External Fixation or Arteriogram in Bleeding Pelvic Fracture: Initial Therapy Guided by Markers of Arterial Hemorrhage

Preston R. Miller, MD, Phillip S. Moore, MD, Eric Mansell, MD, J. Wayne Meredith, MD, and Michael C. Chang, MD

Background: **Bleeding pelvic fractures (BPF) carry mortality as high as 60%, yet controversy remains over optimal initial management. Some base initial intervention on fracture pattern, with immediate external fixation (EX FIX) in amenable fractures aimed at controlling venous bleeding. Others feel ongoing hemodynamic instability indicates arterial bleeding, and prefer early angiography (ANGIO) before EX-FIX. Our aim was to evaluate markers of arterial bleeding in patients with BPF, thus identifying patients requiring early ANGIO regardless of fracture pattern.**

Methods: **Patients with pelvis fracture were identified from a Level I trauma center registry over a 7-year period and records reviewed. From this group, two subsets were analyzed: those with initial hypotension related to pelvic fracture, and those without hypotension who underwent pelvic ANGIO. Data included hemodynamics, response to resuscitation, presence of contrast blush on CT, fracture treatment and outcome. Adequate response to initial resuscitation (R) was defined as a sustained (>2 hours) improvement of systolic blood pressure to >90 mm Hg systolic after the administration of ≤2 units packed red blood cells. Those with repeated episodes of hypotension despite resuscitation were classified as nonresponders (NR)**

Results: **From 1/94–1/01, 1171 patients were admitted with pelvic ring fracture. Thirty-five (0.3%) had hypotension attributable to pelvis fracture. 28 fell into the NR group, and 26 of these underwent ANGIO. Nineteen (73%) showed arterial bleeding while 3 resuscitation response patients underwent ANGIO with none demonstrating bleeding ($p = 0.03$). Sensitivity and specificity of inadequate response to initial resuscitation for predicting the presence of arterial bleeding on ANGIO were 100% and 30% respectively while negative and positive predictive value were 100% and 73%. In patients with fractures amenable to external fixation (n = 16), 44% had arterial bleeding on ANGIO, and all were in the NR group. An additional 17 patients without hypotension also underwent ANGIO. Contrast blush on admission CT was seen in 4, 3 of which had arterial bleeding seen on ANGIO (75%). Sensitivity and specificity for contrast blush in predicting bleeding on ANGIO were 60% and 92% with positive and negative predictive value being 75% and 85%.**

Conclusions: **In patients with hypotension and pelvic fracture, therapy selection based on initial response to resuscitation in BPF yields a 73% positive ANGIO rate in NR patients. Delay in ANGIO for EX FIX in patients with amenable fractures would have delayed embolization in the face of ongoing arterial bleeding in 44% of patients. In stable patients with pelvic fracture, contrast blush also indicates a high likelihood of arterial injury and ANGIO is indicated. Optimal therapy in the face of BPF requires early determination of the presence of arterial bleeding so that ANGIO can be rapidly obtained, and response to initial resuscitation as well as the presence of contrast blush aid in this decision.**

Key Words: **Bleeding pelvic fracture External fixation arteriogram arterial hemorrhage**

J Trauma. 2003;54:437–443.

Pelvic fractures after trauma present in two broad categories: those that disrupt the mechanical stability of the pelvis with therapy addressing reconstruction and rehabilitation, and those that present with life threatening hemorrhage and thus require prompt therapy aimed at hemostasis. Decision making in the former category is usually made in the first days to weeks after injury. Decisions concerning bleeding pelvic fracture however, must be made rapidly if exsanguination and death are to be avoided.

Pelvic hemorrhage may stem from several sources and the interventions used in management of these patients address these sources in different ways. Significant venous bleeding may occur from the pelvic soft tissue, pelvic veins, and fracture ends. Hemorrhage may also occur from the large arteries that traverse the pelvis if they are lacerated during injury. Venous bleeding is well addressed with external fixation, and this has been shown by several investigators to limit blood loss when applied appropriately.[1–3] Arteriography and embolization of bleeding vessels has emerged as an excellent method of management when arterial bleeding exists.[4] Although both modalities are vital to improved outcome in patients with bleeding pelvic fracture, controversy remains over the timing and optimal order of external fixation and angiography. Some have used EX-FIX as a first line therapy in amenable fractures and reserved ANGIO for patients who exhibit ongoing hemodynamic instability after application of EX-FIX.[2,3,5] Others have aggressively employed ANGIO in the face of hemodynamic instability, with EX-FIX following ANGIO if required based on fracture pattern.[4,6,7] Given that each therapy addresses different bleeding sources,

Submitted for publication October 8, 2002.

Accepted for publication December 7, 2002.

From the Departments of General Surgery (P.R.M., P.S.M., J.W.M., M.C.C.) and Radiology (E.M.), Wake Forest University, Winston-Salem, North Carolina, U.S.A.

Presented at the 61st Annual Meeting of the American Association for the Surgery of Trauma, September 26-28, 2002, Orlando, Florida.

Address for correspondence: Preston R. Miller, MD, Assistant Professor, Department of General Surgery, Wake Forest University, Medical Center Boulevard, Winston-Salem North Carolina, 27157, U.S.A.; email: pmiller@wfubmc.edu.

DOI: 10.1097/01.TA.0000053397.33827.DD

optimal initial therapy would be best chosen based on whether the source of bleeding was predominately arterial or venous. Making this distinction is difficult in the multi-trauma patient, however. Given this diagnostic problem, our goal was to examine patients with pelvic fracture to determine whether there were characteristics present at or shortly after admission, which could indicate arterial bleeding, thus prompting ANGIO. Two groups of patients were evaluated for such factors: a group of patients with hypotension at presentation attributable to pelvis fracture, and a group of stable patients undergoing ANGIO, some of whom, despite hemodynamic stability, had arterial bleeding diagnosed.

PATIENTS AND METHODS

Patients

All patients admitted to Wake Forest University Baptist Medical Center with pelvic fractures over a 7-year period were identified from the institution's trauma registry. From this group, all patients having hypotension in the emergency department attributable to pelvic bleeding and all patients undergoing pelvic arteriogram for bleeding were examined, and records reviewed for demographics, injury and hemodynamic characteristics, hospital course and outcome. Data examined included age, injury characteristics and injury severity score (ISS), admission systolic blood pressure and heart rate, base deficit, response to initial resuscitation, transfusion requirement, contrast blush on initial computed tomography (CT), and fracture pattern. Adequate response to initial resuscitation was defined as a sustained (>2 hours) improvement of systolic blood pressure to >90 mm Hg after the administration of ≤2 units packed red blood cells.

For the purposes of this project, pelvic radiographs and CT scans were reviewed by a radiologist to assist in interpretation and classification. Fractures were classified according to the Young-Burgess modification of the Tile-Pennal classification system.[8] This is shown in Figure 1.

APC (anterior-posterior compression)

Type I: Isolated pubic diastasis and/or pubic ramus disruption <2.5 cm

Type II: Anterior ramus fractures and/or diastasis >2.5 cm with widened SI joint(s). Rotationally unstable

Type III: Disruption of symphysis or significant separation of anterior vertical ramus fractures. Disruption of anterior/posterior ligaments of SI joint. Rotationally and vertically unstable

LC (Lateral Compression)

Type I: Horizontal fractures of pubic rami. Impaction injury/fracture of sacrum

Type II: Horizontal fractures of pubic rami with ligamentous or bony disruption of SI joint

Type III: Horizontal fractures of pubic rami with contralateral ramus and SI joint disruption (APC type injury)

VS (vertical shear)

Complete bony and ligamentous disruption of hemipelvis with vertical displacement

CM (combined mechanism)

Combination of injury patterns

FIG 1. *Young-Burgess modification of the Tile-Pennal pelvic fracture classification system.*

Pelvic Fracture Management

The general practice pattern at our institution has been to proceed with ANGIO for possible embolization before EX-FIX if patients continued to have episodes of hemodynamic instability from pelvic bleeding after admission. Intra-abdominal sources were ruled out by supra-umbilical diagnostic peritoneal tap or CT scan if patients were stable enough to be safely taken to the scanner. If fracture patterns were amenable, the pelvis was closed by being wrapped in a bed sheet before transport to CT or ANGIO. Patients requiring immediate laparotomy have generally had EX-FIX placed in the operating room after laparotomy if the fracture pattern warranted this. Ongoing instability after control of intraperitoneal hemorrhage prompted ANGIO immediately after operation.

Pelvic angiography was performed by interventional radiology attending in conjunction with house staff. Micropuncture was used to obtain access into the right common femoral artery. A catheter was advanced to the distal aorta and angiography performed in multiple views. The catheter was then advanced into the left iliac artery and the internal iliac artery selectively entered. Contrast injection and angiography were again performed in multiple projections. The catheter was then withdrawn to the junction of the external and internal iliac artery on the right and additional injections performed. Areas of ongoing bleeding or vessel injury were selectively embolized using coils, Gelfoam, and polyvinyl alcohol particles as needed. Completion angiogram was used to confirm cessation of bleeding.

External fixators were applied in the operating room by an orthopedic surgery attending in conjunction with residents. Anterior external fixation devices were used with the bars placed in a position to avoid interference with laparotomy if necessary. Fractures considered amenable to EX FIX included APC II, III, LC III, VS and CM type fractures.[2]

Statistical Analysis

Statistical analysis was performed using Statview 5.0 (SAS Institute Inc., Cary, NC, U.S.A.). Dichotomous variables were compared using Chi Square or Fisher's exact test where appropriate. Continuous variables were compared using Student's *t* test. Significance is defined as $p \leq 0.05$.

RESULTS

Between 1/1/1994- 1/31/2001, 1171 patients were admitted to Wake Forest University Baptist Medical Center with pelvic fractures. This group had a mean age of 41 ± 21 years, a mean ISS of 18 ± 13, mean base deficit of -6.8 ± 5.8, and overall mortality of 14%. Of these patients, 35 (0.3%) were hypotensive in the emergency department with hypotension attributable to pelvic fracture, and these are the primary focus of this report. Six of these had intra-abdominal source of hemorrhage ruled out by diagnostic peritoneal tap, 22 by abdominal computed tomography, and 7 remained hemodynamically labile after abdominal procedure (3 splenectomies, 1 hepatorrhaphy, 2 diverting colostomies, and 1 nontherapeutic laparotomy). The demographics and injury characteristics of these patients are shown in Table 1. This is a severely injured group of patients as shown by high injury severity scores (ISS), low admission systolic blood pressures, and significant metabolic acidosis. As predicted by the admission characteristics, the mortality of this group is also high. Of the 12 deaths related to pelvic bleeding, 1 was from ongoing

Table 1 Admission Characteristics of Patients with Hypotension Attributable to Pelvic Bleeding (n = 35)

	Mean ± Standard Deviation
Age (years)	46 ± 21
ISS	35 ± 16
Male/Female	28/7
SBP (mm/Hg)	84 ± 33
Heart rate (beats/minute)	105 ± 25
BD (mEq/L)	−11.4 ± 6.6
Mortality	19 (54%)
Mortality related to pelvis fracture	12 (34%)

ISS, injury severity score; SBP, systolic blood pressure; BD, base deficit.

hemorrhage from bleeding not controlled by ANGIO or EX-FIX and the remaining 11 were from the sequelae of hemorrhagic shock with metabolic exhaustion.

Therapy aimed at management of pelvic bleeding varied with 19 undergoing pelvic ANGIO, 6 undergoing EX-FIX, and 10 having both ANGIO and EX-FIX (5 ANGIO first, 5 EX-FIX first). Of the 5 patients receiving EX-FIX first, all but 1 were already in the operating room for emergent laparotomy when fixation was applied. In the 5 patients undergoing EX-FIX after ANGIO, 3 were done due to concern for ongoing bleeding, and 2 were done for skeletal stabilization only. Table 2 shows a comparison of characteristics and outcomes in these subgroups. The group undergoing both ANGIO and EX-FIX is indistinguishable from the group undergoing ANGIO alone, but is more severely injured with greater shock than the group receiving only EX-FIX. This generally reflects our institutions management pattern with those patients perceived to have ongoing bleeding and severe shock undergoing ANGIO. While it is not possible to completely exclude arterial bleeding in the 6 patients managed with EX-FIX alone because no ANGIO was done, sustained response to resuscitation combined with a mean transfusion requirement of only 4 units PRBCs would seem to make ongoing arterial bleeding unlikely.

Of the 35 patients exhibiting hypotension in the emergency department, 29 underwent ANGIO (with or without EX-FIX). Twenty-six underwent ANGIO due to repeated episodes of hemodynamic instability, and 3 because the fracture pattern was felt to warrant arterial evaluation. Mean time elapsed from admission to ANGIO in patients without preceding EX-FIX was 155 ± 46 minutes. Nineteen (65%) of these were positive for ongoing arterial bleeding. An additional 3 showed some sign of arterial injury (vessel irregularity, pseudoaneurysm), but did not exhibit ongoing hemorrhage. To examine characteristics associated with ongoing arterial bleeding and therefore need for arteriogram, patients with and without angiographic evidence of continued bleeding are compared in Table 3. While there is a trend toward higher heart rate and greater prevalence of CT contrast blush in the group with arterial bleeding, the only statistically significant difference was that those with ongoing bleeding were less likely to show a sustained response to initial resuscitation (NR). Of the patients with initial hypotension, 28 were NR patients. A total of 26 NR patients underwent ANGIO with 19(73%) showing arterial bleeding while 3 of 7 patients demonstrating adequate resuscitation response underwent ANGIO. None of these 3 demonstrated bleeding on ANGIO ($p = 0.03$). The 2 NR patients not undergoing ANGIO received EX-FIX and showed no further evidence of bleeding. The sensitivity, specificity, as well as negative and positive predictive value for NR in predicting arterial bleeding in patients with any hypotension in the emergency department are shown in Table 4. Had only NR patients undergone ANGIO, positive ANGIO rate would have increased, and no patients with arterial bleeding would fail to undergo ANGIO.

Of the 35 hypotensive patients, 16(46%) had pelvic fractures amenable to external fixation. ANGIO was performed in 11 of these with 7 showing arterial bleeding. Thus any delay in ANGIO for EX-FIX in these patients would have subjected 7/16 (44%) to ongoing arterial bleeding and its consequences.

Performing early ANGIO in NR patients who present with hypotension appears reasonable given the preceding data. In a broader review of our ANGIO experience over the same time period, however, it was noted that some positive ANGIOs oc-

Table 2 Comparison of Patient Characteristics and Outcome in Hypotensive Patients Undergoing ANGIO, EX-FIX, and Both Therapies

	ANGIO (n = 19)	EX-FIX (n = 6)	Both (n = 10)
ISS	36	22	40*
BD (mEq/L)	−12.7	−7.2	−11.5*
SBP (mmHg)	86	92	75
24 hour xfusion (units PRBCs)	16*	4	19*
Mortality	13 (68%)	1 (17%)	5 (50%)

ANGIO, angiogram; EX-FIX, external fixation; ISS, injury severity score; BD, base deficit; SBP, systolic blood pressure; xfusion, transfusion; PRBCs, packed red blood cells.

* $p < 0.05$ vs. EX-FIX groups.

Table 3 Injury and Hemodynamic Characteristics in Patients with Initial Hypotension Undergoing Angiogram

	Bleeding (n = 19)	No bleeding (n = 10)	*p* Value
Age (years)	44	56	0.15
ISS	38	30	0.74
SBP (mm/Hg)	78	91	0.34
Heart rate (beats/minute)	113	98	0.13
BD (mEq/L)	−12.9	−11.2	0.54
Transient/no response to resuscitation	19 (100%)	7 (70%)	0.03
CT contrast blush	8/12 (67%)	2/8 (25%)	0.17

ISS, injury severity score; SBP, systolic blood pressure; BD, base deficit; CT, computed tomography.

Table 4 Sensitivity, Specificity, Negative Predictive Value and Positive Predictive Value for Inadequate Response to Initial Resuscitation (NR) in Predicting Arterial Bleeding on Angiogram*

	(%)
Sensitivity	100
Specificity	30
Negative predictive value	100
Positive predictive value	73

* Applies to patients with any hypotension in emergency department.

Table 5 Injury and Hemodynamic Characteristics in Pelvic Fracture Patients Without Hypotension Undergoing Angiogram

	Arterial bleeding (n = 5)	No bleeding (n = 12)	*p* Value
Age (years)	53	41	0.16
ISS	29	24	0.50
SBP (mm/Hg)	127	130	0.84
Heart rate (beats/minute)	104	96	0.50
BD (mEq/L)	−9.0	−4.8	0.14
CT contrast blush	3/5 (60%)	1/12 (8%)	0.05

ISS, injury severity score; SBP, systolic blood pressure; BD, base deficit; CT, computed tomography.

curred in patients without any episodes of hypotension. Thus the records of all patients undergoing ANGIO with pelvis fracture but no hypotension were reviewed to determine whether there were specific characteristics associated with positive ANGIO in this population.

During the same time period, 17 patients with no hypotension received pelvic ANGIO. These patients underwent ANGIO on the basis of the presence of contrast blush on CT (n = 4), size of pelvic hematoma on CT (n = 2), or fracture pattern perceived to place patient at high risk of arterial injury (n = 11). Of these, 5 (29%) were positive for arterial bleeding. The characteristics of those with positive and negative ANGIO are compared in Table 5. The hemodynamic characteristics of the groups are similar, but the group with positive ANGIO was more likely to show a contrast blush on admission CT. The predictive ability of contrast blush on CT for arterial bleeding on ANGIO is shown in Table 6. The presence of contrast blush identifies those likely to have positive ANGIO with reasonable reliability. Had inadequate response to initial resuscitation in those with initial hypotension been paired with contrast blush on CT in the remaining non-hypotensive patients as a trigger for ANGIO, 22 of 24 patients with positive arterial bleeding on ANGIO (92%) would have been identified.

Incidence of arterial bleeding in each fracture pattern was compared in all patients undergoing ANGIO (n = 46) to determine whether important differences existed. Overall there were 18 APC lesions (10 APC I, 4 APC II, and 4 APC III), 25 LC lesions (8 LC I, 11 LC II, and 5 LC III), 2 VS lesions, and 1 CM lesion. Eleven of the APC lesions (61%) had positive ANGIO (7 APC I, 1 APC II and 3 APC III) as compared with 13 (52%) of the LC lesions ($p = 0.55$). Positive ANGIO in the LC patients included 5 LC I, 5 LC II, and 3 LC III fractures. No VS or CM lesions had arterial bleeding on ANGIO. The incidence of sciatic notch fracture association with arterial bleed in patients undergoing angiogram was also examined. Of the 46 ANGIOs performed, 10 were in patients with sciatic notch involvement. Seven of these 10 (70%) showed arterial bleeding. This is compared with 17 positive ANGIOs in 36 patients (47%) without sciatic notch fracture ($p = 0.20$).

Table 6 Sensitivity, Specificity, Negative Predictive Value and Positive Predictive Value for Contrast Blush on Computed Tomography in Predicting Pelvic Arterial Bleeding on Angiogram*

	(%)
Sensitivity	60
Specificity	92
Negative predictive value	85
Positive predictive value	75

* Applies to patients without hypotension in emergency department.

DISCUSSION

Although varying algorithms for initial management of BPF have been proposed in the past, a central question in the decision making process is whether arterial bleeding is present. If this question can be reliably answered, the subsequent management with early ANGIO falls into place. It has long been recognized that BPF is an immediately life threatening injury and much work has been done to increase our understanding of its pathophysiology. This dangerous hemorrhage can come from fracture bleeding, injury to the rich venous plexus in the pelvis or the major pelvic veins, and finally, laceration of the arteries of the pelvis. As this understanding has emerged, methods of arresting this bleeding have been developed, and the two most commonly employed are external fixation of the pelvic fracture, and ANGIO for identification and embolization of pelvic bleeding. Some have advocated immediate EX-FIX for BPF and document control of hemorrhage, lower transfusion requirement, and improved survival.[1,3,9] This method is believed to provide a tamponade effect aimed at venous bleeding and perhaps small vessel arterial bleeding.[10,11] Aggressive early ANGIO is advocated by others even in the face of fracture pattern amenable to EX-FIX.[4,6,7,10] This approach is effective in dealing with large arterial injury via embolization. Controversy remains over the relative contribution and appropriate order of the two therapies to BPF management. Given that each therapy addresses different sites of bleeding, initial treatment should optimally be aimed at the predominant source of bleeding: arterial or venous. Arterial bleeding is known to occur in pelvic fracture patients both with and without initial hypotension. These data support the concept of using response to initial resuscitation in hypotensive patients, and contrast blush on CT in stable patients to identify patients likely to have arterial bleeding who will therefore benefit from ANGIO with embolization. These markers have clinical utility in that they are discernable at or shortly after admission and lead to a high rate of bleeding identification on angiography in both populations.

Angiography

ANGIO and embolization has emerged as one of the cornerstones of management of BPF in the face of arterial injury. The technique was initially described as early as 1972 and is currently well established as an effective means of dealing with arterial hemorrhage.[12] Panetta et al. demonstrated ANGIO and embolization to be an effective means of controlling massive retroperitoneal hemorrhage in the face of pelvic fracture.[4] They cautioned that early embolization was "imperative in reducing transfusion requirements and associated complications." Others have echoed the utility of ANGIO in controlling arterial bleeding and found that timely performance of embolization to be associated with improved outcome.[7] Certainly unchecked arterial bleeding has detrimental effects. It is for this reason that the markers for the early identification of patients likely to have arterial bleeding are important.

Fracture Pattern

Others have sought patterns of injury associated with arterial laceration and these may give clues as to which patients are

at risk. Fracture pattern and its relationship to outcome has been examined, and Burgess et al. found that APC type injuries were associated with higher transfusion requirement and mortality than other patterns.[2] Several groups have demonstrated that patients requiring embolization were significantly more likely to have fracture patterns associated with major ligamentous disruption (APC II, III, LC III, VS and CM).[2,13] Fractures through the sciatic notch are also felt to be associated with a high rate of arterial injury due to the proximity of the superior gluteal artery.[14] Our data show no clear relationship of fracture pattern to arterial bleeding, but meaningful conclusions concerning this are difficult because not all patients admitted during the study period with each fracture pattern were evaluated. It is clear, however, that exsanguinating hemorrhage can and does occur in seemingly low risk patterns such as APC I. The understanding of which patterns are more likely to have associated arterial bleeding is important, but decision to obtain arteriogram based on fracture pattern alone would lead to very low overall yield.

Computed Tomography

Blush indicating extravasation of contrast on CT scan has been examined as a method of determining the presence of arterial bleeding and therefore the need for ANGIO. This method has been found to be a reliable marker with sensitivities from 80 to 84% and specificities from 85 to 98% being reported.[15–17] Our experience with this has been similar, and it appears clear that patients with blush on admission CT are likely to require embolization on ANGIO. Arterial bleeding frequently produces repeated episodes of hypotension however, and transporting such patients to the CT scanner places them at risk. For this reason CT blush cannot serve as the sole trigger for ANGIO. These data indicate that it is in such patients that the response to initial resuscitation can serve as a valuable indicator of likely arterial bleeding. Seventy-three percent of patients who were initially hypotensive and did not respond to initial resuscitation required embolization, while no patient showing a sustained response went on to embolization.

External Fixation

External fixation remains one of the mainstays in pelvic fracture management. The framework provides skeletal stabilization thus aiding in healing. In addition, it has been shown by many authors to aid in hemorrhage control. The mechanism by which this happens is not completely clear, however. Some have proposed that closure of the pelvis reduces pelvic volume, therefore providing a tamponade effect.[18] Grimm et al. however, demonstrated in a cadaveric open book pelvic fracture model that pelvic closure was unlikely to provide adequate pressure for effective tamponade.[19] Other proposed mechanisms include reduction of bleeding by re-apposition of bony fragments, or promotion of hemostasis by avoiding clot disruption with bony movement.[11] Certainly all of these mechanisms may play complimentary roles in the efficacy of EX-FIX in controlling bleeding, but this form of therapy is unlikely to be effective in dealing with significant arterial bleeding.

The data concerning the role of EX-FIX in hemorrhage control have led some investigators to recommend initial use of EX-FIX in amenable fractures if there is evidence of ongoing bleeding.[1,3,9] This is followed by ANGIO if there is continued evidence of bleeding after EX-FIX placement. The current study suggests that such strategy will lead to delay in effective control of arterial bleeding in over 40% of patients presenting with initial hypotension. EX-FIX is commonly placed in the operating room necessitating delays in ANGIO if it is needed. There

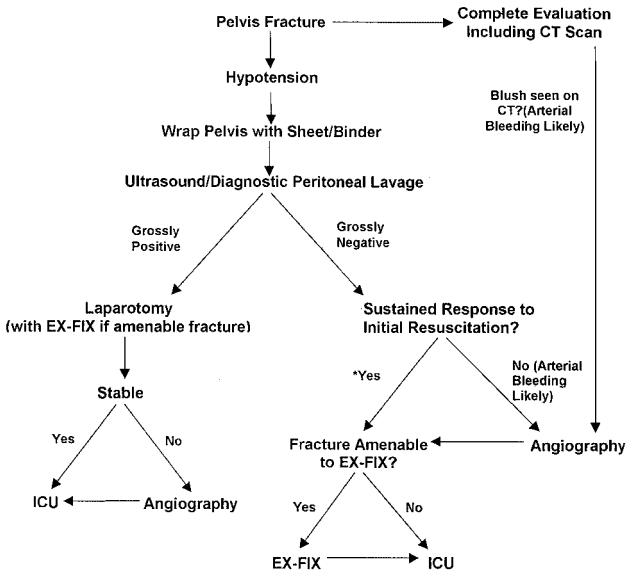

FIG 2. *Algorithm for management of bleeding pelvic fracture.*

are institutions in which the resources exist for EX-FIX placement in the emergency department, or alternative, more rapid methods of fixation used such as a "C" clamp. In such situations, there is no delay of ANGIO for placement of EX-FIX if signs of arterial bleeding are present and such a system represents a viable alternative. At institutions where one therapy delays application of the other however, the most important question to be answered becomes "Is arterial bleeding likely?" If the answer is yes, rapid ANGIO is necessary. If no, EX-FIX may then be applied.

Alternatives to EX-FIX have been proposed including MAST suit, bean bags, or wrapping of the pelvis with bedsheet or a specialized binder. We have had no experience with the MAST device, but bean bags and in recent years, pelvic wrapping have been employed extensively. This would appear to accomplish some of the goals of EX-FIX until more definitive means can be employed.

In summary, the management of BPF requires a rapid, early determination of whether or not arterial bleeding is likely, and therapy is determined by the answer to this question. These data provide a framework within which that likelihood can be rapidly and accurately assessed in both normotensive and hypotensive patients. This is summarized in the algorithm in Figure 2. If patients present with hypotension from pelvic fracture, transient or no response to initial resuscitation indicates the presence of arterial bleeding in over 70% of patients while adequate response to resuscitation makes arterial bleeding unlikely (negative predictive value of 100% in this series). In stable patients, contrast blush on CT also indicates a high likelihood of arterial injury and ANGIO should be pursued. With accurate assessment of the possibility of arterial injury, appropriate therapeutic choices can be more easily made.

REFERENCES

1. Gylling SF, Ward RE, Holcroft JW, et al. Immediate external fixation of unstable pelvic fractures. *Am J Surg.* 1985;150:721–724.
2. Burgess AR, Eastridge BJ, Young JWR, et al. Pelvic ring disruptions: effective classification system and treatment protocols. *J Trauma.* 1990;30:848–856.

3. Flint L, Babikian G, Anders M, et al. Definitive control of mortality from severe pelvic fracture. *Ann Surg.* 1990;211:703–707.
4. Panetta T, Sclafani SJA, Goldstein AS, et al. Percutaneous transcatheter embolization for massive bleeding pelvic fractures. *J Trauma.* 1985;25:1021–1029.
5. Bassam D, Cephas, GA, Ferguson KA, et al. A protocol for the initial management of unstable pelvic fractures. *Am Surg.* 1998; 64:862–867.
6. Gruen GS, Leit ME, Gruen RJ, et al. The acute management of hemodynamically unstable multiple trauma patients with pelvic ring fractures. *J Trauma.* 1994;36:706–713.
7. Agolini SF, Shah K, Jaffe J, et al. Arterial embolization is a rapid and effective technique for controlling pelvic fracture hemorrhage. *J Trauma.* 1997;43:395–399.
8. Young JWR, Burgess AR, Brumback RJ, et al. Pelvic fractures: Value of plain radiography in early assessment and management. *Radiology.* 1986;160:445–451.
9. Evers BM, Cryer HM, Miller FB, et al. Pelvic fracture hemorrhage: Priorities in management. *Arch Surg.* 1989;124:422–424.
10. Ben-Menachem Y, Coldwell DM, Young JWR, et al. Hemorrhage associated with pelvic fractures: Causes, diagnosis, and emergency management. *Am J Rad.* 1991;157:1005–1014.
11. Huittenen VM, Slättis P. Post mortem angiography and dissection of the hypogastric artery in pelvis fractures. *Surgery.* 1973;73:454–462.
12. Margolies MN, Ring EG, Waltman AC, et al. Arteriography in the management of hemorrhage from pelvic fractures. *NEMJ.* 1972; 287:317–321.
13. Hamill J, Holden A, Paice R, et al. Pelvic fracture patterns predict pelvic arterial hemorrhage. *Aust N Z J Surg.* 2000;70:338–343.
14. Smith KJ, Ben-Menachem Y, Duke JH, et al. The superior gluteal artery: An artery at risk in blunt pelvic trauma. *J Trauma.* 1976; 16:273–279.
15. 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.
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. Cerva DS, Mirvis SE, Shanmuganthan K, et al. Detection of bleeding in patients with major pelvic fractures: value of contrast enhanced CT. *Am J Rad.* 1996;166:131–135.
18. Moss MC, Bircher MD. Volume changes within the true pelvis during disruption of the pelvic ring. *Injury.* 1996;27:S-A21–23.
19. Grimm MR, Vrahas MS, Thomas KA. Pressure-volume characteristics of the intact and disrupted pelvic retroperitoneum. *J Trauma.* 1998;44:454–459.

DISCUSSION

Dr. Thomas M. Scalea (Baltimore, Maryland): The authors have analyzed a large group of patients with pelvic fractures. Over 7 years they admitted nearly 1,200 such patients; 35.3 percent were hypotensive in the emergency department and formed the basis for this report.

The authors' algorithm for the management of these patients involved angiography for ongoing hypotension; external fixation was used for specific fracture patterns and was performed in the operating room. The authors demonstrated that patients that did not respond to initial resuscitation, which they defined as achieving a blood pressure over 90mmHg with less than two units of blood, were very likely to benefit from angiography. Those patients who were able to be treated with external fixation alone were also severely injured and had better survival. Moreover, the appearance of a contrast blush on computed tomography predicted the presence of vascular injury at the time of angiography. Their proposed algorithm based on initial response to resuscitation and fracture pattern seems quite reasonable. I have a number of questions. How did you select your patients for inclusion? Patients had to have hypotension referable to pelvic fracture bleeding. These patients were obviously multiply injured, as their mean ISS was 35. By design, they were all hypotensive, but the mean base deficit was minus 11.4. They certainly could have had bleeding from other sources. In my experience, one of the most difficult judgments is to identify the source of bleeding in these multiply injured patients.

At your institution, you apparently apply external fixation to severe AP compression injuries as well as lateral compression and vertical shear injury. Why do you believe that external fixation will benefit these patients? We abandoned this approximately 5 years ago, believing that reducing the anterior elements in these patients may serve only to further distract the posterior bony fragments and increase bleeding. Our current practice is to temporize using commercially available pelvic binders and then to use very early operative posterior pelvic fixation. How much experience have you had with these pelvic binders? Can you better characterize the patients who stop bleeding with external fixation alone? How many of them have severe posterior injuries?

While these patients were obviously badly injured, a third of them died from direct hemorrhage or the sequelae of bleeding, the mean time from patient admission to angiography without proceeding external fixation was in excess of 2.5 hours. What is the availability of angiography at your institution, particularly on off hours? Could you have made the decision to do angiography earlier? Do you believe that this might have changed your outcome? Seven patients had angiography when they were hemodynamically labile after laparotomy. Three of those patients were explored for what appears to be non-life-threatening hemorrhage. Two had diverting colostomies, and one had a non-therapeutic exploration. Were patients with laparotomy and ongoing pelvic bleeding treated with damage control in an attempt to get them to angiography as quickly as possible?

Finally, your yield of angiography is much higher than many other reported series, and you found vascular injuries in a surprising number of patients with seemingly minor pelvic fractures. Can you theorize as to why your results are so different than those previously reported? The early diagnosis of pelvic fracture bleeding continues to be a vexing clinical problem for those caring for polytrauma. The algorithm suggested by the authors is simple and easy to use. They have been quite successful in identifying patients who will benefit from early angiographic embolization. I applaud the authors on their efforts.

Dr. Preston R. Miller (Winston-Salem, North Carolina): You asked about how the patients were selected, more specifically, how was it determined that their hemorrhage was from their pelvic fracture and not some other source of bleeding. I think we use an algorithm that's used at a lot of institutions around the country, and that is, basically, a hypotensive patient comes in and an immediate search for the source of hemorrhage is begun. They're evaluated for external sources of hemorrhage. A physical exam and chest X-ray is conducted to try to rule out hemorrhage into the chest or some reason for hypotension in the chest. Diagnostic peritoneal lavage or ultrasound is conducted to try to determine if there is hemorrhage within the abdomen.

If those patients have pelvic fracture, and all those other tests are negative, we then assume that bleeding is likely to be coming from within the pelvic fracture.

Your point is well taken, and that is that it isn't always that simple. There are certainly other sources that could be causing bleeding, such as multiple fractures. There are certainly other

reasons for patients to be hypotensive. So, it certainly isn't always that easy to sort out.

As far as the use of external fixation in particular fracture types, you asked, specifically, about the six patients that had external fixation placed and stopped bleeding without any further intervention—were there posterior or severe posterior ligamentous disruptions in any of those patients. Indeed, three of those patients had anterior-posterior compression Type 3 injuries, so they did. But I think your point is important, and that is, certainly not all pelvis fractures are amenable to fixation.

Our orthopaedists are moving away from using it in certain fracture patterns, going on to other types of operative stabilization. I think the real point is we are really not using fracture pattern as a decision point in our initial triage of the bleeding patient as much as hemodynamic parameters and their response to initial resuscitation.

You commented on the time to angiography. I think you're exactly right on that. Our time to angiography was over 2 hours. I think, in analyzing this data, we really uncovered what is a real problem at our institution in getting angiography done in a timely fashion.

This tends to occur more in off hours, and it's something we're currently trying to remedy. Certainly, ongoing arterial bleeding—no one would argue that that's dangerous and perhaps a fatal problem—that's something we need to work on.

As far as the patients in the operating room who went to the operating room and then went on to angiography, for the three that had non-life threatening hemorrhage, that is, indeed, the case.

They were chosen to be taken to the operating room first, as opposed to angiography, because they had initial instability and a positive diagnostic peritoneal lavage, grossly positive, or positive ultrasound. So, they were found to have bleeding injuries, but their major bleeding source was not in the abdomen at the time. The angiography yield is, indeed, high in this group. I think it's because we were really just concentrating on looking at hypotensive patients. There's a recent article out of Denver looking at the utility of a multi-disciplinary approach to problems like this and the severe bleeding pelvis fractures. As an aside in that article, it's mentioned the high yield of angiography and hypotensive patients. I think the figures are similar.

As far as bleeding in lower grade injuries, certainly, there has been a lot of work done by several authors on correlating fracture pattern with the probability of arterial hemorrhage. That's important, and that's obviously real. But I think this data shows, and I think other authors have shown, that the science of identifying arterial bleeding or likelihood of arterial bleeding by fracture pattern is not a perfect one.

Indeed, we saw exsanguinating hemorrhage in a reasonable number of seemingly innocuous injuries—anterior-posterior compression type 1, lateral compression type 1.

I think it's important not to be lulled into a false sense of security by the X-ray.

Dr. Carl J. Hauser (Newark, New Jersey): In distinction to Dr. Scalea, I think that your positive rate might even be higher. If you looked at a computed tomography scan and you saw a blush, you know that there was a bleeder there. So, the real question is whether you found them with your arteriograms. Our experience has been that these patients can bleed and stop, bleed and stop, and that is a common scenario if they are hypotensive and if you don't over resuscitate them. So if you only embolize overt bleeders, you will have a significant re-bleed rate.

Rather than just embolizing overt bleeders, we think it's important to embolize the cut-offs and the beaded vessels—All those things that Dr. Ben-Menachem taught us how to do.

We've been very aggressive about that, and our approach in Newark is really very simple. If you have a hypotensive or an acidotic patient who is not bleeding onto the floor, not bleeding into their chest, and not bleeding into their abdomen, and if they do have a pelvic fracture—any pelvic fracture—then they go to angiography.

We find lesions on almost all of them and we embolize them, and this group does very well. We have not placed an external fixator for the control of pelvic fracture bleeding in Newark in the last 4 or 5 years that I can remember, and we're not about to look back.

Dr. Preston R. Miller (Winston-Salem, North Carolina): I think you're exactly right, Dr. Hauser. I think that if patients that have hemodynamic instability with pelvic fracture, really, it's usually a manifestation of arterial bleeding and not venous bleeding. In addition to the 19 patients in the hypotension group, there were three more who had the type of injury you're describing—cut-offs, pseudoaneurysms, that type of thing. They were embolized. I think you're exactly right.

Dr. Robert C. Mackersie (San Francisco, California): I had a quick question just in follow up to Dr. Hauser's comments about the bleed, stop, bleed, stop. That's what your failure rate was for the angiography both with and without embolization—recognizing this is a real factor?

Dr. Preston R. Miller (Winston-Salem, North Carolina): Right. The failure rate of these 19 patients who were hypotensive and had angiography—one died because of inability to control hemorrhage.

All the others—there were a large number of deaths, but the rest of those were from what would be metabolic exhaustion or irreversible shock. But, one did bleed to death, and it was because of inability to control arterial hemorrhage.

Dr. Joseph P. Minei (Dallas, Texas): Very nice study. I would also agree with the point of view that fracture pattern does not predict who is going to be in shock. Adam Starr, an orthopedic surgeon from our institution, has published similar results. However, my colleague Brian Eastridge, who is now in Afghanistan, showed in a paper that would have been presented at last year's meeting, that once a patient is in shock, fracture pattern may be helpful in guiding further care.

In that study, patients in shock with an unstable fracture pattern (LC 2 or 3, APC 2 or 3, or VS) and intra-abdominal bleeding did better if they went to the angiography suite before the operating room. Those patients in shock with a stable fracture pattern (AP 1, or LC 1) and intra-abdominal bleeding were better served in the operating room first.

Unfortunately, our numbers were small, so it was difficult to draw any direct conclusions. In the algorithm that you showed us, do you have any specific data that supports going to the operating room before the angiography suite in patients in shock with an unstable fracture pattern? Your initial discussion about the three patients who had minimal intra-abdominal bleeding would suggest that this may not be the correct order of events.

Dr. Preston R. Miller (closing): Right, no, we don't have any data to back that up. We based our algorithm and that statement on work done by others.

Certainly, that paper that you refer to brings that into question, and that's something that needs to be looked further into. Currently, we tend to go to the operating room in patients who have what looks to be significant intra-abdominal hemorrhage. I think we'll keep that for the moment, but certainly that's a question that's open to study.