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ORIGINAL RESEARCH

Contrast extravasation and hematoma volume as predictors of the need for embolization in patients with pelvic fractures

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Abstract

Angioembolization is effective and safe in patients with pelvic bone fractures with arterial bleeding. However, there is still no consensus regarding the indications for angiography after pelvic fractures. This study investigated predictors of embolization in patients with pelvic bone fractures through a comparative analysis of patients who had extravasation on angiography. From January 2009 to December 2021, 1431 patients with pelvic fractures were admitted to a single trauma center. After the application of exclusion criteria, 949 patients were enrolled in the study. We divided the patients into two groups to identify predictors of patients with arterial bleeding: the therapeutic embolization (TE) group (n = 149) versus the non-TE group (n = 800). Vital signs and laboratory data were significantly worse in the TE group, except for the Glasgow Coma Scale. When the fracture patterns were compared, the vertical shearing type and the anteroposterior compression type were significantly more common in the TE group. Multivariate logistic regression analysis identified five predictors of therapeutic embolization: systolic blood pressure <90 mmHg in the emergency department (odds ratio (OR) = 2.63; 95% credible intervals (CI) = 1.52–4.53; p = 0.001), combined injury to the abdomen (Abbreviated Injury Scale ≥3) (OR = 3.94; 95% CI = 2.23–6.97; $p < 0.001$), contrast extravasation on enhanced computed tomography (OR = 30.41; 95% CI = 16.08–57.52; $p < 0.001$), sacroiliac joint disruption (OR = 2.40; 95% CI = 1.35–4.28; p = 0.003), and hematoma volume >25 mL (OR = 3.79; 95% CI = 2.06–6.98; $p < 0.001$). Systolic blood pressure less than 90 mmHg, contrast extravasation on enhanced computed tomography, sacroiliac joint disruption, and pelvic hematoma were significant predictors of embolization in pelvic fracture patients. Trauma surgeons' clinical decision-making for patients with pelvic bone fractures should consider clinical features and radiologic findings.

Keywords

Pelvic bone fracture; Angioembolization; Predictor; Hematoma

1. Introduction

The effective treatment of patients with unstable pelvic bone fractures is a challenge. It is important for trauma surgeons to make decisions based on patient's clinical features and radiologic information. Despite advances in many diagnostic and therapeutic techniques for patients with pelvic bone fractures, the mortality rate remains as high as 40% [1–4].

About 80% of deaths in these patients result from uncontrolled bleeding and delayed hemostasis [5]. Approximately 85% of pelvic hemorrhages are due to disruption of bone structure and venous hemorrhage, and 10% to 15% of patients present with arterial hemorrhage. However, in pelvic fractures, arterial bleeding frequently causes hemodynamic instability [2, 6–8]. These pelvic bleedings are not tamponade, and they can lead to massive bleeding. Therefore, early recognition of pelvic bleeding and appropriate hemostasis are important [9].

Advanced hemostatic or stabilization techniques for pelvic fractures have recently been developed, including preperitoneal pelvic packing, angioembolization, resuscitative endovascular balloon occlusion, pelvic binders, and external fixation. Angioembolization is very effective and safe in patients with pelvic bone fractures with arterial bleeding [10, 11]. Many guidelines have stated that embolization is necessary for patients with unstable pelvic bone fractures [12]. In general, systolic blood pressure, hematocrit, heart rate, age, blood transfusion, a blush on computed tomography (CT), a large pelvic hematoma on CT, and the fracture pattern have been reported as predictors of arterial bleeding in pelvic fracture patients [9, 13–17]. Nonetheless, there is still no consensus re-

garding the indications for angiography after pelvic fractures.

The purpose of this study was to investigate the predictors of embolization in patients with pelvic bone fractures through a comparative analysis of patients who had extravasation on angiography.

2. Materials and Methods

2.1 Patients and data collection

This study retrospectively analyzed patients with blunt traumatic pelvic fractures who were treated at Gachon University Gil Hospital Trauma Center from January 2009 to December 2021. During this period, 1431 patients with pelvic bone fractures were admitted to the hospital. Among them, patients younger than 18 years of age, patients without enhanced CT, and patients who died at the emergency department (ED) due to other causes (traumatic brain injury, thoracic injury, hemoperitoneum, *etc.*) were excluded. Finally, 949 patients were enrolled in the study. Data were acquired for these patients through Korea Trauma Data Bank (KTDB) and electronic medical records.

Among these patients, 240 patients underwent angiography, and 149 patients had arterial bleeding on angiography. We divided the patients into two groups to identify predictors of arterial bleeding. In the therapeutic embolization (TE) group, extravasation was confirmed by angiography, and embolization was performed (n = 149). In the non-TE group, extravasation was not confirmed on angiography or the patients were stable without angiography (n = 800) (Fig. 1). We compared demographics, fracture type, combined injury, and radiologic findings between the two groups. The size of hematoma in the pelvis was measured on enhanced CT, with the diameter of the largest hematoma in the axial view determined as the hematoma width and depth. The diameter in the coronal view was recorded as the hematoma height. The volume of the hematoma was measured using manual tracing with PiViewSTAR software (version 5.0.9.2, INFINITT Co. Ltd., Seoul, Korea). After the radiologist measured the length, width, and height of the largest hematoma in the pelvic cavity, the volume was automatically calculated using the volumetry tool in the PiViewSTAR software, using the formula of an ellipsoid (width/2 $\times$ depth/2 $\times$ height/2 $\times$ 4/3 $\times$ π).

2.2 Management protocol of patients with pelvic bone fractures

At the regional level I trauma center where this study was conducted, trauma surgeons and emergency physicians are on duty 24 hours a day, and interventional radiologists are available around the clock. When a severe trauma patient arrives, the trauma team is activated immediately, and the patient quickly receives standard care, such as initial assessment, resuscitation, and a portable X-ray examination. If a pelvic fracture is suspected and vital signs are stable, enhanced CT may be performed. Patients with confirmed contrast leakage on CT are referred for angiography. In patients with unstable vital signs, thoracotomy or laparotomy is performed immediately if bleeding from other sites is suspected based on a focused assessment with sonography in trauma. If pelvic bone bleeding is suspected, angiography is arranged, and if a delay is expected, preperitoneal pelvic packing (PPP) is performed (Fig. 2).

2.3 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-square test for categorical variables. Logistic stepwise regression analysis was performed to predict the need for therapeutic embolization based on clinical variables and radiologic findings. Statistical significance was defined as $p < 0.05$. The odds ratios and 95% confidence intervals were derived. All statistical analyses were performed using SPSS version 20.0 (IBM Corp., Armonk, NY, USA).

3. Results

In total, 949 patients with pelvic fractures were included in the study. Of these patients, 149 patients underwent embolization with arterial bleeding confirmed on angiography, and we defined them as comprising the TE group. The non-TE group was defined as patients who were stable without angiography or in whom arterial bleeding was not confirmed on angiography. The demographics of these two groups were compared. In the TE group, age was significantly higher, and there was no significant difference in the sex ratio between groups. As for the injury mechanism, falls and pedestrian traffic accidents were common in both groups. Vital signs upon arrival at ED were significantly worse in the TE group, except for the Glasgow Coma Scale, and laboratory data in the ED were also significantly worse in the TE group. The TE group received more blood transfusions and had a higher rate of massive transfusions. The injury severity score and 30-day mortality were also higher in the TE group (Table 1).

When the fracture patterns were compared, the vertical shearing type and the anteroposterior compression (APC) type were significantly more common in the TE group. Pelvic bone fractures of Abbreviated Injury Scale (AIS) grade 3 or higher were more common in the TE group (Table 2). Table 3 shows the combined injuries. When analyzing accompanying injuries of AIS grade 3 or higher in each area, chest and abdominal injuries were significantly more common in the TE group (Table 3).

Comparing the radiologic findings between the two groups, contrast extravasation (CE) around the pelvic bone fracture on enhanced CT was significantly more common in the TE group, and there were also more sacroiliac joint (SIJ) injuries. Significant between-group differences were found in the width, length, and volume of hematomas (Table 4). Receiver operating characteristic curve analysis for pelvic hematoma volume was performed to predict arterial bleeding. At a cut-off value of 25 mL, hematoma volume predicted therapeutic embolization (area under the curve: 0.838; sensitivity: 81.2%; specificity: 74.0%) (Fig. 3). In the TE group, 81.2% of patients had a hematoma volume above the cut-off value (Table 4).

Multivariate logistic regression analysis identified five variables as predictors of therapeutic embolization: systolic blood pressure <90 mmHg in the ED (odds ratio (OR) = 2.63; 95%

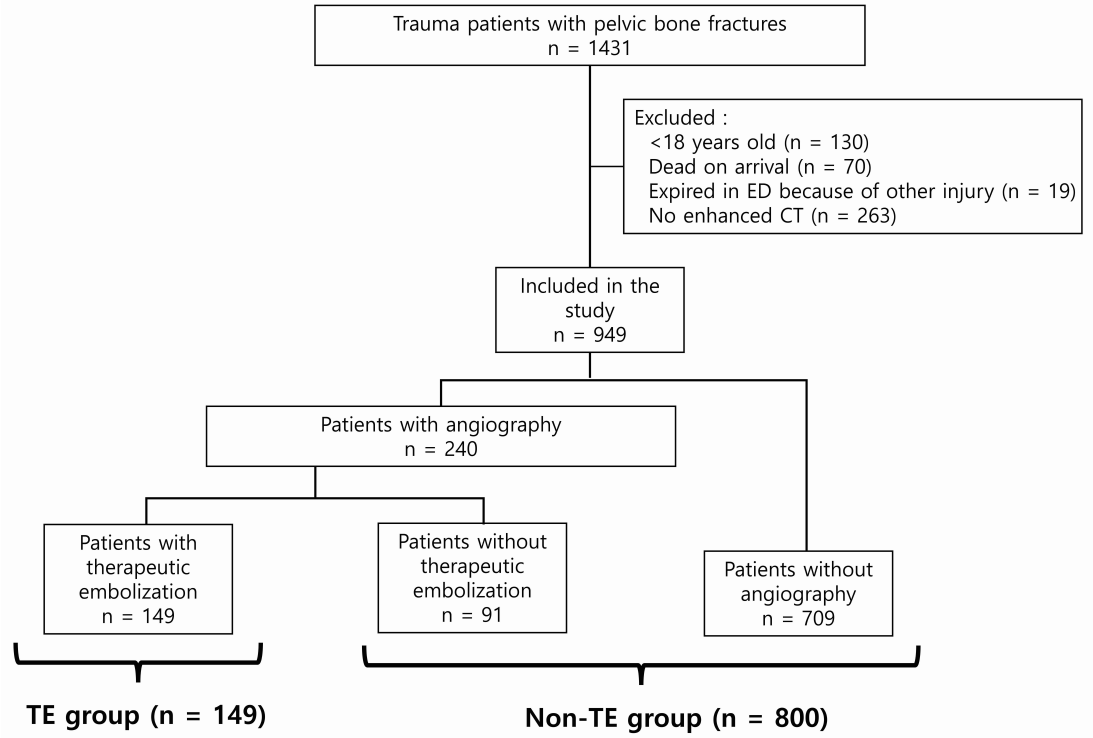

FIGURE 1. Flowchart of patient inclusion. ED: emergency department; CT: computed tomography; TE: therapeutic embolization.

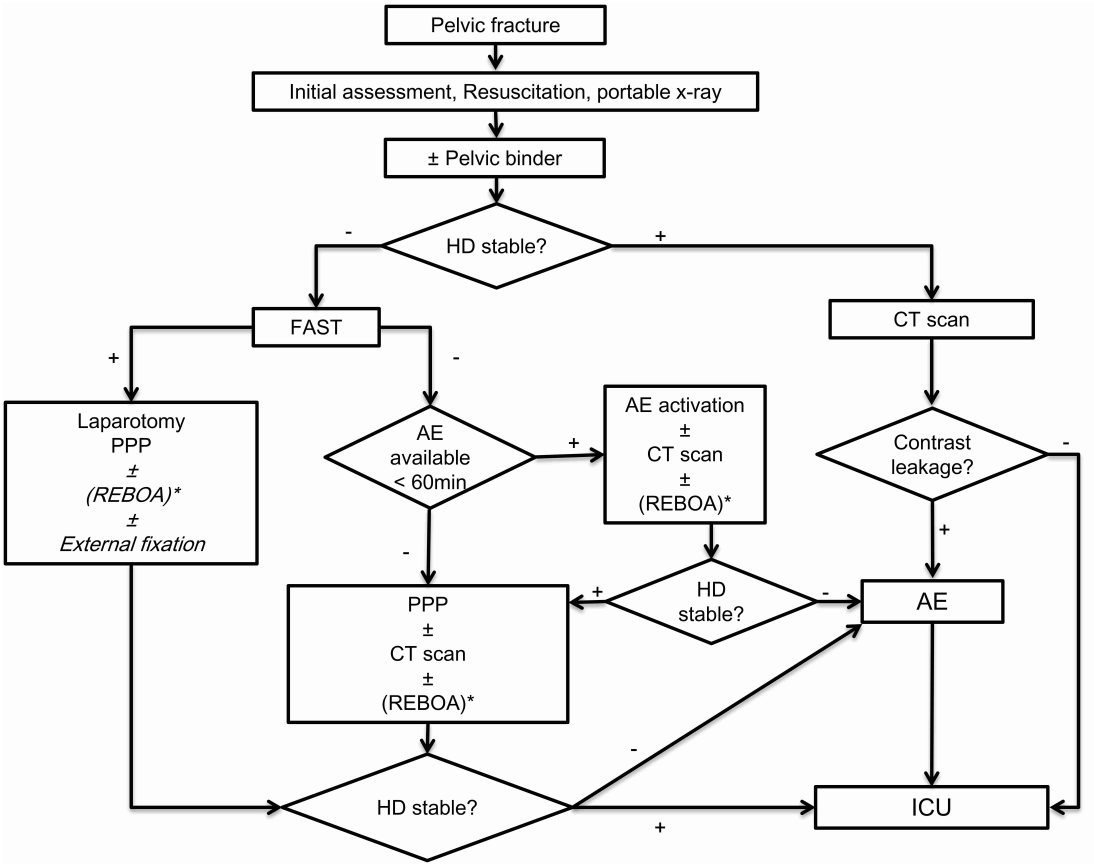

FIGURE 2. An algorithm for the management of pelvic fracture during the study period.
CT: computed tomography; PPP: preperitoneal pelvic packing; HD: hemodynamics; AE: angioembolization; ICU: intensive care unit; REBOA: resuscitative endovascular balloon occlusion of aorta; FAST: focused assessment with sonography for trauma.
*REBOA was added to the algorithm in 2016.

TABLE 1. General characteristics of all patients with pelvic fracture.

	TE group n = 149	Non-TE group n = 800	Total n = 949	*p* value
Age	56.6 ± 19.0	53.4 ± 18.0	52.2 ± 18.2	0.001
Age ≥65, (%)	53 (35.6%)	198 (24.8%)	251 (26.4%)	0.006
Sex (male, %)	82 (55.5%)	502 (62.0%)	584 (61.5%)	0.075
Mechanism				
In car TA (%)	6 (4.0%)	61 (7.6%)	67 (7.1%)	
Pedestrian TA (%)	47 (31.5%)	259 (32.4%)	306 (32.2%)	
Motorcycle TA (%)	5 (3.4%)	63 (7.9%)	68 (7.2%)	0.099
Fall down (%)	73 (49.0%)	336 (42.0%)	409 (43.1%)	
Struck by object (%)	18 (12.1%)	81 (10.1%)	99 (10.4%)	
SBP in ED	84.0 ± 29.1	108.2 ± 29.2	116.4 ± 32.2	<0.001
SBP <90 mmHg in ED	100.0 (67.1%)	198.0 (24.8%)	298.0 (31.4%)	<0.001
PR in ED	101.1 ± 23.3	92.0 ± 21.0	93.4 ± 21.6	<0.001
GCS in ED	12.6 ± 3.8	13.3 ± 3.4	13.2 ± 3.5	0.054
Hb in ED	11.8 ± 2.8	12.8 ± 2.8	12.6 ± 2.4	<0.001
PH in ED	7.34 ± 0.12	7.37 ± 0.10	7.36 ± 0.10	0.004
BE in ED	−4.6 ± 6.0	−3.5 ± 5.4	−3.7 ± 5.5	0.025
Lactate in ED	4.5 ± 3.2	3.3 ± 2.6	3.5±2.7	<0.001
Transfusion	135 (90.6%)	350 (43.8%)	485 (51.1%)	<0.001
Transfusion pRBC <4 h	5.7 ± 7.1	1.7 ± 4.0	2.4 ± 4.8	<0.001
Transfusion pRBC <24 h	4.6 ± 7.9	1.3 ± 3.3	1.8 ± 4.5	<0.001
4 h MT (%)	74 (49.7%)	131 (16.4%)	205 (21.6%)	<0.001
24 h MT (%)	20 (13.4%)	29 (3.6%)	49 (5.2%)	<0.001
ISS	32.3 ± 12.5	19.5 ± 10.9	21.5 ± 12.1	<0.001
ISS >15 (%)	139 (93.3%)	490 (61.3%)	629 (66.3%)	<0.001
TICU length	10.2 ± 14.9	6.5 ± 12.2	7.1 ± 12.7	0.005
LOH	37.2 ± 34.8	31.0 ± 32.2	32.0 ± 32.7	0.045
30 day mortality (%)	36 (24.2%)	70 (8.8%)	106 (11.2%)	<0.001

TE: therapeutic embolization; TA: traffic accident; SBP: systolic blood pressure; ED: emergency department; PR: pulse rate; GCS: Glasgow Coma Scale; Hb: hemoglobin; PH: hydrogen ion concentration; BE: base excess; pRBC: packed red blood cell; MT: massive transfusion; ISS: Injury Severity Score; TICU: trauma intensive care unit; LOS: length of stay.

CI = 1.52–4.53; $p = 0.001$), a combined injury of the abdomen (AIS $\geq$ 3) (OR = 3.94; 95% CI = 2.23–6.97; $p < 0.001$), CE on enhanced CT (OR = 30.41; 95% CI = 16.08–57.52; $p < 0.001$), SIJ disruption (OR = 2.40; 95% CI = 1.35–4.28; $p = 0.003$), and hematoma volume >25 mL (OR: 3.79; 95% CI: 2.06–6.98; $p < 0.001$) (Table 5).

4. Discussion

Early hemostasis can improve the survival rate of unstable pelvic fractures. Pelvic embolization is considered to be an effective alternative to surgery for the treatment of pelvic bone fractures. Therefore, when angiography is used as the main treatment method for pelvic fractures, an early diagnosis of bleeding and appropriate patient selection are important. Our study confirmed that vital signs in the ED, the presence of an associated abdominal injury, pelvic fracture pattern, CE on CT, SIJ disruption, and hematoma volume were significant predictors of TE.

Many guidelines have suggested that hemodynamic instability is an important predictor of the need for hemostasis in patients with pelvic fractures [9, 18]. Miller *et al.* [19] reported that pelvic arterial bleeding was present in 73% of non-responders. Eastridge *et al.* [20] emphasized that angiography should be performed quickly in patients with unstable pelvic bone fractures who remain in shock. Bramos *et al.* [21] suggested that patients with stable pelvic bone fractures with risk factors of a hematocrit of 30% or less, systolic blood pressure of 90 mmHg or less, and blush on CT should immediately undergo emergency angiography or PPP.

In our study, vital signs and laboratory data in ED were significantly worse in the TE group. In particular, a systolic blood pressure of less than 90 mmHg was identified as a predictor of therapeutic embolization in the multivariable regression

TABLE 2. Pelvic and extremity AIS grades and fracture patterns.

	TE group n = 149	Non-TE group n = 800	Total n = 949	*p* value
Grade ≥3	114 (76.5%)	345 (43.1%)	459 (48.4%)	<0.001
Grade	3.8 ± 1.2	2.6 ± 0.9	2.8 ± 1.0	<0.001
Y&B type				
APC	21 (14.1%)	49 (6.1%)	70 (7.4%)	<0.001
LC	104 (69.8%)	568 (73.3%)	6990 (72.7%)	
VS	15 (10.1%)	15 (1.9%)	30 (3.2%)	
Combined	9 (6.0%)	150 (18.8%)	159 (16.8%)	

AIS: Abbreviated Injury Scale; TE: therapeutic embolization; Y&B type: Young and Burgess type; APC: Anteroposterior compression; LC: lateral compression; VS: vertical shearing.

TABLE 3. Combined injuries in pelvic fracture patients by AIS[a].

	TE group n = 149	Non-TE group n = 800	Total n = 949	*p* value
HN	41 (27.5%)	175 (21.9%)	219 (22.8%)	0.027
Face	3 (2.0%)	5 (6.0%)	8 (0.8%)	0.092
Chest	75 (50.3%)	328 (41.0%)	403 (42.5%)	0.008
Abdomen	83 (55.7%)	136 (17.0%)	219 (23.1%)	<0.001
P&E	123 (82.6%)	436 (54.5%)	559 (58.9%)	<0.001
External	2 (1.3%)	2 (0.3%)	4 (0.4%)	0.105

AIS: Abbreviated Injury Scale; TE: therapeutic; HN: head & neck; P&E: pelvis & extremity; [a]AIS: 2005 version.

TABLE 4. Comparison of radiologic findings between the TE and non-TE groups.

	TE group n = 149	Non-TE group n = 800	Total n = 949	*p* value
CE on CT	134 (89.9%)	106 (13.3%)	240 (25.3%)	<0.001
SIJ disruption	77 (51.7%)	133 (16.6%)	210 (22.1%)	<0.001
Hematoma width	5.3 ± 2.0	2.1 ± 2.3	2.6 ± 2.5	<0.001
Hematoma length	5.5 ± 2.1	2.4 ± 2.7	2.9 ± 2.9	<0.001
Hematoma volume	71.3 ± 62.5	22.6 ± 45.1	30.2 ± 51.4	<0.001
Hematoma volume >25 mL	121 (81.2%)	207 (25.9%)	328 (34.6%)	<0.001

TE: therapeutic embolization; CE: contrast extravasation; CT: computed tomography; SIJ: sacroiliac joint.

TABLE 5. Logistic regression analysis of the predictors for therapeutic embolization.

variables	Multivariate analysis	
	Odds ratio (95% CI)	*p* value
SBP <90 mmHg in the ED	2.63 (1.52–4.53)	0.001
Combined injury of the abdomen (AIS ≥3)	3.94 (2.23–6.97)	<0.001
CE on CT	30.41 (16.08–57.52)	<0.001
SIJ disruption	2.40 (1.35–4.28)	0.003
Hematoma volume >25 mL	3.79 (2.06–6.98)	<0.001

SBP: systolic blood pressure; ED: emergency department; AIS: Abbreviated Injury Scale; CE: contrast extravasation; CT: computed tomography; SIJ: sacroiliac joint; CI: credible intervals.

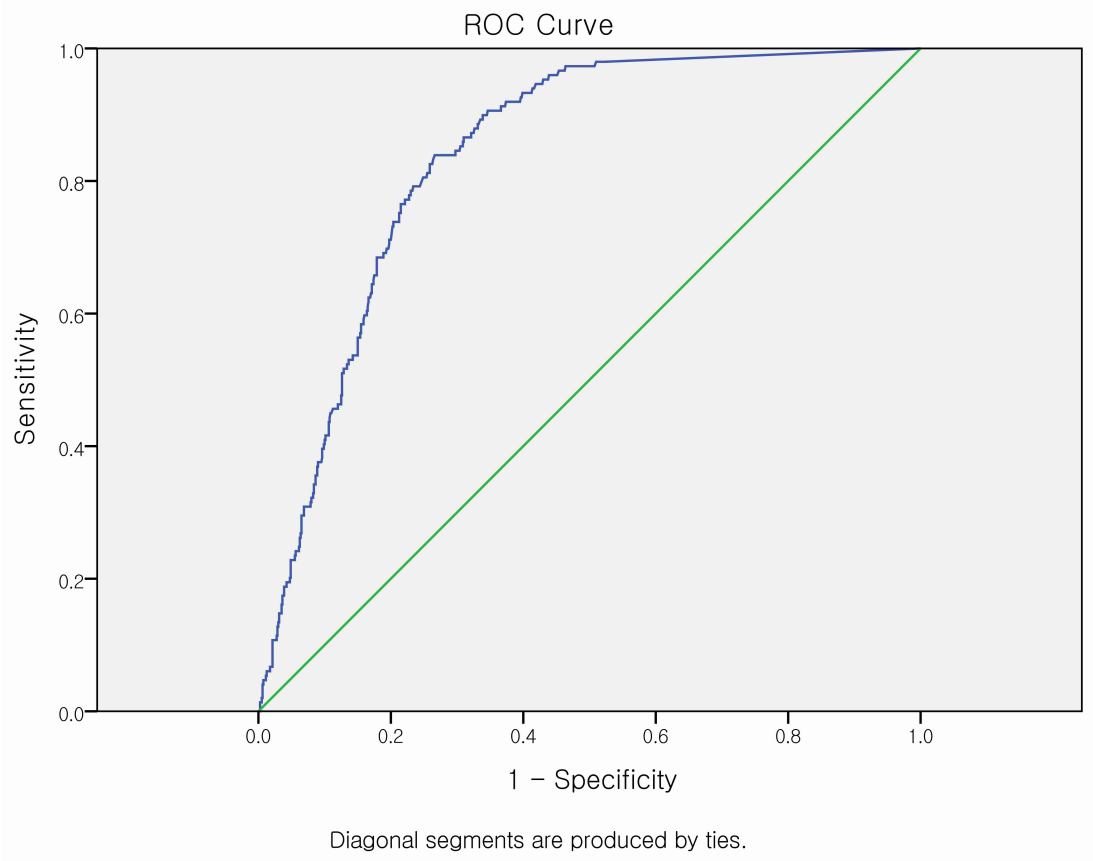

FIGURE 3. A receiver operating characteristic (ROC) curve of the volume of pelvic hematoma as a predictor of therapeutic embolization. At a cut-off value of 25 mL, hematoma volume predicted therapeutic embolization. The area under the ROC curve is 0.838. ROC: receiver operator characteristic.

analysis.

Multiple studies have been conducted on the relationship between pelvic fracture patterns and arterial bleeding [20, 22]. The Young and Burgess classification is widely used for pelvic ring fractures. This system classifies pelvic fractures into three types, taking into account force type, severity, direction, and injury instability. Each type is classified according to the severity of the ligamentous disruption of the sacroiliac joints.

According to Miller *et al.* [19], arterial bleeding occurred more frequently in APC II and III, lateral compression II and III, vertical shearing, and combined mechanism fractures. Costantini *et al.* [23], in a study conducted at multiple centers, found that APC fractures had the highest risk of significant arterial bleeding. Cryer *et al.* [24] stated that arterial bleeding was found most frequently in APC II and III fractures [24, 25]. Salim *et al.* [26] reported that the following factors significantly predicted embolization: duration of hypotension, female sex, and SIJ disruption.

In our study, actual arterial bleeding was significantly higher in APC and vertical shearing type fractures. In addition, the risk of embolization substantially increased if there was SIJ disruption due to the severe degree of injury.

It has been reported that APC pelvic fractures involve a greater disruption of the vessels and more hemorrhage than other injury mechanisms. This APC pattern of injury force might be associated with bilateral sacroiliac joint injuries and further bilateral arterial injuries.

Smith *et al.* [28] reported a higher frequency of injuries to the superior gluteal artery than to other arteries due to its relationship to the SIJ and the sharp fascia of the piriformis. Frequent injuries were also observed in the internal pudendal artery due to its location near the urogenital membrane, the pubic ramus, and the inferior ligaments of the pelvis [27–29].

In this study, patients with severe abdominal injuries associated with pelvic fractures were also at an increased risk of arterial bleeding in the pelvic cavity. The combination of a pelvic fracture and abdominal injury most likely occurs due to high-energy trauma and is often accompanied by hemodynamically instability [30, 31]. According to Markus *et al.* [32], 20% of patients with pelvic fractures also had abdominal injuries, which increased mortality and morbidity.

CE on CT is a major factor to consider when deciding whether to perform embolization. The size of the hematoma in the pelvic cavity should also be considered. In our multivariable regression analysis, CE on CT was an important predictor of embolization. Specifically, CE was associated with a 30 times higher probability of having arterial bleeding on angiography.

Many recent guidelines have described extravasation on CT scans as the most important radiological predictor of embolization [33]. The prediction rates have been reported to range widely, from 25% to 100% depending on the study [8, 15, 34–37]. Cerva *et al.* [38] reported that the finding of CT extravasation demonstrated a sensitivity of 84% and specificity

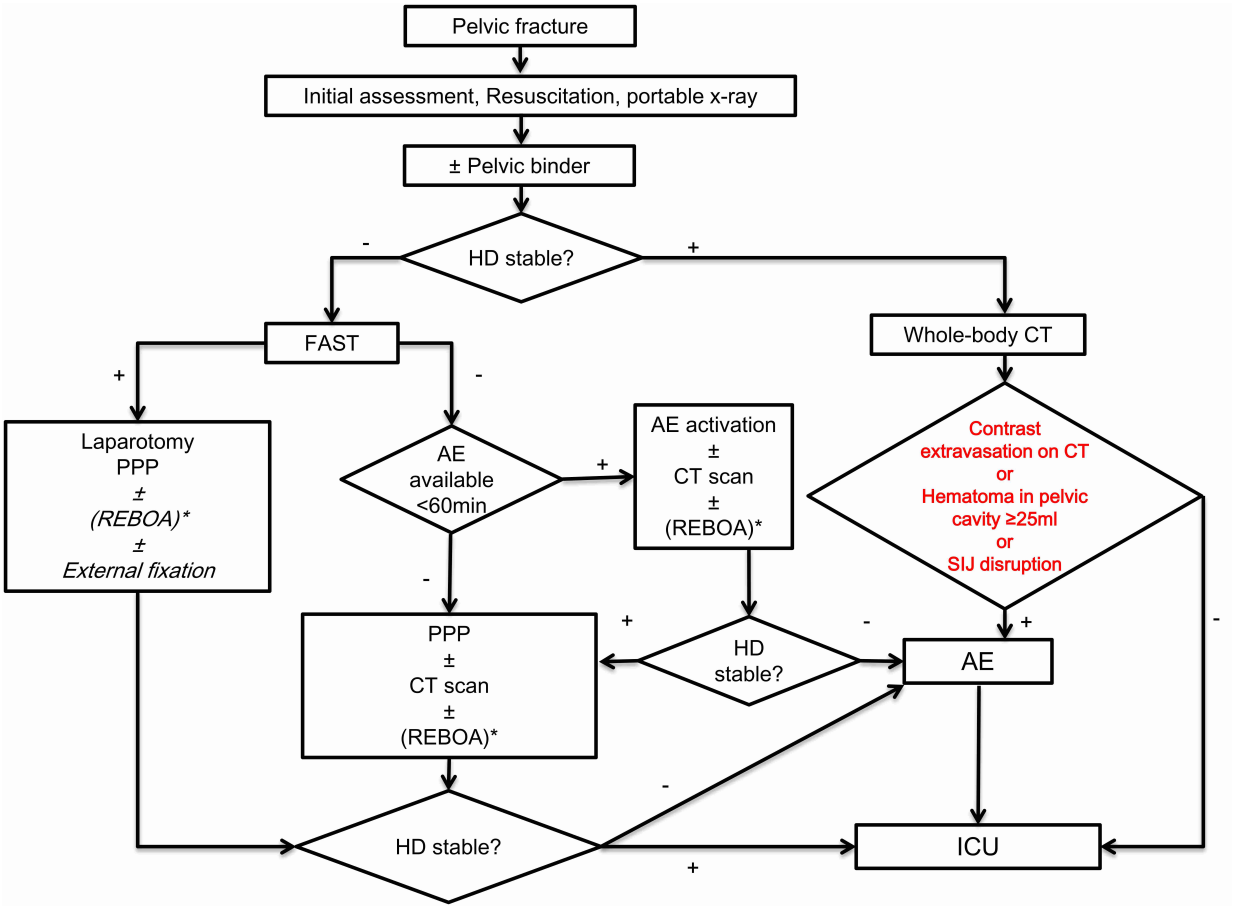

FIGURE 4. The modified algorithm for the management of pelvic fractures. CT: computed tomography; PPP: preperitoneal pelvic packing; HD: hemodynamics; AE: angioembolization; ICU: intensive care unit; REBOA: resuscitative endovascular balloon occlusion of aorta; FAST: focused assessment with sonography for trauma. In the modified protocol, angiography is performed if there is contrast leakage, pelvic hematoma greater than 25 mL, or SIJ disruption in CT.

of 85% for the detection of active bleeding. Pereira stated that blush on CT was a reliable marker with 90.9% sensitivity and 98.6% specificity [15]. Bozeman *et al.* [35] and Miller *et al.* [19] reported that the presence of CE in patients with pelvic fractures was highly associated with embolization.

Some have argued that CE on CT is relatively insensitive and is an inappropriate predictor in patients without signs of ongoing bleeding [19, 36, 37]. Another limitation is that CE is only confirmed on enhanced CT. Several studies have also identified pelvic hematoma as a significant predictor of arterial bleeding [16, 17, 39–41]. Blackmore *et al.* [16] reported that patients with large pelvic hematoma were more likely to have arterial bleeding. Lee *et al.* [39] argued that aggressive embolization should be performed if the size of the pelvic hematoma on a CT scan is 3.35 cm or more. Yoshikawa *et al.* [41] demonstrated that blush on CT, the laterality of muscle swelling around the pelvis, and the thickness of the retroperitoneal hematoma were predictors of embolization in patients with pelvic fractures. In our study, embolization was performed more frequently in patients with larger pelvic hematomas. The cut-off value for pelvic hematoma volume obtained through receiver operating characteristic curve analysis was 25 mL. In our study, the risk of TE was 3.7-fold higher in patients with pelvic hematomas larger than 25 mL. Therefore, pelvic hematoma on CT should also be an important consideration in determining whether embolization is required. In ED, time is very limited when resuscitation of trauma patients and treatment decisions are made. We used a simple method to measure hematoma volume that did not require a specialized program, but nonetheless showed a substantial correlation with the results.

Based on these results, we modified the existing protocol regarding the decision to perform angiography (Fig. 4). In the modified protocol, angiography is performed if there is contrast leakage, pelvic hematoma greater than 25 mL, or SIJ disruption in CT. This new protocol is expected to facilitate more appropriate and accurate management of pelvic fracture patients.

This study has some limitations. First, it was a retrospective cohort study. Since we have established a modified protocol through this study, we plan to conduct a follow-up study. Second, because this was a single-center study, it may be difficult to generalize its results. Third, patients with unstable pelvic fractures are generally polytrauma patients. Therefore, several factors may be related to the outcomes of these patients.

5. Conclusions

In our study, systolic blood pressure less than 90 mmHg, CE on CT, SIJ disruption, and pelvic hematoma were significant

predictors of embolization in pelvic fracture patients. Trauma surgeons' clinical decision-making for patients with pelvic bone fractures should be based on a consideration of clinical features and radiologic findings. We intend to establish an improved protocol through the results of this study and promote follow-up research.

AVAILABILITY OF DATA AND MATERIALS

Data and materials can be made available to the public through direct requests to the corresponding author.

AUTHOR CONTRIBUTIONS

MAL and BY—had full access to all the data and drafted the manuscript; GJL, YP, SHL, MJJ, YBJ, JC and KKC—participated in the study design, data collection, and the education.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was reviewed and approved by Gachon University Ethics Committee (GDIRB2022-209). Written informed consent was obtained from each patient included in the study.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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