Pelvic fracture pattern predicts the need for hemorrhage control intervention—Results of an AAST multi-institutional study

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BACKGROUND: Early identification of patients with pelvic fractures at risk of severe bleeding requiring intervention is critical. We performed a multi-institutional study to test our hypothesis that pelvic fracture patterns predict the need for a pelvic hemorrhage control intervention.

METHODS: This prospective, observational, multicenter study enrolled patients with pelvic fracture due to blunt trauma. Inclusion criteria included shock on admission (systolic blood pressure <90 mm Hg or heart rate >120 beats/min and base deficit >5, and the ability to review pelvic imaging). Demographic data, open pelvic fracture, blood transfusion, pelvic hemorrhage control intervention (angioembolization, external fixator, pelvic packing, and/or REBOA [resuscitative balloon occlusion of the aorta]), and mortality were recorded. Pelvic fracture pattern was classified according to Young-Burgess in a blinded fashion. Predictors of pelvic hemorrhage control intervention and mortality were analyzed by univariate and multivariate regression analyses.

RESULTS: A total of 163 patients presenting in shock were enrolled from 11 Level I trauma centers. The most common pelvic fracture pattern was lateral compression I, followed by lateral compression I, and vertical shear. Of the 12 patients with an anterior-posterior compression III fracture, 10 (83%) required a pelvic hemorrhage control intervention. Factors associated with the need for pelvic fracture hemorrhage control intervention on univariate analysis included vertical shear pelvic fracture pattern, increasing age, and transfusion of blood products. Anterior-posterior compression III fracture patterns and open pelvic fracture predicted the need for pelvic hemorrhage control intervention on multivariate analysis. Overall in-hospital mortality for patients admitted in shock with pelvic fracture was 30% and did not differ based on pelvic fracture pattern on multivariate analysis.

CONCLUSION: Blunt trauma patients admitted in shock with anterior-posterior compression III fracture patterns or patients with open pelvic fracture are at greatest risk of bleeding requiring pelvic hemorrhage control intervention. (*J Trauma Acute Care Surg.* 2017;82: 1030–1038.

LEVEL OF EVIDENCE: Prognostic/epidemiologic study, level III.
KEY WORDS: Angioembolization; external fixator; fracture pattern; hemorrhage control; pelvis.

Mortality rates for patients admitted to a Level I trauma center in shock with pelvic fracture remain high despite advances in the diagnosis and management of pelvic hemorrhage.[1] Pelvic fractures often occur in the setting of multisystem trauma and are associated with significant injuries and hemorrhage in other anatomic areas that make the management of severe pelvic fracture challenging. Pelvic bleeding originates from arterial, venous, or bony sources often requiring a multidisciplinary treatment approach that may include the trauma surgeon, interventional radiologist, and orthopedic surgeon. Therefore, the early identification of significant pelvic bleeding that necessitates urgent hemorrhage control is critical in the timely management of severely injured patients with pelvic fracture.[2]

Young et al.[3] recognized the importance of fracture pattern and developed a classification of pelvic fracture based on pelvic radiography that describes the pattern of force applied to the pelvis. They identified fracture patterns caused by anterior-posterior compression (APC), lateral compression (LC), and vertical shear (VS) mechanisms that produced distinctive radiographic appearance and could guide management by the trauma and orthopedic surgeon. Several studies have attempted to determine whether specific fracture patterns could predict outcomes in patients admitted with severe pelvic fracture.[4,5]

Pelvic fracture pattern has not consistently been associated with the need for pelvic angioembolization to treat pelvic arterial hemorrhage.[6–8] Modern trauma care for patients with hemorrhage from severe pelvic fracture includes multiple hemorrhage control modalities including angioembolization,[9] preperitoneal pelvic packing,[10] pelvic external fixator placement,[11] and resuscitative balloon occlusion of the aorta (REBOA).[12] We conducted a prospective, observational, multicenter study to characterize the modern management and outcomes for patients admitted with pelvic fracture. Our previous study found significant variability across participating trauma centers in the method of pelvic hemorrhage control utilized to treat pelvic bleeding.[1] The purpose of this analysis was to identify patient factors that predicted the need for any pelvic hemorrhage control intervention in patients admitted with pelvic fracture meeting criteria for shock.

METHODS

Patient Enrollment and Data Collection

Patients with pelvic fracture were enrolled from 11 Level I trauma centers participating in this multicenter, prospective, observational study conducted with the American Association for

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TABLE 1. Young-Burgess Classification of Pelvic Fracture

Pelvic Fracture Pattern	Description
LC I	Oblique or transverse pubic ramus fracture, ipsilateral sacral compression fracture
LC II	Pubic rami fracture and ipsilateral crescent iliac wing fracture
LC III	LC fracture on ipsilateral side with contralateral external rotation causing anterior sacroiliac ligament disruption
APC I	Pubic symphysis widening <2.5 cm
APC II	Pubic symphysis widening > 2.5 cm with anterior sacroiliac joint diastasis
APC III	Disruption of anterior and posterior sacroiliac joint ligaments
VS	Vertically oriented pubic rami fractures with posterior fractures of the sacrum or sacroiliac complex

the Surgery of Trauma Multi-institutional Trials Committee. Adult trauma patients 18 years or older with pelvic fracture after blunt trauma were enrolled during a 2-year period ending in January 2015. Patients meeting criteria for shock at the time of admission defined as systolic blood pressure (SBP) less than 90 mm Hg or heart rate (HR) greater than 120 beats/min and base deficit greater than 5 were included in this analysis. Exclusion criteria included lack of pelvic imaging (radiograph or computed tomography scan), pregnancy, penetrating mechanism of injury, or isolated hip fracture. All clinical decisions for the diagnosis and treatment of pelvic fracture were at the discretion of the attending trauma surgeon at each participating center. Data collection for this study was approved by the institutional review board at each participating trauma center.

Patient data collection included demographic data, admission vital signs, admission Glasgow Coma Scale score, admission laboratory studies including pH, base deficit, hematocrit, international normalized ratio, and partial thromboplastin time. Injury mechanism, the highest Abbreviated Injury Scale (AIS) score in each anatomic region, Injury Severity Score (ISS), Revised Trauma Score, transfusion of blood products, ventilator days, intensive care unit (ICU) and hospital length of stay (LOS), discharge disposition, and in-hospital mortality. The presence of an open pelvic fracture was recorded and defined as a perineal laceration associated with an underlying pelvic fracture. Methods of pelvic hemorrhage control recorded in this study included pelvic angioembolization, preperitoneal pelvic packing, pelvic external fixator placement, and REBOA. Radiology studies including pelvic radiograph and computed tomography scan were reviewed by a trauma surgeon or orthopedic surgeon, and/or radiologist in a blinded fashion, and classified according to the system described by Young et al.[3] (Table 1). Data from each participating center were entered into the AAST Multi-institutional Trials online data entry tool.

Statistical Analysis

Data are presented as the mean ± SD, the median ± interquartile range (IQR), or the raw percentage score, where appropriate. Categorical data were analyzed using a two-sided Fisher exact test, whereas Student *t* test was used for continuous variables. The *p* values were considered significant at $p < 0.05$. Multivariable analysis was performed to identify factors associated with the need for any pelvic hemorrhage control (pelvic angioembolization, preperitoneal pelvic packing, pelvic external fixator placement, or REBOA). To adjust for potential clustering effects within hospitals, we used generalized estimating equations with a Poisson probability distribution and a log link function and robust variance. Covariates in the model included pelvic fracture pattern, age, mechanism of injury, ISS, open pelvic fracture, and transfusion of packed red blood cells, fresh frozen plasma, or platelets. The area under the receiver operating characteristic (ROC) curve for the logistic regression model was calculated. Data analysis was performed using IBM SPSS Statistics version 21.0 (IBM Corp., Armonk, NY).

RESULTS

Of the 46,716 patients admitted to the 11 participating Level I trauma centers, there were 163 patients with pelvic fracture meeting criteria for shock (SBP <90 mm Hg or HR >120 beats/min or base deficit <−5) on admission who were included in this study (Fig. 1). The mean age of patients meeting inclusion criteria for this analysis was 44.1 ± 20.2 years. A majority of patients were male (57.7%). The most common mechanism of injury for patients in this analysis was motor vehicle crash (42.3%), followed by pedestrian versus auto, fall, and motorcycle crash (Table 2). The mean admission SBP was 92.7 ± 32.5; HR, 116.7 ± 28.2 beats/min; and base deficit, −9.8 ± 6.3, supporting the physiologic illness of the patients analyzed in this study. Patients with pelvic fracture meeting criteria for shock had a median ISS of 28.0 (IQR, 17.0–38.0), including 44.1% with a head AIS of 3 or greater, 55.0% with a chest AIS of 3 or greater, and 36.3% with an abdominal AIS of 3 or greater.

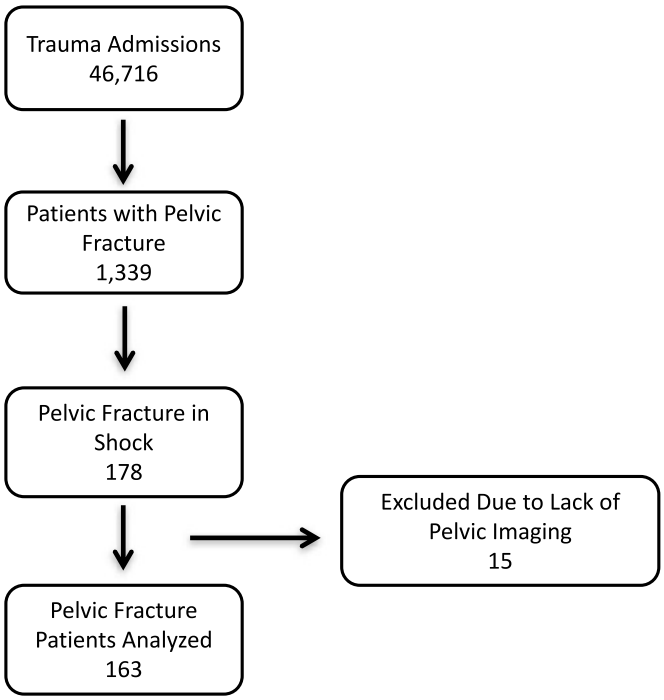

Figure 1. Patient enrollment.

TABLE 2. Demographics of the Study Population

n	163
Age, y	44.1 ± 20.2
Male (%)	94 (57.7%)
Mechanism	
Motor vehicle crash	69 (42.3%)
Pedestrian vs. auto	37 (22.7%)
Fall	30 (18.4%)
Motorcycle crash	24 (14.7%)
Crush	2 (1.2%)
Bicycle	1 (0.6%)
Admission vitals	
SBP, mm Hg	92.7 ± 32.5
HR, beats/min	116.7 ± 28.2
Admit pH	7.19 ± 0.14
Admission base deficit	−9.8 ± 6.3
Admission GCS	9.6 ± 5.3
ISS	28.0 (17.0–38.0)
Open pelvic fracture	12 (7.4%)
Pelvic binder application	28 (17.2%)
Pelvic hemorrhage control intervention	56 (34.4%)
ICU LOS, d	6.0 (1.0–11.5)
Ventilator, d	3.0 (0–9.0)
Hospital LOS, d	12.0 (3.5–23.0)
Mortality	49 (30.0%)

Values are presented as n (%), mean ± SD, or median (IQR [25th and 75th percentile]), where appropriate.
GCS indicates Glasgow Coma Scale.

Hospital LOS was 12.0 days (IQR, 3.5–23.0 days), and the in-hospital mortality was 30%.

Patients requiring a pelvic hemorrhage control intervention were more likely to be older (49.3 ± 19.4 vs. 41.4 ± 20.2 years, $p = 0.02$) and more likely to require transfusion of packed red blood cells and fresh frozen plasma (Table 3). There was no significant difference in ISS between patients who underwent a pelvic hemorrhage control intervention and those who did not. Patients requiring a pelvic hemorrhage control intervention had significantly longer ICU and hospital LOS compared with patients with pelvic fracture who did not undergo a hemorrhage control intervention. There were 12 patients with an open pelvic fracture. Patients with open pelvic fracture were more likely to require a hemorrhage control intervention ($p = 0.02$). There was no difference in mortality between patients who underwent a hemorrhage control intervention compared with those who did not require an intervention for hemorrhage control.

TABLE 3. Descriptive Statistics for Patients Requiring Hemorrhage Control Intervention

	Hemorrhage Control Intervention (n = 56)	No Hemorrhage Control Intervention (n = 107)	*p*
Age, y	49.3 ± 19.4	41.4 ± 20.2	0.02
ISS	29.0 (22.0–43.0)	(14.8–34.0)	0.09
PRBC transfusion, units	13.4 ± 13.1	7.3 ± 10.7	<0.01
FFP transfusion, units	9.8 ± 12.3	4.9 ± 9.2	0.01
Platelet transfusion, units	3.6 ± 7.5	2.4 ± 6.1	0.27
Ventilator days	4.0 (1.25–9.75)	2.0 (0–8.0)	0.09
ICU days	7.5 (3.0–17.0)	4.0 (1.0–11.0)	0.04
Hospital days	14.0 (4.0–33.8)	11.0 (3.0–18.0)	0.03
Pelvic binder application	13 (23.2%)	15 (14.0%)	0.19
Open pelvic fracture	8 (14.3%)	4 (3.7%)	0.02
Mortality (n = 49)	19 (33.9%)	30 (28.0%)	0.47

Values are presented as n (%), mean ± SD, or median (IQR [25th and 75th percentile]), where appropriate.
FFP indicates fresh frozen plasma; PRBC, packed red blood cell.

TABLE 4. Pelvic Fracture Pattern for Patients Admitted in Shock

Fracture Pattern (n = 163)	n (%)
LC I	58 (35.6)
LC II	37 (22.7)
VS	22 (13.5)
LC III	18 (11.0)
APC III	12 (7.4)
APC II	11 (6.7)
APC I	5 (3.0)

Lateral compression I (35.6%) was the most common pelvic fracture pattern seen in patients admitted with pelvic fracture in shock followed by LC II and VS (Table 4). There was a wide variability in the pelvic hemorrhage control method utilized based on each pelvic fracture pattern (see Table, Supplemental Digital Content 1, http://links.lww.com/TA/A927). There were eight different combinations of hemorrhage control intervention performed. Angioembolization alone and external fixator placement alone were the most common method of hemorrhage control utilized. There was no significant use of hemorrhage control intervention across institutions, with the exception of REBOA, which was performed at only 1 of the 11 centers.

Patients with APC III (83.3% vs. 16.7%, $p < 0.001$) and VS (54.5% vs. 45.5%, $p = 0.01$) fracture patterns were more likely to undergo a pelvic hemorrhage control intervention on univariate analysis (Table 5). Patients with LC I and LC II pelvic fracture patterns were more likely to not require a pelvic hemorrhage control intervention. Factors associated with the need for pelvic fracture hemorrhage control intervention on univariate analysis included VS pelvic fracture pattern, increasing ISS, and the need for transfusion of packed red blood cells, fresh frozen plasma, or platelets. Multivariable analysis found that APC III

TABLE 5. Descriptive Statistics for Patients Requiring Hemorrhage Control Intervention Based on Pelvic Fracture Pattern

	n	Hemorrhage Control Intervention (n = 56)	No Hemorrhage Control Intervention (n = 107)	*p*
LC I	58	12 (22.4%)	46 (77.6%)	0.01
LC II	37	7 (18.9%)	30 (81.1%)	0.03
LC III	18	7 (38.9%)	11 (61.1%)	0.79
APC I	5	3 (60.0%)	2 (40.0%)	0.34
APC II	11	4 (36.4 %)	7 (63.6%)	1.00
APC III	12	10 (83.3%)	2 (16.7%)	<0.001
VS	22	13 (54.5%)	9 (45.5%)	0.032

TABLE 6. Independent Predictors for Undergoing a Pelvic Hemorrhage Control Intervention After Admission With Pelvic Fracture in Shock

Variables	Adjusted RR	Lower 95% CI	Upper 95% CI
APC III fracture	6.23	1.83	21.18
Open pelvic fracture	2.56	1.08	6.08
Age 45–64 y*	3.50	1.12	10.96
Age ≥65 y*	5.16	1.46	18.30

Area under the ROC curve = 0.79 ($p < 0.001$).
*Age 18 to 24 years as reference group.
CI indicates confidence interval; RR, relative risk.

pelvic fracture pattern, open pelvic fractures, and age older than 45 years were independently associated with the need for a pelvic hemorrhage control intervention (Table 6). The area under the ROC curve for the logistic regression model was 0.790, with 95% confidence interval of 0.71 to 0.87 ($p < 0.001$). There was no difference in mortality based on pelvic fracture pattern on univariate or multivariable analysis.

DISCUSSION

The objective of this study was to identify patient factors that predicted the need for a pelvic hemorrhage control intervention in patients admitted with pelvic fracture meeting criteria for shock. Anterior-posterior compression III pelvic fracture pattern and open pelvic fracture predicted the need for pelvic hemorrhage control intervention on multivariate analysis. Pelvic fracture pattern did not predict in-hospital mortality on either univariate or multivariate analysis.

Several previous, single-center studies have attempted to identify markers of arterial bleeding after pelvic fracture that require angioembolization.[11] A prospective, single-center study of 137 patients with pelvic fracture by Salim et al.[6] found sacroiliac joint disruption (as evidence of VS mechanism) on imaging as an independent predictor of the need for therapeutic angioembolization with an odds ratio of 4.5. They found no relationship between open-book pelvic fracture and the need for therapeutic angioembolization on logistic regression analysis. A study by Eastridge et al.[13] also evaluated the importance of pelvic fracture pattern on hemorrhage in hypotensive patients with pelvic fracture. In a retrospective study of 231 hypotensive patients with pelvic fracture, they compared stable pelvic fracture patterns (APC I and LC I) with unstable fracture patterns (defined as APC II, APC III, LC II, LC III, and VS) and found that 59% of patients with unstable fracture patterns required angiography to treat pelvic hemorrhage. Other studies have found no relationship between pelvic fracture pattern and the need for pelvic arterial hemorrhage control. A single-center retrospective study by Sarin et al.[7] analyzed 283 patients with pelvic fracture who presented with hypotension. They found no difference in the need for pelvic angioembolization for arterial hemorrhage based on pelvic fracture pattern classification.[7] A small, single-center study by Toth et al.[8] also found that pelvic fracture pattern was a poor predictor of the need for pelvic arterial hemorrhage control.

This study was a prospective, observational, multicenter study of patients admitted to 11 Level I trauma centers with pelvic fracture meeting criteria for shock at the time of admission. As this was an observational study, diagnostic studies obtained and treatment paradigms were left to the attending trauma surgeon at each center. A previous study published by this Pelvic Fracture Study Group[1] characterized the current management of pelvic fracture in the United States and found that treatment strategies for control of pelvic hemorrhage were variable across institutions. While angioembolization was the most commonly used pelvic hemorrhage control intervention in that study, pelvic external fixator placement and preperitoneal pelvic packing were also commonly used alone or in combination with another hemorrhage control intervention. In this analysis from the Pelvic Fracture Study Group, we chose to measure the need for any hemorrhage control intervention rather than a specific hemorrhage control technique because of practice variability across the participating centers.

Pelvic radiography was reviewed and classified based on pelvic fracture pattern according to the Young-Burgess classification[3] and correlated with the need for hemorrhage control intervention and patient outcome. A previous study demonstrated that there is no difference between the Young-Burgess classification and Tile classification in predicting mortality or transfusion requirement, suggesting findings from this study could be extrapolated to patients with pelvic fracture characterized by the Tile classification.[14] Patients with severe pelvic fracture frequently have significant associated injuries[1,15] that may result in hemorrhage from the torso, making it difficult to decipher the contribution of pelvic hemorrhage compared with hemorrhage from other sources when assessing the need for hemorrhage control.

We found that open pelvic fracture was an independent predictor of the need for a hemorrhage control intervention. A majority of the open fractures were associated with unstable fracture patterns; however, there were three patients with LC I pattern with open fracture. These data suggest that there should be a higher index of suspicion in patients with open fracture, even if they have a fracture pattern that is typically believed to be at low risk of pelvic hemorrhage.

Severe pelvic fracture is associated with high mortality and significant disability that has improved little over the past several decades despite advances in pelvic hemorrhage control strategies.[1,15–18] Mortality for patients with pelvic fracture presenting with evidence of shock on admission was 30%, which is comparable to several modern series evaluating patients with severe pelvic fracture.[2,15,19] Mortality rates for patients admitted with severe pelvic fracture are similar to patients requiring damage control laparotomy for intra-abdominal hemorrhage.[20,21] Patients with severe pelvic fracture frequently have other, significant associated injuries that can contribute to hemorrhage and mortality. Therefore, it is difficult to determine the relative contribution of hemorrhage from the pelvis versus other sources in the abdomen or chest in patients with multiple severe injuries. It is also difficult to determine the contribution of traumatic brain injury on outcomes in this study of patients with pelvic fracture admitted in shock.

It is recognized that delays in hemorrhage control after blunt pelvic trauma can lead to potentially preventable deaths

in mature trauma systems.[22,23] Pelvic radiography can be obtained and evaluated quickly in the trauma bay at the time of initial resuscitation and may provide an early indicator of risk of significant ongoing hemorrhage. As we have shown in this study, any pelvic fracture pattern can cause enough bleeding to require a hemorrhage control intervention, demonstrating that a pelvic source of hemorrhage cannot be ruled out based on fracture pattern alone. A better understanding of pelvic fracture patterns that are associated with a need for prompt hemorrhage control intervention, as shown in this study, may lead to more rapid deployment of resources to the operating room or angiography suite and improve time to hemorrhage control.

Findings from this study may also help refine algorithms[24,25] defining the optimal method to control hemorrhage in patients admitted with severe pelvic fracture. While there are several options available in the armamentarium to treat pelvic hemorrhage including arterial angioembolization, preperitoneal pelvic packing, pelvic external fixator placement, and REBOA, the ideal scenario for the deployment of these various techniques is unclear and more frequently chosen based on trauma surgeon experience and resource availability.[2] Future prospective studies are needed to better define the specific hemorrhage control technique, either alone or in combination, which leads to the best outcome for patients presenting with significant pelvic hemorrhage.

This is the first prospective, observational, multicenter study to characterize the effects of pelvic fracture pattern on need for hemorrhage control intervention. Using data collected at 11 Level I trauma centers, we found that blunt trauma patients with pelvic fracture admitted in shock with APC III or VS fracture patterns or patients with open pelvic fracture are at greatest risk of severe bleeding requiring pelvic hemorrhage control intervention.

AUTHORSHIP

T.W.C. and R.C. designed the study. All authors contributed to data collection. T.W.C and R.C. performed data analysis. All authors contributed to data interpretation and critical revision of the manuscript.

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DISCLOSURE

The authors declare no conflicts of interest.

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DISCUSSION

Dr. Joseph M. Galante (Sacramento, California): President Rozycki, Dr. Spain, Dr. Costantini, members and guests. I would like to thank the Program Committee for the opportunity to discuss this paper.

I would also like to commend Dr. Costantini and his coauthors on their ability to conduct a multi-center trial on patients in shock and rely on x-ray data.

The authors' work is important because it examines all forms of hemorrhage control, not just arterial embolization in the treatment of pelvic fractures and attempts to predict based upon those fracture patterns who will need embolization.

The ability to predict who will need hemorrhage control allows for earlier mobilization of resources, both in the operating room, hybrid suite, or interventional suite, in addition to the resuscitation bay.

The presentation and manuscript were well presented but they did prompt me to think a bit more about pelvic fractures and I'd like to ask Dr. Costantini for some clarifications.

The first, since the study should help mobilize resources, what was the timing of hemorrhage control? Was it in terms of minutes, hours or days? Was it the surgeons' intent to do all these procedures or was it just a matter of convenience?

Was the patient already on the operating table or in the hybrid suite for some other reason and it was just decided at that time to pack the pelvis while they were there?

Were all the patients in shock because of their pelvic fracture? Were there other etiologies such as liver laceration, spleen laceration, or even traumatic brain injury?

In the manuscript you noted that open fractures were predictors for hemorrhage control. Why? At our institution we've seen perineal lacerations and bladder injuries, even from simple public rami fractures.

We've also had water slide and Jet Ski accidents related to injuries where the laceration was the cause of bleeding and that was separate from fractures. What were the Young-Burgess classifications for those open fractures?

And, finally, how does this help me? And by me I mean the patient. With the exception of the data just presented by Denver, mortality is 30% and that's been consistent for decades, even with newer strategies for hemorrhage control.

Perhaps hemorrhage is not the main contributing factor to death in these patients and recognizing it earlier in intervention only places a strain on trauma centers and doesn't improve outcomes.

Or, since you relied on the providing surgeon to make the decisions, maybe we are incorrect in our thinking and seemingly the more innocuous pelvic fractures actually do need more aggressive hemorrhage control.

I'd like to thank you again for the opportunity to discuss the paper and I commend the authors on their work.

Dr. H. Gill Cryer (Los Angeles, California): I enjoyed the paper. You know we did a similar study almost 25–30 years ago now, and there has been several since that have shown almost the same data. And it's really a question of how you interpret the data and how you, then, take it and use it clinically.

So I think what you found, according to the way that I saw the data, is that about 50% of the patients who are going to bleed are in that group of pelvic fracture patterns that you identified—high risk, half your bleeding patients are going to be in there.

The problem is that the other half of bleeding patients are in that much larger group of lower-risk fracture pattern so it doesn't really tell you that, "okay, if I've got a low-risk pattern I'm not going to have to worry about bleeding." And I think that is the cautionary tale here.

Yes, when you've got one of the high-risk patterns, you probably are going to have bleeding. But just because you don't have that pattern doesn't mean you won't.

Thank you.

Dr. Ernest E. Moore (Denver, Colorado): One of the potential limitations of your analysis is that plain x-rays in the emergency department often don't reflect the pelvic fracture pattern. Even if you have a radiologist and orthopedic surgeon standing next to you, we often debate what type of pelvic fracture exists. Your analysis is presumably based upon CT scanning because orthopedic surgeons obtain a scan on virtually every pelvic fracture. Have you looked at the correlation between the initial impression in the ED and the ultimate CT scan findings?

Perhaps we could predict fracture patterns based on injury mechanism; specifically, have you analyzed the vector of impact —falls, auto/ped, motorcycle, or motor vehicle — and the resulting pelvic fracture classification?

The clinical implications may be substantial, and this is exactly what Young and Burgess proposed doing in Baltimore. They wanted to see patterns of extrapelvic injury based on the type of pelvic fracture implied by the vector.

Have you examined the association of life-threatening injuries outside the pelvis, with the pelvic fracture classification?

When these patients are in the emergency department, triage is critical. While the hybrid OR has largely resolved the dilemma of how to approach pelvic hemorrhage, whole body CT scanning is optimal to identify extrapelvic injuries, particularly TBI. The question is in which patient is the added time for scanning warranted from the perspective of risk: benefit. The REBOA may help in this scenario.

Dr. Marc A. Demoya (Boston, Massachusetts): Great study. Great review. I think that there are two things that I wanted to just kind of spin off a little bit.

Dr. Cryer actually pointed out the fact that one of the most interesting parts of this study actually had to do with the LC-1s and 2s that although 80% of them didn't need intervention 20% of them did.

So one out of fivefor those low-grade injuries is really important to emphasize to the reader meaning to not drop our guard.

Could you just expand on LC-1s versus 2s in terms ofis there a step-wise fashion increase in the need for interventions

The second question that I had was related to the failure of your interventions to stop bleeding. It would be interesting to see how often your interventions require a second or a third attempt as well?

Thank you very much.

Dr. Zsolt J. Balogh (Newcastle, Australia): Thank you. Congratulations for the study. I just would like to clarify that this

is not a trial. This is a multi-institutional observational study. You haven't trialed anything. Maybe I'm wrong.

The other comment, including LC-1s or LC-2s in that is just kind of a bit unfair because LC-1 is not displaced, physically cannot bleed.

The other thing is, as Dr. Moore alluded to, Young-Burgess when they described these injuries they described the associated injuries and for LC-3—sorry, for APC-3s and vertical shear the associated injury was blood loss.

So they have a table when they show different fractures and they've shown the units of blood lost with these patterns. And APC-3 and vertical shear were already identified decades ago that these are the ones which are more likely to bleed.

To me the most important thing is see that the patient has a pelvic fracture and then the physiology is going to guide us rather than the fracture pattern.

And we know that a couple of fracture patterns are more likely to bleed but certainly not the LC-1s, LC-2s as Young and Burgess identified.

Thank you.

Dr. Todd W. Costantini (San Diego, California): Thank you, Dr. Galante, for your thoughtful comments. To first address timing of hemorrhage control, nearly all the hemorrhage control was done within the first few hours of admission.

The mean time to hemorrhage control intervention was approximately two hours. There were one or two outliers that happened several hours after admission, but nearly all happened very quickly.

You asked whether or not it was the surgeons' intent to do these procedures or they just did a pelvic angiogram because they were performing and angiogram to evaluate another intra-abdominal injury

Almost all of the angiograms were done specifically to evaluate for bleeding from the pelvic fracture. We actually collected the indication for angiography as a part of our data set.

You asked if pelvic packing occurred as the primary operative procedure of if it was done since the patient was in the OR to treat another intra-abdominal injury. I can't necessarily say whether or not pelvic packing was done because patients were in the OR for another cause or whether centers intended that as their initial treatment for pelvic hemorrhage based on the data we collected.

You asked why did patients with open pelvic fracture need more hemorrhage control interventions and the distribution of their Young-Burgess classification. You are correct that any fracture pattern can occur with an open fracture. Most of the fractures were unstable patterns. Vertical shear was the most common. However, there were three patients with LC-1 or 2 fractures that actually had an open fracture based on our data.

These findings just add more information to your decision making process, when you are standing in the trauma bay treating a patient with an open pelvic fracture, that you may need an even higher index of suspicion that they have a pelvic source of hemorrhage.

You asked, were all the patients in shock due to pelvic bleeding. The answer is no. As you know, patients with severe pelvic fracture frequently have a high rate of associated injuries. There were approximately 40% of patients with AIS abdominal scores of at least three.

Unfortunately, based on the data collection, it's a little difficult to determine what is the contribution of hemorrhage from the liver versus the spleen versus the pelvis in any of these patients with multiple injuries. We do know that these patients all had severe pelvic fractures.

And then your final question, which is a very interesting and important one, how can we use this to help the patient?

First, these data support prior studies demonstrating that APC-3 and vertical shear fracture pattern is associated with the need for intervention for pelvic hemorrhage. These findings have been seen before, however, this study adds important information as it includes treatment of patients in multiple centers and represents patients treated with modern hemorrhage control techniques. I think these findings add information to our clinical decision making process, and help answer a critically important question in the care of these patients. Which is where to manage these severely injured patients, in the operating room, the angio suite, or the ICU.

And then, ultimately, the real question is can we do better than 30% mortality in patients with severe pelvic fracture which is a question that Dr. Burlew just addressed with her study.

As we showed both in this study and in the results published from this Pelvic Fracture Study Group last year, there is a lot of variability across the country, at least in the centers participating in the study, in how they are addressing pelvic hemorrhage. The question is whether we can either refine our algorithms or consider that we need better compliance with current algorithms to improve outcomes?

Pelvic packing is not used that frequently based on our data collection in these patient and if we used that more how is that going to affect mortality?

It is also important to note that during this data collection, REBOA was just beginning to be used—only 3 patients in this study group received REBOA—so how that is going to affect patient outcomes is an important question to answer in the future.

Dr. Cryer, you noted an important point, that low-risk fracture patterns can also bleed. I think these data should not be seen as a definitive, meaning that a certain pelvic fracture precludes pelvic hemorrhage. You need to take into consideration the full clinical picture.

Dr. Moore, you asked whether there was a correlation between the initial pelvic x-ray and CT. I don't have any quantification of that at this point. But after reviewing images from both x-ray and CT scans and radiology reports from these patients, there were several fracture patterns that were misdiagnosed or underdiagnosed on the initial pelvis x-ray that were obviously much more clear on better imaging with the CT scan.

You asked, does mechanism matter? We evaluated that as a potential factor that would predict the need for hemorrhage control. We didn't see any specific mechanism that made you more likely to require a pelvic hemorrhage control intervention.

And then you asked an interesting question: does the vector of force correlate with the bleeding source? I don't have any data to support that, but obviously the more severe fracture patterns were associated with increased risk of hemorrhage.

Dr. DeMoya, you asked if there was any difference between LC-1 and LC-2 as far as intervention. There wasn't. The need for intervention was actually quite similar between the two groups.

And then you asked, was there a failure of intervention and need for repeat intervention? For the most part I would say no. Several patients underwent multimodality treatment where they got an ex-fix and then angiogram, or an ex-fix and then pelvic packing but it seems that was a planned management for those patients rather than need for repeat intervention.

And, Dr. Balogh, you asked about associated injuries and their contribution to hemorrhage. Certainly, again, associated injuries are high and there are other sources of hemorrhage outside the pelvis in these severely injured patients.

And you noted that LC-1 and LC-2 fractures should not bleed based on the fact that they are not a displaced fracture. However, we did see bleeding on some of these CT scans in these patients and they did require interventions.

Again, I thank the AAST for the privilege of the podium. Thank you very much.