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Minimally Invasive Treatment of Penetrating Thoracic Injuries at a National Trauma Centre - Introduction of an Algorithm and Conduct of a Proof-of-concept Study

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Abstract

Introduction: The minimally invasive approach of video-assisted thoracoscopic surgery (VATS) has become standard practice in thoracic surgery. Its role in the management of penetrating thoracic trauma has not yet been clearly defined, however. Considering the growing threat of terrorist attacks in Europe, the injury patterns that such attacks typically cause and the resulting increase in the number of cases of penetrating thoracic trauma, it is of utmost importance that the management of such trauma be standardised and the role of VATS evaluated.

In particular because of the relatively low number of penetrating thoracic injuries in Germany, it is vital that surgeons know the optimised and standardised methods of trauma management.

Material and Methods: This paper presents an algorithm for the management of penetrating thoracic trauma in which VATS is firmly established. In addition, the data of all thoracic trauma patients who received treatment at a national trauma centre between 2012 and 2016 were recorded in databases and evaluated. The aim was to examine the practicability of the introduced algorithm within the framework of a proof-of-concept study. Furthermore, the treatment concepts for the more common blunt thoracic trauma and the far less frequent penetrating thoracic trauma are compared. Finally, the literature search helped to verify our algorithm and identify possible contraindications for VATS in penetrating thoracic trauma management.

Results: A total of 340 patients with thoracic trauma received treatment between 2012 and 2016. Of those, 19 patients (6%) suffered from penetrating thoracic trauma. All penetrating thoracic injuries were treated based on the algorithm and using minimally invasive techniques. The most common reason for VATS was haemothorax, followed by injuries to the lung parenchyma. Unlike blunt thoracic trauma, which was most commonly treated conservatively or with chest tube insertion, penetrating thoracic trauma was usually treated invasively. The median length of hospital stay was 15 days (6–37 days). The mean ISS (injury severity score) was 17 (16–25) and the intraoperative and postoperative morbidity rate was 33.3%. There were no cases of intraoperative or postoperative mortality.

Discussion: VATS is a safe method for managing penetrating thoracic trauma in haemodynamically stable patients. It must therefore be firmly established in the management algorithm. Studies with a larger number of cases are necessary to support these results along with the practicability of the algorithm introduced in this paper.

Keywords: Penetrating thoracic injury; Thoracoscopic surgery; Thoracic trauma; VATS; Stab wounds

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Introduction

Thoracic trauma accounts for 10–25% of trauma-related fatalities and, after traumatic brain injury and injury to the extremities, is the third most frequent type of trauma to result from serious traffic accidents [1,2]. In Germany, the majority of thoracic injuries are from a blunt mechanism of injury (95%). Penetrating injuries are still rare in Western Europe, constituting only 5% of all injuries. They include stab wounds (1.8%), gunshot wounds (0.6%) and other injuries (2.6%). Stab

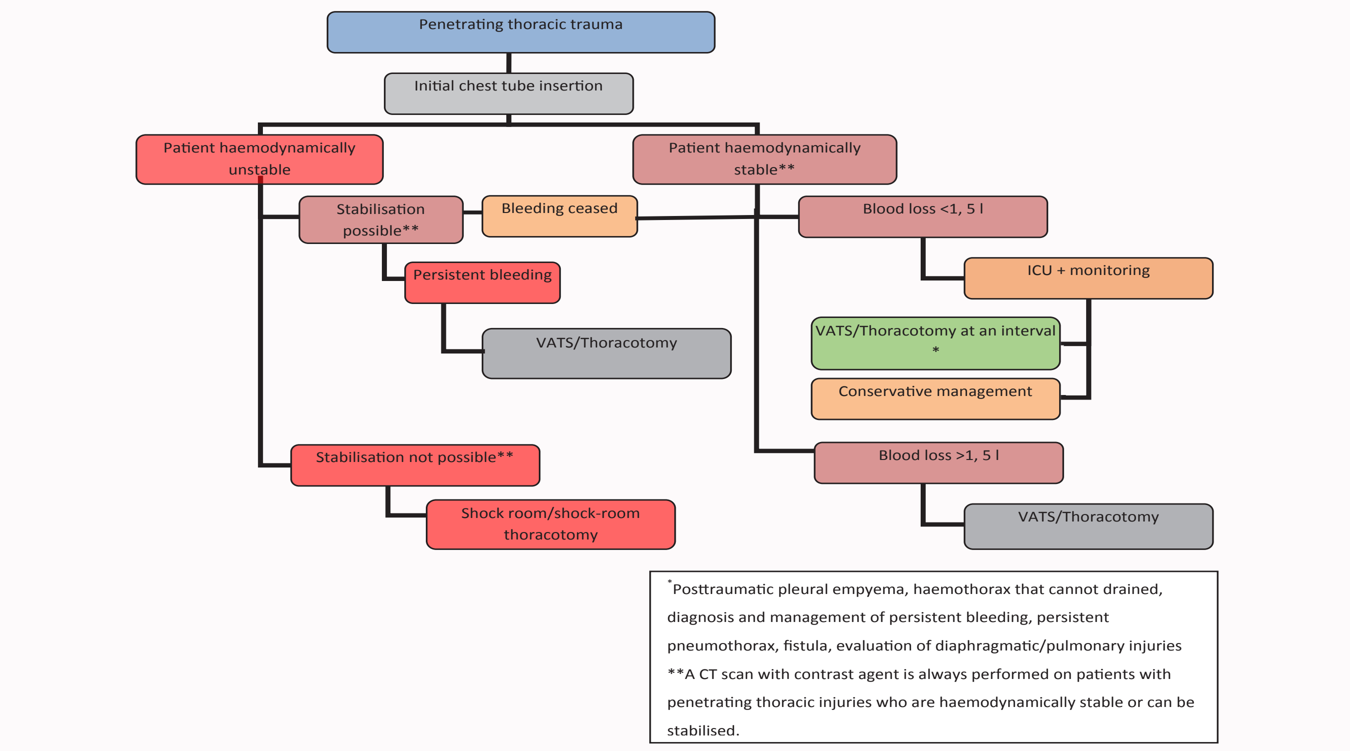

Figure 1: Algorithm for the management of penetrating thoracic trauma.

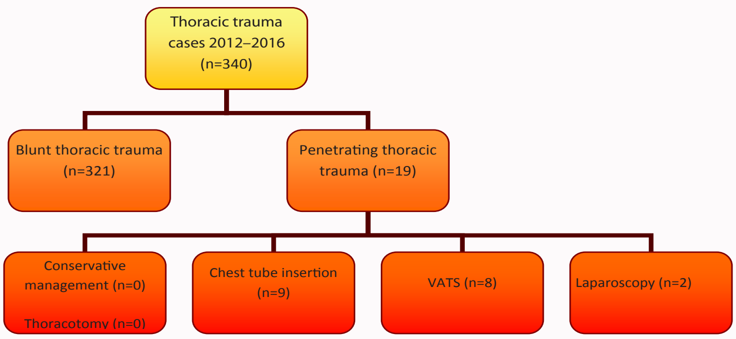

Figure 2: Overview of thoracic trauma cases 2012–2016.

wounds are mostly the result of violent crime (69.1%), followed by accidents (16.4%) and suicide attempts (14.5%) [3].

Owing to events such as those in Brussels, Paris, Munich, Istanbul, Nizza, Berlin, London and Manchester as well as the increased risk of penetrating thoracic injury even in Europe (although prevalence remains low), it is of vital importance that attending medical teams know which treatment is best for their patient.

In the past, if surgical treatment was indicated, penetrating thoracic trauma was managed with anterolateral thoracotomy or – time permitting – with sternotomy. Today, however, there is a growing tendency to use minimally invasive techniques [4,5].

The german S3 medical guideline on the treatment of patients with severe and multiple injuries recommends thoracotomy if the initial chest tube output is greater than 1,500 ml of blood or if bleeding continues at a rate of more than 250 ml/h for more than four hours. According to the guideline, immediate exploratory thoracotomy must be performed to manage penetrating thoracic trauma that causes haemodynamic instability. The guideline does not yet address minimally invasive approaches, in particular to the management of penetrating thoracic trauma [6].

There is, however, ongoing debate about indications for minimally invasive therapy and case- and patient-specific approaches [2]. A well-structured approach is particularly important if the clinical outcome for thoracic trauma patients is to be improved [7]. Algorithms have proven successful in this regard [8]. Patients with penetrating chest injuries who are treated with chest tube insertion in the shock room should, once they are haemodynamically stable, undergo additional CT imaging as soon as possible to identify any life-threatening injuries. This allows the medical team to quickly decide if surgical intervention is necessary in haemodynamically stable patients [9].

The aim of this paper is to introduce an algorithm for the treatment of penetrating thoracic trauma that integrates video-assisted thoracoscopic surgery (VATS). The practicability of this standardised treatment recommendation was assessed in a monocentric study of a homogenous patient population. Furthermore, a detailed literature search helped define the criteria that would facilitate or prevent minimally invasive treatment.

Material and Methods

Patients

Our study includes all thoracic injuries treated at the Department of General, Visceral and Thoracic Surgery of the German Armed Forces Central Hospital of Koblenz between 1 January 2012 and 31 December 2016 and recorded in the database. Patients transferred to another hospital before the end of treatment were excluded. For the purposes of this study we distinguished between blunt and penetrating thoracic trauma and analysed the treatment methods separately. Well over 100 multiple trauma patients with an average ISS >25 are treated each year at the German Armed Forces Central Hospital of Koblenz, which is a national trauma centre.

Algorithm for the management of penetrating thoracic trauma

The algorithm (Figure 1) introduced in this study was evaluated on the basis of the data of patients treated in our department. In this context, criteria for and against a minimally invasive approach to managing penetrating thoracic trauma were identified.

Initial management of penetrating thoracic trauma involved placing a chest tube. Patients are then divided into two groups depending on haemodynamic stability or instability.

If a patient is haemodynamically stable, the quantity of blood loss is a crucial parameter. With an initial blood loss of less than 1,500 ml, a patient will be closely monitored in the interdisciplinary intensive care unit. Persistent bleeding (more than 250ml/h over 4 hr) or retained haemothorax require VATS after 7 to 10 days. VATS is performed if blood loss exceeds 1,500 ml and the patient is haemodynamically stable or can be stabilised.

Shock-room thoracotomy is performed if a patient is haemodynamically unstable.

Statistical analysis

IBM SPSS Statistics© 20 (SPSS, Chicago, IL, USA) was used to perform a descriptive and statistical analysis of collected data. This included a calculation of the absolute numbers and mean values (Figure 1).

Review

In addition, available literature was analysed to be able to make reliable recommendations regarding indications and contraindications for VATS in the management of penetrating thoracic trauma. For the literature review, we searched the MEDLINE database (Pubmed) using the following search terms (MESH headings): (thoracic trauma OR penetrating thoracic injury OR penetrating thoracoabdominal trauma OR diaphragmatic injuries OR diaphragmatic rupture) AND (VATS OR thoracoscopy OR algorithm).

The literature search covered the relevant period from 1 January 1985 to 31 December 2016. We found 2748 related articles published during this period. A total of 311 abstracts were included as relevant, 154 of which prompted an analysis of the full text of the study. We included studies that included or focused on patients with thoracic trauma regardless of the duration and method of treatment. Studies on all indications for VATS were included, as were studies covering all levels of evidence and study designs. Case reports and case series with fewer than six patients were excluded.

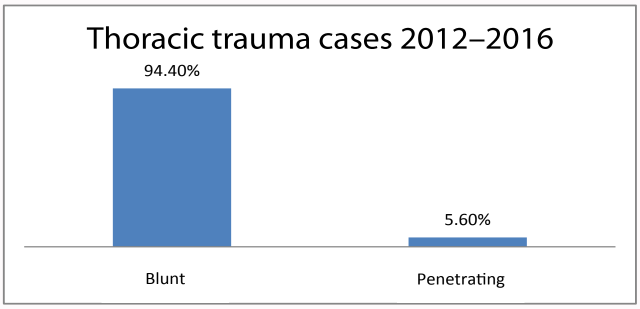

Diagram 1: Overview of thoracic trauma cases 2012–2016.

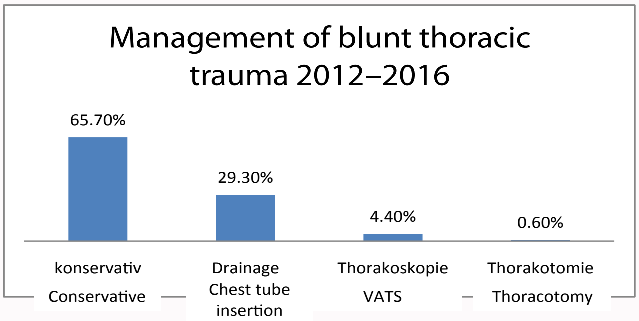

Diagram 2: Management of blunt thoracic trauma 2012–2016.

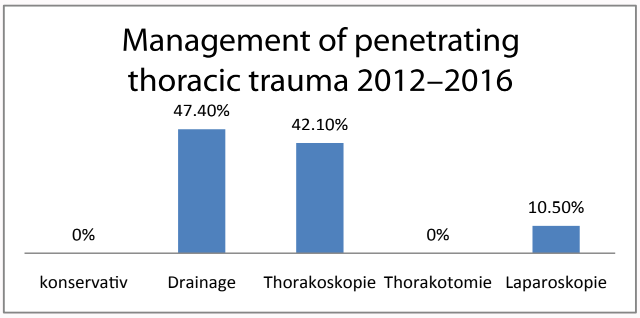

Diagram 3: Management of penetrating thoracic trauma 2012–2016.

Results

During this period, a total of 340 thoracic trauma patients underwent treatment at the German Armed Forces Central Hospital. Of these, 19 (6%) were patients who had sustained a penetrating thoracic injury, 7 of which were isolated and iatrogenic injuries with pneumothorax, which will not be considered any further to avoid bias due to the minor mechanism of injury. In terms of treatment, it became evident that most cases of blunt thoracic trauma were managed conservatively with analgesia and respiratory therapy (211, 65.7%) as well as chest tube insertion (94, 29.3%). Out of all cases of penetrating thoracic injury, 42.1% were managed with VATS, 10.5% with laparoscopy and 47.4% with drainage alone. A chest tube was always inserted after minimally invasive surgery. Thoracotomy was not required in any of the patients with penetrating thoracic trauma (Figure 2) (Diagrams 1-3) (Tables 1-3).

All 12 patients (the remaining cases after those with iatrogenic isolated pneumothorax had been excluded) with penetrating thoracic trauma were successfully treated with minimally invasive surgery based on the algorithm introduced in this paper. In nine cases, stab wounds were the cause of injury (among them injuries to the

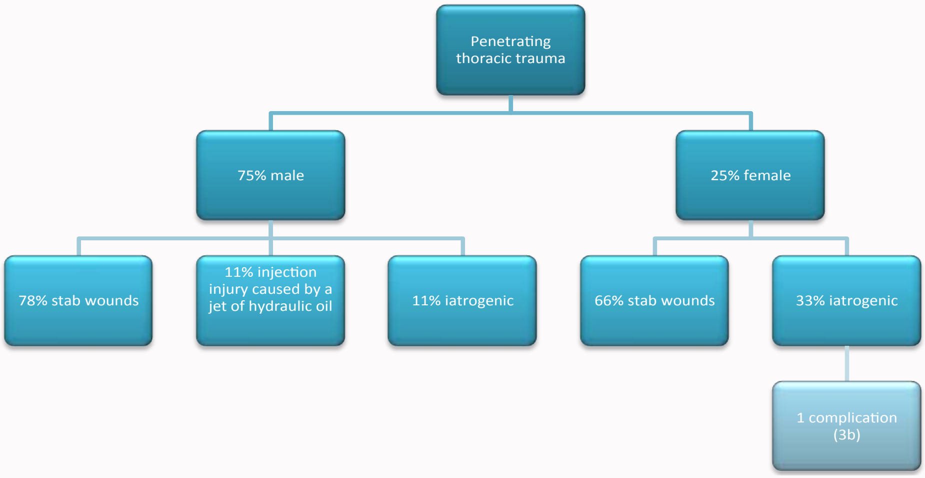

Figure 3: Overview of penetrating thoracic trauma.

Table 1:

Aetiology	Number (percentage)
Blunt thoracic trauma cases	321 (94.4%)
Penetrating thoracic trauma cases	19 (5.6%)
Total	340 (100%)

Table 2:

Management of penetrating thoracic trauma 2012–2016	Number (percentage)
Conservative treatment	0 (0%)
Chest tube insertion	9 (47.4%)
VATS	8 (42.10%)
Thoracotomy	0 (0%)
Laparoscopy	2 (10.5%)
Total	19 (100%)

Table 3:

Management of blunt thoracic trauma 2012–2016	Number (percentage)
Conservative treatment	211 (65.7%)
Chest tube insertion	94 (29.3%)
VATS	14 (4.4%)
Thoracotomy	2 (0.6%)
Total	321 (100%)

diaphragm or internal thoracic artery), two were iatrogenic lung injuries and one was an injection injury caused by a jet of hydraulic oil. Nine out of 12 patients were male and the mean age was 45 years. Three out of 12 patients immediately underwent VATS while in three other cases VATS was performed later after treatment with a chest tube alone was not successful. Another four patients were treated with chest tube insertion and diagnostic laparoscopy was performed in two patients (Table 4).

Patients were also examined with regard to hours of ventilation, need for catecholamines and blood products, length of stay in intensive care and total length of stay at hospital as well as the rate of complications. The Clavien-Dindo classification was used to grade complications during treatment. The time (in hours) between arrival at the shock room and surgery/chest tube insertion was also evaluated. In patients who received primary treatment, surgery/chest tube insertion was performed after 1 hr to 3 hr, except for one female patient who was treated with VATS for a progressive haemothorax after 72 hr. Patients were ventilated for an average of 18 hr (1 hr to 120 hr of ventilation). Two patients needed catecholamines and three needed erythrocyte concentrates. The median length of stay in hospital was 15 days (6–37 days), including an average of 5 days (0–30 days) in intensive care. The mean ISS was 17 (16–25). There were no cases of intraoperative or postoperative mortality. One patient (8.3%) developed complications graded 3b according to the Clavien-Dindo classification (Table 5) (Figure 3).

Results of review of literature regarding indications and contraindications for VATS

A literature review was conducted simultaneously to verify the postulated algorithm. In our analysis of the relevant literature of the last 28 years we were able to identify the following indications and contraindications.

VATS is an option for haemodynamically stable patients with a haemothorax or in patients with bleeding that requires diagnosis/treatment. One-lung ventilation and the possibility of placing the patient in a lateral position during surgery are vital criteria for VATS. Indications for secondary VATS following thoracic trauma include an incompletely drained haemothorax, posttraumatic pleural empyema and persistent pneumothorax/fistula [5,6,8,10,11]. VATS is a particularly important tool for diagnosing diaphragmatic rupture [10]. Benefits of a minimally invasive procedure include less postoperative pain, better postoperative lung function, preservation of respiratory muscle function and shorter hospital stays [12,13].

Contraindications for VATS include haemodynamic instability and all indications for thoracotomy described below. Relative contraindications are a chemical pleurodesis or decortication [14].

Indications for shock-room thoracotomy, on the other hand, include tracheobronchial injuries or thoracic wall defects, transmediastinal gunshot wounds, traumatic oesophageal or aortic rupture as well as haemodynamically relevant cardiac tamponade in haemodynamically unstable patients [15].

As it is generally associated with an unfavourable prognosis, thoracotomy is only performed in the shock room in patients in extremis, e.g. if open-chest cardiac massage is required. Any such attempt is be associated with a poor prognosis when cardiopulmonary resuscitation after blunt trauma exceeds 10 minutes without a return

Table 4: Overview of epidemiology, kinematics, and management of perforating thoracic trauma at the German Armed Forces Central Hospital of Koblenz 2012–2016.

Patient	Age	Sex	Kinematics	Injury	Treatment	Time between admission to hospital and surgery in hrs
Patient 1	22	Male	Stab wound	Diaphragm	Primary laparoscopy	1
Patient 2	46	Male	Stab wound	Haemopneumothorax	Secondary VATS	648
Patient 3	45	Female	Stab wound	Internal thoracic artery	Primary VATS	1
Patient 4	23	Male	Iatrogenic	Bronchopulmonary segment 5 (left lung)	Secondary VATS	400
Patient 5	17	Male	Injection injury caused by jet of hydraulic oil	Left upper lobe of lung	Primary VATS	3
Patient 6	73	Male	Stab wound	Haemopneumothorax	Drainage	2
Patient 7	62	Male	Stab wound	Pleura	Drainage	1
Patient 8	36	Male	Stab wound	Haemopneumothorax	Drainage	1
Patient 9	18	Male	Stab wound	Haemopneumothorax	Secondary VATS	600
Patient 10	58	Male	Stab wound	Pneumothorax	Drainage	1
Patient 11	82	Female	Iatrogenic	Haemopneumothorax	Primarily VATS	72
Patient 12	59	Female	Stab wound	Haemopneumothorax	Primary laparoscopy	1

Table 5: Overview of intensive parameters.

Patient	Hours of ventilation	Catecholamines	Blood products	Length of stay	Length of stay in intensive care	Complications according to Clavien-Dindo	ISS
Patient 1	15	none	none	6	4	none	17
Patient 2	3	none	1 g tranexamic acid	12	2	none	16
Patient 3	10	yes	8 units of PRBCs, 8 units of FFP, 4 g fibrinogen, 1 g tranexamic acid, 24 ug Minirin	20	1	none	25
Patient 4	120	none	none	18	10	none	16
Patient 5	8	none	none	10	6	none	16
Patient 6	28	yes	1 unit of PRBCs	12	6	none	18
Patient 7	2	none	none	10	1	none	16
Patient 8	1	none	none	8	0	none	16
Patient 9	20	none	none	25	2	none	16
Patient 10	10	none	none	6	3	none	16
Patient 11	2	none	None	37	30	3b Surgical intervention under general anaesthesia (evacuation of thoracic wall haematoma)	16
Patient 12	2	none	none	12	1	none	16

Table 6: Indications and contraindications for VATS.

Indications	Contraindications
Haemodynamic stability+haemothorax	Haemodynamic instability
Haemothorax that cannot be drained completely (secondary VATS)	(chemical pleurodesis/decortication -> relative contraindications)
Posttraumatic pleural empyema (secondary VATS)	Impossibility of one-lung ventilation and placing patient in lateral position
Persistent pneumothorax/fistula (secondary VATS)	Tracheobronchial injury
Diagnosis of perforated diaphragm	Transmediastinal gunshot wounds
Evaluation of pulmonary injuries	Traumatic oesophageal/aortic rupture
	Haemodynamically relevant pericardial tamponade

of spontaneous circulation (ROSC) or when cardiopulmonary resuscitation after a penetrating trauma exceeds 15 minutes without a ROSC [7]. Thoracotomy in the shock-room room also appears to be futile in patients with multiple penetrating injuries to the heart or great vessels [16] (Table 6).

Discussion

Until a few years ago, thoracotomy was the gold standard in managing penetrating thoracic trauma. Since VATS with all its advantages for patients has become standard procedure in elective thoracic surgical intervention, its importance in managing penetrating thoracic injuries has also steadily increased over recent years [4,5].

The current german S3 medical guideline provides recommendations for the treatment of thoracic trauma but does not address penetrating thoracic trauma [6]. The role of VATS in the management of penetrating trauma is not mentioned either. There are relevant differences between blunt and penetrating thoracic trauma when it comes to aetiology, diagnostics, treatment and complications, which surgeons involved in trauma management, must be aware of [17-20]. Injuries that affect two cavities are particularly relevant because a decision must be made on which to treat first. This decision should always be made on as the case may be and depending on the urgency [8,21-24].

On the basis of the obvious and increasing terrorist threat in Europe, guidelines that include relevant recommendations as well as appropriate training are required, in particular for the management of penetrating thoracic trauma.

Other studies describe chest tube insertion as the only treatment required in 75% to 85% of cases of thoracic injury [4,25,26]. Surgical intervention is required in 15% to 30% of penetrating thoracic trauma patients [1,25,27]. Of haemodynamically stable patients with thoracic trauma, 75% to 81% can be treated with VATS and 19% to 25% with thoracotomy. Conversion from VATS to thoracotomy is required in 15% to 24% of cases [12,28].

In our study, VATS was afforded a significant role within the algorithm presented. Based on the algorithm, six of the 12 patients were treated with VATS, four with chest tube insertion and two with laparoscopy. The length of stay in intensive care was short and only few patients needed catecholamines. Polytrauma patients with an ISS >16 can also undergo VATS with a low rate of complications. We conclude that the algorithm is of considerable help in choosing the most effective treatment for penetrating thoracic trauma. VATS is a safe treatment method for haemodynamically stable patients with penetrating thoracic trauma within the first 24 hr. The results of patients included in our study who received primary treatment support this assertion. VATS should also be considered when diagnosing non-specific thoracic/abdominal injuries [5,6,8,10,11,26,29,30]. In haemodynamically stable patients, VATS is not only a safe method if performed by an experienced surgeon but also associated with low complication rates (less postoperative pain, better lung function and shorter hospital stay with faster recovery) [12,13]. VATS is becoming an increasingly important tool in the diagnosis and management of penetrating thoracic trauma. The algorithm introduced here is one option to integrate VATS into standardised treatment.

In addition to the established ATLS and DSTC concepts, VATS is particularly useful in emergencies to ensure that patients receive optimal treatment as early as possible [31]. The results of our patient group confirmed the algorithm we developed. Nevertheless, contraindications must be taken into account. They include haemodynamic instability, tracheobronchial injuries, transmediastinal gunshot wounds, traumatic oesophageal/aortic rupture, haemodynamically relevant pericardial tamponades, and impossibility of one-lung ventilation and, in some cases, chemical pleurodesis/decortication [14-16].

Owing to the small number of patients included in this study, further prospective studies are needed to confirm our findings and the algorithm we developed.

Conclusion

Early diagnosis and immediate treatment of life-threatening injuries following penetrating thoracic trauma are of vital importance. Still there is no generally applicable and specific algorithm for differentiated treatment of penetrating thoracic trauma that integrates VATS. Our algorithm can make a substantial contribution to ensuring appropriate management of penetrating thoracic trauma.

Overall, we can conclude that chest tube insertion is sufficient treatment in most cases [25,26,4,31]. Otherwise, if surgical treatment is indicated, haemodynamically stable patients should undergo VATS as soon as possible and thoracotomy should be performed if a patient is haemodynamically unstable [31]. In haemodynamically stable patients with penetrating thoracic injuries, VATS can often replace thoracotomy and is, quite rightly, becoming ever more important [12,2].

Conclusions for clinical practice:

- Thoracic trauma accounts for 10% to 25% of trauma-related mortality.
- In 75% to 97% of cases, conservative treatment with a chest tube is sufficient; however, 10% to 30% of penetrating trauma patients require surgical intervention.
- VATS is only indicated in patients who are haemodynamically stable or can be stabilised.
- In case of haemodynamic instability, shock-room thoracotomy is the procedure of choice.

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