Angiographic embolization for hemorrhage following pelvic fracture: Is it "time" for a paradigm shift?

Ronald Brian Tesoriero, MD, Brandon R. Bruns, MD, Mayur Narayan, MD, MPH, MBA, Joseph Dubose, MD, Sundeep S. Guliani, MD, Megan L. Brenner, MD, Sharon Boswell, MS, Deborah M. Stein, MD, MPH, *and* **Thomas M. Scalea, MD**, *Baltimore, Maryland*

INTRODUCTION: Major pelvic disruption with hemorrhage has a high rate of lethality. Angiographic embolization remains the mainstay of treatment. Delays to angiography have been shown to worsen outcomes in part because time spent awaiting mobilization of resources needed to perform angiography allows ongoing hemorrhage. Alternative techniques like pelvic preperitoneal packing and aortic balloon occlusion now exist. We hypothesized that time to angiographic embolization at our Level 1 trauma center would be longer than 90 minutes.

METHODS: A retrospective review was performed of patients with pelvic fracture who underwent pelvic angiography at our trauma center over a 10-year period. The trauma registry was queried for age, sex, injury severity score, hemodynamic instability (HI) on presentation, and transfusion requirements within 24 hours. Charts were reviewed for time to angiography, embolization, and mortality.

RESULTS: A total of 4712 patients were admitted with pelvic fractures during the study period, 344 (7.3%) underwent pelvic angiography. Median injury severity score was 29. Median 24-hour transfusion requirements were five units of red blood cells and six units of fresh frozen plasma. One hundred fifty-one patients (43.9%) presented with HI and 104 (30%) received massive transfusion (MT). Median time to angiography was 286 minutes (interquartile range, 210–378). Times were significantly shorter when stratified for HI (HI, 264 vs stable 309 minutes; $p = 0.003$), and MT (MT, 230 vs non-MT, 317 minutes; $p < 0.001$), but still took nearly 4 hours. Overall mortality was 18%. Hemorrhage (35.5%) and sepsis/multiple-organ failure (43.5%) accounted for most deaths.

CONCLUSION: Pelvic fracture hemorrhage remains a management challenge. In this series, the median time to embolization was more than 5 hours. Nearly 80% of deaths could be attributed to early uncontrolled hemorrhage and linked to delays in hemostasis. Earlier intervention by Acute Care Surgeons with techniques like preperitoneal packing, aortic balloon occlusion, and use of hybrid operative suites may improve outcomes. (*J Trauma Acute Care Surg.* 2017;82: 18–26. Copyright © 2016 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Therapeutic study, level V.

KEY WORDS: Pelvic fracture; hemorrhage; angiography; time.

The management of pelvic fracture hemorrhage remains a significant challenge for the Acute Care Surgeon. Though multidisciplinary approaches have improved outcomes, mortality in those presenting with hemodynamic instability is 40% to 60%, with nearly a third dying from uncontrolled hemorrhage.[1–6] These patients often have multiple competing priorities, nearly 90% will have associated injuries, and up to 50% have sources of significant hemorrhage other than the pelvis.[4] Hemorrhage remains the most common cause of early in-hospital deaths among trauma patients, with most succumbing within the first 3 hours of admission.[7,8] For those who survive the initial hemorrhage, administration of early large-volume transfusions increases the risk of infection, multiple-organ failure (MOF), and mortality.[9–13]

Angiography and embolization was first described for control of pelvic fracture arterial hemorrhage in 1972, and since that time, its use has been shown to be safe and effective.[14–17] Angiography and embolization in combination with temporary pelvic stabilization has since become widely used for the treatment of pelvic fracture hemorrhage.[5,17–21] Early access to angiography has been associated with reduced mortality. However, delay to angiography greater than 60 to 90 minutes, or to embolization greater than 3 hours are associated with worse outcomes.[16,22,23] Unfortunately, many modern series report times to angiography that exceed these windows, and time to angioembolization has been shown to be increased by admission at night and on weekends.[3,16,24–26]

As time spent awaiting the mobilization of resources that are not immediately available at the bedside of unstable patients, and prolonged procedure times may allow ongoing bleeding, there has been interest in developing alternative methods to control pelvic fracture hemorrhage. Preperitoneal pelvic packing (PPP) has been used to salvage patients in extremis from pelvic fracture hemorrhage, or as an early intervention in those presenting with hemodynamic instability and failure to respond to standard resuscitation.[3,26–30] It has been advocated as either a bridge

Submitted: September 11, 2015, Revised: August 18, 2016, Accepted: August 22, 2016, Published online: September 3, 2016.

From the Division of Critical Care (R.B.T., B.R.B., M.N., M.L.B., S.B., D.M.S., T.M.S.), R Adams Cowley Shock Trauma Center, University of Maryland School of Medicine, Baltimore, Maryland; Department of Surgery (J.D.), David Grant Medical Center, Travis AFB, California, and Voluntary Faculty, University of California–Davis, Sacramento, California; and Department of Surgery (S.S.G.), University of New Mexico School of Medicine, Albuquerque, New Mexico.

This study was presented at the 74th annual meeting of the American Association for the Surgery of Trauma, September 9–12, 2015, in Las Vegas, Nevada.

Address for reprints: Ronald Brian Tesoriero, MD, 22 S Greene St, Baltimore, MD 21201; email: rtesoriero@umm.edu.

DOI: 10.1097/TA.0000000000001259

to angiography or as a primary treatment modality alone.[3,26,28] Resuscitative endovascular balloon occlusion of the aorta (REBOA) has also been used to rescue patients in extremis from pelvic fracture hemorrhage and interest in the technique has been growing.[8,31–33] However, neither has been routinely adopted, and angiography and embolization remain the mainstay of therapy in North America.[1,22,34]

The purpose of the current study was to examine the time to angiography after pelvic fracture in the traumatically injured patient at a mature trauma center with robust angiographic resources. We hypothesize that the time to angiography for pelvic fracture hemorrhage would be significantly longer than expected; exceeding 90 minutes, and that shorter times to angiography represent an opportunity for improvements in outcomes.

METHODS

After institutional review board approval, a retrospective review of patients with pelvic fracture admitted to the R Adams Cowley Shock Trauma Center and undergoing pelvic angiography from July 2002 through July 2012 was performed. Patients who underwent angiography more than 12 hours after admission were excluded, as they likely had delayed presentation of indications for angiography or had prolonged periods of time with operative treatment of multiple injuries. The trauma registry was queried for patients' demographic and physiologic data including age, sex, type of admission (scene vs transfer), time of admission, hemodynamic instability (HI) on presentation (systolic blood pressure (SBP) ≤ 90 mm Hg, heart rate ≥ 120 beats per minute), injury severity score (ISS) and Abbreviated Injury Scale (AIS), 24-hour transfusion requirements, and massive transfusion (MT) (>10 units packed red blood cells in 24 hours). The medical record and radiologic images were reviewed for the following: pelvic fracture classification; receipt of and time to computed tomographic (CT) scan; surgical intervention before angiography; indications for and time to angiography; and time to hemostasis by embolization, mortality, and cause of death.

Daytime was defined as 7:00 AM through 5:00 PM, and the weekend as 5:01 PM Friday through 6:59 AM Monday. Time of imaging and procedures were defined as follows: CT scan, time of trauma radiologist–dictated report; operation, nursing-documented start time of procedure and exit of room; angiography, documented time of first angiographic image; pelvic hemostasis, time of last pelvic angiographic image in those receiving embolization.

Time to angiography was compared between patients with and without HI and MT, and receipt of CT or operation (OR) before angiography. The Student *t*-test was used for continuous variables of normal distribution, and the Mann-Whitney *U*-test was used to compare non-normally distributed variables. Categorical variables were compared using χ^2 and Fisher exact test. A multivariate logistic regression analysis was performed in a stepwise fashion evaluating effects of age, ISS, HI at admission, MT, OR before angiography, and time to angiography on mortality. Area under the receiver operating curve and odds ratios with 95% confidence intervals (CI), and Hosmer and Lemeshow Goodness-of-fit tests were calculated for each model in the multivariate regression analysis. All analyses were performed using SAS version 9.4 (SAS Institute Inc, Cary, NC).

RESULTS

There were 61,180 trauma admissions over the study period. A total of 4,712 (7.7%) sustained a pelvic fracture. Of those, 379 (8%) underwent pelvic angiography. Thirty-five were done more than 12 hours from admission and were excluded, leaving 344 patients in the study population. The median age was 45 years (interquartile range [IQR], 29–60 years), and 72% were male. The median ISS was 29 (IQR, 22–41), and 68% had an ISS ≥ 25. Most patients had associated injuries (AIS ≥ 1), with abdominal (80.8%), thoracic (66%), and brain (44.2%) injuries occurring most commonly. Pelvic embolization was performed in 212 patients (62% of the study population). Demographics for the study population are shown in Table 1.

Median SBP and heart rate at admission were 115 mm Hg (IQR, 95–136) and 105 beats per minute (IQR, 85–125), respectively. Hemodynamic instability (HI) was present on admission in 151 patients (43.9%), and 104 patients (30%) received MT. The median 24-hour transfusion requirements were 5 units (IQR, 0–10.3) of packed red blood cells and 6 units (IQR, 0–14) of fresh frozen plasma.

Computed tomographic scans were obtained in 289 patients (84%) before angiography, although its use was less

TABLE 1. Demographics of Patients With Pelvic Fracture Undergoing Pelvic Angiography

Age, median (IQR)	45 (29–60)
Male, n (%)	247 (71.8)
Mechanism of injury, n (%)	
Motor vehicle crash	138 (40.1)
Motorcycle crash	68 (19.8)
Bicyclist/Pedestrian struck	55 (16)
Fall from height	32 (9.3)
Crush	21 (6.1)
Other	30 (8.7)
Origin of admission	
Scene, n (%)	257 (74.7)
Transfer, n (%)	87 (25.3)
Injury severity score (ISS)	
ISS, median (IQR)	29 (22–41)
ISS ≥ 15, n (%)	299 (87)
Physiology at admission	
SBP, median (IQR), mm Hg	115 (95–136)
HR, median (IQR), beats per minute	105 (85–125)
GCS, median (IQR)	15 (11–15)
Hemodynamic instability*, n (%)	151 (43.9)
Type of pelvic fracture	
Anteroposterior compression, n (%)	142 (41.3)
Lateral compression, n (%)	179 (52)
Vertical shear, n (%)	16 (4.7)
Mixed/other, n (%)	7 (2)
Time of Admission	
Weekday/Day, n (%)	123 (35.7)
Weekend and night, n (%)	221 (64.3)

*Hemodynamic instability: SBP ≤ 90 mm Hg or HR ≥ 120 beats per minute.
GCS, Glasgow coma scale; HR, heart rate in beats per minute.

frequent in patients who received angiography in less than 3 hours (51.8%). The median time to CT scan was 99 minutes (IQR, 75–130). Of patients who presented with HI and of those who received MT, 78.8% and 70.1%, respectively, underwent CT before angiography. Forty-seven (62.6%) of those who received operative intervention before angiography also underwent CT before angiography with equal distribution preoperatively (51.1%) and postoperatively (48.9%). For those who underwent CT after operative intervention, the median time between OR and CT was 29 minutes (IQR, 9–54).

Seventy-five patients (21.8%) had operative intervention before angiography (Table 2). Median time to OR was 64 minutes (IQR, 32–132) and median operative time was 87 minutes (IQR, 50–146). Sixty-one patients (81.3%) underwent laparotomy and 26 patients (34.6%) had PPP. Twenty-eight patients (37.3%) underwent multiple operative procedures. The most common combination, laparotomy and PPP, occurred in 20 patients (71.4%). The median time to angiography after OR was 78 minutes (IQR, 31–141 minutes) and was longer for those undergoing CT (*n* = 22) after OR (160 minutes; IQR, 103–276) than those who went directly to angiography (46 minutes; IQR, 25–105).

The most common single indication for angiography was contrast blush on CT, in 111 patients (32.2%), followed by pelvic hematoma on CT in 102 patients (29.6%). Overall, 113 patients (32.8%) had HI as one of the indications for angiography (Table 3).

The median time to angiography was 286 minutes (IQR, 210–378) (Table 4). Time to angiography for those who underwent embolization was 280 minutes [IQR, 201–367], time to embolization was 344 minutes (IQR, 262–433), and median procedure time was 51 minutes (IQR, 37–83). The time between CT and angiography was 197 minutes (IQR, 140–278). Times to angiography were shorter when stratified for HI (HI, 264 minutes vs stable, 309 minutes; $p = 0.003$), and those receiving MT (MT, 230 minutes vs non-MT, 317 minutes; $p < 0.001$) (Table 5). Times to angiography were shorter in those who presented during the weekend/night and in those who presented as an interfacility transfer, but these differences were not significant. Times were no faster in the last 2 years (278 minutes; IQR, 210–365) than in the first 8 years (297 minutes; IQR, 210–384) of the study; $p = 0.25$.

TABLE 2. Surgical Interventions Performed Before Pelvic Angiography, n = 75 (21.8%)

Surgical Intervention	No. of Patients (%)
Laparotomy	61 (81.3)
Preperitoneal pelvic packing	26 (34.6)
Pelvic external fixation	17 (22.6)
Thoracotomy	8 (10.6)
Craniotomy	2 (2.6)
Other*	3 (4)
More than one procedure**	28 (37.3)

*Other procedures included: superficial femoral artery repair (1), above-knee amputation of leg (1), and thigh fasciotomy (1).

**Most common combination: laparotomy and preperitoneal pelvic packing, n = 20 (71.4% of those undergoing more than one procedure).

TABLE 3. Indications for Angiography and Rate of Embolization

Indication	Angiography, n (%)	Embolization, n (%)
Contrast blush on CT (CB)	111 (32.2)	71 (63.9)
Pelvic hematoma on CT (PH-CT)	102 (29.6)	49 (48)
Pelvic hematoma in OR (PH-OR)	14 (4)	13 (92.8)
Hemodynamic instability (HI) alone	45 (13)	27 (60)
HI + CB	36 (10.4)	30 (83.3)
HI + PH-CT	15 (4.3)	9 (60)
HI + PH-OR	17 (4.9)	12 (70.5)
Unaccounted	4 (1.1)	1 (25)

Overall mortality was 18%. Sepsis/MOF (43.5%) and hemorrhage (35.5%) accounted for most deaths (Table 4). Mortality was higher in those presenting with HI (27.8%; $p < 0.001$), in those who received MT (41.3%; $p < 0.001$), and in those who underwent operative intervention before angiography (41.3%; $p < 0.001$). Forty-three (69.4%) of the patients who died had an associated severe injury (AIS ≥ 4), with brain (40.3%), thoracic (38.7%), and abdominal (35.4%) injuries occurring most commonly. When considering indications for angiography, the mortality associated with HI (35.4%) was higher than contrast blush (9%) and pelvic hematoma on CT (7.8%). Mortality in relation to HI at admission, receipt of MT, and time to angiography are shown in Table 6. There were 12 deaths (40% mortality) in those who received angiography within the first 180 minutes, four of whom went to the OR before angiography. Hemorrhage (75%)

TABLE 4. Outcomes in Patients Undergoing Pelvic Angiography

Time to diagnostic study or intervention in minutes	
CT* (n = 298)	99 (75–130)
OR** (n = 76)	64 (32–135)
Angiography (n = 344)	286 (210–378)
Embolization (n = 212)	344 (262–433)
Embolization procedure time	51 (37–83)
24-hour resuscitation	
Packed red blood cells, units	5 (0–10.3)
Fresh frozen plasma, units	6 (0–14)
Crystalloid, mL	9,500 (5,950–13,535)
Massive transfusion†, n (%)	104 (30.2)
Length of stay	
Hospital, days	11 (6–23)
Intensive care unit, days	5 (0–13)
Mortality	
Overall, n (%)	62 (17.7)
Hemorrhage, n (%)‡	22 (35.5)
Sepsis/organ failure, n (%)‡	27 (43.5)
Traumatic brain injury, n (%)‡	10 (16.1)
Other, n (%)‡	3 (4.8)

All values reported as median (interquartile range) unless otherwise indicated.
*Patients undergoing computed tomography scan (CT) before angiography.
**Patients undergoing operative intervention (OR) before angiography.
†Patients receiving ≥10 units packed red blood cells in the first 24 hours.
‡Attributable percentage of total mortality.

TABLE 5. Impact of Admission Factors, Interventions, and Patient Physiology on Time to Angiography in Patients With Pelvic Fracture

	Time to Angiography Minutes (IQR)	*P**
All (n = 344)	286 (210–378)	NA
Embolized (n = 212)	280 (201–367)	NA
Time of admission		
Weekday (n = 123)	306 (222–402)	0.27
Night/Weekend (n = 221)	279 (208–372)	
Origin of admission		
Scene (n = 257)	296 (224–390)	0.07
Transfer (n = 87)	266 (184–364)	
Interventions before angiography		
No OR prior (n = 269)	291 (217–373)	0.23
OR prior (n = 75)	278 (207–421)	
CT prior (n = 289)	307 (242–390)	<0.0001
No CT prior (n = 55)	183 (137–390)	
Patient physiology		
HI at admission (n = 151)	265 (199–343)	0.003
HS** at admission (n = 193)	309 (234–401)	
Massive transfusion (n = 104)	230 (172–306)	<0.0001
No massive transfusion (n = 240)	317 (244–404)	

**p* values are in relation to All time to angiography.
**HS, hemodynamically stable.

and sepsis/MOF (25%) accounted for all of these deaths. There were documented sources of significant hemorrhage other than the pelvis in 50% of the patients. Two additional patients who went to angiography without other intervention or diagnostic study died of cardiac arrest after completion of angiography but before further evaluation, and their death was likely due to hemorrhage from secondary sources. The highest mortality rates were seen in those who received angiography in less than 90 minutes (66%) and between 181 and 240 minutes (32.8%). In no model of the multivariate regression analysis was time to angiography associated with mortality. The model most correlated with mortality (area under the receiver operating curve, 0.869; 95% CI, 0.8237–0.9144, Lemeshow Goodness-of-fit, 2.193; $p = 0.9746$) included age, HI, ISS ≥ 25, OR before angiography, MT, and time to angiography. The odds ratio of time to angiography in this model was 1.00 (95% CI, 0.996–1.002; $p < 0.0001$).

DISCUSSION

Management of pelvic fracture hemorrhage is challenging; most patients in North America continue to be treated by resuscitation with blood products, temporary mechanical stabilization, and pelvic angioembolization.[1,14,16,17,22,26] More than 80% of pelvic fracture hemorrhage is venous or bony in origin and generally responds well to temporary stabilization with external fixation or circumferential compression with a pelvic binder or sheet wrapping.[26,34] Angiography and embolization address pelvic arterial hemorrhage, is required in 3% to 15% of patients with pelvic fracture, and is successful in 85% to 100% of cases.[5,15,16,18,28,34,35] Despite its effectiveness, several studies have reported mortality rates of approximately 50% after successful arterial embolization.[4,16,36] The rates of angiography (8%), embolization, and mortality in those with HI (35.5%) in this series are similar to previously reported series.

Predictors of need for angiography in pelvic fracture include HI, contrast blush on CT, presence of pelvic hematoma >500 cm^3, and advanced age.[34] Contrast extravasation on CT seems to have a sensitivity of 60% to 84% and specificity of 85% to 98%.[34] Fracture pattern does not seem to predict the need for angiography, although it may help guide the location of angioembolization.[34] In this series, HI was the most common indication for angiography, and most received embolization. At 35%, the mortality rate in unstable patients was significantly higher than in stable patients who had only anatomic indications for angiography. These unstable patients represent a group in whom earlier intervention may improve outcomes.

Time to control of pelvic arterial hemorrhage in patients with HI would be expected to improve mortality, and several studies support this hypothesis. Agolini et al.[16] reported that embolization within 3 hours improved survival from 25% to 86%. Balogh et al.[22] showed that an institutional protocol improving time to angiography to less than 90 minutes decreased mortality from 35% to 7%. More recently, Schwartz et al.[25] showed that delays to angiography in after-hours admissions were associated with higher mortality (32% vs. 21%).Tanizaki et al.[23] reported that angiography within 60 minutes was associated with a reduction in mortality from 64.7% to 14.3%.

Despite the suggestion that time to angiography improves mortality, most reported series document considerable delays. In a review of the available literature, Gannslen et al.[37] reported that the average time between admission and angiographic embolization was 10.7 hours. Schwartz et al.[25] reported times to angiography between 3 and 5 hours depending on time of admission. Morozumi et al.[24] found that while times to angiography could be improved with a mobile angiography suite, time to intervention was more than 90 minutes, and completion of embolization required nearly 3 hours. Osborn et al.[3] compared angiography to

TABLE 6. Mortality in Relation to Hemodynamics at Presentation, Receipt of Massive Transfusion, and Time to Angiography

	Mortality		
	Overall n (%)	Hemorrhage n (%)	Sepsis/MODS* n (%)
All (n = 344)	**62 (17.7)**	22 (35.5)	27 (43.5)
Embolized (n = 212)	**40 (18.8)**	13 (32.5)	17 (42.5)
HI at admission (n = 151)	**42 (27.8)**	15 (35.7)	19 (45.2)
Massive transfusion (n = 104)	**43 (41.3)**	19 (44.2)	14 (32.5)
Time to angiography, minutes			
≤90 (n = 3)	**2 (66.7)**	2 (100)	
91–120 (n = 21)	**5 (23.8)**	4 (80)	1 (20)
121–180 (n = 30)	**5 (16.7)**	3 (60)	2 (40)
181–240 (n = 58)	**19 (32.8)**	7 (36.8)	11 (57.9)
241–300 (n = 72)	**15 (20.8)**	4 (26.7)	6 (40)
>300 (n = 160)	**16 (10)**	2 (12.5)	7 (43.8)

*MODS, multiple-organ dysfunction syndrome.

PPP and found that more than 2 hours was required to obtain angiography. The current series demonstrates similar times to angiography. The nearly 5 hours to reach the angiography suite in this study is comparable to the after-hours group reported by Schwartz et al.[25] Although times were faster in those who presented with HI or received MT, the intervals between admission and angiography were still nearly 4 hours with delays often due to need for operative intervention before angiography. Even when obtained postoperatively, when advanced notification of need for angiography was likely, the median time to intervention was more than 1 hour. Unlike previous reports,[25] after-hours admission did not worsen time to angiography in this series.

Even with institutional protocols and increased access to angiography, patients with pelvic fracture hemorrhage and instability continue to have mortalities between 40% and 60%.[1–5] The reasons for this are unclear. Although they may include poor trauma center compliance with recommendations for early angiography, it is likely reflective of the multiple competing priorities present in patients with major pelvic fracture.[38] Up to 30% of these patients will have significant associated abdominal injury, and nearly 50% of patients who die have multiple sources of hemorrhage.[4,39,40] Intuitively, prompt control of the most serious cause of hemorrhage should improve outcomes. However, it is unclear which source of hemorrhage should take precedence. Eastridge et al. reported that patients with pelvic fracture hemorrhage who required both laparotomy and angiography had a higher chance of mortality when undergoing laparotomy first, but others have shown the opposite.[5,18] Irrespective of the major source of hemorrhage, it seems that intra-abdominal injuries are often a significant contributor to mortality.[25] Although the overall mortality in our series was 18%, the rates in those presenting with HI and receiving MT were significantly higher. When considering that transfusion has been directly linked to infection and MOF, nearly 80% of mortality in this series can be attributed to early uncontrolled hemorrhage and directly linked to delays in hemostasis. There was a nearly 70% rate of major extrapelvic injury in those who died, including a 35% rate of significant intra-abdominal injury, and many patients had multiple sites of hemorrhage. These numbers are remarkably similar to the rates reported in the literature, and it is likely that these factors in addition to pelvic hemorrhage and times to angiography contribute to the increased mortality.

Unfortunately, identifying the leading cause of hemorrhage in patients with pelvic fracture remains difficult. Focused assessment with sonography in trauma (FAST) has a low specificity and negative predictive value when pelvic fractures are present, and negative FAST does not seem to predict whether laparotomy or angiography is needed in these patients presenting with HI.[34,41] For some, a positive FAST due to minor intra-abdominal injury or rupture of a preperitoneal pelvic hematoma will lead to laparotomy and delays to angiography. The desire for definitive diagnosis of injury leads to the frequent use of CT in trauma patients, and the study is sometimes obtained even in the face of HI. Cook et al.[42] reported that the use of CT in selected hemodyamically unstable patients with positive FAST examinations did not worsen mortality and resulted in decreased odds of emergency surgery. However, the nearly three times increased 24-hour mortality in the group of unstable positive FAST patients who went directly to the operating room suggests differences in the two groups not reflected in the matched ISS. Huber-Wagner et al.[43] showed that whole body CT in select unstable patients improved outcomes compared to those who did not receive the study. Despite these studies' findings, the inherent delays to definitive care due to the acquisition of CT have the potential to negatively affect outcomes. Computed tomography was obtained before angiography in 84% of the patients in the current series. Even when patients presented with HI or received MT, CT was obtained before angiography more than 70% of the time. Although time to CT was similar to previous large studies,[25] the time spent obtaining these images represents potential significant delays to definitive care.

The retrospective nature of this review made it difficult to delineate the specific reason for delays. As we were unable to determine the time that the interventional radiology service was consulted, it is difficult to know how much of the time to angiography was due to delays in recognition of its need and delayed consultation. However, in some instances, CT may have been obtained while awaiting the mobilization of the angiographic team. This is almost certainly the case in those who underwent CT after operative intervention but before angiography. Delay to angiography overall seemed to be multifactorial, including diagnostic decisions made by the Trauma team (frequent use of CT scan), factors dictated by patients' disease (need for operative intervention in unstable patients), and delays in mobilization of the resources needed for angioembolization.

In an effort to expedite hemorrhage control, PPP was first described in 1994 and has since been widely used in Europe for salvage of unstable patients with pelvic fracture hemorrhage.[29,30] Its use in North America increased after Cothren et al. reported 2 series of patients in whom primary treatment with PPP was used as part of an institutional protocol for the early management of patients with pelvic fracture and HI.[6,26] Significantly, they reported an 85% rate of additional operative interventions at the time of PPP, and a mortality of 21%, with none due to acute hemorrhage. The need for post-PPP angiography was uncommon in this series, suggesting that most arterial hemorrhage was controllable with PPP. Osborn et al.[3] showed that median times to intervention for PPP were significantly shorter than for early angiography and were associated with a lower mortality and no deaths due to hemorrhage. In the current series, PPP was used in 34.6% of those who underwent operative intervention before angiography and more than 75% underwent laparotomy at the time of PPP. The mortality in this cohort was 50%, suggesting that patients were multiply injured and that PPP was used as a salvage technique rather than as early primary management. Given the association of improved mortality rates compared to series of unstable patients undergoing angiography, PPP has been proposed as a primary management strategy for patients with pelvic fracture and instability.[3,4,6,26–28]

Resuscitative endovascular balloon occlusion of the aorta was originally described for the treatment of shock[44] in 1954. It has the potential for improvement in outcomes of patients presenting with noncompressible torso hemorrhage by rapidly controlling abdominal and pelvic blood loss and improving central perfusion pressure while allowing time to definitive hemorrhage control.[8] It is minimally invasive relative to ED thoracotomy and establishes access for catheter-based techniques of hemorrhage control. Martinelli et al.[31] reported the successful use of intra-aortic balloon occlusion in 13 patients with pelvic fracture and such critically uncontrollable hemorrhagic shock that they were unable to be safely transported from the emergency department. Morrison et al.[32] compared the use of aortic balloon occlusion to packing with kaolin-impregnated gauze in a swine model of arterial pelvic hemorrhage with dilutional coagulopathy and found that placement of REBOA significantly improved SBP and was associated with lower mortality. Brenner et al.[33] found REBOA to be feasible for both blunt and penetrating mechanisms when performed by nonvascular trained acute care surgeons. These reports have generated interest in the technique and have led to the development of several training courses for acute care surgeons.[45,46] The current series predates the use of REBOA at our institution. However, given the protracted time required to mobilize angiography and the high rate of associated injury in most series, REBOA offers the bedside acute care surgeon the ability to temporarily control ongoing pelvic hemorrhage and address other sites of noncompressible torso hemorrhage in a minimally invasive fashion.

Trauma hybrid operating rooms may represent the next step forward in the management of these difficult patients. The combination of surgical, angiographic, and advanced imaging capabilities in a single site provides flexibility and the potential simplification of patient care algorithms and surgical decision making while allowing clinical specialists to come to the patient, thus minimizing the transport of unstable patients.[8] Acute care surgeons could use a trauma hybrid operating room in combination with initial inflow control with REBOA or PPP to temporize bleeding. It would provide a single location for resuscitation and allow basic and advanced operative intervention while allowing time for those with expertise in advanced catheter-based techniques to arrive.

This study includes the inherent limitations of retrospective work. It is unclear at what time the decision to pursue angiography was made and the reported indications were inferred based on chart review. It is likely that some patients with HI quickly responded to resuscitation, had delays to angiography, but were included in the analysis of HI patients. Other initially stable patients may have developed subsequent instability and contributed to delays in angiography. Transfusion registry data were missing for a number of patients and is likely underreported. The possibility of selection bias exists, as only patients who underwent angiography were included and those who died before proceeding to angiography may have been missed, thus affecting mortality rates. Additionally, overall reported times in the study included a number of stable patients whose indications for angiography were purely anatomic in nature. Although the 10-year period is a potential limitation, there were no significant changes in facilities or interventional radiology staffing, and this is reflected in the times and mortality in the final 2 years being similar to the study as a whole.

In conclusion, pelvic fracture hemorrhage remains a significant management challenge. Although significant time delays to angiography have been a consistent finding in previous reports, as have increased mortality due to those delays, angiography continues to be the mainstay of treatment in North America. This is the largest series to date reporting on time to angiography, comes from an institution with robust angiographic resources, and accurately reflects the daily operations at a busy trauma center. In this study, the mortality of those presenting with HI and significant hemorrhage is similar to the mortality rates in other published series and remains high, in part due to multiple sources of hemorrhage present in these patients. Although times to angiography were faster in the highest-risk patients, they still required almost 4 hours to reach angiography. Delays were multifactorial and included the use of CT scan, the frequent need for operative intervention for other sources of hemorrhage before angiography, and the inherent delay of mobilizing resources not readily present in the hospital. Although times to angiography were not a significant contributor to mortality after adjusting for injury severity, most patients who underwent angiography early and died had a second source of hemorrhage and may have benefited from a strategy that allowed for control of multiple sites of bleeding in parallel.

While strategies such as mobile angiography suites and dedicated trauma angiography teams may improve times to angiography, they do not address the extrapelvic sources of hemorrhage that are commonly present in these patients. The current paradigm of addressing these competing sources of hemorrhage in series allows for ongoing hemorrhage from the nonaddressed site. Perhaps the question should not be "can we get to the angiography suite faster" but "should we be there at all?" Novel techniques like PPP, REBOA, and the use of trauma hybrid operating rooms require additional study but offer the acute care surgeon tools to obtain immediate hemostasis of multiple sites of hemorrhage simultaneously and may improve outcomes.

AUTHORSHIP

R.T. contributed to the study design, data collection, data analysis, data interpretation, literature search, and writing. B.B. contributed to the study design, data collection, data interpretation, literature search, and writing. M.N. contributed to the study design, data collection, and data interpretation. J.D. contributed to the study design and data collection. S.G. contributed to the study design and data collection. M.B. contributed to the study design and data interpretation. S.B. contributed to the data analysis. D.S. contributed to the study design, data interpretation, data analysis, and critical revision. T.S contributed to the study design and critical revision.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES

1. Biffl WL, Smith WR, Moore EE, Gonzalez RJ, Morgan SJ, Hennessey T, Offner PJ, Ray CE Jr, Franciose RJ, Burch JM. Evolution of a multidisciplinary clinical pathway for the management of unstable patients with pelvic fractures. *Ann Surg*. 2001;233(6):843–850.
2. Moreno C, Moore EE, Rosenberger A, Cleveland HC. Hemorrhage associated with major pelvic fracture: a multispecialty challenge. *J Trauma*. 1986;26(11):987–994.
3. Osborn PM, Smith WR, Moore EE, Cothren CC, Morgan SJ, Williams AE, Stahel PF. Direct retroperitoneal pelvic packing versus pelvic angiography: a comparison of two management protocols for haemodynamically unstable pelvic fractures. *Injury*. 2009;40(1):54–60.
4. Suzuki T, Smith WR, Moore EE. Pelvic packing or angiography: competitive or complementary? *Injury*. 2009;40(4):343–353.
5. Thorson CM, Ryan ML, Otero CA, Vu T, Borja MJ, Jose J, Schulman CI, Livingstone AS, Proctor KG. Operating room or angiography suite for hemodynamically unstable pelvic fractures? *J Trauma Acute Care Surg*. 2012;72(2):364–370; discussion 71-2.
6. Burlew CC, Moore EE, Smith WR, Johnson JL, Biffl WL, Barnett CC, Stahel PF. Preperitoneal pelvic packing/external fixation with secondary

angioembolization: optimal care for life-threatening hemorrhage from unstable pelvic fractures. *J Am Coll Surg*. 2011;212(4):628–635; discussion 35-7.
7. Holcomb JB, del Junco DJ, Fox EE, Wade CE, Cohen MJ, Schreiber MA, Alarcon LH, Bai Y, Brasel KJ, Bulger EM, et al. The prospective, observational, multicenter, major trauma transfusion (PROMMTT) study: comparative effectiveness of a time-varying treatment with competing risks. *JAMA Surg*. 2013;148(2):127–136.
8. Holcomb JB, Fox EE, Scalea TM, Napolitano LM, Albarado R, Gill B, Dunkin BJ, Kirkpatrick AW, Cotton BA, Inaba K, et al. Current opinion on catheter-based hemorrhage control in trauma patients. *J Trauma Acute Care Surg*. 2014;76(3):888–893.
9. Bochicchio GV, Napolitano L, Joshi M, Bochicchio K, Meyer W, Scalea TM. Outcome analysis of blood product transfusion in trauma patients: a prospective, risk-adjusted study. *World J Surg*. 2008;32(10):2185–2189.
10. Claridge JA, Sawyer RG, Schulman AM, McLemore EC, Young JS. Blood transfusions correlate with infections in trauma patients in a dose-dependent manner. *Am Surg*. 2002;68(7):566–572.
11. Moore FA, Moore EE, Sauaia A. Blood transfusion. An independent risk factor for postinjury multiple organ failure. *Arch Surg*. 1997;132(6):620–624; discussion 4-5.
12. Malone DL, Dunne J, Tracy JK, Putnam AT, Scalea TM, Napolitano LM. Blood transfusion, independent of shock severity, is associated with worse outcome in trauma. *J Trauma*. 2003;54(5):898–905; discussion -7.
13. Sihler KC, Napolitano LM. Complications of massive transfusion. *Chest*. 2010;137(1):209–220.
14. Margolies MN, Ring EJ, Waltman AC, Kerr WS Jr, Baum S. Arteriography in the management of hemorrhage from pelvic fractures. *N Engl J Med*. 1972;287(7):317–321.
15. Panetta T, Sclafani SJ, Goldstein AS, Phillips TF, Shaftan GW. Percutaneous transcatheter embolization for massive bleeding from pelvic fractures. *J Trauma*. 1985;25(11):1021–1029.
16. Agolini SF, Shah K, Jaffe J, Newcomb J, Rhodes M, Reed JF 3rd. Arterial embolization is a rapid and effective technique for controlling pelvic fracture hemorrhage. *J Trauma*. 1997;43(3):395–399.
17. Velmahos GC, Toutouzas KG, Vassiliu P, Sarkisyan G, Chan LS, Hanks SH, Berne TV, Demetriades D. A prospective study on the safety and efficacy of angiographic embolization for pelvic and visceral injuries. *J Trauma*. 2002; 53(2):303–308; discussion 8.
18. Eastridge BJ, Starr A, Minei JP, O'Keefe GE, Scalea TM. The importance of fracture pattern in guiding therapeutic decision-making in patients with hemorrhagic shock and pelvic ring disruptions. *J Trauma*. 2002;53(3):446–450; discussion 50-1.
19. Flint L, Cryer HG. Pelvic fracture: the last 50 years. *J Trauma*. 2010;69(3): 483–488.
20. White CE, Hsu JR, Holcomb JB. Haemodynamically unstable pelvic fractures. *Injury*. 2009;40(10):1023–1030.
21. Stein DM, O'Toole R, Scalea TM. Multidisciplinary approach for patients with pelvic fractures and hemodynamic instability. *Scand J Surg*. 2007; 96(4):272–280.
22. Balogh Z, Caldwell E, Heetveld M, D'Amours S, Schlaphoff G, Harris I, Sugrue M. Institutional practice guidelines on management of pelvic fracture-related hemodynamic instability: do they make a difference? *J Trauma*. 2005;58(4):778–782.
23. Tanizaki S, Maeda S, Matano H, Sera M, Nagai H, Ishida H. Time to pelvic embolization for hemodynamically unstable pelvic fractures may affect the survival for delays up to 60 min. *Injury*. 2014;45(4):738–741.
24. Morozumi J, Homma H, Ohta S, Noda M, Oda J, Mishima S, Yukioka T. Impact of mobile angiography in the emergency department for controlling pelvic fracture hemorrhage with hemodynamic instability. *J Trauma*. 2010; 68(1):90–95.
25. Schwartz DA, Medina M, Cotton BA, Rahbar E, Wade CE, Cohen AM, Beeler AM, Burgess AR, Holcomb JB. Are we delivering two standards of care for pelvic trauma? Availability of angioembolization after hours and on weekends increases time to therapeutic intervention. *J Trauma Acute Care Surg*. 2014;76(1):134–139.
26. Cothren CC, Osborn PM, Moore EE, Morgan SJ, Johnson JL, Smith WR. Preperitonal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift. *J Trauma*. 2007;62(4):834–839; discussion 9-42.
27. Smith WR, Moore EE, Osborn P, Agudelo JF, Morgan SJ, Parekh AA, Cothren C. Retroperitoneal packing as a resuscitation technique for hemodynamically unstable patients with pelvic fractures: report of two representative cases and a description of technique. *J Trauma*. 2005; 59(6):1510–1514.
28. Totterman A, Madsen JE, Skaga NO, Roise O. Extraperitoneal pelvic packing: a salvage procedure to control massive traumatic pelvic hemorrhage. *J Trauma*. 2007;62(4):843–852.
29. Ertel W, Keel M, Eid K, Platz A, Trentz O. Control of severe hemorrhage using C-clamp and pelvic packing in multiply injured patients with pelvic ring disruption. *J Orthop Trauma*. 2001;15(7):468–474.
30. Pohlemann T, Gansslen A, Bosch U. H T The technique of packing for control of hemorrhage in complex pelvic fractures. *Tech Orthop*. 1995;9:267–270.
31. Martinelli T, Thony F, Declety P, Sengel C, Broux C, Tonetti J, Payen JF, Ferretti G. Intra-aortic balloon occlusion to salvage patients with life-threatening hemorrhagic shocks from pelvic fractures. J Trauma 2010; 68(4):942–948.
32. Morrison JJ, Percival TJ, Markov NP, Villamaria C, Scott DJ, Saches KA, Spencer JR, Rasmussen TE. Aortic balloon occlusion is effective in controlling pelvic hemorrhage. *J Surg Res*. 2012;177(2):341–347.
33. Brenner ML, Moore LJ, DuBose JJ, Tyson GH, McNutt MK, Albarado RP, Holcomb JB, Scalea TM, Rasmussen TE. A clinical series of resuscitative endovascular balloon occlusion of the aorta for hemorrhage control and resuscitation. *J Trauma Acute Care Surg*. 2013;75(3):506–511.
34. Cullinane DC, Schiller HJ, Zielinski MD, Bilaniuk JW, Collier BR, Como J, Holevar M, Sabater EA, Sems SA, Vassy WM, et al. Eastern Association for the Surgery of Trauma practice management guidelines for hemorrhage in pelvic fracture—update and systematic review. *J Trauma*. 2011;71(6): 1850–1868.
35. Fang JF, Shih LY, Wong YC, Lin BC, Hsu YP. Repeat transcatheter arterial embolization for the management of pelvic arterial hemorrhage. *J Trauma*. 2009;66(2):429–435.
36. Miller PR, Moore PS, Mansell E, Meredith JW, Chang MC. External fixation or arteriogram in bleeding pelvic fracture: initial therapy guided by markers of arterial hemorrhage. *J Trauma*. 2003;54(3):437–443.
37. Gänsslen A, Giannoudis P, Pape HC. Hemorrhage in pelvic fracture: who needs angiography? *Curr Opin Crit Care*. 2003;9(6):515–523.
38. Shafi S, Barnes SA, Rayan N, Kudyakov R, Foreman M, Cryer HG, Alam HB, Hoff W, Holcomb J. Compliance with recommended care at trauma centers: association with patient outcomes. *J Am Coll Surg*. 2014; 219(2):189–198.
39. Demetriades D, Karaiskakis M, Toutouzas K, Alo K, Velmahos G, Chan L. Pelvic fractures: epidemiology and predictors of associated abdominal injuries and outcomes. *J Am Coll Surg*. 2002;195(1):1–10.
40. Papadopoulos IN, Kanakaris N, Bonovas S, Triantafillidis A, Garnavos C, Voros D, Leukidis C. Auditing 655 fatalities with pelvic fractures by autopsy as a basis to evaluate trauma care. *J Am Coll Surg*. 2006;203(1):30–43.
41. Friese RS, Malekzadeh S, Shafi S, Gentilello LM, Starr A. Abdominal ultrasound is an unreliable modality for the detection of hemoperitoneum in patients with pelvic fracture. *J Trauma*. 2007;63(1):97–102.
42. Cook MR, Holcomb JB, Rahbar MH, Fox EE, Alarcon LH, Bulger EM, Brasel KJ, Schreiber MA. An abdominal computed tomography may be safe in selected hypotensive trauma patients with positive Focused Assessment with Sonography in Trauma examination. *Am J Surg*. 2015; 209(5):834–840.
43. Huber-Wagner S, Biberthaler P, Häberle S, Wierer M, Dobritz M, Rummeny E, van Griensven M, Kanz KG, Lefering R. Whole-body CT in haemodynamically unstable severely injured patients—a retrospective, multicentre study. *PLoS One*. 2013;8(7):e68880.
44. Hughes CW. Use of an intra-aortic balloon catheter tamponade for controlling intra-abdominal hemorrhage in man. *Surgery*. 1954;36(1):65–68.
45. Brenner M, Hoehn M, Pasley J, Dubose J, Stein D, Scalea T. Basic endovascular skills for trauma course: bridging the gap between endovascular techniques and the acute care surgeon. *J Trauma Acute Care Surg*. 2014; 77(2):286–291.
46. Villamaria CY, Eliason JL, Napolitano LM, Stansfield RB, Spencer JR, Rasmussen TE. Endovascular Skills for Trauma and Resuscitative Surgery (ESTARS) course: curriculum development, content validation, and program assessment. *J Trauma Acute Care Surg*. 2014;76(4):929–935; discussion 35-6.

DISCUSSION

Dr. John B. Holcomb (Houston, Texas): First, let me say I'm a believer in this problem. We started doing REBOA at our center exactly for this issue. Dr. Dianne Schwartz published a paper describing our IR time to embolization experience where we documented a much longer time to embolization on nights and weekends, which was associated with increased mortality.

I agree totally with the authors. Hemorrhage control is important and four hours for a life-saving intervention is unacceptable. So the question is, what do we do to solve the problem? The authors have provided a little bit of an exploration of this problem at the end of their presentation. And I will just make some comments.

Trauma centers were established in the '60s and '70s and were designed largely for penetrating injury. Move forward four to five decades and I think we all recognize most of our patients don't have that problem.

Who enjoys going from the ED, the OR, the ICU, to CT scan, back and forth to IR in that travel that happens at two o'clock in the morning? It's very painful for patients, staff, and is associated with increased mortality and largely associated with the multi-system blunt injured patient.

Wouldn't it be nice to go from the ED to one place, like a trauma hybrid OR, and solve all these problems in one place and then deposit the patient safely in the ICU, or some variation on that theme?

I am aware of the Baltimore group's interest in hybrid ORs and the REBOA technology. Dr. Brenner has a paper at this meeting describing the acute care surgeon's approach to emergency angiography and embolization and 11 of her cases were in pelvic embolization.

Is this the answer? Or can we suggest the IR physicians take in-house IR call? Not at my center. Can we enforce the 30-minute response time? Who came up with 30 minutes when somebody is really bleeding hard? That's too long.

Isn't it time to make time-to-embolization, and importantly, time-to-hemostasis for these patients a quality indicator for all trauma centers just like time to time to thrombolytic therapy is for hospitals taking care of acute MI and stroke patients?

For the massively injured blunt trauma patient I think the answer is we take the patient to one location in the hospital and take care of the patients with a scalpel and a sheath, as Dr. Brenner proposes in her paper tomorrow. This is the future of acute care surgery and I hope we can all craft our specialty along these lines.

So I have just a few questions.

Ten years is a long time for a retrospective review, introducing substantial change in the practice. Did you see a change in IR times during this time period? And were any of the changes in times during the time period associated with differences in mortality?

Was there a change in IR faculty's approach to the problem? And did something change in the way they did this because you guys used to talk about very rapid IR times at your facility.

And I didn't notice the use of REBOA in your data. Can you explain that? Thank you for the opportunity to review the paper and the privilege of the podium.

Dr. Eileen M. Bulger (Seattle, Washington): While I agree with you that the future is the hybrid operating room, a lot of hospitals don't have that capability. I think it's really important to think about how we can address these systems issues in our current environment as we work towards the future.

I think there are two key things that come out of your presentation to me. One is we should stop taking unstable patients to the CT scanner. We talk about it and then we do it anyway. I think we need to address that as a system. You talked about the unreliability of a FAST exam, maybe the DPL shouldn't be dead.

The second issue is, as John alluded to, this needs to be a QA metric for us. Just like we measure door-to-balloon time for a STEMI we need to measure door-to-puncture time or door-to-hemostasis time in these patients.

We've been doing that in our center and it has driven our interventional radiologists to be more responsive and more engaged and our times are no where near the four hours that you are describing.

I think we need to think about these system solutions to these problems as we move to the future of the hybrid OR. Thank you.

Dr. Matthew Wall, Jr. (Houston, Texas): I enjoyed your presentation with the message that even in well-run centers it takes us longer to do things than we think sometimes.

My question is do you think a hybrid suite is required? Our service at a county hospital doesn't have a hybrid suite. For a few critically-unstable patients we have brought them to the operating room to lap them and do pelvic packing.

Simultaneously, the acute care surgeon could get access and do a flush aortogram and that gives time for the vascular surgeon to come in to do the embolization.

The C-arm also have the advantage that you are not tied to a given room that might be busy when you need it. So one might argue that a hybrid suite might not be mandatory.

Dr. David Harrington (Providence, Rhode Island): Right after this long period of study, what was the rate of needing an internal ligation of artery? I know we don't like to think about "unleashing the hounds" and getting that retroperitoneal hemorrhage going, but did it change over time?

I would also, as Dr. Bulger mentioned, not advocate taking hypotensive patients to CT scan. If you just move quickly though, I know as we can't bring our VIR colleagues alone, sometimes we have to do what is right for the patient and even though it is not the ideal the old-fashioned laparotomy and closing off the internal iliacs is an option. Did that change over time in your study?

Dr. Babak Sarani (Washington, D.C.): As Dr. Holcomb alluded, the Orange Manual now stipulates a 30-minute response time for an interventional radiologist to be physically present at the bedside—and I think state verification standards will shortly follow suit. So my question is there really a need to further pursue this?

At 30 minutes time, whether it is an acute care surgeon performing the angio or an interventional radiologist performing the angio we will have hemorrhage control. Thirty minutes is not very long when you are trying to resuscitate a patient.

Dr. Ronald Tesoriero (Baltimore, Maryland): I would like to thank Dr. Holcomb for his insightful comments and questions and all the questions from the floor.

In response, ten years is a long time for a retrospective review. But we wanted to make sure we had enough patients for a problem that occurs only about three times per month.

Over that entire study period there was really no significant times in the response times to interventional radiology/angiography. And if you look at the 60 patients that were admitted in the last two years of the study, there was no difference.

Their ISS was the same. Their transfusion rate was the same. Their hemodynamic instability was the same. And the times were exactly the same with the same rates of mortality and the same rates of outcomes.

There has been really no difference in the approach that I can find to our interventionalists to how they approach this problem.

We are staffed with six interventional radiologists who actually cover four different hospitals so we have two interventional radiologists at our institution during the days and one at night who is covering more than one institution.

We have five angio suites with one specific trauma suite. And that really hasn't changed during the study time period.

And I think, frankly, we were quite surprised that our times were this long. And I think most people that would have looked at this are surprised that their times are as long as they are.

In response to Dr. Bulger's question, we should stop taking unstable patients to the CT scan but it's really a reflection of our, how good we are at resuscitating the patients. We often resuscitate them to some degree of stability for a period of time.

It's also a reflection of our desire not to be wrong. Nobody wants to be in the angio suite if we need to be in the operating room and vice versa.

FAST isn't very good. And I think, as your point is, DPA is underutilized in our series and probably in most series at identifying these patients.

In response to Dr. Wall's question, most patients aren't going to have a hybrid operating room and a hybrid operating room is what you make it. It can be an OR with a C-arm and the ability to do angiography; although I will say it is technically difficult to do advanced embolization techniques using just a C-arm.

Additionally, there are, you know, the series out of Denver Health have shown that peritoneal pelvic packing is a viable alternative embolization. They showed a low mortality and a low rate of requirement for subsequent embolization in those patients.

What we don't know is long-term outcomes. We know that they have about a 15% rate of pelvic infection after the procedure but we have no idea what the ultimate rates are on urinary or sexual dysfunction when you pack a bunch of rags against the nerves in that region.

In regard to Dr. Harrington's question, there are very few patients that underwent internal artery ligation. It was generally patients that were so unstable when they got to the operating room that their pelvic hematoma had ruptured and necessitated direct arterial intervention.

And as far as Dr. Sarani's question, I think one of the points I wanted to bring out in this presentation is that how many of these patients that die have a source of hemorrhage other than the pelvis.

Even if you can get them to angio in 30 minutes they often need to be someplace else. And so I think the right place for all of these patients is the operating room where you can be extremely flexible in what decisions you make and which way you go in your algorithm to care for these patients.