Eastern Association for the Surgery of Trauma Practice Management Guidelines for Hemorrhage in Pelvic Fracture—Update and Systematic Review

Daniel C. Cullinane, MD, Henry J. Schiller, MD, Martin D. Zielinski, MD, Jaroslaw W. Bilaniuk, MD, Bryan R. Collier, DO, John Como, MD, Michelle Holevar, MD, Enrique A. Sabater, MD, S. Andrew Sems, MD, W. Matthew Vassy, MD, and Julie L. Wynne, MD

Background: Hemorrhage from pelvic fracture is common in victims of blunt traumatic injury. In 2001, the Eastern Association for the Surgery of Trauma (EAST) published practice management guidelines for the management of hemorrhage in pelvic trauma. Since that time there have been new practice patterns and larger experiences with older techniques. The Practice Guidelines Committee of EAST decided to replace the 2001 guidelines with an updated guideline and systematic review reflecting current practice.

Methods: Building on the previous systematic literature review in the 2001 EAST guidelines, a systematic literature review was performed to include references from 1999 to 2010. Prospective and retrospective studies were included. Reviews and case reports were excluded. Of the 1,432 articles identified, 50 were selected as meeting criteria. Nine Trauma Surgeons, an Interventional Radiologist, and an Orthopedic Surgeon reviewed the articles. The EAST primer was used to grade the evidence.

Results: Six questions regarding hemorrhage from pelvic fracture were addressed: (1) Which patients with hemodynamically unstable pelvic fractures warrant early external mechanical stabilization? (2) Which patients require emergent angiography? (3) What is the best test to exclude extrapelvic bleeding? (4) Are there radiologic findings which predict hemorrhage? (5) What is the role of noninvasive temporary external fixation devices? and (6) Which patients warrant preperitoneal packing?

Conclusions: Hemorrhage due to pelvic fracture remains a major cause of morbidity and mortality in the trauma patient. Strong recommendations were made regarding questions 1 to 4. Further study is needed to answer questions 5 and 6.

Key Words: Pelvic fracture, Hemorrhage, Angiography, Embolization, External fixator, C-clamp, Temporary pelvic binder, Pelvic packing, Trauma, Intravenous contrast extravasation, Blush, PASG, Pelvic hematoma, FAST, CT scan, Fracture pattern.

(*J Trauma.* 2011;71: 1850–1868)

Submitted for publication April 21, 2011.
Accepted for publication October 18, 2011.

From the Departments of Surgery (D.C.C., H.J.S., M.D.Z.) and Orthopedics (S.A.S.), Mayo Clinic, Rochester, Minnesota; Department of Surgery, Morristown Memorial Hospital (J.W.B.), Morristown, New Jersey; Department of Surgery, Vanderbilt University Medical Center (B.R.C.), Nashville, Tennessee; Department of Surgery, MetroHealth Medical Center (J.C.), Cleveland, Ohio; Department of Surgery, Mount Sinai Hospital (M.H.), Chicago, Illinois; Department of Radiology, HIMA-San Pablo Hospital (E.A.S.), Bayamon, Puerto Rico; Department of Surgery, Evansville Surgical Associates (W.M.V.), Newburgh, Indiana; and Department of Surgery, University of Arizona (J.L.W.), Tucson, Arizona.
Presented at the 22nd Annual Scientific Assembly of the Eastern Association for the Surgery of Trauma, January 16, 2009, Lake Buena Vista, Florida.
Address for reprints: Daniel C. Cullinane, MD, Department of Surgery, Mayo Clinic, 200 First St, SW, Rochester, MN 55905; email: cullinane.daniel@mayo.edu.

DOI: 10.1097/TA.0b013e31823dca9a

STATEMENT OF THE PROBLEM

Hemorrhage from pelvic fracture is common in victims of blunt traumatic injury. In 2001, the Eastern Association for the Surgery of Trauma (EAST) published practice management guidelines for the management of hemorrhage in pelvic trauma.[1] Since that time there have been a number of new practice patterns and larger experiences with older techniques. The Practice Guidelines Committee of EAST decided to update the 2001 EAST guidelines and systematic review for hemorrhage due to pelvic fracture. The design of the project was to update the previous guideline as well as to evaluate new treatment methods and techniques. Six specific questions are addressed regarding the management of pelvic fracture hemorrhage:

1. Which patients with hemodynamically unstable pelvic fractures warrant early external mechanical stabilization?
2. Which patients require emergent angiography?
3. What is the best test to exclude extrapelvic bleeding?
4. Are there radiologic findings which predict hemorrhage?
5. What is the role of noninvasive temporary external fixation devices?
6. Which patients warrant preperitoneal packing (PPP)?

PROCESS

The Practice Management Guidelines Committee of the EAST (www.east.org) developed the process used by this committee for review and development of practice management guidelines. A computerized search of the National Library of Medicine MEDLINE database was undertaken using the OVID interface. English language citations were included for the period of 1999 through 2010 using the primary search strategy: pelvis, fracture hemorrhage, trauma, and retroperitoneal hematoma. The dates were selected to allow comprehensive review of articles published since the prior systematic review with minimal overlap.

Review articles and case reports were excluded. Moreover, studies not directly addressing hemorrhage with pelvic fracture were excluded. The PubMed Related Articles algorithm was also used to identify additional articles similar to the items retrieved by the primary strategy. Of the 1,432 articles identified by these two techniques, those

dealing with prospective or retrospective studies were selected, comprising 50 studies specifically evaluating hemorrhage associated with pelvic fracture in adult or pediatric patients.

The EAST, "Utilizing evidence based outcome measures to develop practice management guidelines: a primer," was used as a quality assessment instrument applied to develop this guideline.[2]

The workgroup for the Practice Management Guidelines for Hemorrhage in Pelvic Trauma consisted of nine Trauma Surgeons, an Orthopedic Surgeon specializing in trauma (S.A.S.), and an Interventional Radiologist (E.A.S.) (Table 1). Articles were compiled by the committee chair (D.C.C.) and were distributed among committee members for formal review. Each article was entered into a review data sheet with detailed summaries of the articles. Deficiencies and conclusions not validated by the data were also noted. The reviewers correlated the references with the methodology established by the Agency for Health policy and Research of the US Department of Health and Human Service. Each reference was classified as class I, class II, or class III data. There was no class I data found for the search period. Fifteen class II articles and 35 class III articles were included in the review. All references were reviewed by at least two committee members for purposes of cross-validation. An evidentiary table was constructed using the 50 references (Table 2).

Level I

This recommendation is convincingly justifiable based on the available scientific information alone. It is generally based on class I data or strong class II evidence may form the basis for a Level I recommendation. Conversely, weak or contradictory class I data may not be able to support a Level I recommendation.

Level II

This recommendation is reasonably justifiable by available scientific evidence and strongly supported by expert opinion. It is usually supported by class II data or a preponderance of class III evidence.

Level III

This recommendation is supported by available data, but adequate scientific evidence is lacking. It is generally supported by class III data. This type of recommendation is useful for educational purposes and in guiding future studies.

Although there were not any class I references available, four Level I recommendations were made due to the strong class II data (large retrospective and nonrandomized prospective data) available for specific questions. Level II recommendations were supported by class II data and are justified by available scientific evidence and strongly supported by expert opinion. Nine Level II recommendations were made from the available data. Level III recommendations were based on class III data, where adequate scientific evidence is lacking. Twelve Level III recommendations are included in these recommendations.

RECOMMENDATIONS

Which Patients With Hemodynamically Unstable Pelvic Fractures Warrant Early External Mechanical Stabilization?

1. The use of a pelvic orthotic device (POD) does not seem to limit blood loss in patients with pelvic hemorrhage. **Level III recommendation**
2. The use of a POD effectively reduces fracture displacement and decreases pelvic volume. **Level III recommendation**

Scientific Foundation: Early External Stabilization

It is well known that the volume of the pelvis increases after a mechanically unstable pelvic fracture (Tile B/C; Table 3). This increased pelvic volume in complex pelvic fractures is thought to reduce the tamponade effect of the retroperitoneal tissues and intrapelvic organs, leading to further bleeding into the pelvic space. Baque et al.[3] demonstrated a 20% increase in the volume of the pelvis with a 5-cm pubic diastasis in a cadaver pelvic-fracture model. The iliolumbar vein was noted to be disrupted in 60% of the pelvic fractures created, accounting for the venous hemorrhage seen with fractures of the sacroiliac portion of the pelvis. Using com-

TABLE 1. Members of the EAST Hemorrhage in Pelvic Fracture Workgroup

Name	Organization/Place	Email
Daniel C. Cullinane, MD—Chair	Mayo Clinic, Rochester, MN	cullinane.daniel@mayo.edu
Henry J. Schiller, MD	Mayo Clinic, Rochester, MN	schiller.henry@mayo.edu
Jaroslaw W. Bilaniuk, MD	Morristown Memorial Hospital, Morristown, NJ	jwbil@hotmail.com
Bryan R. Collier, DO	Vanderbilt University Medical Center, Nashville, TN	bryan.collier@vanderbilt.edu
John Como, MD	MetroHealth Medical Center, Cleveland, OH	jcomo@metrohealth.org
Michelle Holevar, MD	Mount Sinai Hospital, Chicago, IL	michellehmail-career@yahoo.com
Enrique A. Sabater, MD	HIMA-San Pablo Hospital, Bayamon, PR	easabater@gmail.com
S. Andrew Sems, MD	Mayo Clinic, Rochester, MN	sems.andrew@mayo.edu
W. Matthew Vassy, MD	Evansville Surgical Associates, Newburgh, IN	thevassys@yahoo.com
Julie L. Wynn, MD	University of Arizona, Tucson, AZ	jwynne@surgery.arizona.edu
Martin D. Zielinski, MD	Mayo Clinic, Rochester, MN	zielinski.martin@mayo.edu

TABLE 2. Evidentiary Table 1999–2010

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Smith et al.[80]	2005	Retroperitoneal packing as a resuscitation technique for hemodynamically unstable patients with pelvic fracture: report of two representative cases and a description of technique	2	6	The ISS, RTS, number of transfusions, and age >60 were statistically significant predictors of early mortality. Fx pattern and treatment with angio/embolization were not predictive of death	*J Trauma*. 2005;59:1510–1514
Totterman et al.[77]	2007	Extraperitoneal pelvic packing: a salvage procedure to control massive traumatic pelvic hemorrhage	3	2, 6	Patients underwent retroperitoneal packing as a salvage maneuver after pelvic embolization. All had class III and class IV hemorrhage. 30-d survival was 72% and correlated inversely to the age of the patient. The authors concluded that packing may be lifesaving procedure	*J Trauma*. 2007;62:843-852
Cothren et al.[78]	2007	Preperitoneal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift	3	1, 6	28 consecutive hemodynamically unstable patients with pelvic Fxs underwent pelvic Fx fixation with an anterior external fixator or posterior pelvic C-clamp followed by preperitoneal pelvic packing. Unstable patients then underwent angioembolization (25%). The blood transfusion requirements before packing were significantly greater than after (12 ± 2.0 vs. 6 ± 1.1; $p = 0.006$). Mortality was 25%, and there were no deaths as a result of acute blood loss. Preperitoneal packing is a rapid method for controlling pelvic Fx-related hemorrhage that can supplant the need for emergent angiography. They stated that this approach seems to reduce mortality in this selected group of patients	*J Trauma*. 2007;62:834–839
Brasel et al.[61]	2007	Significance of contrast extravasation in patients with pelvic fracture	3	3	CE on CT scan was calculated to have a sensitivity of 90.5%, specificity of 96.1%, PPV of 45.2%, and NPV of 99.6%. Not all patients with CE required embolization; hence, the low PPV. Some patients required angiography despite not having CE	*J Trauma*. 2007;62:1149–1152
Totterman et al.[17]	2006	A protocol for angiographic embolization in exsanguinating pelvic trauma	2	2	46 patients underwent angio based on protocol (unstable hemodynamics + 6 PRBC or stable hemodynamics + 4 PRBC). All pelvic Fx patterns represented in those undergoing angio. 31 of 46 patients underwent embolization. Survival 84%. No patients died of hemorrhage	*Acta Orthop*. 2006;77:462–468
Velmahos et al.[29]	2002	A prospective study on the safety and efficacy of angiographic embolization for pelvic and visceral injuries	2	2	Prospective study. Sixty-five of the 100 patients had angiography because of pelvic Fxs; the rest were due to visceral injuries. The safety rate of angiography was 94%, and efficacy for controlling bleeding was 93%. Analysis identified three independent predictors of positive angiography: age >55, absence of long bone Fxs, and emergent procedure. The model was most robust when all three factors were present	*J Trauma*. 2002;52:303–308

TABLE 2. Evidentiary Table 1999–2010 (continued)

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Velmahos et al.[31]	2000	Angiographic embolization for intraperitoneal and retroperitoneal injuries	3	2	137 consecutive patients underwent angio with the intent of embolization. 97 of 137 for pelvic Fxs. Of the 137 patients, 91% success to control bleeding; pelvic bleeding not isolated as a data point. 9 patients failed embolization, with 66% mortality. One-third of pelvic embolizations were for bilateral internal iliac arteries, but no postprocedure morbidity was noted	*World J Surg*. 2000;24: 539–545
Shapiro et al.[30]	2005	The role of repeat angiography in the management of pelvic fractures	3	2	Retrospective review of 31 pelvic Fx patients who underwent pelvic angiography. Fifteen patients had no evidence of pelvic arterial hemorrhage, and 5 patients required repeat angiography for recurrent hypotension, with 80% having a treatable lesion. Moreover, 3 patients who underwent coiling initially also required repeat angiography. Independent predictors of need for repeat angiography were recurrent hypotension, persistent base deficit greater than 10, and absence of intra-abdominal injury	*J Trauma*. 2005;58:227–231
Metz et al.[28]	2004	Pelvic fracture patterns and their corresponding angiographic sources of hemorrhage	3	4	Retrospective review of imaging and clinical course of 49 consecutive hemodynamically unstable patients with pelvic Fx. Patients with OTA type A or C Fx patterns or APC Fx patterns had higher mortality rates, ISS, and transfusion requirements than OTA type B or LC patterns. Patients with APC injuries tended to demonstrate posterior vascular injuries, while LC Fx pattern was more likely to be associated with anterior branch vascular injury	*Orthop Clin North Am*. 2004;35:431–437
Kimbrell et al.[27]	2004	Angiographic embolization for pelvic fractures in older patients	2	2	Analyses of prospective collected data to determine whether age can predict the need for therapeutic embolization. During this time period, indications for embolization were hypotension in the context of pelvic Fx and no other source of bleeding, or specific Fx patterns, or large pelvic hematoma. 92 of 332 patients with severe pelvic Fx underwent angiography. Age >60 was found to be associated with a 94% likelihood of positive angiography. The authors recommend liberal arteriography for severe pelvic Fx patients older than 60 yr	*Arch Surg*. 2004;139:728–732
Miller et al.[18]	2003	External fixation or arteriogram in bleeding pelvic fracture: initial therapy guided by markers of arterial hemorrhage	3	2, 4	Retrospective trauma registry review of all patients with hypotension related to pelvic Fxs who underwent angiography, as well as normotensive pelvic Fx patients who underwent angiography, to determine factors predicting arterial bleeding. 35 patients had initial hypotension, and 28 who were considered to be nonresponders underwent angiography, with 73% demonstrating arterial bleeding. 17 normotensive patients underwent angiography based on Fx pattern, presence of pelvic hematoma, or CE, and 29% were positive for arterial bleeding. The authors recommend that pelvic Fx patients who do not respond to initial resuscitation and patients with CE on CT scan, under arteriography	*J Trauma*. 2003;54:437–443

TABLE 2. Evidentiary Table 1999–2010 (continued)

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Gourlay et al.[22]	2005	Pelvic angiography for recurrent traumatic pelvic arterial hemorrhage	2	2	Study cohort of 39 patients who had repeat angiography for recurrent pelvic hemorrhage. The 33 patients with a positive second angiogram had bleeding at a new site in 28 (85%) and at the previously embolized site in 11 (33%). All embolizations at the repeat angiogram were thought to be technically successful. Significant risk factors for recurrent pelvic arterial hemorrhage are (1) preangiogram hypotension, (2) pubic symphysis disruption, (3) greater number of injured arteries on initial arteriogram, (4) coagulopathy, and (5) require more blood transfusion. The authors concluded that patients with these characteristics may manifest recurrent arterial bleeding, and it may be prudent to retain the angio sheath for up to 72 h	*J Trauma.* 2005;59:1168–1173
Takahira et al.[32]	2001	Gluteal muscle necrosis following transcatheter angiographic embolisation for retroperitoneal haemorrhage associated with pelvic fracture	3	2	Review of patients who went bilateral angioembolization for pelvic Fx-related hemorrhage found that 5 of 151 patients (3.3%) developed gluteal muscle necrosis. All had embolization of bilateral internal iliac arteries. Mortality was 60% due to sepsis/DIC	*Injury*. 2001;32:27–32
Yasumura et al.[33]	2005	High incidence of ischemic necrosis of the gluteal muscle after transcatheter angiographic embolization for severe pelvic fracture	3	2	8 patients underwent angiography for bleeding pelvic Fxs. 6 of 8 underwent embolization. 4 of 6 patients had bilateral internal iliac embolizations. 2 of 6 patients had bilateral superior/inferior gluteals embolized. 3 cases of tissue infection, 4 cases of gluteal necrosis, and 2 cases of sepsis. Patients underwent MRI at 1 wk and 4 wk. All were noted to have gluteal muscle necrosis, and 2 patients developed necrotizing soft tissue infection necessitating I&D	*J Trauma.* 2005;58:985–990
Fangio et al.[20]	2005	Early embolization and vasopressor administration for management of life-threatening hemorrhage from pelvic fracture	3	2	32 hemodynamically unstable patients underwent pelvic angiography, which was followed by embolization in 25 cases. Angiography was successful in 24 cases (96%). There was hemodynamic improvement in 21 (84%). Liberal use of vasopressors was used during the early stages of hemorrhagic shock and during angioembolization. Mortality 36%	*J Trauma* 2005;58:978–984
Brown et al.[62]	2005	Does pelvic hematoma on admission computed tomography predict active bleeding at angiography for pelvic fracture?	3	2, 4	Retrospective review of 37 pelvic Fx patients who underwent CT and angiography. It was found that the size of the pelvic hematoma on CT did not correlate with active pelvic bleeding on angiogram. In addition, the absence of a contrast blush did not reliably exclude active bleeding seen on angiography	*Am Surg.* 2005;71:759–762
Cook et al.[19]	2002	The role of angiography in the management of haemorrhage from major fractures of the pelvis	3	2, 4	23 patients with ongoing hypotension had angiogram with unstable pelvic Fxs. Fx pattern did not predict associated vascular injury	*J Bone Joint Surg.* 2002;84:178–182

TABLE 2. Evidentiary Table 1999–2010 (continued)

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Netto et al.[64]	2008	Retrograde urethrocystography impairs computed tomography diagnosis of pelvic arterial hemorrhage in the presence of a lower urologic tract injury	3	2, 4	49 patients with pelvic Fx and either a urethral or bladder rupture. 23 had RUG or cystogram performed before CT, and 26 had cystography after CT scanning. Performing cystography before CT was associated with considerately more indeterminate scans (N = 9) and false negatives (N = 2) for pelvic arterial extravasation. Consideration should be given to performing retrograde urethrography and cystography after CT scanning as they interfere with the detection of active extravasation on CT	*J Am Coll Surg*. 2008; 206:322–327
Wong et al.[25]	2000	Mortality after successful transcatheter arterial embolization in patients with unstable pelvic fractures: rate of blood transfusion as a predictive factor	3	2, 4	Retrospective review. 17 hemodynamically unstable pelvic Fx patients underwent therapeutic embolization, and 3 of the patients subsequently died, for a mortality rate of 17.6%. Blood transfusion rate before embolization as well as time interval to embolization were significant predictors of mortality, but size of CE was not. The authors concluded that early recognition of arterial pelvic bleeding with early embolization is essential	*J Trauma*. 2000;49:71–75
Hagiwara et al.[26]	2003	Predictors of death in patients with life-threatening pelvic hemorrhage after successful transcatheter arterial embolization	2	2, 4	61 patients evaluated with prospective protocol. 13 of 61 died despite 100% successful angioembolization. Posterior pelvic bleeding and APACHE II scores predicted mortality. Fx patterns did not predict mortality. Nonsurvivors required more fluid to achieve hemodynamic stability	*J Trauma*. 2003;55:696–703
Croce et al.[69]	2007	Emergent pelvic fixation in patients with exsanguinating pelvic fracture	2	1, 5	186 patients with multiple severe pelvic Fxs underwent stabilization of the pelvis with a POD (C-Clamp) (93) vs. temporary external pelvic binder (93). Transfusion requirements were reduced with the use of the binder, as was hospital length of stay. There was no statistically significant difference in the mortality rates. The authors conclude that the use of the binder reduces transfusion requirements and length of hospital stay	*J Am Coll Surg*. 2007; 204:935–939
Bottlang et al.[70]	2002	Emergent management of pelvic ring fractures with use of circumferential compression	3	1, 5	Open-book pelvic Fxs were induced in 7 cadavers. Stabilization was initially provided with the pelvic sling. Subsequently, stabilized with a posterior pelvic C-clamp/anterior external fixator. Stability provided by the pelvic sling was directly comparable to that provided by the posterior pelvic C-clamp, but the sling provided only 1/3rd of the flexion-extension stability and 1/10th of the internal-external rotation stability as compared with the external fixator. The authors conclude that the sling is well suited for temporarily stabilization of the acutely injured patient	*J Bone Joint Surg Am*. 2002;84:43–47
Bottlang et al.[71]	2002	Noninvasive reduction of open-book pelvic fractures by circumferential compression	3	5	Partially stable and unstable external rotation injuries of the pelvic ring were created in 7 cadavers. A pelvic strap was applied at 3 different levels around the pelvis. The strap achieved complete reduction of symphysis diastasis	*J Orthop Trauma*. 2002; 16:367–373

TABLE 2. Evidentiary Table 1999–2010 (continued)

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Tiemann et al.[13]	2005	Emergency treatment of multiply injured patients with unstable disruption of the posterior pelvic ring by using the "C-clamp"	3	1	28 patients with an unstable posterior pelvic ring Fx had a C-clamp applied immediately after diagnosis. The average time from trauma to C-clamp application was 64.7 min (10–240 min). Application of the C-clamp resulted in stabilization of BP and oxygenation in survivors; in the nonsurvivor group (7 of 28 patients) there was no stabilization of BP or oxygenation. The authors conclude that the C-clamp leads to stabilization of vital parameters within a short period of time	*Eur J Trauma*. 2005;3: 244–251
Kreig et al.[14]	2005	Emergent stabilization of pelvic ring injuries by controlled circumferential compression: a clinical trial	3	1, 5	16 patients with pelvic ring Fxs had a PCCD temporarily applied until definitive stabilization was provided. In the external rotation group, the PCCD significantly reduced the pelvic width by 9.9% ± 6%, similar to the 10.0% ± 4.1% reduction in achieved by definitive stabilization. In the internal rotation group, the PCCD did not cause significant overcompression. The authors conclude that a PCCD can effectively reduce pelvic ring injuries while posing minimal risk for overcompression and complications	*J Trauma*. 2005;59:659–664
Ghaemmaghami et al.[68]	2007	Effects of early use of external pelvic compression on transfusion requirements and mortality in pelvic fractures	3	5	Pelvic binders were applied to 118 patients with unstable pelvic Fx, pelvic Fx in a patient older than 55 yr, or a pelvic Fx associated with hypotension. These patients were compared with historical controls. The pelvic binder had no effect on mortality, need for pelvic angioembolization, or 24-h transfusions. The authors concluded that early use of pelvic binders does not reduce hemorrhage or mortality associated with pelvic Fxs	*Am J Surg*. 2007;194:720–723
Stover et al.[4]	2006	Three-dimensional analysis of pelvic volume in an unstable pelvic fracture	3	1	A model was developed comparing intact and postfracture pelvic volumes in 10 cadavers; the pelvic volume was calculated using CT. The observed volume changes with increasing pubic diastasis were smaller than previously reported	*J Trauma*. 2006;61:905–908
Sadri et al.[11]	2005	Control of severe hemorrhage using C-clamp and arterial embolization in hemodynamically unstable patients with pelvic ring disruption	3	1, 2	14 hemodynamically unstable patients with types B and C pelvic ring Fxs underwent application of pelvic C-clamp. 5 patients remained in shock and underwent angio/embolization within 24 h. The mortality rate of the patients who underwent angioembolization was 14%). Although the C-clamp is effective in controlling hemorrhage, arterial embolization may be needed to restore hemodynamic stability	*Arch Orthop trauma Surg*. 2005;125:443–447
Blackmore et al.[85]	2003	Assessment of volume of hemorrhage and outcome from pelvic fracture	3	2, 4	CT scans of 592 patients with pelvic Fx were retrospectively reviewed to estimate volume. These estimates were then correlated with pelvic arterial bleeding diagnosed by angiography. The risk ratio for pelvic arterial injury was 4.8 in subjects with >500 mL of pelvic Fx-related hematoma compared with subjects with <500 mL. Volume >500 mL was associated with high transfusion requirement (risk ratio = 4.7) and with any adverse outcome (risk ratio = 7.0). The authors conclude that pelvic hemorrhage volumes derived from pelvic CT scan can predict the need for pelvic arteriography and transfusions	*Arch Surg*. 2003;138:504–509

TABLE 2. Evidentiary Table 1999–2010 (continued)

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Baque et al.[3]	2005	Anatomical consequences of "open book" pelvic ring disruption. a cadaver experimental study	3	1	Bilateral open-book pelvic Fxs were created in 10 cadavers. Pelvic volume was determined after total pelvic exenteration. The mean volume of pelvic cavity was 872.5 mL (580–756 mL). The average increase of pelvic volume was 20.8% after 5 cm of pubic diastasis. In 60%, a laceration of the iliolumbar vein occurred after 5 cm of pubic diastasis. No arterial laceration occurred. The authors concluded that open-book Fxs create an increase of pelvic volume that facilitates blood diffusion from the pelvic vessels. The iliolumbar pedicle seems to be very vulnerable in this type of Fx	*Surg Radiol Anat.* 2005; 27:487–490
Jowett and Bowyer[72]	2007	Pressure characteristics of pelvic binders	3	5	10 volunteers were fitted with a flexible pressure-sensitive sensor over the skin covering the anterior superior iliac spine, greater trochanter and sacrum. A pelvic binder was then applied and tightened according to the manufacturers' instructions. The pressures obtained correlated inversely with BMI. The authors conclude that the pressures developed between the binder and the skin over the prominences were all greater than the pressure recommended at interfaces to avoid the development of pressure sores, suggesting that patients with pelvic Fxs treated with temporary pelvic binders are at risk of developing pressure sores	*Injury*. 2007;38:118–121
Kataoka et al.[86]	2005	Iliac vein injuries in hemodynamically unstable patients with pelvic fractures caused by blunt trauma	3	2, 3, 6	72 patients with unstable pelvic Fxs who presented in shock were reviewed. 36 of 61 patients recovered from shock after angioembolization. 18 of 25 who did not recover from shock died. In 11 of 25 who did not recover from shock after angio/embolization, transfemoral venography was performed, revealing significant venous extravasation in 9 (5 common iliac vein, 3 internal iliac vein, and 1 external iliac vein). The authors conclude that iliac vein injury is the principal cause of hemorrhagic shock in patients with unstable pelvic Fxs and that venography is useful for identifying these injuries	*J Trauma*. 2005;58:704–710
Stephen et al.[16]	1999	Early detection of arterial bleeding in acute pelvic trauma	3	2,4	Retrospective review of 111 patients with pelvic/acetabular Fxs w/CT scan, including stable and unstable patients. 11 patients had extravasation. Obturator artery was #1 cause of hemorrhage requiring embolization with superior gluteal #2. CE was 80% sensitive and 98% specific for requiring angiography. They conclude that CE seen on CT (whether hemodynamically stable or unstable) requires angiography, although some hemorrhage will have stopped by the time angiography is undertaken	*J Trauma*. 1999;47:638–642

TABLE 2. Evidentiary Table 1999–2010 (continued)

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Pereira et al.[58]	2000	Dynamic helical computed tomography scan accurately detects hemorrhage in patients with pelvic fracture	3	2, 4	Helical CT has high NPV (99.6%) to determine need for embolization PPV 69.2%; therefore, appropriate for screening polytrauma patients with pelvic Fxs to eliminate need for emergent angio embolization. 290 pelvic Fxs studied with CT, only 13 with CE. They recommend angio in patients who are unstable and have CE	*Surgery*. 2000;128:678–685
Ryan et al.[59]	2004	Active extravasation of arterial contrast agent on post-traumatic abdominal computed tomography	3	2, 4	Retrospective review of 28 initially hemodynamically stable patients w/extravasation on CT. Sensitivity was 87.5%, Specificity was 99.5%, PPV was 77.8%, and NPV was 99.8%. Mortality for CE group was 64% and 13% for those without. Authors recommend angio in patients with pelvic Fxs and CE become unstable	*Can Assoc Radiol J*. 2004; 55:160–169
Ruchholtz et al.[45]	2004	Free abdominal fluid on ultrasound in unstable pelvic ring fracture: is laparotomy always necessary?	2	1, 2, 3, 4, 6	Retrospective review of 80 patients with type B or C pelvic ring Fxs. Fluid group (free fluid on initial FAST) had 31 patients, all underwent laparotomy. 30 of 31 had an abdominal source of bleeding. 6 patients in the no fluid group (n = 49) were hemodynamically unstable, and none had an abdominal sources of bleeding. Hemodynamically unstable patients w/o free fluid require early Ex fix stabilization and hemodynamically unstable patients with a positive FAST require laparotomy first, retroperitoneal packing as needed, and ex fixation after abdominal bleeding is controlled. Further imaging (CT scan) is needed in hemodynamically stable patients and patients w/o free fluid who continue to be unstable after ex fixation	*J Trauma*. 2004;57:278–285
Niwa et al.[24]	2000	The value of plain radiographs in the prediction of outcome in pelvic fractures treated with embolisation therapy	3	2, 4	Review of 40 patients requiring angiographic embolization for pelvic hemorrhage. Plain pelvic films were reviewed retrospectively for location of bony injury (L or R ischiopubic or sacroiliac) and Foley deviation to see if hemorrhagic source could be predicted. The authors concluded that in this patient group, plain X-ray has 81% sensitivity and 91% specificity in identifying location of hemorrhage. Selection bias of reviewing only those requiring embolization and does not to help identify those who may require embolization	*Br J Radiol*. 2000;73:945–950
Tayal et al.[46]	2006	Accuracy of trauma ultrasound in major pelvic injury	3	2,3,4	Sensitivity of FAST in patients with pelvic fx 80.8% and specificity 86.9%. PPV 72.4%, NPV 91.4%. Of 21 true positive FAST, free fluid was urine in 4. Propose peritoneal tap in hemodynamically unstable patients to determine whether fluid is blood or urine from bladder injury	*J Trauma*. 2006;61:1453–1457

TABLE 2. Evidentiary Table 1999–2010 (continued)

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Friese et al.[47]	2007	Abdominal ultrasound is an unreliable modality for the detection of hemoperitoneum in patients with pelvic fracture	3	2, 3, 4	96 patients with pelvic Fx and increased risk for hemorrhage (age >55, SBP <90 mm Hg in ED, or UFP) studied w/FAST where results confirmed with CT or laparotomy. In detecting free fluid in peritoneal cavity, FAST had sensitivity of 26%, specificity 96%, PPV 85%, NPV 63%. With a negative FAST, a second test needs to be done: CT scan in stable patients, DPL in unstable patients. Authors conclude FAST does not help determine laparotomy	*J Trauma*. 2007;63:97–102
Ballard et al.[48]	1999	An algorithm to reduce the incidence of false-negative FAST examinations in patients at high risk for occult injury. Focused assessment for the sonographic examination of the trauma patient	2	3, 4	Prospective, nonrandomized study of blunt trauma patients w/pelvic Fxs, FAST, and subsequent CT or laparotomy. There were 70 pelvic trauma patients w/sensitivity of 24% and specificity of 100% and 13 false negatives. The authors conclude that any patient with pelvic trauma and FAST requires a CT scan to evaluate for further injury due to the high false-negative rate	*J Am Coll Surg*. 1999; 189:145–150
Hamill et al.[51]	1999	Pelvic fracture pattern predicts pelvic arterial haemorrhage	3	3, 4	Review of 76 patients with pelvic Fxs who required >6 units PRBC in 1st 24 h: (MLD as defined by Fx classes APC II or III, LC III, VS, or Combined Mechanism) was shown to correlate with increased need for embolization, but sensitivity 63% and specificity 44%. Unable to use pelvic fx class to identify patients who require embolization	*Aust N Z J Surg*. 2000;70: 338–343
Blackmore et al.[55]	2006	Predicting major hemorrhage in patients with pelvic fracture	2	2, 3, 4	627 patients with pelvic fx. Major pelvic hemorrhage (defined as any of 3 criteria were present: (1) arterial extravasation on angiography, (2) high volume pelvic hematoma on CT (>600 mL), or (3) high transfusion requirement in the absence of other source of hemorrhage) was identified in 128 of 627 subjects (20%). Four factors remained as predictors of major pelvic hemorrhage: pulse >130, hematocrit of 30% or less, displaced (1 cm) obturator ring Fx, or diastasis of the pubic symphysis of 1 cm or more. The final predictive model was able to stratify pelvic Fx patients into groups with probabilities of major hemorrhage ranging from less than 2% (4 of 247) for 0 predictors to over 60% (39 of 59) for 3 or more predictors	*J Trauma*. 2006;61:346–352
Eastridge et al.[50]	2002	The importance of fracture pattern in guiding therapeutic decision-making in patients with hemorrhagic shock and pelvic ring disruptions	3	2, 3, 4	Retrospective of 193 patients w/hypotension and pelvic Fxs. Defined stable pelvic Fxs as LC and APC 1. Defined unstable pelvic Fxs as APC 2/3, LC 2/3, and VS 85% of SFP w/persistent hypotension had abdominal source of hemorrhage while 28% of UFP had an abdominal source. Authors conclude that persistent hypotension in pelvic Fx patients can be subdivided by SFP or UFP and can be predictive of outcome. Recommend laparotomy in hypotensive patients w/SFP and strong consideration of angio before laparotomy in hypotensive patients w/UFP	*J Trauma* 2002;53:446–450

TABLE 2. Evidentiary Table 1999–2010 (continued)

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Sarin et al.[56]	2005	Pelvic fracture pattern does not always predict the need for urgent embolization	3	2, 4	Retrospective review of 283 patients w/hypotension and MLD, i.e., APC II/III, LC III, and VS Mortality, ISS, and PRBCs were greater in the MLD group. Did not find correlation to MLD and the need for angiography. Authors conclude that despite other reports, pelvic Fx pattern cannot be used to determine whether hypotension is from pelvic hemorrhage or another source	*J Trauma*. 2005;58:973–977
Magnussen et al.[53]	2007	Predicting blood loss in isolated pelvic and acetabular high-energy trauma	3	1, 2	289 Isolated pelvic Fxs reviewed for PRBC transfused in first 24 h. Patients divided into pelvic fx only (111), acetabular fx only (143), and both (35). Patients with both required more PRBC than those with pelvic or acetabular alone. PRBC requirements equal between pelvic and acetabular group. Within pelvic group, 44% of those with MLD (fx patterns LCIII, APC II–III, VS, combined) required PRBC while only 8.5% of those w/o MLD required PRBC	*J Orthop Trauma*. 2007; 21:603–607
Lunsjo et al.[54]	2007	Associated injuries and not fracture instability predict mortality in pelvic fractures: a prospective study of 100 patients	2	1, 2, 4	100 consecutive patients with pelvic Fx, mortality (9%). Pelvic Fx classified as O (no instability), R (rotational instability), or RV (rotational and vertical instability). Of ISS, RTS, pelvic fx classification, PRBC transfused, logistic regression showed only ISS to be an independent predictor of mortality. Pelvic Fx patterns do not predict mortality and therefore does not predict active hemorrhage requiring angiography	*J Trauma*. 2007;62:687–691
Smith et al.[57]	2007	Early predictors of mortality in hemodynamically unstable pelvis fractures	2	2, 4	Retrospective review of prospective trauma database. 187 HD unstable patients w/pelvic Fxs. Analyzed factors related to mortality. Fx pattern (Young and Burgess) and need for angiography were not predictive of mortality. Age, ISS, and PRBC Transfusion were predictors of mortality	*J Orthop Trauma*. 2007; 21:31–37
Starr et al.[21]	2002	Pelvic ring disruptions: prediction of associated injuries, transfusions requirement, pelvic arteriography, complications, and mortality	2	3, 4	Retrospective review of 325 patients w/closed pelvic Fxs. Shock and RTS were significantly associated w/mortality, PRBC Transfusion, ISS, and AISS. Older age and RTS were significantly associated w/ need for angiography. LC 2/3 had higher rate of angiography, but no other Fx pattern to need for angio was found. Patients that underwent angio had higher mortality and PRBC TX need. Unable to demonstrate a statistical relationship between Fx pattern and need for arteriography or mortality	*J Orthop Trauma* 2002; 16:553–561
Balogh et al.[83]	2005	Institutional practice guidelines on management of pelvic fracture-related hemodynamic instability: do they make a difference?	2	1, 2, 3, 4	PG established including (1) abdominal "clearance" (AC) using FAST ± DPT; (2) Pelvic binding w/sheet, C-clamp (PB); (3) Pelvic angio within 90 min, and; 4) OF within 24 h; patients meeting guidelines pre/post PG: AC 67%/100%; PB 0%/86%; PA 30%/93%; OF 52%/86%. Mortality 6 of 17 pre-PG (35%) and 1 of 14 post-PG (7%). Multidisciplinary guidelines seem to improve outcome	*J Trauma*. 2005;58:778–782

TABLE 2. Evidentiary Table 1999–2010 (continued)

Author(s)	Year	Title	Level of Evidence	Question Addressed	Synopsis	Reference
Biffl et al.[82]	2001	Evolution of a multidisciplinary clinical pathway for the management of unstable patients with pelvic fractures	2	1, 2, 3, 5	Retrospective review of 143 patients in "early group" vs. 73 "late group" which was defined as before and after the time when 2 ortho trauma staff were in the trauma bay for decision making upon patient arrival. Lower rate of hypotension, increased use of PB, and improved mortality (31% vs. 15%). There were no differences in the number of packed red cells or fresh-frozen plasma units transfused. There were no significant differences between the 2 groups in terms of the overall complication rate or the occurrence of acute respiratory distress syndrome, multiple organ failure, or pneumonia	*Ann Surg.* 2001;233:843–850

ISS, injury severity score; RTS, revised trauma score; CE, contrast extravasation; PRBC, packed red blood cells; OTA, Orthopedic Trauma Association; APC, anteroposterior compression; LC, lateral compression; DIC, disseminated intravascular coagulopathy; MRI, magnetic resonance imaging; I&D, incision and drainage; APACHE, acute physiology and chronic health evaluation; BP, blood pressure; PCCD, pelvic circumferential compression device; BMI, body mass index; Fx, fracture; CT, computed tomography; PPV, positive predictive value; NPV, negative predictive value; SBP, systolic blood pressure; ED, emergency department; VS, vertical shear; MLD, major ligamentous disruption; SFP, stable fracture pattern; UFP, unstable fracture pattern; AISS, abbreviated injury severity score; PB, pelvic binding; PG, practice guideline; OF, operative pelvic fixation; TX, transfusion.

Questions: (1) Which patients warrant early external mechanical stabilization? (2) Which patients require emergent angiography? (3) What is the best test to exclude extra-pelvic bleeding? (4) Are there radiographic findings which predict hemorrhage? (5) What is the role of non-invasive temporary external fixation devices? and (6) Which patients warrant pre-peritoneal packing?

TABLE 3. Tile Classification

Type A	Stable pelvic ring injury
Type B	Partially stable pelvic ring injury
	B1: Open book injury (anteroposterior compression, external rotation)
	B2: Lateral compression (internal rotation)
	B3: Bilateral injuries
Type C	Completely unstable (allows all degrees of translational displacement)

puted tomography (CT) scanning with mathematical modeling, Stover et al.[4] demonstrated an increase in pelvic volume of 35% to 40% with a large 10-cm pubic diastasis, again in a cadaver model.

Pelvic stabilization has been practiced for a number of years in an attempt to control pelvic bleeding by decreasing the pelvis volume, leading to earlier tamponade. Methods that close the pelvic ring are thought to tamponade bleeding by diminishing the pelvic volume, hastening clotting of the pelvic hematoma.[5] Initially, the pneumatic antishock garments (PASG) was used to stabilize the pelvis and decrease the pelvic volume. In retrospective studies, Flint et al. and others have demonstrated less blood loss when the PASG was applied.[6–8] Other studies have questioned the ability of PASG to limit hemorrhage from pelvic fracture.[9,10] PASG have largely fallen out of favor due to concerns about abdominal compartment syndrome and fluid and electrolyte complications and because they are bulky, difficult to apply, and interfere with physical examination.

External pelvic fixation (EPF) and the pelvic C-clamp have been used more recently in an attempt to reduce pelvic volume and control hemorrhage associated with pelvic fracture. In a study of 14 hemodynamically unstable patients with pelvic fractures, Sadri et al.[11] found that blood loss was not statistically different before/after placement of the pelvic C-clamp. Angiography was required in many of these patients to control hemorrhage. Application of the pelvic C-Clamp is generally done quickly (5 minutes)[12]although others have reported that it can take longer, averaging 64 minutes to apply (range, 10–240 minutes).[13] When EPF is compared with a temporary pelvic binder (TPB) in patients with sacroiliac fractures, EPF was found to have higher blood transfusion needs at 24 hours and 48 hours compared with the TPB. The reduced blood loss has been attributed to the ease and rapidity of TPB application compared with EPF.[14]

Placement of a C-Clamp or EPF decreases the pelvic volume by 10% to 20% and reduces pelvic fractures.[3,14,15] Whether this leads to less blood loss and better outcomes has yet to be shown in the literature. The standard use of external fixation in the initial treatment algorithms of patients with unstable pelvic injuries is common and remains a useful tool in the initial management of these patients.[13,16] However, because of their ease of use and fast application, TPBs have largely replaced the pelvic C-Clamp and EPF for early mechanical stability in pelvic fracture.

Which Patients Require Emergent Angiography?

1. Patients with pelvic fractures and hemodynamic instability or signs of ongoing bleeding after nonpelvic sources of blood loss have been ruled out should be considered for pelvic angiography/embolization. **Level I recommendation**
2. Patients with evidence of arterial intravenous contrast extravasation (ICE) in the pelvis by CT may require pelvic angiography and embolization regardless of hemodynamic status. **Level I recommendation**
3. Patients with pelvic fractures who have undergone pelvic angiography with or without embolization, who have signs of ongoing bleeding after nonpelvic sources of blood loss have been ruled out, should be considered for repeat pelvic angiography and possible embolization. **Level II recommendation**
4. Patients older than 60 years with major pelvic fracture (open book, butterfly segment, or vertical shear) should be considered for pelvic angiography without regard for hemodynamic status. **Level II recommendation**
5. Although fracture pattern or type does not predict arterial injury or need for angiography, anterior fractures are more highly associated with anterior vascular injuries, whereas posterior fractures are more highly associated with posterior vascular injuries. **Level III recommendation**
6. Pelvic angiography with bilateral embolization seems to be safe with few major complications. Gluteal muscle ischemia/necrosis has been reported in patients with hemodynamic instability and prolonged immobilization or primary trauma to the gluteal region as the possible cause, rather than a direct complication of angioembolization. **Level III recommendation**
7. Sexual function in males does not seem to be impaired after bilateral internal iliac arterial embolization. **Level III recommendation**

Scientific Foundation: Emergent Angiography

Pelvic angiography is useful control of arterial hemorrhage associated with pelvic fractures. In many pelvic fractures, much of the bleeding is venous in nature, generally from bone fracture edges or the iliolumbar vein. Angiography with embolization only controls arterial hemorrhage and therefore is beneficial in only a minority of patients. Indeed, it seems that pelvic angiography is indicated in only 3% to 10% of patients with pelvic fracture.[17–23] Hemodynamic instability associated with pelvic fractures without another significant source of bleeding is an indication for pelvic angiography.[18–20,24,25] In a retrospective study of 325 patients at a Level I trauma center, Starr et al. found that Revised Trauma Score alone was predictive of the need for angiography. Age, shock on admission, and fracture pattern did not predict need for angiography.[21]

There are several predictors to help determine which patients will need angiography. The presence of ICE seen on CT scan has a sensitivity of 60% to 84% and specificity of 85% to 98% for the need for pelvic embolization.[18] ICE is a strong predictor of need for angioembolization. Fracture pattern alone has not been predictive of who will or will not require angiography.[21,24,26] The combination of age >60 and major pelvic fracture is highly associated with need for angiography with embolization (odds ratio, 15) regardless of the patient's hemodynamic status. Indeed, 62% of patients older than 60 years requiring angiographic embolization had normal vital signs on hospital admission.[27] Although hemorrhage from major pelvic fractures is common, several retrospective studies contain patients with arterial bleeding from isolated sacral or acetabular fractures.[17] Although fracture type does not predict need for angiography, in general, anterior fractures are associated with anterior vascular injuries, whereas posterior fractures are associated with posterior vascular injuries.[28]

Pelvic angiography with embolization seems to be 85% to 97% effective in controlling bleeding. Some patients will continue to bleed and require repeat embolization to control hemorrhage.[22,23,29,30] 4.6% to 24.3% of patients with either no bleeding seen on the initial angiogram or initially successful pelvic embolization will require repeat pelvic angiography with repeat embolization. Independent risk factors for recurrent pelvic bleeding include transfusing greater than two units packed red blood cells per hour before angiography, finding more than two injured vessels requiring embolization,[22] repeated hypotension after initial angiography, absence of intra-abdominal injury, and persistent base deficit.[30] The standard embolization technique for an unstable patient bleeding from an internal iliac artery source is to nonselectively embolize both internal iliac arteries. In more stable patients, some operators may attempt more selective embolization. However, a study by Fang et al.[23] demonstrated that recurrent pelvic bleeding also seems to be more common after selective embolization than after nonselective treatment, suggesting this practice should be limited.

The safety of pelvic angiography/embolization seems to be well established in several series.[29,31] There are occasional reports of femoral artery injury requiring repair and transient increases in serum creatinine in older patients.[27] Cases of gluteal necrosis associated with embolizations seem to be related to primary trauma to the gluteal region along with protracted hypotension rather than a direct complication of embolization.[17,32] In one report, six of eight pelvic fracture patients undergoing bilateral angioembolization for shock showed magnetic resonance imaging changes consistent with soft tissue infection or necrosis[33] without primary gluteal trauma, suggesting that gluteal muscle ischemia may be subclinical. Ramirez et al.[34] examined sexual dysfunction in males undergoing bilateral internal iliac embolization and found no difference compared with case-matched pelvic fracture patients not undergoing embolization.

What Is the Best Test to Exclude Intra-Abdominal Bleeding?

1. Focused Assessment with Sonography for Trauma (FAST) is not sensitive enough to exclude intraperitoneal bleeding in the presence of pelvic fracture. **Level I recommendation**

2. FAST has adequate specificity in patients with unstable vital signs and pelvis fracture to recommend laparotomy to control hemorrhage. **Level I recommendation**
3. Diagnostic peritoneal tap (DP)/Diagnostic peritoneal lavage (DPL) is the best test to exclude intra-abdominal bleeding in the hemodynamically unstable patient. **Level II recommendation**
4. In the hemodynamically stable patient with a pelvic fracture, CT of the abdomen and pelvis with intravenous contrast is recommended to evaluate for intra-abdominal bleeding regardless of FAST results. **Level II recommendation**

Scientific Foundation: Tests to Exclude Intra-Abdominal Bleeding With Pelvic Fracture

Early detection of hemoperitoneum after blunt abdominal injury allows for rapid implementation of decision-making algorithms and decreasing the time to abdominal exploration in patients at high risk for intraperitoneal hemorrhage. The indications for laparotomy in the patient with a pelvic fracture are the same for all trauma patients. With concomitant pelvic fracture, differentiating between pelvic-bleeding and intra-abdominal hemorrhage is critical to the initial decision-making and management of the patient.

Four methods are commonly used to help exclude intra-abdominal bleeding: DPL, ultrasound (FAST), DP, and CT.[1] Each test has advantages and disadvantages specific to their use in patients with pelvic fracture. DPL has been shown to have a high rate of false positives in patients with pelvic fractures.[7,35,36] This is thought to be due to a high rate of red cell diapedesis across the peritoneum. DP without lavage performed in the supraumbilical region seems to offer similar sensitivity as DPL with a lower rate of false-negative examinations.[7,36,37]

The FAST has been an effective tool for the evaluation of patients with intra-abdominal injuries and hypotension.[38–42] Patients with pelvic fractures are at high risk to have other associated intra-abdominal injuries as a source of bleeding.[43,44] Although the specificity of the FAST in patients who have pelvic fractures examination is reasonable as an initial screening tool (87–100%), the sensitivity of the examination in the presence of a mechanically unstable pelvic fracture (Tile B/C) is unacceptably low.[45–48] Ruchholz et al.[45] reported 75% sensitivity with concomitant pelvic fracture in a series of patients with type B/C pelvic fractures. This finding was consistent with other reports in the literature.[46,48] In a more recent report from a high volume trauma center, Freise et al.[47] reported a very low sensitivity of 26% in patients with pelvic fracture.

Because of the low sensitivity and low negative predictive value of FAST when pelvic fracture is present, CT of the abdomen and pelvis with intravenous contrast is recommended in patients with pelvic fracture and a negative FAST examination who are hemodynamically stable. A negative FAST examination in a patient with pelvic fracture does not aid in determining whether a laparotomy or angiography is warranted.[46–48] Hemodynamically unstable patients with pelvic fracture and a positive FAST should undergo emergent laparotomy, whereas hemodynamically normal patients with pelvic fracture and a positive FAST should receive an abdominal/pelvic CT scan.

Are There Radiologic Findings Which Predict Hemorrhage?

1. Fracture pattern on pelvic X-ray does not single-handedly predict mortality, hemorrhage, or the need for angiography. **Level II recommendation**
2. Presence/location of hematoma does not predict or exclude the need for angiography and possible embolization. **Level II recommendation**
3. CT of the pelvis is an excellent screening tool to exclude pelvic hemorrhage. **Level II recommendation**
4. Absence of contrast extravasation on CT does not always exclude active hemorrhage. **Level II recommendation**
5. Pelvic hematoma >500 cm^3 in size has an increased incidence of arterial injury and need for angiography. **Level II recommendation**
6. Isolated acetabular fractures are as likely to require angiography as pelvic rim fractures. **Level III recommendation**
7. If a retrograde urethrocystogram is required, it should be performed after CT with intravenous contrast. **Level III recommendation**

Scientific Foundation: Radiographic Predictors of Hemorrhage

Two radiographic modalities have the potential to provide clinically useful information during the evaluation of traumatic pelvic fractures in the acute setting: pelvic X-ray and CT scan. Several recent studies attempt to correlate radiographic findings to clinical outcomes and specifically the need for angiography.

The Young-Burgess classification system[49] (Table 4) divides pelvic fractures by vector; anteroposterior, lateral compression, vertical shear, and combined mechanical. Each type of fracture is also graded by severity (I, II, and III). Correlating the fracture pattern to the need for angiography has shown mixed results. Niwa et al.[24] was able to show an association. This study was unable to define the cause of death in 20% of their population. Posterior bleeding sources seem to correlate with anteroposterior type fractures, whereas lateral compression fractures are more likely to have an anterior (iliac) source of bleeding.[28]

In an effort to determine whether patients should undergo laparotomy or angiography in hemodynamically unstable patients with pelvic fractures, Eastridge et al.[50] found that those with higher grade or rotationally unstable pelvic fractures were more likely to have a pelvic source of bleeding. Patients with rotationally stable fractures were more likely to have an abdominal source of hemorrhage and therefore should have a laparotomy performed as the primary procedure. Two studies were able to show a relationship between major ligamentous disruption and the need for pelvic embolization.[51,52] The authors concede that, although positive, the correlation was too weak to assist in clinical decision-making. When looking at pelvic fractures outside the pelvic ring, isolated acetabular fractures were shown to have the same blood transfusion requirements and presumably the need for

TABLE 4. Young-Burgess Classification System

Fracture Type	Common Characteristic	Differentiating Characteristic
Lateral compression 1	Transverse pubic rami fracture	Sacral Compression on side of impact
Lateral compression 2	Transverse pubic rami fracture	Crescent (iliac wing) fracture
Lateral compression 3	Transverse pubic rami fracture	Contralateral open-book (anteroposterior compression) injury
Anterior-posterior compression 1	Symphyseal diastasis (1–2 cm)	Slight widening of symphysis and/or sacroiliac (SI) joint, stretched but intact anterior and posterior SI joint ligaments
Anterior-posterior compression 2	Symphyseal diastasis or vertical pubic rami fracture	Widened SI joint, disrupted anterior SI ligaments with intact posterior SI ligaments
Anterior-posterior compression 3	Symphyseal diastasis or vertical pubic rami fracture	Complete hemipelvis separation but no vertical displacement, anterior and posterior SI joint ligaments ruptured
Vertical shear	Symphyseal diastasis or vertical pubic rami fracture	Vertical hemipelvis displacement, usually through SI joint, occasionally through iliac wing or sacrum
Combined mechanism	Vertical or transverse pubic rami fractures	Combination of patterns; lateral compression with vertical shear or lateral compression with anterior-posterior compression

SI, sacroiliac.

angiography.[53] Two other studies concluded that injury severity score was a better predictor of pelvic hemorrhage than fracture pattern.[50,54] Blackmore et al.[55] developed a multiple logistic regression model that was able to predict the probability of pelvic arterial hemorrhage.[55] The model included the following factors: initial hematocrit 30 or less, heart rate 130 or greater, and pelvic fracture patterns including obturator ring fracture greater than 1 cm or pubic symphysis diastasis of at least 1 cm. The presence of three or four of these risk factors was only able to predict pelvic hemorrhage in 66% of patients. The remaining studies were unable to correlate pelvic fracture pattern with need for angioembolization.[21,56,57] The available literature suggests that pelvic fracture pattern alone is insufficient to predict the need for angioembolization.

CT scanning has become a valuable asset in the acute management of pelvic trauma. Two factors have been studied to determine the need for angioembolization: ICE and the pelvic hematoma size. The absence of ICE on the admission CT is an excellent screening test to exclude the presence of active arterial hemorrhage and therefore the need for angioembolization, with the negative predictive values ranging from 98.0% to 99.8%.[58–60] The presence of ICE, however, has shown varied results. Stephen et al.[16] showed that the positive predictive value of ICE needing angioembolization was 80%. The negative predictive value was 98%. They concluded that the presence of ICE was an indication for angiography, regardless of hemodynamic status. Pereira et al.[58] demonstrated a lower positive predictive value of 69.2% with ICE. Four of five patients who were hemodynamically stable with a blush did not require embolization. They recommend angiography only in hemodynamically unstable patients with ICE. Ryan et al.[59] reported their experience with 18 patients with mechanically unstable pelvic fractures and ICE. Nine of these patients underwent angiography for hemodynamic instability of which seven required embolization. The presence of ICE on CT was predicted the site of bleeding found angiographically in all patients. They concluded that ICE on CT scan with a major pelvic fracture mandates angiography regardless of hemodynamics. There were no complications from angiography reported in these studies.

Other studies have demonstrated a higher mortality rate from a delay in angiography.[60] Brasel et al.[61] retrospectively examined CT scans with ICE and found 90% sensitivity for needing angiography. They noted, however, that 33% of patients without ICE who were hemodynamically unstable also required angiography. The data suggest that any hemodynamically unstable patient with pelvic fractures and ICE requires angiography in the absence of other bleeding sources. When patients are hemodynamically stable, the evidence is mixed. In a patient with stable hemodynamics, the data suggest that angiography may be useful to prevent further bleeding but may not be required in all patients.[61] Need for angiography in hemodynamically stable patients with ICE from pelvic trauma requires further study to determine its usefulness.

Attempts at correlating the presence and size of a pelvic hematoma seen on CT with the need for angiography have been undertaken. Brown et al.[62] retrospectively studied 37 patients who underwent CT and angiography. Contrast extravasation during angiography was noted in 83% of patients without hematoma (67% of patients with small hematoma and 73% of patients with significant hematoma). Blackmore et al.[55] found that hematomas >500 cm^3 had a significant increased risk ratio of 4.8 for arterial injury at angiography. In general, the presence of pelvic hematoma is insufficient to alter the indications for angiography and is not a predictor of need for transfusion or ongoing blood loss. Large hematomas with volumes over 500 cm^3 may have an increased risk of arterial injury requiring angiography.

The presence of bladder and urethral injuries with concomitant pelvic fractures is common. Retrograde urethrogram (RUG) should be performed before placement of a urinary catheter; however, the sequencing of RUG and CT has been controversial.[63] Netto et al.[64] was able to show a higher rate of indeterminate and false-negative CT if RUG was performed first. This was due to contrast from the RUG interfering with determining if ICE was present. The detection of hemorrhage needs to take priority over detecting urologic injuries, and therefore CT scan with contrast should be performed before the evaluation of the genitourinary tract in most settings.

What Is the Role of Noninvasive Temporary External Fixation Devices?

1. TPBs effectively reduce unstable pelvic fractures as well as definitive stabilization and decrease pelvic volume. **Level III recommendation**
2. TPBs may limit pelvic hemorrhage but do not seem to affect mortality. **Level III recommendation**
3. TPBs work as well or better than emergent EPF in controlling hemorrhage. **Level III recommendation**

Scientific Foundation: Temporary External Fixation Devices

Temporary binders have been used to control hemorrhage from pelvic fractures for many years. Pneumatic antishock trousers were one of the early attempts to decrease the pelvic volume and limit hemorrhage. Sheets have been used for this task more recently.[65–67] Commercial devices have recently evolved to provide consistent compression in a convenient prepackaged device. Results from studies of these commercial binders have been mixed. In a large study performed at Parkland Hospital, the use of a commercial binder had no effect on transfusion requirements, need for angiographic embolization, or mortality when compared with historical controls.[68] Croce et al. compared the use of EPF placed in the operation room with TPB placed in the emergency department in a series of patients with hemodynamically instability and structurally unstable fractures. The use of the T-POD (Cybertech Medical, La Verne, CA) reduced blood transfusion needs at 24 hours and 48 hours compared with historical controls. Both the groups were in similar degree of shock. The authors attributed the reduced blood loss to the rapidity of T-POD placement compared with EPF. No differences in mortality were found.[69]

Evidence suggests temporary binders decrease pelvic volume with a pelvic fracture and may improve biomechanical stability. Bottlang et al.[70,71] noted fracture reduction and 55% to 61% improvement in biomechanical stability of pelvic fractures in seven nonembalmed cadavers after application of an external compression device. In a study of 16 patients with mechanically unstable pelvic fractures, Kreig et al.[14] demonstrated a 9.9% decrease in pelvic width using a TPB with no complications related to the binder. The data confirming efficacy of pelvic binders in controlling hemorrhage from pelvic fracture remain unclear because of conflicting studies in the literature.[14,68–72]

The use of pelvic binders may predispose to skin breakdown with prolonged use due to high pressure at bony prominences.[72] Shearing force applied when tightening the binder might result in tissue trauma. Users of these devices need to be aware of the risk of pressure induced ischemic wounds. Because of the ease of application, relatively inexpensive cost, low potential for complications, and benefit to pelvic stability, temporary external stabilization devices should be considered for emergent application to all hemodynamically unstable patients with pelvic injuries.

Which Patients Warrant Retroperitoneal (Preperitoneal) Packing?

1. Retroperitoneal pelvic packing is effective in controlling hemorrhage when used as a salvage technique after angiographic embolization. **Level III recommendation**
2. Retroperitoneal pelvic packing is effective in controlling hemorrhage when used as part of a multidisciplinary clinical pathway including a POD/C-clamp. **Level III recommendation**

Scientific Foundation: Retroperitoneal Packing

Emergent PPP is a newer technique in the trauma surgeon's armamentarium. Its use is currently evolving. Originally described in the European literature,[73] several European centers have described using PPP in combination with external mechanical fixation of the pelvis.[74–77] Some trauma centers in the United States have adopted this technique and published on its use as a first-line therapy in-lieu of angiography.[78] It is reportedly easy to learn.[79]

The technique involves creating a midline incision 8 cm in length just above the pubis extending toward the umbilicus.[80,81] Skin and subcutaneous tissue is opened in the midline, as is the fascia. The bladder is retracted away from the fracture and three laparotomy pads are placed in the retroperitoneal space on each side toward the iliac vessels. The procedure is repeated on the opposite side and the fascia and skin are closed. The procedure can be performed in 20 minutes by experienced surgeons.[80,81]

Cothren et al.[78] reported using PPP as part of a clinical pathway in treating hemorrhage from pelvic fracture. In this group of severely injured patients (injury severity score = 55), PPP was performed immediately after placement of a TPB in-lieu of angiography. There were no deaths attributed to hemorrhage after packing along with significantly fewer blood transfusions. This study reported an 83% success rate in controlling hemorrhage in hemodynamically unstable patients who underwent PPP. The other 17% required angiography. In a follow-up study at their institution, pelvic packing was found to occur faster than with angiography (45 minutes vs. 130 minutes). There was also a decrease need for transfusion. The results of the study are difficult to interpret because time to control hemorrhage was significantly different between the groups.[81]

PPP seems to have some advantage in controlling hemorrhage, particularly when angiography is unavailable or would result in significant delay. Future comparative studies will be needed to directly compare PPP with angiography for the control of pelvic hemorrhage.

SUMMARY

Hemorrhage from pelvic fracture remains a difficult problem facing the trauma surgeon. Today, there have been many changes in practice pattern that have been shown to predict and limit hemorrhage in the patient with a pelvic fracture. Biffl et al.[82] found that a multidisciplinary team, including an Orthopedic Surgeon, improved outcomes compared with historical controls. Institutional guidelines also have been shown to improve outcomes and their use is

encouraged to limit variability in care.[82–84] Emergent external fixation and the pelvic C-clamp used to control hemorrhage is not supported by the available literature. Although they do reduce fractures effectively, they do not seem to limit hemorrhage based on the available literature. Angiography for control of hemorrhage has come of age and has an important role in the treatment of patients with pelvic fracture and is supported by the highest level of evidence. Pelvic angiography with embolization can be performed bilaterally if needed and even repeated to control bleeding without undo consequence. The data on using the FAST examination to exclude intra-abdominal hemorrhage are clear. FAST examination, although highly specific, does not have the sensitivity to rule out an extrapelvic (abdominal) source of hemorrhage with major pelvic fracture. Although X-ray patterns of injury do not seem to predict hemorrhage, the use of CT scan with a finding of ICE is highly predictive of active bleeding and supported by the literature. The use of pelvic external fixation and C-Clamps has largely given way to TPBs. The hope with these devices is that by stabilizing the fracture, bleeding will be limited. Although the data are limited, early studies seem promising. Further studies will be needed to asses the ability of temporary abdominal binders to minimize hemorrhage from pelvic fracture. Finally, retroperitoneal packing is an effective tool to limit hemorrhage in the small studies that have investigated the technique. Its role in the management of pelvic hemorrhage at this time remains unclear and will need direct comparison with angiography in future studies.

REFERENCES

1. DiGiacomo JG, Bonadies JA, Cole FJ. Practice management guidelines for hemorrhage in pelvic fracture [EAST Website], 2001. Available at: http://www.east.org/tpg/pelvis.pdf. Accessed October 1, 2009.
2. Eastern Association for the Surgery of Trauma. *Practice Management Guidelines for Traum a East Ad Hoc Committee on Guideline Development*. Chicago, IL: EAST; 1998.
3. Baque P, Trojani C, Delotte J, et al. Anatomical consequences of "open-book" pelvic ring disruption: a cadaver experimental study. *Surg Radiol Anat.* 2005;27:487–490.
4. Stover MD, Summers HD, Ghanayem AJ, Wilber JH. Three-dimensional analysis of pelvic volume in an unstable pelvic fracture. *J Trauma.* 2006; 61:905–908.
5. Grimm MR, Vrahas MS, Thomas KA. Pressure-volume characteristics of the intact and disrupted pelvic retroperitoneum. *J Trauma.* 1998;44: 454–459.
6. Flint LM, Brown A, Richardson JD, Polk HC. Definitive control of bleeding from severe pelvic fractures. *Ann Surg.* 1979;189:709–716.
7. Moreno C, Moore EE, Rosenberger A, Cleveland HC. Hemorrhage associated with major pelvic fracture: a multispecialty challenge. *J Trauma.* 1986;26:987–994.
8. Batalden DJ, Wickstrom PH, Ruiz E, Gustilo RB. Value of the G suit in patients with severe pelvic fracture. Controlling hemorrhagic shock. *Arch Surg.* 1974;109:326–328.
9. Ali J, Qi W. Fluid and electrolyte deficit with prolonged pneumatic anti-shock garment application. *J Trauma.* 1995;38:612–615.
10. Chang FC, Harrison PB, Beech RR, Helmer SD. PASG: does it help in the management of traumatic shock? *J Trauma.* 1995;39:453–456.
11. Sadri H, Nguyen-Tang T, Stern R, Hoffmeyer P, Peter R. Control of severe hemorrhage using C-clamp and arterial embolization in hemodynamically unstable patients with pelvic ring disruption. *Arch Orthop Trauma Surg.* 2005;125:443–447.
12. Richard MJ, Tornetta P. Emergent management of APC-2 pelvic ring injuries with an anteriorly placed C-Clamp. *J Orthop Trauma.* 2009;23: 322–326.
13. Tiemann AH, Bohme J, Josten C. Emergency treatment of multiply injured patients with unstable disruption of the posterior pelvic ring by using the "C-clamp": analysis of 28 consecutive cases. *Eur J Trauma.* 2005;31:244–251.
14. Krieg JC, Mohr M, Ellis TJ, Simpson TS, Madey SM, Bottlang M. Emergent stabilization of pelvic ring injuries by controlled circumferential compression: a clinical trial. *J Trauma.* 2005;59:659–664.
15. Galois L, Pfeffer F, Mainard D, Delagoutte JP. The value of external fixation for unstable pelvic ring injuries. *Acta Orthop Belg.* 2003;69: 321–327.
16. Stephen DJG, Kreder HJ, Day AC, et al. Early detection of arterial bleeding in acute pelvic trauma. *J Trauma.* 1999;47:638–642.
17. Totterman A, Dormagen J, Madsen JE, Klow NE, Skaga NO, Roise O. A protocol for angiographic embolization in exsanguinating pelvic trauma: a report on 31 patients. *Acta Orthop.* 2006;77:462–468.
18. 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;54:437–443.
19. Cook RE, Keating JF, Gillespie I. The role of angiography in the management of haemorrhage from major fractures of the pelvis. *J Bone Joint Surg.* 2002;84:178–182.
20. Fangio P, Asehnoune K, Edouard A, Smail N, Benhamou D. Early embolization and vasopressor administration for management of life-threatening hemorrhage from pelvic fracture. *J Trauma.* 2005;58:978–984.
21. Starr AJ, Griffin DR, Reinert CM, et al. Pelvic ring disruptions: prediction of associated injuries, transfusion requirement, pelvic arteriography, complications, and mortality. *J Orthop Trauma.* 2002;16:553–561.
22. Gourlay D, Hoffer E, Routt M, Bulger E. Pelvic angiography for recurrent traumatic pelvic arterial hemorrhage. *J Trauma.* 2005;59: 1168–1173.
23. Fang JF, Shih LY, Wong YC, Lin BC, Hsu YP. Repeat transcatheter arterial embolization for the management of pelvic arterial hemorrhage. *J Trauma.* 2009;66:429–435.
24. Niwa T, Takebayashi S, Igari H, et al. The value of plain radiographs in the prediction of outcome in pelvic fractures treated with embolisation therapy. *Br J Radiol.* 2000;73:945–950.
25. Wong YC, Wang LJ, Ng CJ, Tseng IC, See LC. Mortality after successful transcatheter arterial embolization in patients with unstable pelvic fractures: rate of blood transfusion as a predictive factor. *J Trauma.* 2000;49:71–75.
26. Hagiwara A, Minakawa K, Matsuda T, Murata A, Masuda H, Shimazaki S. Predictors of death in patients with life-threatening pelvic hemorrhage after successful transcatheter arterial embolization. *J Trauma.* 2003;55: 696–703.
27. Kimbrel BJ, Velmahos GC, Chan LS, Demetriades D. Angiographic embolization for pelvic fractures in older patients. *Arch Surg.* 2004;139: 728–732.
28. Metz CM, Hak DJ, Goulet JA, Williams D. Pelvic fracture patterns and their corresponding angiographic sources of hemorrhage. *Orthop Clin North Am.* 2004;35:431–437.
29. Velmahos GC, Toutouzas KG, Vassiliu A, et al. A prospective study on the safety and efficacy of angiographic embolization for pelvic and visceral injuries. *J Trauma.* 2002;53:303–308.
30. Shapiro M, McDonald AA, Knight D, Johannigman JA, Cuschieri J. The role of repeat angiography in the management of pelvic fractures. *J Trauma.* 2005;58:227–231.
31. Velmahos GC, Chahwan S, Falabella A, Hanks SE, Demetriades D. Angiographic embolization for intraperitoneal and retroperitoneal injuries. *World J Surg.* 2000;24:539–545.
32. Takahira N, Shindo M, Tanaka K, Nishimaki H, Ohwada T, Itoman M. Gluteal muscle necrosis following transcatheter angiographic embolisation for retroperitoneal haemorrhage associated with pelvic fracture. *Injury.* 2001;32:27–32.
33. Yasumura K, Ikegami K, Kamohara T, Nohara Y. High incidence of ischemic necrosis of the gluteal muscle after transcatheter angiographic embolization for severe pelvic fracture. *J Trauma.* 2005;58: 985–990.

34. Ramirez JI, Velmahos GC, Best CR, Chan LS, Demetriades D. Male sexual function after bilateral internal Iliac artery embolization for pelvic fracture. *J Trauma.* 2004;56:734–739.
35. Panetta T, Sclafani SGA, Goldstein AS, Phillips TF, Shaftan GW. Percutaneous transcatheter embolization for massive bleeding from pelvic fractures. *J Trauma.* 1985;25:1021–1029.
36. Evers BM, Cryer HM, Miller FB. Pelvic fracture hemorrhage. *Arch Surg.* 1989;124:422–424.
37. Flint L, Babikian G, Anders M, Rodriguez J, Steinberg S. Definitive control of mortality from severe pelvic fracture. *Ann Surg.* 1990;211: 703–706.
38. Branney SW, Moore EE, Cantrill SV, Burch JM, Terry SJ. Ultrasound based key clinical pathway reduces the use of hospital resources for the evaluation of blunt abdominal trauma. *J Trauma.* 1997;42:1086–1090.
39. Healey MA, Simons RK, Winchell RJ, et al. A prospective evaluation of abdominal ultrasound in blunt trauma: is it useful? *J Trauma.* 1996;40: 875–883.
40. Glaser K, Tschmelitsch J, Klingler P, Wetscher G, Bodner E. Ultrasonography in the management of blunt abdominal and thoracic trauma. *Arch Surg.* 1994;129:743–747.
41. Liu M, Lee CH, P'eng FK. Prospective comparison of diagnostic peritoneal lavage, computed tomographic scanning, and ultrasonography for the diagnosis of blunt abdominal trauma. *J Trauma.* 1993;35:267–270.
42. Boulanger BR, McLellan BA, Brenneman FD, et al. Emergent abdominal sonography as a screening test in a new diagnostic algorithm for blunt trauma. *J Trauma.* 1996;40:867–874.
43. Eastridge BJ, Burgess AR. Pedestrian pelvic fractures; 5-year experience of a major urban trauma center. *J Trauma.* 1997;42:695–700.
44. Allen CF, Goslar PW, Barry M, Christiansen T. Management guidelines for hypotensive pelvic fracture patients. *Am Surg.* 2000;66:735–738.
45. Ruchholtz S, Waydhas C, Lewan U, et al. Free abdominal fluid on ultrasound in unstable pelvic ring fracture: is laparotomy always necessary? *J Trauma.* 2004;57:278–285.
46. Tayal V, Nielsen A, Jones AE, Thomason MH, Kellam J, Norton HJ. Accuracy of trauma ultrasound in major pelvic injury. *J Trauma.* 2006;61:1453–1457.
47. 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;63:97–102.
48. Ballard RB, Rozycki GS, Newman PG, et al. An algorithm to reduce the incidence of false-negative FAST examinations in patients at high risk for occult injury. Focused assessment for the sonographic examination of the trauma patient. *J Am Coll Surg.* 1999;189:145–150; discussion 150–151.
49. Young JWR, Burgess AR. Radiologic Management Of Pelvic Ring Fractures in Systematic Radiographic Diagnosis. Baltimore: Urban and Scwarzenberg; 1987.
50. 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;53:446–450.
51. Hamill J, Holden A, Civil I. Pelvic fracture pattern predicts pelvic arterial haemorrhage. *Aust N Z J Surg.* 2000;70:338–343.
52. Fu CY, Wu SC, Chen RJ, et al. Evaluation of pelvic fracture stability and the need for angioembolization: pelvic instabilities on a plain film have an increased probability of requiring angioembolization. *Am J Emerg Med.* 2009;27:792–796.
53. Magnussen RA, Tressler MA, Obremskey WT, Kregor PJ. Predicting blood loss in isolated pelvic and acetabular high-energy trauma. *J Orthop Trauma.* 2007;21:603–607.
54. Lunsjo K, Tadros A, Hauggaard A, Blomgren R, Kopke J, Abu-Zidan FM. Associated injuries and not fracture instability predict mortality in pelvic fractures: a prospective study of 100 patients. *J Trauma.* 2007; 62:687–691.
55. Blackmore CC, Cummings P, Jurkovich GJ, Linnau KF, Hoffer EK, Rivara FP. Predicting major hemorrhage in patients with pelvic fracture. *J Trauma.* 2006;61:346–352.
56. Sarin EL, Moore JB, Moore EE, et al. Pelvic fracture pattern does not always predict the need for urgent embolization. *J Trauma.* 2005;58: 973–977.
57. Smith W, Williams A, Agudelo J, et al. Early predictors of mortality in hemodynamically unstable pelvis fractures. *J Orthop Trauma.* 2007;21: 31–37.
58. Pereira SJ, O'Brien DP, Luchette FA, et al. Dynamic helical computed tomography scan accurately detects hemorrhage in patients with pelvic fracture. *Surgery.* 2000;128:678–685.
59. Ryan MF, Hamilton PA, Chu P, Hanaghan J. Active extravasation of arterial contrast agent on post-traumatic abdominal computed tomography. *Can Assoc Radiol J.* 2004;55:160–169.
60. Evers BM, Cryer HM, Miller FB. Pelvic fracture hemorrhage: priorities in management. *Arch Surg.* 1989;124:422–424.
61. Brasel KJ, K. Pham, Yang H, Christensen R, Weigelt JA. Significance of contrast extravasation in patients with pelvic fracture. *J Trauma.* 2007; 62:1149–1152.
62. Brown CVR, Kasotakis G, Wilcox A, Rhee P, Salim A, Demetriades D. Does pelvic hematoma on admission computed tomography predict active bleeding at angiography for pelvic fracture? *Am Surg.* 2005;71:759–762.
63. Brandes S, Borrelli J. Pelvic fracture and associated urologic injuries. *World J Surg.* 2001;25:1578–1587.
64. Netto FA, Hamilton P, Kodama R, et al. Retrograde urethrocystography impairs computed tomography diagnosis of pelvic arterial hemorrhage in the presence of a lower urologic tract injury. *J Am Coll Surg.* 2008;206: 322–327.
65. Routt ML Jr, Falicov A, Woodhouse E, Schildhauer TA. Circumferential pelvic antishock sheeting: a temporary resuscitation aid. *J Orthop Trauma.* 2006;20:S3–S6.
66. Simpson T, Krieg JC, Heuer F, Bottlang M. Stabilization of pelvic ring disruptions with a circumferential sheet. *J Trauma.* 2002;52:158–161.
67. Warme WJ, Todd MS. The circumferential antishock sheet. *Mil Med.* 2002;167:438–441.
68. Ghaemmaghami V, Sperry J, Gunst M, et al. Effects of early use of external pelvic compression on transfusion requirements and mortality in pelvic fractures. *Am J Surg.* 2007;194:720–723; discussion 723.
69. Croce MA, Magnotti LJ, Savage SA, Wood GW II, Fabian TC. Emergent pelvic fixation in patients with exsanguinating pelvic fractures. *J Am Coll Surg.* 2007;204:935–939; discussion 940–942.
70. Bottlang M, Krieg JC, Mohr M, Simpson TS, Madey SM. Emergent management of pelvic ring fractures with use of circumferential compression. *J Bone Joint Surg Am.* 2002;84:43–47.
71. Bottlang M, Simpson T, Sigg J, Krieg JC, Madey SM, Long WB. Noninvasive reduction of open-book pelvic fractures by circumferential compression. *J Orthop Trauma.* 2002;16:367–373.
72. Jowett AJL, Bowyer GW. Pressure characteristics of pelvic binders. *Injury.* 2007;38:118–121.
73. Pohlemann T, Gansslen A, Hufner T, Tscherne H. Extraperitoneal packing at laparotomy. Presented at: *OTA-AAST Annual Meeting*, October 12–14, 2000, San Antonio, Texas.
74. Ertel W, Karim E, Keel M, Trentz O. Therapeutical strategies and outcome of polytraumatized patients with pelvic injuries. *Eur J Trauma.* 2000;26:278–286.
75. 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;15:468–474.
76. Giannoudis PV, Pape HC. Damage control orthopaedics in unstable pelvic ring injuries. *Injury.* 2004;35:671–677.
77. Totterman A, Madsen JE, Skaga NO, Roise O. Extraperitoneal pelvic packing: a salvage procedure to control massive traumatic pelvic hemorrhage. *J Trauma.* 2007;62:843–852.
78. Cothren CC, Osborn PM, Moore EE, Morgan SJ, Johnson JL, Smith WR. Preperitoneal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift. *J Trauma.* 2007;62:834–839; discussion 839–842.
79. Bach A, Bendix J, Hougaard K, Christensen EF. Retroperitoneal packing as part of damage control surgery in a Danish trauma centre—fast, effective, and cost-effective. *Scand J Trauma Resusc Emerg Med.* 2008;16:4.
80. Smith WR, Moore EE, Osborn P, et al. 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;59:1510–1514.
81. Osborn PM, Smith WR, Moore EE, et al. Direct retroperitoneal packing versus pelvic angiography: a comparison of two management

protocols for heamodynamically unstable pelvic fractures. *Injury*. 2009;40:54–60.
82. Biffl WL, Smith WR, Moore EE, et al. Evolution of a multidisciplinary clinical pathway for the management of unstable patients with pelvic fractures. *Ann Surg.* 2001;233:843–850.
83. Balogh Z, Caldwell E, Heetveld M, et al. Institutional practice guidelines on management of pelvic fracture-related hemodynamic instability: do they make a difference? *J Trauma.* 2005;58:778–782.
84. Jeske HC, Larndorfer R, Krappinger D, et al. Management of hemorrhage in severe pelvic injuries. *J Trauma.* 2010;68:415–420.
85. Blackmore CC, Jurkovich GJ, Linnau KF, Cummings P, Hoffer EK, Rivara FP. Assessment of volume of hemorrhage and outcome from pelvic fracture. *Arch Surg*. 2003;138:504–509.
86. Kataoka Y, Maekawa K, Nishimaki H, Yamamoto S, Soma K. Iliac vein injuries in hemodynamically unstable patients with pelvic fractures caused by blunt trauma. *J Trauma*. 2005;58:704–710.