Incidence and Predictive Factors of Massive Hemothorax Due to Thoracic Vertebral Fractures

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Abstract:
Introduction: Massive hemothorax due to thoracic vertebral fractures (MHTVF) is a potentially lethal condition; however, its epidemiological and clinical data have been rarely described. Thus, in this study, we aimed to evaluate the incidence, predictive factors, and clinical features of MHTVF.

Methods: This retrospective cohort study enrolled 202 consecutive patients (136 male and 66 female patients) with thoracic vertebral fractures treated at our institute between January 2009 and December 2019. Their mean age was 60.7 (range, 17-90) years. Unstable fractures accounted for 57.4% (n=116) of the total fractures. The patients were then divided into MHTVF and non-MHTVF groups. We assessed the following MHTVF-associated factors: sex, age, history of medical conditions, anticoagulation/antiplatelet drug use, injury severity score, anatomical distribution of levels of the vertebral fractures, fracture type, and presence or absence of diffuse idiopathic skeletal hyperostosis (DISH) fracture.

Results: In total, eight patients (six men and two women) with a mean age of 68.9 years (range, 22-85 years) were determined to exhibit MHTVF. The incidence of MHTVF in patients with unstable thoracic spinal fractures was 6.9%, whereas none of those with stable spinal fractures exhibited MHTVF. Factors like type B (p=0.049) and DISH (p=0.017) fractures were noted to be significantly associated with the MHTVF. Three patients experienced shock upon arrival, whereas two exhibited delayed shock. Chest tube insertion and/or emergency thoracotomy was performed. The survival rate was 100.0%.

Conclusions: MHTVF is not rare. Because type B and DISH fractures are identified as predictive factors of MHTVF, it must be carefully treated to avoid preventable death even after hospitalization in patients with these thoracic fractures.

Keywords: Massive hemothorax due to thoracic vertebral fractures, Unstable thoracic vertebral fracture, Incidence, Predictive factors, Diffuse idiopathic skeletal hyperostosis, Type B spinal fracture, Delayed shock

Introduction

Traumatic hemothorax has been described as a result of thoracic organ injuries such as pulmonary parenchymal laceration or damage to chest wall vessels, mediastinal chest injuries, and ruptured aorta or pulmonary artery. Patients with traumatic hemothorax often present with bruises or ecchymomas, subcutaneous emphysema, spontaneous pain, or thoracic tenderness. They may also have a traumatic thoracic cage deformity. In patients with rib or sternum fractures, the symptoms may easily lead to the diagnosis of hemothorax via computed tomography (CT) scan or other exams. In contrast, several studies have reported the pathology of massive hemothorax due to thoracic vertebral fractures (MHTVF)¹⁻¹². Patients with MHTVF do not complain of thoracic pain because such fractures do not include usual thoracic trauma such as rib or sternum fractures. Patients with MHTVF may complain only of back pain or neurological deficits, owing to their spinal fracture early in the injury³⁰. Furthermore, signs of hemothorax in MHTVF may not be evident early on or during the initial clinical examination³⁰. Thus, patients with MHTVF may only be treated for their thoracic verte-
bral fracture, and hemothorax may remain undiagnosed after hospitalization. They may subsequently experience delayed shock and death due to MHTVF. The MHTVF mortality rate was reported at 33.3%. Absence of clinical signs of massive hemothorax during the initial examination may lead to inappropriate treatment and a complicated clinical course. It is thus crucial to understand the clinical features of MHTVF for the early identification and adequate treatment of this life-threatening compound trauma. However, clinical data on MHTVF in the literature have remained to be limited, owing to their rarity; however, the incidence of MHTVF remains unknown, as are predictive factors for MHTVF. Further, there is no established therapeutic strategy for the management of MHTVF. Herein, we demonstrate the incidence, predictive factors, management, and clinical outcomes of MHTVF.

**Materials and Methods**

In this retrospective cohort study, we assessed the incidence and predictive factors of MHTVF. We also evaluated the diagnostic methods, treatments, and clinical outcomes of patients with MHTVF. The study design was approved by our university's institutional review board before study initiation and complied with the principles of the Declaration of Helsinki. All patients or their families provided written consent for the publication of case details.

**Materials**

We searched the trauma registry of the critical care medical center in our hospital for patients who sustained thoracic vertebral fractures between January 2009 and December 2019. The review included emergency department records, inpatient and outpatient visits, operative records, and radiographic images. We recruited 202 consecutive patients (136 males and 66 females) with thoracic vertebral fractures (Fig. 1). Their mean age was 60.7 years (range 17-90 years), and their mean injury severity score (ISS) was 21.9 (range 4-66) (Table 1). There were 86 cases (42.6%) with stable thoracic vertebral fractures, whereas there were 116 cases (57.4%) with unstable fractures.

**Definition of MHTVF**

We have performed whole-body CT on all patients with suspected vertebral fractures. We defined MHTVF as (i) thoracic vertebral fracture(s) and massive hemothorax and (ii) confirmed active bleeding in the neighborhood of the fracture site following thoracotomy or using radiological methods, such as dynamic CT and angiography. We then excluded patients with thoracic trauma, such as injury to the great vessels (i.e., aorta, superior and inferior vena cava, and pulmonary arteries and veins), pulmonary parenchymal laceration, sternum injury, rib fractures, and injury to intercostal arteries and veins associated to rib fractures that lead to extreme hemothorax. Massive hemothorax was defined as initial bleeding with chest drainage >1000 mL or unstable hemodynamic status due to persistent bleeding secondary to hemothorax.

**Incidence and predictive factors of MHTVF**

All assessed patients were divided into MHTVF and non-MHTVF groups. First, the incidence of MHTVF was calcu-
Table 1. Characteristics of Consecutive 202 Cases of Thoracic Vertebral Fractures.

| Characteristic                        | No. of Cases |
|--------------------------------------|--------------|
| Sex (male)                           | 136 (67.3%)  |
| Age (mean±SD)                        | 60.7±19.1    |
| Injury severity score (mean±SD)      | 21.9±12.7    |
| Type of fractured vertebra in AO classification* |             |
| (A)                                  | 169 (81.6%)  |
| (B)                                  | 24 (11.6%)   |
| (C)                                  | 14 (6.8%)    |
| No. of patients with unstable spinal fractures | 116 (57.4%)  |
| No. of patients with DISH/ASH fracture | 40/0 (19.8/0.0%) |

*Duplicate counting in type of fractured vertebra was allowed if multiple fractures.

DISH, diffuse idiopathic skeletal hyperostosis; ASH, ankylosing spinal hyperostosis; SD, standard deviation

lated. Second, we assessed the characteristics of MHTVF, including its mechanism of injury, ISS, neurological deficits according to the American Spinal Injury Association (ASIA) impairment scale13, anatomic distribution of vertebral fracture levels (upper [T1-T6] or lower [T7-T12]), type of thoracic vertebral fracture based on the AO classification14, whether the fracture is stable or unstable, presence or absence of diffuse idiopathic skeletal hyperostosis (DISH) and ankylosing spinal hyperostosis (ASH), and associated trauma. Third, the following potential influencing factors were also examined: sex; age; presence or absence of diabetes mellitus (DM), hypertension (HT), liver cirrhosis (LC), and artificial hemodialysis (HD); regular use of anticoagulation/platelet drugs before injury; ISS; neurological deficits; anatomic distribution of vertebral fracture levels; type of thoracic vertebral fracture; and the presence or absence of DISH and ASH. These potential predictive factors were compared between patients with stable and unstable thoracic vertebral fractures. When potential predictive factors were detected, they were then compared between the MHTVF and non-MHTVF groups. We defined types A3 (incomplete burst fracture due to compression force), A4 (complete burst fracture due to compression force), B (tension band injury), and C (displacement or translational injury) thoracic spinal fractures as unstable fractures. We referred to a report by Resnick et al. to determine the presence or absence of DISH15.

Clinical findings and course of MHTVF

To describe the clinical features of MHTVF, we have assessed the associated trauma, vital signs upon arrival, disturbance of consciousness upon arrival based on the Glasgow Coma Scale score, status of their shock during the first visit and after admission, time taken to go into shock after injury, evaluation of the bleeding source using dynamic CT, treatment methods for extreme hemothorax, and survival rate.

Statistical analysis

Using Fisher’s exact test, we then compared the MHTVF and non-MHTVF groups based on the following factors: sex; presence or absence of DM, HT, LC, HD; regular use of anticoagulation/platelet drugs before injury; anatomic distribution of vertebral fracture levels; type of fracture per the AO classification; and the presence or absence of DISH and ASH. The Mann-Whitney U test was used to analyze age and ISS. We considered p<0.05 as significant.

Results

Incidence and demographics of MHTVF cases

No MHTVF case was overlooked using the whole-body CT at the first examination. Table 1 summarizes the characteristics of the consecutive 202 cases of thoracic vertebral fractures. Among the 202 patients, 6 males and 2 females were determined to have MHTVF (Table 2), and their mean age was 68.9 years (range, 22-85 years). The incidence of MHTVF was 4.0%. Notably, no stable thoracic spinal fracture cases demonstrated MHTVF, yielding an incidence of 6.9%. The mechanisms of injury included traffic accidents (n=4; 50.0%) and falls from heights of 2-3 m (n=4; 50.0%). There was one case for ASIA levels A, B, and C (12.5% each) and five cases (62.5%) of level E. We then observed type A (n=3), B (n=4), and C (n=1) fractures. No cases of stable fracture were noted, and all MHTVF cases comprised of patients with unstable thoracic spinal fractures. Six patients had DISH fractures, and there were no ASH fractures. No cases of massive bilateral hemothorax were also noted.

Associated factors with the occurrence of MHTVF

There were no missing data. With unstable thoracic spinal fractures, age; sex; presence or absence of DM, HT, LC, HD; and regular use of anticoagulation/platelet drugs before injury, ISS, and the anatomic distribution of vertebral fracture levels were found to be not associated with MHTVF (Table 3). However, type B fractures (p=0.049) and DISH (p=0.017) were determined to be significantly associated with MHTVF. In total, 40 patients with DISH fractures in the thoracic spine were divided into two groups, that is, MHTVF group and non-MHTVF group. There were no significant factors in the investigated items (Table 4).
Table 2. A Demographics of Patients with Massive Hemothorax Due to Thoracic Vertebral Fracture.

| Case | Age | Sex | ISS | Mechanism of injury | ASIA impairment scale [12] | Fracture levels of thoracic vertebra | Type of vertebral fracture in AO classification [13] | Stable or unstable fracture | DISH fracture | Associated trauma |
|------|-----|-----|-----|---------------------|---------------------------|-----------------------------------|-------------------------------------|---------------------------|-------------|--------------------|
| 1    | 74  | Male| 26  | TA                  | E                         | T6-7                              | C                                   | Unstable                   | Yes          | Subdural hematoma   |
| 2    | 22  | Male| 30  | TA                  | A                         | T6-7                              | A                                   | Unstable                   | No           | None                |
| 3    | 65  | Male| 33  | Fall                | E                         | T11                               | B                                   | Unstable                   | Yes          | Subdural hematoma   |
| 4    | 77  | Female| 14  | TA                  | E                         | T11                               | A                                   | Unstable                   | No           | L3 fracture         |
| 5    | 85  | Male| 19  | Fall                | E                         | T9-10                             | B                                   | Unstable                   | Yes          | C2 fracture         |
| 6    | 69  | Female| 20  | Fall                | B                         | T5-6                              | A                                   | Unstable                   | No           | None                |
| 7    | 75  | Male| 9   | Fall                | E                         | T11                               | B                                   | Unstable                   | Yes          | None                |
| 8    | 84  | Male| 26  | TA                  | C                         | T12                               | B                                   | Unstable                   | Yes          | None                |
| mean | 68.9| -   | 22.1| -                   | -                         | -                                 | -                                   | -                         | -            | -                  |

ISS, injury severity score; ASIA, American Spinal Injury Association; DISH, diffuse idiopathic skeletal hyperostosis; TA, traffic accident

Table 3. A Comparison with MHTVF and Non-MHTVF in 116 Cases with Unstable Thoracic Spinal Fractures.

|                          | MHTVF (N=8 pts., 8 vertebrae) | Non-MHTVF (N=108 pts., 133 vertebrae) | p value |
|--------------------------|--------------------------------|----------------------------------------|---------|
| Age (mean±SD)            | 68.9±20.1                      | 61.1±19.5                              | 0.233†  |
| Sex (male)               | 6 (75.0%)                      | 73 (67.6%)                             | 1.000*  |
| Diabetes mellitus (presence) |
|                         | 2 (25.0%)                      | 11 (10.2%)                             | 0.220*  |
| Hypertension (presence)  | 3 (37.5%)                      | 29 (26.9%)                             | 0.683*  |
| Liver cirrhosis (presence) |
|                         | 0 (0.0%)                       | 0 (0.0%)                               | 1.000*  |
| Artificial hemodialysis (presence) |
|                         | 0 (0.0%)                       | 1 (0.9%)                               | 1.000*  |
| Regular use of anticoagulation/platelet drugs (presence) |
|                         | 0 (0.0%)                       | 8 (7.4%)                               | 1.000*  |
| ISS (mean±SD)            | 22.1±8.1                       | 23.3±13.1                              | 0.965†  |
| Anatomic distribution of vertebral fracture |
| (upper)                  | 3 (37.5%)                      | 32 (24.7%)                             | 0.719*  |
| (lower)                  | 5 (62.5%)                      | 76 (57.3%)                             |         |
| Type of fractured vertebra in AO classification |
| (B)                      | 4 (50.0%)                      | 20 (17.7%)                             | 0.049*  |
| (non-B)                  | 4 (50.0%)                      | 93 (82.3%)                             |         |
| DISH fracture (presence) | 6 (75.0%)                      | 34 (30.1%)                             | 0.017*  |

MHTVF, massive hemothorax due to thoracic vertebral fractures; SD, standard deviation; ISS, injury severity score; Upper and lower in anatomic distribution of vertebral fracture mean at T1-6 and T7-12, respectively (duplicate counting was allowed if multiple fractures); DISH, diffuse idiopathic skeletal hyperostosis; *Fisher’s exact test, †Mann-Whitney U test

Clinical courses of MHTVF cases

Three patients (37.5%) were already in shock upon arrival at our institute, including one patient with cardiopulmonary arrest immediately after arrival (CPAAA) (Table 5) and five (62.5%) did not. However, two of them experienced a delayed shock that did not exist at the first examination and appeared later. Chest tubes were inserted in seven cases as the initial treatment for massive hemothorax. However, three cases underwent emergency thoracotomy to stop the bleeding and treat shock. One case of CPAAA underwent emergent thoracotomy first. Transcatheter arterial embolization (TAE) was performed in one case. Bleeding from the segmental artery was diagnosed in five cases, and venous bleeding was detected in three cases using dynamic CT. All cases underwent posterior spinal fusion surgery for unstable fractures with instrumentation after their general condition recovered. The survival rate was 100.0%.

Representative case

A 74-year-old man was injured in a motor vehicle accident and presented with complaints of back pain. On presentation, he had a respiratory rate of 20, oxygen saturation 99% on room air, heart rate 66, blood pressure 145/80 mmHg, and a Glasgow Coma Scale score of E4V4M6. He displayed no neurological deficits. He exhibited mild subdural hematoma as an associated injury but was not in shock at the time. His chest radiography results did not reveal any obvious hemothorax in the lung field (Fig. 2A). Whole-body CT—performed routinely for high-energy trauma patients in our institution—revealed fractures of the thoracic spine accompanied by DISH in the T6-T7 vertebrae (Fig. 2B) and a massive right hemothorax. Similarly, dynamic CT revealed extravasation into the thoracic cavity from the right segmental artery (Fig. 2C). There was initial bleeding of 1000 mL upon insertion of a chest drainage tube. Considering that bleeding was not continuous and the hemodynamic status was stable, he was admitted to the intensive care unit. Over
Table 4. A Comparison with MHTVF and Non-MHTVF in 40 Cases with DISH Fractures.

|                  | MHTVF (N=6 pts.) | Non-MHTVF (N=34 pts.) | p value |
|------------------|-----------------|-----------------------|---------|
| **Age (mean±SD)** | 73.8±6.7        | 71.0±13.7             | 0.985   |
| **Sex (male)**    | 5 (83.3%)       | 34 (100.0%)           | 0.150*  |
| **Diabetes mellitus (presence)** | 2 (33.3%) | 6 (17.6%) | 0.583* |
| **Hypertension (presence)** | 2 (33.3%) | 13 (38.2%) | 1.000* |
| **Liver cirrhosis (presence)** | 0 (0.0%) | 0 (0.0%) | 1.000* |
| **Artificial hemodialysis (presence)** | 0 (0.0%) | 1 (2.9%) | 1.000* |
| **Regular use of anticoagulation/platelet drugs (presence)** | 0 (0.0%) | 6 (17.6%) | 0.564* |
| **ISS (mean±SD)** | 22.2±8.2        | 22.4±14.0             | 0.718†  |
| **Anatomic distribution of vertebral fracture** | | | |
| (upper)          | 2 (33.3%)       | 7 (20.6%)             | 0.602*  |
| (lower)          | 4 (66.7%)       | 27 (79.4%)            |         |
| **Type of fractured vertebra in AO classification** | | | |
| (B)              | 4 (66.7%)       | 12 (35.3%)            | 0.666*  |
| (non-B)          | 2 (33.3%)       | 22 (64.7%)            |         |

MHTVF, massive hemothorax due to thoracic vertebral fractures; DISH, diffuse idiopathic skeletal hyperostosis; SD, standard deviation; ISS, injury severity score; Upper and lower in anatomic distribution of vertebral fracture mean at T1-6 and T7-12, respectively; *Fisher’s exact test, †Mann-Whitney U test

Table 5. Hemodynamic Clinical Findings at the First Observation and Subsequent Course in Patients with Massive Hemothorax Due to Thoracic Vertebral Fracture.

| Case | Blood pressure at arrival (mmHg) | Heart rates at arrival (/min.) | Respiratory rates at arrival (/min.) | GCS at arrival | Time to delayed shock after arrival (hours) | Sources of bleeding identified by dynamic CT | Treatment for MH |
|------|----------------------------------|-------------------------------|-------------------------------------|----------------|---------------------------------------------|--------------------------------------------|-----------------|
| 1    | 145/80                           | 66                            | 24                                  | 14             | 11                                          | Segmental artery                           | Chest drainage → thoracotomy               |
| 2    | 65/46                            | 127                           | 22                                  | 15             | Segmental artery                            | Chest drainage → thoracotomy               |
| 3    | 121/71                           | 59                            | 15                                  | 15             | Segmental artery                            | Chest drainage → thoracotomy               |
| 4    | 70/40                            | 78                            | 30                                  | 15             | Segmental artery                            | Chest drainage and TAE                     |
| 5    | 116/84                           | 106                           | 21                                  | 15             | Segmental artery                            | Chest drainage                             |
| 6    | 130/80                           | 80                            | 24                                  | 15             | Vein*                                        | Chest drainage                             |
| 7    | 187/119                          | CPAAA                         | CPAAA                               | 3              | Vein*                                        | Thoracotomy                                |
| 8    | CPAAA                            | CPAAA                         | CPAAA                               |                |                                              |                                            |

GCS, Glasgow Coma Scale; CT, computed tomography; MH, massive hemothorax; CPAAA, cardiopulmonary arrest immediately after arrival; TAE, transcatheter arterial embolization; *The detailed anatomical name of the vascular was unclear

time, the bleeding from the drain increased, and the patient experienced delayed shock owing to the extreme hemothorax 11 hours after arrival at our hospital. A thoracic surgeon performed an emergency thoracotomy and successfully controlled the bleeding due to the rupture of the T6 segmental artery using topical hemostatic agents (Fig. 2D).

Discussion

To the best of our knowledge, this study is the first to describe the incidence, demographics, potential predictive factors, and clinical outcomes of MHTVF. As per our findings, the incidence of MHTVF was 6.9% among unstable thoracic spinal fractures, and such compound traumas were commonly observed at our institute. The predictive factors were type B fracture according to the AO classification and presence of a DISH fracture; however, age, sex, ISS, or the fracture level was not associated with the incidence of MHTVF. With regard to the clinical course of hemothorax in MHTVF cases, some patients experienced shock immediately after injury. Others had delayed shock after conservative treatment with chest drainage. Shock timing affected the choice of treatment. Therefore, we must always pay careful attention to its management after admission. In our cohort, the only useful procedures were chest drainage in three cases, TAE in one case, and an emergency thoracotomy in four cases. There were no fatalities owing to the combined efforts of the thoracic surgeon and radiologist.

To the best of our knowledge, only 13 case studies of patients with MHTVF have been reported since 1990. Among the different modes of injury encountered in our study, the majority were due to high-energy trauma, which is consistent with previous reports. However, MHTVF has also been reported in patients who sustained low-energy trauma. There are reported cases of MHTVF due to DISH fractures, and the results of this present study showed that DISH fractures are significantly associated with the occurrence of MHTVF. DISH has often been characterized by...
Figure 2. (A) Chest radiography shows no marked decrease in permeability and dullness of the costophrenic angle in the lung field. (B) Sagittal images of multiplanar reconstruction computed tomography (CT) show a type C fracture and the dislocation of diffuse idiopathic skeletal hyperostosis at T6-T7. (C) The arterial phase (left) and venous phase (right) in dynamic CT reveal a massive hemothorax on the right side and extravasation into the right thoracic cavity from the segmental artery of the right side (arrow). (D) Arterial bleeding from a fracture site of the T6-T7 vertebra (arrowheads) (*the diaphragm; **the deflated lung).

the calcification and ossification of soft tissues such as entheses and joint capsules. As per Resnick et al., DISH is the radiographic features of calcification or ossification along with the anterolateral aspects of at least four contiguous vertebral levels\textsuperscript{15}. DISH can predict cardiovascular disease, stroke, cerebrovascular disease, and even vascular disease\textsuperscript{16,17}. Studies have demonstrated that DISH is associated with older age and a higher body mass index\textsuperscript{18}, and patients with DISH are noted to have significantly higher uric acid and alkaline phosphatase levels\textsuperscript{17}. This suggests that the presence of DISH facilitates blood vessel calcification and coronary artery calcification is significantly more common in patients with DISH\textsuperscript{19}. In patients with DISH, vertebral fractures are more likely to occur in the center of the vertebra where segmental arteries and veins localize because it is deemed more fragile than the bony bridge. When a type B fracture with traction force occurs at this site, the calcified vasculature around the fractured vertebra may be simultaneously ruptured, thus resulting in bleeding.

Concerning therapy for MHTVF, spinal fracture stabilization using spinal instrumentation surgery has been determined to be effective at controlling bleeding\textsuperscript{9}. However, this method should be reserved for patients with a relatively good general condition because this type of surgery is performed while prone. In addition, it is not certainly known whether this method has a hemostatic effect on various sources of bleeding. Morita et al. reported that TAE was useful for MHTVF\textsuperscript{8}. However, TAE is limited in its applications in patients with arterial bleeding, as it may cause a complication of spinal infarction depending on the level of spinal injury.

Avoiding preventable death is of paramount importance in the treatment of MHTVF. However, there have been some reports of related fatalities\textsuperscript{6}. In cases of life-threatening massive hemothorax that do not respond to initial thoracic drainage, urgent surgical intervention is strongly recommended\textsuperscript{20}. Emergency thoracotomy is recommended if there is an (i) initial drainage of 1000 mL or more, (ii) a drainage of 1500 mL or more for 1 h after the insertion of the drainage tube, (iii) continuous bleeding with 200 mL/h or more for 2-4 h after drainage, or (iv) 1200 mL of intrathoracic hemorrhage\textsuperscript{21,22}. MHTVF may develop because of massive bleeding into the thoracic cavity because the soft tissue’s tamponade effect is broken when the vasculature in and around the vertebral body and visceral pleura is simultaneously injured during vertebral fractures. Given this etiology, achieving hemostasis with conservative treatment may be deemed difficult. It is also difficult to diagnose injuries of the great vas-
culation of the venous system, such as pulmonary veins orazygos veins and superior and inferior vena cava, using CT alone. Furthermore, hemostasis achieved using TAE is deemed not effective for such injuries. Therefore, the best treatment would include collaboration with thoracic surgeons and radiologists after identifying the approximate location of the bleeding source using a dynamic CT. For suspected MHTVFms, emergency thoracotomy may help avoid preventable death. Three patients recovered with the use of only thoracic drainage in this study. However, emergency thoracotomy would be considered if the drainage volume was large or the hemodynamics became unstable. In thoracotomy, compression and coagulation were first attempted after identifying the bleeding site. If hemostasis remained difficult, a local hemostatic agent was then applied. In this series, hemostasis was achieved using multiple layers of local hemostatic agents. TAE may be indicated for bleeding from the mediastinum, where achieving surgical hemostasis is difficult. Ultimately, it is important to carefully manage the patient’s general status to avoid preventable death.

This study has limitations, for example, its retrospective and single-center design. Additionally, our MHTVF cohort was small. Large-scale, prospective, multicenter studies are thus needed to confirm the pathology and clinical outcomes of MHTVF. Second, time to delayed shock in this study may be different from that found in MHTVF patients when massive hemotorax was not known to be present; thus, the patients were left untreated. In our hospital, which is an advanced medical institution, there were no cases in which massive hemotorax was overlooked in patients with thoracic vertebral body fracture. Additionally, all patients with MHTVF were intervened in the early stage because all patients with thoracic vertebral fractures were hospitalized for follow-up under adequate management, and they underwent whole-body CT.

In conclusion, we found that 6.9% of patients with unstable thoracic spinal fractures demonstrated MHTVF; such compound trauma was deemed to be relatively common. Type B fractures, according to the AO classification and DISH fractures, were associated with the occurrence of MHTVF. MHTVF should be considered in patients who experience delayed shock following an unstable thoracic spinal fracture. While thoracic drainage was effective in some patients with MHTVF, their general condition worsened, owing to either shock at arrival or delayed shock. These patients require carefully considered treatment—including emergency thoracotomy—and collaboration with thoracic surgeons and/or radiologists to avoid preventable death.

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Ethical Approval: This study was conducted with the approval of the Research Ethics Committee of Wakayama Medical University (No. 2824).

Informed Consent: Informed consent for publication was obtained from all participants in this study.

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