Contemporary management of pelvic fractures

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Abstract

Background: Pelvic fractures occur when there is high kinetic energy transfer to the patient such as would be expected in motor vehicle crashes, auto-pedestrian collisions, motorcycle crashes, falls, and crush injuries. High-force impact implies an increased risk for associated injuries to accompany the pelvic fracture, as well as significant mortality and morbidity risks. Choosing the optimum course of diagnosis and treatment for these patients can be challenging. The purpose of this review is to supply a contemporary view of the diagnosis and therapy of patients with this important group of injuries.

Methods: A comprehensive review of the medical literature, focusing on publications produced in the last 10 years, was undertaken. The principal sources were found in surgical, orthopedic, and radiographic journals.

Conclusions: The central challenge for the clinician evaluating and managing a patient with a pelvic fracture is to determine the most immediate threat to life and control this threat. Treatment approaches will vary depending on whether the main threat arises from pelvic fracture hemorrhage, associated injuries, or both simultaneously. Functional outcomes in the long-term depend on the quality of the rigid fixation of the fracture, as well as associated pelvic neural and visceral injuries. © 2006 Excerpta Medica Inc. All rights reserved.

Keywords: Pelvic fracture; Angiography; External fixation; Open-book fracture; Trauma

Pelvic fractures are serious injuries associated with a diverse assortment of morbidities. Mortality rates for patients sustaining pelvic fractures range from 10% to 50% depending, for the most part, on the severity of pelvic fracture bleeding and the presence of associated injuries to the brain, thorax, and abdomen [1–4].

Pertinent Anatomy

Three bones combine to form the pelvic ring. The 2 innominate bones arise from the fusion of the embryonic pubis, ilium, and ischium to the midline sacrum, which is the caudal end of the axial skeleton. The acetabulum, or hip socket, is located at the center of the fusion site where the embryonic bones join.

The pelvic bones unite anteriorly in the midline via the articulation between the pubic bones and the symphyseal ligaments. Posteriorly, the sacrum is situated between the right and left iliac portions of the innominate bones forming the bilateral sacra-iliac (SI) joints, which are secured by the dorsal and ventral components of the SI ligaments. Additional ligaments providing structural support for the pelvis and the contained visceral structures are the bilateral sacra-tuberous and sacra-spinous ligaments (Fig. 1). Because of the inherent bony instability of the pubic symphysis and SI joints, the integrity of the pelvic ring depends completely on the strength of these ligaments. Fractures that result in separation of the pubic symphysis and SI joints imply that damage to the supporting ligaments has occurred. Besides supplying structural support for the bony pelvis, the ligaments supply a stable compartment for the vascular, neural, and visceral structures contained within the pelvis. These critical functions of the ligaments explain why ligamentous disruption is associated with increased short and long term morbidity [5].

The iliac arterial and venous trunks pass near the ventral aspect of the SI joints bilaterally (Fig. 2). Disruption of the SI joints and associated ligaments in-
increases the risk of vascular injury and resultant hemorrhage, which usually arises from the anterior and posterior divisions of the internal iliac vessels. We have, however, observed injury to the main trunk of the external iliac artery in 2 instances due to acetabular fracture with femoral head protrusion into the pelvis.

The bladder and urethra are located immediately posterior to the pubic symphysis and the rectum lies immediately ventral to the sacrum. The intimate association of these viscera with the pelvic skeleton increases the risk of injury when pelvic fracture occurs.

The pubic symphysis is the weakest link in the pelvic ring, supplying only 15% of the inherent pelvic stability. The SI joints are the strongest in the body, relying primarily on the posterior SI ligaments to resist vertical and anterior-posterior (AP) displacement. Being a ring structure, disruption and displacement in one area implies a second disruption in another part of the ring.

Epidemiology of Pelvic Fracture

In decreasing order of frequency, pelvic fractures are caused by motorcycle crashes, auto-pedestrian collisions, falls, and motor vehicle crashes [6]. Crush injuries may also cause pelvic fracture (Table 1). As the incidence of high-velocity motor vehicle crashes increases, so does the incidence of pelvic fracture. Side impact with lateral force transfer and vehicle incompatibility (small vehicles impacted by large vehicles) are the main risk factors for pelvic fracture morbidity and mortality [7–9].

Pre-hospital Management

Information gleaned from witnesses at the crash scene in addition to data from pre-hospital care professionals regarding patient presentation and examination findings may raise the suspicion for pelvic injury. Uniform pre-hospital transport protocols are helpful and improve efficiency of early injury care and the delivery of the patient to the appropriate hospital. Appropriate immobilization, airway protection, and initial circulatory support with expedient transport are the main goals. Application of the pneumatic anti-shock garment (MAST) is an option to assist with stabilization of the fracture. However, this device is associated with inherent complications and many pre-hospital care systems no longer use the MAST.

Initial Assessment

The multiple-injury patient is at risk for thoracic, intra-abdominal, soft tissue, pelvic, and extremity hemorrhage. Once the primary survey is completed, the airway is secured and a search for sources of controllable bleeding begins. Radiographs of the chest and pelvis may assist in localizing a bleeding site. The focused abdominal ultrasound for trauma (FAST) can detect intra-peritoneal fluid. A positive FAST in an unstable patient is an indication for exploration of the abdomen [10]. Diagnostic peritoneal lavage (DPL) may be helpful where ongoing bleeding is suspected and the FAST is equivocal. In patients with known or suspected pelvic fracture, DPL is done via a supra-umbilical entry point to minimize the chance for piercing the pelvic hematoma and producing a false positive result. If the DPL is grossly positive (>8

**Table 1**

<table>
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<tr>
<th>Etiologies of pelvic fractures in descending order of frequency</th>
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<tr>
<td>Motorcycle crash</td>
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<tr>
<td>Vehicle-pedestrian collision</td>
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<tr>
<td>Side impact motor vehicle collision</td>
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<tr>
<td>Fall &gt; 15 feet</td>
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<tr>
<td>Motor vehicle crash</td>
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Fig. 1. Pelvic anatomy showing the supporting sacratuberous ligaments.

Fig. 2. Major pelvic arteries and veins course near the sites of bone and ligament disruption.
mL of blood aspirated on entry into the peritoneum), operative exploration is indicated.

The sequence of assessments outlined in the Advanced Trauma Life Support course (American College of Surgeons, Chicago, IL) is helpful for organizing an approach to managing potentially unstable trauma patients. This sequence is not helpful in determining hemodynamic instability for individual patients. Individual hemodynamic measurements are snapshots in time and by themselves are not helpful. Hemodynamic trends are helpful and the time required in the trauma resuscitation area to make a decision as to hemodynamic stability is a worthwhile investment.

**Early Detection and Management of Associated Injuries**

As a result of the energy required to cause pelvic fracture, injuries to other areas are commonly encountered. The thorax, long bones, brain, abdominal organs, and spine are most frequently involved. An early decision to explore the pleural space or peritoneum when bleeding or intestinal injury is suspected will reduce the risk of death or serious complications. Most of the time, this decision can be made during the primary survey. More extensive diagnostic procedures can be postponed until bleeding is controlled.

When ongoing bleeding has been controlled or excluded on clinical grounds, the secondary survey focuses on identifying the pelvic injuries that may contribute to blood loss or complications [11]. Clinical findings that are suggestive of pelvic fracture are listed in Table 2. A listing of clinical evidence suggestive of pelvic fracture bleeding is provided in Table 3. Clinical evaluation of the pelvis can document pelvic instability when AP and lateral compression on the iliac wings produces pain or rotational instability. A gap in the pubic symphysis may also be palpable. External rotation and shortening of 1 of the lower extremities is a sign of “open-book” or vertical shear (VS) injury (see classification below). Gonzales et al [12] documented that clinical examination in conscious patients who could comply with the physical examination yielded a 90% sensitivity for the diagnosis of pelvic fracture. The addition of the AP pelvic radiograph will permit accurate identification and initial classification of the fracture type.

Other observations may yield valuable insight as to the presence and amount of bleeding from the pelvic fracture. The presence of scrotal/labial hematoma and the presence of blood at the urethral meatus indicate, indirectly, the extent of injury. The presence of blood in the vaginal vault and/or in the rectal lumen helps to define the presence of open pelvic fracture, which is associated with serious infectious morbidity. The rectal examination will also disclose the “high riding” prostate, indicative of periprostatic and periurethral hematoma associated with pelvic hemorrhage and genitourinary injury.

An accurate neurologic examination is often difficult to obtain secondary to the patient’s inability to cooperate with the examination. Because the sciatic nerve and the branches of the sacral plexus are subject to injury with pelvic fracture, it is important to document neurologic function if possible. Recording the presence of rectal tone and the bulbocavernous reflex is important. Distal motor and sensory function at the foot and ankle should be assessed where possible. Table 4 lists motor groups and function tests for the nerves passing through the pelvis to the lower extremity.

Patients who arrive hemodynamically stable or who become immediately stable with initial fluid infusion may be safely moved to receive further diagnostic studies. The trauma team leader must decide which diagnostic maneuver(s) are safest and most appropriate given the clinical circumstances.

Computed tomographic (CT) scanning is useful in gauging the amount of pelvic hemorrhage that has oc-

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<th>Table 2</th>
<th>Pelvic fracture clinical examination</th>
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<tr>
<td>1. Does the patient have pelvic pain?</td>
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<td>2. Are there neurologic deficits involving sciatic, femoral, or obturator nerves?</td>
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<tr>
<td>3. Are there contusions, ecchymoses, or abrasions at or near the bony prominences of the pelvis?</td>
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<td>4. Are there ecchymoses of the scrotum or perineum?</td>
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<td>5. Is there blood at the urethral meatus?</td>
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<td>6. Is there blood in or around the rectum and is the prostate normal?</td>
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<tr>
<td>7. Are there open wounds of the groin, buttock, or perineum?</td>
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<tr>
<td>8. Is there a leg length difference or is the resting position of one leg different from the other?</td>
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<tr>
<td>9. Is there pain or abnormal pelvic motion on compression of the anterior iliac spines, lateral compression of the iliac crests, rotation of the lower extremity, or hip flexion-extension?</td>
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<th>Table 3</th>
<th>Clinical signs that suggest an increased risk of ongoing pelvic fracture bleeding</th>
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<tr>
<td>1. Pre-hospital hypotension</td>
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<tr>
<td>2. Admission base deficit ≥ 5</td>
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<td>3. Persistent tachycardia in face of normal oxygenation and adequate pain control</td>
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<tr>
<td>4. Recurrent hypotension during resuscitation</td>
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<td>5. Requirement for &gt; 6 U blood during first 24 hours</td>
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<th>Table 4</th>
<th>Functions of the nerves supplying the lower extremity that pass in proximity to pelvic fractures</th>
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<tbody>
<tr>
<td>Neural origin of lower extremity motor function</td>
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<tr>
<td>L1/2: hip flexors</td>
<td></td>
</tr>
<tr>
<td>L3/4: quadriceps/knee extension</td>
<td></td>
</tr>
<tr>
<td>L4/5: ankle and toe dorsiflexion</td>
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occurred. CT is also helpful in planning the strategy for definitive fixation of the fracture(s). The presence of a contrast blush seen on CT, strongly suggests, even in stable patients, ongoing bleeding and the need for therapeutic angiography.

Classification of Pelvic Fractures

Classification of pelvic fractures and dislocations requires adequate plain radiography (AP, inlet, and outlet x-rays) and thin-cut (3-mm) CT scanning. If possible, the AP pelvis film is obtained prior to bladder catheterization and cystography to avoid obscuring landmarks. The purposes of classifying pelvic fracture are to provide a common language to facilitate communication among medical professionals caring for the patient and to provide a means for relating clinical findings to prognosis. Several classification schemes are currently employed, but all have evolved from the early work performed by Pennal et al [13] and Tile [14] (Table 5). The most widely utilized classification scheme is that of Burgess et al [15], which focuses on the mechanism of injury (Table 6). The classification system put forth by the Orthopaedic Trauma Association (OTA) and Association for the Study of Internal Fixation (AO-ASIF) group is more comprehensive and serves primarily to provide a widely accepted and standardized classification system for data collection and reporting [16].

Treatment is based on accurate assessment of the resultant injury and instability pattern. It is important to remember 2 points: first, that the posterior pelvic ring injury defines ultimate stability; and second, although in an intact pelvis the anterior ring (symphysis) supplies only 10% to 15% of the total stability, in an unstable pelvis where there is complete disruption of the posterior ring, stabilization of the anterior ring contributes significantly to the strength of the reconstruction and maintenance of reduction. Possible posterior ring injuries are iliac wing fractures, SI dislocations, and sacral fractures. Possible anterior ring injuries are rami fractures and symphyseal disruptions. Pelvic injuries can include any combination of anterior and posterior injuries, unilateral or bilateral.

Lateral compression fractures are the most commonly encountered. At the time lateral forces are applied, the impacted hemipelvis is pushed into the contralateral hemipelvis. This usually involves rami fractures anteriorly with a sacral impaction iliac wing fracture. This type of injury is rotationally unstable but usually vertically stable (Fig. 3).

AP compression (APC) injuries result in the commonly termed “open-book” pelvis (Fig. 4). The impact causes external rotation of 1 or both hemi-pelvis, with the fulcrum or point of rotation being the SI joints. The first point of failure is the symphysis pubis. As increasing external rotation is applied, the sacrotuberous, sacrospinous, and anterior SI ligaments fail under tension. Anterior SI ligament disruption is present when there is more than 2.5 cm of diastasis of the symphysis. With further external rotation, the posterior SI ligaments ultimately fail as well. When this stage is reached, all of the supporting ligaments of the pelvic ring are disrupted in addition to the pelvic floor and perineal musculature.

VS injuries are the most unstable and usually encompass

Table 5

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<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>A</td>
<td>Fracture involving the ring (i.e. avulsions, iliac wing or crest fractures)</td>
</tr>
<tr>
<td>B</td>
<td>Stable minimally displaced fractures of the pelvic ring</td>
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<tr>
<td>C</td>
<td>Associated with acetabular fracture</td>
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Table 6

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<tr>
<th>Type</th>
<th>Description</th>
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<tr>
<td>LC</td>
<td>Anterior injury-rami fractures</td>
</tr>
<tr>
<td>APC</td>
<td>Anterior injury = symphysis diastasis/rami fractures</td>
</tr>
<tr>
<td>VS</td>
<td>Vertical displacement of hemipelvis with symphysis diastasis or rami fractures anteriorly, iliac wing, sacral fracture or SI dislocation posteriorly</td>
</tr>
<tr>
<td>CM</td>
<td>Any combination of above injuries</td>
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some form of rotational injury as well. In these cases, a cranially directed force shears the hemi-pelvis causing severe skeletal, muscular, and ligamentous disruption. The iliac crest of the injured hemi-pelvis is seen to be riding cephalad compared to the contralateral side, often with a fracture of the ipsilateral transverse process of L5 (Fig. 5).

Significant urogenital, vascular, and neurological injury is accompanied by the APC and VS injuries due to the stretch and traction placed on these structures as the injuring forces are applied.

Diagnosis of Pelvic Fracture Bleeding

Bleeding secondary to vascular lacerations and bone edge bleeding is the most important life-threatening problem due to pelvic fractures. Huittinen and Slatis [17], in a classic contribution to the field of pelvic fracture care, showed with postmortem angiography that pelvic fracture hemorrhage results most frequently from the venous structures and bleeding bone edges. This hemorrhage stops in most patients secondary to tamponade from increasing tissue pressure in the pelvic retroperitoneal space. However, in patients who died of pelvic fracture hemorrhage, single or multiple arterial lacerations were more likely to be present. Arterial bleeding can overcome the tamponade effect of the retroperitoneal tissues, leading to shock; this is the most common cause of death related to the pelvic fracture itself. Arterial bleeding usually arises from branches of the internal iliac system with the superior gluteal and pudendal arteries being the most commonly identified source.

As outlined above, bleeding and hemorrhage from pelvic fracture alone is and should be a diagnosis of exclusion. Once resuscitation is underway and a search for thoracic and abdominal bleeding has been completed, further analysis of the fracture pattern can be performed to see if this may be the cause of ongoing blood loss. However, the radiographic representation of the fracture alone is inadequate for determining the risk of ongoing hemorrhage since only the current degree of displacement is visible and not that which occurred at the time of impact. Metz et al [18] documented an equal number of arterial bleeding sites seen on angiography in patients with anterior-posterior compression and lateral compression injury patterns. The take-home message is that severe bleeding can occur in all fracture patterns and the whole clinical picture should dictate clinical strategy rather than just the radiograph.

Supporting this assertion is a report by Miller et al [19] which suggested that patients could be chosen for pelvic angiography based on the recurrence of hypotension within 2 hours of an initially successful resuscitation. They discovered that active arterial bleeding occurred in 73% of patients selected by these means. Details of our preferences and treatment strategies are diagrammed in the accompanying algorithm and discussed in the following section (see Appendix 1).

If pelvic fracture bleeding is suspected, patients get blood transfusions as needed. Four to six units of blood may be given before venous bleeding subsides. CT scans of the pelvis may allow quantification of the volume of blood loss and may disclose a contrast “blush” indicating active arterial bleeding.

Treatment of Pelvic Fracture Hemorrhage—Persistent Controversies

Fortunately, most bleeding from pelvic fracture arises from torn small- and medium-sized veins and edges of fractured bone. These sites will usually stop by natural hemostatic mechanisms if patient cardiovascular function, blood volume, and coagulation status are kept within acceptable limits. We transfuse all patients who do not immediately stabilize after 2000 mL of balanced salt...
solution. If a patient requires transfusion of more than 4 U of blood, support of coagulation with fresh-frozen plasma infusion is begun. Platelets are given to keep the platelet count above 100,000/μL. For patients with persistent bleeding, controversy has continued concerning the desirability of efforts to reduce pelvic volume and stabilize bone edges versus the use of selective angiography and embolization or emergent surgical exploration with packing. There is a large body of evidence to suggest that closure of symphysis pubis separations with reduction of pelvic volume improves the prospect of tamponade of pelvic bleeding. Holding bone edges so that motion is minimized is intuitively appealing as a means of stopping hemorrhage. The time-honored tenet of fracture care—“splint them where they lie”—is an example of the long-held conviction that immobilization of fractures controls bleeding around fracture sites and improves pain control.

Reports of the efficacy of the MAST supported this concept for the management of bleeding due to pelvic fracture [20,21]. This device served 3 potential functions: first, it returned blood from the lower extremities to the central vascular system; second, it could close, at least partially, open-book type injuries; and third, it stabilized the pelvis. Brotman et al [22] discussed the shortcomings and failures of the MAST, particularly the fact that the garment had to be partially or completely removed to allow access to the abdomen in patients who required abdominal exploration, as well as reports of compartment syndrome and skin necrosis following use of the device, hindered acceptance of this approach.

The adoption of aggressive fracture fixation strategies pioneered by European trauma surgeons accelerated interest in early application of external fixation for control of bleeding, and several experienced orthopedic trauma surgeons currently support using early external fixation as a means of controlling pelvic bleeding. Although some assert that external fixation is superior to angiography for control of bleeding, no head-to-head comparison has been done.

Two basic types of external skeletal fixation are currently employed: anterior frames (which are applied percutaneously to the iliac bones either above the acetabulum or into the iliac crest) and pelvic clamps (which are applied to the posterior iliac fossae at the iliac groove) [23]. Both devices can be positioned so that access to the abdomen is possible. Anterior frames function by internally rotating and restoring alignment to an externally rotated pelvis (an open book) but only if the posterior ring is intact. Pelvic clamps apply an internal vector that translates the hemi-pelvis medially and thus does not rely on an intact posterior ring. Ertel et al [24] reported use of the c-clamp in patients with severe pelvic bleeding and noted that laparotomy with pelvic packing was occasionally needed when the c-clamp failed to control bleeding. Their overall mortality due to bleeding was 25%.

This approach is also supported in a report by Gansslen et al [25].

Potential drawbacks to the use of external fixation are the need for expert orthopedic surgery support, which must be readily available soon after the patient arrives at the definitive care facility. Specific training is needed for successful application of external fixation devices. Indeed, there have been reports of pelvic visceral injury following application of external fixation devices [26,27]. Some surgeons feel strongly that application in the operating room (rather than in the resuscitation area) using sterile technique and image intensifier control is necessary for safe placement of external fixators. Because of these concerns and the availability of other devices for pelvic compression, application of external fixators for persistent hemodynamic instability in the resuscitation area has not been universally accepted.

The application of a folded bed sheet anchored anteriorly by towel clips can reduce pelvic volume and can be applied safely and quickly in the emergency room by caregivers who are not trained orthopedic surgeons. The bed sheet is applied in a straight transverse fashion, with the primary force vector being delivered to the greater trochanters. Recently, Bottlang et al [28] reported an adjustable fabric device for pelvic compression, which is now commercially available (T-Pod, Bio-cybernetics International, La Verne, CA).

One potential hazard of applying external compression devices is overcorrection of the fracture. This is particularly true in fractures where the posterior ring is completely unstable. Compression of the ilium with overcorrection can result in injury to the neurovascular and pelvic visceral structures. Thus, in conscious, responsive patients, careful assessment of neurovascular status is essential prior to and following the application of any pelvic fixation device in addition to follow-up radiographs. Another complication of external compression devices such as sheets or pelvic binders is the development of pressure ulceration and full-thickness skin necrosis and slough. These devices are often employed in critically ill patients who will spend many days in the intensive care unit. If the binder is successful at controlling pelvic hemorrhage and is left in place for more than 48 hours because of fear of recurrent bleeding, the potential for major skin and soft tissue problems is significant [29].

For patients who have persistent hemodynamic instability despite pelvic compression, appropriate resuscitation, and exclusion of thoracic, abdominal, and extremity hemorrhage, expeditious clinical decisions are necessary. The 2 options at this point are angiographic embolization of presumed pelvic arterial bleeding versus open exploration and packing. The lack of readily available experts in angiography obviously limits any radiologic approach. Experienced trauma surgeons have reported instances of death during angiography in desperately ill patients who were actively bleeding. Rather than delay hemostatic efforts in an unstable patient when angiography is not immediately available,
laparotomy with pelvic packing prior to angiography is preferable.

The choice of angiography versus external fixation or pelvic compression is made based on a careful assessment of the fracture pattern and resources available at each hospital and agreement, in advance, as to which specialists will participate in the management of pelvic fracture with hemorrhage. Commitment to immediate availability is critical from all specialists involved. If the fracture pattern is not amenable to compression, then angiography should be sought. If the fracture pattern is amenable to compression, then at least a trial of sheet wrapping or pelvic binder is indicated. These basic tenets are well outlined in the practice management guidelines promulgated by the Eastern Association for the Surgery of Trauma [30].

It is occasionally necessary to employ angiographic techniques of hemorrhage control in patients who are actively bleeding from arterial sources and who are hemodynamically unstable. In these patients, it is important that all of the life support capability present in the operating room is available for use in the angiography suite. A full complement of anesthesia personnel and equipment for monitoring, and the presence of rapid infusers for the delivery of warmed blood, blood products, and fluids, as well as the constant presence of the trauma surgeon, are essential for clinical success.

Trans-femoral angiography offers the opportunity to identify bleeding points and stop bleeding using selective embolization. Concern has been expressed, especially by Hak [31], that many patients who undergo angiography do not have active bleeding sites visualized. With improved patient selection, as noted below, the number of positive studies has progressively increased. In some cases of multiple bilateral bleeding points, filling of the internal iliac vessels bilaterally with embolic material has been utilized. Necrosis of pelvic viscera such as the rectum is a risk of bilateral internal iliac occlusion. Sexual dysfunction, a feared long-term complication of bilateral internal iliac occlusion, has not been regularly observed [32]. There is, apparently, a small chance of tissue necrosis in patients who have undergone definitive pelvic fixation following angiography via large “extensive exposure” incisions. So far, these reports have been single case experiences.

Patients older than 60 years are more likely to have arterial bleeding in conjunction with pelvic fracture, and increasing mortality risk as age rises has been well documented [33,34]. The demonstration of bleeding sites is common when angiography is used in these patients, perhaps due to aging of the vessels and atherosclerosis. Despite successful angiography, mortality remains significant in this group at 11% to 15%. Similar findings were reported by Velmahos et al [35], who observed a higher frequency of positive angiograms in patients over 55 years of age. Recurrent bleeding after embolization occurred in 6% of their patients after “successful” embolization.

It is clear that successful management of pelvic fracture bleeding is best accomplished by a multidisciplinary team approach with choices as to the strategy for optimizing the critical clinical decisions made on the basis of availability of local resources and clearly agreed upon protocols for management.

**Diagnosis and Management of Genitourinary Injuries in Patients With Pelvic Fracture**

Injuries to the bladder and urethra are common with pelvic fractures, with an incidence as high as 15% to 20% [36–38]. Because of the significant force required to rupture a hollow viscus within the pelvis, mortality can be as high 22% to 34% when pelvic fractures are accompanied by a bladder rupture [39]. Bladder injuries tend to cluster in those patients with a lateral compression mechanism, while urethral injury is seen with both anterior compression and lateral compression mechanisms.

The clinical finding most consistently observed after bladder injury is gross hematuria, which is present in 95% of patients. The remaining 5% of patients will have microscopic hematuria. Patients with gross hematuria and pelvic fracture are evaluated carefully for urethral injury or bladder rupture, as discussed below. The presence of a pelvic fracture, particularly combined with penile and scrotal ecchymosis, should raise suspicion for a bladder and/or urethral injury. When bladder injury is suspected, contrast cystography is performed in stable patients following placement of a Foley catheter. Stable patients who are to undergo CT scanning can have CT cystography as described by Peng et al [40]. Properly performed CT cystography is equally as accurate as conventional cystography. Extraperitoneal bladder injury is treated, usually, with Foley catheter drainage. Intraperitoneal bladder rupture is treated with exploration and suture closure. Suprapubic catheterization is not usually necessary, but when indicated, placement of the catheter must take into account the potential for contamination of anterior internal fixation. The suprapubic catheter may prevent the use of a suprapubic incision approach for skeletal fixation of the pelvic fracture. Where this approach to skeletal fixation is contemplated, another option for bladder drainage such as endoscopic placement of a transurethral catheter should be considered.

The classic findings of abnormal position of the prostate, inability to void, and blood at the urethral meatus are seen in a minority of patients. Lowe et al [41] documented that the appearance of these symptoms and signs is a function of the interval between injury and evaluation. Patients seen early after injury are unlikely to manifest clear-cut clinical evidence of bladder or urethra injury. A high index of suspicion is necessary.

Clinical examination and pelvic x-rays are obtained and, based on these, a decision to attempt bladder catheterization is made. When pelvic fracture is present, catheterization should be attempted by a clinician experienced in passing
catheters in patients with urethral injury. Unless there is easy and unobstructed passage of the catheter into the bladder, efforts at passing the catheter are stopped and a contrast urethrogram is obtained by infusing the Foley catheter balloon in the penile urethra with 2 to 3 mL of saline and instilling 10 to 15 mL of water-soluble contrast material and obtaining an oblique film of the pelvis. Table 7 lists the steps in performing retrograde contrast urethrography (RUG). The grading scale for urethral injury as promulgated by the American Association for the Surgery of Trauma is shown in Table 8 [42].

Failure to pass contrast into the bladder indicates urethral disruption. Extravasation of contrast into the surrounding soft tissues may be observed. Cephalad displacement of the bladder by the pelvic hematoma with passage of the contrast into the bladder is the finding typical of stretch injury to the urethra with continuity maintained. Endoscopic placement of a transurethral bladder drainage catheter is indicated, where possible, to facilitate management and later repair. When transurethral catheterization of the bladder is not possible, open or ultrasound-guided percutaneous suprapubic cystography is indicated.

Despite the short length of the urethra in women, anterior compression fractures and VS injuries associated with perineal injury cause urethral tears in women. Blood around the urethral orifice and lacerations of the vaginal introitus suggest an elevated risk of this injury. Most urethral injuries in women are amenable to treatment with Foley catheter drainage.

Open, frequent, and frank communication among the specialists providing care for the patient with pelvic fracture is necessary to make certain that the choices and sequencing of interventions lead to an optimal outcome.

## Open Pelvic Fractures

Open pelvic fractures occur when there is communication between a fracture fragment and the skin or a pelvic visceral cavity. These injuries are observed in 4% to 5% of patients with pelvic fracture [43]. The incidences of pelvic infection including soft tissue infection and osteomyelitis, as well as high mortality and long-term disability, are raised in patients with open pelvic fracture as documented in the reports by Brenneman et al [44] and Raffa et al [45]. Skin lacerations communicating with pelvic fracture sites may be found along the course of the iliac crest, in the groin, and in the perineum, and should raise the suspicion of rectal or vaginal injury. During the acute evaluation of genitourinary injury in the patient with a pelvic fracture, a careful digital rectal is mandatory and a vaginal examination, if the patient can be comfortably positioned, is highly desirable. Palpable vaginal lacerations indicate open pelvic fracture. Occasionally, rectal lacerations can also be palpated but, in the majority, the most consistent finding indicating rectal injury in the patient with pelvic fracture is the finding of blood in the rectal lumen.

Vaginal speculum examination and proctoscopic examination are postponed until it is safe to place the patient in the lithotomy or lateral decubitus position. Speculum and sigmoidoscopic examinations, when they may be safely done, supplement the careful digital vaginal and rectal examination. Pelvic and anal sphincter muscle damage may accompany perineal lacerations. Evaluation for fecal continence is not an emergency diagnostic procedure for patients with pelvic fracture. Damage to the anal sphincter with a perineal laceration suggests the need for diverting colostomy. Fecal diversion is done selectively based on the position of the laceration (perineal lacerations will usually require diversion and groin lacerations may sometimes require diversion). When fecal soilage of an open wound is possible, diversion is performed to reduce the chance of pelvic wound infection. Five patients with perineal lacerations in Brenneman’s series did not undergo fecal diversion and all suffered serious infectious complications.

Plans for definitive repair of the pelvic fracture need to be understood before the decision to perform fecal diversion is made so that best placement of the ostomy can be assured. Supraumbilical placement of the ostomy is preferred to minimize contamination of the incisions used for skeletal fixation. If colostomy is to be performed, it should be done within the first 6 to 8 hours following injury to reduce the incidence of sepsis and death [46].

Wounds of the perineum, anorectum, and vagina are managed using open techniques with repeated dressing changes/irrigations using general anesthesia as necessary.

### Table 7
Steps for performing an retrograde urethrograph

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Carefully insert bladder catheter</td>
</tr>
<tr>
<td>2.</td>
<td>Cease insertion immediately for any resistance to passage or drainage of thick blood or thick bloody urine</td>
</tr>
<tr>
<td>3.</td>
<td>Withdraw catheter until 4 cm of catheter is in penile urethra</td>
</tr>
<tr>
<td>4.</td>
<td>Inflrate catheter balloon with 3 mL saline</td>
</tr>
<tr>
<td>5.</td>
<td>Inject 15–20 mL of water-soluble contrast</td>
</tr>
<tr>
<td>6.</td>
<td>Obtain oblique pelvis x-ray</td>
</tr>
</tbody>
</table>

### Table 8
American Association for the Surgery of Trauma urethral injury severity scale

<table>
<thead>
<tr>
<th>Grade</th>
<th>Designation</th>
<th>Clinical findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Contusion</td>
<td>Blood at meatus, RUG normal</td>
</tr>
<tr>
<td>2</td>
<td>Stretch injury</td>
<td>Elongation of urethra, no extravasation</td>
</tr>
<tr>
<td>3</td>
<td>Partial disruption</td>
<td>Extravasation, contrast in bladder</td>
</tr>
<tr>
<td>4</td>
<td>Complete disruption</td>
<td>Extravasation, no contrast in bladder, &lt;2 cm separation</td>
</tr>
<tr>
<td>5</td>
<td>Complete disruption</td>
<td>Complete transection, &gt;2 cm separation or extension into vagina or prostate</td>
</tr>
</tbody>
</table>

RUG = retrograde contrast urethrography.
These wounds are usually allowed to heal by secondary intention in order to maintain an open tract to the fracture site. Our bias is that maintaining an open tract offers some protection against infection, but data to support this bias are not available. Similarly, there is no convincing evidence that antibiotic treatment, either systemically, by topical application, or by irrigation, lowers pelvic infection rate or osteomyelitis. Groin and iliac crest wounds are managed selectively. Some of these are amenable to early closure if contamination and tissue damage are not severe.

Principles of Definitive Fixation of Pelvic Fractures

The basic tenets of pelvic fracture fixation are:

1. With complete instability of the posterior ring (i.e., the posterior SI ligaments are disrupted), anterior fixation alone is inadequate.
2. With complete instability of the posterior ring and vertical instability, any posterior fixation should be supplemented with some form of anterior stabilization.
3. With partial instability of the pelvic ring (i.e., the posterior SI ligaments are intact), anterior fixation alone is adequate and full weight-bearing may be permitted.

Disruptions of the Pubic Symphysis

The options for stabilizing symphyseal disruptions include anterior external fixators or internal fixation with plate and screws. Available data from biomechanical studies have shown that there is no significant difference between external or internal fixation of the pelvis for controlling the symphysis [47,48]. In addition, there is significant improvement in pelvic stability when posterior fixation is augmented with some form of anterior fixation in VS injury patterns [49]. Fig. 6 shows the CT image of an open-book pelvic fracture complicated by ongoing bleeding, which was controlled angiographically. Fixation using a combined anterior and posterior approach was then accomplished (Fig. 7). Earlier clinical studies have shown no difference between 2-hole plates and multi-hole plates; however, newer data suggest that 2-hole plates may have a higher reoperation rate and incidence of pelvic mal-reduction. External fixation approaches may be used for pelvic fractures, as well as internal fixation approaches. The advantages of external fixations are that these can be easily applied to pubic rami fractures as well as symphyses disruptions. Moreover, the devices can be applied in the emergency room, intensive care unit, or operating room. External fixators can be applied when contamination from abdominal and genitourinary injuries makes internal fixation approaches hazardous. Finally, external fixation devices can be removed in the clinic or office setting. A disadvantage of external fixation is that there is an external device, which interferes with positioning, sitting, and clothing. Pin site care and infection can be problematic, particularly with obese patients. Finally, it is more difficult to obtain and maintain an anatomic reduction of the anterior pelvic ring with external fixation devices.

Similarly, there are advantages and disadvantages to internal fixation. The advantages include the absence of interference with positioning, sitting, or with clothing and that there are no attendant problems of pin site care. One disadvantage is that internal fixation cannot be employed when there is contamination of the operative field. An additional disadvantage is that formal reoperation is necessary if the fixation hardware must be removed. Finally, internal fixation potentially limits pelvic relaxation in women during childbirth.

Fixation options are essentially the same for pubic ramus fractures as for pubic symphysis diastasis. However, internal fixation with plating does not carry the same long-term obstetrical or hardware failure sequelae. Retrograde medullary ramus screws represent a novel technique that allows percutaneous application of internal fixation of the ramus fracture; however, a closed percutaneous reduction must be possible.

Fixation of Posterior Pelvic Fractures

Iliac wing fractures can be fixed with the patient prone via a posterior approach with an incision along the crest and elevation of the gluteal musculature from the outer table of the ilium, or supine via an anterior approach with the lateral window of the ilioinguinal or Smith-Peterson exposures of the inner table. Depending on the fracture pattern and the patient’s condition and/or associated injuries, one approach may offer advantages over the other. As a general rule, the anterior approach is better tolerated by the patient and associated with less blood loss. However, if the iliac wing fracture is very posterior (Fig. 8), then exposure of both sides of the fracture and application of fixation may be difficult.
Usually, a single pelvic reconstruction plate or lag screw along the crest supplemented with a second reconstruction plate or lag screw at the level of the pelvic brim or sciatic buttress will suffice in neutralizing deforming forces until healing has occurred (Fig. 9).

The SI joint can be approached from either anterior or posterior as described above, but it is often easier to reduce the SI joint and apply reduction clamps from posterior. Attention must be paid to closing the anterior aspect of the SI joint, which can be difficult from the posterior approach. Fixation options include iliosacral screws, anterior SI plating, and posterior trans-iliac plating or compression rods; however, biomechanical studies have not shown any significant differences among these techniques [50–56].

The main disadvantage to iliosacral screw fixation is that experienced surgeons and excellent intraoperative fluoroscopic quality with clear imaging are essential to success [54–56].

Anterior plating to achieve fixation of pelvic fractures is particularly useful if additional ipsilateral anterior pelvic/acetabular procedures are performed. The disadvantages include the fact that the procedure requires dissection and placement of fixation onto the sacral ala, which places the L5 nerve root at risk. Trans-iliac bars or plates are associated with two disadvantages; one is that the fixation hardware crosses the normal contra-lateral SI joint. In addition, on thin patents, fixation can be prominent and bothersome, occasionally causing skin breakdown.

A particularly difficult fracture pattern is the crescent fracture associated with posterior SI joint and ligament disruption. This injury involves a fracture of the iliac wing posteriorly that starts at the crest and exits into the SI joint. A variable-sized fragment of posterior crest containing the posterior superior iliac spine remains attached to the sacral ala via the posterior SI ligaments. This constant fragment can be used as an aid to reduction as it is located anatomically. Standard fixation involves a superiorly placed reconstruction plate along the crest with supplemental lag screws from the posterior inferior iliac spine into the sciatic buttress just above the greater notch. As the constant fragment becomes smaller, this injury approaches an SI dislocation, and consideration must be given to supplemental SI screws or plates.

The topic of sacral fractures encompasses a whole discussion. Suffice it to say that these injuries, depending on fracture pattern, can be regarded as pelvic ring injuries or spinal injuries. In addition, sacral fractures often involve some form of neurologic deficit, either unilateral peripheral nerve root (as in the case of VS injuries) or cauda equina lesions (as in the case of transverse fractures that involve the central spinal canal). Occasionally, the L5/S1 joint is disrupted and the stability of the lumbosacral junction is compromised. All of these issues need to be taken into consideration when treating sacral
fractures. Fig. 10 illustrates a CT image of a sacral fracture causing both neural and skeletal damage.

Fixation largely depends on what is disrupted, i.e. the pelvic ring, the lumbosacral junction, or both. Some sacral fractures that arise from lateral compression injuries result in impaction of the ala and may be inherently stable, not requiring any fixation. Other fractures that are unstable will incorporate some form of posterior fixation as outlined above.

**Clinical Outcomes of Pelvic Fracture Fixation**

Stabilization of unstable pelvic injuries has only recently evolved to include early internal fixation and restoration of anatomic relations. Prior to the 1980s, very little was understood regarding the biomechanics and contributions to stability of the various pelvic bony and ligamentous structures. As recently as the 1970s, many pelvic ring disruptions were treated with nonoperative techniques; generally skeletal traction and pelvic slings to prevent excessive cephalad migration of the hemipelvis. However, many clinicians have documented the high incidence of poor functional outcome and chronic pain in patients with vertically unstable pelvic fractures treated nonoperatively [57–60]. The results of these and other studies provided the impetus to pursue operative means to achieve and maintain anatomic reduction.

Operative stabilization began with anteriorly placed external fixators alone, which were found to be nearly totally ineffective at controlling vertical and posterior displacement of the posterior aspect of the ring. Clinical outcome studies with the use of external fixators subsequently found that results were not improved over nonoperative management and, in fact, traction and pelvic sling alone may have been more successful at treating this unstable injury [61,62].

Improved short-term patient outcome with early stabilization of the pelvic fracture and mobilization of the patient, as well as numerous reports citing improved outcome with anatomic reduction of the posterior ring, continued to provide the impetus to develop more rigid and stable posterior fixation constructs [63,64].

Supplemental fixation of the anterior aspect of the pelvic ring has been shown to provide further biomechanical stability in the case of the vertically unstable hemi-pelvis. Whether this is in the form of an external fixator or symphyseal plate seems to be of little significance; however, more orthopedic trauma surgeons are moving toward routine use of symphyseal plates that can be placed at the time of exploratory laparotomy, and do not give rise to the attendant pin-site complications seen with external fixators.

Early outcome studies support the position that the long-term functional results are improved if reduction with less than 1 cm of combined displacement of the posterior ring is obtained, especially with pure dislocations of the SI complex. Fractures of the posterior ring tend to do better, presumably because bone healing can restore initial strength and stability, SI dislocations rely purely on ligamentous healing and scar formation, and these patients tend to fair worse in terms of short- and long-term problems with pain and ambulation when compared to patients with other fracture patterns.

However, despite seemingly anatomic (or near anatomic) reductions, more recent clinical outcome studies have shown that with modern fixation techniques, a substantial proportion of patients continue to have poor outcomes with chronic posterior pelvic pain [65,66]. This is likely related to multiple confounding factors:

1. Trauma patients often have a borderline socioeconomic status with poor social and financial support groups.
2. Extensive soft tissue damage and associated long-bone and extremity fractures.
3. Associated neurologic, visceral, and urogenital injuries with dyspareunia, sexual dysfunction, and incontinence prolong recovery and rehabilitation time with loss of job, home, and family relationships.

Outcome studies after fixation of pelvic injuries are difficult to interpret because of poor follow-up, heterogeneity of the injury pattern, associated visceral and neurologic injury, and the lack of a reliable outcome measure for pelvic ring injuries. Debate continues regarding the definition of adequate reduction of the pelvic ring and how mal-reduction affects functional outcome, if at all. Recent clinical outcome studies have shown that with current fixation techniques, a substantial proportion of patients continue to have poor outcomes with chronic posterior pelvic pain despite seemingly anatomic reductions and healing, with less than 50% returning to previous level of function and work status [67,68].
Appendix 1. Pelvic fracture management algorithm.

References


