Preperitoneal Pelvic Packing/External Fixation with Secondary Angioembolization: Optimal Care for Life-Threatening Hemorrhage from Unstable Pelvic Fractures

Clay Cothren Burlew, MD, FACS, Ernest E Moore, MD, FACS, Wade R Smith, MD, FACS, Jeffrey L Johnson, MD, FACS, Walter L Biffl, MD, FACS, Carlton C Barnett, MD, FACS, Philip F Stahel, MD, FACS

BACKGROUND: Preperitoneal pelvic packing/external fixation (PPP/EF) for controlling life-threatening hemorrhage from pelvic fractures is used widely in Europe but has not been adopted in North America. We hypothesized that PPP/EF arrests hemorrhage rapidly, facilitates emergent operative procedures, and ensures efficient use of angioembolization (AE).

STUDY DESIGN: In 2004 we initiated a PPP/EF guideline for pelvic fracture patients with refractory shock requiring ongoing blood transfusion at our regional trauma center.

RESULTS: Among 1,245 patients admitted with pelvic fractures, 75 consecutive patients underwent PPP/EF (age 42 ± 2 years and injury severity score 52 ± 1.5). Emergency department systolic blood pressure was 76 ± 2 mmHg and heart rate 119 ± 2 beats/min. Time to operation was 66 ± 7 minutes, and 65 patients (87%) underwent 3 ± 0.3 additional procedures. Blood transfusion before PPP/EF compared with the first postoperative 24 hours was 10 ± 0.8 units versus 4 ± 0.5 units ($p < 0.05$). The fresh frozen plasma–red blood cell ratio was 1:2. After PPP/EF, 10 patients (13%) underwent angioembolization with a documented blush; time to angioembolization was 10.6 ± 2.4 hours (range 1 to 38 hours). Mortality for all pelvic fractures was 8%, with 21% mortality in this high-risk group. There were no deaths due to acute hemorrhage.

CONCLUSIONS: PPP/EF was effective in controlling hemorrhage from unstable pelvic fractures. None of these high-risk patients died due to pelvic bleeding. Secondary angioembolization was needed in a minority, permitting selective use of this resource-demanding intervention. Additionally, PPP/EF temporizes arterial hemorrhage, providing valuable transfer time for facilities without angiography. With other urgent operative interventions required in >85% of patients, combining these procedures with PPP/EF for operative pelvic hemorrhage control appears to optimize patient care. (J Am Coll Surg 2011;212:628–637. © 2011 by the American College of Surgeons)

Despite the implementation of early multidisciplinary management for patients with hemodynamic instability due to pelvic fractures, mortality remains >40%,[1-11] with one-third of patients dying secondary to uncontrolled hemorrhage.[12-15] Current management algorithms in the majority of trauma centers in the United States emphasize angioembolization (AE) for hemorrhage control.[16,17] Advocates of emergency angiography have shown the technique to be efficacious in controlling pelvic hemorrhage.[18-23] However, transporting an unstable patient from the emergency department (ED) to the interventional radiology (IR) suite may be a fatal error if the patient requires a laparotomy or thoracotomy to arrest ongoing torso hemorrhage. Additionally, AE only addresses arterial hemorrhage, not the more

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From the Department of Surgery, Denver Health Medical Center and the University of Colorado Denver, Denver, CO (Burlew, Moore, Johnson, Biffl, Barnett), Department of Orthopedics, Denver Health Medical Center, Denver, CO (Stahel); and Department of Orthopedics, Geisinger Health System, Danville, PA (Smith).

Correspondence address: Clay Cothren Burlew, MD, FACS, Director, Surgical Intensive Care Unit, Program Director, Trauma and Acute Care Surgery Fellowship, Department of Surgery, Denver Health Medical Center, 777 Bannock Street, Denver, CO 80204. email: clay.cothren@dhha.org

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Abbreviations and Acronyms

AE = angioembolization
ED = emergency department
EF = external fixation
FFP = fresh-frozen plasma
IR = interventional radiology
ISS = injury severity score
OR = operating room
PPP = preperitoneal pelvic packing
RBC = red blood cell
SBP = systolic blood pressure
SICU = surgery intensive care unit

prevalent venous or bony hemorrhage within the pelvis.[24]

Another option for emergency control of pelvic hemorrhage in patients with unstable pelvic fractures is preperitoneal pelvic packing (PPP). PPP can eliminate the often difficult decision of whether to take the patient to the operating room (OR) or the IR suite. Originally described in Europe by Pohlmann et al in Hannover[25] and Ertel et al in Zurich[26] as packing of the retroperitoneum for hemorrhage control, we have modified the technique[27,28] to ensure direct packing of the pelvic space through a preperitoneal approach. Because 85% of bleeding due to pelvic fractures is venous or bony in origin,[24] hemorrhage is often arrested only by increasing tamponade within the retroperitoneal space. The combination of external fixation (EF) and PPP address the major sources of hemorrhage by reapproximating bony edges and tamponading the venous bleeding. Additionally, by surgically packing the pelvic space, the overall potential space required to tamponade bleeding from the pelvis is markedly reduced. Moreover, in facilities where AE is not available, PPP/EF can be life saving. We hypothesized that PPP/EF arrests hemorrhage rapidly, facilitates emergency operative procedures, and ensures efficient use of AE.

METHODS

All patients since September 2004 at our American College of Surgeons–verified and state-certified level I urban trauma center (Rocky Mountain Regional Trauma Center at Denver Health) with hemodynamic instability and a pelvic fracture underwent PPP/EF according to our protocol (Fig. 1). Indication for PPP is persistent systolic blood pressure (SBP) <90 mm Hg in the initial resuscitation period despite the transfusion of 2 units of packed red blood cells (RBCs). Those patients with thoracic or abdominal sources of blood loss are taken to the operating room to address these sources in addition to PPP. Skeletal fixation of the pelvis with an external fixator or pelvic C-clamp is done concurrent with PPP. Realignment of the pubic rami is facilitated with digital assessment of their location.

Our technique of PPP has been described previously.[27,28] Briefly, a 6- to 8-cm lower midline incision is made from the pubic symphysis cephalad. The midline fascia is divided leaving the peritoneum intact. The pelvic hematoma is typically encountered on transection of the posterior fascial layer, or on blunt dissection toward the symphysis pubis. The hematoma often dissects the preperitoneal and paravesical space down to the presacral region, and minimal blunt dissection is required. PPP is performed by placing 3 standard surgical laparotomy pads on each side of the bladder, into the true pelvis below the pelvic brim (Fig. 2). The first laparotomy pad is placed deep posteriorly, with the aid of a ringed forceps, onto the sacrum after retracting the bladder to the opposite side; the deep position is confirmed manually. Then 2 additional laparotomy pads are placed anterior to this, lateral to the bladder. Occasionally the hematoma-dissected space is large enough to accommodate an additional seventh pad in the midline anteriorly. In the pediatric population, fewer laparotomy pads are required for tamponade. Suprapubic urinary catheters are placed for urethral or bladder injuries after packing but before closure of the fascia. The fascia is closed with a running O-PDS suture and the skin with staples. Patients undergoing midline laparotomy for abdominal hemorrhage should have separation of the 2 incisions, if technically feasible, to optimize PPP tamponade. Angiography is performed for ongoing pelvic bleeding after admission to the surgery intensive care unit (SICU). Patients undergo standard post-trauma resuscitative care, including restoration of coagulation guided by thromboelastography.[29] Pelvic pack removal is performed within 48 hours. The pelvis is repacked if there is persistent bleeding at the time of reoperation.

All patients undergoing PPP/EF have been prospectively followed since initiation of the technique at our institution. In addition, patient demographics, admission hemodynamics, physiologic indices, transfusion requirements, angiography results, length of SICU stay, and hospital course were reviewed. The Young and Burgess classification was used to categorize fracture patterns.[30] The Colorado Multi-Institutional Review Board exempted this study.

RESULTS

During the 5½ year study period, 75 consecutive patients underwent PPP/EF among 1,245 patients admitted with pelvic fracture. The majority (75%) of patients undergoing PPP were men, with a mean age of 42 ± 2 years. Patients were multiply injured, with a mean injury severity score (ISS) of 52 ± 1.5; in addition to their pelvic fractures, 49% of patients had associated head injuries, 67% thoracic in-

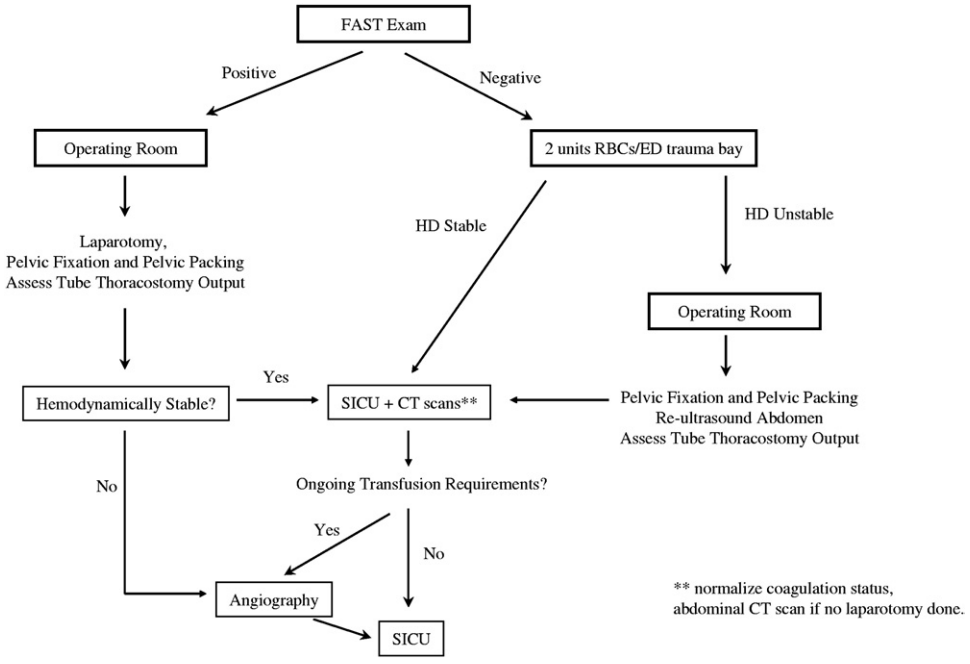

Figure 1. Management algorithm for patients with hemodynamic instability with pelvic fractures. Resuscitate with 2 L crystalloid; measure base deficit; rule out thoracic source (portable chest radiograph); sheet the pelvis. If immediate red blood cell (RBC) transfusion, discuss the role of pelvic packing (alert the operating room). Transfuse fresh frozen plasma and RBC 1:2; 1 apheresis unit of platelets for each 5 units RBCs; perform thromboelastography. Immediate notification: Attending Trauma Surgeon, Attending Orthopaedic Surgeon, blood bank resident, interventional radiology fellow. CT, computerized tomography; ED, emergency department; FAST, focused abdominal sonography for trauma; SICU, surgical intensive care unit.

juries, 65% abdominal injuries, 81% extremity injuries, and 29% spine injuries. The most common mechanism was an auto-pedestrian accident (22), followed by motor vehicle collision (21), motorcycle collision (14), fall (8), crush injury (6), and other (4). The mean ED systolic blood pressure was 76 ± 2 mmHg, heart rate 119 ± 2 beats/min, and base deficit 12 ± 0.5 mmol/L. Pelvic fracture classifications were APC III (17), LC II (12), LC III (11), APC II (11), LC I (10), vertical shear (10), and APC I (4). Six patients had open pelvic fractures.

Hemorrhage-control interventions

Time to operative intervention was 66 ± 7 minutes, and 65 patients (87%) underwent 3 ± 0.3 procedures in addition to PPP/EF. These included external fixation of long bone fractures (44), debridement of open wounds/fasciotomy (43), laparotomy (34), urologic procedures (15), extremity vascular exploration/on-table angiography (4), neurosurgical/spine procedures (4), thoracotomy (2), and operative control of facial bleeding (1). Fifteen patients (20%) underwent repacking of the pelvis when returned to the OR; the indication for repacking of the pelvis was persistent oozing deep in the preperitoneal space on pack removal. In these 15 patients, repeated packing was performed in 1 patient returned to the OR within 12 hours, 3 patients between 12 and 24 hours, and 11 patients between 24 and 48 hours. The mean time for the removal of all packs was 2 ± 0.1 days (range 1 to 7 days).

After PPP/EF, 10 patients (13%) underwent subsequent AE with a documented arterial blush; mean time to AE was 10.6 ± 2.4 hours after admission. Specific vessels or vascular arcades embolized with a documented blush were: 1) the right obturator artery and the right anterior division of the internal iliac artery; 2) the left anterior division of the internal iliac artery; 3) the left internal iliac artery and right gluteal artery branches; 4) the right anterior division of the internal iliac artery, the right obturator artery, and the right pudendal artery; 5) bilateral anterior divisions of the internal iliac artery; 6) the left obturator artery; 7) the right anterior division of the internal iliac artery and the left superior gluteal artery; 8) the left internal pudendal artery; 9) the left anterior and posterior divisions of the internal iliac artery; and 10) the left anterior division of the internal iliac artery. Of those undergoing AE, pelvic fracture classifications were LC I (3), APC III (2), LC II (2), LC III (1), APC II (1), and vertical shear (1).

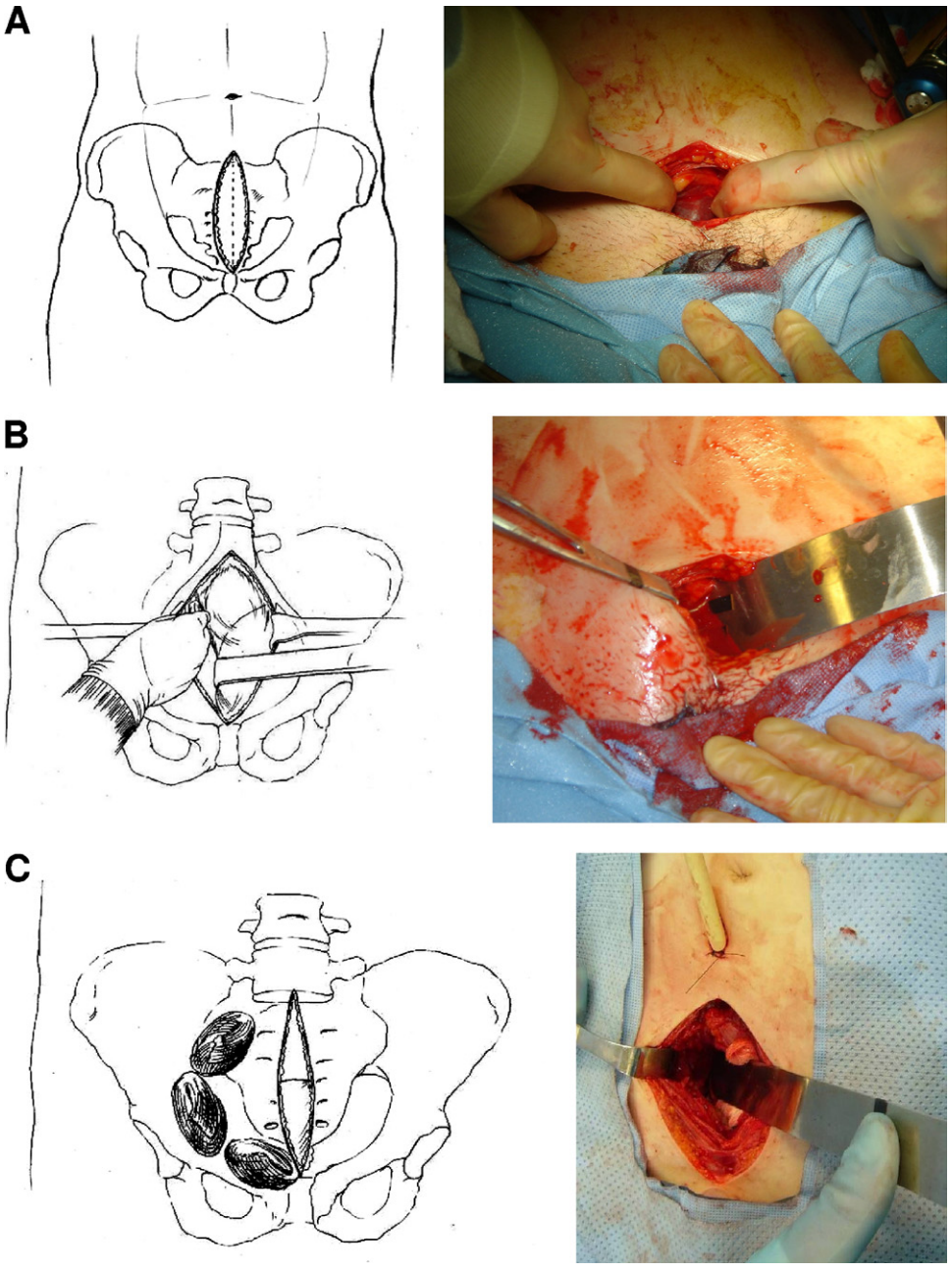

Figure 2. (A) Pelvic packing is performed through a 6- to 8-cm midline incision made from the pubic symphysis cephalad, with division of the midline fascia. (B) The pelvic hematoma often dissects the preperitoneal and paravesical space down to the presacral region, facilitating packing; alternatively, blunt digital dissection opens the preperitoneal space for packing. (C) Three standard surgical laparotomy pads are placed on each side of the bladder, deep within the preperitoneal space, and the fascia is closed with polydioxanone suture and the skin with staples.

There were no significant differences in age, ISS, presenting SBP, presenting base deficit, or ED blood product transfusions between those who had an arterial blush at angiography (AE group) and those that did not undergo therapeutic AE (NA group). The only apparent difference was a lower admission heart rate in the AE group compared with those patients not undergoing angiography (AE group 105 ± 7.5 beats/min vs NA group 121 ± 2.5 beats/min). The AE group received more RBCs before SICU admission (AE group 15 ± 2.7 units vs NA group 9 ± 0.8 units),

more fresh frozen plasma (FFP) before SICU admission (AE group 9 ± 2.4 units vs NA group 4 ± 0.5 units), more RBCs in the subsequent 24 hours (AE group 7 ± 1.7 units vs NA group 3 ± 0.5 units), and more FFP in the subsequent 24 hours (AE group 6 ± 1.5 units vs NA group 2 ± 0.4 units) than the NA group.

Patient outcome

Overall, patients required 4 ± 0.4 units of packed RBCs during their ED course of 66 ± 7 minutes. Blood transfusion requirements before postoperative SICU admission compared with the subsequent 24 postoperative hours were 10 ± 0.8 units versus 4 ± 0.5 units ($p < 0.005$). Transfusion ratio of FFP to RBC was 1:2. There were 11 pelvic space infections (15%). Three polymicrobial infections occurred in patients with open fractures or those with perineal degloving injuries (n = 6); 1 patient underwent hardware removal 26 months after injury. Three infections developed in patients with associated bladder injuries (*Escherichia coli*, *Stenotrophomonas/Enterococcus*/yeast, and *Enterococcus/E. coli*); none of these patients required hardware removal. Five pelvic space infections occurred in patients without bladder or bowel injuries (*Enterobacter/Enterococcus*, methicillin-resistant *Staphylococcus aureus*, *Enterobacter*, *Acinetobacter*, and polymicrobial); 2 patients had hardware removed at 38 days and 16 months after injury. There was a difference in pelvic space infection rates between those patients requiring repacking of the pelvis (7 out of 15 patients, 47%) and those who had a single packing of the pelvis (4 out of 60 patients, 6%).

Patients required a mean of 12 ± 1.3 days of mechanical ventilation and remained in the SICU for 16 ± 1.5 days. Overall length of hospital stay was 26 ± 2.1 days. Overall mortality for all pelvic fractures during the study period was 8%, with 16 patients (21%) dying in this high-risk group. There were no differences in ISS, presenting heart rate, ED base deficit, time in the ED before PPP/EF, or number of additional procedures performed between those who lived and those who died. There was a difference between the 2 groups in mean patient age (alive 39 ± 2.3 years vs dead 51 ± 5.3 years), presenting SBP (alive 78 ± 2.1 mmHg vs dead 67 ± 6.0 mmHg), and RBC transfusion in the ED (alive 4 ± 0.3 units vs dead 6 ± 1.4 units), before SICU admission (alive 9 ± 0.8 units vs dead 13 ± 2.3 units), and in the subsequent 24 hours (alive 3 ± 0.6 units vs dead 6 ± 1.3 units). FFP:RBC transfusion ratios were similar between the 2 groups (pre-SICU: alive 1:3 vs dead 1:2.2; subsequent 24 hours: alive 1:1.5 vs dead 1:1.2). Deaths were due to traumatic brain injury (5), multiple organ failure (5), pulseless electrical activity arrest/cardiac arrest (2), aspiration and progressive pulmonary failure (1), hypoxic pulmonary failure (1), pneumonia and liver failure in a patient with Child class C cirrhosis (1), and invasive mucormycosis (1). Mean time to death was 6 ± 1.5 days after admission. There were no deaths due to acute blood loss.

DISCUSSION

Patients with pelvic fractures who are hemodynamically unstable are a diagnostic and therapeutic challenge for the trauma team. Management of these complex injuries remains controversial, and there is no clear standard for hemorrhage control. Pelvic angiography has been used widely in the United States for 3 decades and can be an effective means of controlling hemorrhage from the internal iliac arterial arcade in patients with pelvic trauma.[18,19,21,22,26,31-34] Suggested indications for AE include hemodynamic instability despite RBC transfusion or evidence of either a large retroperitoneal hematoma or active contrast extravasation on helical computerized tomographic (CT) scan.[18,35-40] Contrast extravasation on CT scan, however, should not be used in isolation as an indication for angiography, because not all patients require intervention.[41,42] Selective embolization at a targeted site of bleeding is most often performed with Gelfoam (Pfizer, New York, NY). If the patient's bleeding is substantial and there is no localized source, proximal embolization of the internal iliac arteries may be done for life-threatening bleeding.[14,43] Complications of AE include gluteal claudication, pelvic necrosis, and renal failure.[44-46] Although angioembolization may be effective in controlling pelvic arterial bleeding, not all published series demonstrate that it decreases the necessity for blood product resuscitation.[47,48]

The question of the optimal management for patients with hemodynamic instability due to pelvic fractures has not been definitively answered. At the majority of centers in the United States, IR staff is not in-house, and time lost for mobilization of the team is compounded by requisite time for intravascular access and identification of bleeding sites. And some centers simply do not have IR capabilities available. Additionally, AE only addresses arterial hemorrhage within the pelvis. A number of groups have sought to predict the need for angiography based on fracture classification and physiologic criteria.[11,18,23,36,49] A minority of patients who undergo angiography have lesions embolized, and angiography does not address the potentially torrential venous bleeding that comprises >85% of the bleeding seen in lethal pelvic fractures.[24,47,50-52] Therefore, predicting the patient who may benefit from emergent angioembolization remains a challenge.[53]

The concept of pelvic packing was originally described by Pohlmann et al. in Hannover,[25] followed shortly thereafter by Ertel et al. in Zurich.[26] Subsequently, several Eu-

ropean groups have advocated external bony pelvic fixation followed by pelvic packing of the retroperitoneum for hemorrhage control.[31,54,55] We modified this technique slightly[27] to ensure direct packing of the pelvis through a preperitoneal approach for all patients with hemodynamic instability and a pelvic fracture.

PPP/EF addresses the major source of bleeding in pelvic fractures by reapproximating bony edges and tamponading the venous ooze. In our study population, there was a significant reduction in blood transfusion requirements in the postoperative 24 hours compared with the pre-SICU period. Because blood transfusion is an independent risk factor for the development of multiple organ failure and mortality,[56-58] reducing the need for transfusion is a compelling objective. With reports that patients undergoing AE and those that do not undergo angiography have similar blood transfusion requirements, and that AE may not affect the overall amount of blood product transfused in these patients,[47,48] PPP/EF may offer an advantage simply by limiting blood product requirements during acute resuscitation.

PPP/EF simplifies the often difficult decision point between immediate operative intervention and interventional radiology. The trauma surgeon no longer has to decide between OR and IR. All patients can be rapidly transported to the operating room and PPP/EF completed within 30 minutes. In our experience, this results in abrupt cessation of blood product transfusion and restoration of hemodynamic stability in the vast majority of cases. Additional necessary procedures, such as laparotomy, fasciotomy, external fixation of fractures, open fracture washout, craniotomy, or thoracotomy, can be performed concomitantly. In our series, patients were severely injured with a mean ISS of 52, and the majority required 3 additional operative procedures when undergoing PPP/EF. Procedures performed included EF of long bone fractures, debridement of open wounds, fasciotomy, laparotomy, urologic procedures, extremity vascular exploration, on-table angiography, neurosurgical procedures, thoracotomy, and operative control of facial bleeding. Moreover, PPP/EF may be ideally suited for hospitals where AE is not immediately available and in military combat. In fact, we have been informed of success with this technique in Iraq and Afghanistan. After undergoing pelvic packing and damage-control surgery of other injuries, patients could then be transported to tertiary care centers. Even in the small group of patients that required AE for ongoing bleeding, a delay of 10 hours did not result in a single hemorrhage-related mortality in our experience. The 21% mortality rate in this cohort is markedly lower than in reports of similar patient populations.[1-11,13,15] Most critically, there were no deaths due to bleeding.

Morbidity, however, remained significant in the present study population. There were 11 pelvic space infections, although the majority occurred in patients with open fractures or those with bladder or bowel injuries. Patients who had repeated packing of the pelvis had a higher incidence of pelvic space infections, raising the question of the optimal timing for unpacking as well as the indication for repacking. Three patients ultimately underwent removal of their hardware owing to infectious causes.

CONCLUSIONS

Although pelvic packing is used frequently in Europe, PPP/EF has not been widely adopted in the United States. In patients with pelvic fractures and hemodynamic instability, such an approach eliminates the often difficult decision point between the OR and IR. This approach directly addresses the primary source of bleeding with pelvic fractures, ie, venous and bony hemorrhage. Concurrent operative procedures, such as laparotomy, thoracotomy, fasciotomy, and stabilization of extremity fractures, permit comprehensive care for the multiply injured patient. With $<15\%$ of patients requiring AE for ongoing arterial hemorrhage, this resource-intense invasive procedure can be reserved for the few patients that manifest ongoing hemorrhage after SICU admission. Thus, AE should be seen as a complementary procedure for life-threatening hemorrhage control following PPP/EF.

Author Contributions

Study conception and design: Burlew, Moore, Smith, Stahel
Acquisition of data: Burlew, Moore, Smith
Analysis and interpretation of data: Burlew, Moore, Johnson, Biffl, Barnett
Drafting of manuscript: Burlew
Critical revision: Moore, Smith, Johnson, Biffl, Barnett, Stahel

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Discussion

DR LD BRITT (Memphis, TN): From the outset, let me publicly recognize the Denver group for being a leader in the management of unstable pelvic fractures. Although Dr Turner, from Hanover, is credited with the original description of packing, the Denver group has certainly popularized preperitoneal pelvic packing and external fixation with secondary angioembolization.

I have the following questions for the authors, and I will ask the most difficult questions first.

Question 1: with more and more level I trauma centers having immediate access to interventional radiology, some even having hybrid operating suites with such capabilities, do the authors feel that this arrangement will soon obviate the need for preperitoneal pelvic packing? And what sort of access do you have to the angiography suites at your facility?

Question 2: the average number of laparotomy pads used by your group is 6 to 7. Others institutions have reported having to use more pads in order to successfully achieve preperitoneal packing. Why are you requiring fewer pads? Could it be interpreted by a pundit that you might be packing too early, that you might need to resuscitate more?

Question 3: the question of superiority of preperitoneal packing could easily be answered if a randomized control study were designed to do a head-to-head comparison of the management approach. Why haven't you done this?

Question 4: if you are truly doing bladder packing, aren't you actually entering into the peritoneal cavity? And does that predispose you to the pelvic sepsis infection that you have highlighted?

Last you repeatedly highlight that in patients with pelvic fractures in hemodynamic instability, preperitoneal packing and external fixation eliminates the often difficult decision point between the operating room and interventional radiology. Please critique the following management option: A patient comes in with a pelvic fracture, is hemodynamically labile, Advanced Trauma Life Support (ATLS) protocol is initiated, application of a pelvic wrap is done, and expeditiously ruling out any sort of hemorrhage loss in the chest and abdomen is obviously done, and then the patient has angiography embolization. Why is that not a reasonable algorithm?

Again, I want to thank the authors for presenting this cutting edge work. And I commend them for their leading role in this particular management paradigm.

DR GAGE OCHSNER (Savannah, GA): Dr Burlew and colleagues from Denver Health have taken a novel approach on how to manage hemodynamically unstable patients with an unstable pelvic fracture by taking them to the operating room and performing open, surgical preperitoneal packing and external fixation of the pelvic fracture. They had an incredibly ill cohort of patients, with an average Injury Severity Score of 52 $\pm$ 2 on either side, an average of 3.3 procedures done in addition to the pelvic packing, given 2 units of blood and still remaining unstable, and had a very admirable 21% mortality rate in this very ill group of patients. They believe that this simplifies the approach to taking the patient to the operating room. You don't have to struggle with the decision of which procedure to do first, because everything can be accomplished at the same time.

I have a couple of comments and questions. At our institution, we do a Focused Assessment with Sonography for Trauma (FAST) examination, as they do, and even if we see a moderate amount or small amount of fluid, and we believe that the hypotension is most likely not due to intra-abdominal bleeding and is probably a result of hemorrhage from the vascular structures injured by the pelvic fracture. Second, we also apply a commercially available pelvic binder, which rapidly closes down the volume of the pelvis and accomplishes the same thing as the preperitoneal packing. It has been our experience that often those hypotensive patients become stable, at which point we go to CT scan. If we identify a significant vascular blush on the CT scan, we go to angiography.

The authors identified about 13%, which is the estimated number of patients who have actual arterial bleeding in their cohort. That is in

agreement with other large series of pelvic fracture patients. Therefore, 87%, or most of the patients treated, were those with venous bleeding that was successfully tamponaded with packing. I have several questions.

Given the severe nature of injuries at multiple sites, the average Injury Severity Score of 52, how can you be sure that the hemodynamic instability in the study population was due to the pelvic fracture? The fracture may have been unstable but not the source of hypotension.

Second how can you be certain that the decrease in blood product transfusion postoperatively was due to the pelvic packing and not one of the other 3 procedures performed at the same time?

Third, how much of an impact has your improved massive resuscitation protocol using thromboelastograph to direct specific blood product replacement contributed to correction of coagulopathy and decreased transfusion requirement, independent of pelvic packing?

Fourth, have you considered a less invasive method of reducing the pelvic volume to help tamponade venous bleeding, such as commercially available products like the pelvic binder, or old homemade methods, such as using a sheet or a bean bag device?

I would submit, as Dr Britt suggested, that you make a head-on comparison. Maybe you ought to make a head-on comparison between pelvic packing and a binder sort of device, because I think it's the venous patients who were bleeding and benefited from packing–the subset of patients that we usually control with a binder.

And finally, I think all of us can think of the patient for whom this would be a handy technique to know. How do you propose to teach this technique to us? It seems like we will need to use it occasionally and usually in the most unstable patients. So how are you going to make us facile with this technique when we encounter it? I would like to compliment Dr Cothren-Burlew on a beautifully presented and clinically relevant paper produced by the outstanding Department of Surgery at Denver Health.

DR PHILIP BARIE (New York, NY): Nicely presented and excellent results. I have 2 questions and a comment. My first question relates to whether or not you observed any circumstances in which the patient became more unstable, even transiently, as a result of the necessary opening of the pelvic retroperitoneal hematoma in order to place the packs.

My second question is analogous to the question Dr Ochsner asked. And that is, in some cases one can never be absolutely certain as to the cause of the hypotension. And going to the operating room with the intent of performing preperitoneal pelvic packing, you're right there. Why not just perform a laparotomy and be absolutely certain that you are not missing another injury that might have even been missed by FAST?

My third is a brief comment apropos of Dr Britt's remarks. We don't consider this an either/or situation. We take these patients, who usually present at night, to 1 of our 2 hybrid operating rooms. And we can very simply call one of our vascular surgery colleagues if we think that they need angiography on the table, and it's performed within minutes. Isn't that really the direction for the future?

DR NORMAN McSWAIN (New Orleans, LA): Very provocative paper from an institution that has been a leader in trauma for a long time. I have 3 questions. First, in our institution, 1:1 or 1:2 transfusion means that's the only fluid that the patient got. Did, in fact, your patients get a lot of crystalloid and are you reporting only on the blood products as a 1:1 and 1:2? The reason I ask this is that most of us have been using 1:1 or 1:2 transfusions for about 2 years, 3 at the most. You reported using it 5½ years. That was way before the rest of us started. If so, once again, you're a real leader. Second, did you use any kind of additional clotting materials, such as tranexamic acid or factor 7? And what was the total volume of crystalloid that you used on these patients?

DR DONALD TRUNKEY (Portland, OR): I find the preperitoneal pelvic packing a very useful tool in the armamentarium of controlling pelvic bleeding, but I do it a little bit differently. As soon as the patient has intravenous lines in, we do a FAST exam. If that's positive in the abdomen and the patient is hemodynamically unstable, I would take him or her to the operating room. But that doesn't preclude doing preperitoneal packing. If you can get the patient stable or semistable, then I prefer to do a CT with arteriogram. Any CT with 64 slices or greater can help you distinguish between arterial blushes and venous blushes. And if you don't have any intraperitoneal injuries, and you don't have a typical arterial blush, I would prefer to do the technique that's been described. Finally, I would probably use preperitoneal packing in all patients, nearly all patients, who have an open pelvic fracture. That really does help control the pelvic bleeding.

DR CLAY COTHREN BURLEW (Denver, CO): First Dr Britt, I appreciate your insightful commentary and discussion of our paper. Regarding your first question about a hybrid suite or access to interventional radiology, in our trauma center our interventionalists are on call and available 24 hours a day, so I think we're fairly representative of most level I trauma centers. We do not have in-house interventionalists, unlike a sprinkling of trauma centers across the country. So although our interventionalists come in immediately, it still is between 1 and 2 hours before angioembolization is underway. And I think all of us have had patients who either died on the angiography table or in transport because they couldn't be stabilized. I agree that a hybrid suite might be considered, but only 15% of these patients have an arterial source that could be addressed with angioembolization. So one would hate to subject the patient to what could be a morbid procedure, with potential renal insufficiency, access complications, or tissue ischemia, if you don't need to embolize these patients.

Regarding your question about how many laparotomy pads we place, if you are actually inside the true pelvis, 6 pads are really all that you can place once the pelvic ring has been closed by the external fixator. I wonder if those groups that are describing more packing are actually doing a transabdominal opening of the retroperitoneal space versus a straightforward anterior, preperitoneal, paravesical packing within the true pelvis.

Why have we not done a randomized study? Our mortality rate is approximately half that reported in angioembolization series, with the most recent series presented 3 months ago at the annual American Association for the Surgery of Trauma meeting. We believe that the pelvic packing technique has a profound impact on mortality, with no deaths due to acute hemorrhage. Therefore, in our opinion, packing is actually the preferred technique versus angioembolization, with its associated mortality rates in the 40% range in modern series.

Regarding pelvic space infections, we recognize this is the major morbidity. In this most recent evaluation of our experience we have noted that repacking of the pelvis seems to have an impact on pelvic space infections. As a result, we question now whether we should wash them out after unpacking, whether we should pack them only once and then if they have persistent venous ooze at unpacking drain the space, or consider some other option. I think we would now think twice about repacking the pelvis.

And finally, why is wrapping and angioembolization, as stated in your example, not reasonable? We are not suggesting that angioembolization doesn't have a role, but we are concerned that it is needed only in the 15% of patients who have arterial bleeding. Although we would like to think that it is a great place to resuscitate the patient, we all recognize the limitations of the interventional radiology suite.

Dr Ochsner, we appreciate your comments and some of them touched on Dr Britt's. First, you asked about the pelvic source of bleeding and whether or not we could really ascribe the source of hypotension to the pelvis fracture. I think that we are faced with the same dilemma that every trauma surgeon has in the emergency department, which is, as you are evaluating the patients, determining whether they are hypotensive due to the pelvis fracture; whether you use angioembolization or pelvic packing to control pelvic fracture-related hemorrhage, you still are at that juncture of deciding what to do about the pelvis fracture. It is clinical acumen and experience that really dictate what you believe is the source of the patient's hypotension.

Similarly, you asked whether or not it was the other operative procedures that actually limited blood loss and reduced our blood transfusion. I can think of only 1 of the 70 patients, when the trauma surgeon actually came out of the operating room and said, "Wow, that pelvic hematoma was not quite as big and the blood didn't fly out of the preperitoneal space quite as rapidly as I had expected." And the remainder of them, we believed, had required pelvic packing to arrest hemorrhage.

You asked about our massive transfusion protocol. We had a massive transfusion protocol in place before initiation of this pelvic packing protocol. We adopted thromboelastography and recently have used it to direct specific blood product transfusion in these patients. But I think it is just in the last 6 months to a year of this study that thromboelastography might have had an influence. We are curious in future evaluation of our experience whether thromboelastography has a more profound effect on our blood product transfusion ratios.

We do actually sheet the pelvis in the emergency department during our initial evaluation, so I apologize if that was not clear in our protocol. And it is those patients who remain unstable despite the sheeted pelvis, bound ankles, and 2 units of blood, that go on to intervention.

Finally, you asked how we propose to teach this technique? I've been asked this question by several groups around the country. I think there are 2 ways. First, in Europe they actually use cadaver teaching in order to show surgeons the extent of the preperitoneal space and how to pack the pelvis. We have also discussed doing a video of the technique as well as constructing a hands-on model that could be used for instruction for surgeons interested in learning the technique.

Dr Barie, I appreciate your comment about whether or not the patient becomes unstable when you actually open the pelvic hematoma. Honestly, pelvic packing is a rapid maneuver. It takes us about 30 seconds after opening the posterior fascia to dissect into the hematoma and pack the preperitoneal space. So whether or not, in that short period, the patient's blood pressure dips or not, I honestly could not tell you because it is so quick.

Similar to Dr Ochsner, you asked about the source of hypotension. In some patients, they clearly have a positive FAST, where the stripe is increasing and you feel they need a splenectomy or liver packing. In those patients, once they go to the operating room, have their splenectomy or get their liver packs in place, if they have a streaking or expanding pelvic hematoma, they also undergo pelvic packing. In patients undergoing pelvic packing, a laparotomy is not contraindicated, but obviously you'd prefer not to open the abdomen if it isn't necessary. So in these patients we determine the need for laparotomy based on the patient's response to pelvic packing.

Finally, you touched on the hybrid room, which I agree might be a consideration. However, again, only 15% of patients need arterial access and embolization. So I would argue that not every patient should undergo angiography to address pelvic fracture-related bleeding.

Dr McSwain, you asked about crystalloid transfusion. It's an excellent question, but we did not look at that particular variable. Overall, we do try to resuscitate these patients, based on thromboelastography, with red cells and fresh frozen plasma as indicated. We have used a massive transfusion protocol with 1:1 to 1:2 ratios since before 2000.

Regarding additional clotting factors, now that we are using thromboelastography, we are using adjuncts such as Amicar (aminocaproic acid) when indicated. Factor VIIa was used, to my knowledge, in 1 patient in this series, and that was probably 4 or 5 years ago, when factor VIIa was more often used.

Finally, Dr Trunkey, thank you for your comments. Regarding your question on how to manage these patients initially using FAST or CT scan, I think CT scan, if you can stabilize these patients, might be helpful; however, we all recognize that a blush on CT scan is not necessarily an indication for angioembolization. I would suggest that, in these patients, evaluation in the trauma bay and their response to initial intervention and resuscitation will dictate whether you go to the operating room or to the ICU after imaging.