



# Effects of the establishment of a trauma center and a new protocol on patients with hemodynamically unstable pelvic fractures at a single institution in Korea

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## Abstract

**Purpose** The aim of this study was to determine whether the outcomes of patients with hemodynamically unstable pelvic bone fractures changed after the introduction of a protocol including extraperitoneal pelvic packing (EPP) and the establishment of a trauma center.

**Methods** We analyzed data of adult patients ( $\geq 18$  years old) with hemodynamically unstable pelvic bone fractures who visited a single trauma center from February 2009 to October 2016. In July 2014, a new protocol for pelvic fractures was implemented, and a trauma center was established. Therefore, patient outcomes were compared by period (period I: pre-protocol vs. period II: post-protocol).

**Results** Seventy-nine patients with hemodynamically unstable pelvic bone fractures were recruited. The time to angiographic embolization after arrival at the emergency room decreased significantly in period II when compared to period I (182.9 vs. 268.9 min, respectively,  $p < 0.001$ ). The time required to intervention, including EPP, also decreased, from  $268.9 \pm 132.4$  min in period I to  $141.9 \pm 79.9$  min in period II ( $p < 0.001$ ). The overall mortality rate decreased from 47.2% in period I to 23.3% in period II ( $p = 0.033$ ), and mortality related to hemorrhagic shock in particular, was significantly lowered, from 27.8% in period I to 4.7% in period II ( $p = 0.009$ ).

**Conclusions** The establishment of a trauma center and the implementation of a new protocol that included EPP were effective in the treatment of patients with hemodynamically unstable pelvic fractures.

**Keywords** Trauma · Fracture · Pelvis · Protocol

## Abbreviations

ER	Emergency room
OR	Operating room
ICU	Intensive care unit
EPP	Extraperitoneal pelvic packing
ISS	Injury Severity Score
RBC	Red blood cells
AIS	Abbreviated Injury Scale
ATLS	Advanced Trauma Life Support
CT	Computed tomography
GCS	Glasgow Coma Scale

TRISS	Trauma-related Injury Severity Score
AE	Angiographic embolization

## Introduction

Hemodynamically unstable pelvic fractures are considered to be severe traumatic injuries and can be difficult to treat. In addition, they are associated with high mortality and morbidity, even when treated by well-trained trauma teams. Despite the multidisciplinary approaches and advanced resuscitation used in many trauma centers, mortality rates of up to 40% have been reported [1, 2]. Unstable pelvic fractures are predominantly caused by high-energy blunt injuries associated with many injuries and results in massive bleeding and shock. Therefore, for patients with hemodynamically unstable pelvic fracture, early treatment is vital and may affect the prognosis. For the early treatment

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of those patients, taking a multidisciplinary approach from the start is essential and should involve physicians from the trauma surgery, emergency medicine, orthopedics, neurosurgery, radiology, urology, and anesthesiology departments. A multidisciplinary approach should focus on providing appropriate treatment throughout the process, beginning in the trauma emergency room and angiography suite, to the operating room and intensive care unit. For early treatment, quick diagnosis is required—ideally in specialized centers under the care of resident doctors specializing in severe trauma. Close cooperation between related departments is also essential. It is important for every medical center to create an appropriate protocol and conduct the relevant training. The purpose of this study was to determine if the introduction of a protocol that includes extraperitoneal pelvic packing (EPP) along with the establishment of a trauma center affected the outcomes of patients with hemodynamically unstable pelvic fracture.

## Methods

### Setting

The Gachon University Gil Hospital is a 1500-bed teaching hospital located in Incheon city, South Korea, and serves a population of 3 million people. The trauma center of our hospital was the first trauma center established in Korea, with the overriding goal of establishing a regional level I trauma center. Annually, there are > 3000 trauma-related admissions, of which 500–550 patients present with major trauma. The trauma center is equipped with a trauma bay, two operating rooms dedicated to trauma, a 20-bed dedicated trauma intensive care unit, and a trauma angiography suite. 16 full-time trauma surgeons, 4 trauma coordinators, and 8 physician extenders currently work at the center. A team of emergency physicians, anesthesiologists, and residents resides at the center, and interventional radiologists as well as neurosurgery and orthopedics consultants are available around the clock (Table 1).

### Study population

The study included patients with traumatic pelvic fractures who visited the trauma center of the Gachon University Gil Hospital from February 2009 to October 2016. Patients with hemodynamic instability, defined as a systolic blood pressure < 90 mmHg during the initial resuscitation period despite the transfusion of two units of packed red blood cells (pRBCs) were enrolled. We excluded patients < 18 years old and those with Abbreviated Injury Scale (AIS) scores of the pelvis < 4. The outcomes of the included patients were analyzed by time period: period I (pre-protocol: 2009

**Table 1** Comparison between period I and period II

	Period I	Period II
Admission	Emergency room	Trauma bay
Initial assessment	ER physician	Trauma team
Operator	General surgeon	Dedicated trauma surgeon
ICU	Surgical ICU	20-bed trauma ICU
OR and equipment	Not dedicated	Dedicated to trauma
Pelvic protocol	No	Yes

*ER* emergency room; *ICU* intensive care unit; *OR* operating room

to June, 2014) and period II (post-protocol: July 2014 to 2016). Period II began in July 2014 with the introduction of a new protocol for the management of pelvic fractures and the opening of a new trauma center at our hospital.

### Protocol

We generally followed the Advanced Trauma Life Support (ATLS) guidelines for evaluation and initial resuscitation throughout the study period (2009–2016).

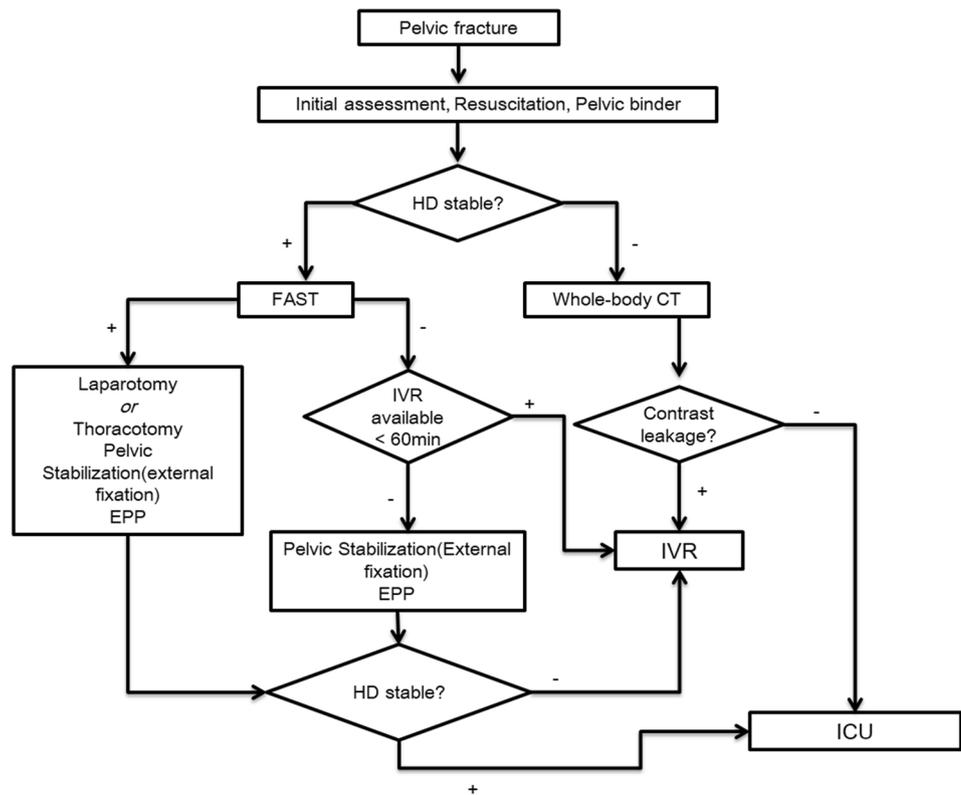
During period I, patients with pelvic injuries were initially evaluated and managed at the emergency room by emergency physicians. After evaluation and initial resuscitation, the general and orthopedic surgeons on-call decided on further treatment. Angiography (by two radiologists who were alternately on-call) was mainly performed if extravasation of contrast was seen on computed tomography (CT).

During period II, patients were treated in the trauma bay by a trauma team composed of two attending trauma surgeons, one emergency physician, one orthopedic surgeon, one anesthesiologist, one radiologist, and physician assistants. Pelvic injuries were managed according to a new protocol that included EPP (Fig. 1).

Upon arrival of the patients at the trauma bay, initial assessment with resuscitation was performed by trauma surgeon and emergency physician. A pelvic binder was applied when a pubic diastasis was seen on radiography or extravasation on CT, as well as in hemodynamically unstable patients with pelvic bone fractures. Focused Assessment with Sonography in Trauma (FAST) was performed in continuously hemodynamically unstable patients. Hemodynamic instability was defined as a systolic blood pressure of 90 or less on arrival at the trauma bay and no or transient response to the initial 2L fluid therapy.

When the FAST results were positive, a laparotomy and EPP were performed. Moreover, external fixation was performed in the operation room, if available. After the EPP, angioembolization (AE) was performed, if deemed necessary. When the FAST results were negative but pelvic bone bleeding was suspected, AE was attempted first. If AE was not immediately available, EPP was performed first. During

**Fig. 1** Protocol for the treatment of unstable pelvic bone fractures. *CT* computed tomography; *HD* hemodynamically; *EPP* external pelvic packaging; *FAST* Focused Assessment Sonography in Trauma; *ICU* intensive care unit; *IVR* interventional radiology



EPP, the pelvic binder was temporarily removed and re-wrapped thereafter. No c-clamps were performed due to the lack of orthopedic trauma surgeons and physicians experienced in this method. Because the initial management of patients with hemodynamically unstable pelvic bone fractures was mainly performed by trauma surgeons (i.e., general or thoracic surgeons), external compression in the trauma bay was typically achieved through the use of pelvic binders. The pelvic binder was removed within 24–48 h.

### Data and outcomes

We retrospectively reviewed the medical records of the enrolled patients and collected demographic and clinical data including sex, age, initial vital signs, mechanism of injury, Injury Severity Score (ISS), Glasgow Coma Scale (GCS), and trauma-related ISS (TRISS). Laboratory variables included initial blood pH, base deficit, hemoglobin levels, prothrombin time, and platelet count. Outcome variables included the time to intervention, transfusion requirements, length of stay, and mortality.

### Statistical analysis

Continuous data are presented as means and standard deviations or medians and interquartile ranges. Univariate analysis was performed using the Student's *t* test for continuous

variables and the  $\chi^2$  test for categorical variables. Statistical significance was defined as  $p < 0.05$ . All statistical analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA).

### Results

During the study period, 79 patients (36 and 43 patients in periods I and II, respectively) with unstable pelvic fractures and hemodynamic instability were enrolled. There were no significant differences in the demographic and clinical characteristics between the two groups (Table 2). The mean time to intervention, including EPP, decreased from  $268.9 \pm 132.4$  min in period I to  $141.9 \pm 79.9$  min in period II ( $p < 0.001$ ). The mean time to AE after arrival at the ER also significantly decreased, from  $268.9 \pm 132.4$  min in period I to  $182.9 \pm 102.4$  min in period II ( $p < 0.001$ ). The mean time to intervention in the EPP-only group was  $52 \pm 27.5$  min. We found no significant difference in the amounts of transfused pRBCs before the procedure and during the first 24 h between the two groups (Table 3).

All patients in period I underwent AE alone; in period II, various treatment modalities, such as pelvic binding and EPP, were utilized alongside AE. In period II, 30.2% of patients underwent both EPP and AE; 3 patients were hemodynamically stable after EPP and did not undergo

**Table 2** Demographic and clinical characteristics of the patients by period

	Total (n=79)	Period I (n=36)	Period II (n=43)	p value
Age (years)	52.1 ± 19.4	50.6 ± 19	53.2 ± 19.8	0.557
Sex, male (%)	40 (50.6)	18 (50.0)	22 (51.2)	0.549
Initial SBP (mmHg)	85.7 ± 31.1	88.4 ± 26.1	83.8 ± 34.4	0.507
Lowest SBP (mmHg)	65.2 ± 27.5	66.9 ± 22.4	64.0 ± 30.8	0.638
Hb (g/dL)	10.9 ± 2.6	10.5 ± 2.3	11.2 ± 2.8	0.211
Platelets (k/mm <sup>3</sup> )	193.8 ± 86.5	197.5 ± 88.7	191.2 ± 85.8	0.753
Lactate (mmol/L)	4.65 ± 3.04	4.33 ± 2.81	4.87 ± 3.2	0.433
BD (mmol/L)	8.79 ± 5.77	8.10 ± 5.91	9.29 ± 5.67	0.380
GCS	12.3 ± 4	12.5 ± 3.9	12.1 ± 4.2	0.275
ISS	38.1 ± 12.3	37.2 ± 12.3	38.7 ± 12.5	0.619
TRISS	0.66 ± 0.30	0.69 ± 0.31	0.64 ± 0.30	0.543
Pelvis AIS	4.67 ± 0.52	4.79 ± 0.41	4.59 ± 0.58	0.093

AIS Abbreviated Injury Scale; BD base deficit; GCS Glasgow Coma Scale; Hb hemoglobin; ISS Injury Severity Score; SBP systolic blood pressure; TRISS trauma-related ISS

**Table 3** Treatment modalities and outcomes

	Total (n=79)	Period I (n=36)	Period II (n=43)	p value
Treatment modality, n (%)				
IVR only	63 (79.7)	36 (100)	27 (62.8)	
IVR + EPP	13 (16.5)	0	13 (30.2)	
EPP only	3 (3.8)	0	3 (7)	
External fixation	3 (3.8)	0	3 (7)	
Pelvic binder	34 (43)	1 (2.8)	31 (72.1)	
Time to intervention <sup>a</sup> (min)	205.1 ± 122.9	268.9 ± 132.4	141.9 ± 79.9	< 0.001
Time to IVR only (min)	225.9 ± 123.2	268.9 ± 132.4	182.9 ± 102.4	< 0.001
Time to EPP only (min)	52 ± 27.5	NA	52 ± 27.5	
Time to EPP + IVR (min)	104.5 ± 57.8	NA	104.5 ± 57.8	
pRBC transfusion before intervention <sup>a</sup> (units)	6.32 ± 4.6	7.09 ± 5.53	5.76 ± 3.77	0.237
pRBC transfusion during first 24 h (units)	15.54 ± 12.61	13.14 ± 9.61	17.56 ± 14.47	0.122
FFP transfusion during first 24 h (units)	9.53 ± 8.77	7.53 ± 4.88	11.21 ± 10.8	0.063
Overall mortality, n (%)	27 (34.2)	17 (47.2)	10 (23.3)	0.033
24 h mortality, n (%)	13 (16.5)	9 (25)	4 (9.3)	0.067
30-day mortality, n (%)	14 (17.7)	8 (22.2)	6 (20)	0.091
Mortality due to acute hemorrhage, n (%)	12 (15.2)	10 (27.8)	2 (4.7)	0.009

IVR interventional radiology; pRBC packed red blood cells; FFP fresh frozen plasma

<sup>a</sup>Intervention: pelvic packing or IVR

additional AE. The use of pelvic binders for pelvic bone stabilization increased from 2.8% in period I to 72.1% in period II (Table 3). Patients in period II experienced a longer mean ICU stay than those in period I (15.0 vs. 7.1 days, respectively;  $p = 0.072$ ). No differences for the mean time on mechanical ventilation and the length of the hospital stay were observed between the two groups.

During the study period, the overall mortality rate was 34.2%. However, mortality significantly decreased after the implementation of the new protocol, from 47.2% in period I to 23.3% in period II ( $p = 0.033$ ). We also analyzed the

mortality rate associated with hemorrhagic shock. In period I, ten patients (27.8%) died of hemorrhagic shock, whereas only two patients (4.7%) died of hemorrhagic shock in period II ( $p = 0.009$ ) (Table 3).

## Discussion

The management of hemodynamically unstable pelvic fractures is difficult and associated with high mortality despite resuscitation with blood products, temporary mechanical

stabilization, and pelvic AE [3]. Nearly 80% of deaths among these patients can be attributed to uncontrolled early hemorrhage and delays in hemostasis [4]. Therefore, rapid hemostasis is important in the treatment of unstable pelvic bone fractures.

AE for hemorrhage control in patients with pelvic bone fractures was first used in 1972. Since then, this treatment has been proven effective and remains the most widely used hemostatic method [5, 6]. However, AE alone may not be able to effectively stop pelvic bleeding because 80% of patients with pelvic fractures present with bone or venous bleeding [7]. Moreover, the immediate availability of AE varies by hospital. During nights or weekends, AE might not immediately be available, which can cause increased mortality rates [7–9]. Tesoriero et al. reported that the median time to embolization was > 5 h, which increased mortality [4]. In two other studies, the average time between ER and AE was 10.7 h and the time to perform angiography was 3–5 h, depending on the time of admission [8, 10]. Furthermore, in a comparison of AE and EPP, Osborn et al. found that > 2 h were required to perform AE [9]. In our study, the time to angiography was 4 h in period I. A recent study reported that every delay of 3 min in the resuscitation room leads to a 1% increase in mortality in hemodynamically unstable patients with blunt abdominal trauma during the first 90 min [11]. At a level I major trauma center, any delay exposes patients to unnecessary risks [12]. Therefore, early hemostasis is important and should not be delayed for > 4 h.

At our center, trial runs of the EPP were conducted in 2014, and the new protocol (including EPP) has been used since July 2014 (period II), when the trauma center was established. In this protocol, a pelvic binder is used first. When used early, pelvic binders are effective in reducing the pelvic volume, improving the hemodynamic status, as well as elevating mean arterial pressure and stabilizing the heart rate [13]. Several guidelines, including Prehospital Trauma Life Support and ATLS, have recommended the suspension of pelvic fractures in patients with hemodynamically unstable traumatic injuries and the use of binders in the early stages of hospitalization without any special diagnostic tests [14–16]. However, the use of binders after a fracture diagnosis is controversial because they can cause certain types of fractures to worsen [17]. Under the new protocol used in period II, a pelvic binder was used when the pubic diastasis was > 2 cm, as observed radiographically, in hemodynamically unstable patients with pelvic bone fractures, or when active bleeding or a hematoma in the pelvic cavity was seen on contrast-enhanced CT. In both periods, no prehospital pelvic binder was used. Pelvic binders were introduced in Korea in 2014. Since then, they have only been used at hospitals and not at the prehospital stage.

EPP has been primarily used in Europe so far. Recently, some centers in the United States achieved good treatment

outcomes by replacing AE with EPP [7, 18, 19]. EPP can be performed in the resuscitation room by a trauma surgeon within 1 h of arrival. In the United States, Cothren et al. used gauze filling and pelvic fixation as the main treatment modalities in hemodynamically unstable patients, resulting in a mortality rate of 21%; this rate is significantly lower than that reported in previous studies [20]. Gauze packing can reduce bleeding of the fracture surface and veins; however, as there is little hemostatic effect on the arteries, AE may have to be performed before and after packing. However, Cothren et al. reported that the need for post-EPP AE was uncommon in their study, indicating that most arterial hemorrhages are controllable with EPP [20].

Osborn et al. reported that the median time to intervention for EPP was significantly shorter than that for early AE; furthermore, EPP was associated with a lower mortality rate and no deaths due to hemorrhage [9]. In our study, EPP was predominantly used during period II and mainly performed in the OR during the first year (2014). Later in period II (2015–2016), EPP was performed in the resuscitation room for rapid bleeding control before AE. The average time from ER arrival to the OR for EPP was 92.9 min in 2014; this duration was further decreased to 58.4 min when EPP was performed in the resuscitation room later in period II (2015–2016). In 3 of 11 (27.2%) cases, no additional AE was performed after EPP. We found a significantly lower mortality rate in patients with unstable pelvic bone fractures in period II when compared to period I; in particular, mortality due to hemorrhagic shock was significantly reduced in period II. This decreased mortality rate is likely due to the establishment of a team-centric approach based on a new protocol, early diagnosis, and early hemostasis using various methods.

The establishment of evidence-based protocols for hemodynamically unstable pelvic fracture decreases the time needed for decision-making time as well as the times to AE and the OR [11]. The establishment of a new protocol improved the outcomes of patients in our study. Balogh et al. reported that the adherence to an institutional guideline contributed to reducing mortality by 35% [21]. Another study showed that patient survival improved through a multidisciplinary clinical approach in which trauma surgeons and orthopedic trauma specialists participated in decision-making [3]. Moreover, Cheng et al. reported that patient outcomes were significantly improved by developing a protocol using AE and EPP [22]. In this study, the time to intervention was significantly reduced after protocol establishment. Although the time to AE was also shortened, it remained still long in a modern trauma management setting. The angiography facility is available, but it lacks manpower; two radiologists work on alternate call schedules. This should be improved in the future.

The amounts of transfused pRBCs remained unchanged in periods I and II. Resuscitation using blood products was preferred than crystalloid while opening the trauma center. Thus, the time to hemostasis was reduced, but not the amount of transfused pRBCs within 24 h. We speculate that there was insufficient of resuscitation during period I.

Regarding mortality related to hemorrhagic shock, two patients died from this cause in period II. The first case occurred during the early stage of protocol establishment; at this time, the protocol was not being followed yet, and both, PPP and AE times were long. The transfer of the second patient to the hospital took > 40 min. As soon as the patient arrived, a cardiac arrest occurred, and cardiopulmonary resuscitation was performed for 15 min. The patient recovered and progressed to EPP but eventually died within 24 h.

This study has some limitations. First, it was a retrospective cohort study. Whereas, during period I, data were collected retrospectively, they were collected prospectively using a trauma database during period II. This might have introduced bias; therefore, studies with a more appropriate study design should be conducted in the future. Second, patients with unstable pelvic fractures are usually polytrauma patients. Thus, several factors might be associated with mortality in these patients. Third, the performance level of our team changed throughout the study period because the trauma center was newly established. During period II, the performance times even differed between the first year (2014) and the following 2 years (2015–2016) because the staff were undergoing training and were not very familiar with the new protocol during the first year. Further research on the subject is required once the protocol is fully adopted.

## Conclusions

The successful treatment of unstable pelvic fractures requires early hemostasis. Therefore, trauma centers should establish a consensus algorithm for treatment; all members of the trauma team and medical staff should be aware of this protocol and be able to implement it properly. The implementation of our new protocol, which included EPP, was associated with a significant decrease in mortality. Therefore, this treatment strategy seems to be an effective method for the treatment of patients with traumatic pelvic hemorrhage.

## Compliance with ethical standards

**Conflict of interest** Min A. Lee, Byungchul Yu, Jungnam Lee, Jae Jeong Park, Gil Jae Lee, Kang Kook Choi, Youngeun Park, Jihun Gwak and Ahram Han declare that there are no conflicts of interest.

**Research involve human participants/animals** This research does not involve human participants and/or animals.

**Informed consent** Informed consent obtained from subjects.

**Role of the funding source** There are no sources of funding in our study.

**Ethical standards** The work has been approved by the appropriate ethical committees related to the institution in which it was performed.

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