Factors Associated With Pelvic Fracture-Related Arterial Bleeding During Trauma Resuscitation: A Prospective Clinical Study

Laszlo Toth, MD, Kate L. King, RN, MN, Benjamin McGrath, MD, and Zsolt J. Balogh, MD, PhD, FRACS

Objectives: To determine predictors of pelvic fracture-related arterial bleeding (PFRAB) from the information available in the Emergency Department (ED).

Design: Prospective cohort study.

Setting: Single level-1 Trauma Center.

Patients: In a 3-year period ending in December 2008, consecutive high-energy pelvic fracture patients older than 18 years were included. Patients who arrived >4 hours after injury or dead on arrival were excluded. Patient management followed advanced trauma life support and institutional guidelines. Collected data included patient demographics, mechanism of injury, vital signs, acid-base status, fluid resuscitation, trauma scores, fracture patterns, procedures, and outcomes. Potential predictors were identified using standard statistical tests: Univariate analysis, Pearson correlation (r), receiver operator characteristic, and decision tree analysis.

Intervention: Observational study.

Outcome Measures: PFRAB was determined based on angiography or computed tomography angiogram or laparotomy findings.

Results: Of the 143 study patients, 15 (10%) had PFRAB. They were significantly older, more severely injured, more hypotensive, more acidotic, more likely to require transfusions in the ED, and had higher mortality rate than non-PFRAB patients. No single variable proved to be a strong predictor but some had a significant correlation with PFRAB. Useful predictors identified were worst base deficit (BD), receiver operator characteristic (0.77, cutoff: 6 mmol/L, r = 0.37), difference between any 2 measures of BD within 4 hours (ΔBD) >2 mmol/L, transfusion in ED (yes/no), and worst systolic blood pressure <104 mm Hg. Demographics, injury mechanism, fracture pattern, temperature, and pH had poor predictive value.

Conclusions: BD <6 mmol/L, ΔBD >2 mmol/L, systolic blood pressure <104 mm Hg, and the need for transfusion in ED are independent predictors of PFRAB in the ED. These predictors can be valuable to triage blunt trauma victims for pelvic hemorrhage control with angiography.

Key Words: pelvic fracture, arterial bleeding, shock trauma, polytrauma, prediction model

Level of Evidence: Prognostic Level I. See Instructions for Authors for a complete description of levels of evidence.

(*J Orthop Trauma* 2014;28:489–496)

INTRODUCTION

Hemodynamic instability in pelvic ring injury patients warrants expeditious hemorrhage control with simultaneous emergency skeletal stabilization and resuscitation. According to a previous study from the same institution, the incidence of pelvic fracture-related arterial bleeding (PFRAB) is 1.3/100,000 per year.[1] A delay in hemorrhage control in blunt pelvic trauma accounts for most of the preventable mortality in mature trauma systems.[2] The liberal use of angiography as a screening tool is not feasible because of logistics, cost, and the invasive nature and time involved in performing the procedure in a critically injured patient. It is crucial to identify those patients who have PFRAB and who may benefit from a therapeutic procedure. Previous studies have identified predictors of PFRAB such as Injury Severity Score (ISS >25) and Abbreviated Injury Scale Score (AIS pelvis ≥4),[3] and the size of the pelvic hematoma measured on computed tomography (CT) scans.[4,5] These parameters are not uniformly available initially in the Emergency Department (ED) and less likely to be useful for clinical decision making. The purpose of this study was to identify the predictors of arterial bleeding associated with pelvic ring injuries because of high-energy mechanisms, which are readily available in the ED during the initial resuscitation period. We hypothesized that the PFRAB could be predicted from the variables available in ED.

PATIENTS AND METHODS

Consecutive trauma resuscitation patients with high-energy pelvic ring injuries admitted to a level-1 trauma center from March 2005 to December 2008 were included in this study. High-energy injury mechanisms included driver or

passenger involved in a motor vehicular accident with speed (or combined speed in case of more than 1 vehicle) higher than 60 km/h, motorbike accident at any speed, pedestrian or cyclist hit by a vehicle at any speed, fall from height greater than 3 m, a horse-related accident, compression or entombment of the body, or any industrial accident. Patients with other low-energy injury mechanisms (eg, falling from standing height, falling from a chair, or from a bed) were excluded. Patients younger than 18 years, dead on arrival, and transfers from another hospital with more than 4 hours of delay after the injury were excluded from the study. The initial management in the ED was based on advanced trauma life support[6] and New South Wales guidelines.[7,8] Initial resuscitation workup included antero-posterior chest and pelvis radiographs, serial observations of vital parameters including blood pressure, heart rate, respiratory rate measurements, pulse-oximetry, serial arterial blood gas analysis, and focused abdominal sonography in trauma (FAST) and/or diagnostic peritoneal lavage/aspiration. External bleeding was immediately controlled by direct pressure or sutures. Emergency noninvasive pelvic ring stabilization (pelvic binding) was performed either in the prehospital phase or in the ED within a few minutes of arrival. A decision for blood transfusion in the ED was made by the trauma team leader (ED physician or trauma surgeon/fellow) individually in each case considering vital parameters, response to initial fluid resuscitation, the hemoglobin level, and estimated blood loss. The initial FAST (and/or diagnostic peritoneal lavage/aspiration) examination was used to triage shocked patients; those with positive result were taken to the operating theater for an immediate laparotomy. A pelvic binder was moved down around the proximal thighs to maintain some pelvic stability during the laparotomy. Hemorrhagic shock was evident on arrival or confirmed later by any of the following signs any time in the ED: Systolic blood pressure (SBP) of <100 mm Hg, Base deficit (BD) of >6 mmol/L, or transfusion requirement (based on vital parameters, response to initial fluid resuscitation, estimated blood loss, and hemoglobin levels). Pelvic packing through laparotomy or extraperitoneal approach was not part of the institutional protocol and was not performed. Patients with a negative initial FAST result, or a positive result but no signs of shock, were further assessed with CT scans and/or a pelvic angiogram. A pelvic angiogram was indicated based on the discretion of the attending surgeon. The time to angiography was 30–240 minutes after arrival in the ED in all cases. PFRAB was defined, if identified, based on (1) pelvic angiography (extravasation of contrast), (2) on CT angiogram (contrast blush into the pelvic hematoma), or (3) during laparotomy (rapidly expanding pelvic hematoma). Those patients who were identified as candidates for angiography (either on pelvic CT angiogram or laparotomy finding) but died before it could be carried out (4 cases), were categorized as having pelvic arterial bleeding (PFRAB).

Prospective data collection included patient demographics (age, gender), physiology in the ED (serial measures of blood pressure, acid-base parameters including lactate, pH, BD), trauma scores (AIS score for the pelvis, and ISS), fracture types (according to OTA/AO[9] and Young–Burgess classification systems[10]), blood transfusions in ED and total

<24 hours, procedures (pelvic binding, invasive pelvic fixation, laparotomy, angiography/embolization), and outcomes (mortality, length of stay). Measures of physiological parameters were collected within 4 hours of arrival.

Potential predictors were analyzed using standard statistical tests (SPSS for Windows version 13.0). Univariate analysis (Student t test and Fisher exact test) was performed for each variable. After testing normality of continuous variables (one-sample Kolmogorov–Smirnov test), the association between PFRAB and all variables were measured by Pearson correlation. Receiver operator characteristics (ROC) were analyzed for all continuous variables. Area under the curve was assessed and a cutoff value was determined. Decision tree analysis was also performed for all variables and cutoff values were determined. Data is presented as mean ± SD or percentages, $P < 0.05$ was considered significant.

RESULTS

There were 182 patients who were admitted with pelvic ring injuries associated with high-energy mechanisms during the study period. Patients with low-energy mechanisms (167 patients in the same period) were not considered in this study. After exclusion of patients because of age younger than 18 years (15 patients), dead on arrival (5 patients), and admitted >4 hours after the accident (19 patients), 143 patients were included in the study. There were 15 patients (10%) identified as PFRAB: 11 on pelvic angiography, 1 on CT angiogram, and 3 on laparotomy findings.

Univariate analysis showed that patients with PFRAB were significantly older, more severely injured, had lower blood pressures, were more acidotic, required transfusions more often than non-PFRAB patients. They also had a higher mortality rate, 47% (7/15) versus 2.3% (3/125) (Tables 1–3). All variables were tested for correlation with arterial bleeding using the Pearson correlation test. Correlation with PFRAB ($r > 0.3$) was found with the need for transfusion in the ED, ISS, AIS pelvis, OTA class, positive FAST in the ED, pH worst, BD worst, ΔBD (difference between BD first and BD worst) and SBP worst (Table 4). Trauma scores (ISS, AIS pelvis) though having a predictive value, were difficult or

TABLE 1. Variables of Significance on Univariate Analysis

Variable	PFRAB	Non-PFRAB	P
Age, y	54.93 (±20.11)	42.57 (±18.85)	0.018
ISS	42.33 (±16.53)	21.71 (±12.39)	0.000
AIS pelvis	4.2 (±1.15)	2.86 (±0.91)	0.000
SBP first, mm Hg	101.6 (±24.17)	121.64 (±23.26)	0.002
SBP worst, mm Hg	82.13 (±27.89)	106.72 (±19.99)	0.000
MAP, mm Hg	79.38 (±23.21)	90.88 (±18.09)	0.025
pH worst	7.10 (±0.21)	7.28 (±0.10)	0.000
BD worst, mmol/L	11.38 (±11.29)	4.51 (±4.90)	0.035
Transfusion in ED, %	86.7	19.4	0.000
Transfusion in ED, units	13.53 (±9.55)	1.66 (±3.36)	0.000
Mortality, %	46.7	2.3	0.000

MAP, mean arterial pressure.

TABLE 2. Univariate Analysis of Continuous Variables

	Total, N = 143 Mean (±SD)	PFRAB, N = 15 Mean (±SD)	Non-PFRAB, N = 128 Mean (±SD)	*P**
Age, y	43.87 (±19.29)	54.93 (±20.11)	42.57 (±18.85)	0.018
ISS	23.88 (±14.30)	42.33 (±16.53)	21.71 (±12.39)	0.000
AIS pelvis	3.0 (±1.01)	4.2 (±1.15)	2.86 (±0.91)	0.000
pH first	7.29 (±0.10)	7.31 (±0.09)	7.21 (±0.13)	0.014
pH worst	7.26 (±0.14)	7.10 (±0.21)	7.28 (±0.10)	0.000
BD first	4.11 (±5.64)	6.09 (±9.84)	3.74 (±4.47)	0.378
BD worst	5.58 (±6.73)	11.38 (±11.29)	4.51 (±4.90)	0.035
ΔBD	1.58 (±3.43)	5.76 (±6.06)	0.79 (±1.86)	0.007
SBP worst	104.15 (±22.17)	82.13 (±27.89)	106.72 (±19.99)	0.000
SBP first	119.59 (±24.07)	101.6 (±24.17)	121.64 (±23.26)	0.002
MAP	89.67 (±18.93)	79.38 (±23.21)	90.88 (±18.09)	0.025
Temperature	36.07 (±1.04)	36.02 (±0.72)	36.07 (±1.07)	0.849
LOS, d	26.46 (±30.17)	24.07 (±33.11)	26.74 (±29.94)	0.850
Transfusion <24 h, units	2.90 (±5.69)	13.53 (±9.55)	1.66 (±3.36)	0.000

*$P < 0.05$ was considered significant.

pH first, first measured value; pH worst, worst measured value; ΔBD, difference between BD first and BD worst; LOS, length of stay; MAP, mean arterial pressure; SBP first, first measures systolic blood pressure; SBP worst, worst measured value.

TABLE 3. Univariate Analysis of Categorical Variables

	Total			PFRAB		Non-PFRAB		*P**	
		N	%	N	%	N	%		
Mechanism of injury	MVA driver	48	33.3	4	26.7	44	34.4	0.566	
	MVA passenger	12	8.4	1	6.7	11	8.6		
	Motorbike rider	28	19.6	4	26.7	24	18.8		
	Pedestrian hit by car	22	15.4	2	13.3	20	15.6		
	High fall	13	9.1	2	13.3	11	8.6		
	Severe compression	5	3.5	0	0	5	3.9		
	Horse rider	6	4.2	0	0	6	4.7		
	Bicycle rider	9	6.3	2	13.3	7	5.5		
Young–Burgess	APC1	4	2.8	0	0	4	3.1	0.290	
	APC2	13	9.1	3	20	10	7.8		
	APC3	5	3.5	3	20	2	1.6		
	LC1	73	50.3	3	20	69	53.9		
	LC2	20	14.0	0	0	20	15.6		
	LC3	3	2.1	0	0	3	2.3		
	VS	9	6.3	0	0	9	7.0		
	CM	17	11.9	6	40	11	8.6		
OTA	A1, 2, 3	33	23.1	0	0	33	25.8	0.000	
	B1	15	10.5	3	20	12	9.4		
	B2	62	42.7	3	20	58	45.3		
	B3	10	7.0	1	6.7	9	7.0		
	C1	14	9.8	2	13.3	12	9.4		
	C2	8	5.6	5	33.3	3	2.3		
	C3	2	1.4	1	6.7	1	0.8		
Transfusion in ED	Yes	38	26.6	13	86.7	25	19.4	0.000	
	No	105	73.4	2	13.3	104	80.6		
Mortality	Survived	133	93.0	8	53.3	125	97.7	0.000	
	Died	10	7.0	7	46.7	3	2.3		
FAST	Negative	133	93.0	9	60.0	124	96.9	0.000	
	Positive	10	7.0	6	40.0	4	3.1		

*$P < 0.05$ was considered significant.

TABLE 4. Pearson Correlation Test for all Variables

	Correlation coefficient (r)
Age	0.19*
Sex	−0.05
ISS	0.44†
AIS pelvis	0.40†
Mechanism of injury	0.05
Young–Burgess	0.08
OTA	0.34†
Transfusion in ED	0.46†
FAST	0.44†
Pelvic binding	0.26†
pH first	−0.34†
pH worst	−0.47†
BD first	0.15
BD worst	0.37†
ΔBD	0.53†
SBP worst	−0.34†
SBP first	−0.25†
MAP	−0.19*
Temperature	−0.01

*Correlation is significant at the 0.05 level (2-tailed).
†Correlation is significant at the 0.01 level (2-tailed).
MAP, mean arterial pressure.

impossible to determine early, therefore were less useful for clinical decision making and were not assessed further. FAST was used as a clinical triage tool to select those patients who needed immediate laparotomy, therefore a positive result could not be used to triage for another treatment modality.

Regarding the pelvic fracture pattern, the Young–Burgess classification system[10] had poor correlation (r = 0.08). The OTA classification system[9] had better correlation (r = 0.34). Those potential predictors that were easy to determine within a few-minutes of arrival in the ED such as physiological (SBP first, SBP worst, MAP), and resuscitation parameters [transfusion needed in ED (yes/no)] and acid/base status (pH first, pH worst, BD first, BD worst, and ΔBD) were further evaluated.

For continuous variables, ROC curves were determined. BD worst had the most favorable ROC curve pattern; the area under the curve was 0.77 (Fig. 1). Cutoff value was determined by expert opinion (senior trauma surgeon with subspecialty practice in pelvic surgery in consultation with statistician). At BD = 6 mmol/L, there was sensitivity = 0.71 and 1-specificity = 0.33 (Table 5).

Patients with BD ≥6 mmol/L had significantly larger proportion of arterial bleeders than those with BD <6 mmol/L as demonstrated on the χ^2 test (Table 6). Decision tree analysis showed worst SBP to be the only useful predictor with cutoff value at 104 mm Hg (Table 7). For other predictors, no such value could be determined with this test.

DISCUSSION

Previous studies have reported the use of pelvic angiography for evaluation and control of PFRAB.[11,12] The incidence of PFRAB varies with the patient group and timing of the angiogram with a wide range of values between 10% and 92%.[11,13–15] In our study, PFRAB occurred in 10% of the patients with pelvic fractures associated with high-energy mechanisms.
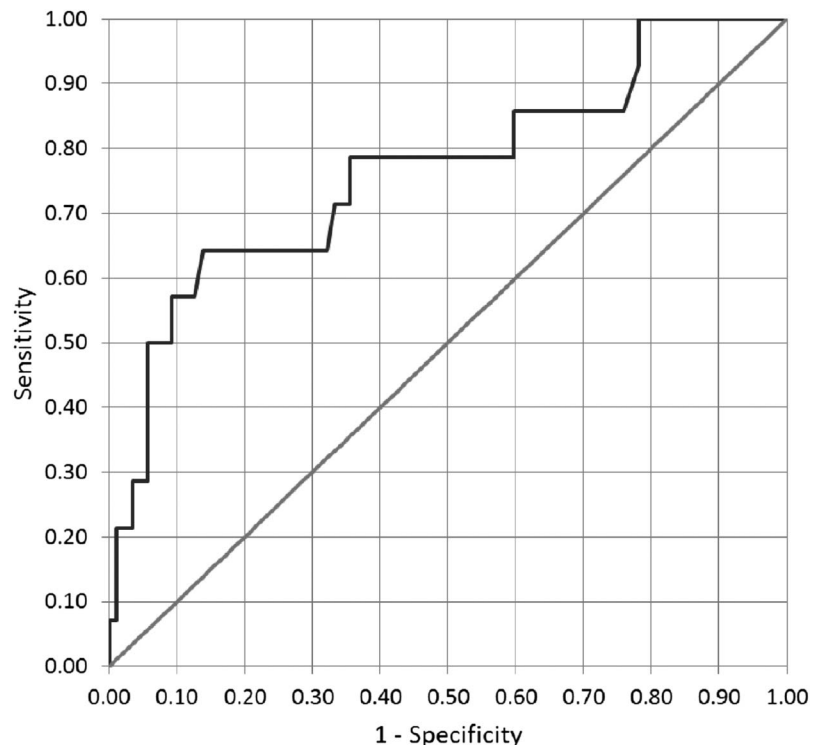

FIGURE 1. Receiver operator characteristics curve of BD worst (area under the curve, 0.771).

TABLE 5. Sensitivity and 1-Specificity Values of BD Worst

BD worst	Sensitivity	1-Specificity
3.15	0.78	0.59
4.15	0.78	0.51
5.15	0.78	0.39
6.05	0.71	0.33
7.00	0.64	0.26
8.05	0.64	0.20
9.25	0.64	0.15
10.10	0.57	0.12

There are 2 fundamentally different approaches to the use of angiography for patients with PFRAB. After exclusion or control of other major bleeding sources, some authors[11,14,16–18] recommend pelvic ring reduction and stabilization with external fixator or pelvic C-clamp and pelvic packing. They reserve angiography for those patients who remain hemodynamically unstable after these efforts. Others,[19] including us, advocate noninvasive emergency pelvic ring stabilization followed by early angiography with the aim to interrupt the physiologic insult of shock and perform invasive pelvis stabilization, if needed, after this. In both approaches, there is emphasis on the development of institutional guidelines based on local resources and organized team efforts to avoid delays. A study by Osborn et al[20] compared 2 management protocols of direct retroperitoneal packing versus pelvic angiography during 2 different time periods in the same institution. They showed comparable results in efficacy for stabilizing hemodynamically unstable casualties with pelvic fractures, and better outcomes with packing, in terms of postprocedure transfusion requirements and decreased mortality. To interpret the results of different studies, it is important to identify what management algorithm was used with attention to timing of the angiography. Studies with a retrospective design may have limitations because of a lack of strict indications for angiography and possible selection bias. There are only a few previous studies on predictors of PFRAB that have prospective design.[19,21,22]

Many previous studies reviewed and commented on potential predictors of PFRAB. Some independent predictors were identified, but most of them have limited clinical value. The decision for angiography should be made early, while the patient is in the ED. In our study, we identified predictors of PFRAB that can be easily measured shortly after the patients' arrival in ED. The focus of interest was on physiologic measures and parameters of resuscitation and acid/base status. We found that the presence of significant acidosis with BD <6 mmol/L,

TABLE 6. Chi-square Test for PFRAB and Non-PFRAB Groups on the Determined BD Cutoff Value

Group	PFRAB, N (%)	Non-PFRAB, N (%)
BD <6 mmol/L	3 (20)	55 (69)
BD ≥6 mmol/L	12 (80)	27 (31)

Chi-square test: *P* = 0.000.

TABLE 7. Decision Tree Analysis for SBP Worst

Group	PFRAB, N (%)	Non-PFRAB, N (%)
SBP ≤104 mm Hg	14 (93.3)	55 (43)
SBP >104 mm Hg	1 (6.6)	73 (57)

worsening of the acidosis with ΔBD >2 mmol/L, SBP of 104 mm Hg or less, and the need for transfusion in the ED at any time within 4 hours of arrival can predict PFRAB.

Using BD <6 mmol/L as a single criterion to triage patients for angiography, we were able to pick up 73% of the cases that presented with PFRAB, accepting a certain rate of nontherapeutic angiograms. Our data clearly demonstrates that the more severe the acidosis during the ED period the more likely the angiography was positive for PFRAB. Sensitivity can be increased using ΔBD >2 mmol/L as an adjunct, especially for those patients who have alkalosis on arrival. BD was assessed in only one previous study, by Starr et al,[21] and was not linked to the use of angiography. Combining predictors could have a better predictive value than using single ones. Although this could result in higher specificity, it could also result in lower sensitivity, which could be detrimental to patients.

Our data demonstrates that SBP of 104 mm Hg or less at any time during the ED stay also was predictive of PFRAB. A previous study by Salim et al[22] suggested that persistent hypotension with an SBP <100 mm Hg predicted PFRAB. The longer the hypotensive episode the more likely the patient is to have arterial bleeding.

We also found that the need for blood transfusion in the ED can also be predictive of PFRAB (r = 0.46). Indications for blood transfusion in the ED are poorly defined. Decisions are made individually, by assessing physiologic parameters, response to fluid resuscitation, hemoglobin levels, and estimated blood loss. We recommend the use of this as a predictor with caution, because of these potential modifying factors. Other physiologic variables such as the initial ED SBP (SBP first), initial MAP, temperature, and pH were found to be poor predictors as well. There was no previous study assessing resuscitation parameters as potential predictors.

Trauma scores, such as ISS >25 and AIS pelvis ≥4 can predict PFRAB.[3] We also found a correlation between those scores and PFRAB. Unfortunately, these scores are not available initially in the ED and most clinicians do not use them in daily decision making. The Revised Trauma Score was associated with the use of pelvis angiogram (no report on PFRAB however) in a study by Starr et al.[21]

A large number of studies assessed and reported pelvic fracture patterns as potential predictors. Unstable fractures such as Young–Burgess APC II, III, LC II, III, VS, and CM were associated with PFRAB.[15,23,24] Other studies found no correlation between this fracture classification and PFRAB.[14,21,25] We were able to find a weak correlation with PFRAB and the OTA classification (r = 0.34). Accurate fracture classification, however, warrants a CT scan, which not only requires an expert surgeon to correctly read the study but is time consuming, making it less valuable in the initial clinical setting.

Other authors evaluated features on the initial AP pelvis radiographs taken in the ED. Niwa et al[26] found plain radiographs to be useful for predicting hemorrhagic sites, especially in those with anterior fractures. Fracture patterns associated with PFRAB included sacroiliac joint disruption with displacement,[22] displaced obturator ring fractures, and pubic symphysis diastases.[27] These features are easily detected by the first care providers who are not necessarily experts. However, PFRAB cannot be ruled out if those obviously fracture patterns on the AP pelvic radiograph are not present. The relevance of these plain radiographic features is also limited because of the fact that most patients now have pelvic binders applied before any imaging. In the presence of a well-bound pelvic ring, it might be easy to underestimate the severity of the injury.

Measurement of the size of the pelvic hematoma on CT scan is recommended by Blackmore et al,[4] and size >500 mL strongly suggests PFRAB. Generally, hemorrhaging patients are poor candidates for CT scans before their bleeding is controlled, and we did not use CT pelvis angiogram as a screening tool to identify PFRAB.

Contrast blush into a pelvic hematoma on a CT angiogram (CT-A) is accepted as evidence of PFRAB.[28,29] In our study, only 9 of 22 patients who were indicated for angiography had a CT-A of their pelvis before angiography. Four had contrast blush into the pelvis: 1 patient died before angiography could be performed, 2 patients had PFRAB demonstrated on angiography, and 1 patient had active bleeding from a lumbar artery (classified as non-PFRAB). Pereira et al[5] determined the sensitivity, specificity, and accuracy (90%, 98%, and 98%, respectively) of the pelvic CT-A to detect PFRAB. Two other studies suggested that the absence of contrast blush on the CT-A does not reliably exclude PFRAB.[30,31]

Increasing age was found to predict PFRAB in several studies with cutoff values between 55 and 65 years.[19,21,32,33] This could be because of the older patients' sclerotic vessels inability to arrest bleeding with vasospasm or the increased chance of antithrombotic or platelet aggregation inhibitor medication. We found increasing age to be a weak predictor (r = 0.19). Although female gender predicted PFRAB in a study by Salim et al,[22] we did not find it to have any predictive value.

There are several traumatic shock studies indicating that lactate and BD values are predictive of outcome and these parameters are frequently interchanged in the description of metabolic acidosis during shock.[34–36] The unexpected fact, that first pH values in the non-PFRAB group were lower than in the PFRAB group (Table 1), is most likely due to combined or predominantly respiratory acidosis in the non-PFRAB group rather than due to shock.

In our study, the 4 patients with PFRAB who died before the angiogram could be carried out were the focus of our attention. Three of them had a positive FAST examination associated with hemorrhagic shock in the ED and were taken for an immediate laparotomy. After detection of a large pelvic hematoma but no other major source of bleeding, they were indicated for pelvic angiography. One patient died on the operating table. Other 2 patients had pelvic external fixators applied and died on their way to the angiography suite. The

fourth patient had a pelvic CT-A, which was positive for a contrast blush into a large pelvic hematoma. He was indicated for formal angiography but died before it could be carried out. Potentially, all 4 patients could have been saved if pelvic angiography and embolization had been performed earlier in their care, but the need for angiography and embolization could not be determined accurately. It is possible that in these cases, a combined operating room and angiography (hybrid facility) is probably the best solution for their management.

We have realized certain limitations of our study, one being the relatively small study population. Running the study for a longer period was not feasible in our center because delays in changes in resuscitation strategies would potentially influence the results. A multicenter study with pooling of data may cause paucity because of different treatment protocols and local logistics. Utility of transfusion requirement in the ED as a single predictor is limited because of a lack of precise indications of transfusion, as mentioned earlier. The decision for transfusion was unique in each patient and potential bias might be associated as a result. Another potential bias was that the indication for angiography was based on the discretion of the attending surgeon. Some indications were generally accepted such as contrast blush into a pelvic hematoma on CT-A and hemorrhagic shock in association with a pelvic fracture without any other major sources of bleeding, but these indications were not followed consistently throughout the study period.

In conclusion, physiologic parameters such as BD worse than 6 mmol/L, decrease of BD of >2 mmol/L between 2 measures, SBP < 104 mm Hg, and the need for transfusion in the ED can all predict PFRAB in the initial resuscitation setting. After exclusion of abdominal, chest, and extremity bleeding, these predictors can be valuable to triage blunt trauma victims for pelvic hemorrhage control with angiography or pelvic packing depending on the institutional protocol.

REFERENCES

1. Balogh ZJ, King KL, Mackay P, et al. The epidemiology of pelvic ring fractures: a population-based study. *J Trauma.* 2007;63:1066–1073.
2. Tien HC, Spencer F, Tremblay LN, et al. Preventable deaths from haemorrhage at a level 1 Canadian trauma center. *J Trauma.* 2007;62:142–146.
3. Demetriades D, Karaiskakis M, Toutouzas K. Pelvic fractures: epidemiology and predictors of associated abdominal injuries and outcomes. *J Am Coll Surg.* 2002;195:1–10.
4. Blackmore CC, Jurkovich GJ, Linnau KF, et al. Assessment of volume of hemorrhage and outcome from pelvic fracture. *Arch Surg.* 2003;138:504–509.
5. Pereira S, O'Brien D, Luchette FA. Dynamic helical computed tomography scan accurately detects hemorrhage in patients with pelvic fracture. *Surgery.* 2000;128:678–685.
6. *Advanced Trauma Life Support for Doctors, American College of Surgeons Committee on Trauma.* 8th ed. Chicago, IL: American College of Surgeons; 2008.
7. *Institute of Trauma and Injury Management, New South Wales, Australia, Adult Trauma Clinical Practice Guidelines: The Management of Haemodynamically Unstable Patients With a Pelvic Fracture.* North Ryde, Australia: NSW Institute of Trauma and Injury Management; 2007.
8. Heetveld MJ, Harris I, Schlaphoff G, et al. Guidelines for the management of haemodynamically unstable pelvic fracture patients. *Aust N Z J Surg.* 2004;74:520–529.

9. Marsh JL, Slongo TF, Agel J, et al. Fracture and dislocation classification compendium—2007: Orthopaedic Trauma Association Classification, Database and Outcomes Committee. *J Orthop Trauma.* 2007;21(suppl 10):S1–S133.

10. Burgess AR, Eastridge BJ, Young JWR, et al. Pelvic ring disruptions: effective classification system and treatment protocols. *J Trauma.* 1990; 30:848–856.

11. Gansslen A, Giannoudis P, Pape HC, et al. Hemorrhage in pelvic fracture: who needs angiography? *Curr Opin Crit Care.* 2003;9:515–523.

12. Hak DJ. The role of pelvic angiography in evaluation and management of pelvic trauma. *Orthop Clin North Am.* 2004;35:439–443.

13. Metz CM, Hak DJ, Goulet JA, et al. Pelvic fracture patterns and their corresponding angiographic sources of haemorrhage. *Orthop Clin North Am.* 2004;35:431–437.

14. Cook RE, Keating JF, Gillespie I. The role of angiography in the management of haemorrhage from major fractures of the pelvis. *J Bone Joint Surg Br.* 2002;84:178–182.

15. O'Neill PA, Riina J, Sclafani S, et al. Angiographic findings in pelvic fractures. *Clin Orthop Relat Res.* 1996;329:60–67.

16. Tötterman A, Madsen JE, Skaga NO, et al. Extraperitoneal pelvic packing: a salvage procedure to control massive traumatic pelvic haemorrgahe. *J Trauma.* 2007;62:843–852.

17. Sadri H, Nguyen-Tang T, Stern R. Control of severe haemorrhage using C-clamp and arterial embolization in haemodynamically unstable patients with pelvic ring disruption. *Arch Orthop Trauma Surg.* 2005;125:443–447.

18. Ertel W, Keel M, Eid K, et al. Control of severe haemorrhage using C-clamp and pelvic packing in multiply injured patients with pelvic ring disruption. *J Orthop Trauma.* 2001;15:468–474.

19. Kimbrell BJ, Velmahos GC, Chan LS, et al. Angiographic embolization for pelvic fractures in older patients. *Arch Surg.* 2004;139:728–733.

20. Osborn PM, Smith WR, Moore EE, et al. Direct retroperitoneal pelvic packing versus pelvic angiography: a comparison of two management protocols for haemodynamically unstable pelvic fractures. *Injury.* 2009; 40:54–60.

21. Starr AJ, Griffin DR, Reinert CM, et al. Pelvic ring disruptions: prediction of associated injuries, transfusion requirement, pelvic arteriography, complications and mortality. *J Orthop Trauma.* 2002;16: 553–561.

22. Salim A, Teixeira P, DuBose J, et al. Predictors of positive angiography in pelvic fractures: a prospective study. *J Am Coll Surg.* 2008;207:656–662.

23. Eastridge BJ, Starr A, Minei JP, et al. The importance of fracture pattern in guiding therapeutic decision-making in patients with haemorrhagic shock and pelvic ring disruptions. *J Trauma.* 2002;53:446–451.

24. Hamill J, Holden A, Paice R. Pelvic fracture pattern predicts pelvic arterial haemorrhage. *Aust N Z J Surg.* 2000;70:338–343.

25. Sarin EL, Moore JB, Moore EE, et al. Pelvic fracture pattern does not always predict the need for urgent embolization. *J Trauma.* 2005;58: 973–977.

26. Niwa T, Takebayashi S, Igari H, et al. The value of plain radiographs in the prediction of outcome in pelvic fractures treated with embolisation therapy. *Br J Radiol.* 2000;73:945–950.

27. Blackmore CC, Cummings P, Jurkovich GJ, et al. Predicting major hemorrhage in patients with pelvic fracture. *J Trauma.* 2006;61:346–352.

28. Miller PR, Moore PS, Mansell E, et al. External fixation or arteriogram in bleeding pelvic fracture: initial therapy guided by markers of arterial hemorrhage. *J Trauma.* 2003;54:437–443.

29. Stephen DJ, Kreder HJ, Day AC, et al. Early detection of arterial bleeding in acute pelvic trauma. *J Trauma.* 1999;47:638–642.

30. Brown CVR, Kasotakis G, Wilcox A. Does pelvic haematoma on admission computed tomography predict active bleeding at angiography for pelvic fracture? *Am Surg.* 2005;71:759–762.

31. Brasel KJ, Yang H, Christensen R. Significance of contrast extravasation in patients with pelvic fracture. *J Trauma.* 2007;62:1149–1152.

32. Velmahos GC, Toutouzas KG, Vassiliu P, et al. A prospective study on the safety and efficacy of angiographic embolization for pelvic and visceral injuries. *J Trauma.* 2002;52:303–308.

33. Henry SM, Pollak AN, Jones AL, et al. Pelvic fracture in geriatric patients: a distinct clinical entity. *J Trauma.* 2002;53:15–20.

34. Callaway DW, Shapiro NI, Donnino MW, et al. Serum lactate and base deficit as predictors of mortality in normotensive blunt elderly trauma patients. *J Trauma.* 2009;66:1040–1044.

35. Neville AL, Nemstev D, Manasrah R, et al. Mortality risk stratification in elderly trauma patients based on initial arterial lactate and base deficit levels. *Am Surg.* 2011;77:1337–1341.

36. Paladino L, Sinert R, Wallace D, et al. The utility of base deficit and arterial lactate in differentiating major from minor injury in trauma patients with normal vital signs. *Resuscitation.* 2008;77:363–368.

Invited Commentary

This report confirms the historical expectation that pelvic fracture-related arterial bleeding (PFRAB) occurs in 10%–20% of patients with high-energy pelvic fractures. Without urgent intervention patients with PFRAB have one of the highest mortality rates of all trauma patients. Ideally, traumatologists would be able to identify at-risk patients within minutes of arrival. CT angiography is an accurate diagnostic tool for the detection of PFRAB but is too time-consuming to be clinically useful for those patients already in severe hemorrhagic shock.[1,2] Thus several reviews have sought to identify predictors of PFRAB in the emergency department (ED). These predictors have included an hematocrit of 30 or less, a pulse rate of 130 or greater, a pelvic radiograph with a displaced obturator ring fracture, wide symphyseal diastasis, or sacroiliac joint disruption, female gender, duration of hypotension, transfusion requirement, and older age among others.[1] In contradistinction to previous reports, this review did not confirm the predictive value of anatomic fracture patterns or patient demographics. In congruence, however, this review confirms that signs of severe shock are predictive.

Are these findings useful for the trauma surgeon evaluating an unstable trauma patient in the ED? Yes. First, this study confirms many surgeons' long experience that fracture characteristics and demographics do not help when a decision must be made. In 20 years of trauma care I have seen life-threatening PFRAB in male and female, old and young, and all varieties of pelvic fractures. I have seen PFRAB in those with minimal injury and I have seen patients with astonishingly displaced pelvic fractures without PFRAB. Second, this study emphasizes the fundamental principle of trauma care: recognize internal hemorrhage and move decisively to stop it. Acidosis, hypotension, and transfusion of blood in the ED are red flags that a patient needs urgent intervention. The authors' call for the development of hybrid operating rooms

with both angiographic and surgical capability is thus very appropriate. My congratulations to the authors on a seminal study clarifying and supporting this important message.

John Mayberry, MD
Boise, Idaho

REFERENCES

1. Cullinane DC, Schiller HJ, Zielinski MD, et al. Eastern Association for the Surgery of Trauma practice management guidelines for hemorrhage in pelvic fracture—update and systemic review. *J Trauma.* 2011;71:1850–1868.
2. Brun J, Guillot S, Bouzai P, et al. Detecting active pelvic arterial haemorrhage on admission following serious pelvic fracture in multiple trauma patients. *Injury.* 2014;45:101–106.