon T.F. Jr. Aggressive management of potential penetrating cardiac injuries. *J Thorac Cardiovasc Surg*. 1980; 79 (6): 833–837.
14. Goiti J.J., Smith G.H. Emergency surgery for stab wound to the heart. *Ann R Coll Surg Engl*. 1984; 66 (3): 221–222.
15. Pons F., Lang-Lazdunski L., de Kerangal X., et al. The role of videothoracoscopy in management of precordial thoracic penetrating injuries. *Eur J Cardiothorac Surg*. 2002; 22 (1): 7–12.
16. Valentine C., East J. Subxiphoid pericardial window in stable cardiac proximity injuries. *West Indian Med J*. 2003; 52 (4): 296–299.
17. Navsaria P.H., Nicol A.J. Video-assisted thoracoscopic pericardial window for penetrating cardiac trauma. *S Afr J Surg*. 2006; 44 (1): 18–20.
18. Thorson C.M., Namias N., Van Haren R.M., et al. Does hemopericardium after chest trauma mandate sternotomy? *Trauma Acute Care Surg*. 2012; 72 (6): 1518–1524; discussion 1524-1525.
19. Nicol A.J., Navsaria P.H., Hommes M., et al. Sternotomy or drainage for a hemopericardium after penetrating trauma: a randomized controlled trial. *Ann Surg*. 2014; 259 (3): 438–442.
20. Martinez M., Briz J.E., Carillo E.N. Video thoracoscopy expedites the diagnosis and treatment of penetrating diaphragmatic injuries. *Surg Endosc*. 2001; 15 (1): 28–32.
21. Förster R., Storck M., Schäfer J.R., et al. Thoracoscopy versus thoracotomy: a prospective comparison of trauma and quality of life. *Langenbeck's Arch Surg*. 2002; 387 (1): 32–36.
22. Voskresenskiy O.V., Abakumov M.M., Radchenko Yu.A. Znachenie shokovogo indeksa Al'govera v vybore khirurgicheskoy taktiki pri ranenii grudi [The value of Allgower's shock index in the choice of surgical approach for chest wound]. *Khirurgiya*. 2009; 12: 43–48. (In Russian).
23. Voskresensky O.V. Kriterii bezopasnogo vypolneniya torakoskopii u postradavshikh s raneniem grudi [Criteria for the safe performance of videothoracoscopy in patients with chest wound]. *Zhurnal im N V Sklifosovskogo Neotlozhnaya meditsinskaya pomoshch'*. 2015; 1: 33–37. (In Russian).
24. Abakumov M.M. *Mnozhestvennye i sochetannye raneniya shei, grudi, zhivota* [The multiple and combined injuries of the neck, chest, abdomen]. Moscow: Binom-Press Publ., 2013. 688 p. (In Russian).
25. Abakumov M.M., Voskresenskiy O.V., Zhestkov K.G. Torakoskopiya v lechenii vnutriplevral'nogo krovotecheniya pri raneniyakh sosudov grudnoy stenki [Thoracoscopy in the treatment of intrapleural bleeding wounds of the chest wall vessels]. *Khirurgiya*. 2007; 2: 4–9. (In Russian).
26. Abakumov M.M., Voskresenskiy O.V., Zhestkov K.G. Torakoskopiya v diagnostike i lechenii raneniy legkogo [Thoracoscopy in the diagnosis and treatment of lung wounds]. *Khirurgiya*. 2007; 10: 4–9. (In Russian).
27. Vagner E.A. *Pronikayushchie raneniya grudi* [Penetrating chest wounds]. Moscow: Meditsina Publ., 1975. 177 p. (In Russian).
28. Morales C.H., Salinas C.M., Henao C.A., et al. Thoracoscopic pericardial window and penetrating cardiac trauma. *J Trauma*. 1997; 42 (2): 273–275.

ARTICLE RECEIVED ON 26 AUG, 2015

FOR CORRESPONDENCE:
OLEG VYACHESLAVOVICH VOSKRESENSKY.,
SENIOR RESEARCHER, DEPARTMENT OF EMERGENCY THORACOABDOMINAL SURGERY
N.V. SKLIFOSOVSKY RESEARCH INSTITUTE FOR EMERGENCY MEDICINE OF THE MOSCOW HEALTHCARE DEPARTMENT, MOSCOW, RUSSIAN FEDERATION
E-MAIL: OLEGVSKR@MAIL.RU