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Preperitoneal pelvic packing reduces mortality in patients with life-threatening hemorrhage due to unstable pelvic fractures

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Abstract

Background—A 2015 AAST trial reported a 32% mortality for pelvic fracture patients in shock. Angioembolization (AE) is the most common intervention; the Maryland group revealed time to AE averaged 5 hours. The goal of this study was to evaluate the time to intervention and outcomes of an alternative approach for pelvic hemorrhage. We hypothesized preperitoneal pelvic packing (PPP) results in a shorter time to intervention and lower mortality.

Methods—In 2004 we initiated a PPP protocol for pelvic fracture hemorrhage.

Results—During the 11-year study, 2293 patients were admitted with pelvic fractures; 128 (6%) patients underwent PPP (mean age 44 ± 2 years and ISS 48 ± 1.2). The lowest emergency department SBP was 74 mmHg and highest heart rate was 120. Median time to operation was 44 minutes and 3 additional operations were performed in 109 (85%) patients. Median RBC transfusions prior to SICU admission compared to the 24 postoperative hours were 8 versus 3 units ($p<0.05$). After PPP, 16 (13%) patients underwent AE with a documented arterial blush.

Mortality in this high-risk group was 21%. Death was due to brain injury (9), multiple organ failure (4), pulmonary or cardiac failure (6), withdrawal of support (4), adverse physiology (3), and Mucor infection (1). Of those patients with physiologic exhaustion, 2 died in the OR at 89 and 100 minutes after arrival while 1 died 9 hours after arrival.

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Conclusions—PPP results in a shorter time to intervention and lower mortality compared to modern series utilizing AE. Examining mortality, only 3 (2%) deaths were attributed to the immediate sequelae of bleeding with physiologic failure. With time to death under 100 minutes in 2 patients, AE is unlikely to have been feasible. PPP should be employed for pelvic fracture related bleeding in the patient who remains unstable despite initial transfusion.

Background

Despite advances in the care of the critically injured patient, mortality rates for patients with hemodynamic instability due to pelvic fractures remain greater than 30% in modern series (1–8), with up to one-third of patients dying due to uncontrolled hemorrhage (9–13). The most recent analysis, a multicenter observational study by the American Association for the Surgery of Trauma (AAST), reported a 32% mortality rate for complex pelvic fracture patients who presented in shock (14). The majority of trauma centers in that study, and in the United States, emphasize angioembolization (AE) for primary hemorrhage control (14–16). While angioembolization is effective in controlling arterial sources of hemorrhage, it does not address the venous or bony hemorrhage within the pelvis (17). Ideally, diagnostic angiography of the pelvis would be performed in a hybrid operating room while addressing other sources of acute blood loss, as well as restoring pelvic bony stability, in the multiply injured patient. This, however, is not currently a reality in many trauma centers. Additionally, time to arterial hemorrhage control using AE, even in the most advanced level I trauma centers with hybrid facilities requires 3–5 hours to accomplish, particularly on nights and weekends (18,19).

Preperitoneal pelvic packing (PPP) combined with external fixation (EF) has been advocated to rapidly arrest hemorrhage, facilitate other emergent operative procedures, and provide an efficient use of AE (19–26). We implemented PPP because despite protocolized care utilizing hemostatic resuscitation, pelvic stabilization, and emergent angiography (34), patients continued to die acutely of hemorrhage. Several international studies have reported equivalence (24,27) or a reduction (28,29) in mortality in patients undergoing PPP compared to AE. The goal of this study was to evaluate the time to intervention and outcomes of an operative approach to hemorrhage from pelvic fractures. We hypothesized direct PPP results in a shorter time to intervention and lower mortality in our institution.

Methods

Since September 2004, all patients at our American College of Surgeons-verified and state certified level-I urban trauma center (Rocky Mountain Regional Trauma Center at Denver Health) with persistent hemodynamic instability despite red blood cell (RBC). transfusion and a pelvic fracture underwent PPP/EF, according to our protocol (Figure 1); local expertise with resuscitative endovascular balloon occlusion of the aorta (REBOA) was introduced to the protocol in January 2015. Indication for PPP is persistent systolic blood pressure (SBP) <90 mmHg in the initial resuscitation period despite the transfusion of 2 units of packed RBCs. Initial stabilization of the pelvis is performed in the emergency department (ED) with pelvic sheeting or a binder. Skeletal fixation of the pelvis with an external fixator or pelvic C-clamp is done concurrent with PPP in the operating room (OR). Additional operative procedures such as thoracotomy or laparotomy for hemorrhage were performed at the initial PPP operation as indicated. Patients with pre-hospital arrest or those undergoing ED resuscitative thoracotomy were included for descriptive purposed but excluded from the analysis.

Our technique of PPP has been described previously (20,30). Angiography is performed for ongoing pelvic bleeding, defined as 1) greater than 4 units of RBCs after the patient's coagulopathy is corrected or 2) ongoing hemodynamic instability despite PPP/EF. Restoration of coagulation is guided by thromboelastography (31). Pelvic pack removal is performed at 24–48 hours once physiologic restoration is complete. Repacking of the pelvis is avoided due to infectious risks.

All patients undergoing PPP/EF have been prospectively followed since the initiation of PPP as our primary hemorrhage control technique for unstable pelvic fractures. The study period for this analysis encompassed an 11 year period from September 1, 2004 to September 1, 2015. An initial report on the first 5½ years of experience was published in 2011 (21). Patient demographics, admission physiology, transfusion requirements, need for angiography, and hospital course were reviewed. The Young and Burgess classification was used to categorize fracture patterns (32). Normally distributed data are expressed as mean (standard error of the mean); non-normally distributed data are expressed as median (range). The Colorado Multi-Institutional Review Board approved this study.

Results

During the 11 year study period, 138 (6%) consecutive patients in refractory shock underwent PPP/EF among 2293 patients admitted with pelvic fractures. The majority (70%) of patients were severely injured men, with a mean age of 44 ± 2 years and mean ISS of 48 ± 1.2. The most common mechanism was motor vehicle collision (42), followed by an auto-pedestrian accident (37), motorcycle collision (27), fall (12), crush injury (9) and other (11).

Patients with Prehospital Arrest/Emergency Department Resuscitative Thoracotomy

Of the 138 patients who underwent PPP, 10 patients had prehospital arrest and/or underwent ED resuscitative thoracotomy. The majority (60%) of patients were men, with a mean age of 45 ± 4 years and mean ISS of 56 ± 4. Mechanisms of injury included auto-pedestrian accident (5), motorcycle collision (2), motor vehicle collision (1), fall (1), and bicycle crash (1). Plain radiographs were obtained in 7 patients; pelvic fracture classification included LCIII (4), LCII (2) and LCI (1) patterns. Survival rate to hospital discharge was 30%; all underwent EDT. Of those who died, one patient survived 11 days in the ICU only to succumb to multiple organ failure. The remaining 6 patients died within the first 24 hours. There was no significant difference in age, ISS, length of time in the ED, or number of RBCs transfused in the ED between survivors and non-survivors.

Hemodynamically Unstable Patients with Pelvic Fractures

For the remaining 128 patients, 70% were men with a mean age of 44 ± 1.7 years and a mean ISS of 48 ± 1.2. Pelvic fractures patterns included APC III (29), LC II (26), LC III (20), APC II (20), LC I (13), vertical shear (14), APC I (4) and CM (2). Of these, 18 patients had open pelvic fractures. In addition to their pelvic injuries, 43% of patients had associated head injuries, 65% thoracic injuries, 63% abdominal injuries, 70% extremity injuries, and 38% spine injuries. Mean emergency department SBP was 74 ± 2 mmHg and heart rate was 120 ± 2. Mean base deficit in the emergency department was 12 ± 5, however, 41 (32%) patients did not have an arterial blood gas recorded during this time. Following the introduction of REBOA in January, 2015, 3 out of 7 patients undergoing PPP had a REBOA placed in the ED. Median time to operation was 44 minutes (range 0–274) and an additional 3 ± 0.2 operative procedures were performed in 109 (85%) patients in addition to PPP/EF. Median blood transfusion requirements prior to SICU admission compared to the subsequent 24 postoperative hours were 8 units versus 3 units; $p<0.05$. FFP:RBC ratio was 1:2. Overall mortality for all 2293 pelvic fracture patients was 8%; in this group with refractory shock there was a 21% overall mortality rate with 2% of patients dying within hours of admission due to physiologic exhaustion.

Angiography and Therapeutic Embolization

During the study period, 35 (27%) patients underwent diagnostic angiography after PPP. Angiography was performed in 31% of patients during the first half of the study and 23% of patients in the second half of the study. Of these, 16 (13%) patients underwent AE with a documented blush; 19 of 35 (54%) patients undergoing diagnostic angiography had no evidence of arterial bleeding. The mean time to the need for AE was 10 hours after admission (601 minutes ± 200 minutes; range 175 to 2280 minutes). Of those undergoing angioembolization, pelvic fractures classifications were LC I (4), APC III (2), LC II (4), LC III (2), APC II (2), and vertical shear (2). Empiric embolization was performed in 7 of the 19 patients without evidence of a blush at angiography. One patient with empiric embolization of bilateral internal iliac arteries developed perineal necrosis (Figure 2).

There were no significant differences in age, ISS, presenting hemodynamics (SBP, base deficit), or ED blood product transfusions between those who had an arterial blush at angiography (AE group) versus those that did not undergo AE (NA group). The only variable that reached statistical significance was a *lower* emergency department HR in the AE group compared to those patients not undergoing angiography (AE group 110 ± 6 beats/min versus NA group 121 ± 3 beats/min; $p=0.05$). The AE group did receive more RBCs and fresh frozen plasma (FFP) pre-SICU admission (AE group 14 ± 2.5 units RBCs and 8 ± 1.6 units FFP versus NA group 9 ± 0.8 units RBCs and 4 ± 0.5 units FFP) and more RBCs and FFP in the subsequent 24 hours (AE group 8 ± 1.6 units RBCs and 5 ± 1.0 units FFP versus NA group 3 ± 0.5 units RBCs and 2 ± 0.4 units FFP) than the NA group. No patient undergoing diagnostic angiography or angioembolization died from acute blood loss or early physiologic derangements.

Pelvic Space Management and Complications

The majority (84%) of patients underwent a single operative packing of the preperitoneal space. Over the study period, 20 (16%) patients underwent repacking of the pelvis when returned to the OR; indication for repacking of the pelvis was persistent oozing deep in the preperitoneal space upon pack removal. All of the patients who had repacking of the pelvis occurred prior to July 2011. In these 20 patients, repeat packing was performed in 1 patient returned to the OR within 12 hours, 5 patients returned to the OR between 12–24 hours, and 14 patients between 24–48 hours.

There were 15 (12%) pelvic space infections. Four infections (3 polymicrobial, 1 Bacillus) occurred in patients with open fractures or those with perineal degloving injuries (n=6); one patient underwent hardware removal 26 months postinjury. Four infections developed in patients with associated bladder injuries (E. Coli, Candida, stenotrophomonas/Enterococcus/Candida, and Enterococcus/E. Coli); none of these patients required hardware removal. Seven pelvic space infections occurred in patients without bladder or bowel injuries (Enterobacter/Enterococcus, Pseudomonas/Staphlycoccus, Staphlycoccus, MRSA, Enterobacter, Acinetobacter, and polymicrobial); two patients had hardware removed at 38 days and 16 months postinjury. There was a difference in pelvic space infection rates between those patients requiring repacking of the pelvis (9 out of 20 patients – 45%) and those who had a single packing of the pelvis (6 out of 108 patients – 6%).

Patient Outcomes

Overall, patients required 4 ± 0.3 units of PRBCs during their median ED course of 44 minutes. Median blood transfusion requirements prior to SICU admission compared to the subsequent 24 postoperative hours were 8 units versus 3 units ($p<0.005$). Transfusion of FFP to RBC ratio was 1:2. Patients required a mean of 12 ± 0.9 days of mechanical ventilation and remained in the surgical intensive care unit for 15 ± 1.1 days. Overall length of hospital stay was 25 ± 1.7 days. Excluding those who died, patients required a mean of 14 ± 1.1 days of mechanical ventilation and had ICU and hospital lengths of stay of 17 ± 1.2 and 31 ± 1.8 days respectively.

Overall mortality for all 2293 pelvic fracture patients during the study period was 8%, with 27 patients (21%) dying in this high-risk group of 128 patients. Fracture classification of those who died included LC II (7), LC I (7), LC III (5), APC III (4), APC II (2), APC I (1), and CM (1). Death was due to traumatic brain injury (9), multiple organ failure (4), withdrawal of support by family (4), pulmonary failure (3), cardiac failure (3), refractory metabolic collapse (3), and invasive Mucor infection (1). Of those three (2%) patients with physiologic exhaustion, two died in the OR at 89 min and 100 minutes after hospital arrival while one died in the ICU 9 hours after arrival.

The three patients that died acutely of refractory metabolic exhaustion had significant physiologic derangements. The first patient was an 18 year old woman who sustained an LC1 fracture as well as a grade V liver and a grade V renal injury. In addition to PPP she underwent nephrectomy and liver packing. She had a pH of 6.9 and a base deficit of 30 mmol/L and went into ventricular fibrillation in the operating room 100 minutes after arrival; despite a resuscitative thoracotomy and heroic efforts she died. The second patient was a 42 year old man transferred from an outside facility with an LC II fracture. En route via helicopter he was receiving his 6th unit of RBCs. In the operating room his blood pressure initially stabilized following PPP; labs revealed a pH of 7.0, base deficit of 17, lactate of 23, and INR of 5.4. Soon thereafter he arrested, 89 minutes after arrival. The third patient was a 48 year old man with an APC III fracture who despite an apparent isolated pelvic injury developed an uncontrolled coagulopathy. He had a pH of 7.0, base deficit of 20 and his INR was 8.5. His TEG never normalized prior to his death in the SICU.

There were no differences in ISS, presenting SBP, presenting HR, ED base deficit, time in the ED before PPP/EF, RBC transfusion in the ED, or number of additional procedures performed between those patients who lived versus those who died. FFP:RBC transfusion ratios were similar between the two groups (alive group, pre-SICU transfusion ratio of 1:2 versus dead group ratio of 1:2; alive group, subsequent 24 hour transfusion ratio of 1:1.5 versus dead group ratio of 1:1.1). There was a difference between the two groups in mean patient age (alive 42 ± 1.7 years versus dead 53 ± 3.8 years), RBC transfusion pre-SICU admission (alive 8 ± 0.6 units versus dead 16 ± 1.9 units) and in the subsequent 24 hours (alive 3 ± 0.4 units RBCs versus dead 8 ± 1.5 units RBCs).

Discussion

The purpose of this study was to evaluate the time to intervention and outcomes of an alternative approach to emergent AE for uncontrolled hemorrhage from pelvic fractures. Our group has had an interest in complex pelvic trauma since the early 1980s (35) and we have critically reviewed our management over the past four decades. Following that initial 1986 publication, we implemented a multidisciplinary clinical pathway in the 1990s which incorporated hemostatic resuscitation in a 1:1:1 ratio, pelvic stabilization, and emergent angiography (34). Despite a marked reduction in mortality, we continued to have patients die acutely of hemorrhage. Having heard of its success in Europe, we adopted and modified the technique of pelvic packing combined with external fixation (30). Patients with refractory shock, defined as persistent hypotension despite 2 units of RBC transfusion, were transported for PPP/EF. Median time to operation in this group was 44 minutes. Following PPP/EF there was a significant reduction in RBC transfusion in the 24 hours post-operatively compared to pre-SICU period. The 13% of patients treated with post-packing AE were temporized and resuscitated; AE was performed a mean of 10 hours after presentation. All cause mortality in this multiply injured patient cohort was 21% with only 2% of the cohort dying acutely of physiologic exhaustion.

PPP as the first intervention for hemorrhage control in pelvic fracture patients with refractory shock has been advocated due to the recognition that 85% of the bleeding is not arterial (17). Furthermore, PPP has the advantage of immediacy and rapidity of the procedure (25–27). A small, quasi-randomized (based upon time of day the patient presented) study of 56 hemodynamically unstable patients demonstrated a significantly faster time to operative packing and a shorter procedure duration compared to the angiography group (27). A similar finding was reported in a small study of 24 patients from China; time to packing was 79 minutes while time to angiography was 140 minutes (24). Time to emergency angiography in a Korean evaluation of PPP was 194 minutes compared to 55 minutes with operative intervention (3). Our group previously demonstrated that time to packing was significantly faster than time to angiography, with angiography taking three times longer despite interventional radiology availability at a level I trauma center (33). Our time to PPP in the current study, 44 minutes, is within the framework of these international publications. When compared to the time to angiography of 286 minutes (18) and 193–301 minutes (19) reported in the two most recent AE series, PPP is faster.

Timing to arrest of pelvic fracture hemorrhage is only one variable in the complex equation surrounding pelvic fracture management; the availability and location of angiography may also be a complicating factor. Ideally a complex pelvic fracture patient in hemorrhagic shock is transported to a hybrid operating room. This should be the standard for every level I trauma center as it enables the clinicians to perform any operative or endovascular procedure warranted. Unfortunately, this is not a reality in many trauma centers; the ability to perform AE is often housed in interventional radiology which is geographically separate from the operating room. In these scenarios, PPP affords one the ability to address pelvic hemorrhage while also addressing other needed urgent patient interventions such a laparotomy, thoracotomy, fasciotomy, extremity vascular reconstructions, and fracture fixation. In fact, the vast majority of patients in our study required at least three additional procedures at the time of the initial PPP/EF. Transporting a patient to the angiography suite limits or delays other essential operations.

There is a subset of patients that benefit from complementary AE. In our experience, 13% of patients underwent therapeutic AE following PPP/EF. This is not surprising as PPP may temporize arterial bleeding but does not directly address it, particularly as vasospasm resolves with resuscitation. PPP aids in stabilizing the patient to afford the time window for angiography to be performed. Time to angiography in this study, 10 hours following admission on average, is reflective of that stabilization period. As AE was not considered a primary goal, and was only performed once the patient was transfused at least 4 units of RBCs post-packing, this is a descriptive variable rather than a recorded time to intervention variable. With a mean time to angiography of 10 hours, patients can undergo additional necessary operative procedures and even be transported to level I trauma centers to undergo endovascular interventions. This stabilization following PPP is apparent in the transfusion requirements in the pre-SICU period compared to the 24 hour post-operative period. There was a significant reduction in the number of RBCs required following PPP/EF.

More recently the reduction in mortality rates with PPP has been emphasized. In fact, our original impetus to change our pelvic fracture management algorithm (34) in 2004 was to lower our mortality rate further. Despite active involvement by the trauma and orthopedic services with clear protocols including pelvic stabilization and hemostatic resuscitation, as well as excellent angiographers, we still had patients that were dying on the angiography table. All of the comparative studies on PPP to date are small, single institution, internal analyses of available techniques. A single center, longitudinal study identified a drop in mortality through three phases of management: 64% mortality during the preangiography phase, 42% in the angiography phase, and 31% in the PPP phase (28). On multivariate analysis, PPP was a significant independent predictor for 24 hour survival. A similar reduction in mortality was identified with the institution of PPP, from 38% in the non-PPP group to a 14% mortality rate due to acute hemorrhage over a 3 year study (3). Interestingly, those who died due to acute hemorrhage in the PPP group had actually undergone angioembolization first only to require packing for ongoing hemorrhage and instability. In a propensity matched, comparative study of hemodynamically unstable pelvic fracture patients, mortality was significantly reduced with PPP compared to no-PPP (20% vs 52%) (29). This cohort of patients was multiply injured, evidenced by an ISS > 40 for both groups and associated injuries in over 70%. Additional studies demonstrate mortality reduction rates of over 30% with PPP compared to AE but the findings are not significant due to small patient numbers (24). Our own internal comparison of 20 patients undergoing PPP and 20 patients requiring AE demonstrated a faster time to intervention and a decrease in blood transfusions; mortality in the AE group was 30% with two patients dying of acute hemorrhage while mortality in the PPP group was 13% and none died of acute hemorrhage (33). Other groups report equivalent mortality rates between AE and PPP, but deaths due to exsanguination only occurred in the AE group (27).

Since all of the aforementioned studies of PPP have an internal comparison of management strategies, what comparative group would provide a reasonable analysis to our single institution series on PPP? As we have adopted PPP as our primary intervention for pelvic fracture patients with refractory shock, we felt a comparison to the modern management of a similar group of patients in US trauma centers was appropriate. The recently published AAST prospective multicenter study is an evaluation of the current day management of pelvic fractures by 11 US trauma centers (14). Of the 1,339 patients enrolled, only 178 patients met the criteria for shock defined as a SBP < 90 mmHg, HR > 120, or BD > 6. Of these, 84% received at least 1 unit RBC transfusion. Mortality in this group was 32% which is markedly higher than our reported mortality rate of 21% with PPP.

Is the comparison to the AAST multicenter study a good or valid one? First, contemporary prospective observational studies provide a benchmark of current practice standards. Second, our patients were more severely injured (Table 1). The AAST group we used for comparison were the 178 patients defined to be in shock: SBP < 90 mmHg, HR > 120, or BD > 6. In reality, though, our study population consists of 128 patients who are in refractory shock despite 2 units of RBCs. This group appears to be a more physiologically deranged group with a higher ISS. The mean vital signs of the AAST group were a SBP of 91 mmHg and HR of 116; the reported BD of 10 must have been the primary determinant of the classification of shock in this group for the majority of patients. Our group had a mean SBP of 74 mmHg and HR of 120. ISS was markedly different between the groups (AAST = 28 versus our PPP group = 48); interestingly, the range of ISS scores for the AAST group was reported to be 17–38. Despite the differences in study population, the AAST study is the most current representation of modern day pelvic fracture management in the United States. As such, it is our best point of comparison despite the acknowledged limitations.

An alternate comparison is to a modern day series of pelvic fracture patients undergoing angiography (18). Indications for angiography in this study included contrast blush on CT scan (32%), pelvic hematoma (30%), and hemodynamic instability defined as a SBP < 90 mmHg (33%). With such a wide range on intervention “triggers”, identifying a subset of this study group that is similar to our study population is critical. For those presenting with hemodynamic instability, mortality was 28% while those patients receiving a massive transfusion, defined as 10 units of RBCs in the first 24 hours, had a mortality rate of 41%. Our mean transfusion requirements in the PPP group were > 10 units of RBCs in the first 24 hours.

One of the difficulties of any analysis of pelvic trauma management is reflected in patient populations. Each study may have a slightly different interpretation of what constitutes hemodynamic instability or which patient should undergo an intervention for pelvic bleeding. For example, shock as defined by the AAST study was a slightly different population compared to our PPP group. Even when we compare our outcomes with PPP to our original report in 2001 on pelvic fracture management, the study populations are not comparable. The study population in the 2001 report had an ISS of 28 and only 52% had a SBP < 90mmHg. Additionally, mortality rates may be attributed to all causes of mortality versus only those related to acute hemorrhage. Only by delving into the specifics of the data on any one study will this become apparent. For example, our overall mortality rate was 21% but only 2% of the patient population expired in the first 24 hours due to adverse physiology. As is true in any series, overall mortality is multifactorial and the impact of early hemorrhagic shock can impact late causes of mortality such as cardiopulmonary failure and MOF. Finally, as is true of many published series, this is a single institution's report and has the inherent limitations therein.

Our prospective observational study of patients with complex pelvic fractures permits one to reflect on the lessons learned. Technical aspects of the procedure are perhaps the easiest to incorporate. Early activation of the trauma and orthopedic teams is essential. Rapid transport to the operating requires active involvement of both teams. External fixation prior to PPP provides stabilization of the bony pelvis, reduces the pelvic volume for packing, and permits removal of sheeting or binders that often can hinder a sterile procedure. The anterior bar of the external fixator should be rotated to permit access for the PPP incision and can be placed either high or low above this space. If an associated laparotomy is performed, the fixator bars should be positioned low across the pelvis to permit free access to the abdominal contents. Laparotomy incisions should be made separate from the packing space, optimally above the umbilicus to prevent entering the pelvic hematoma. Early recognition or concern for a urethral injury while in the ED is critical. Blood at the meatus, inability to pass the foley catheter, or placement of the catheter through the urethral injury into the pelvic hematoma with decompression of frank blood should all herald the need for placement of a suprapubic tube (SP). The SP tube should be placed at the time of PPP. It should ideally exit the fascia and skin through a separate stab incision, rather than through the midline, due to its long-term need. It should be placed following pack placement but before closure of the midline fascia. It may be necessary to delay positioning of the final anterior pack until after the SP tube is in place. Drainage of the bladder during this first exploration for PPP is imperative. Unpacking the pelvis to gain access to the bladder may result in recurrent bleeding, while allowing urine to leak through the urethral injury into the pelvic space is suboptimal; Foley decompression also permits accurate urine output recording to guide resuscitation. Division of labor by the available teams is a key component; with both the orthopedic and trauma teams able to perform PPP, the actual procedure can be relegated to the team with less urgent other necessary procedures. For example, if the patient needs a laparotomy, the trauma team does the abdominal exploration while the orthopedic team performs PPP. If the patient needs bilateral fixation of lower extremity fractures with washout, the trauma team performs PPP while the orthopedic team focuses below the inguinal ligament.

Following PPP, some management principles have been gleaned. First, identifying associated injuries, which are common in these critically ill patients, is paramount; once the patient stabilizes, urgent CT scanning should be performed, ideally directly from the operating room. Timing of diagnostic angiography is based upon the number of RBCs transfused acutely; however, this count should start after the patient's coagulopathy has been corrected and should be due to a pelvic source. For example, a patient with an uncorrected TEG who also has significant chest tube output or oozing from their open abdomen via Jackson-Pratt drains in the temporary abdominal dressing is not necessarily the candidate for angiography. The patient with a normalized TEG who then receives more than 4 units of RBCs in the first 12 hours in the SICU without a clear extra-pelvic source should undergo diagnostic angiography. If angiography is negative, empiric embolization of bilateral internal iliac arteries should be carefully weighed against the risks of pelvic claudication and perineal necrosis. In an attempt to limit the infectious morbidity of PPP, repacking of the pelvis should be avoided. Patients should not be returned for pack removal until they are physiologically replete and their coagulopathy resolved. Pack removal should involve the trauma team at a minimum so that bleeding may be controlled with direct ligation or topical agents as necessary. Rarely, large venous injuries are encountered at unpacking and may require reconstruction.

Finally, why are patients continuing to die in the immediate 24 hours after injury? Three (2%) patients' deaths were attributed to physiologic exhaustion with marked derangements in their laboratory values. With time to death under 100 minutes in two of those patients, AE is unlikely to have been feasible. The advent of REBOA may have been helpful to temporize the patient with pelvic hemorrhage as the predominant source. Early anecdotal experience with the use of REBOA has shown promise, particularly in this subset of patients; future reports will undoubtedly describe the role and limitations of this developing technology. Similarly, utilization of hybrid operating rooms only expands the available hemorrhage control options in the exsanguinating patient. Expanded training of trauma surgeons to perform endoluminal interventions would serve as a natural corollary.

PPP is advocated as the first-line treatment for pelvic fracture patients with persistent hemodynamic instability; multiple algorithms incorporating pelvic packing as the primary technique followed by postoperative AE when necessary have been published in the international literature (13, 24–26,29). Our study echoes these reports. PPP has a faster time to intervention for pelvic fracture related hemorrhage. Arterial bleeding was present in only 13% of patients, rendering angiography of limited utility. Outcomes with PPP appear to have a reduction in mortality compared to management schema that does not include PPP.

Despite this reduction in mortality, PPP should not be adopted for use in all pelvic fracture patients; this invasive procedure should be reserved for the patient in refractory shock despite hemostatic resuscitation. We feel this "trigger" for intervention for pelvic fracture related bleeding, hypotension despite 2 units of RBCs, is a reasonable one. Would these patients have stopped bleeding if we had simply continued to transfuse them? That is hard to say. The mean transfusion was 4 units of RBCs in the ED and the patients remained hypotensive. The "trigger" for angiography at other institutions includes a pelvic hematoma, a blush on CT scan in a stable patient, a SBP < 90mmHg regardless of transfusion requirements, or for the first unit of RBCs transfused (18). A similar statement could be made of patients undergoing AE; perhaps they didn't need the intervention and simply would have stopped bleeding. In the end, we feel we need a "trigger" to intervene for pelvic fracture related bleeding and believe ours is a reasonable one. In our experience, only 6% of all patients with pelvic fractures required this life-saving intervention. PPP should be utilized for pelvic fracture related bleeding in the patient who remains hemodynamically unstable despite initial blood transfusion.

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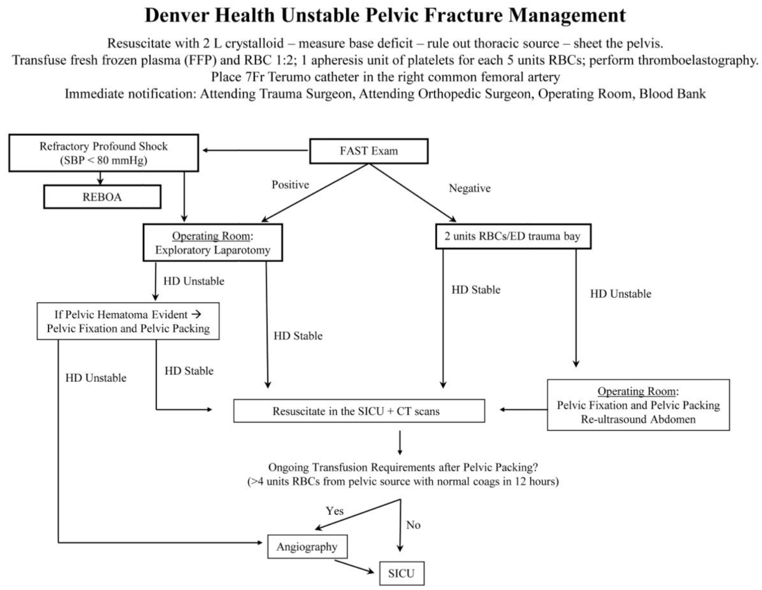

Figure 1.

Management algorithm for patients with hemodynamic instability with pelvic fractures.

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Figure 2.
Perineal necrosis following empiric embolization of bilateral internal iliac arteries.

Table 1

Comparison of available demographics of the AAST study population (14) to this PPP/EF study population. Variables presented as mean ± standard deviation.

	Denver Study of PPP/EF	AAST Study Population Patient Admitted in Shock
n (% of all pelvic fracture patients)	128 (6%)	178 (13%)
Age, y	44 ± 19	44 ± 20
Male, n (%)	90 (70%)	105 (59%)
ISS	48	28
Mechanism, n (%)		
Motor vehicle crash	41 (32%)	76 (43%)
Pedestrian vs. auto	32 (25%)	34 (19%)
Fall	11 (9%)	31 (17%)
Motorcycle crash	25 (19%)	28 (15%)
Crush	9 (7%)	2 (1%)
Other	10 (8%)	7 (4%)
SBP in ED (mmHg)	74 ± 18	91 ± 34
HR in ED (bpm)	120 ± 23	116 ± 30
Base deficit	12 ± 5	10 ± 6
Patients requiring RBCs	128 (100%)	150 (84%)
Mortality, n (%)	27 (21%)	57 (32%)