ORIGINAL SCIENTIFIC ARTICLE

Pelvic Fractures: Epidemiology and Predictors of Associated Abdominal Injuries and Outcomes

Demetrios Demetriades, MD, PhD, FACS, Marios Karaiskakis, MD, Konstantinos Toutouzas, MD, Kathleen Alo, RN, George Velmahos, MD, PhD, FACS, Linda Chan, PhD

BACKGROUND: Pelvic fractures are often associated with major intraabdominal injuries or severe bleeding from the fracture site.

OBJECTIVE: To study the epidemiology of pelvic fractures and identify important risk factors for associated abdominal injuries, bleeding, need for angiographic embolization, and death.

METHODS: Trauma registry study on pelvic fractures from blunt trauma. Stepwise logistic regression was used to identify risk factors of severe pelvic fractures, associated abdominal injuries, need for major blood transfusion, therapeutic embolization, and death from pelvic fracture. Adjusted relative risks and 95% confidence intervals were derived.

RESULTS: There were 16,630 trauma registry patients with blunt trauma, of whom 1,545 (9.3%) had a pelvic fracture. The incidence of abdominal injuries was 16.5%, and the most common injured organs were the liver (6.1%) and the bladder and urethra (5.8%). In severe pelvic fractures (Abbreviated Injury Scale [AIS] $\geq$ 4), the incidence of associated intraabdominal injuries was 30.7%, and the most commonly injured organs were the bladder and urethra (14.6%). Among the risk factors studied, motor vehicle crash is the only notable risk factor negatively associated with severe pelvic fracture. Major risk factors for associated liver injury were motor vehicle crash and pelvis AIS $\geq$ 4. Risk factors of major blood loss were age $>$ 16 years, pelvic AIS $\geq$ 4, angiographic embolization, and Injury Severity Score (ISS) $>$ 25. Age $>$ 55 years was the only predictor for associated aortic injury. Factors associated with therapeutic angiographic embolization were pelvic AIS $\geq$ 4 and ISS $>$ 25. The overall mortality was 13.5%, but only 0.8% died as a direct result of pelvic fracture. The only pronounced risk factor associated with mortality was ISS $>$ 25.

CONCLUSIONS: Some epidemiological variables are important risk factors of severity of pelvic fractures, presence of associated abdominal injuries, blood loss, and need of angiography. These risk factors can help in selecting the most appropriate diagnostic and therapeutic interventions. (J Am Coll Surg 2002;195:1–10. © 2002 by the American College of Surgeons)

Pelvic fractures have special significance for trauma and orthopedic surgeons. They are markers of injury from a major force and are often associated with injuries to other important organs. Also, the fractures themselves can cause morbidity and mortality from bleeding. The purpose of the present article is to study the epidemiology of pelvic fractures and identify risk factors associated with severe pelvic fracture, associated abdominal injuries, thoracic aortic injuries, major blood loss, need of angiography, and survival. Better understanding of these issues can help in the selection of patients who might benefit from a more aggressive evaluation and management.

PATIENTS AND METHODS

This is a trauma registry study that included all pelvic fractures from blunt trauma admitted at the Los Angeles County and University of Southern California trauma center during an eight-year period (January 1993–December 2000). The trauma registry captures 130 data fields and is maintained by eight full-time trained nurses. The quality of data is controlled by the Los An-

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From the Department of Surgery, Division of Trauma and SICU, Keck School of Medicine, University of Southern California, Los Angeles, CA.
Correspondence address: Demetrios Demetriades, MD, PhD, FACS, Director of Trauma and SICU, Healthcare Consultation Center, 1510 San Pablo St, Suite 514, Los Angeles, CA 90033.

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Abbreviations and Acronyms

AIS = Abbreviated Injury Scale
ISS = Injury Severity Score
MVC = motor vehicle crash

geles Emergency Medical Services agency on a quarterly basis. The following data were retrieved from the registry for the purpose of the study: mechanism of injury (including motor vehicle crash [MVC] pedestrian, motorcycle, fall >15 feet, other mechanism), age, gender, Abbreviated Injury Scale (AIS) for each body area, severity of pelvic fracture, Injury Severity Score (ISS), intraabdominal injuries, bladder and urethral injuries, thoracic aortic injury, angiographic evaluation, angiographic embolization, blood transfusion requirements, internal or external pelvic fixation, days in ICU, length of hospital stay, survival, and cause of death. The AIS is a consensus-derived system that classifies injury severity of individual organs by body region on a severity scale ranging from 1 (minor) to 6 (lethal). By adding the squares of the three highest AIS scores from the various body regions, the ISS is derived and represents the overall trauma severity. Because the retrospective nature of the study, no efforts were made to classify the pelvic fractures according to fracture geometry or vectors of force. A death was classified as directly related to the pelvic fracture if the pelvis AIS was ≥ 4, the patient required massive transfusions, died within the first 48 hours of admission, and had no other body area injury with AIS ≥ 4. Pelvic AIS ≥ 4 includes fractures with substantial deformation and displacement with ICD-9 (1999) codes 852606.4, 852608.4, and 852610.5. More details about angiographic findings and procedures were obtained from interventional radiology reports.

STATISTICAL ANALYSIS

Incidence of pelvic fracture was estimated with a 95% confidence interval (CI) for the entire study population of pelvic fracture injuries from blunt trauma as a whole and for each mode of injury.

For the assessment of the association of risk factors with outcomes, we first performed a univariate analysis for each risk factor to identify the level of significance of the association with each outcome variable. We then selected risk factors with a p-value less than 0.20 for inclusion as independent factors in the stepwise logistic regression analysis. Factors with a level of significance of < 0.05 were considered as significant risk factors and were kept in the logistic regression model. Adjusted relative risk and 95% CI for each risk factor in the model were derived. The Max-rescaled R-square was used to measure the degree of variation explained by the risk factors. The SAS statistical software was used for all analyses (The SAS System, Release 8.0, SAS Institute, Inc, Cary, NC).

RESULTS

Incidence of Pelvic Fracture in Blunt Trauma

During the study period, there were 42,283 admissions for trauma, 28,066 of which met the criteria for major trauma and were included in the trauma registry. Blunt trauma was the mechanism of injury in 16,630 trauma registry patients, and this group formed our study population. The incidence of pelvic fractures was 9.3% (1,545 patients). There were 937 (60.6%) males and 608 (39.4%) females. The mean age $\pm$ SD was 37.1 $\pm$ 17.7 years.

Risk Factors Associated with Severe Pelvic Fracture

Overall, motorcycle injuries were associated with the highest incidence of pelvic fractures (15.5%), followed

Table 1. Incidence of Pelvic Fracture in Blunt Trauma by Mechanism of Injury

Mechanism of injury	All patients with blunt injury (n)	Patients with pelvic fracture (n)	Incidence of pelvic fracture %	(95% CI)
All patients	16,630	1,545	9.3	(8.8, 9.7)
Motor vehicle crash	5,926	605	10.2	(9.4, 11.0)
Pedestrian	4,675	647	13.8	(12.8, 14.8)
Fall $\geq$ 15 ft	1,395	180	12.9	(11.1, 14.7)
Motorcycle	303	47	15.5	(11.4, 19.6)
Other mechanism	496	28	5.6	(3.6, 7.7)

Table 2. Risk Factors of Severe Pelvic Fracture (AIS ≥ 4)

Risk factor	Subgroup	Severe pelvic fracture % (x/n)	Relative risk (95% CI)	p-Value*
Age (y)	>55	8 (20/241)	0.9 (0.6, 1.5)	0.81
	≤55	9 (117/1,304)	1.0	
Gender	Male	10 (92/937)	1.3 (0.9, 1.9)	0.12
	Female	7 (45/608)	1.0	
Fall>15 ft	Yes	8 (15/180)	0.9 (0.6, 1.6)	0.89
	No	9 (122/1,365)	1.0	
Motorcycle	Yes	17 (8/47)	2.0 (1.0, 3.8)	0.06
	No	9 (129/1,498)	1.0	
Other mode of injury	Yes	7 (2/28)	0.8 (0.2, 3.1)	1.00
	No	9 (135/1,517)	1.0	
Motor vehicle crash	Yes	7 (42/605)	0.7 (0.5, 1.0)	0.03
	No	10 (95/940)	1.0	
Pedestrian	Yes	11 (68/647)	1.4 (1.0, 1.9)	0.06
	No	8 (69/898)	1.0	
	Total	8.9 (137/1,545)		

*Two-sided Fisher's exact test. Stepwise logistic regression, using gender, age, and mechanism of injury in the model, identified motor vehicle crash as the only independent risk factor associated with severe pelvic fracture. The adjusted relative risk of severe pelvic fracture for motor vehicle accident is 0.7 (0.5, 1.0), p = 0.03. The Max-rescaled R-square is 0.7%.
AIS, Abbreviated Injury Scale.

by pedestrian injuries (13.8%), falls from height >15 ft (12.9%), and car occupants (10.2%) (Table 1). The overall mean ISS ± SD was 15.2 ± 12.6 and 526 patients (34.1%) had an ISS ≥ 16. Only 137 (8.9%) of the pelvic fractures were classified as severe (AIS ≥ 4). There was an indication of more severe pelvic fractures (AIS ≥ 4) in pedestrian and motorcycle injuries (p = 0.06), compared with other mechanisms of injury (Table 2). Pelvic fractures from MVCs were less likely to be severe (AIS ≥ 4) than other mechanisms. Stepwise logistic regression using gender, age, and mechanism of injury (fall > 15 ft, motorcycle, MVC, pedestrian, and other mode of injury) in the model identified MVC as the only independent risk factor associated with less severe pelvic fractures. The adjusted relative risk of severe pelvic fracture for MVC was 0.7 (95% CI: 0.5, 1.0), p = 0.03.

Associated Abdominal or Urogenital Injuries

Overall, 255 patients (16.5%) had associated intraabdominal or urogenital injuries; 180 patients (11.8%) had associated solid organ injuries, 68 patients (4.4%) had gastrointestinal perforations, and 90 patients

Table 3. Associated Abdominal or Urogenital Injuries by Severity of Pelvic Fractures

	All pelvic fractures (n = 1,545)		Pelvic fractures AIS ≥ 4 (n = 137)		Pelvic fractures AIS ≤3 (n = 1,408)		
Injured organ	n	%	n	%	n	%	p Value
Liver	94	6.1	14	10.2	80	5.7	0.04
Bladder and urethra	90	5.8	20	14.6	70	5.0	<0.001
Spleen	80	5.2	8	5.8	72	5.1	0.68
Diaphragm	33	2.1	5	3.6	28	2.0	0.21
Small bowel	31	2.0	12	8.8	19	1.3	<0.001
Colon	18	1.2	3	2.2	15	1.1	0.21
Rectum	14	0.9	2	1.5	12	0.9	0.36
Pancreas	6	0.4	0	0	6	0.4	1
Stomach	4	0.3	1	0.7	3	0.2	0.31
Duodenal	1	0.1	0	0	1	0.1	1
Any abdominal injury	255	16.5	42	30.7	213	15.1	<0.001

AIS, Abbreviated Injury Scale.

Table 4. Risk Factors Associated with Liver Injury in Patients with Pelvic Fracture

Risk factor	Subgroup	Liver injury %	Liver injury (x/n)	Relative risk (95% CI)	p Value*
Age (y)	>55	4.6	(11/241)	0.7 (0.4, 1.3)	0.38
	≤55	6.4	(83/1,304)	1.0	
Gender	Male	6.2	(58/937)	1.0 (0.7, 1.6)	0.91
	Female	5.9	(36/608)	1.0	
Fall >15 ft	Yes	4.4	(8/180)	0.7 (0.4, 1.4)	0.41
	No	6.3	(86/1,365)	1.0	
Motorcycle	Yes	4.3	(2/47)	0.7 (0.2, 2.7)	1.00
	No	6.1	(92/1,498)	1.0	
Other mode of injury	Yes	0.0	(0/28)	—	0.41
	No	6.2	(94/1,517)		
Motor vehicle crash	Yes	8.4	(51/605)	1.8 (1.2, 2.7)	0.003
	No	4.6	(43/940)	1.0	
Pedestrian	Yes	5.1	(33/647)	0.8 (0.5, 1.1)	0.20
	No	6.8	(61/898)	1.0	
Pelvis AIS	5	14.9	(7/47)	2.7 (1.3, 5.5)	0.04
	4	7.8	(7/90)	1.4 (0.7, 3.0)	
	3	8.7	(6/69)	1.6 (0.7, 3.5)	
	2	5.5	(74/1,339)	1.0	
Pelvis AIS	≥4	10.2	(14/137)	1.8 (1.0, 3.1)	0.04
	<4	5.7	(80/1,408)	1.0	

*Two-sided Fisher's exact test. Stepwise logistic regression, using age, gender, mechanism of injury, and pelvis AIS in the model, identified MVC and pelvis AIS ≥ 4 as significant independent risk factors associated with liver injury. The adjusted relative risk of liver injury for MVC is 1.9 (1.3, 2.8), p = 0.002. The adjusted relative risk of liver injury for pelvic AIS ≥ 4 is 1.9 (1.1, 3.1), p = 0.02. The Max-rescaled R-square is 2.5%.
AIS, Abbreviated Injury Scale; MVC; motor vehicle crash.

(5.8%) had urogenital injuries (Table 3). The most commonly injured organs were the liver (6.1%), bladder and urethra (5.8%), and spleen (5.2%).

In the subgroup of 137 patients with severe pelvic fractures (AIS ≥ 4), there were 42 cases (30.7%) with associated intraabdominal or urogenital injuries. In the subgroup of 1,408 patients with less severe (AIS ≤ 3) pelvic fractures, there were 213 cases (15.1%) with associated injuries ($p < 0.001$). Patients with severe pelvic fractures were significantly more likely to have associated liver injuries ($p = 0.04$), bladder and urethra ($p < 0.001$), and small bowel injuries ($p < 0.001$) than patients with less severe pelvic fractures (Table 3). Stepwise logistic regression using age, gender, mechanisms of injury, and severity of pelvic fracture in the model identified MVC and pelvis AIS = 4 as predictors of liver injury (Table 4). The adjusted relative risk of liver injury for MVC was 1.9 (1.3, 2.8), $p = 0.002$, and for pelvis AIS ≥ 4 the adjusted risk was 1.9 (1.1, 3.1), $p = 0.02$. If both MVC and pelvis AIS = 4 were present, the relative risk of liver injury was 3.0 (95% CI: 1.2, 7.2; $p = 0.03$), compared with patients without the two risk factors.

The overall incidence of bladder and urethra injuries was 5.8% (90/1,545) (Table 3). Stepwise logistic regression analysis including age, gender, mechanism of injury, and severity of pelvic fracture in the model identified male gender and pelvis AIS ≥ 4 as independent risk factors associated with bladder and urethral injuries (Table 5). The adjusted relative risk for males was 1.9 (95% CI: 1.1, 3.6; $p = 0.03$) and for pelvis AIS = 4 was 3.0 (95% CI: 1.6, 5.2; $p < 0.001$). The relative risk of bladder and urethral injury for patients with and without the two risk factors was 4.8 (95% CI: 2.5, 9.2; $p < 0.001$).

Of 16,630 blunt trauma injuries, 67 (0.4%) cases had thoracic aortic rupture. Of the 1,545 blunt trauma patients with pelvic fracture, 21 (1.4%) had thoracic aortic rupture. This incidence is significantly higher than that of aortic rupture in blunt trauma patients without pelvic fracture (46/15,085 or 0.3%, $p < 0.001$). All aortic ruptures occurred in the adult group. Among the risk factors

Table 5. Risk Factors Associated with Bladder and Urethral Injuries in Patients with Pelvic Fractures

Risk factor	Subgroup	Bladder and urethra injury %	(x/n)	Relative risk (95% CI)	p Value*
Age (y)	>55	5.0	(12/241)	0.8 (0.5, 1.5)	0.65
	≤55	6.0	(78/1,304)	1.0	
Gender	Male	7.0	(66/937)	1.8 (1.1, 2.8)	0.01
	Female	3.9	(24/608)	1.0	
Fall >15 ft	Yes	3.3	(6/180)	0.5 (0.2, 1.2)	0.17
	No	6.1	(84/1,365)	1.0	
Motorcycle	Yes	12.8	(6/47)	2.3 (1.0, 4.9)	0.05
	No	5.6	(84/1,498)	1.0	
Other mode of injury	Yes	10.7	(3/28)	1.9 (0.6, 5.5)	0.22
	No	5.7	(87/1,517)	1.0	
Motor vehicle crash	Yes	5.0	(30/605)	0.8 (0.5, 1.2)	0.27
	No	6.4	(60/940)	1.0	
Pedestrian	Yes	7.1	(46/647)	1.5 (1.0, 2.2)	0.08
	No	4.9	(44/898)	1.0	
Pelvis AIS	5	14.9	(7/47)	3.2 (1.6, 6.6)	<0.001
	4	14.4	(13/90)	3.1 (1.8, 5.5)	
	3	11.6	(8/69)	2.5 (1.2, 5.0)	
	2	4.6	(62/1,339)	1.0	
Pelvis AIS	≥4	14.6	(20/137)	2.9 (1.8, 4.7)	<0.001
	≤3	5.0	(70/1,408)	1.0	

*Two-sided Fisher's exact test. Stepwise logistic regression, using gender, other mode of injury, pedestrian and pelvic AIS ≥ 4 in the model, identified gender and pelvic AIS ≥ 4 as important independent risk factors associated with bladder and urethra injury. The adjusted relative risk of bladder and urethra injury for male is 1.7 (1.1, 2.7), p = 0.02. The adjusted relative risk of bladder and urethra injury for pelvic AIS ≥ 4 is 2.9 (1.7, 4.4), p < 0.001. The Max-rescaled R-square is 3.9%.
AIS, Abbreviated Injury Scale.

studied, age >55 years was the only major risk factor associated with aortic rupture in patients with pelvic fracture. The relative risk of aortic rupture for patients more than 55 years of age was 4.9 (95% CI: 2.1, 11.2, p = 0.001) (Table 6).

Blood Transfusions

Overall, 594 patients (38.5%) with pelvic fractures required blood transfusions, with a mean transfusion requirement of 954 mL. In the group of 137 patients with pelvic AIS ≥ 4, 83 (60.6%) received blood transfusions (mean 3,540 mL). In the group of 81 patients with severe pelvic fracture (AIS ≥ 4), but no other major associated injury (all other body areas had AIS ≤ 3), 41 (50.6%) received blood transfusions (mean 2,718 mL). Among the group of 56 patients with severe pelvic fracture (AIS ≥ 4) and other major associated injury (other body areas with AIS ≥ 4), 42 (75%) received blood transfusion (p = 0.007).

Overall, 257 patients (16.6%) with pelvic fractures required major blood transfusion of more than 2,000 mL. In the group of 137 patients with pelvic AIS ≥ 4, 46 (33.6%) received major blood transfusions. Among them, 55 patients also had other major associated injury (all other body areas had AIS ≥ 4), and 29 (52.7%) received major blood transfusion; of the 81 severe pelvic injury patients who did not have other major associated injury, 17 (20.7%) received major blood transfusion (p = 0.007). Stepwise logistic regression including age, gender, mechanism of injury, ISS, severity of pelvic fracture, and need of angiographic embolization in the model identified age > 55, ISS > 25, pelvic AIS ≥ 4, and angiographic embolization as significant independent risk factors associated with major blood transfusions (> 2,000 mL) (Table 7). The relative risk of major blood transfusion for patients who had these four risk factors, compared with those who did not have any, was 8.6 (95% CI: 5.7, 12.8; p < 0.001).

Angiography

Angiography was performed in 72 patients (4.7%) with pelvic fractures. Therapeutic embolization was achieved

Table 6. Risk Factors Associated with Aortic Rupture in Patient with Pelvic Fracture

Risk factor	Subgroup	Aortic rupture %	Aortic rupture (x/n)	Relative risk (95% CI)	p Value*
Age (y)	>55	4.2	(10/241)	4.9 (2.1, 11.4)	0.005
	≤55	0.8	(11/1,304)	1.0	
Gender	Male	1.5	(14/937)	1.3 (0.5, 3.2)	0.66
	Female	1.2	(7/608)	1.0	
Fall >15 ft	Yes	2.2	(4/180)	1.8 (0.6, 5.2)	0.30
	No	1.2	(17/1,365)	1.0	
Motorcycle	Yes	0.0	(0/47)	—	1.00
	No	1.4	(21/1498)		
Other mode of injury	Yes	3.6	(1/28)	2.7 (0.4, 19.5)	0.32
	No	1.3	(20/1,517)	1.0	
Motor vehicle crash	Yes	1.5	(9/605)	1.2 (0.5, 2.8)	0.82
	No	1.3	(12/940)	1.0	
Pedestrian	Yes	1.1	(7/647)	0.7 (0.3, 1.7)	0.51
	No	1.6	(14/898)	1.0	
Pelvic AIS	5	2.1	(1/47)	1.6 (0.2, 11.6)	0.65
	4	2.2	(2/90)	1.6 (0.4, 7.0)	
	3	0.0	(0/69)	—	
	2	1.3	(18/1,321)	1.0	
Pelvic AIS	≥4	2.2	(3/137)	1.7 (0.5, 5.7)	0.42
	<4	1.3	(18/1,408)	1.0	

*Two-sided Fisher's exact test. The only significant risk factor is Age>55. The adjusted relative risk for age 55 is 4.9 (2.1, 11.2), p = 0.001. The Max-rescaled R-square for age>55 is 5.8%.
AIS, Abbreviated Injury Scale.

in 36, 2.3% of all pelvic fracture patients, or 50% of patients who had undergone angiography. Stepwise logistic regression using age, gender, ISS, mechanism of injury, and severity of pelvic fracture in the model identified pelvis AIS ≥ 4 and ISS > 25 as major factors associated with therapeutic angiographic embolization. The adjusted relative risk for AIS ≥ 4 was 5.4 (95% CI: 2.7, 10.2; $p < 0.001$) and for ISS > 25 was 3.3 (95% CI: 1.7, 6.4; $p < 0.001$) (Table 8). The relative risk of angiographic embolization for patients with and without both risk factors was 16.4 (95% CI: 7.5, 35.7; $p < 0.001$).

Mortality

Overall, 208 of 1,545 patients (13.5%) with pelvic fractures died, while 38 of 137 patients (27.7%) with severe pelvic fractures (AIS ≥ 4) died. Only 12 deaths (0.8%) were directly related to the pelvic fracture as defined by patients who had pelvis AIS ≥ 4, required massive transfusions, died within 48 hours, and had no other body area injury with AIS ≥ 4. All 12 deaths occurred in patients > 16 years. Stepwise logistic regression analysis including age, gender, mechanism of injury, ISS, severity of pelvic fracture, and therapeutic angiogram in the model, identified ISS > 25 as the only risk factor associated with mortality. The relative risk of mortality for patients with ISS > 25 was 5.6 (95% CI: 2.3, 8.9; $p < 0.001$) (Table 9).

DISCUSSION

Pelvic fractures are markers of severe injury and are often associated with major intraabdominal injuries and severe bleeding from the fracture site. Identification of significant risk factors associated with abdominal injuries and pelvic bleeding can improve patient outcomes by optimizing the selection and timing of diagnostic and therapeutic interventions.

Despite the relatively high incidence of pelvic fractures after blunt trauma (9.3%), severe pelvic fractures (AIS ≥ 4) occur rather infrequently (0.8% of all blunt trauma patients or 8.9% of all pelvic fractures). MVC is the least likely mechanism of injury to produce severe pelvic fractures.

The major force required to produce a pelvic fracture often results in notable intraabdominal or bladder and urethral injuries. The reported incidence of such injuries varies from 11% to 20.3%.[1-3] Ismail and coworkers[1] re-

Table 7. Risk Factors Associated with Major Blood Transfusion (>2,000 mL) in Patients with Pelvic Fracture

Risk factor	Subgroup	Massive blood transfusion %	Massive blood transfusion (x/n)	Relative risk (95% CI)	p Value*
ISS	>25	42.3	(113/267)	5.2 (4.0, 6.6)	<0.001
	16–25	23.6	(61/259)	2.9 (2.1, 3.9)	
	<16	8.2	(82/1,002)	1.0	
Age (y)	>55	27.4	(66/241)	1.9 (1.5, 2.4)	<0.001
	≤55	14.6	(191/1,304)	1.0	
Gender	Male	17.5	(164/937)	1.1 (0.9, 1.4)	0.26
	Female	15.3	(93/608)	1.0	
Fall >15 ft	Yes	15.0	(27/180)	0.9 (0.6, 1.3)	0.59
	No	16.8	(230/1,365)	1.0	
Motorcycle	Yes	23.4	(11/47)	1.4 (0.8, 2.4)	0.23
	No	16.4	(246/1,498)	1.0	
Other mode of injury	Yes	10.7	(3/28)	0.6 (0.2, 1.9)	0.61
	No	16.7	(254/1,517)	1.0	
Motor vehicle crash	Yes	15.9	(96/605)	0.9 (0.7, 1.2)	0.53
	No	17.1	(161/940)	1.0	
Pedestrian	Yes	17.9	(116/647)	1.1 (0.9, 1.4)	0.27
	No	15.7	(141/898)	1.0	
Therapeutic angiogram	Yes	48.6	(35/72)	3.2 (2.5, 4.2)	<0.001
	No	15.1	(222/1,473)	1.0	
Pelvis AIS	5	68.1	(32/47)	4.7 (3.7, 5.9)	<0.001
	4	15.6	(14/90)	1.1 (0.6, 1.8)	
	3	24.6	(17/69)	1.7 (1.1, 2.6)	
	2	14.5	(194/1,339)	1.0	
Pelvis AIS	≥4	33.6	(46/137)	2.2 (1.7, 2.9)	<0.001
	≤3	15.0	(211/1,408)	1.0	

*Two-sided Fisher's exact test. Stepwise logistic regression, including age>55, ISS > 25, need of angiographic immobilization, and pelvic AIS ≥ 4 in the model, identified all as major independent risk factors associated with massive blood transfusion. The adjusted relative risk of massive blood transfusion for age>55 is 1.7 (1.2, 2.4), p = 0.005; for pelvic AIS ≥ 4 is 1.8 (1.2, 2.7), p = 0.009; for ISS > 25 is 4.7 (3.5, 6.5), p < 0.001; and for angiographic embolization is 3.9 (2.3, 6.6), p < 0.001. The Max-rescaled R-square = 17.4%.
AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.

ported an incidence of 11% of associated solid organ injury in 722 pediatric patients with pelvic fractures obtained from the National Pediatric Trauma Registry. In another group of 532 pelvic fractures in adults, the incidence of solid visceral injury was 12%.[1] In this study, the overall incidence of associated intraabdominal or bladder and urethral injuries was 16.5%. In patients with severe pelvic fractures (AIS ≥ 4), the incidence of associated injuries was notably higher (30.7%). The most important risk factors associated with liver injury were the mechanism of injury (MVC) and severity of pelvic fracture (AIS ≥ 4). In the presence of both risk factors, the relative risk for liver injury was 3.0, compared with patients without the two risk factors. Similarly, stepwise logistic regression identified male gender and pelvis AIS ≥ 4 as the risk factors associated with bladder and urethral injuries. When both risk factors are present, the relative risk for bladder and urethra injury was 4.8, compared with patients with both risk factors absent.

In less severe pelvic fractures (AIS < 4), the most commonly injured organ was the liver (5.8% of patients). In severe pelvic fractures (AIS ≥ 4), injuries to the bladder or urethra were the most common (14.6%), followed by liver injuries (10.2%). The incidence of injuries to the spleen, rectum, diaphragm, and aorta was not notably affected by the severity of pelvic fracture.

Of particular interest was the incidence of associated thoracic aortic rupture. Ochsner and colleagues[3,4] suggested that pelvic fractures are associated with an increased incidence of aortic injury. In a review of 5,006 blunt trauma patients from the Washington Hospital Center, the incidence of pelvic fracture was 9.0%, and the incidence of thoracic aortic rupture was 1.0%.[3]

Table 8. Risk Factors Associated with Therapeutic Angiographic Embolization in Patients with Pelvic Fracture

Risk factor	Subgroup	Needed angiographic embolization %	(x/n)	Relative risk (95% CI)	p Value*
ISS	>25	6.7	(18/267)	5.6 (2.8, 11.5)	<0.001
	16–25	2.3	(6/259)	1.9 (0.7, 5.1)	
	<16	1.2	(12/1,002)	1.0	
Age (y)	>55	4.2	(10/241)	2.1 (1.0, 4.3)	0.06
	≤55	2.0	(26/1,304)	1.0	
Gender	Male	2.7	(25/937)	1.5 (0.7, 3.0)	0.30
	Female	1.8	(11/608)	1.0	
Fall >15 ft	Yes	1.1	(2/180)	0.4 (0.1, 1.8)	0.43
	No	2.5	(34/1,365)	1.0	
Motorcycle	Yes	4.3	(2/47)	1.9 (0.5, 7.6)	0.30
	No	2.3	(34/1,498)	1.0	
Other mode of injury	Yes	0.0	(0/28)	—	1.00
	No	2.4	(36/1,517)		
Motor vehicle crash	Yes	2.3	(14/605)	1.0 (0.5, 1.9)	1.00
	No	2.3	(22/940)	1.0	
Pedestrian	Yes	2.6	(17/647)	1.2 (0.6, 2.4)	0.61
	No	2.1	(19/898)	1.0	
Pelvis AIS	5	19.2	(9/47)	12.8 (6.2, 26.6)	<0.001
	4	6.7	(6/90)	4.5 (1.8, 10.8)	
	3	1.4	(1/69)	1.0 (0.1, 7.1)	
	2	1.5	(20/1,339)	1.0	
Pelvis AIS	≥4	11.0	(15/137)	7.3 (3.9, 13.9)	<0.001
	≤3	1.5	(21/1,408)	1.0	

*Two-sided Fisher's exact test. Stepwise logistic regression identified pelvic AIS > 3 and ISS > 25 as the predictors of therapeutic angiographic embolization. The adjusted relative risk for AIS≥ 4 is 5.4 (2.7, 0.2), $p < 0.001$. The adjusted relative risk for ISS > 25 is 3.3 (1.7, 6.4), $p = 0.001$. The Max-rescaled R-square is 12.9%.
AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.

There were 27 aortic ruptures in the group of 461 patients with pelvic fracture (5.9%). Further analysis of 63,763 Major Trauma Outcome Study patients showed an incidence of 8.5% pelvic fractures and 0.7% of aortic ruptures. The incidence of aortic rupture in patients with pelvic fractures was 1.6%. In this study, the incidence of aortic rupture in the presence of a pelvic fracture was seven times higher than in patients without pelvic fracture (1.4% versus 0.2%). Age > 55 year was the only significant predictor of aortic rupture in patients with pelvic fracture (relative risk: 4.9, $p < 0.001$).

There have been reports of an association between pelvic fractures and diaphragmatic injury.[5,6] Diaphragmatic rupture was found in 2.1% of our patients with pelvic fractures, which is very similar to the incidence reported in other series. This is not higher than the incidence of diaphragmatic rupture in blunt trauma patients undergoing laparotomy, which has been reported to be 4% to 6%.[7]

Angiographic embolization can be life-saving in some cases with severe pelvic bleeding. Early identification of patients who might benefit from this procedure could reduce blood loss and improve outcome.[8,9] Overall, 4.7% of all pelvic fractures in this series underwent angiography, a figure consistent with other published experience.[10,11] Only half of the angiographically evaluated patients had therapeutic embolization. The patients most likely to undergo therapeutic embolization were those with pelvic AIS ≥ 4 or ISS ≥ 25. In the presence of both parameters, the relative risk was 16.4, compared with patients without the risk factors. Various studies attempted to predict the risk of major pelvic bleeding on the basis of geometry of fracture and vectors of force.[8,12,13] Because of the retrospective nature of our

Table 9. Risk Factors Associated with Mortality Among Patients with Severe Pelvic Fracture (Pelvis AIS ≥ 4, Excluding Patients with Associated Severe Injuries [ie, Head AIS ≥ 4, or Chest AIS ≥ 4, or Abdomen AIS ≥ 4])

		Died			
Risk factor	**Subgroup**	**%**	**(x/n)**	**Relative risk (95% CI)**	**p Value***
ISS	>25	50	(7/14)	6.8 (2.0, 22.0)	0.002
	16–25	12	(3/26)	1.6 (0.3, 7.2)	
	<16	7	(3/41)	1.0	
Age (y)	>55	43	(3/7)	3.5 (1.2, 9.9)	0.08
	≤55	14	(9/73)	1.0	
Gender	Male	22	(11/51)	3.2 (0.7, 13.0)	0.12
	Female	7	(2/30)	1.0	
Fall >15 ft	Yes	29	(2/7)	2.1 (0.6, 7.7)	0.31
	No	15	(11/74)	1.0	
Motorcycle	Yes	17	(1/6)	1.1 (0.2, 6.7)	1.00
	No	16	(12/75)	1.0	
Other mode of injury	Yes	100	(1/1)	7.2 (4.0, 11.2)	0.16
	No	15	(12/80)	1.0	
Motor vehicle crash	Yes	8	(2/26)	0.4 (0.1, 1.6)	0.21
	No	20	(11/55)	1.0	
Pedestrian	Yes	18	(7/40)	1.0 (0.4, 3.2)	0.77
	No	15	(6/41)	1.0	
Therapeutic angiogram	Yes	43	(3/7)	3.2 (1.1, 8.9)	0.08
	No	14	(10/74)	1.0	
Pelvis AIS	5	26	(7/27)	2.3 (0.9, 6.8)	0.55
	4	11	(6/54)	1.0	

*Two-sided Fisher's exact test. Stepwise logistic regression, identified ISS > 25 as the only major risk factor associated with mortality from pelvic fracture. The adjusted relative risk of mortality for ISS > 25 is 3.6 (2.3, 8.9), $p < 0.001$. The Max-rescaled R-square is 22.7%.
AIS, Abbreviated Injury Scale; ISS, Injury Severity Score.

study, no efforts were made to analyze the role of these variables.

Death directly related to exsanguination from a pelvic fracture is not common, and in this series the incidence was 0.8%. Similar rates were reported in other studies.[11,14,18] In our study, multivariate analysis showed only ISS > 25 to be an independent risk factor of mortality. Age, gender, mechanism of injury, and pelvic AIS were not major risk factors.

Patients with pelvic fractures have a high incidence of associated abdominal injuries. The incidence increases markedly with the severity of pelvic fracture. Important risk factors for liver injury were the mechanism of injury (MVC) and severity of pelvic fracture (AIS ≥ 4). Predictors of associated bladder and urethra injuries were male gender and severity of pelvic fracture (AIS ≥ 4). The only major risk factor of aortic rupture was age 55 > years. Patients with severe pelvic fracture (AIS ≥ 4) and ISS > 25 are the most likely to benefit from angiographic evaluation. With a modern multidisciplinary approach, the mortality from pelvic fracture is very low.

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