



ORIGINAL ARTICLE

# Strategies for the management of hemodynamically unstable pelvic fractures: From preperitoneal pelvic packing to definitive internal fixation



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## KEYWORDS

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**Summary** *Background/Objective:* Preperitoneal pelvic packing is useful, and favorable treatment outcomes have been reported. However, the timing of subsequent internal fixation of the pelvis is still debatable. We report the outcomes of a study on patients that underwent internal fixation after preperitoneal packing.

*Methods:* A retrospective review was performed for patients with hemodynamically unstable pelvic fracture who underwent preperitoneal pelvic packing and internal fixation. Patients who underwent internal fixation with simultaneous packing removal were placed in Group 1. Patients who underwent definitive internal fixation later were placed in Group 2.

*Results:* Of the 56 patients (mean age 44.7 years), 36 were male. The mean time from injury to internal fixation was 1.3 (1–2) days and 5.6 (3–10) days in Group 1 and 2, respectively. There was a significant difference in the mean duration of stay in the intensive care unit: 10.9 (3–54) days in Group 1 vs. 14.4 (5–43) days in Group 2 ( $p = 0.019$ ). Thirty-one cases of complications occurred among 14 patients (25%), including six cases of surgical site infection. Among the six cases of infection, four were superficial and two were deep; five of these cases occurred in Group 2, including both cases of deep infection ( $p = 0.013$ ).

*Conclusion:* Performing internal fixation with packing removal should aid the return of the patient to a stable state, as it is possible to utilize the same incision line used for the original packing procedure, while providing stability to the pelvis.

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## 1. Introduction

High-energy pelvic bone injury, including pelvic ring injury and acetabular fracture, is associated with high morbidity and mortality.<sup>1,2</sup> Hemodynamically unstable pelvic trauma is life-threatening and is often accompanied by other life-threatening injuries. Although several treatment algorithms are available for these injuries, no single algorithm has been conclusively established.<sup>3,4</sup> Nevertheless, the majority of treatment algorithms aim to reduce patient bleeding, provide volume replacement, stabilize the patient hemodynamically, and then achieve bony stabilization. Even with this multidisciplinary approach, high-energy pelvic bone injury has a fatality rate of 40%.<sup>5–7</sup>

Current treatment trends include resuscitation according to the Advanced Trauma Life Support (ATLS) guidelines,<sup>8</sup> and utilization of a damage control approach, by stabilizing a patient's condition prior to definitive fixation for stabilization of the pelvic bone. Various studies in hemodynamically stable patients have reported that early definitive fixation produces favorable outcomes.<sup>9,10</sup> However, there has been no research on the timing of definite fixation for hemodynamically unstable patients who undergo preperitoneal pelvic packing (PPP), or for patients who undergo explorative laparotomy and packing. Because of the risk of infection, packed materials (gauzes or pads) should be removed within 1–2 days of packing. Here, the incision wound for packing or laparotomy is closed, meaning that it must be reopened for reduction and definitive internal fixation of the pelvic bone fracture. This approach increases the extent of soft tissue injury, and we believe that this could be a cause of wound breakdown or infection.<sup>7</sup>

In patients who have undergone explorative laparotomy or PPP, when the patient's condition is stabilized, a protocol for packing removal and anterior fixation and stabilization during the second-look operation is followed. Our study aimed to report the outcomes of this protocol, which we hypothesized would reduce the number of operations per patient, reduce the risk of infection, and reduce the length of stay in the intensive care unit (ICU).

## 2. Methods

This was a retrospective cohort study of prospectively enrolled patients who visited a Level I trauma center between January 2013 and January 2017. The study was approved by our institutional review board. Acute pelvic fracture management was performed in accordance with the ATLS guidelines.<sup>8</sup>

All the patients included in this study had hemodynamically unstable pelvic fracture and mature skeletal development (age >18 years). Patients with the following

characteristics were included in this study: 1) acute pelvic bone fracture (pelvic ring injury or acetabular fracture); 2) explorative laparotomy or PPP; 3) definitive internal fixation for the treatment of the pelvic bone fracture; and 4) availability for at least 1 year of follow-up. The exclusion criteria were as follows: 1) resuscitative thoracotomy or death before arriving at the hospital; 2) acute pelvic bone fracture, but with hemodynamic stability; 3) transfer from another hospital following trauma; 4) conservative treatment or external fixation for the acute pelvic bone fracture alone; 5) death or unavailability during follow-up; and 6) refusal to be included in the study. During the 4 years of the study, a total of 3189 patients visited the trauma bay, of which 1343 patients had sustained an acute pelvic bone injury. Of these, there were 97 hemodynamically unstable patients, of which 21 died (mortality rate, 21.6%). Ultimately, the 56 patients who satisfied the inclusion criteria were included in the study.

Hemodynamic instability was defined as persistent hypotension (systolic blood pressure [SBP] <90 mmHg), even after 2 L crystalloid loading or transfusion of 2 units of packed red blood cells (RBCs). When patients were admitted to the trauma bay, resuscitation was performed according to ATLS guidelines, followed by a trauma series (plain film radiographs of the lateral cervical spine, chest, and pelvis) and Focused Assessment with Sonography in Trauma (FAST). Patients who demonstrated persistent hemodynamic instability even after resuscitation were scheduled for surgery. In patients with pelvic ring injury, PPP was performed alongside external fixation using an external fixator or pelvic C-clamp to stabilize the pelvic bone. In patients with acetabular fracture, PPP was performed first, followed by the insertion of a pin into the distal femur for skeletal traction. In patients with positive FAST findings, explorative laparotomy or thoracotomy was also performed at the same time. The patient's course was monitored in the trauma ICU (TICU). Patients with persistent hemodynamic instability underwent angiography, followed by embolization or re-exploration and bleeding control in the operating theatre. Transfusion was performed according to our hospital's massive transfusion protocol, using a 1:1:1 ratio of packed RBCs, fresh frozen plasma (FFP), and platelet concentrate. A second-look operation was performed within 24–48 h of the initial procedure, and the packing was removed. At this time, if the patient was stable, the surgical wound from the initial procedure was extended, and reduction and anterior fixation of the pelvic ring or acetabulum was performed, followed by wound closure (Group 1). In patients with a poor systemic condition, when it was determined that the wound could not be closed because of severe swelling of abdominal organs following packing removal, and in patients who could not undergo pelvic bone fixation for reasons such as surgeon preference or availability of the operating theatre,

the surgical wound was closed, and surgery was planned while monitoring the patients' course in the TICU; the pelvic bone was stabilized in a later operation (Group 2). Concurrent surgical procedures were conducted within the scope of using surgical incision for PPP or laparotomy. Surgical techniques commonly used in this study included reduction and fixation of the anterior pelvic ring or reduction and fixation of the anterior part of the acetabulum with the modified Stoppa approach. Posterior pelvic ring fixation or fixation of the posterior part of the acetabulum (posterior wall or column) was not performed.

We collected all patient data prospectively via a trauma database, and retrospectively reviewed patient demographics, mechanism of injury, initial hemodynamic status, associated injury, laboratory findings, requirement of transfusion, hospital course, and complications. Pelvic ring injury was classified using the Young and Burgess classification,<sup>11</sup> and acetabular fracture was classified using the method by Judet et al.<sup>12</sup> We investigated complications that occurred during treatment, including pulmonary complications (pneumonia, pulmonary embolism, and acute respiratory distress syndrome), deep vein thrombosis, surgical site infection (superficial and deep), organ failure (renal failure, multiple organ failure), and pressure sores.

SPSS software version 22.0 (SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. Normally distributed data are expressed as mean  $\pm$  standard deviation or mean (range); non-normally distributed data are expressed as median. The Kruskal–Wallis test, Mann–Whitney test, Chi-square test, Fisher's exact test, and regression analysis were used to determine the relationships between each group. A *p* value of  $<0.05$  was considered statistically significant.

### 3. Results

During the 4-year study period, a total of 56 patients were included, of which 36 were male and 20 were female. The mean age was 44.7 (20–85) years, and the mean time from injury to trauma bay admission was 64.5 (22–160) min. The mean SBP at the time of admission was 111 (50–160) mmHg, while the mean of the lowest SBP during the resuscitation stage was 77.0 (50–90) mmHg. The mean duration of hypotension (SBP  $<90$  mmHg) was 42.3 (range 27–64) min, measured immediately after admission to the hospital. The mean injury severity score (ISS) was 31.3 (13–58). The median amount of packed RBCs transfused during the first 4 h and 4–24 h after admission to the trauma bay was 4 (2–18) units and 3 (0–20) units, respectively. The total amount of packed RBCs transfused in three patients over 4 h after admission was two units. These patients received 2 L volume loading after being initially diagnosed with hypotension but were later classified as non-responders and preperitoneal pelvic packing (PPP) was immediately performed. Of these, two had stable vital signs after PPP, but two units of packed RBCs were additionally transfused for these patients 4 h after admission. One of the two patients maintained stable vital signs after PPP. This young patient no longer required blood transfusion and, instead, received volume replacement as the hemoglobin level was higher than 9.0 g/dL. The mean

length of ICU stay was 12.9 (3–54) days, and the mean duration of mechanical ventilation was 8.2 (0–36) days.

Concerning pelvic bone injury classification, 40 patients had pelvic ring injury and 16 patients had acetabular fracture. Among the pelvic ring injuries, 16 patients presented with the anterior posterior compression (APC) type (APC II, 14 patients; APC III, 2 patients), 17 patients with the lateral compression (LC) type (LC II, 11 patients; LC III, 6 patients), and seven patients with vertical shear. Among the acetabular fractures, six patients presented with both column fracture type, six patients with anterior column with posterior hemi-transverse fracture type, three patients with T-shape fracture type, and one patient with transverse fracture type. There were two patients with an open pelvic fracture.

Of the 56 patients in the study, 26 underwent simultaneous anterior pelvic internal fixation during the second-look operation to remove the packing (Group 1). For the remaining 30 patients, the packing was removed and the wound was closed in the second-look operation. An additional operation was planned for pelvic internal fixation (Group 2). Table 1 shows the demographic data of the patients according to the time of internal fixation. The mean time from the first operation to the second-look operation and pelvic anterior internal fixation for patients in Group 1 was 1.3 (1–2) days. For patients in Group 2, the mean time to the second-look operation was 1.3 (1–2) days, and the mean time from injury to pelvic anterior internal fixation was 5.6 (3–10) days. There were no statistically significant differences between Group 1 and 2 in terms of age, time from injury to trauma bay admission, lowest SBP, ISS, time to second-look operation, or duration of mechanical ventilator use. The abbreviated injury scale (AIS) scores for the head, face, thorax, abdomen, and pelvic/extremity were calculated for each group, with no significant differences found. Pelvic bone injury type, injury severity score, Glasgow coma scale, and initial lactate level showed no statistically significant differences between Group 1 and 2. Blood volumes transfused within the first 4 and 24 h, which are indicators of blood loss, showed no statistical difference between Group 1 and 2 (Table 1).

The mean length of TICU stay for Group 1 was 10.9 (3–54) days, compared to 14.4 (5–43) days for Group 2, with a statistically significant difference being noted ( $p = 0.019$ ) (Table 2). Thirty-one cases of complication were found among 14 patients (25%). There were 14 cases of pulmonary complications, four cases of deep vein thrombosis, two cases of organ failure, six cases of infection, and four cases of pressure sores. Among the six cases of infection, five were in Group 2, including two cases of deep infection ( $p = 0.013$ ). Apart from infection, there were no significant differences in the incidence and distribution of other complications between the two groups. The rate of pulmonary complications was significantly higher in patients with  $AIS_{Thorax} \geq 3$  ( $p = 0.021$ ).

### 4. Discussion

Pelvic ring injury and acetabular fracture account for 3–8% of all fractures; however, mortality after pelvic bone fracture is approximately 5–18%. In hemodynamically

**Table 1** Patient characteristics.

	Group I (n = 26)	Group II (n = 30)	Total (n = 56)	p value
Age (years)	47.0 ± 15.4	42.6 ± 13.9	44.7 ± 14.6	0.260
Sex (male)	15 (57.7%)	21 (70%)	36 (64.3%)	0.338
Injury mechanism				0.856
Auto-pedestrian accident	10 (38.5%)	10 (33.3%)	20 (35.7%)	
Motor vehicle collision	8 (30.8%)	12 (40.0%)	20 (35.7%)	
Fall	4 (15.4%)	5 (16.7%)	9 (16.1%)	
Crush	4 (15.4%)	3 (10.0%)	7 (12.5%)	
Time from injury to admission (min)	62.2 ± 34.4	66.5 ± 31.8	64.5 ± 32.8	0.355
Initial SBP (mmHg)	111.7 ± 29.1	110.7 ± 30.6	111.2 ± 29.7	0.805
Lowest SBP (mmHg)	77.1 ± 11.4	76.9 ± 12.1	77.0 ± 11.7	0.947
Initial lactate (mmol/L)	5.08 ± 3.1	5.12 ± 2.9	5.10 ± 3.0	0.765
Pelvic bone injury type				0.735
Pelvic ring injury	18 (69.2%)	22 (73.3%)	40 (71.4%)	
Acetabular fracture	8 (30.8%)	8 (26.7%)	16 (28.6%)	
Glasgow coma scale	10.8 ± 5.0	12.5 ± 3.7	11.7 ± 4.4	0.212
Injury Severity Score	29.7 ± 109	32.9 ± 109	31.4 ± 109	0.311
Packed RBCs transfusion for 4 h (units)	4 (2–16)	4 (2–18)	4 (2–18)	0.316

Values are presented as mean ± standard deviation, count and percentage, or median (range). RBC, red blood cell; SBP, systolic blood pressure.

**Table 2** Comparison between groups.

	Group I (n = 26)	Group II (n = 30)	Total (n = 56)	p value
Time to second-look operation (days)	1.3 ± 0.5	1.3 ± 0.5	1.3 ± 0.5	0.839
Time to definitive fixation (days)	1.3 ± 0.5	5.6 ± 2.6	3.6 ± 2.9	<0.001
Length of ICU stay (days)	10.9 ± 9.8	14.4 ± 8.4	12.8 ± 9.1	0.019
Mechanical ventilation (days)	6.4 ± 7.3	9.2 ± 7.8	7.9 ± 7.6	0.138
Any complication	6 (23.1%)	8 (26.7%)	14 (25%)	0.757
Infection (deep)	1 (0)	5 (2)	6 (2)	
Pulmonary complication	6	8	14	
Deep vein thrombosis	2	4	6	

Values are presented as mean ± standard deviation, count and percentage, or count. ICU, intensive care unit.

unstable patients with pelvic bone injury, suppressing bleeding via PPP or angiographic embolism and stabilizing a patient's condition are of primary importance in preventing mortality. Stabilization of the pelvic ring or acetabulum alleviates pain and allows movement on the bed, which helps with patient care. In addition, decreasing the size of the bony fracture surface through reduction can minimize bone bleeding. Early bony stabilization by "early total care" in patients with isolated femoral fracture enables rapid rehabilitation and mobility, helping to prevent complications and reduce the length of ICU and hospital stay, as well as mortality.<sup>13</sup> Likewise, early definitive fixation has been reported to be effective in improving the ease of reduction and in reducing bleeding, blood transfusion, complication rate, and length of ICU stay for patients with unstable pelvic and acetabulum fractures.<sup>10</sup> However, in the case of hemodynamically unstable patients, it is usually difficult to perform early definitive fixation within 24 h because of the need for initial damage control via PPP, explorative laparotomy, external fixation, pelvic C-clamp, or skeletal traction.<sup>6</sup>

Even with reports on the advantages of early fixation in hemodynamically stable patients with pelvic bone injury, there is a lack of research on the timing of pelvic bone fixation for polytraumatized patients. Enninghorst et al.<sup>14</sup> reported favorable outcomes using a sequential approach of basic early fixation within 1 h of injury and late total care. Their study was similar to ours, with the difference being that we investigated patients who had undergone PPP or explorative laparotomy and thus had packing in place. There has been no report on performing early definitive fixation at the same time as packing; we believe that this was contrary to the idea of damage control, since it would increase the duration of surgery. Moreover, even if it was possible to simultaneously perform definitive fixation and pad packing, we believe that this would increase the risk of infection if the wound could not be closed for some reason or, even after wound closure, when the wound is reopened 1–2 days later for the second-look operation.

Although controversy persists regarding the effects of PPP compared to angiographic embolization, it is considered an effective method.<sup>15–19</sup> PPP is performed by making

a 6–10 cm midline incision in the cephalad direction at the pubic symphysis, and packing pads into the incision. This surgical wound is the same as the approach for the definitive fixation of pelvic bone fractures (the modified Stoppa approach). If a patient remains stable, anterior fixation of the pelvic bone via the same surgical wound is possible. Although there have been no reports that using the same surgical incision for multiple surgeries increases the risk of infection or wound breakdown, we anticipated these problems due to soft tissue damage and scarring.

In bony stabilization for trauma, prevention of pulmonary and thromboembolic complications by removing traction and avoiding recumbency is more important for polytraumatized patients than for those with simple trauma.<sup>20</sup> In cases of unstable pelvic fractures, because it is important to minimize bleeding by reducing the pelvic volume, methods such as temporary sheets, blinders, clamps, and external fixation are employed. However, unlike in a pelvic ring injury, these methods cannot provide provisional stabilization of acetabular fractures. Early reduction and internal fixation are required to provide early mobility and stability to the patient. The method we present here reduces the frequency of anesthesia and surgery. In addition, since the recommended time for removing the packing after PPP is 1–2 days, thus, making early definitive fixation within 24 h infeasible, stabilization of the pelvic bone can be achieved within 24–48 h of injury.

Our findings indicated that definitive fixation was only achieved 5.6 days after the injury in Group 2. The reasons for delaying definitive internal fixation included difficulties in maintaining prolonged anesthesia due to severe head or chest trauma (10 patients), and expected difficulty in wound closure after internal fixation due to severe swelling of abdominal organs (8 patients). Although a study on PPP by Cothren et al. did not specify difficulty with wound closure due to abdominal organ swelling, in our study, wound closure was impossible in eight out of the 56 patients (14.3%) as a result of this. These eight patients underwent definitive fixation after the swelling had subsided, when wound closure was expected to be possible; even then, wound closure failed in two patients, one of whom was among the two patients who experienced deep infection. In this patient, wound closure occurred 3 days after definitive fixation; however, the implant was removed after 6 days because of wound necrosis and infection, and external fixation was applied.

Before the surgical wound was closed, a second-look (packing removal) procedure was performed 1–2 days after PPP or laparotomy performed for damage control. We experienced wound breakdown, infection, increase in the number of operations, and prolonged length of ICU stay, following surgical wound reopening for fixation of pelvic ring and acetabular injuries. We believe that those complications could be minimized if the definitive fixation is performed from the anterior side through the open wound when performing a second-look procedure, and we have developed a treatment protocol. One limitation of this study is that although we used prospectively collected data, the analysis was still retrospective in nature, and the sample size was small. In addition, the patients were not randomized, and patients were placed into Group 2 based on non-medical reasons (surgeon preference or availability

of operating theatre) rather than on medical judgments (difficulty in sustaining anesthesia intraoperatively, anesthesiologist judgment, or perceived difficulty in achieving wound closure). Although all operations were decided and performed by the same pelvic trauma surgeon, we cannot exclude the possibility of bias in deciding the timing of definitive fixation.

## 5. Conclusion

Our protocol can be considered as an excellent option for reducing the duration of ICU stay, number of operations, and risk of deep infection. Furthermore, early definitive fixation allows bed mobility (position change for lung or back care) and rehabilitation. Multicenter, prospective, and large-scale studies on this topic are needed.

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## Competing interests

The authors declare that they have no competing interests.

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