


Original Article

Impact of emergency physicians competent in severe trauma management, surgical techniques, and interventional radiology on trauma management

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Aim: Despite recent advancements in trauma management following introduction of interventional radiology (IVR) and damage-control strategies, challenges remain regarding optimal use of resources for severe trauma.

Methods: In October 2014, we implemented a trauma management system comprising emergency physicians competent in severe trauma management, surgical techniques, and IVR. To evaluate this system, of 5,899 trauma patients admitted to our hospital from January 2011 to January 2018, we selected 107 patients with severe trauma (injury severity score ≥ 16) who presented with persistent hypotension (two or more systolic blood pressure measurements <90 mmHg), regardless of primary resuscitation. Patients were divided according to the date of admission: Conventional (January 2011–September 2014) or Current (October 2014–January 2018). The primary end-point was in-hospital mortality. Secondary end-points included time from arrival to start of surgery/IVR.

Results: There were 59 patients in the Conventional group and 48 in the Current group. Although patients in the Current group were more severely ill compared with those in the Conventional group, mortality in the Current group was significantly lower (Conventional 64.4% versus Current 41.7%, $P = 0.019$), especially among patients whose first intervention was IVR (Conventional 75.0% versus Current 28.6%, $P = 0.001$). Time from arrival to initiation of surgery/IVR was shorter in the Current group (Conventional 71.5 [53.8–130.8] min versus Current 41.0 [26.0–58.5] min, $P < 0.0001$).

Conclusions: This trauma management system based on emergency physicians competent not only in severe trauma management, but also surgical techniques and IVR, could improve outcomes in patients with severe multiple lethal trauma.

Key words: Hybrid treatment, interventional radiology, life-threatening trauma management, resuscitative hemostasis

INTRODUCTION

RECENTLY, TRAUMA MANAGEMENT has markedly improved due to rapid advances in medical equipment and procedures such as interventional radiology (IVR)¹ and damage-control strategies.^{2,3} Interventional radiology is a novel method for trauma management.¹ As a part of resuscitative IVR, resuscitative endovascular balloon occlusion of the aorta (REBOA) is used widely.⁴ Furthermore, hybrid trauma operating rooms^{5,6} have been introduced into the emergency department (ED). Several institutions have

expanded the indication of transcatheter arterial embolization (TAE) to relatively unstable patients.⁷ Thus, a multidisciplinary approach, including IVR, is required in current trauma management.⁸ In contrast, if a condition exists, resuscitative surgery for diagnosis and treatment prior to adequate examination is necessary, especially in patients with lethal trauma. We believe that the availability of computed tomography (CT) and IVR could be effective in some cases, even in patients with severe multiple trauma, whereas their misuse could result in death. Discretion is important to ensure prompt and seamless resuscitative treatment, which might consist of only surgery, only IVR, or a combination of both. Taken together, it is still challenging to carry out complete management that makes the best use of both surgery and IVR for severe multiple trauma patients.

In the present study, we evaluated the impact of our trauma management system based on emergency physicians competent in severe trauma management, surgical techniques, and interventional radiology on trauma management.

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Trauma management in our hospital

In October 2014, we created a trauma management system that comprises trained emergency physicians (TEPs) who are physicians specializing in emergency medicine and general surgery and are also trained in cardiovascular surgery and IVR, which is a modification of the pre-existing system in which emergency physicians (EPs) assembled several specialists who were necessary to carry out emergency surgery and/or IVR. The decision to undertake urgent surgery or IVR was based on the discretion of EPs in the ED or several specialists in the Conventional group. Similarly, the procedures were carried out by several specialists. However, in the Current group the decision to perform surgery or IVR was based on the discretion of TEPs in the ED, with consideration of which procedure was immediately necessary to save the patient's life. All procedures were also carried out by TEPs.

The CT scan, angiography suite, and operating room (OR) are integrated into the ED in our hospital and are available for use at all hours. The management system in the Current group was constructed as follows.

There were three or four EPs on duty at our ED at all hours. Among them was at least one TEP based on a shift system. The TEPs possessed leadership skills and made critical decisions including surgery and IVR. The surgery and/or IVR were carried out by another TEP with the assistance of an instructor without delay. For example, a patient with life-threatening trauma would be directly admitted into the OR of the ED and would be able to undergo surgery performed by the TEPs as soon as possible. For patients who are able to undergo CT scan, it would be possible to decide

on treatment strategies immediately, based on the CT scan findings. It is possible to change strategies from IVR to surgery and vice versa, on a case-by-case basis.

METHODS

Study design and patient selection

IN THE PRESENT study, we evaluated the impact of trauma management by TEPs on mortality among patients with severe multiple trauma. This retrospective historical control study was carried out in Japan. A total of 5,899 severe trauma patients were admitted to our hospital between January 2011 and January 2018. Among them, there were 386 severe trauma patients (injury severity score [ISS] ≥ 16) whose systolic blood pressure (SBP) was <90 mmHg on arrival (pre-admission and on admission) without cardiopulmonary arrest on admission and non-traumatic cardiac arrest. Furthermore, we selected 107 patients who showed persistent hypotension (two or more SBP values <90 mmHg) regardless of primary resuscitation (airway management, massive transfusion, and/or reversal of obstructive shock) to evaluate this trauma management system (Fig. 1). The patients were divided into two groups: the Conventional (managed from January 2011 to September 2014) and Current (managed from October 2014 to January 2018) groups.

Data collection

The ED variables (Glasgow coma scale, respiratory rate, SBP, body temperature, pulse rate, blood pH, base excess,

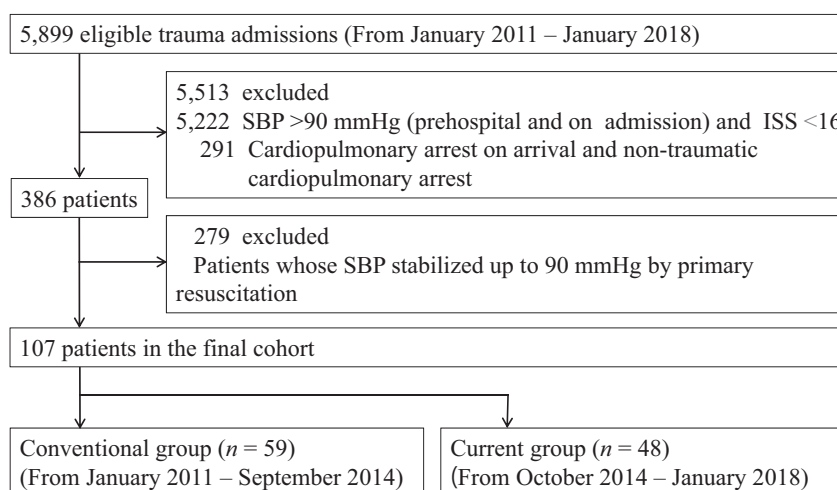


Fig. 1. Flow diagram for patient inclusion in the study of the impact of emergency physicians competent in severe trauma management, surgical techniques, and interventional radiology on trauma management. Conventional group, admitted January 2011–September 2014; Current group, admitted October 2014–January 2018. ISS, Injury Severity Score; SBP, systolic blood pressure.

lactate value, D-dimer, and prothrombin time – international normalized ratio) were recorded as the initial set of vital signs and laboratory tests. Revised trauma score (RTS), ISS, and probability of survival calculated using the Trauma and Injury Severity Score (TRISS-Ps) were used to determine patient characteristics and injury severity.

Outcome measures

The primary end-point was defined as in-hospital mortality. We set several secondary end-points to evaluate the effectiveness of this trauma management system described as follows: pre-intervention CT scan performance ratio, aortic clamp

ratio, administered red blood cells (RBCs), and fresh frozen plasma (FFP); the ratio of patients who underwent intervention; the number of regions that required intervention per person; the ratio of patients who underwent surgery as first intervention (FI) among those who underwent intervention; the time course from arrival to start of surgery/IVR; length of stay in the OR or angiography suite; intervention-related morbidity that required additional treatment; amount of blood transfused; 24-h mortality; standardized mortality ratio (SMR, ratio of observed to predicted mortality calculated by the TRISS method); number of preventable trauma-related deaths (deaths with TRISS-Ps $\geq 50\%$); and the number of unexpected survivors (survivors with TRISS-Ps $< 50\%$).

Table 1. Characteristics of 107 patients with severe trauma treated at the same hospital, grouped according to date of admission

	Conventional (n = 59)	Current (n = 48)	P-value
Age, years	51.4 \pm 20.4	53.2 \pm 21.3	0.8230
Male gender (%)	41 (69.5)	29 (60.4)	0.3260
Mechanism of injury			0.0660
Motor vehicle accident	25	24	
Fall from a height	20	20	
Stabbing	8	3	
Compression	4	1	
Gun shot	1	0	
Violence	1	0	
Vital signs on admission			
GCS total score	14.0 (6.0–15.0)	12.0 (6.0–15.0)	0.2620
RR, per min	26.0 (20.0–32.0)	24.0 (18.0–30.0)	0.1140
SBP, mmHg	68.4 \pm 18.2	72.1 \pm 22.3	0.1570
BT, °C	35.8 \pm 1.2	36.1 \pm 1.0	0.8720
Pulse rate, beats per min	112.4 \pm 28.3	109.0 \pm 28.0	0.6060
Laboratory evaluation			
pH	7.25 (7.10–7.33)	7.28 (7.06–7.39)	0.2980
Base excess, mmol/L	–11.4 (–18.1 to –5.9)	–8.4 (–17.3 to –4.6)	0.2990
Lactate, mg/dL	66.0 (39.8–101.3)	50.0 (34.0–90.0)	0.1780
D-dimer, μ g/mL	27.0 (11.7–60.2)	78.0 (34.2–121.2)	0.1410
PT-INR	1.1 (1.0–1.3)	1.2 (1.0–1.5)	0.0070
Trauma score			
RTS	5.6 (4.1–6.4)	5.3 (2.6–6.8)	0.4900
ISS	34.0 (27.0–50.0)	50.0 (41.0–66.0)	<0.0001
TRISS-Ps All	53.2 (12.9–83.5)	21.3 (1.0–66.2)	0.0040
TRISS-Ps FI-surgery	74.7 (39.1–89.0)	2.8 (0.6–58.6)	0.0010
TRISS-Ps FI-IVR	47.7 \pm 34.3	40.1 \pm 34.1	0.9220
TRISS-Ps None	20.5 \pm 22.9	15.1 \pm 8.5	0.1920

Conventional, January 2011–September 2014; Current, October 2014–January 2018.

BT, body temperature; FI, first intervention; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; IVR, interventional radiology; PT-INR, prothrombin time – international normalized ratio; RR, respiratory rate; RTS, Revised Trauma Score; SBP, systolic blood pressure; TRISS-Ps, probability of survival calculated by the Trauma Revised Injury Severity Score.

Statistical analysis

Statistical analyses were carried out using SPSS software (Windows version 22.0; SPSS, Chicago, IL, USA). The values are presented as either the mean \pm standard deviation or the median (interquartile range, 25–75). Categorical variables were compared using the χ^2 -test or Fisher's exact test, and continuous variables were analyzed using Student's *t*-test or the Mann–Whitney *U*-test. Standardized mortality ratios were compared using the Wald-type test with logistic regression. Statistical significance was defined as a *P*-value of <0.05 or was assessed using 95% confidence intervals.

This study was approved by the institutional review board for clinical research, Tokai University (Kanagawa, Japan) (approval no. 17R-344).

RESULTS

THERE WERE 59 patients in the Conventional group and 48 patients in the Current group. Table 1 summarizes the patients' baseline characteristics. The ISS (Conventional 34.0 [27.0–50.0] versus Current 50.0 [41.0–66.0], *P* < 0.0001), TRISS-Ps All (Conventional 53.2 [12.9–83.5] versus Current 21.3 [1.0–66.2], *P* = 0.004), and TRISS-Ps FI-surgery (Conventional 74.7 [39.1–89.0] versus Current 2.8 [0.6–58.6], *P* = 0.001) were statistically different between the two groups. The Current group had more severe trauma than did the Conventional group.

The primary end-point and other outcomes are shown in Table 2 and Figure 2. Although the patients in the Current group had more severe trauma compared with those in the Conventional group, their in-hospital mortality was significantly lower compared with the Conventional group (Conventional 64.4% versus Current 41.7%, *P* = 0.019), especially among patients whose FI was IVR (Conventional 75.0% [21/28] versus Current 28.6% [6/21], *P* = 0.001). The SMR of the Current group was also markedly lower compared with that of the Conventional group (Conventional 132.1% versus 60.0%, *P* = 0.001). The 24-h mortality was not significantly different between groups. However, the SMR of the Current group was markedly lower compared with that of the Conventional group (Conventional 82.1% versus Current 38.2%, *P* = 0.026). Although 12 patients died from preventable trauma-related causes in the Conventional group, no deaths in the Current group were preventable. Furthermore, there were more unexpected survivors in the Current group compared with that in the Conventional group (Conventional 3 versus Current 14, *P* = 0.001).

The secondary end-points are shown in Table 3 and Figure 3. There was no significant difference in the ratio of

Table 2. Treatment outcome for 107 patients with severe trauma treated at the same hospital, grouped according to date of admission

	Conventional (n = 59)	Current (n = 48)	<i>P</i> -value
24-h mortality (%)			
All	23 (39.0)	13 (26.5)	0.195
FI-surgery	6/22 (27.3)	10/24 (40.0)	0.306
FI-IVR	11/28 (39.3)	0	0.001
None	6/9 (66.7)	3/3 (100.0)	0.248
Standardized mortality ratio, % (24-h mortality)			
All	82.1	38.2	0.026
FI-surgery	120	55.6	0.392
FI-IVR	78.6	0	0.999
None	75	100	1.000
In-hospital mortality (%)			
All	38 (64.4)	20 (41.7)	0.019
FI-surgery	8/22 (36.4)	11/24 (45.8)	0.515
FI-IVR	21/28 (75.0)	6/21 (28.6)	0.001
None	9/9 (100.0)	3/3 (100.0)	NA
Standardized mortality ratio, % (in-hospital mortality)			
All	132.1	60	0.001
FI-surgery	133.3	63.2	0.313
FI-IVR	158.3	46.2	0.003
None	112.5	100	NA
Preventable trauma deaths (deaths with TRISS-Ps \geq50%)			
All	12	0	0.001
FI-surgery	4	0	0.045
FI-IVR	7	0	0.007
None	1	0	1.000
Unexpected survivors (survivors with TRISS-Ps <50%)			
All	3	14	0.001
FI-surgery	2	7	0.139
FI-IVR	1	7	0.015
None	0	0	NA

Conventional, January 2011–September 2014; Current, October 2014–January 2018.

FI, first intervention; IVR, interventional radiology; NA, not applicable; TRISS-Ps, provability of survival calculated by Trauma and Injury Severity Score.

patients who underwent a CT scan before FI between the two groups. On the contrary, more patients in the Current group underwent aortic clamping by using left anterior thoracotomy or REBOA before FI. Although there was no significant difference in the total number of blood transfusions between the groups, the number of administered RBCs and FFPs before FI were significantly higher in the Current group. The ratio of patients who underwent intervention, the ratio of patients who underwent surgery for FI among those who underwent intervention, and the number of regions that

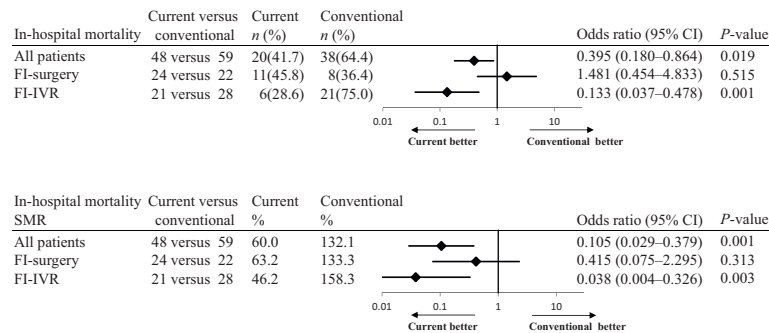


Fig. 2. Effects on in-hospital mortality and standardized mortality ratios (SMRs) in 107 patients with severe multiple lethal trauma, grouped as all patients, those with surgery only, and those with interventional radiology (IVR) only. Odds ratios with 95% confidence interval (CI) plots indicate the association of the treatment group with in-hospital mortality; SMRs are also expressed. In-hospital mortality was compared using the χ^2 -test, and SMRs were compared using the Wald-type test with logistic regression. Conventional group, admitted January 2011–September 2014; Current group, admitted October 2014–January 2018. FI, first intervention.

required intervention per person were not significantly different between the two groups. The time from arrival to initiation of surgery/IVR (min) among all patients, surgery first, or IVR first groups in the Current group were shorter than those in the Conventional group. The median time spent in the OR among the surgery first group was significant shorter in the Current group compared with that in the Conventional group. The number of intervention-related morbidities that required additional treatment was not significantly different between the two groups.

DISCUSSIONS

THE MAIN FINDING of this study was that trauma management by TEPs might be associated with reduced in-hospital mortality among patients with multiple lethal trauma.

Previous published reports regarding decision-making has suggested that it is possible to immediately and accurately undertake trauma management by the formation of a trauma team.⁹ Furthermore, trauma specialists have shortened the time of resuscitation and the time to start surgery by offering their support at all times.¹⁰ Trauma surgeons and centers are assessed using multiple valid tools to improve the quality of trauma management.¹¹ Thus, it is possible to smoothly manage severe multiple trauma patients if trauma specialists make prompt judgments as team leaders.

Nevertheless, we consider that it is not clear whether it is sufficient to carry out all treatments, including IVR immediately and seamlessly, with discretion. Moreover, in many countries, including ours, the number of trauma patients has decreased. Therefore, the number of both doctors solely specializing in trauma, as well as the number of emergency medical centers solely specializing in trauma, have also

decreased. As such, it is still challenging to save patients with multiple severe trauma, while creating trauma management systems with those competencies.

To address this issue, we have created a trauma management system that is based on TEPs. A TEP stays in the ED at all hours and usually engages in the primary care of patients transported by ambulance with all sorts of conditions, and the intensive care of patients admitted through the ED and the department of critical care medicine. When a patient with fatal trauma is transported to our hospital, a TEP can decide on the appropriate treatment approach immediately by judging the necessity of surgery and IVR under their leadership. Trained EPs can also carry out surgery and/or IVR seamlessly for all types of fatal trauma on their own. Moreover, there are many non-trauma patients who require emergency surgery or IVR in the current ED. Therefore, we believe that such competencies exert a beneficial effect.

In this study, we used several parameters to compare both groups. The RTS and ISS are good indicators of the severity of injury in trauma patients,^{12,13} as is the measurement of base deficits,¹⁴ serum lactate levels,¹⁵ and D-dimer values¹⁵ from blood examination. Moreover, we used the TRISS-Ps method to evaluate outcomes. This method is one of the most commonly used survival prediction tools for trauma patients. Although drawbacks to this method have recently been identified, there are presently no comparable survival prediction methods.¹⁶ Using the patients' vital signs and several parameters, an interpretation was made that all the cases in this study were markedly life-threatening. However, the severity of trauma among the patients was not similar between the two groups. The cases in the Current group were markedly more severe than those in the Conventional group. We speculated that this result was attributable to

Table 3. (A) Pre-first intervention (FI) computed tomography (CT) scan, aorta clamp, and intervention-related characteristics in 107 patients with severe trauma treated at the same hospital, grouped according to date of admission; (B) Intervention-related characteristics and total number of blood transfusions in severe trauma patients with surgery/interventional radiology (IVR)

(A)	Conventional (n = 59)	Current (n = 48)	P-value
Pre-FI CT scan performance ratio (%)	40 (67.8)	29 (60.4)	0.4280
Aorta clamp ratio (%)			
All	5 (8.5)	25 (52.1)	<0.0001
Open	0 (0.0)	11 (22.9)	<0.0001
Endovascular	5 (8.5)	14 (29.2)	0.0050
Intervention performance ratio (%)	50 (84.7)	45 (93.8)	0.1420
Total number of interventions	1.0 (1.0–1.0)	1.0 (1.0–2.0)	0.1190
(B)	Conventional (n = 50)	Current (n = 45)	P-value
Patients who underwent surgery as FI (%)	22 (44.0)	24 (53.3)	0.3630
Time to initiation FI, min			
FI-All	71.5 (53.8–130.8)	41.0 (26.0–58.5)	<0.0001
FI-surgery	69.0 (53.8–119.5)	28.5 (18.3–43.0)	<0.0001
FI-IVR	71.5 (47.5–146.3)	57.0 (41.5–71.0)	0.0320
Time in OR/AS, min			
FI-All	70.0 (43.8–133.5)	74.0 (35.0–123.0)	0.5840
FI-surgery	130.0 (70.0–263.5)	70.5 (27.8–117.0)	0.0200
FI-IVR	48.0 (30.0–80.0)	89.0 (41.0–123.0)	0.0680
Intervention-related morbidity (%)			
All	5 (10.0)	1 (2.2)	0.2760
Surgery	4/22 (18.2)	0 (0.0)	0.0450
IVR	1/28 (3.6)	1/21 (4.8)	0.8350
Preoperative blood transfusion, mL			
Red blood cells	560.0 (280.0–1120.0)	560.0 (560.0–1120.0)	0.0040
Fresh frozen plasma	0.0 (0.0–60.0)	240.0 (0.0–3000.0)	0.0020
Total number of blood transfusions, units			
Red blood cells	19.0 (6.0–32.5)	13.0 (7.5–21.5)	0.9610
Fresh frozen plasma	12.0 (4.0–20.5)	11.0 (7.5–20.5)	0.3660

Conventional, January 2011–September 2014; Current, October 2014–January 2018.
AS, angiography suit; OR, operating room.

several pre-hospital activities; however, the exact cause of this was unclear.

As mentioned above, TEPs achieved a markedly higher survival rate compared with the Conventional group, no adverse sequelae caused by intervention-related morbidity, and high unexpected survival rate in severe multiple trauma patients who showed persistent hypotension regardless of primary resuscitation. The time from arrival to initiation of both surgery and IVR was extremely short, similar to the hybrid operating environment.^{5,6} Furthermore, the TEPs were able to convert one form of treatment to another and were able to deal with all complications. They also prevented unnecessary invasive procedures, leading to good

functional prognoses. We found that TEPs were capable of immediately and seamlessly making the best use of both surgery and IVR in the appropriate order, including optimal timing of CT scans for treating patients with severe multiple injuries, while enabling decisions concerning the necessity of early administration of blood transfusions or the necessity of aortic clamp before cardiac arrest. Trained EPs master trauma-based specialties, not limited by anatomical location or therapeutic approach. Based on these findings, we believe that it is essential that future studies evaluate whether CT scan, REBOA, and early blood transfusions (RBCs, FFP) affect outcomes of patients with severe multiple trauma.

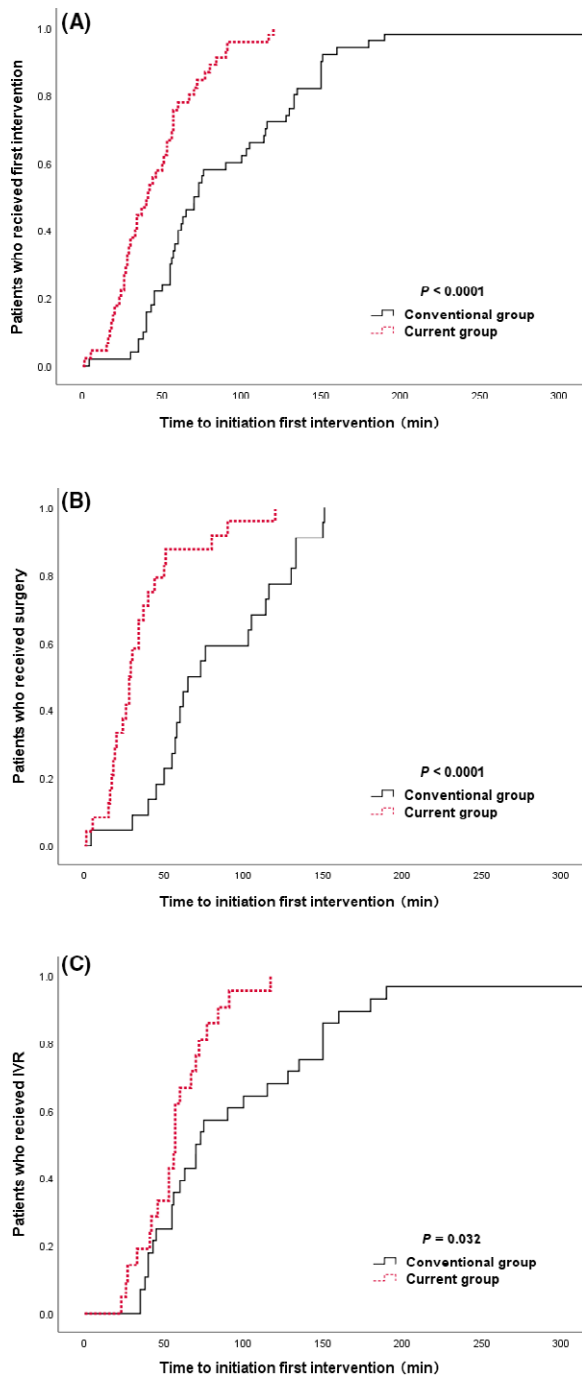


Fig. 3. Kaplan–Meier curves showing time to initiation of the first intervention in 107 patients with severe multiple lethal trauma. A, All patients. B, Those with surgery only. C, Those with interventional radiology only. Conventional group, admitted January 2011–September 2014; Current group, admitted October 2014–January 2018.

Furthermore, we found the following important results in this study. Among patients whose FI was IVR, the severity was not significantly different between groups. However, mortality was markedly lower in the Current group than in the Conventional group. These results suggest that the use of IVR alone or in combination with surgery might be effective in some cases to control hemorrhage even in lethal trauma, given efficient decisions, actions, and the ability to deal with complications. Conversely, their misuse without efficient competence might result in death. Based on these findings, such competencies are essential to perform IVR to control hemorrhage successfully in patients with multiple lethal trauma.

There are several limitations to this study. This was a small, retrospective, single-center study. The severe trauma cases at our center were highly specific, complex, and had low interdisciplinarity. Over time, medical equipment and procedures have developed rapidly. Therefore, it is difficult to substantiate whether our trauma management system with TEPs is the best approach. Thus, it is necessary to accumulate more cases for investigation in future studies.

CONCLUSION

THIS TRAUMA MANAGEMENT system based on TEPs competent not only in severe trauma management but also surgical techniques and IVR, could improve outcomes in patients with severe multiple lethal trauma. Such competencies are essential to successfully undertake IVR alone, or in combination with surgery, in such trauma patients.

DISCLOSURE

Approval of the research protocol: This study was approved by the institutional review board for clinical research, Tokai University (Kanagawa, Japan) (approval no. 17R-344).

Informed consent: N/A.

Registry and registration no. of the study/trial: N/A.

Conflict of interest: None.

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