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How early should VATS be performed for retained haemothorax in blunt chest trauma?

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ABSTRACT

Background: Blunt chest injury is not uncommon in trauma patients. Haemothorax and pneumothorax may occur in these patients, and some of them will develop retained pleural collections. Video-assisted thoracoscopic surgery (VATS) has become an appropriate method for treating these complications, but the optimal timing for performing the surgery and its effects on outcome are not clearly understood.
Materials and methods: In this study, a total of 136 patients who received VATS for the management of retained haemothorax from January 2003 to December 2011 were retrospectively enrolled. All patients had blunt chest injuries and 90% had associated injuries in more than two sites. The time from trauma to operation was recorded and the patients were divided into three groups: 2–3 days (Group 1), 4–6 days (Group 2), and 7 or more days (Group 3). Clinical outcomes such as the length of stay (LOS) at the hospital and intensive care unit (ICU), and duration of ventilator and chest tube use were all recorded and compared between groups.
Results: The mean duration from trauma to operation was 5.9 days. All demographic characteristics showed no statistical differences between groups. Compared with other groups, Group 3 had higher rates of positive microbial cultures in pleural collections and sputum, longer duration of chest tube insertion and ventilator use. Lengths of hospital and ICU stay in Groups 1 and 2 showed no statistical difference, but were longer in Group 3. The frequency of repeated VATS was lower in Group 1 but without statistically significant difference.
Discussion: This study indicated that an early VATS intervention would decrease chest infection. It also reduced the duration of ventilator dependency. The clinical outcomes were significantly better for patients receiving VATS within 3 days under intensive care. In this study, we suggested that VATS might be delayed by associated injuries, but should not exceed 6 days after trauma.

Introduction

Blunt injury is the leading cause of chest trauma. Pneumothorax and haemothorax often occur after severe chest trauma. Approximately 85% of patients with pneumothorax and haemothorax can be successfully treated with pain control or simple tube thoracostomies [1–3]. The remaining patients with retained pleural collections should be managed with further surgical interventions to prevent complications such as empyema in the early phase or fibrothorax in the late phase. These complications will increase morbidity and mortality [4–6].

Video-assisted thoracoscopic surgery (VATS) has become a common and acceptable method for diagnosis of intra-thoracic lesions from the 1990s because of advanced developments in this surgical technique [7–9]. It is also widely used in treating retained pleural collections because it is only slightly more invasive

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compared with chest tube thoracostomy, and has been shown as a simple technical alternative to open thoracotomy [10–12]. Although VATS offers many benefits, the optimal timing for performing the surgery and its effects on patient's outcomes are not clearly understood. Numerous recent studies describe that the earlier the interventions of injured chest are performed, the better the prognosis of patients [13–15]. However, there exist wide variations in the exact recommended time for operation after trauma in these studies, especially when complicated with associated injuries [7–9,14–16].

The main reasons for prolonging the hospitalisation of trauma patients are infections and respiratory failure [1,17,18]. We hypothesised that early VATS may play a role in preventing post-traumatic infections and decrease the duration of acute respiratory failure, which in turn can shorten the whole treatment course. The purpose of this study was to identify the most appropriate time for implementing VATS to treat pleural collection and its effects on respiratory failure in patients with multiple traumas.

Materials and methods

Setting and patients

This retrospective study was conducted in a level-1 trauma medical centre located in southern Taiwan, which has 1300 beds with approximately 1200 emergent traumatic visits per month. All patients with blunt thoracic injuries that were admitted to the emergency department (ED) during the study period were included. Data of patients that developed residual haemothorax and received video-assisted thoracoscopy (VATS) were prospectively collected. Patient data including demographics, mechanism of injury, numbers of rib fractures (confirmed by chest CT), associated injuries, injury severity score (ISS), pulmonary contusion score, postoperative complications, respiratory failure, number of ventilator days, length of stay (LOS) in intensive care unit (ICU), and LOS in hospital were all collected. This study was approved by the ethics committee of the hospital in which this study was conducted.

Patients older than 14 years of age that were admitted to the trauma unit in our hospital with blunt chest trauma alone or with other associated injuries in different anatomic regions were included in this study. All patients with haemothorax needing to be drained were treated with a 36Fr (This size of chest tube is chosen due to Asian people having smaller body size) straight thoracostomy tube at the time of initial evaluation. These procedures were performed by trauma surgeons with first-line service. Patients had minimal pleural collections initially without thoracostomy tubes inserted but admitted for further observation were not included. In this study, patients that were hemodynamically unstable with more than 1500 mL of blood drainage from the initial tube thoracostomy or had ongoing blood losses of more than 250 mL/h lasting for at least 4 h and received emergency thoracotomy were excluded. Furthermore, patients with disruptions of mediastinal structures (including heart, great vessels and tracheobronchial trees) were excluded. Patients with severe medical diseases like liver cirrhosis, chronic obstructive pulmonary disease, chronic renal disease under hemodialysis, and chronic heart failure that would increase complications after trauma were also excluded.

All patients received chest-computed tomography (CT) in the emergency department. After completing both primary and secondary surveys at trauma bay, all patients were admitted into trauma ICU for further care because nearly all patients had multiple injured sites. Chest roentgenogram was performed routinely after admission. If the density of the following chest X-ray showed increasing density, secondary chest CT was performed to diagnose and estimate the retained pleural collections. There are two indications for VATS to be performed. One is the retained volumes estimated to exceed 300 mL. The other is formation of para-pneumonic effusions which appeared in CT as separate lobulated pleural collections. Often, retained pleural collections do not happen immediately; hence, all secondary CT and VATS are performed at least 48 h after trauma. The associated injuries were recorded with abbreviated injury score (AIS) following the 2005 edition. Patients with AIS exceeding grade 3 were also excluded.

All patients received VATS performed by thoracic surgeons according to the same standard procedures. The surgery was performed in the operating room under general anaesthesia with the patients in lateral position on the unaffected side. All patients received prophylactic antibiotics before surgical intervention. A double-lumen endobronchial tube was used for one lung procedure and provided a better view for the assessment of the chest and its contents. Two thoracostomies were performed for inserting thoracoscopes and endoscopic instruments, respectively. All patients had collections evacuated, clots removed, the pleura decorticated, and were irrigated with normal saline solutions. Thereafter, the lung was re-expanded. Finally, two 36Fr drainage tubes were fixed to the pleural cavity and the patient was transferred to the trauma ICU for further postoperative care. Routine chest roentgenograms were performed after operations. In case of recurrence of retained pleural collections, secondary VATS would be performed for adequate drainages. Following either procedure, the thoracostomy tubes were removed at the discretion of the thoracic surgeon when the drainage was less than 100 mL/24 h and no air leak was present.

Post-trauma complications included the development of infections and prolonged ventilations. Postoperative outcomes indicated hospital mortality, number of ventilator days, ICU, and hospital LOS. Empyema was defined as an accumulation of pus in the pleural space (confirmed by bacteria culture). Pneumonia was defined as an infective condition with bacteria cultured from the sputum after trauma. Sepsis was defined as a systemic response to lung infection with bacteremia.

Statistical analysis

Patients were divided into three groups according to when VATS was performed, namely Group 1, within 2–3 days; Group 2, within 4–6 days; and Group 3, after more than 6 days. Group 1 was formed on the basis of Meyer's prospective study that showed very early VATS within 3 days provided better clinical outcomes [8]. Group 3 was based initially on intervals that were greater than the average, with exploratory analysis confirming that this gave better discrimination of outcome than a later cut-off point. An initial descriptive analysis was performed for every variable, and the frequencies and averages in the groups were determined. Numerical variables were presented as mean and standard deviation (SD) or median and quartiles. The chi-square or Fisher's test was employed to evaluate the categorical or proportional variables between groups. The continuous variables were compared between groups using tests of analysis of variance. A $P < 0.05$ was considered statistically significant. All data were analysed using the SPSS 16.0 statistical software.

Results

A total of 1663 patients with chest injuries were admitted to our hospital from January 1, 2003 to December 31, 2011. A total of 145 thoracoscopic drainages performed for clotted post-traumatic haemothorax were selected. A 2-year-old patient and 8 adult

Table 1
Demographic analysis of patients treated with VATS for blunt trauma (n = 136).

Mean age (yr) (SD)	51.9 (16.2)
Males (%)	107 (78.7%)
Mechanisms of injury	
Motorcyclist	87
Vesicle driver or passenger	14
Fall accident	21
Cyclist or pedestrian	14
Anatomic injury score (AIS) of thoracic injury (mean, SD)	3.3 (0.5)
Associated injuries	
Head injury (%)	55 (40.4%)
Abdominal injury (%)	39 (28.7%)
Extremity injury (%)	100 (73.5%)
Multiple trauma	120 (88.2%)
ISS (mean, SD)	18.1 (6.0)
Positive microbial cultures after trauma	
From sputum	54 (39.7%)
From pleural effusion	29 (21.3%)
From blood	16 (11.8%)
Time from trauma to perform VATS (days) (mean, SD)	5.9 (4.6)
Secondary VATS	14 (10.3%)
Time of ventilator use (days) (mean, SD)	7.8 (11.4)
Time of chest tube use (days) (mean, SD)	12.7 (9.1)
ICU length of stay (days) (mean, SD)	8.7 (7.1)
In-hospital length of stay (days) (mean, SD)	24.1 (18.4)
Mortality (none related to VATS)	3 (2.2%)

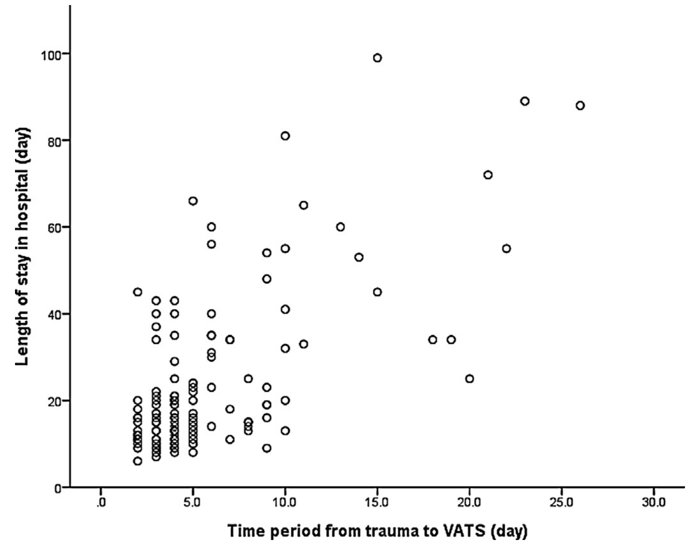

Fig. 1. Relation between LOS in hospital and timing of VATS.

patients with penetrating injuries were excluded. The characteristics of each group are shown in Table 1. There were 107 men and 29 women aged from 16 to 82 years (average 51.9, SD = 16.2). The mechanism of injury was motorcycle-related (motorcyclist or passenger) injury for 87 patients, vehicle-related (driver or passenger) injury for 14 patients, falling injury for 21 patients, and cyclist or pedestrian for 14 patients. Median ISS for all patients was 18 (quartile, 13, 22) and their mean ISS was 18.1 (SD, 6.1). The severity of chest injury is recorded by anatomic abbreviated injury score (AIS) of thoracic injuries. Four patients were recorded as grade 2, eighty-four patients were grade 3 and forty-eight patients were grade 4. Mean AIS of chest in all patients was 3.3 (SD, 0.5) and median was 3 (quartiles, 3, 4). All patients had tube thoracostomy at the trauma bay of emergency department before VATS. Mean time from trauma to residual pleural collections diagnosed from secondary CT is 52.8 h (SD, 9.1). The average time period between the trauma and performance of VATS was 5.9 days (SD, 4.6). No patients had their VATS procedures converted to thoracotomies during surgical interventions. However, 14 patients received secondary VATS because of persistent pleural collections after operation. The mean LOS of ICU and hospital were 8.7 (SD, 7.1) and 24.2 (SD, 18.4) days. Rate of post-trauma infections cultured from sputum, pleural effusion and blood were 40.5%, 21.3% and 11.8% respectively. Overall, the mortality of these patients was 2.2% (3/136).

Fig. 1 shows that shorter hospital lengths of stay were most common in those with shorter intervals from trauma to VATS. Patients with positive microbial culture had longer mean time periods from trauma to VATS (9.1 days vs. 5.0 days, p = 0.004), as did those with positive microbial culture of sputum (7.8 days vs. 4.6 days, p = 0.001). When patients were divided into three groups according to the time from trauma to performance of the VATS (2–3 days, average 2.6, SD, 0.5; 4–6 days, average 4.6, SD, 0.8; >6 days after trauma, average 11.9, SD, 5.2), they were compared for demographic and preoperative status (Table 2). Group 3 has higher head AIS than the others but the Glasgow coma scale at emergency department, AIS of other regions and the overall ISS showed no statistical significant differences between the three groups. Other basic demographics, such as age, gender, mechanism of injury, and number of rib fractures, rate of flail chest, pulmonary contusion scores, rate of acute respiratory failure within 4 h after trauma, retained pleural collections diagnosed time showed no statistical differences between these groups; thus, the demographic and pre-operative status of patients in the three groups were similar.

The outcomes of the three groups are shown in Table 3. As can be seen, Group 3 had longer ICU LOS and in-hospital LOS than the

Table 2
Comparison of basic demographics between patient groups.

	Group 1 (n = 43)	Group 2 (n = 57)	Group 3 (n = 36)	p
Age (mean, SD)	50.1 (14.2)	50.1 (16.1)	56.9 (17.9)	0.099
Gender (male)	32 (74%)	44 (77%)	31 (86%)	0.422
Mechanism of injury				0.407
Motorcycle	26	40	21	
Vesicle	7	5	2	
Fall	5	7	9	
Pedestrian	5	5	4	
Numbers of fractured rib (mean, SD)	5.0 (2.5)	5.8 (3.0)	6.1 (0.2)	0.243
Flail chest	14 (33%)	24 (42%)	17 (47%)	0.394
Pulmonary contusion scores (mean, SD)	6.9 (2.3)	7.1 (2.4)	8.0 (2.7)	0.109
Acute respiratory failure within 4 h after trauma	18 (42%)	30 (53%)	18 (50%)	0.554
Head AIS (mean, SD)	0.5 (1.0)	1.1 (1.3)	1.2 (1.3)	0.017
Thoracic AIS (mean, SD)	3.3 (0.5)	3.3 (0.5)	3.4 (0.6)	0.532
Abdomen AIS (mean, SD)	0.5 (1.0)	0.6 (1.0)	0.7 (1.1)	0.789
Extremity AIS (mean, SD)	1.6 (1.0)	1.5 (1.0)	1.3 (1.1)	0.295
ISS (mean, SD)	16.7 (5.7)	18.7 (6.4)	19.0 (5.7)	0.149
GCS at ED (mean, SD)	14.0 (1.2)	14.1 (1.1)	13.8 (1.3)	0.465

Table 3
Comparison of clinical outcomes between patient groups.

	Group 1 (n = 43)	Group 2 (n = 57)	Group 3 (n = 36)	p
ICU LOS (mean, SD)	5.0 (2.3)	7.7 (5.0)	14.6 (9.6)	<0.001*
Hospital LOS (mean, SD)	16.2 (9.6)	21.3 (13.0)	38.2 (25.0)	<0.001*
Number of total ventilator days (mean, SD)	2.6 (1.9)	6.8 (8.0)	15.5 (17.2)	<0.001*
Number of post-VATS ventilator days (mean, SD)	0.9 (1.4)	5.2 (9.1)	12.1 (17.2)	<0.001*
Duration of total tube drainage (mean, SD)	8.2 (3.7)	11.6 (6.3)	19.8 (12.7)	<0.001*
Duration of post-VATS tube drainage (mean, SD)	6.9 (3.0)	8.3 (5.6)	9.5 (9.3)	0.172*
Secondary VATS (mean, SD)	1 (2%)	8 (14%)	5 (14%)	0.115#
Post trauma infections				
Sputum culture positive	10 (23%)	22 (38%)	23 (64%)	0.001#
Pleural effusion culture positive	5 (11%)	10 (17%)	14 (39%)	0.009#
Blood culture positive	2 (5%)	4 (7%)	10 (28%)	0.002#
Mortality	0	1 (2%)	2 (5%)	0.235#

* Analysis by one-way analysis of variance with Post hoc test by Least Significant Difference. When the three periods were compared for those variables where there was a statistically significant association overall, groups 1 and 2 did not differ significantly in any instance, while groups 2 and 3 always showed statistically significant differences.
\# Analysis by chi-square and Fisher's test.

other groups ($p < 0.05$, respectively). The total durations of ventilator usage and numbers of post-VATS ventilator days are both longer in Group 3 ($p < 0.05$, respectively). Durations of chest tube usage were shorter in Group 1 ($p < 0.05$). However, there was no statistical difference in duration of post VATS tube drainage between the three groups ($p = 0.172$). Although VATS performed within three days had the best clinical outcomes, there were no significant differences between Group 1 and Group 2. Post-trauma infections were all higher in Group 3 for positive microbial cultures from sputum (23.3%, 38.6%, 63.9%, $p = 0.001$), pleural effusion (11.6%, 17.5%, 38.9%, $p = 0.009$) and blood (4.7%, 7.0%, 27.8%, $p = 0.002$). The rates of secondary VATS were equal in three groups. Patients in these three groups showed no difference in mortality.

Discussion

With the advanced development and techniques for VATS, it is widely applied in the diagnosis and treatment of vital signs stable chest-injured patients [7–9]. VATS could provide excellent visualisation of the pleural cavity, which is more beneficial for evacuating pleural collections compared to secondary tube thoracostomies. Although there is a tendency that VATS should be considered early, the exact timing is varied in many research studies [9,14]. In this study, we found that intervention by VATS within 6 days could reduce the LOS in hospital and ICU, duration of ventilator use, and postoperative complications with better clinical outcomes.

Post-trauma infections are the most important factors influencing the durations of in-hospital courses for chest injuries [1,18]. These infections are usually derived from retained pleural collections. Further managements should be performed to treat or to prevent these complications [2,3,13,17,19]. With advances in development and techniques for VATS, it is widely applied in the diagnosis and treatment of chest-injured patients with stable vital signs [10–12]. VATS could provide excellent visualisation of the pleural cavity, which is more beneficial for evacuating pleural collections compared with secondary tube thoracostomies [9,12]. It is also much less invasive than exploratory thoracotomy, thus providing shorter recovery time for trauma patients. Despite of its many advantages, the exact time for performing VATS varies widely in many research studies. Landreneau et al. suggested early performance but did not mention the exact time for VATS to be performed [8]. Heniford et al. recommended that VATS should be performed within 7 days after trauma [7]. Meyer et al. also evaluated the benefits of early VATS for retained haemothorax [9] and indicated that replacing additional tube thoracostomies with early VATS performed within three days after trauma may shorten overall durations of tube thoracostomies and in-hospital length of stay. The same results were obtained by Smith et al. except that the time for VATS performance was suggested within five days after trauma [15]. Morales Uribe et al. also supported that early VATS within five days after trauma could increase the success rate and decrease the rate of conversion to thoracotomy [14]. However, recent research by the American Association for the Surgery of Trauma (AAST) Retained Haemothorax study group found no relationship between timing and success rate of VATS [17]. Although there is a tendency that VATS should be considered as early as possible in many studies, the definite timing is not very clearly understood.

In our hospital, we managed retained pleural collections by VATS. However, the time periods from trauma to operations varied widely. To analyse the relationship between timing of VATS and better clinical outcomes, the patients were divided into three groups in contrast to previous studies. Moreover, patients managed within 2–3 days were studied to explore the roles of very early VATS in prevention of post-traumatic infections. There are two reasons for such. One is that retained pleural collections usually happen 48 h after trauma, and the other is that post-traumatic infections often occur after 72 h [1,18]. The main purpose is not only to determine the optimal timing for performing VATS, but also to explore the possible benefits of very early surgical interventions.

There are several strengths of this study. First, although outcomes are retrospectively reviewed, all data were collected prospectively. Secondary, all the demographics and preoperative characteristics in each group were similar. Thirdly, the secondary CT was arranged in all patients suspected for retained pleural collections. This procedure could help differentiate retained haemothorax from lung parenchyma lesions (e.g., lung contusions or hospital-acquired pneumonia). All these favourable situations enhanced the reliability of results obtained in this study. According to the present findings, Groups 3 had higher rates of all post-traumatic infections. Ultra early VATS interventions in Group 1 led to the lowest post-traumatic infectious rates. Even though there are no statistically significant differences compared with Group 2, VATS performed earlier could prevent and control infections early, thus leading to better clinical outcomes. The lengths of stay and periods of tube usage were significantly shorter for Groups 1 and 2 compared with Group 3. The periods of ventilator usage were also shorter in Groups 1 and 2. Better clinical outcomes may be derived from prevention or early control of post-traumatic chest infections. The other factors that decreased post-trauma complications include early restoration of lung functioning by early VATS. Pleural collections retained in the pleural cavity will induce the lungs to collapse. The earlier the VATS is performed, the earlier the lung parenchyma can be expanded and lung functions can be restored more rapidly, which can shorten the duration of ventilation use.

This study had two interesting findings. One was no statistical differences in duration of post-VATS tube usage among the three groups; and the other was secondary VATS required by 14 patients in this study. Although Group 3 had a higher percentage of secondary VATS required, the overall failure rate of the first operation showed no statistically significant difference between groups. These two findings imply similar success rates of VATS in all groups regardless when VATS was performed, which is compatible with the findings of the AAST Retained Haemothorax study group [16]. The higher failure rate in Group 3 may be related to multiple adhesions in pleural cavity. These fibrotic bands complicated the implementation of VATS and induced inadequate drainage. Many previous studies did not recommend delaying VATS for more than 10 days because the clotted blood would become pleurally adhesive, thus complicating the management [7,19]. Fortunately, no complications occurred in patients after secondary VATS in this study.

Although early VATS have advantages in preventing infections, the timing of VATS performance is usually influenced by many factors. Vital signs and associated injuries are the most important factors that affect the timing of operation. Head injury is the most common reason for delaying VATS because the recovery of cerebral auto-regulation needs at least 96 h [20]. That is why most VATS are usually performed beyond the 4th day after trauma. In this retrospective study, 43 patients received VATS within 3 days after trauma. Most of these patients had associated limb injuries for which early reconstruction or early damage control surgeries should be performed to prevent further peripheral neuro-vascular injuries. VATS was performed together with these regional surgeries. In contrast, Group 3 had more head injuries than the other groups. This group also has the lowest rate of limb injury, so VATS was delayed till the conditions of head injuries became more stable. Although the AIS of head was higher in Group 3 than in the other two groups with statistical significance, the GCS and ISS were all equal in the three groups. The rate of pneumonia caused by enterobacteria was the same in all groups (7.0%, 8.8% and 8.3%, respectively; $p = 0.946$). That is, the possibility of aspiration pneumonia induced by unconscious status is the same in all patients. It means that higher infection rates of Group 3 are not attributed to the higher incidence of head injuries. Instead, different associated injuries are the major reasons behind different timings for VATS performed, which could influence the clinical outcomes.

There are some potential limitations in this study. First, this was a retrospective study. All the data and parameters were collected from chart reviews, and there might be recording errors. Nevertheless, all data were collected with a standard form without missing data and the data were double-checked by a senior trauma surgeon. Second, although the treatment guidelines are the same, the timing arranged and operation methods performed by thoracic surgeons may still be different. However, the preoperative status and demographic matching of the three groups can decrease the bias caused by interrater differences. Third, only less than 15% of blunt chest trauma patients may have retained pleural collections. Although the number of VATS cases is small, the outcome parameters showed statistically significant differences. Fourth, many factors could influence the duration of acute respiratory failure. Severe associated injuries from the head and abdomen are the most common that could lengthen the in-hospital stay. Chronic medical problems such as chronic obstructive pulmonary disease, liver cirrhosis and chronic heart failure could increase morbidity and mortality. All these biases were excluded before enrolment in this study. Fifth, hospital-acquired pneumonia is another important factor that prolongs the in-hospital length of stay. It is difficult to differentiate the post-traumatic infection of lung from hospital-acquired pneumonia in trauma patients because these two conditions could happen simultaneously or in close sequence. Because the relationship between hospital-acquired pneumonia and acute respiratory failure is high, the rate of the latter could be calculated to estimate the possibility of the former. In this study, the rates of acute respiratory failure within 4 h after trauma are the same in all three groups. This could decrease the bias due to hospital-acquired pneumonia that would influence the clinical outcomes.

Conclusion

In this study, all outcomes worsened when the intervention was performed after 6 days. Although there were no significant differences in clinical outcomes with VATS performed within 6 days, early VATS evacuation within 3 days could obtain the lowest post-traumatic complications and improve the outcome. We postulate that under suitable conditions, patients should receive VATS earlier when surgical intervention is indicated.

Conflict of interest

All authors have no conflicts of interest.

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The first two authors made equal contributions to this work and are equally considered to be first author. The last two authors made equal contributions to this work and are equally considered to be corresponding authors. We appreciate the help from editors and anonymous referees for the critical review and statistical suggestions.

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