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Review

Haemodynamically unstable pelvic fractures☆

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ABSTRACT

Bleeding pelvic fractures that result in haemodynamic instability have a reported mortality rate as high as 40%. Because of the extreme force needed to disrupt the pelvic ring, associated injuries are common and mortality is usually from uncontrolled haemorrhage from extra-pelvic sources. Identifying and controlling all sources of bleeding is a complex challenge and is best managed by a multi-disciplinary team, which include trauma surgeons, orthopaedic surgeons and interventional radiologists. Once the pelvis is identified as the major source of haemorrhage, component therapy reconstituting whole blood should be used and the pelvic region wrapped circumferentially with a sheet or pelvic binder. Patients at risk for arterial bleeding who continue to show haemodynamic instability despite resuscitative efforts should undergo immediate arteriography and embolisation of bleeding pelvic vessels. If this is unavailable or delayed, or the patient has other injuries (i.e., head, chest, intra-abdominal, long bone), external fixation and pelvic packing, performed concomitantly with other life-saving procedures, may be used to further reduce pelvic venous bleeding. If however, the patient remains haemodynamically labile without apparent source of blood loss, transcatheter angiographic embolisation should be attempted to locate and stop pelvic arterial bleeding. Institutional practice guidelines have been shown to reduce mortality and should be developed by all centres treating pelvic fractures.

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Haemodynamically unstable pelvic fractures represent a difficult diagnostic and therapeutic challenge for the trauma team. Haemorrhage from cancellous bone surfaces, the presacral venous plexus and/or iliac arterial or venous branches may cause hypotension. In addition, pelvic fractures are a marker of excessive force applied to the human body and are often associated with extra-pelvic haemorrhage from other injuries (chest 15%, intra-abdominal 32%, long bones 40%) which further confounds the initial work-up.[59] Mortality rates in excess of 40% are reported with exsanguinating haemorrhage identified as the major cause of death during the first 24 h after injury, and with multi-organ failure (MOF) causing the majority of deaths thereafter.[1,25,39,40,43,56,114,115,118] One of the potential causes of this late mortality is most likely to be a direct result of the "bloody vicious cycle" of continued haemorrhage and transfusion since blood transfusion is an independent risk factor for increased ICU length of stay, the development of MOF, and death.[24,25,78,83,116,129] Thus, urgent identification and control of haemorrhage is paramount to survival.

Pelvic fractures account for approximately 3% of all skeletal injury after blunt trauma. In large series, most result from motor vehicle crashes.[12,27,43,76,81,105] Though injuries combining mechanically unstable pelvic fractures with haemodynamic instability are rare, comprising less than 10% of all pelvic fractures presenting to Level I centres, they represent the bulk of mortality of this group.[39,43,56] To disrupt the integrity of the pelvic ring requires an instantaneous deceleration of approximately 30 miles per hour and as this energy dissipates, it often causes trauma to the head, chest, abdomen or extremities which adds to the over-all physiological burden of injury.[54,96,105] In fact, more than 80% of patients with unstable pelvic fractures will be found to have additional musculoskeletal injuries.[25,54,80] Injury severity score (ISS) is indicative of the degree of destructive energy applied to the body as a whole, and ISS, not type of pelvic instability, appears to be the most important factor in predicting

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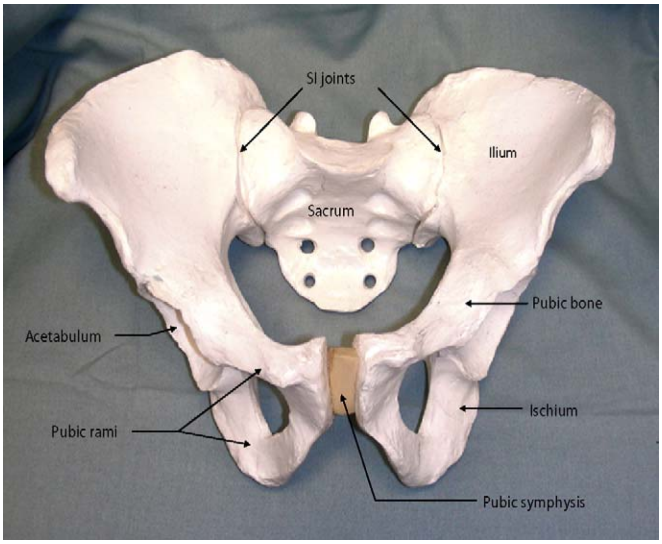

Fig. 1. Photograph of model of bony pelvis.

mortality in patients with pelvic fractures.[3,39,76,80,96,114,118] Only a small proportion of deaths are directly attributable to the pelvic fracture alone.[31,90,95]

The bony pelvis is composed of three bones: the two inominate bones articulate in the anterior midline through the pubic symphysis, and posteriorly with the sacrum forming the sacroiliac (SI) joints (Fig. 1). The SI joints are the strongest in the body and resist both vertical and anterior–posterior displacement; the pubic symphysis is the weakest link in the pelvic ring supplying only 15% of the intrinsic pelvic stability. The pelvic floor muscles and ligaments also contribute to pelvic stability; extensive disruption of this extraperitoneal compartment can lead to loss of tamponade, and uncontrolled haemorrhage and exsanguination.[35,39,40,53,127] Since the pelvis is a ring structure, significant disruption and displacement of one area are accompanied by the same in another and are usually the result of both bone and ligamentous disruption. Pelvic instability is defined as the inability of the pelvic ring to withstand physiological loading, and it is these high energy pelvic injuries, especially those involving posterior structures, that result in the greatest amount of blood loss.[22,28,29,39] This is commonly seen in the elderly where pelvic fracture are more likely to cause haemorrhage and require angiography.[48,60,74,114,118,125]

The primary source of haemorrhage from pelvic fractures is the posterior pelvic venous plexus or bleeding cancellous bone surfaces.[66,112] However, 10–15% of the time this haemorrhage is arterial and its usual source is from named branches of the internal iliac system with pudendal (anterior) and superior gluteal (posterior) arteries being the most commonly identified at arteriography.[35] Posterior fracture along the SI joints may cause disruption of a main iliac trunk, but is rare, occurring less than 1% of the time. These patients may present in extremis.[71,113] Force vectors and fracture patterns inconsistently predict those with arterial bleeding and need for subsequent angiography. This is most likely because radiographs can only capture the degree of displacement at the time of imaging, not that which was present at the time of impact. Exsanguinating haemorrhage can and does occur in all fracture patterns, even simple rami fractures, and may in fact be independent of the bony injury pattern to the pelvis altogether.[11,28,35–38,42,57,58,62,82,114,115,123]

The initial management of the patient with multiple injuries and suspected pelvic fracture largely follows Advanced Trauma Life Support (ATLS) guidelines of the American College of Surgeons Committee on Trauma.[1] During primary survey, an airway is secured and resuscitation begun with intravenous crystalloid solutions while deliberate hypotension is maintained until all sources of haemorrhage have been identified and controlled.[36,37,62] The most important factor in the survival of patients with pelvic fracture is urgent haemostasis thus limiting the detrimental effects of both shock and high volume resuscitation.[39,114] Since bleeding from associated injuries significantly influences patient survival, prompt identification and management of all life-threatening injuries is essential to restoring normal haemodynamics.[39,54,96] Multiple injuries are the rule in this patient population, up to 89% in one series, and persistent resuscitation requirements often herald ongoing haemorrhage or missed injury.[11,54] Haemoglobin and/or haematocrit levels measured within minutes of patient arrival in the trauma bay may be a reliable marker of ongoing haemorrhage and need for massive transfusion, and an admission haematocrit of 30% or less has been shown to be a predictor of major pelvic haemorrhage.[12,21] Once resuscitation is begun, however, both haemoglobin and haematocrit are potentially spurious and should not be trusted to determine amount of blood lost. Furthermore, neither is an end-point of resuscitation. High base deficits and lactate levels have correlated with mortality in pelvic trauma and those with base deficits $\geq$5 mmol/L on arrival were more likely to die.[3,59] Sequential measurements of base deficit and blood lactate in this early period of resuscitation may be a more rapid and reliable measurement of blood loss and further transfusion requirements than other more commonly used haemodynamic and/or laboratory parameters.[30,40] Additionally, improvement in base deficit and blood lactate signals amelioration of oxygen debt and reversal of the shock state.[122] This attests to a positive response to resuscitative measures.

Once the pelvis is shown to be the major source of haemorrhage, component therapy simulating whole blood (i.e., haemostatic or damage control resuscitation) is promptly administered with transfusion of packed red blood cells (PRBC), fresh-frozen plasma (FFP) and platelets ideally in a 1:1:1 (pack) ratio.[11,15,34,50,62,63,72,91] As a result of tissue damage/destruction and resultant hypoperfusion, trauma-induced coagulopathy may be present in 25% of patients on Emergency Department (ED) admission and appears to increase linearly with ISS and risk of death.[19,20,77] Using this ratio of blood products has been shown to improve survival of patients requiring massive transfusions and may reduce the overall volume of blood transfused.[15,34,63,67,68,77,91] The on-call orthopaedic surgeon, blood bank, operating room (OR) and interventional radiologist (IR) are immediately notified and a massive transfusion protocol activated. Crystalloid use is then significantly limited and should serve mainly as a carrier to keep lines open between blood products.[26,61,128] Early transfusion of platelets as six packs to keep platelet counts above 100,000/μL during massive transfusion appears to provide a survival advantage.[68,69,72,91] Cryoprecipitate and recombinant factor VIIa (rFVIIa) may be used as adjuncts to haemostatic resuscitation especially in those patients who are coagulopathic as a result of delayed presentation or ongoing haemorrhage with tris-hydroxymethyl aminomethane (THAM) given to rapidly correct pH and acid base deficits.[14,61,64,79,116,117,119] Furthermore, every effort should be made to maintain the patient at normothermia either by passive means (warm trauma bay, warm blankets, space blanket, Bair Hugger®) or active means (FMS 2000® rapid infuser).

Focus should then be turned to reduction of venous bleeding by stabilisation of pelvic ring injuries. This is most expeditiously accomplished with a longitudinally folded bed sheet

Fig. 2. Photograph of sheeted pelvis.

wrapped circumferentially around the pelvis, placed between the iliac crests and greater trochanters, and secured anteriorly by clamping[97,100,110] (Fig. 2), or with simple commercially available devices which also provide circumferential pelvic stabilisation and may permit the applied reduction force to be controlled to a pre-determined level.[27,100] Both the improvised and commercially available binders stabilise the pelvis and allow for clot formation. While binders and external fixators may decrease the pelvic volume of ''open-book'' injuries,[9] it is controversial whether they can create a tamponade effect, since the retroperitoneum is disrupted.[47,53] The ''splinting'' of pathological pelvic motion is more likely to be the mechanism that aids in haemostasis. Moreover, the reduction in volume of the true pelvis is much less than expected. A large pubic diastasis of 10 cm only corresponds to a 35% increase in pelvic volume or 479 cm^3.[120]

Pelvic binders also assure continued access to the abdomen, pelvis and lower extremities, do not require special training to place and are generally free from complications with short-term use. As such, ATLS guidelines recommend their placement by pre-hospital personnel and providers in rural settings before transport of these patients. In fact, the use of pelvic binders results in significantly lower transfusion amounts and length of hospital stay compared to external fixation.[27] Long periods of tight immobilisation may cause tissue necrosis, nerve injury and/or abdominal or extremity compartment syndrome(s) although this time course is not well defined.[75,100,108,126] There is a case report of skin breakdown affecting patient management secondary to circumferential anti-shock sheeting.[106] A recent study raised concerns about prolonged use of binders due to pressure over bony prominences.[70] Pelvic sheeting or compressive devices usually remain in place until the patient is haemodynamically stable and transfusion requirements have ceased, usually in one to two days, or if the patient continues to bleed and another intervention is necessary.[11,123] Military anti-shock trousers (MAST) trousers limit access to the traumatised regions and have also been associated with these complications with no evidence of benefit and should not be used for this purpose.[32,43]

More invasive means for emergency stabilisation of unstable pelvic fracture can be accomplished by anterior external fixation (EX-FIX) or a pelvic C-clamp. Anterior external fixator application usually limits blood loss by direct compression of bleeding vessels at the fracture site or SI joint disruption for rotationally unstable pelvic fractures that involve partial disruption of the posterior elements. Unfortunately, stability and haemorrhage control for vertically unstable patterns with complete disruption of the posterior elements are limited.[44] Application of EX-FIX may take place in the emergency department; however, it is most often placed in the OR and should be fairly rapid in experienced hands. The EX-FIX should be placed in such a manner that it does not limit access to the abdomen or limit the ability of the abdomen to expand. When used in conjunction with pelvic packing, it is helpful to stabilise the pelvis first with the fixator.[25,115] The external fixator can be placed with pins in the iliac crests or in the supra-acetabular region. There is a slight biomechanical advantage to supra-acetabular pin placement, but there is no data to suggest the technique improves survival.[45,46,55,73,92]

In those patients with posterior pelvic ring disruptions, the major source of bleeding is often from the cancellous bone and/or the presacral venous plexus.[111] In these injuries, rapid reduction and posterior stabilisation can be performed with the pelvic C-clamp, which consists of two pins applied to the ilium in the region of the SI joints. It may be applied in the emergency department, but it is preferable to place the device in the operating room under fluoroscopic control.[44,49] Moreover, it may be superior to other forms of pelvic fixation since it directly addresses the most frequent bleeding site(s). However, the C-clamp requires specific training for its successful application and serious complications (fracture displacement, pin site infection or perforation, nerve injury) have been reported from its use.[10,16,94,107] Anteroposterior (AP) view of the pelvis should be obtained in the trauma bay to[33,86,98,99] determine the extent of pelvic injury. Anterior injuries (pubic rami diastasis/fractures) are more easily identified than those affecting posterior structures, which may be missed in up to 22% of cases. Overall, AP films of the pelvis have a sensitivity of only 78% for identification of pelvic fractures in the acute trauma patient and may be the result of poor film quality or clinician inexperience.[33,86,98,99] Additionally, fracture pattern has inconsistently predicted blood loss and need for transcatheter arterial embolisation (TAE).[12,42,57,82,104,105,114]

Clinically, a palpable haematoma above the inguinal ligament, on the proximal thigh, and/or over the perineum (Destot sign) may indicate pelvic fracture with associated bleeding; ecchymosis about the flank (Grey Turner sign) is associated with retroperitoneal haemorrhage. Pelvic springing involves applying alternating compression and distortion over the iliac wings to detect pelvic ring instability and is a poor predictor of the presence or absence of pelvic fracture. Additionally, it may dislodge adherent clot further exacerbating haemorrhage, is painful to the conscious patient and should therefore be avoided.[52,59]

As the injured pelvis is addressed, a search for extra-pelvic sources of haemorrhage continues as most patients in this group will have at least one associated injury. In fact, 30% of the time bleeding is from extra-pelvic sources.[25] Obvious injuries found on physical examination during primary and secondary survey are addressed according to ATLS guidelines. AP chest X-ray is obtained along with ultrasound evaluation of the pericardium to exclude intra-thoracic injury.

Abdominal injury is the associated injury that most substantially affects patient outcome, and its diagnosis is difficult in the hypotensive patient with pelvic fractures.[39] The presence of intra-abdominal haemorrhage can be evaluated by ultrasound, diagnostic peritoneal lavage (DPL) and/or CT scanning. When performed by properly accredited staff as part of the Focused Assessment with Sonography for Trauma (FAST), abdominal ultrasound is a rapid and accurate means of diagnosing haemoperitoneum and should serve as the primary screening modality in the emergency department.[11,17,85,88,102,103] Additionally, it may be repeated for serial assessment of the patient after transfer to an angiography suite or intensive care unit (ICU). Supra-umbilical diagnostic peritoneal lavage (DPL) may be used in cases of equivocal ultrasound findings, which may be caused by anatomic distortions of the retroperitoneum from injury, or to differentiate haemoperitoneum from uroperitoneum, as between 4% and 8% of patients with pelvic fracture will have an associated bladder injury.[121] Used alone in this patient population however, DPL is associated with a high number of false positive results, non-therapeutic laparotomy and negative impact on outcome.[39,54,65] Those identified to have significant *haemoperitoneum* by FAST and/or DPL are transferred to the OR for pelvic fixation and abdominal exploration and treatment of associated injuries. At laparotomy, pelvic packing as described by Ertel et al. may be attempted to affect tamponade of haemorrhage after skeletal fixation has been achieved. This has met with some success in those patients who are too unstable for immediate transport to angiography.[40,93] However, direct ligation of bleeding pelvic vessels should not be attempted as results have been universally poor.[84,124]

Although highly sensitive and specific for intra-abdominal bleeding, haemodynamic instability limits the use of CT scan in this patient population. In fact, for those able to undergo pelvic CT angiography, this modality may be more sensitive for arterial injury than catheter based angiography.[4,101] A contrast blush may be seen in up to 10% patients with pelvic fractures undergoing CT and the size of this blush or presence of a large pelvic haematoma may predict those who will benefit from TAE;[12,13,18,23,82,101] however, the need for angiography should be based on the patient's haemodynamic status and transfusion burden as described below.

The initial management of unstable pelvic fracture depends on the haemodynamic status of the patient after resuscitative measures have been employed. The majority of patients will cease bleeding after appropriate resuscitation and pelvic stabilisation and this may select for those who now have effective tamponade of their pelvic venous bleeding. However, up to 76% of patients who have persistent haemodynamic instability despite resuscitation with two units PRBC/FFP, pelvic compression and exclusion of associated injuries, will have arterial bleeding and should undergo angiography if *immediately* available.[2,39,82] The success rate of TAE when bleeding is identified in the setting of pelvic fracture has been reported to be 85–100% and has a reasonable safety profile.[42,125] TAE appears to work by stopping arterial bleeding and allowing the haematoma to tamponade the venous component of haemorrhage. Early angiography, especially when performed within 3 h of admission in this subgroup of patients, appears to confer a survival advantage and it may be assumed that this benefit derives from rapid cessation of arterial bleeding and checked transfusion needs.[2,39,82,89] However, this requires experienced interventional radiologists with "at-ready" angiography suites which concomitantly serve as surrogate ICUs and are staffed/equipped as such, not to mention the transport of critically ill patients between sites. The importance of early communication and coordination between specialties cannot be overemphasised and multi-disciplinary clinical pathways with alert rosters developed for this purpose have been shown to improve patient outcomes.[5,11] TAE must be considered *a part* of the ongoing resuscitative efforts under the "damage control" doctrine and as such must control haemorrhage while minimising intervention/insult. However, mean time between admission and TAE has been reported to be 10 h and run-times for TAE can average over 90 min (between 50 and 150 min in one study).[43,82] If the patient remains haemodynamically unstable despite a "quiet or negative" angiogram, this implies venous bleeding or missed injury, in which case urgent laparotomy with pelvic packing and/or preperitoneal pelvic packing (PPP) as described below, should be performed. Some also advocate immediate pelvic venogram to rule out iliac vein injury.[71,82,89]

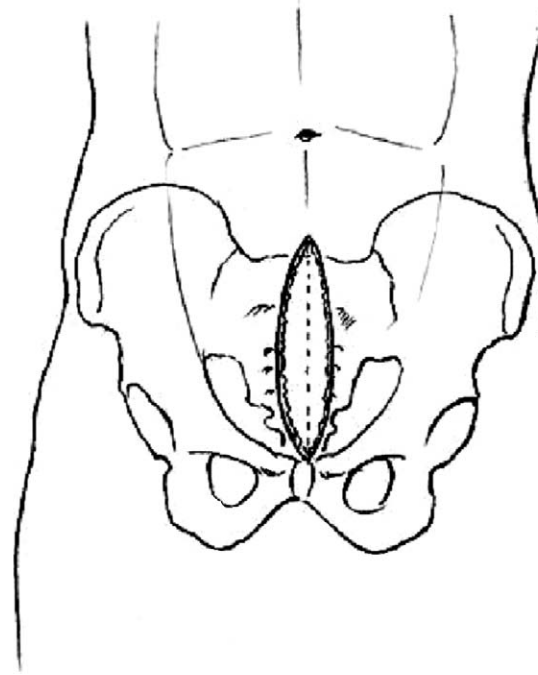

Fig. 3. Illustration of preperitoneal pelvic packing: incision in relation to symphysis pubis and umbilicus.

Recurrent arterial haemorrhage may occur after successful TAE or after normal initial angiogram as evidenced by continued transfusion needs. This is more likely in patients who had multiple arterial injuries on initial angiogram (and therefore larger insult) and may be the result of release of vessels from vasospasm during further resuscitation and warming. Alternatively, it may be caused by dislodgement of the embolisation material. Recurrence is associated with significant increases in morbidity and mortality, and patients at high risk should have an arterial sheath left in place for 48–72 h to be restudied if signs of haemorrhage recur.[51,109]

In cases when angiography is not readily available, the unstable patient should then be taken urgently to the OR where skeletal fixation of the pelvis is performed. In small series, PPP of the pelvis as described by Cothren et al. and Totterman et al. has been shown to stabilise the patient, buying valuable time until angiography is available or obviating the need for angiography altogether.[25,123] In short, a 6–8 cm mid-line incision is made from the symphysis pubis extending cranially (Fig. 3). The linea alba is incised and the peritoneum left intact. The pelvic haematoma encountered here has often dissected the pre-peritoneal and prevesical space to the presacral region. After delivering the haematoma, three surgical laparotomy sponges are placed on each side of the true pelvis below the pelvic brim (Figs. 4 and 5). The fascia and skin are then closed and the packs removed after 24–48 h. For patients requiring concurrent laparotomy, the incisions are kept separate. Total time for packing procedure should be less than 20 min.[115] Intrapelvic infections appear to be the major complication.[25,123] After PPP and associated injuries have been addressed, the patient should be transported

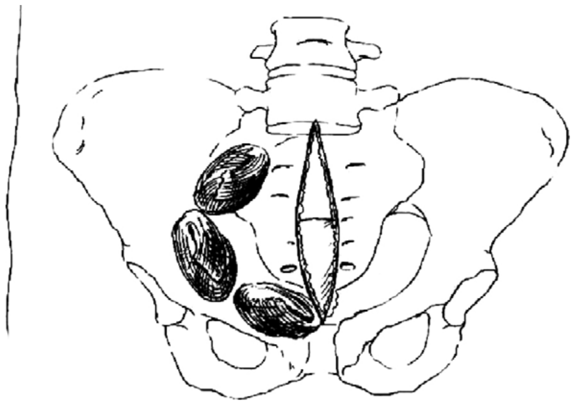

Fig. 4. Illustration of pre-peritoneal packing: placement of laparotomy sponges.

to the angiography suite for ''follow-on'' angiography and TAE if necessary.

Packing is standard technique in damage control surgery to control bleeding in situations such as massive liver trauma when ligation is difficult or impossible and the patient is haemodynamically compromised. Trans-abdominal retroperitoneal pelvic packing, in which surgical sponges are placed in the paravesical and presacral space, has been used with some success in cases of ''torrential'' haemorrhage despite surgical fracture reduction.[40,93] When used in a similar fashion, PPP may serve as a temporising measure and may actually rescue up to 1/3 of patients who have hypotension caused solely by venous bleeding. Moreover, it compares favorably to trans-abdominal retroperitoneal pelvic packing and may spare the patient unnecessary laparotomy and its physiological consequences. The majority of these patients will still have arterial haemorrhage that will continue unabated by packing alone. Therefore, patients who demonstrate persistent hypotension and/or transfusion requirements after PPP or retroperitoneal pelvic packing will need TAE for definitive arterial control.

PPP may ''bridge'' patients to TAE, either when TAE is not available or delayed, the patient requires operation to address associated injuries (i.e., craniotomy, thoracotomy, and/or laparotomy) and/or the patient will not tolerate transport to the angiography suite. Before TAE is performed for definitive control of arterial bleeding, PPP may increase systolic blood pressure and thus reduce transfusion requirements and stabilise the patient in the interim.[25,123] The positive effect of PPP on haemodynamic stability may be the result of controlling the venous component of dual venous/arterial pelvic injuries. Since combined injuries are common, PPP may therefore complement TAE.[71,123] The effect of these therapies may then stay the benefit derived from early angiography in those with unstable pelvic fractures and simultaneous intra-abdominal and pelvic haemorrhage thus making immediate exploratory laparotomy with PPP the unequivocal choice.[39] Because angiography is not universally available, PPP should be considered before transport of patients with unstable pelvic fractures to tertiary care centres.

Fig. 5. Radiograph of pelvis after preperitoneal pelvic packing.

Patients with unstable pelvic fracture are at risk of developing abdominal compartment syndrome (ACS). This can result from retroperitoneal haematoma, associated abdominal injuries and/or massive resuscitation and is a predictor for both MOF and mortality.[8] Up to one-third of all patients who undergo damage control laparotomy develop ACS and those with combined injuries to the abdomen and pelvis have a significantly higher incidence and more rapid onset of ACS compared to those with isolated injuries.[41,87] The amount of crystalloid volume infused into the patient prior to ICU admission is an independent risk factor for ACS and this appears to be an early phenomenon in the shock resuscitation process beginning in the trauma bay.[6,7] Furthermore, retroperitoneal packing may also increase the risk of ACS and require repacking at decompression[40]; however, no cases were reported with PPP.[25,123] ACS in the setting of damage control laparotomy is most often related to primary fascial closure at completion of initial operation. In these cases, the abdominal fascia is routinely left open by any of several techniques (i.e., Bogata Bag, Wound VAC®). Additionally, monitoring of intra-abdominal pressure is mandatory in any patient who has undergone damage-control laparotomy as well as high volume resuscitation and when elevated, prompt decompression is performed even in the absence of overt physiological consequences.

In summary, to improve survival of haemodynamically unstable patients with pelvic fracture, haemorrhage must be stopped expeditiously. All patients with suspected unstable pelvic fracture should be managed by a multi-disciplinary team at a Level I trauma centre. Pelvic compression is attempted before transfer to tertiary centre and is most easily accomplished by sheeting the pelvis. Damage control resuscitation is begun early and monitored through serial base deficits and blood lactate levels. Associated injuries are rapidly identified and treated and the abdomen is screened by FAST for intraperitoneal blood. Patients requiring operation undergo definitive skeletal fixation based on fracture type and either retroperitoneal pelvic packing or PPP. If laparotomy is required, the abdominal fascia is left open at the conclusion of the operation. If no associated injuries are identified during secondary survey, the response to initial resuscitation and pelvic compression is measured; those who remain haemodynamically unstable or continue to require blood/blood products should undergo immediate angiogram with TAE for pelvic arterial bleeding. If angiography is not immediately available, PPP may stabilise the patient in the interim. Stable patients proceed to CT angiography and if large pelvic haematoma or contrast blush is seen are then triaged based on haemodynamic status to angiography. Patients presenting *in extremis* should undergo immediate pelvic stabilisation and laparotomy with retroperitoneal pelvic packing. All patients with unstable pelvic fractures should be monitored for ACS and decompressed when necessary. Clinical pathways (Fig. 6) have been shown to reduce mortality and should be developed by all centres which treat unstable pelvic fractures.

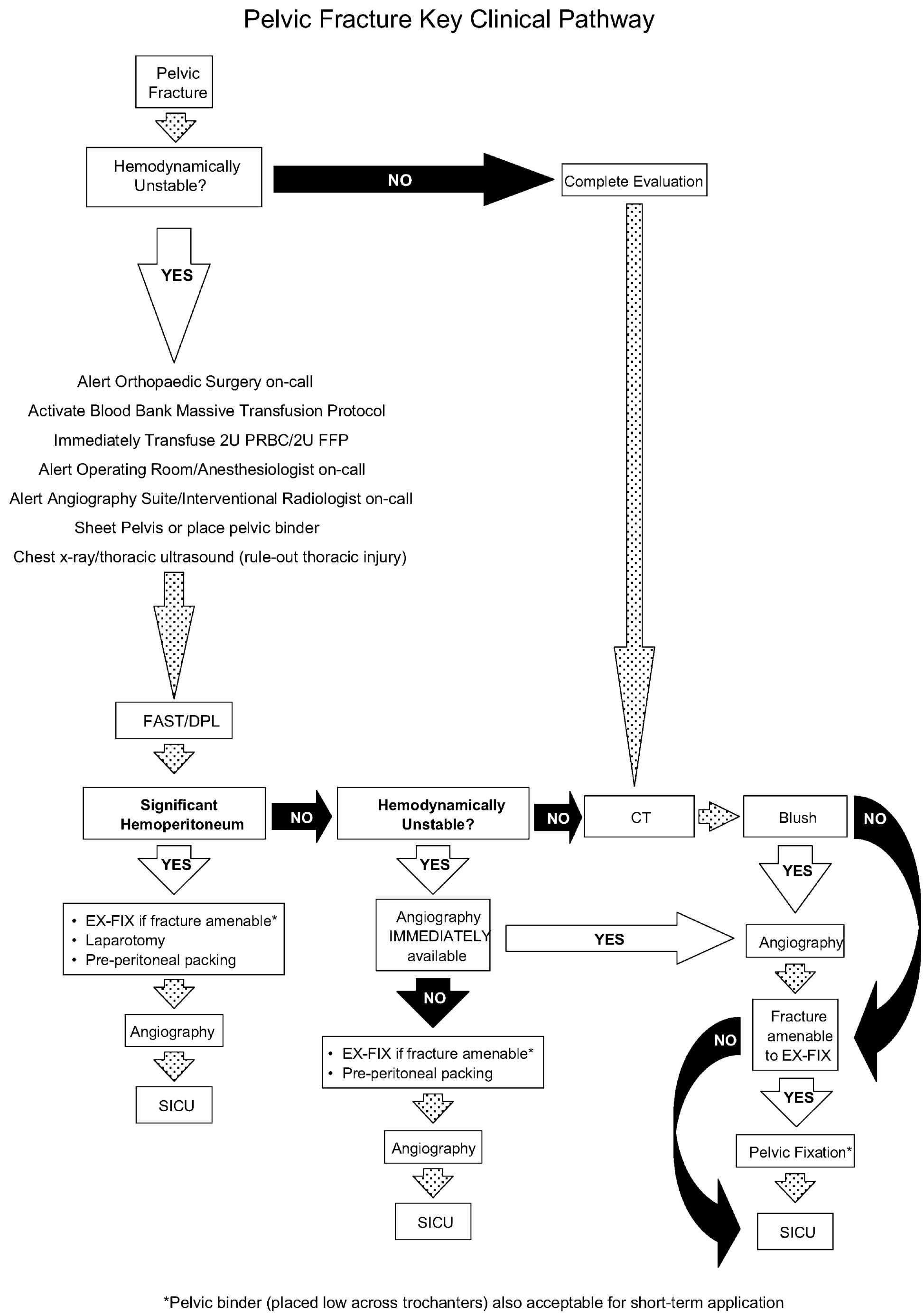

Fig. 6. Flow diagram for multi-disciplinary clinical pathway for pelvic fractures.

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References

1. American College of Surgeons Committee on Trauma. Advanced trauma life support, 6th ed.; 1997.
2. Agolini SF, Shah K, Jaffe J, et al. Arterial embolization is a rapid and effective technique for controlling pelvic fracture hemorrhage. J Trauma 1997;43:395–9.
3. Allen CF, Goslar PW, Barry M, Christiansen T. Management guidelines for hypotensive pelvic fracture patients. Am Surg 2000;66:735–8.
4. Anderson SW, Soto JA, Lucey BC, et al. Blunt trauma: feasibility and clinical utility of pelvic CT angiography performed with 64-detector row CT. Radiology 2008;246:410–9.
5. Balogh Z, Caldwell E, Heetveld M, et al. Institutional practice guidelines on management of pelvic fracture-related hemodynamic instability: do they make a difference? J Trauma 2005;58:778–82.
6. Balogh Z, McKinley BA, Cocanour CS, et al. Patients with impending abdominal compartment syndrome do not respond to early volume loading. Am J Surg 2003;186:602–7 [discussion 607–8].
7. Balogh Z, McKinley BA, Cocanour CS, et al. Supranormal trauma resuscitation causes more cases of abdominal compartment syndrome. Arch Surg 2003;138:637–42 [discussion 642–3].

8. Balogh Z, McKinley BA, Holcomb JB, et al. Both primary and secondary abdominal compartment syndrome can be predicted early and are harbingers of multiple organ failure. J Trauma 2003;54:848–59 [discussion 859–61].
9. Baque P, Trojani C, Delotte J, et al. Anatomical consequences of ''open-book'' pelvic ring disruption: a cadaver experimental study. Surg Radiol Anat 2005;27:487–90.
10. Bartlett C, Asprinio D, Louis S, Helfet D. Intrapelvic dislocation of the left hemipelvis as a complication of the pelvic ''C'' clamp: a case report and review. J Orthop Trauma 1997;11:540–2.
11. 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;233:843–50.
12. Blackmore CC, Cummings P, Jurkovich GJ, et al. Predicting major hemorrhage in patients with pelvic fracture. J Trauma 2006;61:346–52.
13. Blackmore CC, Jurkovich GJ, Linnau KF, et al. Assessment of volume of hemorrhage and outcome from pelvic fracture. Arch Surg 2003;138:504–8 [discussion 508–9].
14. Boffard KD, Riou B, Warren B, et al. Recombinant factor VIIa as adjunctive therapy for bleeding control in severely injured trauma patients: two parallel randomized, placebo-controlled, double-blind clinical trials. J Trauma 2005;59:8–15 [discussion 15–8].
15. Borgman MA, Spinella PC, Perkins JG, et al. The ratio of blood products transfused affects mortality in patients receiving massive transfusions at a combat support hospital. J Trauma 2007;63:805–13.
16. Bottlang M, Simpson T, Sigg J, et al. Noninvasive reduction of open-book pelvic fractures by circumferential compression. J Orthop Trauma 2002;16:367–73.
17. Boulanger BR, McLellan BA, Brenneman FD, et al. Prospective evidence of the superiority of a sonography-based algorithm in the assessment of blunt abdominal injury. J Trauma 1999;47:632–7.
18. Brasel KJ, Pham K, Yang H, et al. Significance of contrast extravasation in patients with pelvic fracture. J Trauma 2007;62:1149–52.
19. Brohi K, Cohen MJ, Ganter MT, et al. Acute coagulopathy of trauma: hypoperfusion induces systemic anticoagulation and hyperfibrinolysis. J Trauma 2008;64:1211–7 [discussion 1217].
20. Brohi K, Singh J, Heron M, Coats T. Acute traumatic coagulopathy. J Trauma 2003;54:1127–30.
21. Bruns B, Lindsey M, Rowe K, et al. Hemoglobin drops within minutes of injuries and predicts need for an intervention to stop hemorrhage. J Trauma 2007;63:312–5.
22. Burgess AR, Eastridge BJ, Young JW, et al. Pelvic ring disruptions: effective classification system and treatment protocols. J Trauma 1990;30:848–56.
23. Cerva Jr DS, Mirvis SE, Shanmuganathan K, et al. Detection of bleeding in patients with major pelvic fractures: value of contrast-enhanced CT. AJR Am J Roentgenol 1996;166:131–5.
24. Ciesla DJ, Moore EE, Johnson JL, et al. A 12-year prospective study of postinjury multiple organ failure: has anything changed? Arch Surg 2005;140:432–8 [discussion 438–40].
25. Cothren CC, Osborn PM, Moore EE, et al. Preperitonal pelvic packing for hemodynamically unstable pelvic fractures: a paradigm shift. J Trauma 2007;62:834–9 [discussion 839–42].
26. Cotton BA, Guy JS, Morris Jr JA, Abumrad NN. The cellular, metabolic, and systemic consequences of aggressive fluid resuscitation strategies. Shock 2006;26:115–21.
27. Croce MA, Magnotti LJ, Savage SA, et al. Emergent pelvic fixation in patients with exsanguinating pelvic fractures. J Am Coll Surg 2007;204:935–9 [discussion 932–40].
28. Cryer HM, Miller FB, Evers BM, et al. Pelvic fracture classification: correlation with hemorrhage. J Trauma 1988;28:973–80.
29. Dalal SA, Burgess AR, Siegel JH, et al. Pelvic fracture in multiple trauma: classification by mechanism is key to pattern of organ injury, resuscitative requirements, and outcome. J Trauma 1989;29:981–1000 [discussion 1000–2].
30. Davis JW, Parks SN, Kaups KL, et al. Admission base deficit predicts transfusion requirements and risk of complications. J Trauma 1996;41:769–74.
31. Demetriades D, Karaiskakis M, Toutouzas K, et al. Pelvic fractures: epidemiology and predictors of associated abdominal injuries and outcomes. J Am Coll Surg 2002;195:1–10.
32. Dickinson K, Roberts I. Medical anti-shock trousers (pneumatic anti-shock garments) for circulatory support in patients with trauma (Cochrane Review). In: The cochrane library, issue 2. Oxford: Update Software; 2003.
33. Duane TM, Dechert T, Wolfe LG, et al. Clinical examination is superior to plain films to diagnose pelvic fractures compared to CT. Am Surg 2008;74:476–9 [discussion 479–80].
34. Duchesne JC, Hunt JP, Wahl G, et al. Review of current blood transfusions strategies in a mature Level I trauma center: were we wrong for the last 60 years? J Trauma 2008;65:272–6 [discussion 276–8].
35. Durkin A, Sagi HC, Durham R, Flint L. Contemporary management of pelvic fractures. Am J Surg 2006;192:211–23.
36. Dutton RP. Low-pressure resuscitation from hemorrhagic shock. Int Anesthesiol Clin 2002;40:19–30.
37. Dutton RP, Carson JL. Indications for early red blood cell transfusion. J Trauma 2006;60:S35–40.
38. Dyer GS, Vrahas MS. Review of the pathophysiology and acute management of haemorrhage in pelvic fracture. Injury 2006;37:602–13.
39. Eastridge BJ, Starr A, Minei JP, et al. The importance of fracture pattern in guiding therapeutic decision-making in patients with hemorrhagic shock and pelvic ring disruptions. J Trauma 2002;53:446–50 [discussion 441–50].
40. Ertel W, Keel M, Eid K, et al. Control of severe hemorrhage using C-clamp and pelvic packing in multiply injured patients with pelvic ring disruption. J Orthop Trauma 2001;15:468–74.
41. Ertel W, Oberholzer A, Platz A, et al. Incidence and clinical pattern of the abdominal compartment syndrome after ''damage-control'' laparotomy in 311 patients with severe abdominal and/or pelvic trauma. Crit Care Med 2000;28:1747–53.
42. Fangio P, Asehnoune K, Edouard A, et al. Early embolization and vasopressor administration for management of life-threatening hemorrhage from pelvic fracture. J Trauma 2005;58:978–84 [discussion 984].
43. Gansslen A, Giannoudis P, Pape HC. Hemorrhage in pelvic fracture: who needs angiography? Curr Opin Crit Care 2003;9:515–23.
44. Ganz R, Krushell RJ, Jakob RP, Kuffer J. Anterior versus posterior provisional fixation in the unstable pelvis. A biomechanical comparison. Clin Orthop 1995;310:245–51.
45. Gardner MJ, Kendoff D, Ostermeier S, et al. Sacroiliac joint compression using an anterior pelvic compressor: a mechanical study in synthetic bone. J Orthop Trauma 2007;21:435–41.
46. Gardner MJ, Nork SE. Stabilization of unstable pelvic fractures with supraacetabular compression external fixation. J Orthop Trauma 2007;21:269–73.
47. Ghaemmaghami V, Sperry J, Gunst M, et al. Effects of early use of external pelvic compression on transfusion requirements and mortality in pelvic fractures. Am J Surg 2007;194:720–3 [discussion 723].
48. Ghanayem AJ, Wilber JH, Lieberman JM, Motta AO. The effect of laparotomy and external fixator stabilization on pelvic volume in an unstable pelvic injury. J Trauma 1995;38:396–400 [discussion 391–400].
49. Giannoudis PV, Pape HC. Damage control orthopaedics in unstable pelvic ring injuries. Injury 2004;35:671–7.
50. Gonzalez EA, Moore FA, Holcomb JB, et al. Fresh frozen plasma should be given earlier to patients requiring massive transfusion. J Trauma 2007;62:112–9.
51. Gourlay D, Hoffer E, Routt M, Bulger E. Pelvic angiography for recurrent traumatic pelvic arterial hemorrhage. J Trauma 2005;59:1168–73 [discussion 1164–73].
52. Grant PT. The diagnosis of pelvic fractures by 'springing'. Arch Emerg Med 1990;7:178–82.
53. Grimm MR, Vrahas MS, Thomas KA. Pressure–volume characteristics of the intact and disrupted pelvic retroperitoneum. J Trauma 1998;44:454–9.
54. Gustavo Parreira J, Coimbra R, Rasslan S, et al. The role of associated injuries on outcome of blunt trauma patients sustaining pelvic fractures. Injury 2000;31:677–82.
55. Haidukewych GJ, Kumar S, Prpa B. Placement of half-pins for supra-acetabular external fixation: an anatomic study. Clin Orthop Relat Res 2003;269–73.
56. Hak DJ. The role of pelvic angiography in evaluation and management of pelvic trauma. Orthop Clin North Am 2004;35:439–43. v.
57. Hamill J, Holden A, Paice R, Civil I. Pelvic fracture pattern predicts pelvic arterial haemorrhage. Aust N Z J Surg 2000;70:338–43.
58. Hawkins L, Pomerantz M, Eiseman B. Laparotomy at the time of pelvic fracture. J Trauma 1970;10:619–23.
59. Heetveld MJ, Harris I, Schlaphoff G, et al. Hemodynamically unstable pelvic fractures: recent care and new guidelines. World J Surg 2004;28:904–9.
60. Henry SM, Pollak AN, Jones AL, et al. Pelvic fracture in geriatric patients: a distinct clinical entity. J Trauma 2002;53:15–20.
61. Holcomb JB. Damage control resuscitation. J Trauma 2007;62:S36–7.
62. Holcomb JB, Jenkins D, Rhee P, et al. Damage control resuscitation: directly addressing the early coagulopathy of trauma. J Trauma 2007;62:307–10.
63. Holcomb JB, Wade CE, Michalek JE, et al. Increased plasma and platelet to red blood cell ratios improves outcome in 466 massively transfused civilian trauma patients. Ann Surg 2008;248:447–58.
64. Hsia CC, Chin-Yee IH, McAlister VC. Use of recombinant activated factor VII in patients without hemophilia: a meta-analysis of randomized control trials. Ann Surg 2008;248:61–8.
65. Hubbard SG, Bivins BA, Sachatello CR, Griffen Jr WO. Diagnostic errors with peritoneal lavage in patients with pelvic fractures. Arch Surg 1979;114:844–6.
66. Huittinen VM, Slatis P. Postmortem angiography and dissection of the hypogastric artery in pelvic fractures. Surgery 1973;73:454–62.
67. Johansson PI. The blood bank: from provider to partner in treatment of massively bleeding patients. Transfusion 2007;47:176S–81S [discussion 182S–3S].
68. Johansson PI, Hansen MB, Sorensen H. Transfusion practice in massively bleeding patients: time for a change? Vox Sang 2005;89:92–6.
69. Johansson PI, Stensballe J, Rosenberg I, et al. Proactive administration of platelets and plasma for patients with a ruptured abdominal aortic aneurysm: evaluating a change in transfusion practice. Transfusion 2007;47:593–8.
70. Jowett AJ, Bowyer GW. Pressure characteristics of pelvic binders. Injury 2007;38:118–21.
71. Kataoka Y, Maekawa K, Nishimaki H, et al. Iliac vein injuries in hemodynamically unstable patients with pelvic fracture caused by blunt trauma. J Trauma 2005;58:704–8 [discussion 708–10].
72. Ketchum L, Hess JR, Hiippala S. Indications for early fresh frozen plasma, cryoprecipitate, and platelet transfusion in trauma. J Trauma 2006;60:S51–8.
73. Kim WY, Hearn TC, Seleem O, et al. Effect of pin location on stability of pelvic external fixation. Clin Orthop Relat Res 1999;237–44.

74. Kimbrell BJ, Velmahos GC, Chan LS, Demetriades D. Angiographic embolization for pelvic fractures in older patients. Arch Surg 2004;139:728–32 [discussion 723–32].
75. Krieg JC, Mohr M, Ellis TJ, et al. Emergent stabilization of pelvic ring injuries by controlled circumferential compression: a clinical trial. J Trauma 2005;59:659–64.
76. Lunsjo K, Tadros A, Hauggaard A, et al. Associated injuries and not fracture instability predict mortality in pelvic fractures: a prospective study of 100 patients. J Trauma 2007;62:687–91.
77. MacLeod JB, Lynn M, McKenney MG, et al. Early coagulopathy predicts mortality in trauma. J Trauma 2003;55:39–44.
78. Malone DL, Dunne J, Tracy JK, et al. Blood transfusion, independent of shock severity, is associated with worse outcome in trauma. J Trauma 2003;54:898–905 [discussion 897–905].
79. Martini WZ, Dubick MA, Wade CE, Holcomb JB. Evaluation of tris-hydroxymethylaminomethane on reversing coagulation abnormalities caused by acidosis in pigs. Crit Care Med 2007;35:1568–74.
80. McMurtry R, Walton D, Dickinson D, et al. Pelvic disruption in the polytraumatized patient: a management protocol. Clin Orthop Relat Res 1980;22–30.
81. Metz CM, Hak DJ, Goulet JA, Williams D. Pelvic fracture patterns and their corresponding angiographic sources of hemorrhage. Orthop Clin North Am 2004;35:431–7. v.
82. Miller PR, Moore PS, Mansell E, et al. External fixation or arteriogram in bleeding pelvic fracture: initial therapy guided by markers of arterial hemorrhage. J Trauma 2003;54:437–43.
83. Moore FA, Moore EE, Sauaia A. Blood transfusion. An independent risk factor for postinjury multiple organ failure. Arch Surg 1997;132:620–4 [discussion 624–5].
84. Mullins RJ, Huckfeldt R, Trunkey DD. Abdominal vascular injuries. Surg Clin North Am 1996;76:813–32.
85. Nunes LW, Simmons S, Hallowell MJ, et al. Diagnostic performance of trauma US in identifying abdominal or pelvic free fluid and serious abdominal or pelvic injury. Acad Radiol 2001;8:128–36.
86. Obaid AK, Barleben A, Porral D, et al. Utility of plain film pelvic radiographs in blunt trauma patients in the emergency department. Am Surg 2006;72:951–4.
87. Offner PJ, de Souza AL, Moore EE, et al. Avoidance of abdominal compartment syndrome in damage-control laparotomy after trauma. Arch Surg 2001;136: 676–81.
88. Ollerton JE, Sugrue M, Balogh Z, et al. Prospective study to evaluate the influence of FAST on trauma patient management. J Trauma 2006;60:785–91.
89. Panetta T, Sclafani SJ, Goldstein AS, et al. Percutaneous transcatheter embolization for massive bleeding from pelvic fractures. J Trauma 1985;25:1021–9.
90. Papadopoulos IN, Kanakaris N, Bonovas S, et al. Auditing 655 fatalities with pelvic fractures by autopsy as a basis to evaluate trauma care. J Am Coll Surg 2006;203:30–43.
91. Perkins JG, Cap PA, Spinella PC, et al. An evaulation of the impact of apheresis platelets used in the setting of massively transfused trauma patients. J Trauma; 66(Suppl.), in press.
92. Poelstra KA, Kahler DM. Supra-acetabular placement of external fixator pins: a safe and expedient method of providing the injured pelvis with stability. Am J Orthop 2005;34:148–51.
93. Pohlemann T, Bosch U, Gansslen A, Tscherne H. The Hannover experience in management of pelvic fractures. Clin Orthop Relat Res 1994;69–80.
94. 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;99:734–43.
95. Poole GV, Ward EF. Causes of mortality in patients with pelvic fractures. Orthopedics 1994;17:691–6.
96. Poole GV, Ward EF, Muakkassa FF, et al. Pelvic fracture from major blunt trauma. Outcome is determined by associated injuries. Ann Surg 1991; 213:532–8 [discussion 538–9].
97. Ramzy AI, Murphy D, Long W. The pelvic sheet wrap. Initial management of unstable fractures. Jems 2003;28:68–78.
98. Resnik CS, Stackhouse DJ, Shanmuganathan K, Young JW. Diagnosis of pelvic fractures in patients with acute pelvic trauma: efficacy of plain radiographs. AJR Am J Roentgenol 1992;158:109–12.
99. Robertson DD, Sutherland CJ, Chan BW, et al. Depiction of pelvic fractures using 3D volumetric holography: comparison of plain X-ray and CT. J Comput Assist Tomogr 1995;19:967–74.
100. Routt Jr ML, Falicov A, Woodhouse E, Schildhauer TA. Circumferential pelvic antishock sheeting: a temporary resuscitation aid. J Orthop Trauma 2002;16:45–8.
101. Roy-Choudhury SH, Gallacher DJ, Pilmer J, et al. Relative threshold of detection of active arterial bleeding: in vitro comparison of MDCT and digital subtraction angiography. AJR Am J Roentgenol 2007;189:W238–246.
102. Rozycki GS, Ballard RB, Feliciano DV, et al. Surgeon-performed ultrasound for the assessment of truncal injuries: lessons learned from 1540 patients. Ann Surg 1998;228:557–67.
103. Ruchholtz S, Waydhas C, Lewan U, et al. Free abdominal fluid on ultrasound in unstable pelvic ring fracture: is laparotomy always necessary? J Trauma 2004;57:278–85 [discussion 277–85].
104. Salim A, Teixeira PG, DuBose J. Predictors of positive angiography in pelvic fractures: a prospective study. J Am Coll Surg 2008;207:656–62.
105. Sarin EL, Moore JB, Moore EE, et al. Pelvic fracture pattern does not always predict the need for urgent embolization. J Trauma 2005;58:973–7.
106. Schaller TM, Sims S, Maxian T. Skin breakdown following circumferential pelvic antishock sheeting: a case report. J Orthop Trauma 2005;19: 661–5.
107. Schutz M, Stockle U, Hoffmann R, et al. Clinical experience with two types of pelvic C-clamps for unstable pelvic ring injuries. Injury 1996;27(Suppl 1):S-A46-50.
108. Shank JR, Morgan SJ, Smith WR, Meyer FN. Bilateral peroneal nerve palsy following emergent stabilization of a pelvic ring injury. J Orthop Trauma 2003;17:67–70.
109. Shapiro M, McDonald AA, Knight D, et al. The role of repeat angiography in the management of pelvic fractures. J Trauma 2005;58:227–31.
110. Simpson T, Krieg JC, Heuer F, Bottlang M. Stabilization of pelvic ring disruptions with a circumferential sheet. J Trauma 2002;52:158–61.
111. Slatis P, Huittinen VM. Double vertical fractures of the pelvis. A report on 163 patients. Acta Chir Scand 1972;138:799–807.
112. Slatis P, Karaharju EO. External fixation of unstable pelvic fractures: experiences in 22 patients treated with a trapezoid compression frame. Clin Orthop Relat Res 1980;73–80.
113. Smith K, Ben-Menachem Y, Duke Jr JH, Hill GL. The superior gluteal: an artery at risk in blunt pelvic trauma. J Trauma 1976;16:273–9.
114. Smith W, Williams A, Agudelo J, et al. Early predictors of mortality in hemodynamically unstable pelvis fractures. J Orthop Trauma 2007;21:31–7.
115. Smith WR, Moore EE, Osborn P, et al. Retroperitoneal packing as a resuscitation technique for hemodynamically unstable patients with pelvic fractures: report of two representative cases and a description of technique. J Trauma 2005;59:1510–4.
116. Spinella PC, Perkins JG, Grathwohl KW, et al. Effect of plasma and red blood cell transfusions on survival in patients with combat related traumatic injuries. J Trauma 2008;64:S69–77 [discussion S68–77].
117. Spinella PC, Perkins JG, McLaughlin DF, et al. The effect of recombinant activated factor VII on mortality in combat-related casualties with severe trauma and massive transfusion. J Trauma 2008;64:286–93 [discussion 284–93].
118. Starr AJ, Griffin DR, Reinert CM, et al. Pelvic ring disruptions: prediction of associated injuries, transfusion requirement, pelvic arteriography, complications, and mortality. J Orthop Trauma 2002;16:553–61.
119. Stinger HK, Spinella PC, Perkins JG, et al. The ratio of fibrinogen to red cells transfused affects survival in casualties receiving massive transfusions at an army combat support hospital. J Trauma 2008;64:S79–85 [discussion S85].
120. Stover MD, Summers HD, Ghanayem AJ, Wilber JH. Three-dimensional analysis of pelvic volume in an unstable pelvic fracture. J Trauma 2006;61:905–8.
121. Tayal VS, Nielsen A, Jones AE, et al. Accuracy of trauma ultrasound in major pelvic injury. J Trauma 2006;61:1453–7.
122. Tisherman SA, Barie P, Bokhari F, et al. Clinical practice guideline: endpoints of resuscitation. J Trauma 2004;57:898–912.
123. Totterman A, Madsen JE, Skaga NO, Roise O. Extraperitoneal pelvic packing: a salvage procedure to control massive traumatic pelvic hemorrhage. J Trauma 2007;62:843–52.
124. Trunkey DD, Chapman MW, Lim Jr RC, Dunphy JE. Management of pelvic fractures in blunt trauma injury. J Trauma 1974;14:912–23.
125. 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;53:303–8 [discussion 308].
126. Vermeulen B, Peter R, Hoffmeyer P, Unger PF. Prehospital stabilization of pelvic dislocations: a new strap belt to provide temporary hemodynamic stabilization. Swiss Surg 1999;5:43–6.
127. Vrahas MS, Wilson SC, Cummings PD, Paul EM. Comparison of fixation methods for preventing pelvic ring expansion. Orthopedics 1998;21: 285–9.
128. Wiedemann HP, Wheeler AP, Bernard GR, et al. Comparison of two fluid-management strategies in acute lung injury. N Engl J Med 2006;354:2564–75.
129. Wong YC, Wang LJ, Ng CJ, et al. Mortality after successful transcatheter arterial embolization in patients with unstable pelvic fractures: rate of blood transfusion as a predictive factor. J Trauma 2000;49:71–5.