Management of Hemorrhage in Severe Pelvic Injuries

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Background: Major pelvic trauma results in high mortality. No standard technique to control pelvic hemorrhage has been identified.

Methods: In this retrospective study, the clinical course of hemodynamically instable trauma patients with pelvic fractures treated according to an institutional algorithm focusing on basic radiologic diagnostics, external fixation, and early angiographic embolization was evaluated. Study variables included demographics, data on the type and extent of injury, achievement of time from admission to hemorrhage control, complications of angiography, red blood cell needs, and outcome. Standard statistical tests were used.

Results: Of 1,476 pelvic fracture patients, 45 fulfilled the inclusion criteria. Two patients presented with severe intra-abdominal hemorrhage and underwent emergency laparotomy with pelvic packing. Forty-two patients underwent angiographic embolization before (n = 24) or after (n = 18) a computed tomography scan. Applying the clinical algorithm, pelvic hemorrhage was controlled in all but one patient who died before any intervention could be initiated (97.8%). The hourly need for red blood cell transfusions decreased during 24 hours after angiographic embolization when compared with before the procedure (3.7 ± 3.5 vs. 0.1 ± 0.1 U/h; $p < 0.001$). In patients undergoing angiographic embolization, the mean time to hemorrhage control was 163 minutes ± 83 minutes. Hospital mortality was 26.2%. Two patients required reembolization because of hemorrhage from other than the primary bleeding site. One patient developed gluteal necrosis, and nine subsequently required renal replacement therapy.

Conclusion: Application of a clinical algorithm focusing on basic radiologic diagnostics, external fixation, and early angiographic embolization was effective and safe to rapidly control hemorrhage in hemodynamically instable trauma patients with pelvic fractures.

Key Words: Pelvic trauma, Algorithm, External fixation, Angiographic embolization.

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Major pelvic trauma results in high mortality. The causes for dismal survival on the one hand is massive hemorrhage from pelvic bleeding sites and on the other hand is the severity of associated injuries involving the abdomen, chest, or central nervous system.[1–4] Although the majority (~85%) of pelvic bleeding sites are venous in origin, arterial bleeds can be found in many pelvic trauma patients with hemorrhagic shock.[5]

Currently, no standards to control posttraumatic pelvic hemorrhage have been defined, but different techniques have been suggested. External fixation of instable pelvic ring or acetabular fractures with the use of C-clamps, belts, or wrappings have been known for long and primarily act through pelvic stabilization and control of venous hemorrhage.[6–10] Since surgical exposition of retroperitoneal hematoma, it consistently resulted in loss of the tamponade effect on venous bleeding and perpetuated hemorrhage, and pelvic bleeding was managed conservatively by many trauma surgeons.[11] In 1994, Pohlemann et al.[12] introduced the technique of immediate exploration of the pelvic retroperitoneum and pelvic packing to control bleeding. However, with this technique packs need to be changed or removed during secondary operative interventions bearing the risk of further tissue trauma, rebleeding, and septic complications.[12,13] Angiographic embolization to control arterial pelvic hemorrhage has been first introduced in 1972[14] and evaluated in several cohorts during the last decades.[13,15–19] Angiographic bleeding control is minimally invasive and effective but has been associated with serious complications and a high-time demand to control hemorrhage.[15,18–21] Independent of the technique applied, the time factor plays an important role in determining patient outcome. Agolini et al.[15] demonstrated that 3 hours passing between hospital arrival and angiographic bleeding control may be a critical time period for patient survival.

In view of these considerations, a clinical algorithm focusing on basic radiologic diagnostics, external fixation, and early angiographic embolization to manage hemodynamically instable trauma patients with pelvic fracture has been introduced at our institution. In this retrospective study, we evaluated the clinical course of patients treated according to this algorithm. Our hypothesis was that management according to the clinical algorithm can effectively, rapidly, and safely control hemorrhage in hemodynamically instable trauma patients with pelvic fractures.

PATIENTS AND METHODS

This retrospective cohort study was performed at a Level I trauma center, and evaluated patients were admitted from January 1995 to December 2007. Medical charts of the

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department of trauma surgery of the Innsbruck Medical University were reviewed for patients who fulfilled both of the following two inclusion criteria: (1) traumatic pelvic fracture diagnosed and classified by at least one senior trauma surgeon; (2) hemodynamic instability at presentation to the emergency department. Hemodynamic instability was defined as the presence of two or more of the following criteria: (a) systolic arterial blood pressure $<$90 mm Hg despite immediate fluid resuscitation ($>$2 L crystalloid or colloid fluids), red blood cell (RBC) transfusions, and/or catecholamines; (b) heart rate $>$110 bpm despite analgesia and fluid resuscitation; (c) documented clinical and laboratory signs of tissue hypoperfusion (e.g., elevated arterial lactate levels $>$2 mmol/L); (d) persistent need for fluid resuscitation, RBC transfusion and/or catecholamine therapy; and (e) need for cardiopulmonary resuscitation. Patients who did not fulfill both inclusion criteria were $<$18 years or in whom the time between injury and admission to the study center exceeded 12 hours were excluded from the analysis.

Patient Management and Clinical Algorithm

All study patients were treated by an around the clock trauma team, which consisted of a senior trauma surgeon, radiologist, and anesthesiologist with facultative involvement of a general or neurosurgeon. A published shock room protocol[22,23] and standards as suggested by the "Advanced Trauma Life Support" guidelines for major trauma[24,25] were routinely followed. In hemodynamically instable trauma patients with pelvic fracture, the algorithm shown in Figure 1 was applied. This algorithm includes anterior-posterior X-rays of the chest and pelvis as well as a focused abdominal sonography for trauma as the primary diagnostic steps. After life-saving procedures (e.g., insertion of a chest tube) and external fixation of instable pelvic fractures (C-clamp, pelvic

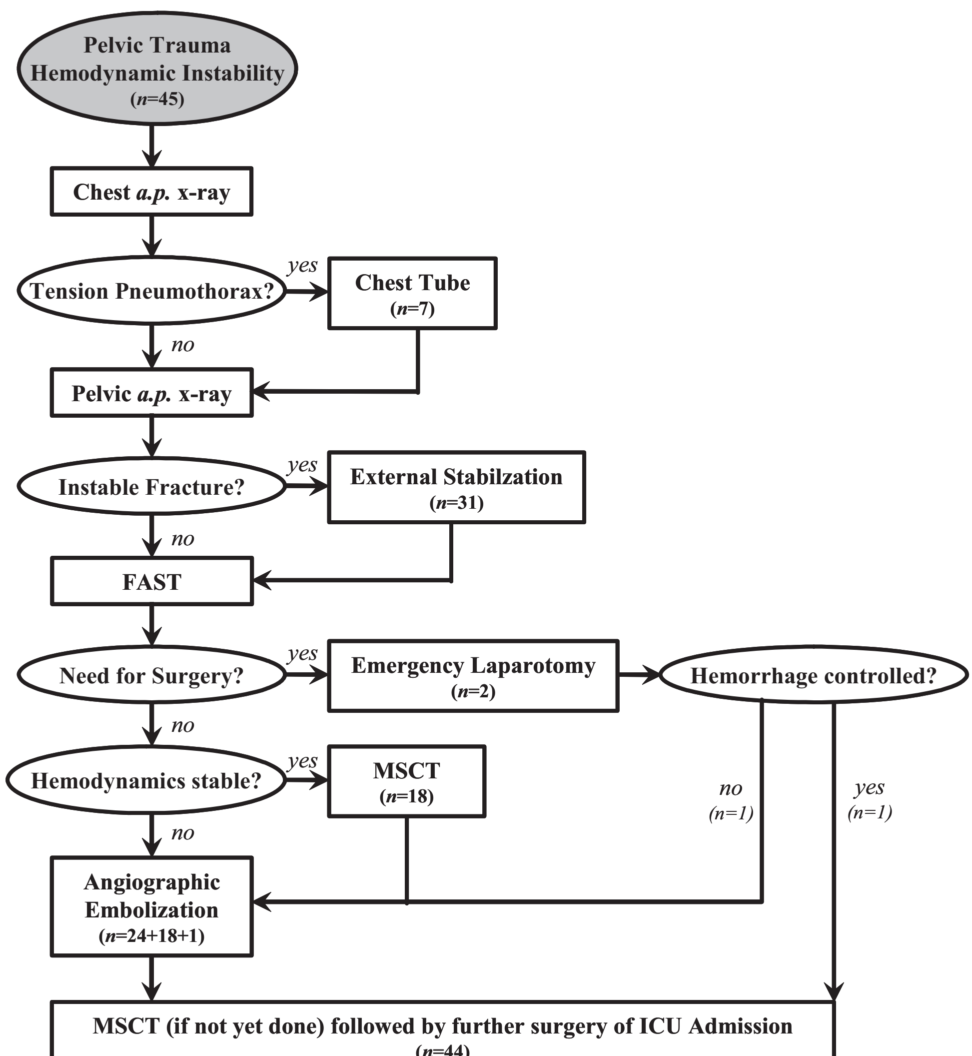

Figure 1. Clinical algorithm to manage hemodynamically instable trauma patients with pelvic fractures. One patient died after performance of the chest X-ray. Resuscitation efforts were performed simultaneously during all diagnostic and therapeutic steps. For definition of hemodynamic instability refer to text. a.p., anterior-posterior; FAST, focused abdominal sonography for trauma; MSCT, multislice computer tomography; ICU, intensive care unit.

wrapping, or fixateur externe) have been performed, further diagnostic and therapeutic steps were based on the hemodynamic function of the patient. If hemodynamics could be stabilized with fluids, RBC transfusion and/or catecholamines (definitions see earlier) a multislice computed tomography scan of the head, cervical spine, and trunk was performed. In case of ongoing hemodynamic instability, the patient was rushed to the angiography suite for embolization, and the computer tomography scan was performed afterward. Angiographic embolization was achieved by injection of either gelatin foam cubes (1- to 3-mm Contour embolization particles; Boston Scientific; Natick, MA) or coils (MWCE macrocoils; Cook Europe; Bjaeverskov, Denmark) into the bleeding artery. Only if abdominal lesions demanding emergency surgery were present, laparotomy with preperitoneal pelvic packing was performed. The decision to perform emergency surgery was based on the results of the focused abdominal sonography for trauma and made by at least one senior trauma surgeon and one senior general surgeon.

Data Documentation

The following variables were collected from the medical charts: age, sex, cause and type of trauma, time from injury to emergency department admission, classification of pelvic ring and acetabular fractures according to the arbeitsgemeinschaft osteosynthese (AO)-classification,[26] additional injuries, the Injury Severity Score (ISS), arterial lactate levels and base deficit after emergency department admission, management pathway of the algorithm, pelvic and extrapelvic bleeding sources, hemorrhage control after completion of the algorithm, time from admission to hemorrhage control, duration of angiography, complications of angiography, units of RBC (450 mL) transfused before and 24 hours after angiographic embolization, type and timing of definite surgical repair of pelvic fractures, intensive care unit length of stay, 24 hours survival, hospital survival, and causes of death.

The ISS was assessed as first described by Baker et al.[27] and calculated on the basis of the Abbreviated Injury Scale. Briefly, only the highest Abbreviated Injury Scale counts of six body regions (head, face, chest, abdomen, extremities, and external) were used. The three most severely injured body regions had their score squared and added together to render the ISS count. The ISS and pelvic fracture classification were both evaluated by two independent senior trauma surgeons. Hemorrhage control was defined as cessation of angiographic contrast dye extravasation accompanied by a reduction of transfusion requirements. The efficacy rate of angiographic embolization was defined as the percentage of patients in whom hemorrhage could be controlled. Medical charts were reviewed for the following/complications that have been reported after embolization of pelvic vessels: major femoral artery site complications (leg ischemia, artery dissection, and pseudoaneurysm formation); bladder, intestinal, or gluteal tissue necrosis; need for reembolization; major allergic reactions; and acute renal failure requiring renal replacement therapy.

Statistical Analysis

The primary endpoint of this analysis was to evaluate the effectiveness of the clinical algorithm in controlling pelvic hemorrhage. Evaluation of the time from emergency department admission to hemorrhage control, complications of angiographic embolization, 24 hours and hospital survival rates, and differences between survivors and nonsurvivors at hospital discharge were secondary endpoints.

The SPSS 15.0 software package (SPSS Inc; Chicago, IL) was used for statistical analysis. Descriptive statistical methods were applied to evaluate the effectiveness of the clinical algorithm in controlling pelvic hemorrhage, survival rates, and the time to hemorrhage control. Kolmogorov-Smirnov tests were used to check for normality distribution of study variables. For comparisons between survivors and nonsurvivors, a t test or a nonparametric Mann–Whitney U test was performed for independent samples. For paired samples, a paired t test or nonparametric Wilcoxon test was applied. A Fisher's exact test was calculated to compare categorical data between groups. Correlations of metric data were quantified using the Pearon's correlation coefficient. A p value <0.05 was considered to indicate statistical significance. Unless otherwise noted, data are presented as mean values ± SD.

RESULTS

During the observation period, 1,476 trauma patients with pelvic fractures were admitted to the trauma center. Of these, 45 were identified as hemodynamically instable and managed according to the clinical algorithm (Fig. 1). All patients suffered from multiple trauma and exhibited injuries in addition to the pelvic trauma (Tables 1 and 2).

TABLE 1. Survivors Versus Nonsurviviors

	Survivors	Nonsurvivors	Significance (p)
Age (yr)	47.8	59.7	NS
Sex (M/F)	22/9	7/7	
ISS	30.6	41.5	0.012
Fracture type			NS
A	2	2	
B	8	3	
C	21	9	
Trauma type			
Traffic	13	9	
Fall from >3 m	8	3	
Fall from <3 m	1	—	
Ski injury	2	—	
Other	7	2	
Initial hemoglobin	9.2	7.4	NS
Lactate	21	49	NS
BE	−3.4	−10.3	0.002
Time for angiographic embolizíation (min)	57	68	NS
Time for hemorrhage control (min)	158	177	NS

NS, not significant.

TABLE 2. Additional Injuries in the 45 Study Patients

Head	
Intracranial hemorrhage	8
Skull fractures	2
Chest	
Serial rib fractures	10
Pneumothorax	7
Hematothorax	5
Abdomen	
Liver laceration	8
Kidney laceration	5
Lower urogenital injury	5
Splenic rupture	4
Bowel injury	1
Pancreatic lesion	1
Spine	
Lumbar vertebral body fracture	11
Thoracic vertebral body fracture	6
Cervical vertebral body fracture	1
Extremities	
Lower leg fracture	14
Femur fracture	10
Forearm fracture	8
Humerus fracture	2
Lower leg amputation	2
Hand amputation	1

TABLE 3. Bleeding Sites

Arteria pudenda interna	16
Arteria iliaca interna	14
Arteria glutealis	9
Arteria obturatoria	4
Arteriae lumbales	3
Arteria profunda femoris	3
Arteria iliaca communis	1
Arteria iliolumbalis	1
Arteria sacralis	1
Arteria lienalis	2
Arteria renalis	1
Arteria mesenterica	1

Two patients presented with severe intra-abdominal hemorrhage underwent emergency laparotomy with preperitoneal pelvic packing to control hemorrhage. Postoperatively, one patient required angiographic embolization because of ongoing hemorrhage. External pelvic stabilization was applied in 31 patients with instable pelvic fractures in the emergency department. Forty-two patients underwent angiographic embolization before (n = 24) or after (n = 18) performance of a computed tomography scan (Fig. 1). In four patients, additional bleeding sites (two splenic, one renal, and one mesenteric bleed) next to pelvic hemorrhage (Table 3) could be controlled by embolization during the angiographic procedure. With the use of the clinical algorithm, pelvic hemorrhage was controlled in all but one patient who died before any surgical or angiographic intervention could be initiated (97.8%). The hourly need for RBC transfusion significantly decreased during 24 hours after angiographic embolization when compared with before the procedure (3.7 ± 3.5 vs. 0.1 ± 0.1 U/h; $p < 0.001$). In patients undergoing angiographic embolization, the mean time to hemorrhage control was 163 minutes $\pm$ 83 minutes with no difference between survivors and nonsurvivors (158 ± 82 vs. 177 ± 91 minutes; p = NS). Hemorrhage could be angiographically controlled within 3 hours in 66.7% of patients.

Three patients required reembolization, whereas one patient had to be reembolized after final operative stabilization of the pelvis, two patients presented with hemorrhage from other than the primary site (mesenteric bleed 14 hours after initial embolization, n = 1; hemorrhage from a lumbar artery 5 days after emergency department admission, n = 1). All three patients survived. One patient developed gluteal necrosis, and nine required renal replacement therapy during their subsequent intensive care unit stay.

The 24 hours and hospital survival rate of the study population was 76% and 67%, respectively. Except for one patient who died in the emergency department because of uncontrolled hemorrhage, no study patient died to exsanguation. Both patients who underwent emergency laparotomy with preperitoneal pelvic packing died because of protracted shock and acute multiple organ failure within 24 hours after admission. Early causes of death (<24 hours) in nonsurvivors after successful angiographic embolization were protracted shock with acute multiple organ failure (n = 6) and malignant brain edema (n = 2). Deaths after 24 hours occurred because of septic shock (n = 3) and fulminant pulmonary embolism (n = 1). Nonsurvivors had higher ISS counts and base deficits at admission than survivors (Table 1).

DISCUSSION

In this retrospective study, we found that a clinical algorithm focusing on basic radiologic diagnostics, external fixation, and early angiographic embolization was effective, rapid, and safe in controlling hemorrhage in hemodynamically instable trauma patients with pelvic fractures. Control of bleeding was not only documented by cessation of contrast dye extravasation in angiography in 100% of patients but also by a significant reduction of RBC transfusion requirements after completion of the algorithm. Similarly, high-efficacy rates of angiographic embolization to control pelvic hemorrhage as observed in our cohort have been reported in previous studies.[13,15,17,19,28,29] Two patients required reembolization because of other bleeding sites, which remained undetected in the initial procedure. In accordance with the results of other authors, mortality in our patient cohort (33%) was, except in one case, not because of ongoing pelvic hemorrhage but associated injuries resulting in early or late multiple organ failure.

The presented clinical algorithm to manage hemodynamically instable trauma patients with pelvic fractures included basic radiologic examinations to identify pelvic fractures and exclude life-threatening injuries of the chest and abdomen. Depending on the severity of hemodynamic failure, the diagnostic pathway was completed with a multislice computer tomography before or after therapeutic measures were initiated. Basically, two therapeutic pathways were considered: open exploration with peritoneal pelvic packaging[12] and angiographic embolization. Open exploration with preperitoneal pelvic packing was suggested when intra-abdominal lesions requiring emergency laparotomy were present. Since then further surgical tissue trauma was inevitable, bleeding control considered to be faster when performed during the same surgical intervention, and the need for second-look interventions mostly anyway given as a result of the abdominal lesions. However, only two patients suffered intra-abdominal lesions, who required immediate laparotomy in our cohort. The remaining study group was managed by external fixation and consequent angiographic embolization. These two methods were combined to control venous, soft tissue, or fracture site bleeding by compression and closure of an instable pelvic ring through external fixation devices and arterial hemorrhage by angiograhpic embolization. By using this minimally invasive approach, we assumed that hemorrhage control could be rapidly achieved, and the efforts to stop arterial hemorrhage did not compromise any tamponade effects on the venous bleeding source.[14,15,18,30,31] Moreover, the patient could be spared from further tissue trauma, the risk of wound infection associated with open exploration, and second-look interventions. In four patients, angiography beared the additional advantage that further abdominal bleeding sites could be controlled during the same session. Even though our study results suggest that this clinical algorithm is effective, they cannot yield any information if one technique to control pelvic hemorrhage is superior over another. This important question must be addressed in future randomized, controlled trials.

In contrast to the current literature[18–20] and common beliefs, the time from hospital admission to pelvic hemorrhage control using angiographic embolization was comparatively short in our cohort (163 $\pm$ 83 minutes) and allowed control of the bleeding site in 66.7% of patients within the critical limit of 3 hours.[15] Moreover, the time required for the angiographic procedure decreased during the observation period (Pearson correlation coefficient $= -0.58$, $p = 0.026$) most probably reflecting improved embolization techniques and growing experience of the investigators. During the past 2 years of the study, the average time for stabilization before embolization was 60 minutes $\pm$ 43 minutes, and the average time for embolization itself was 45 minutes $\pm$ 28 minutes.

Two reasons could explain the short time from hospital admission to hemorrhage control in our patient cohort: first, the clinical algorithm included a concise and strict diagnostic pathway and thereby avoided any unnecessary delay in transferring the patient to the angiography suite. Second, a 24-hour angiography team is available at our institution and can thus rapidly provide angiography. Because all study patients were hemodynamically instable at admission, we can neither conclude whether also patients with pelvic fracture without hemorrhagic shock might benefit if managed according to this clinical algorithm. It is equally unclear if patients who are admitted to the trauma center $>$12 hours after the injury would profit from inclusion into the algorithm.

One patient died to exsanguation despite of inclusion into the algorithm. Because this patient was admitted to the hospital under ongoing cardiopulmonary resuscitation, we do not believe that any current therapeutic intervention could have saved this patient's life. Nonetheless, the fact that two patients had to return to the angiography suite because of relevant hemorrhage from other arterial bleeding sites than initially embolized must be regarded as a potential disadvantage of the angiographic approach. It is conceivable that profuse vasoconstriction during the initial shock state has obscured the bleeding sources during the primary angiograhpy procedure. We cannot exclude if these bleeding sites might have been identified and controlled by open surgical exploration. Two further potential complications of angiographic embolization were observed in this analysis: gluteal necrosis and acute renal failure. Because this was a retrospective, uncontrolled study, no causative association can be established. Accordingly, concomitant gluteal trauma may have contributed to gluteal necrosis in one patient, whereas shock and extensive tissue trauma could have caused acute renal failure in the other study patients. Still, a contributory role of the angiographic intervention cannot be excluded and requires further investigation.

In contrast to previous reports,[32] we did not observe a difference in age or fracture types between survivors and nonsurvivors. A possible explanation for these observations may be the fact that hemorrhagic control could be achieved in two thirds of the study population within the critical time limit of 3 hours as suggested by Agolini et al.[15] However, these findings must be interpreted with caution because the patient population was small, and thus differences between groups may have been missed.

When interpreting the results of this study, additional limitations need to be considered. First, the retrospective design of the analysis is an obvious shortcoming. Because hemorrhage control was clearly identified and documented as cessation of contrast dye extravasation in angiographic pictures in all patients, this limitation may not have relevantly influenced the efficacy rates of angiographic embolization. Moreover, control of hemorrhage was confirmed by a significant reduction in RBC transfusion requirements. However, the rate of complications secondary to angiographic embolization could have been underestimated when choosing a retrospective study design, as it is conceivable that some complications occurred but remained either unnoticed or were not documented in the reviewed charts. Another potential limitation of our analysis is the long observation time during which the comparatively small group of study patients was treated. Therapeutic changes regarding transfusion practices and management of coagulation disorders have taken place during this time.[32–34] Similarly, the strategy of conservative management of traumatic intra-abdominal lesions has become increasingly popular throughout the last decade.[9,35] Because only two patients required emergency laparotomy during the observation period, this does not seem to have relevantly influenced the study results.

In conclusion, application of a clinical algorithm focusing on basic radiologic diagnostics, external fixation, and early angiographic embolization was effective and safe to rapidly control hemorrhage in hemodynamically instable trauma patients with pelvic fractures. Future randomized controlled trials to evaluate the best technique to manage hemorrhage in pelvic trauma patients are needed.

REFERENCES

1. Burgess AR, Eastridge BJ, Young JW, et al. Pelvic ring disruptions: effective classification system and treatment protocols. *J Trauma.* 1990; 30:848–856.
2. Moreno C, Moore EE, Rosenberger A, Cleveland HC. Hemorrhage associated with major pelvic fracture: a multispecialty challenge. *J Trauma.* 1986;26:987–994.
3. Gruen GS, Leit ME, Gruen RJ, Peitzman AB. The acute management of hemodynamically unstable multiple trauma patients with pelvic ring fractures. *J Trauma.* 1994;36:706–711; discussion 711–713.
4. 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.
5. Dyer GS, Vrahas MS. Review of the pathophysiology and acute management of haemorrhage in pelvic fracture. *Injury.* 2006;37:602–613.
6. 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.
7. Heini PF, Witt J, Ganz R. The pelvic C-clamp for the emergency treatment of unstable pelvic ring injuries. A report on clinical experience of 30 cases. *Injury.* 1996;27(suppl 1):S-A38–S-A45.
8. Pohlemann T, Culemann U, Gansslen A, Tscherne H. [Severe pelvic injury with pelvic mass hemorrhage: determining severity of hemorrhage and clinical experience with emergency stabilization]. *Unfallchirurg.* 1996;99:734–743.
9. Ramzy AI, Murphy D, Long W. The pelvic sheet wrap. Initial management of unstable fractures. *JEMS.* 2003;28:68–78.
10. 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.
11. Quinby WC Jr. Pelvic fractures with hemorrhage. *N Engl J Med.* 1971;284:668–669.
12. Pohlemann T, Bosch U, Gansslen A, Tscherne H. The Hannover experience in management of pelvic fractures. *Clin Orthop Relat Res.* 1994;305:69–80.
13. 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 Br.* 2002;84:178–182.
14. Margolies MN, Ring EJ, Waltman AC, Kerr WS Jr, Baum S. Arteriography in the management of hemorrhage from pelvic fractures. *N Engl J Med.* 1972;287:317–321.
15. Agolini SF, Shah K, Jaffe J, Newcomb J, Rhodes M, Reed JF III. Arterial embolization is a rapid and effective technique for controlling pelvic fracture hemorrhage. *J Trauma.* 1997;43:395–399.
16. Kimbrell BJ, Velmahos GC, Chan LS, Demetriades D. Angiographic embolization for pelvic fractures in older patients. *Arch Surg.* 2004;139: 728–732; discussion 732–733.
17. Velmahos GC, Toutouzas KG, Vassiliu P, et al. A prospective study on the safety and efficacy of angiographic embolization for pelvic and visceral injuries. *J Trauma.* 2002;53:303–308; discussion 308.
18. 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.
19. Totterman A, Dormagen JB, Madsen JE, Kløw NE, Skaga NO, Røise O. A protocol for angiographic embolization in exsanguinating pelvic trauma: a report on 31 patients. *Acta Orthop.* 2006;77:462–468.
20. Cothren CC, Osborn PM, Moore EE, Morgan SJ, Johnson JL, Smith WR. Preperitonal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift. *J Trauma.* 2007;62:834–839; discussion 839–842.
21. 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.
22. Rieger M, Sparr H, Esterhammer R, et al. Modern CT diagnosis of acute thoracic and abdominal trauma. *Anaesthesist.* 2002;51:835–842.
23. Rieger M, Czermak B, El Attal R, Sumann G, Jaschke W, Freund M. Initial clinical experience with a 64-MDCT whole-body scanner in an emergency department: better time management and diagnostic quality? *J Trauma.* 2009;66:648–657.
24. Collicott PE. Advanced trauma life support course, an improvement in rural trauma care. *Nebr Med J.* 1979;64:279–280.
25. Skinner DV. Advanced trauma life support. *Injury.* 1993;24:147–148.
26. Isler B, Ganz R. Classification of pelvic ring injuries. *Injury.* 1996;27 (suppl 1):S-A3–S-A12.
27. Baker SP, O'Neill B, Haddon W, Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma.* 1974;14:187–196.
28. 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.
29. 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; discussion 984.
30. Hagiwara A, Minakawa K, Fukushima H, 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.
31. 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; discussion 450–441.
32. Duane TM, Como JJ, Bochicchio GV, Scalea TM. Reevaluating the management and outcomes of severe blunt liver injury. *J Trauma.* 2004;57:494–500.
33. Franklin GA, Casos SR. Current advances in the surgical approach to abdominal trauma. *Injury.* 2006;37:1143–1156.
34. Dent D, Alsabrook G, Erickson BA, et al. Blunt splenic injuries: high nonoperative management rate can be achieved with selective embolization. *J Trauma.* 2004;56:1063–1067.
35. Haan JM, Bochicchio GV, Kramer N, Scalea TM. Nonoperative management of blunt splenic injury: a 5-year experience. *J Trauma.* 2005; 58:492–498.