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VASCULAR-INTERVENTIONAL

Pelvic Trauma: factors predicting arterial hemorrhage and the role of Angiography and preperitoneal pelvic packing

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Abstract

Objectives (1) To identify the factors predicting arterial extravasation in pelvic trauma and (2) to assess the efficacy of preperitoneal pelvic packing (PPP) in controlling arterial hemorrhage.

Methods Institutional review board approved the retrospective study of 139 consecutive pelvic trauma patients who underwent angiographic intervention with or without prior PPP between January 2011 and December 2016. Patient demographics and presenting characteristics were recorded. Both groups of patients were combined for analysis of predictors for arterial extravasation using univariate logistic regression followed by multivariate logistic regression. Significance level was defined as $p < 0.05$.

Results Forty-nine out of 139 patients had PPP prior to pelvic angiogram. Embolization was performed in 85 (61.2%) patients and the technical and clinical success rate was 100%. Sixty-nine (49.7%) patients had unstable Young-Burgess (Y&B) type fractures, of which 58% had arterial hemorrhage compared with 38.6% of those with stable Y&B fractures ($p = 0.02$). Of the patients who had PPP prior to angiogram, 28(57.1%) continued to have arterial extravasation on subsequent angiography. Unstable Y&B type fractures are independent predictors of arterial hemorrhage (OR 2.3, 95%CI 1.1 to 4.7, $p = 0.02$).

Conclusion Unstable Y&B type pelvic fractures are predictors of arterial extravasation. PPP alone is not effective for arterial hemorrhage control in pelvic trauma. Angiographic intervention remains a minimally invasive and definitive treatment of arterial hemorrhage from pelvic trauma.

Key Points

• *Unstable Young-Burgess pelvic fractures are predictors of arterial hemorrhage in pelvic trauma.*
• *Pelvic angiography and embolization should precede PPP wherever feasible.*

Keywords Trauma · Angiography · Pelvis · Hemorrhage · Fracture

Abbreviations

APC	Anterioposterior compression
CM	Combined mechanism
LC	Lateral compression
PPP	Preperitoneal pelvic packing
REBOA	Resuscitative endovascular balloon occlusion of the aorta
VS	Vertical shear
Y&B	Young and Burgess

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Introduction

Bleeding pelvic fractures are life-threatening injuries, with mortality ranging from 5 to 26% [1–3]. Hemorrhage can occur from arterial, venous, or bony sources and successful management depends on a multidisciplinary team approach [4]. Emergency interventions for hemorrhage control in pelvic fractures may be complementary and include external fixation or stabilization, preperitoneal pelvic packing (PPP), angiography followed by therapeutic embolization, or even resuscitative endovascular balloon occlusion of the aorta (REBOA) [5–8]. The efficacy of angiographic embolization as a definitive treatment for arterial hemorrhage in pelvic trauma has been established by several studies [5, 9–11]. However, there is currently no consensus among trauma surgeons as to the optimal treatment paradigm or the sequence of treatments for patients presenting with hemorrhage from severe pelvic fractures.

As hemorrhage remains the number one cause of preventable mortality in pelvic trauma, successful management depends on early identification of patients with potential arterial hemorrhage and to provide them with definitive therapy for hemorrhage control such as angiographic embolization. Preperitoneal pelvic packing (PPP) is a surgical procedure that involves placing laparotomy sponges via a low midline incision into the preperitoneal space on either side. The aim is to provide tamponading effect and to reduce the available retroperitoneal pelvic volume. Originally described in 1926 by Logothetopoulos, this technique has seen a rapid increase in popularity since the 1990s as it is quick and relatively easy to perform [12, 13]. Some centers are advocating the use of PPP as an alternative to angiographic intervention, citing faster time to intervention and lower mortality compared with historic data [13–15]. However, to date, there have been no objective studies evaluating the efficacy of PPP in controlling pelvic arterial hemorrhage. In practice, often patients with a high suspicion for arterial bleed undergo PPP prior to angiography potentially delaying definitive treatment.

With this premise, this study has two specific aims: the first is to identify the clinical and imaging factors that are predictive of arterial hemorrhage in pelvic trauma and the second is to evaluate the efficacy of PPP in controlling arterial hemorrhage from pelvic trauma.

Methods

This is an IRB-approved retrospective study of 139 consecutive patients who underwent angiography for pelvic trauma between January 2011 and December 2016 at a level I trauma center. There are two groups of patients in this study—those that underwent PPP prior to angiogram and those that went straight to angiogram without PPP (Fig. 1). Indications for undergoing preperitoneal packing included unstable patients with a high-grade pelvic fracture, unstable patients with positive Focuses Assessment with Sonography for Trauma (FAST) exams, and patients with visceral injuries in conjunction with a pelvic fracture requiring laparotomy. Demographics and presenting characteristics are shown in Table 1. Both groups are combined for analysis of predictors for arterial extravasation and mortality, and the groups are compared with each other for assessing the efficacy of PPP in controlling arterial hemorrhage. Data was collected by reviewing electronic medical records (EMR) and Picture Archiving and Communication System (PACS).

This study used the Young- Burgess (Y&B) classification for grading the mechanical stability of pelvic fractures [16]. Y&B is an effective way to grade pelvic fractures as it correlates the force and vector of the injury with the type of fracture. The four overall mechanisms include anteroposterior compression (APC), lateral compression (LC), vertical shear (VS), and combined mechanism (CM) fractures (Fig. 2). LC I and APC I fractures are considered stable and LC II/III, APC II/III, and VS fractures are considered unstable according to this classification [17–20]. We also grouped the patients into grades based on their mechanical stability and hemodynamic stability using the WSES pelvic trauma classification [21]. The WSES organizes the categories into 4 grades. Grade I is minor, II and III are moderate, and IV is severe. Patients that are hemodynamically unstable are automatically classified as grade 4. The other grades are separated by the mechanical stability of the fracture. Mechanically stable fractures are LC I and APC I fractures. Mechanically unstable fractures are APC II/III, LC II/III, and VS fractures. Vertical shear are grade III and APC II/III and LC II/III are grade II (Table 2). Arterial hemorrhage was defined by extravasation seen on conventional pelvic angiography. Technical success was determined by the ability to access and embolize the bleeding vessel. Clinical success was determined by the incidence of rebleeding. Procedural complications were documented according to the Society of Interventional Radiology classification [22]. Hemodynamic status was classified by The Advanced Trauma Life Support (ATLS) classification of hypovolemic shock which is divided into classes I to IV based on

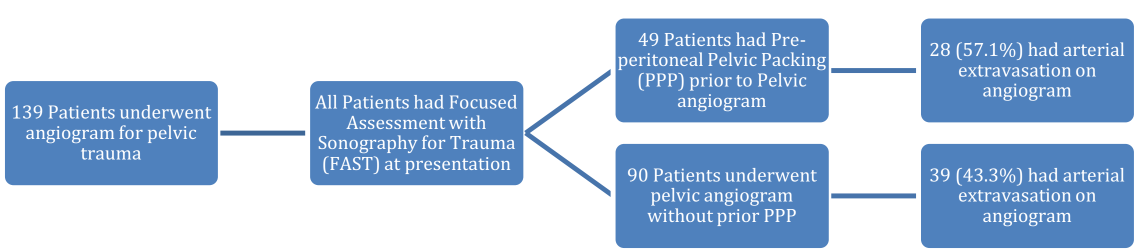


Fig. 1 Flow chart of the different groups and their outcomes

Table 1 Patients' demographics and presenting characteristics

Characteristics	Value
No. of patients (M/F)	139 (80/59)
Mean age (min., max, SD)	50.7 (11, 98, 22)
Mechanism of injury (blunt/penetrating)	131/8
Mean Systolic blood pressure at presentation (min, max, SD)	94 (40, 174, 27)
Hemodynamic instability (class II–IV)	100 (71.9%)
Mean hemoglobin at presentation (min., max, SD)	10.7 (5.1, 15.9, 2.2)
Mean no. of PRBC transfused prior to angiogram (min, max, SD, no. patients receiving PRBC)	10.7 (0, 60, 13.6, 129 [87.1%])
Mean Base deficit in mmol/L at presentation (min, max, SD)	7 (0, 32, 6)

the vital signs [23]. Those presenting with classes II–IV are considered hemodynamically unstable.

IBM SPSS software was used for statistical analysis. Chi-square test and *t* test were used for comparison of categorical and continuous variables, respectively. The initial selection of predictor variables was performed using univariate logistic regression. Individual parameters which proved significant on univariate test were then analyzed using multivariate logistic regression to identify independent predictor variables. Statistical associations were considered significant at $p < 0.05$

Results

Fracture pattern, angiographic findings, and interventions

Seventy (50.3%) patients had stable Young-Burgess fractures (LC I, APC I) and 69 (49.6%) had unstable fractures (LC II/III, APC II/III, VS) on initial imaging (Table 3). Unstable Y&B fractures were associated with higher incidence of arterial extravasation (58% vs 38.6%, $p = 0.02$). On multivariate regression analysis, unstable pelvic fractures based on the

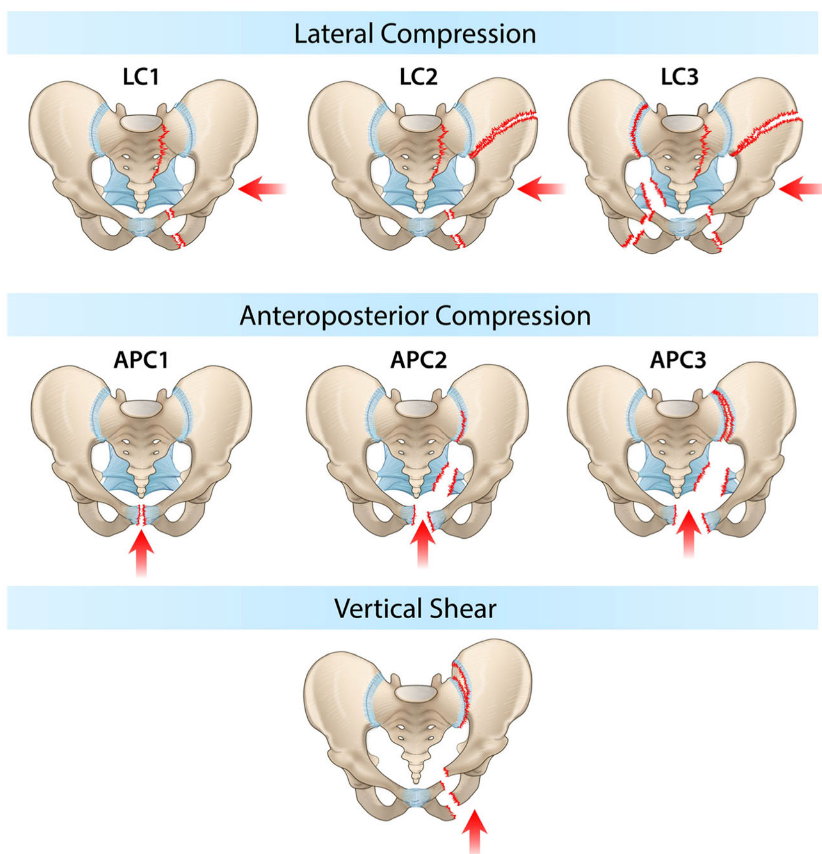


Fig. 2 Depiction of the Y&B fracture pattern classification. (artist: Brad Abraham, co-author)

Table 2 Description of the different WSES fracture grades

WSES classification	Young-Burgess fracture type	Hemodynamic instability
Grade I	APC I, LC I	None
Grade II	APC II/III, LC II/III	None
Grade III	VS, CM	None
Grade IV	Any	Yes

Young-Burgess classification were identified as an independent predictor of arterial extravasation on angiography (OR 2.3, 95% CI 1.1 to 4.7, p = 0.02). The patients were also graded using the WSES classification for pelvic fractures. There were 19 patients who were grade I, 15 patients who were grade II, 5 patients who were grade III, and 100 patients who were grade IV. Of the 100 grade IV patients, 49 had stable Y&B fracture patterns.

On angiography, arterial extravasation was seen in 67/139 (48.2%) patients and embolization was performed in 85/139 (61.2%) patients. Gelfoam (Pfizer) slurry was used for embolization in 62/85 cases (72.9%), Gelfoam was used in combination with coils in 17/85 cases (21.5%), coils alone were used for 5/85 cases (6.3%), and vascular plug along with Gelfoam was used in one case. Overall, the operators were able to achieve a 100% technical and clinical success rate as there were no instances of rebleed in this cohort. Prophylactic embolization was performed in 18/139 (12.9%) patients and Gelfoam slurry was used in all cases. Prophylactic embolization was done in cases where there was a strong suspicion of arterial bleed but no active extravasation on conventional angiogram despite the patient being hemodynamic unstable. Suspicious angiographic findings in such cases included significant vascular spasm or abrupt termination of a vessel. Of the patients who proceeded to angiography without PPP or surgical interventions, the time from decision for angiography to angiographic intervention was able to be calculated in 27/90 (30%) patients, and the mean wait time for angiography was 51.3 min (SD 19.5).

Preperitoneal packing vs. no preperitoneal packing

Out of 139 patients, 49 (35.3%) had PPP prior to angiographic intervention whereas 90 went to angiogram without any surgical intervention. A flowchart showing the basic tests and interventions that each group underwent is shown in Fig. 1. In the PPP group, 18/49 (36.7%) had positive initial FAST scans, 22/49 (44.9%) had negative FAST scans, and 9/49 (18.4%) had equivocal FAST scans. Thirty-nine (79.5%) patients had other surgical interventions performed at the time of PPP. The most common interventions that were performed included splenectomy and hepatorrhaphy.

In the PPP group, 28 (57.1%) had arterial extravasation on subsequent pelvic angiogram despite the procedure. There was no significant difference in the rate of arterial extravasation on angiography between patients who received PPP versus those who did not (28/49 [57.1%] vs. 39/90 [43.3%], p = 0.15) (Fig. 3). The PPP group had a significantly lower SBP (p < 0.01), worse base deficit (p < 0.01), and higher number of packed RBCs transfusions (p < 0.01) when compared with the non-PPP group (Table 4). Nineteen (38.8%) patients in the PPP group had CT angiogram prior to PPP, of which 15/19 (78.9%) were positive. Of these, 11/15 (73.3%) continued to have arterial extravasation on subsequent conventional angiogram despite PPP.

Discussion

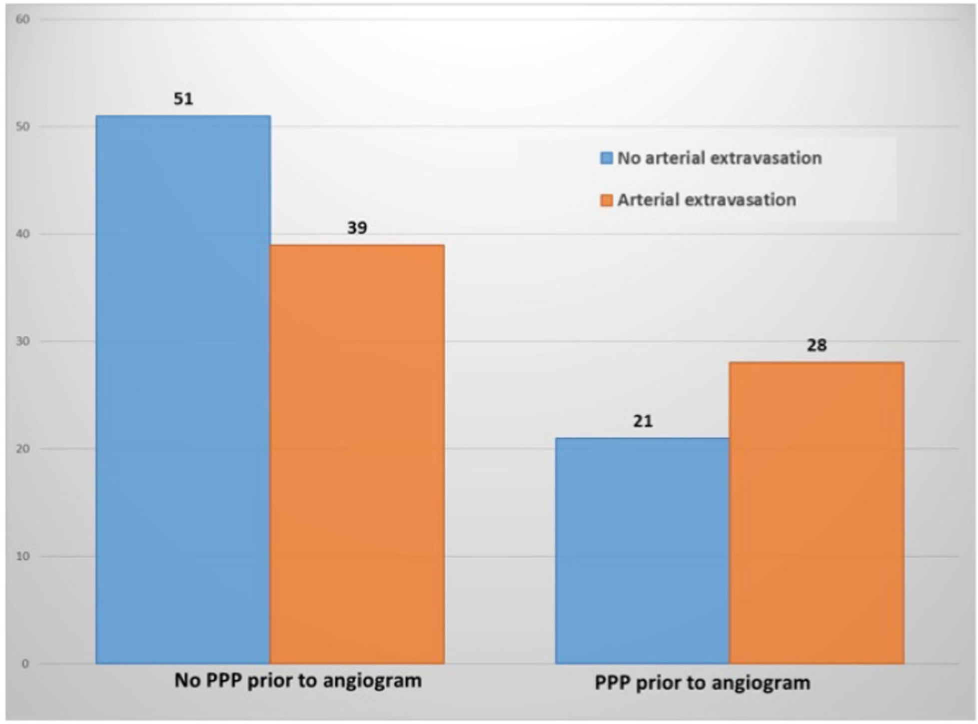
Eastern Association for the Surgery of Trauma Guidelines for management of hemorrhage in pelvic fractures states that hemodynamically unstable patients should be considered for emergent pelvic angiography once major non-pelvic sources of bleeding are ruled out (Fig. 4) [9]. This is considered a level I recommendation and is based on multiple studies showing the efficacy of angiographic embolization [9–11, 18, 24–26]. The identification of potential patients with arterial hemorrhage and proceeding with angiographic embolization without delay is a key component of successful pelvic trauma

Table 3 Comparison between stable and unstable Y&B fractures and findings on angiography

Y&B	APC I/ LC I	APC II/ III	LC II/ III	VS	Hemodynamic instability	Extravasation on angiography
Stable (70)	70	0	0	0	48 (68.5%)	27 (38.6%)
Unstable (69)	0	30	28	11	52 (75.3%)	40 (58%)*

*p < 0.05

Fig. 3 Bar graph comparing arterial extravasation on angiogram between the PPP and non-PPP cohorts



management. Clinical and imaging predictors of arterial hemorrhage would be helpful in identifying such patients and expediting angiography. In this study, unstable Y&B classification pelvic fracture was identified as an independent predictor of pelvic arterial hemorrhage. Patients with such fractures are 2.3 times more likely to have arterial bleed compared with those with other types of fractures. This finding is supported by prior studies presenting similar results. In a series of 193 patients, Eastridge et al showed that unstable pelvic fractures were more commonly associated with pelvic hemorrhage compared with stable fractures [18]. Starr et al performed a study analyzing the correlation between fracture pattern, shock, and the use of pelvic angiography. They found that LC II and LC III fractures were more likely to undergo angiography based on the clinical pictures than others [27]. Based on these findings, we propose that unstable Y&B classification fractures should be considered an additional parameter for selecting patients for angiographic intervention.

PPP is a surgical technique used to control hemorrhage from pelvic trauma that initially appeared in the European literature in 1994. Since then, it has become increasingly popular and some centers have started using it as a first-line therapy in lieu of angiography [15]. Cothren et al published a study in 2007 where PPP was used first as part of a revised clinical pathway for the management of hemorrhage from pelvic fracture in 28 patients [15]. In this group of severely injured patients (injury severity score > 55), PPP was performed immediately after the placement of a pelvic binder instead of angiography. With this protocol, they reported significantly fewer blood transfusion requirement and deaths

Table 4 Baseline characteristics and angiographic findings between preperitoneal packing vs. no preperitoneal packing

	PPP prior to angiography ($N = 49$)	No PPP prior to angiography ($N = 90$)	p value
Mean age	49.9	51.1	$p = 0.75$
High-grade fracture pattern	23 (46.9%)	46 (51.1%)	$p = 0.64$
Mean SBP	77.1 (SD 20.5)	102.6 (SD 26.9)	$p < 0.001$
Base deficit (mmol/L)	9.0 (SD 7.8)	5.8 (SD 4.2)	$p < 0.01$
Number of units of blood products transfused	21.5 (SD 17.2)	4.8 (SD 5.6)	$p < 0.001$
Arterial extravasation on angiography	28 (57%)	39 (43%)	$p = 0.15$
Overall mortality	16 (33%)	7 (8%)	$p < 0.001$

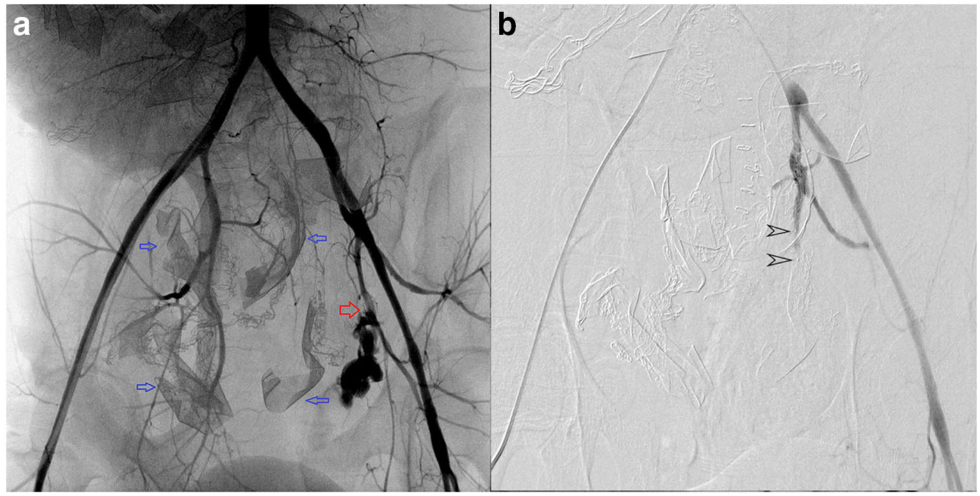


Fig. 4 **a** Pelvic aortogram showing active extravasation from anterior division of the internal iliac artery (red arrow). Also seen are laparotomy pads from PPP (blue arrows). **b** Internal iliac arteriogram after embolization of the anterior division with vascular plug (identified by the 2

attributed to hemorrhage. The paper reported an 83% success rate for PPP with the rest 17% requiring angiography. The mean time to angiographic intervention in this paper was 10 h, which falls far outside of trauma center guidelines and may have contributed to their findings. The same group later published the effects of PPP as the primary treatment for pelvic hemorrhage on overall mortality. In this study, 128 patients underwent PPP first as the definitive management under a revised institutional protocol. This series had an overall mortality of 21%, which the authors state to be better than the historically reported mortality rates for pelvic trauma [14]. However, in this series, 35 (27%) patients still had to undergo angiographic intervention after PPP. Three deaths were attributed to the sequelae of uncontrolled hemorrhage.

Although the adoption of PPP has seen rapid growth in trauma practice, there have been no objective studies evaluating the efficacy of PPP in controlling arterial hemorrhage. In the study presented here, more than half of the patients who underwent PPP showed continued active arterial hemorrhage (28 out of 49 [57.1%]) on subsequent angiography. Even if we assume that all patients in the PPP cohort had pelvic arterial hemorrhage at presentation, PPP was unsuccessful in controlling the hemorrhage in more than half the cases. It would be hard to justify the use of such a treatment as a definitive or initial management option for pelvic arterial bleed which has a high mortality.

There was also no significant difference in the rate of arterial extravasation on angiogram between patients who underwent PPP and those who did not (28 out of 49 [57.1%] vs. 39 out of 90 [43.3%], $p = 0.15$). However, it should be noted that PPP patients had significantly worse hemodynamic parameters at presentation compared with the non-PPP group. It is also important to note that among the patients who underwent PPP with documented arterial extravasation on CT angiogram, 73.3% (11/15) continued to have arterial extravasation on subsequent angiography despite PPP.

The time to angiogram has been highlighted by multiple prior studies. Tesoriero et al found that median time to embolization from trauma arrival was greater than 5 h and 80% of all deaths from their cohort could be attributed to uncontrolled early hemorrhage [28]. Embolization in less than 3 h improves survival from 26 to 86% and time to angiography in less than 90 min can decrease mortality from 35 to 7% [10, 29]. In this study, the mean time from the decision of angiography to the procedure in patients who went straight to angiography without any other surgical intervention was 51.3 min, which is comparable with the best reported delay in obtaining PPP (45 min) [30]. The study institution is a large volume level I trauma center and has a well-established protocol where angiographic intervention for trauma has to be performed within an hour of the request. This shows that standardized trauma protocols, better inter departmental collaboration, and multidisciplinary teams can lead to a more streamlined management of these patients. Hybrid trauma operating rooms with angiographic capabilities are ideal for the optimal management of these patients with active hemorrhage. This avoids the risk associated with transporting a physiologically unstable patient to a distant angiography suite [31, 32].

This study shows that PPP is not an effective method for definitive control of arterial hemorrhage in pelvic trauma. The procedure may also potentially delay the definitive treatment of angiographic intervention, which had 100% technical and clinical success rate in this series. These findings imply that PPP may only be used as a temporizing measure when angiography is unavailable or there is an expected delay in obtaining angiographic intervention. In institutions where angiographic intervention is readily available, we suggest that angiographic intervention should be considered prior to or concurrently with PPP, ideally in hybrid operating rooms. This statement is also supported by a study from Eastridge and colleagues, who reported that in patients with an unstable fracture of the pelvis, there was 60% mortality in patients who underwent laparotomy before angiography versus 25% in patients who underwent angiography before laparotomy [18].

Retrospective design is a limitation of this study, which completely relies on medical records and images for data. Another limitation of this study is that it only looked at patients who underwent PPP with subsequent angiographic intervention and did not include patients who underwent PPP alone. The heterogeneous nature of the cohort in terms of the degree of injury and physiologic status at presentation is also a major limitation. Several patients had extra-pelvic injuries or extra-pelvic source of hemorrhage and the baseline hemodynamic status greatly varied at presentation. We have tried to control for these variations by listing the extra-pelvic sources of hemorrhages and the nature of surgical interventions undertaken other than PPP.

This study shows that patients with unstable pelvic fractures based on the Y&B classification have a higher risk of arterial hemorrhage and these patients should preferentially be considered for angiographic intervention without delay. This study also shows that PPP may not be an effective method for definitive control of arterial hemorrhage in pelvic trauma as more than half the patients undergoing PPP continue to have arterial extravasation on subsequent angiogram. The results imply that in institutions where angiography is readily available, it should precede or be done concurrently with PPP. Angiographic intervention remains a minimally invasive and definitive treatment of arterial hemorrhage in pelvic trauma. Integrated trauma protocols with the participation of multidisciplinary teams and immediate availability of angiographic intervention are crucial in improving the outcomes for pelvic trauma.

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Informed consent Written informed consent was waived by the Institutional Review Board.

Ethical approval Institutional review board approval was obtained.

Methodology
- retrospective
- case-control study
- performed at one institution

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