Original Article

Thoracotomy for blunt chest trauma: is chest tube output a useful criterion?

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Aim: The aim of this study was to determine whether the traditional criteria of chest tube output are useful indicators for urgent thoracotomy in patients with blunt chest trauma.

Methods: Data were collected retrospectively from our trauma registry of 542 blunt chest trauma patients (Chest Abbreviated Injury Scale score of 3 or greater) over a 10-year period (2000–2010). The 1-h chest tube output was calculated from chest tube output and time after admission, and the results were compared between patients who underwent thoracotomy for hemorrhage and those who did not.

Results: Data were available for 24 patients who underwent thoracotomy for hemorrhage and 93 patients who did not undergo thoracotomy. The 1-h chest tube output between the groups was significantly different (708.0 ± 258.3 mL versus 108.9 ± 222.9 mL). Receiver operating characteristic curve analysis of the predictive value of 1-h chest tube output for thoracotomy was conducted. The area under the receiver operating characteristic curve was 0.98, and the cutoff 1-h chest tube output value for predicting thoracotomy was 404 mL (sensitivity, 87.5%; specificity, 96.8%).

Conclusions: The 1-h chest tube output of patients who underwent thoracotomy was lower than the thresholds traditionally reported as indications for urgent thoracotomy. High chest tube output as a traditional indicator for thoracotomy may not apply to patients with blunt chest trauma.

Key words: Blunt chest trauma, chest tube output, traditional criteria, thoracotomy, trauma

INTRODUCTION

THORACIC INJURY IS responsible for 20–25% of trauma-related deaths. However, only 10–15% of patients with thoracic injury require thoracotomy.¹ Most patients with thoracic injuries can be treated with observation, tube thoracostomy, and respiratory support. Early decisions to perform surgical operations can improve outcomes for patients with severe thoracic injury; unnecessary or delayed operations should be avoided. Therefore, it is important to establish well-defined criteria for thoracotomy for treatment of hemorrhagic shock in patients with thoracic injuries.

The traditional indications for thoracotomy by chest tube output are 1,000 mL or greater at insertion, 1,500 mL or greater 1 h after insertion, or 200 mL or greater 2 to 4 h after insertion.^{2–4} These criteria were derived from observations based predominantly on experience with penetrating injuries.^{2,3} We hypothesized that these criteria might not apply to patients with blunt chest trauma. The aim of this study was to determine whether the traditional criteria of chest tube output are useful for urgent thoracotomy in patients with blunt chest trauma.

METHODS

WE CONDUCTED A retrospective data analysis of patients with blunt chest trauma (Chest Abbreviated Injury Scale [AIS] score of 3 or greater) admitted to Senshu Trauma and Critical Care Medical Center, a tertiary care center equivalent to a level I trauma center, between 1 January 2000, and 31 December 2010. Patients who were in cardiopulmonary arrest upon arrival were excluded from the study. Thoracotomies were performed for patients whose

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hemodynamic status was unstable despite fluid resuscitation. Standard trauma resuscitation protocols were used for all other components of care. Fluid therapy was initiated for patients in hemorrhagic shock. When the source of hemorrhage was believed to be the thoracic cavity, thoracotomy was performed regardless of chest tube output. The Institutional Review Board of the affiliated institution approved the study and waived the requirement for informed consent.

Assuming that the chest tube was inserted at the time of admission, the 1-h chest tube output was calculated as the observed chest tube output (mL) divided by the observed number of minutes after admission multiplied by 60. For example, if the chest tube output was 750 mL at 44 min after admission, the 1-h chest tube output was calculated as $750/44 \times 60 = 1,022$ mL. Results were compared between patients who underwent thoracotomy for hemorrhage and those who did not. If multiple chest tube outputs had been recorded, we used the maximum 1-h chest tube output in the analysis. Receiver operating characteristic (ROC) curve analysis of the predictive value of 1-h chest tube output for thoracotomy was conducted.

Statistical analysis

The data were expressed as means $\pm$ standard deviations. Differences between the groups in age, thoracic AIS, Injury Severity Score (ISS), Trauma-Related Injury Severity Score (TRISS), and 1-h chest tube output were compared using Mann–Whitney *U*-test. Sex and mortality rates were compared using the χ^2 and Fisher exact tests. Significance was defined as $P < 0.05$. Statistical analyses were performed using SPSS 11.0 software for Window (SPSS, Chicago, IL, USA).

RESULTS

OVER THE 10-YEAR study period, 542 consecutive patients with severe chest trauma (chest AIS of 3 or greater) were admitted. Of these, 390 were men and 152 were women; the mean age was 44.3 ± 21.3 years and the mean ISS was 27.6 ± 12.2 . The overall mortality rate was 16.8% (91 patients).

Of the 542 patients with chest trauma, 496 (91.5%) did not receive thoracotomy. Of these, 281 patients were treated without chest tubes and 215 received chest tubes. However, in 122 patients, chest tube output was either not measurable or consisted only of air.

Forty-six patients (8.5%) required thoracotomy: 24 for hemorrhage, eight for cardiac injury, four for blunt aortic injuries, and 10 for other indications. Chest tube output volume data were available for the 24 thoracotomy patients

Fig. 1. Initial chest tube output of 24 patients who underwent thoracotomy for thoracic hemorrhage. The line represents the chest tube output traditionally used as a criterion for thoracotomy.

with thoracic hemorrhage and for 93 non-thoracotomy patients who required tube thoracostomy. Thoracotomy patients in this study had active bleeding in the thoracic cavity with an estimated intraoperative blood loss of $4,715 \pm 4,000$ mL.

Chest tube output volume in thoracotomy patients with thoracic hemorrhage

The initial chest tube output of the 24 patients who underwent thoracotomy for thoracic hemorrhage is shown in Figure 1. The average output was 426 mL. Only two patients met the traditional criteria for thoracotomy (initial chest tube output greater than 1,000 mL).

Chest tube output volume in thoracotomy patients and in non-thoracotomy patients who required thoracostomy

The relationship between chest tube output and time after admission in thoracic hemorrhage patients with and without thoracotomy is shown in Figure 2.

There were no significant differences in age, sex, thoracic AIS, ISS between thoracotomy and non-thoracotomy patients. The TRISS of thoracotomy patients was significantly lower than that of non-thoracotomy patients (Table 1). There was a significant difference in 1-h chest tube output between patients who did and did not receive thoracotomy (708.0 ± 258.3 mL versus 108.9 ± 222.9 mL, respectively; $P < 0.001$; Table 1).

The mortality rate in the thoracotomy group was 58.3% ($n = 14$), and that in the non-thoracotomy group was 14.0%

Table 1. Patient characteristics and 1-h chest tube outputs of patients who underwent thoracotomy for hemorrhage and those who did not undergo thoracotomy

	Thoracotomy (n = 24)	Non-thoracotomy (n = 93)	P
Age (years)	51.3 ± 23.7	46.6 ± 20.1	NS
Sex (% male)	75%	72%	NS
Thoracic AIS	4.3 ± 0.7	4.0 ± 0.7	NS
ISS	35.2 ± 9.6	33.1 ± 13.1	NS
TRISS	0.53 ± 0.34	0.73 ± 0.31	<0.01
1-h chest tube output (mL)	708.0 ± 258.3	108.9 ± 222.9	<0.01
Mortality (%)	58.3% (n = 14)	14.0% (n = 13)	<0.01

AIS, Abbreviated Injury Scale; ISS, Injury Severity Score; NS, not significant; TRISS, Trauma-Related Severity Injury Score.

Fig. 2. Relationship between chest tube output and time after admission in thoracic hemorrhage patients with and without thoracotomy.

(n = 13). These values were significantly different. Thirteen thoracotomy patients and eight non-thoracotomy patients died of hemorrhage.

There was no significant difference in 1-h chest tube output between thoracotomy patients who did and did not survive. However, the TRISS of thoracotomy patients who survived was 0.75 ± 0.29 and that of thoracotomy patients who did not survive was significantly lower at 0.38 ± 0.30 .

ROC curves of 1-h chest tube output for predicting thoracotomy

Receiver operating characteristic analysis of the predictive value of 1-h chest tube output for thoracotomy is shown in Figure 3. The area under the curve (AUC) is 0.98, and the cutoff value for predicting thoracotomy is 404 mL (sensitivity, 87.5%; specificity, 96.8%).

Fig. 3. Receiver operating characteristic (ROC) curves of 1-h chest tube output for predicting thoracotomy. The area under the curve (AUC) is 0.98, and the cutoff value for predicting thoracotomy is 404 mL (sensitivity, 87.5%; specificity, 96.8%).

ity, 87.5%; specificity, 96.8%). The 1-h chest tube output of patients who underwent thoracotomy was lower than the thresholds that have been traditionally reported as indications for urgent thoracotomy.

DISCUSSION

SEVERE THORACIC INJURY can pose life-threatening problems if not promptly identified and treated during the primary survey. Esposito *et al.* have shown that most cases of inappropriate care in the emergency department are

related to management of airway control and chest injuries.⁵ Inappropriate care and delayed diagnosis lead to fatal errors and preventable death, especially in thoracic injuries. However, most chest injury patients can be managed conservatively with observation and tube thoracostomy, and only a few patients require thoracotomy. Kulshrestha *et al.* demonstrated that only 2.6% of 1,359 chest trauma patients at a level I trauma center required thoracotomy.⁶ In their study, average ISS was 16.0, and mortality was 9.4%. Our patients had more severe injuries than the patients in their study, and 8.5% required thoracotomy.

It has been argued that urgent thoracotomy for blunt trauma should rarely be based on chest tube output. In studies by Karmy-Jones *et al.*, the use of the traditional chest tube output criteria for thoracotomy was associated with increased blood loss, delayed thoracotomy, and increased mortality and morbidity, especially in patients with blunt trauma.² Another study suggested that patients with blunt trauma might develop coagulopathies before the decision to operate has been made, if the chest tube output criteria are used.³ In our study, the decision to perform thoracotomy was based on patients' hemodynamic status, and the chest tube output of our thoracotomy patients was lower than the traditionally reported criteria for urgent thoracotomy.

Factors other than pleural hemorrhage may result in unstable hemodynamic status in patients with multiple traumas. Physiologic abnormalities were common among our patients who underwent thoracotomy for hemorrhage. The early and frequent use of preventive operations may also prevent the lethal triad of hypothermia, metabolic acidosis, and coagulopathy. In our study, 19 of the 24 patients who required thoracotomy for thoracic hemorrhage had developed more than one component of this triad, and 5 of the 24 had developed all three prior to thoracotomy (data not shown). The TRISS of thoracotomy patients in this study was low (0.53 ± 0.34) with regard to physiologic abnormalities. The two patients who met the traditional criteria for thoracotomy (initial chest tube output of 1,000 mL or greater) died.

In our ROC analysis, the cutoff value for predicting thoracotomy was 404 mL, and sensitivity and specificity were also high. One of the limitations of our study is that we extrapolated the 1-h chest tube output from the chest tube output and time after admission. It remains to be determined whether 1-h chest tube output values are useful criteria for thoracotomy. Our AUC of 0.98 suggests that 1-h chest tube output might be a useful indicator, although the values are lower than those traditionally used.

The accuracy of the indicators of thoracotomy must be verified in order to set cut off values. We decided to perform urgent thoracotomy when a patient's hemodynamic status

remained unstable despite fluid resuscitation. All thoracotomy patients had active bleeding in thoracic cavity; however, the bias of individual surgeons could not be excluded. The cutoff value for predicting thoracotomy in this study should be used only as a reference, because this was a small study in a single center. Further larger studies and external validation are needed to establish a reliable indicator for urgent thoracotomy.

Matsumoto *et al.* reported that blood loss greater than 300 mL/h is associated with a poor prognosis; therefore, thoracotomy should be performed as early as possible in such patients.⁷ In a study performed at the Harborview Medical Center, patterns of errors contributing to inpatient trauma deaths in a 9-year period were identified.⁸ Delayed intervention for ongoing intrathoracic hemorrhage contributed to 9.4% of recognized errors leading to death.⁸ The authors reported that delayed intervention for ongoing intrathoracic hemorrhage most often delays the diagnosis of massive hemothorax with inadequate evacuation of blood from chest, or inadequate recognition of the volume that had already been evacuated.⁸ The main treatment for life-threatening hemorrhagic shock following blunt thoracic trauma is the rapid control of bleeding. Our findings suggest that thoracotomy should not be excluded solely because of chest tube output that is lower than the traditional criteria.

In conclusion, high chest tube output as a traditional indicator for thoracotomy may not apply to patients with blunt chest trauma.

CONFLICT OF INTEREST

NONE.

REFERENCES

- 1 Mattox KL, Wall MJ, Tsai P. Trauma thoracotomy: principles and techniques. In: Mattox KL, Moore EE, Feliciano DV (eds). Trauma, 7th edn. New York: McGraw-Hill, 2013; 461–7.
- 2 Karmy-Jones R, Jurkovich GJ, Nathens AB *et al.* Timing of urgent thoracotomy for hemorrhage after trauma: a multicenter study. Arch. Surg. 2001; 136: 513–8.
- 3 Hoth JJ, Scott MJ, Bullock TK *et al.* Thoracotomy for blunt trauma: traditional indications may not apply. Am. Surg. 2003; 69: 1108–11.
- 4 Developing Committee on the Course of Trauma Care Training of the Japan Association for the Surgery of Trauma. Guideline for Initial Trauma Care. Japan Advanced Trauma Evaluation and Care. 4th edn. [in Japanese]. Herusu Shuppan Company, Tokyo; 2012.

- 5 Esposito TJ, Sanddal ND, Hansen JD *et al.* Analysis of preventable trauma deaths and inappropriate trauma care in a rural state. *J. Trauma* 1995; 39: 955–62.
- 6 Kulshrestha P, Munshi I, Wait R. Profile of chest trauma in a level I trauma center. *J. Trauma* 2004; 57: 576–81.
- 7 Matsumoto K, Noguchi T, Ishikawa R *et al.* The surgical treatment of lung lacerations and major bronchial disruptions caused by blunt thoracic trauma. *Surg. Today* 1998; 28: 162–6.
- 8 Gruen RL, Jurkovich GJ, McIntyre LK *et al.* Patterns of errors contributing to trauma mortality: lessons learned from 2,594 deaths. *Ann. Surg.* 2006; 244: 371–80.