**ORIGINAL ARTICLE**

# Impact of cardiopulmonary resuscitation time on the effectiveness of emergency department thoracotomy after blunt trauma

Ryo Yamamoto[1] · Masaru Suzuki[2] · Rakuhei Nakama[3] · Kenichi Kase[3] · Kazuhiko Sekine[4] · Tomohiro Kurihara[5] · Junichi Sasaki[5]

## Abstract

**Purpose** Debate remains about the threshold cardiopulmonary resuscitation (CPR) duration associated with futile emergency department thoracotomy (EDT). To validate the CPR duration associated with favorable outcomes, we investigated the relationship between CPR duration and return of spontaneous circulation (ROSC) after EDT in blunt trauma.

**Methods** A retrospective observational study was conducted at three tertiary centers over the last 7 years. We included bluntly injured adults who were pulseless and required EDT at presentation, but excluded those with devastating head injuries. After multivariate logistic regression identified the CRP duration as an independent predictor of ROSC, receiver operating characteristic curves were used to determine the threshold CPR duration. Patient data were divided into short- and long-duration CPR groups based on this threshold, and we developed a propensity score to estimate assignment to the short-duration CPR group. The ROSC rates were compared between groups after matching.

**Results** Forty patients were eligible for this study and ROSC was obtained in 12. The CPR duration was independently associated with the achievement of ROSC [odds ratio 1.18; 95% confidence interval (CI) 1.01–1.37, $P = 0.04$], and the threshold CPR duration was 17 min. Among the 14 patients with a short CPR duration, 13 matched with the patients with a long CPR duration, and a short CPR duration was significantly associated with higher rates of ROSC (odds ratio 8.80; 95% CI 1.35–57.43, $P = 0.02$).

**Conclusions** A CPR duration < 17 min is independently associated with higher ROSC rates in patients suffering blunt trauma.

**Keywords** Emergency department thoracotomy · Cardiopulmonary resuscitation · Blunt trauma · Traumatic cardiopulmonary arrest

## Introduction

Emergency department thoracotomy (EDT) was developed as a resuscitative procedure for critically injured patients who presented in extremis. Several studies have reported that EDT can save patients with severe injuries if applied correctly [1–15]. Indeed, most physicians have accepted that EDT may offer hope for survival in moribund trauma victims, although it has been demonstrated that most patients do not survive if they present with no vital signs after blunt trauma [15]. Current guidelines detail the predictors of survival as being mechanisms of injury, anatomic site of injury, signs of life, and duration of cardiopulmonary resuscitation (CPR) [1–13]. Moreover, it has been suggested that, either alone or in combination, these predictors are associated with favorable neurological outcomes [8, 9, 11–13].

✉ Ryo Yamamoto
  ryo.yamamoto@gmail.com

1 Trauma Service, Department of Emergency and Critical Care Medicine, Keio University School of Medicine, 35 Shinanomachi, Shinjuku, Tokyo 160-8582, Japan

2 Department of Emergency Medicine, Tokyo Dental College, Ichikawa General Hospital, Chiba, Japan

3 Department of Emergency Medicine, Saiseikai Utsunomiya Hospital, Tochigi, Japan

4 Department of Emergency and Critical Care Medicine, Tokyo Saiseikai Central Hospital, Tokyo, Japan

5 Department of Emergency and Critical Care Medicine, Keio University School of Medicine, Tokyo, Japan

The optimal length of CPR before EDT that predicts favorable outcomes remains unclear [14–18]. The Western Trauma Association published an EDT algorithm in 2012 recommending EDT for victims of blunt trauma presenting with no signs of life after CPR had been attempted for under 10 min [19]. However, a practice management guideline for EDT published by the Eastern Association for the Surgery of Trauma removed the CPR duration from their recommendations in 2015, citing limitations in the currently available evidence [20]. The poor quality of science behind current CPR time thresholds means that CPR duration must be researched further if it is to be used as an indication for EDT.

In an effort to eventually clarify the CPR time threshold associated with favorable neurocognitive outcomes in victims of blunt trauma, we investigated the relationship between CPR time and return of spontaneous circulation (ROSC) after EDT. We hypothesized that a short CPR time would be associated with a higher rate of ROSC following EDT for blunt trauma.

## Patients and methods

### Study design

This retrospective observational study was conducted between January 2010 and May 2017 in three tertiary care centers in the Kanto area in Japan (Keio University Hospital in Tokyo, Saiseikai Central Hospital in Tokyo, and Saiseikai Utsunomiya Hospital in Tochigi). The study was approved by the review board of each participating hospital or its ethics committee for the conduct of human research.

### Study settings and population

We retrospectively identified trauma patients who were transported by ambulance to the emergency department of a participating hospital during the study period. Patients were included if they met the following criteria: were aged ≥ 18 years; had blunt trauma; were pulseless at presentation; and underwent EDT. Patients were excluded if the mechanism of injury was unknown, or if they had been subject to devastating head injuries.

### EDT indication and procedures incorporated with EDT

The need for EDT was decided by each physician based on the presence of signs of life including electrical cardiac activity, an estimated short CPR time, or obvious chest injury. EDT was performed in the same fashion in all patients, where surgical procedures were provided in the following order: opening the thoracic cavity, pericardiotomy, repairing cardiac injuries as appropriate, and aortic cross-clamp occlusion if ROSC was not achieved.

### Definition of CPR time and covariates

Prehospital data were collected from the records of emergency medical services (EMS) and included EMS dispatch time, lifesaving procedures provided in the field, and the time when cardiopulmonary arrest (CPA) was recognized. Additional information was extracted by review of each patient's hospital records, and we included the arrival time, basic patient information, injury mechanism, injury diagnosed (by physical or radiographic examination), Abbreviated Injury Scale (AIS), Injury Severity Score (ISS), and signs of life including cardiac rhythm at start of EDT. Injuries with an AIS ≥ 3 were considered significant and were analyzed as covariates. Chest injuries found during EDT and treated surgically were defined as treatable injuries and examined as covariates. The transportation time was defined as the duration from EMS dispatch to hospital arrival. Finally, for the purposes of this study, we defined the CPR time as the duration from when CPA was identified to the time when EDT was performed.

### Outcomes

The primary outcome was attainment of ROSC following EDT, which was defined as a palpable pulse with electrocardiographic evidence of cardiac activity. This information was ascertained by medical chart review. Secondary outcomes included overall mortality after EDT, mortality at 3 h after hospital arrival, the time from when EDT was provided to when ROSC was achieved, and the incidence of occupational exposure to blood among healthcare providers.

### Statistical analysis

The CPR time was compared between patients with and without ROSC and multivariate logistic regression was used to determine whether the CPR duration was an independent predictor of ROSC, using odds ratios (ORs) and 95% confidence intervals (95% CIs). We then drew a receiver operating characteristics (ROC) curve for the CPR time against ROSC attainment to determine the CPR time threshold based on the Youden index, where the CPR time is most likely to estimate ROSC with high sensitivity and specificity. Using this threshold, patient data were then divided into short- and long-CPR time groups, and propensity score matching was performed to compare the ROSC rates among them. A propensity score was developed by logistic regression to estimate the probability of being assigned to the short-CPR time group compared with the long-CPR time group. Relevant covariates were identified from known survival predictors

[1–13], and factors associated with a clinically favorable outcome were entered regardless of their relevance to CPR time. This ensured high-fidelity propensity scores. The precision of discrimination and propensity score calibration were analyzed with the $c$-statistic and Hosmer–Lemeshow goodness-of-fit test.

Sensitivity analyses were performed to validate the primary results. To confirm that results were not dependent on the method of matching, inverse probability weighting and logistic regression analyses were performed (using the propensity score as the covariate in logistic regression analysis) for the attainment of ROSC (primary outcome).

Descriptive statistics are presented as means $\pm$ SD or number (%). Results were compared with unpaired $t$ tests, Mann–Whitney $U$ tests, Chi-square tests, or Fisher's exact tests, as appropriate. For testing of all hypotheses, a two-sided $\alpha$ threshold of 0.05 was considered statistically significant. All statistical analyses were conducted using SPSS (SPSS, Chicago, IL, USA) and Microsoft Excel (Microsoft, Redmond, WA, USA).

## Results

A total of 40 patients were eligible for this study (Fig. 1), of which 12 (30%) regained spontaneous circulation and 28 (70%) did not (Table 1). ROSC before arriving at hospital was not identified in any patient and there were no interruptions of CPR during transportation. There were no survivors among the patients with ROSC.

### Impact of CPR time on ROSC

Mean CPR time in the patients with ROSC was shorter than in those without ROSC (18.8 $\pm$ 14.5 and 29.3 $\pm$ 14.3 min, respectively; $P < 0.05$). All covariates were comparable between the two groups. There were also no significant differences in the presence of signs of life (e.g., pulseless electrical activity) when EDT was performed. Information regarding cardiac rhythms was missing in four patients, two of whom achieved ROSC.

Multivariate logistic regression analysis demonstrated that CPR time was an independent predictor for ROSC (OR 1.18 per 1 min decrease in CPR time; 95% CI 1.01–1.37; Table 2). ROC curve analysis [area under the curve (AUC) = 0.698] clarified that the CPR time at the Youden index was 17 min ($J = 0.453$; sensitivity = 0.786; 1-specificity = 0.333; Fig. 2).

### Propensity score-matched analysis

A short CPR time was defined as a CPR time less than 17 min with a long CPR time defined as a CPR time greater than or equal to 17 min, and the data were divided by this threshold (Table 3). The propensity model predicting short CPR time included as covariates age, mechanism of injury, presence of treatable injuries, ISS, presence of PEA when EDT was provided and transportation time. This model was validated with high decimation and calibration for predicting CPR time ($c$-statistic = 0.912 and Hosmer–Lemeshow goodness-of-fit $P = 0.422$).

Among the 14 patients with a short CPR time, 13 matched with patients with a long CPR time (Table 3). In the unadjusted analysis, a short CPR time was significantly associated with higher rate of ROSC (OR 7.33; 95% CI 1.63–32.92), and this finding remained in the propensity score-matched analysis (OR 8.80; 95% CI 1.35–57.43; Fig. 3). Inverse probability weighting analysis confirmed that a short CPR time was significantly associated with a higher rate of ROSC (OR 38.59; 95% CI 4.14–359.54), and logistic regression with the propensity score as the covariate confirmed that the association between short CPR time and ROSC was not dependent on the matching method used (OR 12.96; 95% CI 1.05–160.91).

### Short CPR time and secondary outcomes

The 3-h mortality was significantly lower in the short-CPR time group than in the long-CRP time group (69.2 and 100.0%, $P = 0.02$, data not shown) and these findings remained after the propensity score matching (66.7 and 100.0%, $P = 0.04$, data not shown). The mean duration from EDT to achieve ROSC was not significantly different between the short-CRP time (15.1 $\pm$ 9.3 min) and long-CRP time (11.5 $\pm$ 2.1 min) groups ($P = 0.533$, data not shown). Similar results were observed by propensity score-matching analysis and other sensitivity analyses. Finally, the lack of survivors and lack of documented occupational blood exposure meant that we could not perform statistical analyses of these secondary outcomes.

## Discussion

In this study, we used propensity score matching to show that a CPR time less than 17 min was independently associated with a higher rate of ROSC after EDT in patients who presented without a pulse after blunt trauma. To the best of our knowledge, this is the first study to have reported this relationship using robust statistical methods. Notably, the observed relationship was consistent across several sensitivity analyses, suggesting the results were not dependent on the method of matching, the propensity scores, or the statistical approach.

Various investigators have challenged published dictums for the optimal timing of EDT [8, 9, 11–25]. Reported

**Fig. 1** Study flow diagram. We identified 224 TCPA patients, of whom 40 were included in the analyses and 26 (13 pairs) in the propensity score matching. *TCPA* traumatic cardiopulmonary arrest, *EDT* emergency department thoracotomy, *CPR* cardiopulmonary resuscitation
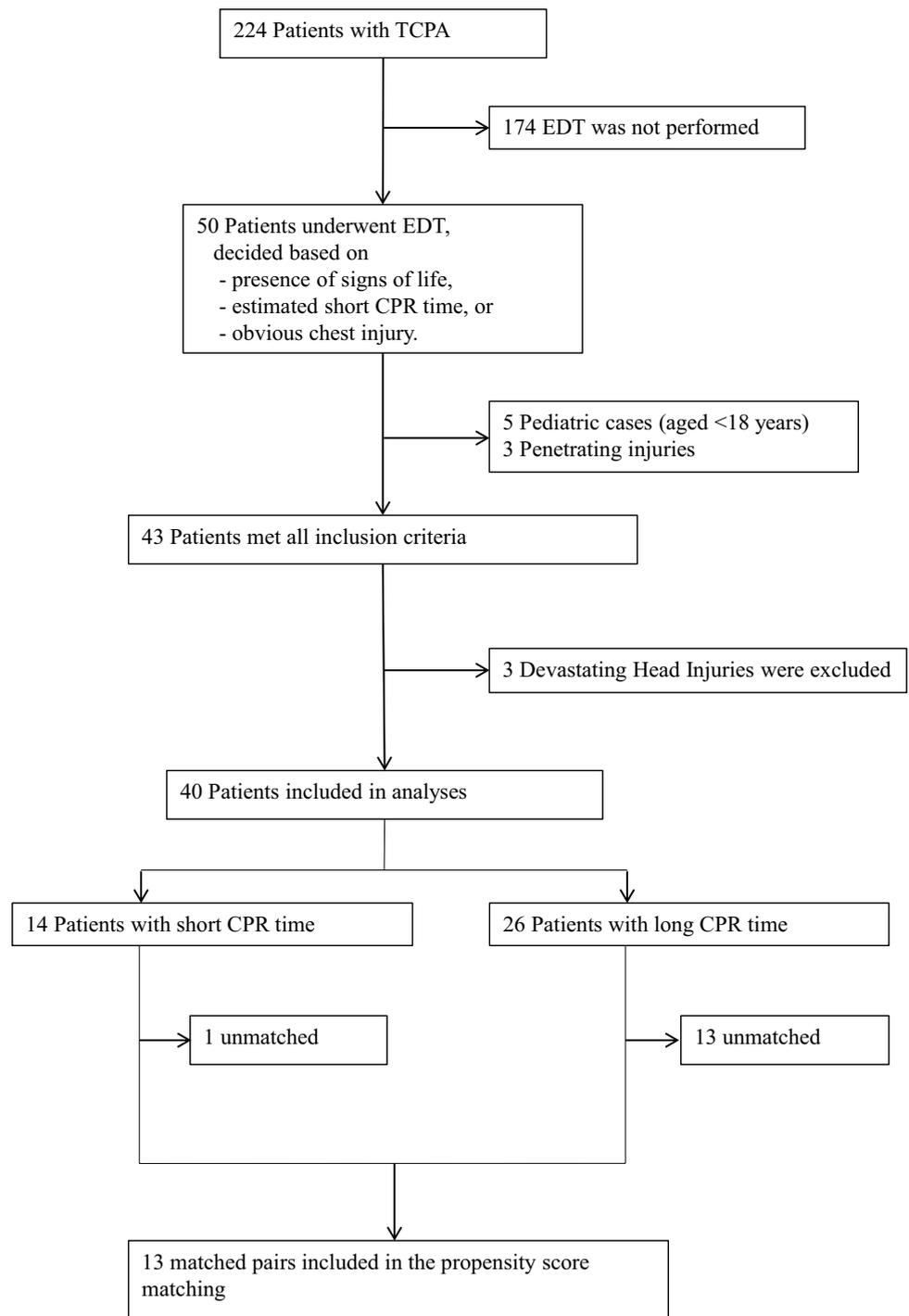


predictors of survival have included the injury mechanism, the anatomic injury location, the presence of injury that may benefit from EDT, the presence of vital signs, the presence of electrical cardiac rhythm or signs of life at presentation, and CPR duration [8, 9, 11–15, 20–25]. Although recommendations have been established based on these by some organizations [16, 19, 20, 26, 27], discussion has been ongoing regarding what the maximum CPR duration should be

before considering that EDT is futile and so terminating resuscitation [8, 14–20, 23, 28, 29].

The threshold CPR time for regaining ROSC in this study, 17 min, was similar to that previously reported [16–19, 23]. In 2001, a statement by the National Association EMS Physicians (NAEMSP) and the American College of Surgeons Committee on Trauma (ACSCOT) indicated that patients with a CPR time of more than 15 min

**Table 1** Characteristics of patients with and without ROSC

| | Total | With ROSC | Without ROSC | P value |
|---|---|---|---|---|
| Patient number | 40 | 12 | 28 | |
| Age (y/o) | 55.9 ± 20.4 | 58.8 ± 21.0 | 54.6 ± 20.7 | 0.57 |
| Gender | | | | |
|   Male:female | 32:8 | 10:2 | 22:6 | 0.73 |
| Mechanisms of injury | | | | |
|   Motor vehicle collision | 10 | 4 (33.3%) | 6 (21.4%) | 0.45 |
|   Motorcycle collision | 9 | 1 (8.3%) | 8 (28.6%) | 0.23 |
|   Pedestrian–auto collision | 14 | 3 (25.0%) | 11 (39.3%) | 0.48 |
|   Falls | 7 | 4 (33.3%) | 3 (10.7%) | 0.17 |
| Injuries (AIS ≥ 3) | | | | |
|   Head and neck | 12 | 4 (33.3%) | 8 (28.6%) | 0.70 |
|   Face | 0 | 0 (0.0%) | 0 (0.0%) | – |
|   Chest | 24 | 8 (66.7%) | 16 (57.1%) | 0.44 |
|   Abdomen | 14 | 5 (41.7%) | 9 (32.1%) | 0.46 |
|   Extremity | 7 | 4 (33.3%) | 3 (10.7%) | 0.08 |
|   External | 0 | 0 (0.0%) | 0 (0.0%) | – |
| Treatable injuries (total) | 17 | 7 (58.3%) | 10 (35.7%) | 0.19 |
|   Cardiac injuries | 6 | 2 (16.7%) | 4 (14.3%) | 1.00 |
|   Intrathoracic injuries | 11 | 5 (41.7%) | 6 (21.4%) | 0.25 |
| ISS | 35.8 ± 16.8 | 38.8 ± 13.8 | 34.5 ± 18.2 | 0.11 |
| Signs of life | | | | |
|   PEA[a] | 23 (63.9%) | 7 (70.0%) | 16 (61.5%) | 0.64 |
|   Pupillary response | 0 | 0 (0.0%) | 0 (0.0%) | – |
|   Spontaneous ventilation | 0 | 0 (0.0%) | 0 (0.0%) | – |
|   Extremity movement | 0 | 0 (0.0%) | 0 (0.0%) | – |
| Transportation time (min) | 33.6 ± 16.3 | 34.8 ± 15.9 | 33.1 ± 17.0 | 0.77 |
|   Min–max | 3–87 | 3–54 | 8–87 | |
| CPR time (min) | 26.8 ± 14.8 | 18.8 ± 14.5 | 29.3 ± 14.3 | 0.049 |
|   Min–max | 3–51 | 3–47 | 0–51 | |

*EDT* emergency department thoracotomy, *ROSC* return of spontaneous circulation, *AIS* Abbreviated Injury Scale, *ISS* Injury Severity Score, *PEA* pulseless electrical activity, *CPR* cardiopulmonary resuscitation

[a]Data were missing in four patients, two of whom achieved ROSC

**Table 2** Predictors for ROSC in multivariate logistic regression

| | Odds ratio | 95% CI | P value |
|---|---|---|---|
| Age | 1.01 | 0.90–1.13 | 0.88 |
| Mechanisms of injury | | | |
|   Motor vehicle collision | 0.35 | 0.00–109.48 | 0.72 |
|   Motorcycle collision | 0.05 | 0.00–21.43 | 0.33 |
|   Pedestrian–auto collision | 20.67 | 0.05–9155.90 | 0.33 |
|   Falls | 0.04 | 0.00–2.84 | 0.14 |
| Treatable injuries | 0.12 | 0.00–3.54 | 0.22 |
| ISS | 0.94 | 0.81–1.09 | 0.40 |
| Signs of life (PEA) | 0.12 | 0.00–3.75 | 0.23 |
| Transportation time | 1.08 | 0.98–1.18 | 0.12 |
| CPR time | 1.18 | 1.01–1.37 | 0.04 |

*CPR* cardiopulmonary resuscitation, *ISS* Injury Severity Score, *PEA* pulseless electrical activity

after traumatic CPA may be non-salvageable and that termination of resuscitation should be considered [16]. In 2004, a retrospective study of 26 survivors who underwent EDT showed that survivors received less than 15 min of prehospital CPR [17], while another case series of patients with CPA after blunt trauma reported two survivors after EDT (the CPR times were 11 and 15 min in these patients) [23]. A multicenter observational study of EDT survivors, published by the Western Trauma Association in 2011, found that the longest CPR duration was 9 min in five survivors of EDT, and that no patients survived EDT if preceded by more than 15 min of CPR [18]. Based on these retrospective case reviews, the Western Trauma Association published the EDT algorithm in 2012, in which it was recommended that EDT only be performed on victims of blunt trauma presenting with no signs of life if CPR had been performed for less than 10 min [19].

**Fig. 2** ROC curve for CPR time and ROSC. ROC curve for the CPR time against ROSC attainment. AUC was 0.698. The dichotomized CPR time threshold was chosen from the Youden index ($J = 0.453$, shown as filled triangle), where the CPR time is most likely to estimate ROSC with high sensitivity and specificity. *ROC* receiver operating characteristics, *CPR* cardiopulmonary resuscitation, *ROSC* return of spontaneous circulation, *AUC* area under the curve
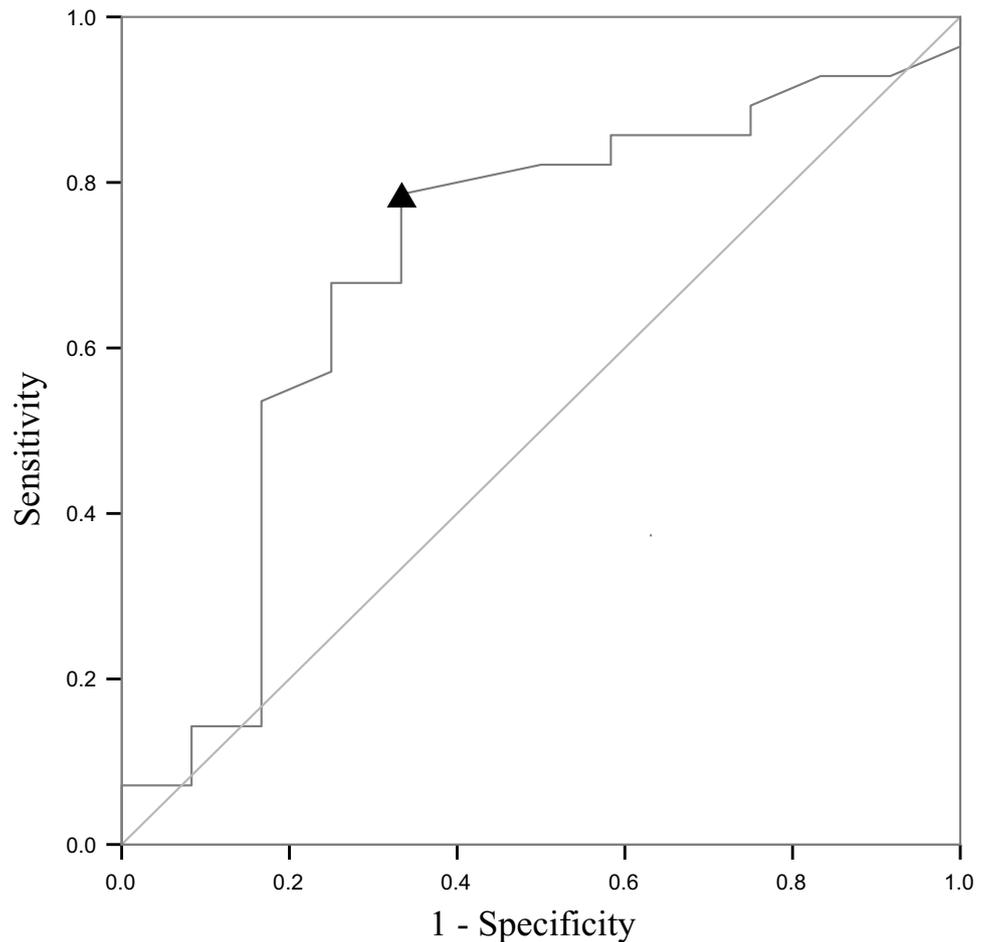
**Table 3** Covariates in short- and long-CRP time group

| | Total study population | | | | Propensity score-matched analysis | | |
|---|---|---|---|---|---|---|---|
| | Short CPR time | Long CPR time | SMD | P value | Short CPR time | Long CPR time | SMD |
| Patient number | 14 | 26 | | | 13 | 13 | |
| Age (y/o) | 68.1 ± 19.7 | 49.3 ± 18.3 | 0.989 | 0.13 | 62.1 ± 21.4 | 52.1 ± 21.0 | 0.472 |
| Mechanisms of injury | | | | | | | |
|   Motor vehicle collision | 3 | 7 | − 0.129 | 1.00 | 3 | 2 | 0.196 |
|   Motorcycle collision | 1 | 8 | − 0.632 | 0.12 | 1 | 4 | − 0.612 |
|   Pedestrian–auto collision | 7 | 7 | 0.488 | 0.18 | 6 | 6 | 0.000 |
|   Falls | 3 | 4 | 0.156 | 0.68 | 3 | 1 | 0.436 |
| Treatable injuries | 6 (35.7%) | 11 (42.9%) | 0.011 | 1.00 | 6 (46.2%) | 4 (30.8%) | 0.320 |
| ISS | 38.9 ± 12.3 | 34.1 ± 19.0 | 0.300 | 0.30 | 39.3 ± 12.7 | 37.5 ± 22.4 | 0.100 |
| Signs of life[a] (PEA) | 10 (71.4%) | 13 (59.1%) | 0.261 | 0.50 | 9 (69.2%) | 8 (61.5%) | 0.162 |
| Transportation time (min) | 37.4 ± 15.3 | 31.5 ± 17.1 | 0.364 | 0.36 | 37.2 ± 15.9 | 32.3 ± 14.3 | 0.324 |
|   Min–max | 15–61 | 3–87 | | | 15–61 | 16–59 | |

*CPR* cardiopulmonary resuscitation, *ISS* Injury Severity Score, *PEA* pulseless electrical activity, *SMD* standardized mean difference

[a]Data were missing in four patients, two of whom achieved ROSC

In contrast, it has been recognized that a number of studies to date have not provided information on the duration of CPR, despite this being a major confounding variable that is likely to affect outcomes [15]. Given this limitation, NAEMSP-ACSCOT removed the duration of CPR from their 2012 decision algorithm in the joint position statement
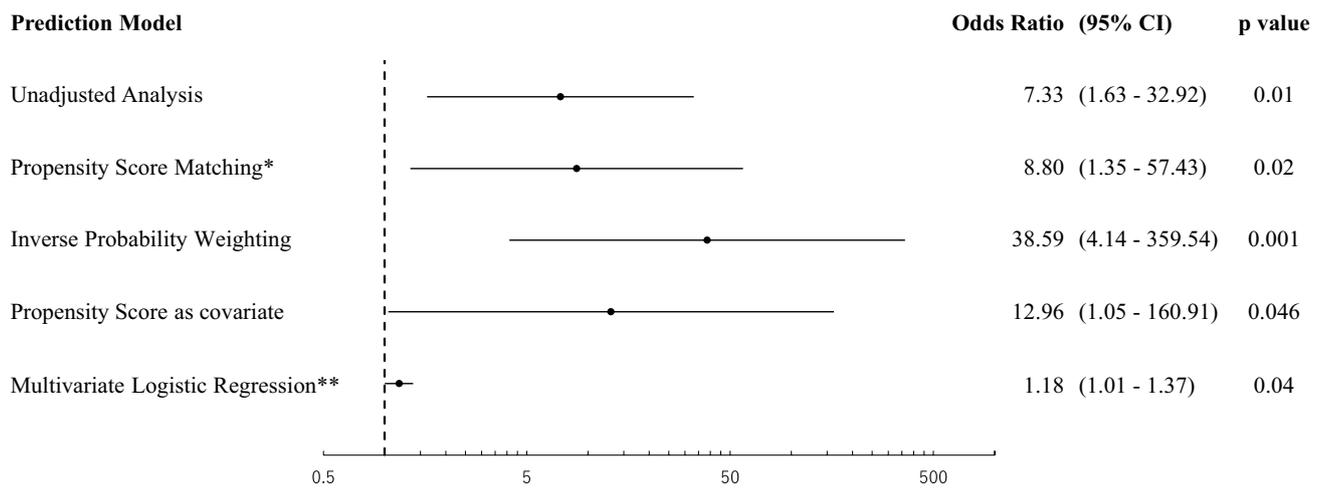
| Prediction Model | | Odds Ratio (95% CI) | p value |
|---|---|---|---|
| Unadjusted Analysis | | 7.33 (1.63 - 32.92) | 0.01 |
| Propensity Score Matching* | | 8.80 (1.35 - 57.43) | 0.02 |
| Inverse Probability Weighting | | 38.59 (4.14 - 359.54) | 0.001 |
| Propensity Score as covariate | | 12.96 (1.05 - 160.91) | 0.046 |
| Multivariate Logistic Regression** | | 1.18 (1.01 - 1.37) | 0.04 |

**Fig. 3** Effect of short CPR time on ROSC. A short CPR time was significantly associated with higher rate of ROSC (odds ratio 8.80; 95% CI 1.35–57.43) in propensity score-matched analysis, which was conducted as primary analysis. To confirm that results were not dependent on the method of matching, inverse probability weighting and logistic regression analyses were performed (using the propensity score as the covariate in logistic regression analysis). Asterisk indicates primary analysis. Double asterisk indicates multivariate logistic regression performed before patient data were divided into short- and long-CPR time groups, where CPR time was entered as a continuous variable and odds ratio (95% CI) for the achievement of ROSC was 1.18 (1.01–1.37) per 1 min decrease in CPR time (data also shown in Table 2). *CPR* cardiopulmonary resuscitation, *ROSC* return of spontaneous circulation, *CI* confidence interval

on the termination of resuscitation in trauma patients [27]. In addition, although the importance of the duration without a perfusing rhythm was recognized, the practice management guidelines for EDT established by the Eastern Association for the Surgery of Trauma in 2015 no longer required the exact CPR time to be considered before EDT [20]. Evidence limitations were cited as the main reason for not incorporating CPR time into their recommendation. Perhaps of greatest concern to formulating definitive guidelines is that there are currently no prospective randomized studies regarding the association between CPR time for blunt trauma and outcomes after EDT.

To provide results that are more robust than those previously reported, we used propensity score matching and sensitivity analyses in this retrospective observational study. Due to ethical concerns surrounding patient randomization, where EDT is considered as the last resort and patients in a non-therapeutic control group would probably have lower chances of survival, we considered that propensity score analyses offered the most reliable method for reducing the effects of confounding factors. Although low evidence quality has been cited as a criticism regarding the threshold CPR time [15, 20, 27], our results suggest that a CPR time less than 17 min could be incorporated into practice recommendations if the association between this threshold and favorable outcome is confirmed in larger cohorts.

The results of this study must be interpreted in the context of the study design. First, attainment of ROSC was chosen as a surrogate marker for favorable neurological outcome. Although ROSC and neurological outcomes do not fully correlate, our results will likely only have overestimated the efficacy of EDT preceded by a short CPR time because patients who did not achieve ROSC did not survive. It should also be noted that the 3-h mortality was significantly lower in the short-CPR time group than in the long-CRP time group. Second, we included all patients with CPA after blunt trauma, regardless of PEA, which would have been an important confounding variable. However, we performed several propensity-adjusted analyses and showed that the relationship between short CPR time and ROSC was not dependent on the presence of signs of life. Finally, because some patients had longer CPR times than estimated at hospital arrival, the mean CPR time was actually 26.1 min in this study, which is longer than that reported in previous studies [15, 18, 20]. Although this selection bias limits the generalizability of our findings, it should be emphasized that the CPR time threshold was still identified as 17 min, close to the 10–15-min thresholds defined in past algorithms.

## Conclusions

A CPR time less than 17 min was independently associated with higher rates of ROSC after EDT for blunt trauma, using robust methods of analysis. We, therefore, recommend that the duration of CPR should again be considered for determining whether to perform EDT.

## Compliance with ethical standards

# References

1. Moore EE, Moore JB, Galloway AC, Eiseman B. Postinjury thoracotomy in the emergency department: a critical evaluation. Surgery. 1979;86:590–8.
2. Cogbill TH, Moore EE, Millikan JS, Cleveland HC. Rationale for selective application of emergency department thoracotomy in trauma. J Trauma. 1983;23:453–60.
3. Baxter BT, Moore EE, Moore JB, Cleveland HC, McCroskey BL, Moore FA. Emergency department thoracotomy following injury: critical determinants for patient salvage. World J Surg. 1988;12:671–5.
4. Powell RW, Gill EA, Jurkovich GJ, Ramenofsky ML. Resuscitative thoracotomy in children and adolescents. Am Surg. 1988;54:188–91.
5. Boyd M, Vanek VW, Bourguet CC. Emergency room resuscitative thoracotomy: when is it indicated? J Trauma. 1992;33:714–21.
6. Durham LA III, Richardson RJ, Wall MJ Jr., Pepe PE, Mattox KL. Emergency center thoracotomy: impact of prehospital resuscitation. J Trauma. 1992;32:775–9.
7. Mazzorana V, Smith RS, Morabito DJ, Brar HS. Limited utility of emergency department thoracotomy. Am Surg. 1994;60:516–20.
8. Branney SW, Moore EE, Feldhaus KM, Wolfe RE. Critical analysis of two decades of experience with postinjury emergency department thoracotomy in a regional trauma center. J Trauma. 1998;45:87–94.
9. Seamon MJ, Pathak AS, Bradley KM, Fisher CA, Gaughan JA, Kulp H, et al. Emergency department thoracotomy: still useful after abdominal exsanguination? J Trauma. 2008;64:1–7.
10. Easter JS, Vinton DT, Haukoos JS. Emergent pediatric thoracotomy following traumatic arrest. Resuscitation. 2012;83:1521–4.
11. Feliciano DV, Bitondo CG, Cruse PA, Mattox KL, Burch JM, Beall AC Jr, et al. Liberal use of emergency center thoracotomy. Am J Surg. 1986;152:654–9.
12. Rhee PM, Acosta J, Bridgeman A, Wang D, Jordan M, Rich N. Survival after emergency department thoracotomy: review of published data from the past 25 years. J Am Coll Surg. 2000;190:288–98.
13. Seamon MJ, Goldberg AJ, Schwab CW. Emergency department thoracotomy for gunshot wounds of the heart and great vessels. J Trauma. 2010;68:1514–5.
14. Seamon MJ, Chovanes J, Fox N, Green R, Manis G, Tsiotsias G, et al. The use of emergency department thoracotomy for traumatic cardiopulmonary arrest. Injury. 2012;43:1355–61.
15. Slessor D, Hunter S. To be blunt: are we wasting our time? Emergency Department thoracotomy following blunt trauma: a systematic review and meta-analysis. Ann Emerg Med. 2015;65:297–307.e16.
16. Hopson LR, Hirsh E, Delgado J, Domeier RM, McSwain NE, Krohmer J, National Association of EMS Physicians, American College of Surgeons Committee on Trauma. Guidelines for withholding or termination of resuscitation in prehospital traumatic cardiopulmonary arrest: joint position statement of the National Association of EMS Physicians and the American College of Surgeons Committee on Trauma. J Am Coll Surg. 2003;196:106–12.
17. Powell DW, Moore EE, Cothren CC, Ciesla DJ, Burch JM, Moore JB, et al. Is emergency department resuscitative thoracotomy futile care for the critically injured patient requiring prehospital cardiopulmonary resuscitation? J Am Coll Surg. 2004;199:211–5.
18. Moore EE, Knudson MM, Burlew CC, Inaba K, Dicker RA, Biffl WL, et al; WTA Study Group. Defining the limits of resuscitative emergency department thoracotomy: a contemporary Western Trauma Association perspective. J Trauma. 2011;70:334–9.
19. Burlew CC, Moore EE, Moore FA, Coimbra R, McIntyre RC Jr, Davis JW, et al. Western Trauma Association critical decisions in trauma: resuscitative thoracotomy. J Trauma Acute Care Surg. 2012;73:1359–63.
20. Seamon MJ, Haut ER, Van Arendonk K, Barbosa RR, Chiu WC, Dente CJ, et al. An evidence-based approach to patient selection for emergency department thoracotomy: a practice management guideline from the Eastern Association for the Surgery of Trauma. J Trauma Acute Care Surg. 2015;79:159–73.
21. Lewis G, Knottenbelt JD. Should emergency room thoracotomy be reserved for cases of cardiac tamponade? Injury. 1991;22:5–6.
22. Lorenz HP, Steinmetz B, Lieberman J, Schecoter WP, Macho JR. Emergency thoracotomy: survival correlates with physiologic status. J Trauma. 1992;32:780–5.
23. Fialka C, Sebök C, Kemetzhofer P, Kwasny O, Sterz F, Vécsei V. Open-chest cardiopulmonary resuscitation after cardiac arrest in cases of blunt chest or abdominal trauma: a consecutive series of 38 cases. J Trauma. 2004;57:809–14.
24. Kalina M, Teeple E, Fulda G. Are there still selected applications for resuscitative thoracotomy in the emergency department after blunt trauma? Del Med J. 2009;81:195–8.
25. Lustenberger T, Labler L, Stover JF, Keel MJ. Resuscitative emergency thoracotomy in a Swiss trauma centre. Br J Surg. 2012;99:541–8.
26. Working group. Ad hoc subcommittee on outcomes. American College of Surgeons' Committee on Trauma. Practice management guidelines for emergency department thoracotomy. J Am Coll Surg. 2001;193:303–9.
27. Millin MG, Galvagno SM, Khandker SR, Malki A, Bulger EM, Standards Clinical Practice Committee of the National Association of EMS Physicians (NAEMSP), Subcommittee on Emergency Services Prehospital of the American College of Surgeons' Committee on Trauma (ACSCOT). Withholding and termination of resuscitation of adult cardiopulmonary arrest secondary to trauma: resource document to the joint NAEMSP-ACSCOT position statements. J Trauma Acute Care Surg. 2013;75:459–67.
28. Esposito TJ, Jurkovich GJ, Rice CL, Maier RV, Copass MK, Ashbaugh DG. Reappraisal of emergency room thoracotomy in a changing environment. J Trauma. 1991;31:881–5.
29. Pahle AS, Pedersen BL, Skaga NO, Pillgram-Larsen J. Emergency thoracotomy saves lives in a Scandinavian hospital setting. J Trauma. 2010;68:599–603.