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Original Article

Comparison of mortality among hemorrhage-control methods performed for hemodynamically unstable patients with traumatic pelvic fractures: A multi-center study

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SUMMARY

Background: /Objective: We aimed to analyze the effects of hemorrhage control methods on the mortality of patients with hemodynamic instability due to pelvic fracture and investigate independent mortality risk factors in these patients.

Methods: Ninety-seven pelvic bone fracture patients with hemodynamic instability who visited the emergency departments of two university hospitals over 5 years were enrolled. These patients were categorized based on 28-day mortality (survival group) and acute hemorrhage mortality (non-survival group). Forty-seven patients (48.5%) underwent pelvic angiography; 45 (46.4%), pre-peritoneal pelvic packing; and 19 (19.6%), external fixation.

Results: Differences in hemorrhage control methods did not significantly affect mortality. However, there was a significant difference in mortality between the groups with and without hemorrhage control methods. Multivariate logistic regression analysis revealed that patient age, trauma and injury severity score (probability of survival), and blood transfusion amount within 24 h were independent risk factors for 28-day mortality. Meanwhile, patient age, Glasgow coma scale (GCS) score, systolic blood pressure (SBP), and blood transfusion amount within 24 h were independent risk factors for mortality due to acute hemorrhage.

Conclusion: Rapid and appropriate application of hemorrhage control methods can reduce acute hemorrhage-related mortality in hemodynamically unstable patients with pelvic fractures. Moreover, none of the hemorrhage control methods were superior for the decreasing mortality rate in these patients.

1. Introduction

The treatment of traumatic pelvic fractures is a major challenge for surgeons in trauma units worldwide. Several studies have reported mortality rates of 50–60% for patients with traumatic pelvic fractures and hemodynamic instability.[1,2] Hemodynamic instability resulting from massive bleeding from arteries, veins, and/or the fractured bone itself may quickly become life-threatening.[3,4] Therefore, based on risk factors that may predispose patients to critical situations, it is necessary to promptly choose the best therapeutic approach.

There are several established methods for hemorrhage control in pelvic fractures, such as angiography and angioembolization (AE), pre-peritoneal pelvic packing (PPP), and external fixation (EF). These methods are routinely used at many institutions and have been successful for the resuscitation of patients with pelvic fractures and hemodynamic instability.[5,6] However, despite these efforts, pelvic fracture remains a life-threatening condition when the patient is hemodynamically unstable. Furthermore, patient outcomes differ across institutions and regions.

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This study investigated the effects of different hemorrhage control methods on the survival of pelvic fracture patients with hemodynamic instability. Furthermore, we investigated independent risk factors potentially associated with mortality in this patient population.

2. Methods

2.1. Patient enrollment and data collection

We conducted a retrospective observational study at two tertiary institutions in Seoul and Wonju in South Korea from January 2013 to October 2017. We reviewed the medical records of patients who visited the emergency department with traumatic pelvic fractures. Of these, patients with hemodynamic instability were included. Patients without pelvic fractures, younger than 18 years, and those with pelvic fractures who were hemodynamically stable were excluded. As a result, 97 patients with traumatic pelvic fractures and hemodynamic instability were enrolled. Hemodynamic instability in adults was defined as (a) a systolic blood pressure (SBP) < 90 mmHg on admission with evidence of skin vasoconstriction (cool and clammy skin, decreased capillary refill), altered level of consciousness, and/or shortness of breath or (b) as SBP >90 mmHg but requiring bolus infusions/transfusions and/or vasopressor drugs and/or admission base excess (BE)>−5 mmol/L and/or shock index>1 and/or transfusion requirement of at least 4–6 units of packed red blood cells within the first 24 h.[7]

Initially, we divided all patients into those who survived up to 28 days (28-day survival group) and those who did not (non-survival group). Additionally, we divided the patients into those who died of acute hemorrhage due to pelvic bone fracture and those who did not. We then assessed the clinical variables between the groups. The proportion of hemorrhage control methods performed at the two institutions and associated patient outcomes such as mortality rates were compared. Additionally, we divided the patients based on whether AE or PPP was used as the primary hemorrhage control procedure and compared the groups.

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Boards of the two medical institutions, which waived the requirement for patient informed consent because of the retrospective nature of the study.

2.2. Clinical variables

We analyzed the sex, age, injury mechanism, vital signs, Glasgow coma scale (GCS) score, current medication, transfusion amount within the first 24 h, abbreviated injury scale (AIS) score, injury severity score (ISS), revised trauma score (RTS), trauma and injury severity score (TRISS), Acute Physiology and Chronic Health Evaluation (APACHE) II score, arterial blood pH, BE levels, and lactate levels. Furthermore, pelvic radiography and abdomen-pelvic computed tomography were performed for almost all patients; pelvic fracture patterns, confirmed by clinical, surgical, and radiology records, were classified as lateral compression 1 to 3, anterior-posterior compression 1 to 3, and vertical shearing according to the Young-Burgess classification.[8,9] Types of hemorrhagic control modalities (pelvic binder wearing, angiography, AE, PPP, and EF) were investigated. We also investigated whether intraperitoneal surgery was performed in conjunction with hemorrhagic control of the pelvic bone fracture.

2.3. Statistical analysis

Statistical analysis of the investigated items was performed using SPSS Statistics 23.0 (IBM Corp., Armonk, NY). Categorical data are presented as numbers (%) and were compared using the chi-square test or Fisher's exact test. Continuous variables are expressed as mean ± standard deviation or as median and interquartile range, and data were compared between the groups using Student's *t*-test or the Mann–Whitney *U* test. Univariate analysis revealed the factors significantly associated with the need for hemorrhage control intervention, and these were included in the multivariate analysis. Logistic regression modeling was performed using the maximum likelihood method and backward stepwise selection. Goodness-of-fit was assessed using the Hosmer–Lemeshow test. Odds ratios (ORs) are provided with 95% confidence intervals (CIs); $p < 0.05$ was considered statistically significant.

3. Results

3.1. Comparisons of baseline characteristics of patients

The baseline characteristics of patients in both groups are summarized in Table 1.

Of the 97 patients, 37 (38.1%) died within 28 days. The mean survival of these deceased patients was 2.81 ± 4.43 days. Twenty-eight (75.7%) patients died from acute hemorrhage, and the cause of death up to 28 days afterward was sepsis in 3 patients (8.1%) and multi-organ failure, including heart failure and hepatic failure, in 6 patients (16.2%). The length of hospital stay for the 28 patients who died of acute hemorrhage was 1.25 ± 0.52 days, while for nine patients who died of MOF or sepsis by 28 days was 7.67 ± 7.25 days. The mean age at the time of the accident among the surviving patients was 50.72 ± 20 years, which was significantly different from the mean age of 66.27 ± 21.6 years for patients who died. Furthermore, the number of blood transfusions performed within the first 24 h ($p = 0.002$) was statistically significant different between the groups.

When categorized according to the injury mechanism, motor vehicle accidents involving pedestrians were the most frequent, followed by motorcycle accidents. Nevertheless, no statistically significant difference in the injury mechanism was noted between the groups (p=0.549). There was no significant difference between the 28-day survival group and the non-survival group with respect to whether a pelvic binder was worn at the time of the patient's visit. Whether the patient underwent intraperitoneal surgery during treatment did not significantly affect 28-day mortality.

In the second analysis, 29 of the 97 patients (29.9%) died of acute hemorrhage associated with pelvic fracture (Table 1). With respect to the injury mechanism, mortality was most frequently caused by acute hemorrhage due to motor vehicle accidents involving pedestrians, followed by injuries resulting from motorcycle accidents. Nonetheless, no significant between-group difference in the injury mechanism was found (p=0.573). The transfusion requirement within 24 h was significantly different between the two groups (p=0.006).

There was no significant difference in acute hemorrhage mortality rates or whether a pelvic binder was worn at the time of the patient's visit. Whether the patient underwent intraperitoneal surgery during treatment did not significantly affect acute hemorrhage mortality; however, it did show a trend toward significance.

3.2. Comparison of trauma-related scores and shock-related parameters between the groups

The trauma-related scores and shock-related parameters, including patients' vital signs and arterial blood gas analysis, are presented in Table 2.

The AIS was not significantly different between the 28-day mortality group and acute hemorrhage mortality group. In

Table 1
Baseline characteristics of patients.

	Mortality (28-day)		*p*	Mortality (acute hemorrhage)		*p*
	Survival ($n = 60$)	Non-survival ($n = 37$)		Survival ($n = 69$)	Non-survival ($n = 28$)	
Age, years, mean ± SD	50.72 ± 20	66.27 ± 21.6	<0.001	53.91 ± 20.8	63.39 ± 23.4	0.053
Sex, *n* (%)			0.286			0.141
Male	29 (48.3)	22 (59.5)		33 (47.8)	18 (64.3)	
Female	31 (51.7)	15 (40.5)		36 (52.2)	10 (35.7)	
Injury mechanism, *n* (%)			0.549			0.573
MVA (pedestrian)	27 (45)	20 (54.1)		32 (46.4)	15 (53.6)	
MVA (passenger)	9 (15)	3 (8.1)		10 (14.5)	2 (7.1)	
Motorcycle accidents	18 (30)	8 (21.6)		19 (27.5)	7 (25)	
Falls	5 (8.3)	4 (10.8)		5 (7.2)	4 (14.3)	
Others	1 (1.7)	2 (5.4)		3 (4.3)	0 (0)	
Transfusion amount (24-h)	10.9 ± 7.1	19.1 ± 13.7	0.002	11.5 ± 7.9	20 ± 14.3	0.006
Pelvic binder	37 (61.7)	21 (60)	0.872	40 (58)	18 (69.2)	0.316
Combined laparotomy	10 (16.7)	10 (27)	0.221	11 (15.9)	9 (32.1)	0.074

MVA, motor vehicle accident SD, standard deviation.

Table 2
Comparison of trauma-related scores and shock-related parameters.

	Mortality (28-day)		*p*	Mortality (acute hemorrhage)		*p*
	Survival ($n = 60$)	Non-survival ($n = 37$)		Survival ($n = 69$)	Non-survival ($n = 28$)	
AIS, mean ± SD						
Head and neck	1.13 ± 1.54	1.46 ± 1.76	0.339	1.12 ± 1.5	1.61 ± 1.87	0.178
Face	0.38 ± 0.8	0.57 ± 1.02	0.325	0.39 ± 0.79	0.61 ± 1.1	0.351
Chest	1.5 ± 1.51	1.95 ± 1.63	0.174	1.55 ± 1.5	1.96 ± 1.71	0.241
Abdomen	1.75 ± 1.56	1.7 ± 1.41	0.881	1.75 ± 1.53	1.68 ± 1.44	0.824
Extremities	4.58 ± 0.53	4.78 ± 0.53	0.076	4.61 ± 0.52	4.79 ± 0.57	0.143
External	0.46 ± 0.54	0.38 ± 0.55	0.485	0.43 ± 0.53	0.43 ± 0.57	0.986
ISS, mean ± SD	34.4 ± 10.1	41 ± 12.9	0.006	34.5 ± 9.8	42.6 ± 14	0.008
RTS, mean ± SD	6.369 ± 1.924	4.681 ± 2.574	0.001	6.325 ± 1.852	4.247 ± 2.742	0.001
TRISS, %, mean ± SD	67.61 ± 31.14	34.45 ± 31.15	<0.001	64.57 ± 31.44	31.27 ± 32.21	<0.001
APACHE II, mean ± SD	16.4 ± 9	37.7 ± 7.1	<0.001	17.4 ± 9.4	41.3 ± 5.3	<0.001
Vital sign, mean ± SD						
SBP	96.6 ± 30.4	70.5 ± 40.9	0.001	94.4 ± 29.9	67.6 ± 45.3	0.007
HR	98 ± 25.4	89.7 ± 47.1	0.325	99 ± 27.2	84.6 ± 49.1	0.153
BT	36.1 ± 0.9	34.7 ± 5.9	0.068	36.1 ± 0.9	34.3 ± 6.8	0.188
GCS score, mean ± SD	11.9 ± 4.7	9.1 ± 4.9	0.007	11.9 ± 4.5	8.2 ± 5.1	0.001
ABGA, mean ± SD						
pH	7.34 ± 0.109	7.264 ± 0.197	0.045	7.342 ± 0.11	7.241 ± 0.208	0.024
BE	−6.8 ± 4.6	−10.1 ± 6.4	0.012	−6.9 ± 4.6	−10.7 ± 6.7	0.013
Lactate	4.3 ± 3	6.6 ± 3.2	0.001	4.4 ± 3	7 ± 3.2	<0.001

ABGA, arterial blood gas analysis; AIS, abbreviated injury scale; APACHE, Acute Physiology and Chronic Health Evaluation; BE, base excess; BT, body temperature; GCS, Glasgow coma scale; HR, heart rate; ISS, injury severity score; RTS, revised trauma score; SBP, systolic blood pressure; SD, standard deviation; TRISS, trauma and injury severity score.

contrast, the ISS (p=0.006; p=0.008), RTS (p=0.001; p=0.001), and TRISS (p<0.001, p<0.001) were significantly different for both mortality criteria. The APACHE II score (p<0.001; p<0.001) was also significantly different between these groups.

With respect to clinical variables, patients who died within 28 days or from acute hemorrhage were found to have significantly lower SBP (p=0.001; p=0.007), and GCS (p=0.007; p=0.001) than the surviving patients. Arterial blood gas analysis showed that patients who died within 28 days or from acute hemorrhage had statistically significantly higher BE (p=0.012; p=0.013) and higher lactate levels (p=0.001; p<0.001) than surviving patients.

3.3. Comparison of hemorrhage control methods between the groups

Bleeding due to pelvic injury can be controlled via various means. As shown in Table 3, in the comparison of the baseline characteristics of the patients who underwent AE as the primary procedure and PPP as the primary procedure, there were slight differences in items such as sex, extremity AIS, body temperature, and time to procedure. However, there were no significant differences in age, injury mechanism, ISS, RTS, and shock-related laboratory markers. The average time to application of AE and PPP was 139.6 ± 173.9 min, 183.5 ± 228.3 for AE and 96.8 ± 89.2 for PPP. However, the differences between the two procedures did not affect patient prognosis including mortality.

Before comparing mortality between the groups, we investigated the percentage difference between the two institutions regarding each hemorrhage control method. Moreover, we investigated whether there were significant differences in mortality between the two institutions. As a result, the percentage of each hemorrhage control method used by the two institutions differed; however, a comparison of 28-day mortality (p=0.081) and acute hemorrhage mortality (p=0.371) rates did not show a significant difference between the two institutions.

We analyzed the differences in mortality for the different hemorrhage control methods of angiography, AE, PPP, and EF between the groups (Table 4).

Among the hemorrhage control methods used for the 97 patients with pelvic fractures and hemodynamic instability in this

Table 3
Group comparison based on whether AE or PPP was performed as the primary procedure.

	AE (n = 38)	PPP (n = 37)	*P* value
Age, years, mean ± SD	56.71 ± 21.1	58.92 ± 20.2	0.645
Sex, *n* (%)			0.028
Male	15 (39.5)	24 (64.9)	
Female	23 (60.5)	13 (35.1)	
Injury mechanism, *n* (%)			0.26
MVA (pedestrian)	21 (55.3)	11 (29.7)	
MVA (passenger)	4 (10.5)	6 (16.2)	
Motorcycle accident	9 (23.7)	12 (32.4)	
Fall	3 (7.9)	6 (16.2)	
Other	1 (2.6)	2 (5.4)	
AIS, mean ± SD			
Head and neck	1.05 ± 1.51	1.19 ± 1.63	0.707
Face	0.63 ± 1.05	0.3 ± 0.78	0.122
Chest	1.32 ± 1.44	1.86 ± 1.72	0.137
Abdomen	2.05 ± 1.47	1.51 ± 1.56	0.127
Extremities	4.58 ± 0.5	4.84 ± 0.5	0.028
External	0.62 ± 0.49	0.16 ± 0.44	0
ISS, mean ± SD	34.8 ± 10.9	39.2 ± 9.9	0.068
RTS, mean ± SD	6.296 ± 2.191	5.464 ± 2.375	0.119
TRISS, %, mean ± SD	65.21 ± 32.24	46.39 ± 33.67	0.016
APACHE II, mean ± SD	18.6 ± 13.1	32 ± 6.6	0.038
Vital signs, mean ± SD			
SBP	90.2 ± 36.6	81.1 ± 36.6	0.28
HR	88.3 ± 31.8	102.4 ± 38.5	0.092
BT	36.1 ± 0.9	35.6 ± 0.9	0.038
GCS score, mean ± SD	12.4 ± 4.3	10.2 ± 4.9	0.043
ABGA, mean ± SD			
pH	7.322 ± 0.178	7.283 ± 0.131	0.323
BE	−7.6 ± 6.5	−9.2 ± 4.6	0.249
Lactate	4.9 ± 3.8	5.3 ± 2.9	0.649
Time to procedure	183.5 ± 228.3	96.8 ± 89.2	0.044
Transfusion amount (24 h)	12.6 ± 10.1	17.4 ± 12.2	0.076
Mortality (28 days)	12 (44.4)	15 (55.6)	0.419
Mortality (acute hemorrhage)	9 (5)	9 (5)	0.948

ABGA, arterial blood gas analysis; AE, angioembolization; AIS, abbreviated injury scale; APACHE, Acute Physiology and Chronic Health Evaluation; BE, base excess; BT, body temperature; GCS, Glasgow coma scale; HR, heart rate; ISS, injury severity score; MVA, motor vehicle accident; PPP, preperitoneal pelvic packing; RTS, revised trauma score; SBP, systolic blood pressure; SD, standard deviation; TRISS, trauma and injury severity score.

study, the most frequent was angiography, which was performed for 47 patients (48.45%) in each group. Among these, 32 patients (32.98%) underwent AE. PPP was the second most frequently used method (45 patients; 46.39%). Nineteen patients (19.58%) underwent EF.

There were no statistically significant differences in mortality among the hemorrhage control methods used for the 28-day and acute hemorrhage groups, except for EF of the acute hemorrhage mortality group (p=0.001). However, a comparison between the group that underwent any of the three aforementioned hemorrhage control methods and the group that did not undergo any one of them showed a significant difference in acute hemorrhage mortality between the survival and non-survival groups (p=0.032).

Table 5 compares whether there was a significant difference in the survival and non-survival groups when each hemorrhage control method was applied alone or when two or more hemorrhage control methods were combined. Most patients underwent AE alone (25 cases), followed by PPP alone with 21 cases. There was one case of EF alone. In total, 23 patients received two treatments, most commonly AE and PPP (11 cases), followed by 7 cases of PPP with EF and 5 cases of AE with EF. For 17 patients who underwent both AE and PPP, the average time between the two procedures was 133.9 ± 111.9 min. Among these, 14 patients underwent both procedures because of ongoing hemodynamic instability, with an average interval of 111.3 ± 78.9 min between the two procedures. For the remaining three patients, AE was performed at a later time based on re-bleeding, with an average interval of 826.5 ± 546.6 min between the two procedures.

As a result of the analysis, there was no significant difference between the survival and non-survival groups at 28 days according to the combination of hemorrhage control methods. In the same analysis, there was also no significant difference between the survival and non-survival groups in terms of acute hemorrhage according to the treatment combination.

3.4. Logistic regression analysis of predictors of mortality for hemodynamically unstable patients with pelvic fracture

Results of the univariate and multivariate regression analyses are shown in Table 6 and Table 7.

Age (OR, 1.056; 95% CI, 1.020–1.093; p=0.002), lower TRISS (OR, 0.976; 95% CI, 0.956–0.997; p=0.022), and large amounts of blood transfused within the first 24 h (OR, 1.084; 95% CI, 1.015–1.156, p=0.016) were identified as independent risk factors for death within 28 days. The different hemorrhage control methods did not significantly affect mortality among these patients.

Age (OR, 1.050; 95% CI, 1.014–1.087; p=0.006) and a large amount of blood transfused within the first 24 h (OR, 1.094; 95% CI, 1.025–1.169; p=0.007) were identified as independent predictors of death with acute hemorrhage. The GCS score (OR, 0.852; CI, 0.740–0.981; p=0.026) and SBP (OR, 0.978; CI, 0.960–0.997; p=0.025) were also independent risk factors for acute hemorrhage mortality of pelvic fracture patients with hemodynamic instability.

4. Discussion

4.1. Effects of the different hemorrhage control methods on survival

To understand the nature of hemodynamic instability in pelvic fractures, the most common causes should be known. There are three major sources of bleeding in pelvic fractures: the surface of the fractured bones, the pelvic venous plexus, and arterial injury. Bleeding in pelvic fractures occurs in approximately 90% of venous cases and approximately 10% of arterial cases.[10] However, arterial bleeding is more common in cases of ongoing bleeding or hemodynamic instability despite adequate treatment. Although the

Table 4
Effect of hemorrhage control methods on patient mortality.

	Mortality (28-day)		*p*	Mortality (acute hemorrhage)		*p*
	Survival (n = 60)	Non-survival (n = 37)		Survival (n = 69)	Non-survival (n = 28)	
Angiography	33 (55.9)	14 (38.9)	0.107	37 (54.4)	10 (37.0)	0.127
Angiography + embolization	23 (38.3)	9 (24.3)	0.154	25 (36.2)	7 (25)	0.286
PPP	26 (43.3)	19 (51.4)	0.442	33 (47.8)	12 (42.9)	0.657
EF	14 (23.3)	5 (13.5)	0.237	18 (26.1)	1 (5.3)	0.011
Angiography or PPP or EF	49 (81.7)	27 (73)	0.313	58 (84.1)	18 (64.3)	0.032

EF, external fixation; PPP, preperitoneal pelvic packing.

Table 5
Comparing the effects of each combination of hemorrhage control methods.

	Mortality (28-day)		p	Mortality (acute hemorrhage)		p
	Survival ($n = 49$)	Non-survival ($n = 27$)		Survival ($n = 58$)	Non-survival ($n = 18$)	
Hemorrhage control methods			0.259			0.350
Angiography alone	19 (38.8)	6 (22.2)		19 (32.8)	6 (33.3)	
PPP alone	9 (18.4)	12 (44.4)		13 (22.4)	8 (44.4)	
EF alone	1 (2)	0 (0)		1 (1.7)	0 (0)	
Angiography + PPP	7 (14.3)	4 (14.8)		8 (13.8)	3 (16.7)	
Angiography + EF	3 (6.1)	2 (7.4)		5 (8.6)	0 (0)	
PPP + EF	6 (12.2)	1 (3.7)		7 (12.1)	0 (0)	
Angiography + PPP + EF	4 (8.2)	2 (7.4)		5 (8.6)	1 (5.6)	

EF, external fixation; PPP, preperitoneal pelvic packing.

Table 6
Multivariable regression analysis of risk factors for 28-day mortality.

Characteristics	Univariate analysis		p	Multivariate analysis	p
	Survival ($n = 60$)	Non-survival ($n = 37$)		OR (95% CI)	
Age	50.72 ± 20	66.27 ± 21.6	<0.001	1.056 (1.020, 1.093)	0.002
Transfusion amount (24-h)	10.9 ± 7.1	19.1 ± 13.7	0.002	1.084 (1.015, 1.156)	0.016
TRISS (%)	67.61 ± 31.14	34.45 ± 31.15	<0.001	0.976 (0.956, 0.997)	0.022
BE	−6.8 ± 4.6	−10.1 ± 6.4	0.012		
Lactate	4.3 ± 3	6.6 ± 3.2	0.001		
GCS	11.9 ± 4.7	9.1 ± 4.9	0.007		
SBP	96.6 ± 30.4	70.5 ± 40.9	0.001		

BE, base excess; CI, confidence interval; GCS, Glasgow coma score; OR, odds ratio; SBP, systolic blood pressure; TRISS, trauma and injury severity score.

Table 7
Multivariable regression analysis of risk factors for acute hemorrhage mortality.

Characteristics	Univariate analysis		p	Multivariate analysis	p
	Survival ($n = 60$)	Non-survival ($n = 37$)		OR (95% CI)	
Age	53.91 ± 20.8	63.39 ± 23.4	0.053	1.050 (1.014, 1.087)	0.006
Transfusion amount (24-h)	11.5 ± 7.9	20 ± 14.3	0.006	1.094 (1.025, 1.169)	0.007
TRISS (%)	64.57 ± 31.44	31.27 ± 32.21	<0.001		
BE	−6.9 ± 4.6	−10.7 ± 6.7	0.013		
Lactate	4.4 ± 3	7 ± 3.2	<0.001		
GCS	11.9 ± 4.5	8.2 ± 5.1	0.001	0.852 (0.740, 0.981)	0.026
SBP	94.4 ± 29.9	67.6 ± 45.3	0.007	0.978 (0.960, 0.997)	0.025

OR, odds ratio; CI, confidence interval; TRISS, trauma and injury severity score; BE, base excess; GCS, Glasgow coma score; SBP, systolic blood pressure.

pelvic capacity during the steady state is only 1.5 L, a pelvic fracture may result in hemodynamic instability because the actual bleeding from the pelvic fracture into the retroperitoneal space can amount to 3–5 L.[11] Therefore, fast and adequate treatment of hemodynamically unstable patients with pelvic fractures is critical.

Based on these pathophysiological considerations, various hemorrhagic control methods are currently used. The most commonly used methods worldwide are AE, PPP, and EF. According to a recent study performed in the United States, angiography was performed for 42.6%, EF for 36.8%, and PPP for 13.2% of hemodynamically unstable patients with pelvic fractures.[6] Depending on the geographic location or institution, there are differences in procedure applications, priorities, equipment, and available human resources. However, because our study showed a significant difference between the groups with and without hemorrhage control methods, there is no doubt that these three methods have essential roles in hemorrhage control in hemodynamically unstable patients with pelvic fractures. There are many ongoing studies about how to apply these methods optimally.

The three individual hemorrhage control methods investigated in this study were not significantly different in terms of survival between the patient groups. Moreover, even when the hemorrhage control method was applied alone or in combination, the differences in these applications did not show specific differences in mortality. In other words, there is no relative superiority in survival among the applied hemorrhage control methods. Two institutions participating in this study provide treatment by referring to the same treatment algorithm (supplementary 1). However, the percentage of actual AE and PPP applications is different due to the difference in feasibility for facilities and specialists. Nevertheless, there was no difference in mortality between the two institutions. This again shows that no particular hemorrhage control method has a significant survival advantage.

Meanwhile, a comparison indicated that the groups that underwent any of the hemorrhage control methods had better survival rates than those that underwent none ($p = 0.032$). These results show that it is not the 'type of hemorrhage control method' that is important to a pelvic fracture patient with hemodynamic instability. What is more important is to apply any hemorrhagic control method as quickly as possible and to find risk factors that affect the patient's prognosis.

When interpreting these results, the characteristics of patients with traumatic pelvic fractures, especially those with hemodynamic instability, should be considered. Blunt injuries cause most fractures sustained by these patients, and most of them have injuries to other body organs in addition to pelvic fractures. In fact,

our survey showed significant scores for the abdomen and chest. Additionally, there was a tendency for increased mortality with combined laparotomy. Therefore, the heterogenicity of this injury site was a limitation of this study, and it was difficult to accurately analyze the effects on the survival rates for hemorrhagic control methods. In other words, for patients with pelvic fractures, most are accompanied by various other bodily damage, which may affect early mortality. Thus, it can be said that the application of appropriate treatments tailored to each patient's situation and the institution's resources is more important than the concerns about prioritizing specific procedures.

4.2. Independent risk factors for mortality in patients with pelvic fracture and hemodynamic instability

We investigated the risk factors for 28-day mortality and mortality related to acute hemorrhage. For 28-day mortality, the most significant cause of death was acute hemorrhage (28/37; 78%). All other patients except three who died from multi-organ failure or sepsis died within seven days.

Our analysis found several independent risk factors for death for hemodynamically unstable patients with pelvic fractures. However, these risk factors were slightly different between the 28-day mortality group and mortality caused by acute hemorrhage group.

Old age was revealed as a common independent risk factor for 28-day mortality (OR, 1.056; 95% CI, 1.020–1.093; $p = 0.002$) and acute hemorrhage mortality (OR, 1.050; 95% CI, 1.014–1.087; $p = 0.006$). Generally speaking, among elderly patients, trauma occurs less often than in young people; however, the extent of injury and mortality is considerably greater when it occurs.[12] The same is true for traumatic pelvic fractures. Studies have shown different cutoff values for age; however, older individuals are at greater risk for severe bleeding from a pelvic fracture than younger individuals. For example, blood vessels show sclerotic changes, meaning that arterial injury may occur even with relatively small trauma forces.[12,13] Additionally, because compensation mechanisms in older patients are limited compared to those in younger patients, shock can easily occur, even with limited amounts of bleeding. Furthermore, elderly patients are more likely to respond less effectively than younger patients to the same resuscitation methods. This can easily lead to multi-organ failure or subsequent deterioration of immune function and death from sepsis. Furthermore, various underlying diseases associated with aging adversely affect the damage caused by pelvic fractures.[14] Therefore, hemodynamically unstable older patients with pelvic fractures require more intensive care.

Moreover, we found that the greater the transfusion need within 24 h, the lower the survival rate of hemodynamically unstable patients. The multivariate analysis revealed transfusion requirements as a common independent risk factor for 28-day mortality (OR, 1.084; 95% CI, 1.015–1.156; $p = 0.016$) and acute hemorrhage-induced mortality (OR, 1.094; 95% CI, 1.025–1.169; $p = 0.007$). The need for many blood transfusions means that bleeding is significant. Instability and poor vital signs in pelvic fractures are caused by more than 2 L bleeding. Massive bleeding leads to decreased hemoglobin levels and cardiac output, causing poor oxygen supply to peripheral tissues and eventually resulting in organ failure, shock, and death.[15] During this process, hypothermia, acidosis, and coagulation disorders are commonly referred to as the lethal triad.[16] Resuscitation attempts to end this complex series of cascades include a massive transfusion to rescue the patient. Massive transfusions have many side effects, such as transfusion-related acute lung injury, increased infection risk due to immune suppression, hypothermia, coagulopathy, and acidosis. Therefore, massive transfusion protocols have been developed to reduce the transfusion volume to achieve sufficient resuscitation while minimizing side effects. Several guidelines recommend that every institution should have a massive transfusion protocol.[17–19] Recently, methods for optimizing transfusions and limiting the side effects through analysis methods such as thromboelastography have been studied and may help reduce the mortality caused by transfusion requirements in the future.[20]

The TRISS was identified as an independent risk factor for 28-day mortality (OR, 0.976; 95% CI, 0.956–0.997; p=0.022). The TRISS indicates the probability of survival and reflects both the ISS and RTS. That is, it is an ideal trauma scoring system that reflects both the degree of anatomic damage and the pathophysiological state of the injured patient.[21] Therefore, recording these scores for patients with pelvic fractures seems appropriate.[22] Our study showed a marked difference in both the acute hemorrhage group and 28-day mortality group, which had a more than 30% lower TRISS compared with the survival group. Furthermore, the TRISS can be easily calculated during the initial evaluation of the injured patient. Patients with a low TRISS should be considered at high risk and in need of rapid hemorrhage control. The rapid application of treatment based on the TRISS will help improve the survival of hemodynamically unstable patients.

In general, it is accepted that trauma patients with SBP <90 mmHg are experiencing hypotension. Recent studies have suggested that an initial SBP in the range of 90–110 mmHg or less in a trauma patient may be indicative of hypoperfusion and is associated with poor patient outcomes.[4,23,24] Although different SBP cutoff values were utilized, previous studies have reported that decreased SBP is an independent risk factor for mortality of patients with pelvic fracture.[4,25,26] In this study, low SBP and low GCS scores were as well identified as independent risk factors for acute hemorrhage mortality with traumatic pelvic fractures. Just as massive transfusion is an independent risk factor for these patients, low blood pressure and altered mental status can additionally be associated with massive heavy bleeding, inadequate response to resuscitation, or hypoperfusion of peripheral organ tissues, including the brain. Therefore, blood pressure and mental status as early predictors of pelvic fracture due to trauma can be important factors for determining the patient's future prognosis.

4.3. Study limitations

This study had some limitations. First, it was a retrospective study. Second, it used data from two different institutions and included different treatment protocols, different equipment, different medical staff policies, and, consequently, different trauma treatments. Furthermore, differences in patient characteristics and trauma mechanisms due to regional differences should be considered. It should also be remembered that data regarding treatment during the pre-hospitalization phase were missing. Information regarding the records of 119 treatments performed in the ambulance and the exact trauma mechanism were missing. Furthermore, the time of the accident or the time from the accident to hospital admission are often missing, and the amounts of fluid or blood administered before admission are not clearly recorded. Therefore, further studies are needed. This study also did not analyze newer techniques used for hemodynamically unstable patients with pelvic fractures, such as resuscitative endovascular balloon occlusion. In future studies, data regarding more cases and clearly defined and standardized treatment protocols, including the more recent techniques, should be used to yield more specific and useful findings.

5. Conclusions

We found that rapid and appropriate application of hemorrhage control methods such as angiography, PPP, and EF can reduce acute hemorrhage-related mortality in hemodynamically unstable patients with pelvic fractures. However, none of the hemorrhage control methods showed any superiority in improving the mortality of pelvic fracture patients who are hemodynamically unstable. Therefore, the application of the appropriate hemorrhage control method for each patient's clinical situation or medical institution's situation should be prioritized over trying to determine which hemorrhage control method should be applied first. When evaluating the clinical situation of patients, old age, massive transfusion requirements, low TRISS, hypotension, and altered mental status were all independent risk factors for patient mortality. Therefore, more active and intensive care is needed for these patients. In the future, more research should address the appropriate use of various hemorrhagic control methods for patients with traumatic pelvic fractures and hemodynamic instability.

Ethics approval and consent to participate

This study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Review Boards of two medical institutions, which waived the requirement for the acquisition of informed consent from patients because of the retrospective nature of the study.

Consent for publication

Not applicable.

Availability of data and materials

There is no additional data available to share with the readers. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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Declaration of competing interest

None.

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Appendix A. Supplementary data

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