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Factors affecting the prognosis of patients with traumatic pelvic bone fractures with hemodynamic instability: multi-center study

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Factors affecting the prognosis of patients with traumatic pelvic bone fractures with hemodynamic instability: multi-center study

Directed by Professor Jae Gil Lee

The Master's Thesis
submitted to the Department of Medicine
the Graduate School of Yonsei University
in partial fulfillment of the requirements for the degree of
Master of Medical Science

Myoung Jun, Kim

December 2019

This certifies that the Master's Thesis of Myoung Jun, Kim is approved.

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December 2019

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ABSTRACT

Factors affecting the prognosis of patients with traumatic pelvic bone fractures with hemodynamic instability: multi-center study

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(Directed by Professor Jae Gil Lee)

INTRODUCTION

We analyzed the effect of hemorrhage control methods on the mortality of patients with hemodynamic instability due to pelvic fracture. We also investigated independent risk factors of mortality of these patients

MATERIALS AND METHODS

From January 2013 to October 2017, 97 pelvic bone fracture patients with hemodynamic instability were enrolled among the patient pelvic bone fracture patients who visited the emergency departments of two university hospitals. These patients were classified into survival and non-survival groups based on '28 day mortality' and 'Acute hemorrhagic mortality', and their clinical data including laboratory finding, trauma severity score, and hemorrhage control modalities were collected. Through statistical analysis of the collected clinical information, the effect of each hemorrhagic control modality on mortality was analyzed. Multivariate logistic regression was performed to determine the independent risk factors for the mortality of pelvic fracture patients with hemodynamic instability.

RESULTS

Among 97 patients who were enrolled, overall mortality was 40 (41.24%), 28 day mortality was 37 (38.14%), and acute hemorrhage mortality was 28 (28.86%). Among the hemorrhage control modality, 47

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patients (48.5%) underwent pelvic angiography, 45 patients (46.4%) underwent pre-peritoneal pelvic packing(PPP), and 19 patients (19.6%) underwent external fixation(EF). The difference in hemorrhage control method had no significant effect on the mortality of these patient. However, there was a significant difference in mortality between the groups with and without any of the hemorrhage control methods. A multivariate logistic regression analysis revealed that age of patient (odds ratio [OR] = 1.056, 95% confidence interval [CI] = 1.020 – 1.093, p = 0.002), TRISS (probability of survival) (OR = 0.976, 95% CI = 0.956 – 0.997, p = 0.022), transfusion amount within 24hours (OR = 1.084, 95% CI = 1.015 – 1.156, p = 0.016) were independent factors for mortality within 28 day. With the same statistical analysis, age of patient (OR = 1.050, 95% CI = 1.014 – 1.087, p = 0.006), transfusion amount within 24hours (OR = 1.094, 95% CI = 1.025 – 1.169, p = 0.007), glasgow coma scale(GCS) (OR = 0.852, 95% CI = 0.740 – 0.981, p = 0.026) and systolic blood pressure(SBP) (OR = 0.978, 95% CI = 0.960 – 0.997, p = 0.025) were revealed as independent factors for mortality of acute hemorrhage.

CONCLUSION

Hemorrhage control methods such as angiography, PPP, EF can help to reduce acute hemorrhage mortality in hemodynamically unstable patients by pelvic fracture, however, there was no significant difference in mortality according to the difference in hemorrhage control methods. Old age, high transfusion requirements, low TRISS score, low GCS, and low SBP are independent risk factors for mortality of pelvic fracture patients with hemodynamic instability.

Key words : pelvic fracture, hemorrhage control methods, hemodynamic instability

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Factors affecting the prognosis of patients with traumatic pelvic bone fractures with hemodynamic instability: multi-center study

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(Directed by Professor Jae Gil Lee)

I. INTRODUCTION

The treatment of traumatic pelvic fractures is still a major challenge for surgeons in charge of trauma units worldwide. Several studies have reported mortality rates of 50–60% in patients with traumatic pelvic fractures and hemodynamic instability. (1, 2) The hemodynamic instability results from massive bleeding from arteries, veins, and/or the fractured bone itself, and the blood loss may quickly become life-threatening.(3, 4) Therefore, appropriate and rapid treatment is required, and it is critical to choose the best therapeutic approach for patients based on risk factors that may predispose them to a critical situation.

There are several established methods for hemorrhage control in pelvic fractures, such as angiography and angio-embolization (AE), pre-peritoneal pelvic packing (PPP), and external fixation (EF). These methods are routinely performed in many institutions and have been successful in the resuscitation of patients with unstable pelvic fractures.(5, 6) However, despite these efforts, patient outcomes are still varied, depending on institutional and regional differences. To date, pelvic bone fractures remain a life-threatening condition when the patient is hemodynamically unstable.

This study investigated the effect of different hemorrhage control methods on the survival of pelvic fracture patients with hemodynamic instability.

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Furthermore, we investigated independent risk factors potentially associated with mortality in this patient population.

II. MATERIALS AND METHODS

1. Patient enrollment and data collection

We conducted a retrospective observational study at two institutions in Seoul and Wonju, South Korea, from January 2013 to October 2017 by reviewing the medical records of patients who came to the emergency room with traumatic pelvic fractures. Of these, patients with hemodynamic instability were included. Patients without pelvic fractures, patients under 18 years of age, or those with pelvic fractures who were hemodynamically stable were excluded from the study. As a result, a total of 97 patients with traumatic pelvic fractures and hemodynamic instability were enrolled. Hemodynamic instability in adults was defined as a systolic blood pressure < 90 mmHg on admission with evidence of skin vasoconstriction (cool, clammy skin, decreased capillary refill), altered level of consciousness and/or shortness of breath; or a systolic pressure > 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 a transfusion requirement of at least 4–6 units of packed red blood cells within the first 24 hours.(7)

Initially, we divided all patients into those who survived up to 28 days and those who did not and compared clinical variables between the two groups. In addition, we divided patients into those who died of acute hemorrhage due to their pelvic bone fracture and those who did not. We then also compared clinical variables between these two groups.

Percentages of each hemorrhage control method performed at two institutions were compared and outcomes, such as mortality, were also compared.

The study was approved by the Institutional Review Board of the two institutions, which waived the requirement for informed consent because of the retrospective

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nature of the study.

2. Clinical Variables

We analyzed gender, age, injury mechanism, vital signs, Glasgow coma scale (GCS) score, current medication, transfusion amount within first 24hr, 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, and arterial blood pH, base excess, and lactate levels. In addition, pelvic radiography and abdomen-pelvic computed tomogram was performed in almost all patients, and patterns of pelvic fracture were classified as lateral compression 1 to 3, and anterio-posterior compression 1 to 3, and vertical shearing according to the Young-Burgess classification (8, 9). The classification was based on the findings of trauma surgeons and orthopedic surgeons, and additionally confirmed by surgery and radiology records. The types of hemorrhagic control modalities such as pelvic binder wearing, angiography, angio-embolization, pre-peritoneal pelvic packing, and external fixation were investigated. In addition, we investigated whether intraperitoneal surgery was performed in conjunction with hemorrhagic control of pelvic bone fracture.

3. Statistical analysis

Statistical analysis for investigated items was performed using SPSS® Statistics 23.0 (IBM Corp., Armonk, NY). Categorical data are presented as numbers (%), and they were compared using the chi-square or Fisher`s exact tests. Continuous variables are expressed as the mean ± standard deviation or median and interquartile range, and data between groups were compared using the Student t-test or Mann-Whitney U test. Factors found in univariate analysis to be significantly associated with the need for hemorrhage control intervention were included in the multivariate analysis. Logistic regression modeling was performed

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using the maximum likelihood method and backward stepwise selection. Goodness-of-fit was assessed using the Hosmer-Lemeshow test. The odds ratios (ORs) are given with 95% confidence intervals (CIs). A p value of less than 0.05 was considered statistically significant.

III. RESULTS

1. Comparison of baseline characteristics of patients

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

Table 1. Baseline characteristics of patients

	Mortality (28 day)		*P* value	Mortality (Acute hemorrhage)		*P* value
	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)	
Medications, n (%)						
Aspirin	0 (0)	4 (12.1)	0.006	3 (4.3)	1 (4.2)	0.97
Clopidogrel	0 (0)	3 (9.1)	0.018	2 (2.9)	1 (4.2)	0.762
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 (24Hr)	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

SD=Standard Deviation, MVA=Motor Vehicle Accident, Hr=Hour

Thirty-seven of 97 patients died within 28 days. The mean age at the time of the accident among the surviving patients was 50.72 ± 20 years, which was statistically significantly different from the mean age of 66.27 ± 21.6 years in the patients that died. There was also a statistically significant difference between the two groups in the number of patients receiving aspirin (p = 0.006) or clopidogrel

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(p = 0.018) and the number of blood transfusions within the first 24 hours (p = 0.002).

No statistically significant difference was observed between the groups for the gender ratio (p = 0.286), which included 22 males (59%) and 15 females (41%) among the patients who died. When categorized according to the injury mechanism, both groups showed the highest frequency for pedestrians involved in a motor vehicle accident, followed by patients involved in a motorcycle accident. However, the injury mechanism showed no statistically significant difference between the two groups (p = 0.549). There was no significant difference between the 28-day survival group and non-survival group on whether the pelvic binder was worn at the time of the patient's visit. Whether the patient underwent intraperitoneal surgery during the treatment did not significantly affect 28-day mortality.

In the second analysis, 29 of the 97 patients died of acute hemorrhage associated with their pelvic fracture (Table 1). The analysis showed no statistically significant difference between the groups for age (p = 0.053) and medications such as aspirin (p = 0.97) and clopidogrel (p = 0.762). With regard to the injury mechanism, mortality caused by acute hemorrhage was most frequent in pedestrians involved in motor vehicle accidents, followed by patients injured in motorcycle accidents. However, there was no significant difference in the injury mechanism between the groups (p = 0.573). The transfusion requirement within 24 hours, however, was significantly different between the two groups (p = 0.006).

There was no significant difference in rates of acute hemorrhage mortality on whether the pelvic binder was worn at the time of the patient's visit. Whether the patient underwent intraperitoneal surgery during the treatment did not significantly affect acute hemorrhage mortality, but showed some trend toward significance.

2. Comparison of trauma related scores between groups

Trauma related scores of patients in groups are listed in Table 2.

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Table 2. Comparison of trauma related scores of patients

	Mortality (28 day)		*P* value	Mortality (Acute hemorrhage)		*P* value
	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

AIS=Abbreviated Injury Scale, SD=Standard Deviation, ISS=Injury Severity Score, RTS=Revised Trauma Score, TRISS=Trauma and Injury Severity Score, APACHE =Acute Physiology And Chronic Health Evaluation

When comparing the AIS values between groups for both 28-day mortality and acute hemorrhage mortality, neither head/neck (p = 0.339, p = 0.178), face (p = 0.325, p = 0.351), chest (p = 0.174, p = 0.241), abdomen (p = 0.881, p = 0.824), extremity (p = 0.076, p = 0.143), or external injuries (p = 0.485, p = 0.986) showed any significant differences.

In contrast, ISS (p = 0.006, p = 0.008), RTS (p = 0.001, p = 0.001), and TRISS (p < 0.001, p < 0.001) showed significant differences in both mortality criteria. The APACHE II score (p < 0.001, p < 0.001) was also statistically significant different between the groups.

3. Comparison of clinical variables between groups

The vital signs and laboratory variables of patients are shown in Table 3.

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Table 3. Comparison of clinical parameters between groups

	Mortality (28 day)		*P* value	Mortality (Acute hemorrhage)		*P* value
	Survival (n = 60)	Non survival (n = 37)		Survival (n = 69)	Non survival (n = 28)	
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
DBP	56.1 ± 18.1	42.8 ± 27.9	0.005	54.6 ± 18.5	42.3 ± 30.5	0.054
HR	98 ± 25.4	89.7 ± 47.1	0.325	99 ± 27.2	84.6 ± 49.1	0.153
RR	18.6 ± 14.9	17.3 ± 10.1	0.642	18.8 ± 13.9	16.4 ± 11.5	0.429
BT	36.1 ± 0.9	34.7 ± 5.9	0.068	36.1 ± 0.9	34.3 ± 6.8	0.188
GCS, 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
pCO2	32.8 ± 8.8	35.5 ± 17.4	0.404	32.5 ± 8.9	36.8 ± 18.8	0.267
pO2	120.7 ± 66.3	106.2 ± 59.6	0.300	120.8 ± 65.1	102.2 ± 60.3	0.206
Sat	92.9 ± 15.6	88.1 ± 20.3	0.213	93.3 ± 14.7	85.9 ± 22.3	0.12
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

SBP=systolic blood pressure, DBP=diastolic blood pressure, HR=heart rate, RR=respiration rate, BT=body temperature, GCS=glasgow coma scale, ABGA=arterial blood gas analysis, BE=base excess

With regard to the clinical variables, patients who died within 28 days or from acute hemorrhage were found to have significantly lower systolic (p = 0.001, p = 0.007) and diastolic blood pressure, (p = 0.005, p = 0.054) and GCS (p = 0.007, p = 0.001) than the surviving patients. In the arterial blood gas analysis, patients who died within 28 days or from acute hemorrhage showed statistically significantly higher base excess (p = 0.012, p = 0.013) and higher lactate (p = 0.001, p <0.001) than surviving patients.

4. Comparison between groups with regard to hemorrhage control methods

Before comparing mortality between groups, we investigated the percentage difference between two institutions in each hemorrhage control method. We investigated whether there were significant mortality differences between the two institutions. As a result, percentage of each hemorrhage control method applied by the two institutions differed, however, when comparing mortalities of two institutions, 28 days mortality (p = 0.081) and acute hemorrhage mortality (p =

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0.371) were not significantly different between two institutions.

We analyzed the difference in mortality between the different hemorrhage control methods such as angiography, angiography and embolization (AE), pre-peritoneal pelvic packing (PPP), and external fixation (EF) between the groups. (Table 4-1) We also compared these hemorrhage control measures' effects on patient mortality (Table 4-2).

Table 4-1. Effect of each hemorrhage control methods on mortality of patients

	Mortality (28 day)		*P* value	Mortality (Acute hemorrhage)		*P* value
	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
Angio. + 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
Angio. or PPP or EF	49 (81.7)	27 (73)	0.313	58 (84.1)	18 (64.3)	0.032

Angio.=Angiography, PPP= Preperitoneal Pelvic Packing, EF= External Fixation

Table 4-2. Comparison of hemorrhage control methods for mortality in patients

	Mortality (28 day)		*P* value	Mortality (Acute hemorrhage)		*P* value
	Survival (n = 49)	Non survival (n = 27)		Survival (n = 58)	Non survival (n = 18)	
Hemorrhage control methods			0.259			0.350
Angio. 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)	
Angio. + PPP	7 (14.3)	4 (14.8)		8 (13.8)	3 (16.7)	
Angio + 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)	
Angio + PPP + EF	4 (8.2)	2 (7.4)		5 (8.6)	1 (5.6)	

Angio.=Angiography, PPP= Preperitoneal Pelvic Packing, EF= External Fixation

Among the hemorrhage control methods used in the 97 patients with pelvic fracture and hemodynamic instability in this study, the most frequent was angiography, which was performed in 47 patients (48.45%) in each group. Among these, 32 patients (32.98%) underwent AE. PPP was the second most frequently used method in 45 patients (46.39%). Nineteen patients (19.58%) underwent EF. A total of 17 patients were treated with angiography and PPP; among them, six

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patients underwent angiography, PPP and EF. Three patients underwent all three methods. Seven patients received PPP and EF.

There were no statistically significant differences of mortality amongst the hemorrhage control methods used between 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 hemorrhage control methods mentioned above and the group that did not undertake any one of them showed that acute hemorrhage mortality showed a significant difference between the survival and non-survival groups (p = 0.032).

Table 4-2 shows the results of analyzing mortality differences between the hemorrhage control methods. As a result, neither 28-day mortality nor acute hemorrhage mortality showed significant differences between hemorrhage control methods.

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

The results of the univariate and multivariate regression analysis models are shown in Table 5-1 and Table 5-2.

Table 5-1. Multivariable regression analysis for risk factor for 28 day mortality

Characteristics	Univariate analysis		*P* value	Multivariate analysis	*P* value
	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 (24Hr)	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		

OR=Odd ratio, CI=Confidence Interval, TRISS=Trauma and Injury Severity Score, Hr=Hour, BE=Base Excess, GCS=Glasgow Coma Score, SBP=Systolic Blood Pressure

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Table 5-2. Multivariable regression analysis for risk factor for acute hemorrhage mortality

Characteristics	Univariate analysis		*P* value	Multivariate analysis	*P* value
	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 (24Hr)	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=Odd ratio, CI=Confidence Interval, TRISS=Trauma and Injury Severity Score, Hr=Hour, BE=Base Excess, GCS=Glasgow Coma Score, SBP=Systolic Blood Pressure

Patient's age (OR = 1.056, 95% CI = 1.020–1.093, *p* = 0.002), lower TRISS score (OR = 0.976, 95% CI = 0.956–0.997, *p* = 0.022), and large amount of blood transfused within the first 24 hours (OR = 1.084, 95% CI = 1.015–1.156, *p* = 0.016) were identified as independent risk factors of death within 28 days. The hemorrhage control method did not show a significant difference in mortality among these patients.

Patient's age (OR = 1.050, 95% CI = 1.014–1.087, *p* = 0.006) and a large amount of blood transfused within the first 24 hours (OR = 1.094, 95% CI = 1.025–1.169, *p* = 0.007) were identified as independent predictors of death in acute hemorrhage. GCS (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 investigated as independent risk factors for acute hemorrhagic mortality of pelvic fracture patients with hemodynamic instability.

IV. DISCUSSION

1. Effect of the different hemorrhage control methods on survival

In order 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

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plexus, and arterial injury. Bleeding in pelvic fractures occurs in about 90% venous and about 10% arterial cases.(10) However, arterial bleeding is more common in cases of ongoing bleeding or hemodynamic instability despite adequate treatment. Although the actual volume in the pelvis is only 1.5 L, a pelvic fracture may result in hemodynamic instability because the actual bleeding 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. Among them, the most common methods used worldwide are AE, PPP, and EF. According to a recent US study, angiography was performed in 42.6%, external fixation in 36.8%, and PPP in 13.2% of hemodynamically unstable patients with pelvic fractures.(6) Depending on the location or institution, there remain differences in procedure application, priorities, equipment, and available human resources. However, as our study also showed a significant difference between the groups with and without hemorrhage control methods, there is no doubt that these three methods play an important role in hemorrhage control in hemodynamically unstable patients with pelvic fractures. There are many ongoing studies about how to optimally apply these methods.

Angiography and AE is one of the first-line hemorrhage control methods applied worldwide. Although it has the disadvantage that it requires more specialized assistants and equipment than other treatment methods, it is the most used hemorrhage control method in pelvic fracture(6) and shows excellent treatment results.(11-13) In our study, most patients underwent angiography for hemorrhage control. Several guidelines recommend that angiography should be performed in patients with pelvic fractures that show contrast extravasation on CT. One study described the importance of excluding arterial bleeding with angiography because it is difficult to rule out this possibility even in the absence of extravasation on CT.

PPP is also a useful and frequently used hemorrhage control method for pelvic fracture related bleeding. PPP was initially used as damage control in patients with extensive intraperitoneal injuries in Germany and Switzerland in the 1980s and

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1990s.(14) It has since been modified by the Colorado-Denver group by using a suprapubic midline incision without opening the abdominal cavity and directly packing the pre-peritoneal and Retzius space.(15) PPP as the first intervention for bleeding control in patients with pelvic fractures and refractory shock is based on the fact that in 85% of cases, the bleeding is not from an artery.(16) Furthermore, PPP is advantageous in that it can be performed fast and immediately, although the learning curve for the operator is steep.(17) It can also be performed easily at a small institution. Therefore, PPP is recommended as a first-line treatment for hemodynamically unstable patients with pelvic fractures in the World Society of Emergency Surgery consensus and the Denver group study.(18, 19)

However, PPP has several limitations. It is important to consider the possibility of infection before and after the procedure. Most PPPs are performed in an emergency situation where the environment is not entirely aseptic. If the pelvic injury is accompanied by an intraperitoneal organ injury, laparotomy should be performed. In that case, tamponade with PPP cannot provide sufficient pressure in the pelvic cavity, which is a disadvantage for bleeding control. In rare cases, angiography after PPP can identify a missed arterial bleeding. This may cause inexplicable re-bleeding that occurs after removing the packed gauze. Lastly, patients who underwent PPP may suffer complications from the surgery in the form of severe adhesions that may already occur during subsequent definite fixation operations (e.g., open reduction and internal fixation) for the pelvic fracture. Therefore, while rapid and aggressive application of PPP is often required in unstable patients with pelvic fractures, it is necessary to minimize the side effects by defining clear and specific indications.

EF is also considered a first-line hemorrhage control method in many treatment protocols.(18, 20, 21) EF substantially reduces venous bleeding and maximizes hemodynamic stabilization by closing an opened sacroiliac joint. It reduces the instability of the fracture, thereby minimizing soft tissue injury and bleeding due to the movement of bone fragments.(22) It can be applied to several types of pelvic fractures, but the effect is maximized in the anterior-posterior compression types (open book type), which show widening of the sacroiliac joint, and can also

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be applied to other types such as lateral compression type III or vertical shearing. When combined with PPP, a more pronounced effect can be expected because of the added counter pressure.(15)

EF, however, requires fast action by an experienced orthopedic surgeon. Since the osteosynthesis material extends from the inside to the outside of the body, it is relatively susceptible to infection. It also needs to be considered that the fixation frame limits imaging studies and patient mobility with consecutive difficulties in bedside care. Recently, it has been investigated whether EF can be replaced by a pelvic binder, but there are not many studies showing significant results.

Each of the three individual hemorrhage control methods studied in this study did not show a significant difference in survival between patient groups. However, between the groups that underwent any of the hemorrhage control methods and those who underwent none, the survival rate was better in the groups that underwent any of the hemorrhage control methods.

Interpretation of these results should also take into account the characteristics of patients with traumatic pelvic fractures, especially those with hemodynamic instability. Most of these patients' fractures are caused by blunt injury, and most of them have combined injury to other body organs besides pelvic fracture. In fact, our survey also showed significant scores in the abdomen and chest, in addition to the AIS score and pelvis' extremity. There is also some tendency to increase mortality in patients with combined laparotomy. Therefore, heterogenicity of this injury site is a limitation of this study, and it is difficult to accurately analyze the effect on the survival rate of hemorrhagic control methods.

In other words, in patients with pelvic fractures, most of the pelvic fractures are accompanied by various other bodily damages, which may affect the early mortality of the patient. Therefore, it can be said that the application of appropriate treatments tailored to the patient's situation or the institution's situation is more important than the concern about prioritizing specific procedures.

Recently, new methods, such as resuscitative endovascular balloon occlusion, have led to increasing numbers of trials investigating the treatment of hemodynamically unstable patients with pelvic fractures. We expect more valid

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results in prospective studies following well-controlled and structured treatment algorithms with clear definitions for time variables.

2. Independent risk factors of mortality in patients with pelvic fracture and hemodynamic instability

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

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

Old age of patients was revealed as a common independent risk factor for 28-day mortality and acute hemorrhage mortality (OR = 1.056, 95% CI = 1.020–1.093, p = 0.002) (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, but when it occurs, the extent of injury and mortality are considerably higher. (23) The same is true for traumatic pelvic fractures. Studies have shown different cut-off values of age, but in older age, in general, the risk of severe bleeding from a pelvic fracture is more common than in younger patients. For example, blood vessels show sclerotic changes, meaning that arterial injury may occur even with relatively small trauma forces.(12, 23) In addition, since compensation mechanisms in older patients are limited compared to younger patients, shock can easily occur even with limited amounts of bleeding. Further, elderly patients are more likely to respond less effectively than younger patients to the same resuscitation methods. This can easily lead to a multi-organ failure or subsequent deterioration of immune function and death from sepsis. Various underlying diseases associated with aging also adversely affect the damage caused by pelvic fractures.(24) Therefore, hemodynamically unstable older patients with pelvic fractures require more intensive care.

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We also found that the greater the transfusion need within 24 hours, the lower the survival rate of hemodynamically unstable patients. The multivariate analysis revealed transfusion requirements as a common independent risk factor for 28-day and acute hemorrhage-induced mortality (OR = 1.084, 95% CI = 1.015–1.156, p = 0.016) and (OR = 1.094, 95% CI = 1.025–1.169, p = 0.007, respectively). The need for many blood transfusions, on the other hand, means that bleeding is significant. Instability and poor vital signs in pelvic fractures are caused by massive bleeding of more than two liters. Massive bleeding leads to a decrease in hemoglobin levels and cardiac output, causing poor oxygen supply in peripheral tissues, eventually resulting in organ failure, shock, and death.(25) In this process, hypothermia, acidosis, and coagulation disorders are commonly referred to as the lethal triad.(26) Resuscitation attempts to break this complex series of cascades include massive transfusion to rescue the patient. Massive transfusion has 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 amount of transfusion in order to achieve sufficient resuscitation while minimizing side effects. Several guidelines recommend that every institution should have a massive transfusion protocol.(27-29) Recently, methods for optimizing transfusion 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.(30)

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 the RTS. In other words, it is an ideal trauma scoring system that reflects both the degree of anatomic damage and pathophysiological state of the injured patient.(31) Recording these scores in patients with pelvic fractures seems appropriate.(32) Our study showed a marked difference for both the acute hemorrhage and 28-day mortality group, with a more than 30% lower TRISS compared with the survival group. In addition, the TRISS can be easily calculated during the initial evaluation of the injured patient. Patients

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with a low TRISS are to be considered high-risk and in need of rapid hemorrhage control. The rapid application of treatment based on the TRISS will help improve the survival of patients with hemodynamically unstable patients.

In general, it is accepted that trauma patients with SBP <90 mmHg are in 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 hypo-perfusion and is associated with poor patient outcomes.(4, 33, 34) Although different SBP cutoff values were utilized, previous studies have reported that decreased SBP is an independent risk factor of mortality in patients with pelvic fracture.(4, 35, 36) In this study, low SBP and low GCS were also identified as independent risk factors for acute hemorrhage mortality in traumatic pelvic fractures. Just as massive transfusion is a risk-independent risk factor for these patients, low blood pressure and altered mental status can also be associated with patients massive heavy bleeding, inadequate response to resuscitation, or hypo-perfusions of peripheral organ tissues include brain. Therefore, blood pressure and mental status as early predictors of pelvic fracture patients due to trauma can be important factors in determining the patient's future prognosis.

This study has some limitations. First, it is a retrospective study. Secondly, it contains data from two different institutions, which may result in different treatment protocols, equipment, policies for medical staff, and consequently, differences in trauma treatment. Furthermore, differences in patient characteristics and in trauma mechanisms due to regional differences should be considered. It should also be taken into account that data on treatment in the pre-hospitalization phase is missing. There are patients in the study for whom information is lacking regarding the records of the 119 ambulance treatment or the exact trauma mechanism. Also, often the time of the accident or the time from the accident to hospital admission, and the amount of fluid or blood administered before admission are not clearly recorded. There is a need for further study in this regard.

This study also did not analyze newer techniques used in hemodynamically unstable patients with pelvic fractures, such as resuscitative endovascular balloon occlusion. In future studies, data on more cases, following clearly defined and

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standardized treatment protocols, including the more recent techniques, should be collected to yield more specific and useful findings.

V. CONCLUSION

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 mortality in pelvic fracture patients with hemodynamic unstable. Therefore, the application of the appropriate hemorrhage control method to each patient's clinical situation or the medical institution's situation should be prioritized over the question of which hemorrhage control method should be applied first. When evaluating the clinical situation of patients, old age, requirement of massive transfusion, low TRISS, hypotension, and altered mental status situations were all found to be 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 the various hemorrhagic control methods for patients with traumatic pelvic fracture and hemodynamic instability.

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ABSTRACT (IN KOREAN)

혈역학적 불안정성을 보이는 외상에 의한 골반골 골절 환자의 예후에 영향을 미치는 인자 분석: 다기관 연구

<지도교수 이 재 길 >

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김 명 준

서론

이번 연구에서 우리는 골반 골 골절에 의한 출혈을 제어하는 각 치료 방법들이 이들 환자의 생존에 미치는 영향을 분석했다. 그리고 이러한 환자들의 예후에 영향을 미치는 인자들을 분석했다.

재료 및 방법

2013년 1월부터 2017년 10월까지 국내 두개의 대학병원에 내원한 외상에 의하여 골반골 골절이 발생한 환자들 중, 혈역학적 불안정성을 나타내는 97명의 환자들을 선별하였다. 이들 환자들을 28일이내 사망, 그리고 급성 출혈 에 의한 사망을 기준으로 각각 분류하여 이들의 임상 정보를 모았다. 모인 임상 정보들을 통계 분석을 통하여 각 지혈 치료법이 사망률에 미치는 영향을 분석하였고, 다변량 회귀분석을 통하여 혈역학적 불안정성을 보이는 골반 골 골절 환자가 사망에 이르게 되는 독립 위험인자를 알아보았다.

결과

선별된 환자 97명의 전체 사망율은 40명(41.24%), 28일 사망은 37명(38.14%), 급성 출혈에 의한 사망은 28명 (28.86%)였다. 출혈

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에 대한 지혈 시술 방법들 중 골반 동맥 촬영술을 시행한 환자는 47명으로 48.5%, 전 복막 골반충전술을 시행한 환자는 45 명으로 46.4%, 골반 외고정술을 시행한 환자는 19명으로 19.6%로 나타났다. 각 지혈 시술 방법에 따른 사망률의 유의한 차이는 나타나지 않았다. 그러나 이들 지혈 시술 중에 하나라도 적용한 군과 하나도 적용하지 않은 군 사이에서는 사망률의 유의한 차이를 보였다. 다중회기분석을 시행한 결과, 환자의 나이 (odds ratio [OR] = 1.056, 95% confidence interval [CI] = 1.020 – 1.093, p = 0.002), TRISS (OR = 0.976, 95% CI = 0.956 – 0.997, p = 0.022), 24시간 이내 수혈 양(OR = 1.084, 95% CI = 1.015 – 1.156, p = 0.016)이 28일 이내 사망의 독립 위험인자로 조사되었다. 그리고 같은 분석 결과 환자의 나이 (OR = 1.050, 95% CI = 1.014 – 1.087, p = 0.006), 24 시간 이내 수혈 양 (OR = 1.094, 95% CI = 1.025 – 1.169, p = 0.007), glasgow coma scale(GCS) (OR = 0.852, 95% CI = 0.740 – 0.981, p = 0.026) 그리고 수축기 혈압(SBP) (OR = 0.978, 95% CI = 0.960 – 0.997, p = 0.025)이 급성 출혈에 의한 사망에서도 독립 위험 인자로 분석되었다.

결론

골반 동맥 촬영술, 전 복막 골반충전술, 그리고 골반 외고정술과 같은 지혈시술은 혈역학적 불안정성을 보이는 골반골 골절 환자에서 급성 출혈에 의한 사망률을 줄일 수 있다. 그러나 각 지혈 시술에 따른 사망률의 유의한 차이는 나타나지 않았다. 환자가 고령인 경우와 낮은 TRISS score, 많은 양의 수혈 요구량, 내원 초기 낮은 수축기 혈압과 낮은 의식상태는 혈역학적 불안정성을 보이는 골반 골 골절 환자에서 발생하는 사망의 독립 위험인자이다.

핵심되는 말 : 골반, 골절, 혈역학적 불안정성