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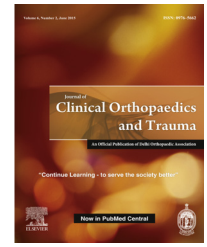

Review Article

Pelvic ring injuries: Emergency assessment and management

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ABSTRACT

Pelvic ring injuries are associated with significant morbidity and mortality. Understanding the anatomy of the pelvic ring is essential for accurate diagnosis and treatment. A systematic approach taking into account the mechanism of injury, physical examination, and radiographic assessment is important to quickly identify unstable pelvic disruptions and associated injuries. Because the pelvis is a ring structure, isolated pubic rami fractures on plain radiographs are unusual and should warrant careful evaluation for posterior pelvic disruption with computed tomography. Hemorrhagic shock can occur in about 10% of pelvic ring injuries. Immediate recognition and treatment of this life-threatening condition is critical in emergency management. In addition to fluid resuscitation and blood transfusion, circumferential wrapping, angiographic embolization, laparotomy with pelvic packing, and external fixation can be important life-saving adjuncts in the setting of hemodynamic instability.

1. Introduction

Pelvic ring disruptions make up 3% of all skeletal fractures.[1] Traffic accidents are the most common mechanism of injury, accounting for the 60% of pelvic fractures followed by falls (30%) and crush injuries (10%).[2] Disruption of the pelvic ring can also result from low energy mechanisms, such as falls from standing height in elderly persons with osteoporosis.[3] The morbidity and mortality associated with pelvic ring injuries are significant. Mortality rate is estimated at 28% from multiple pooled studies,[1] but can be as high as 50% in open fractures.[4] In a multicenter retrospective review of 2551 patients with pelvic ring injures, Gansslen et al. found mortality to be closely associated with the presence of concomitant soft tissue injury.[5]

2. Anatomy

The pelvis is a ring structure consisting of the sacrum and the two innominate bones. It encases important visceral structures and serves as a link between the axial skeleton and the lower extremities. While the pelvic ring lacks inherent bony stability,[6] it is held together by a network of interosseous ligaments. Anteriorly, there are the public symphysis and the anterior sacroiliac (SI) ligaments, which collectively contribute about 40% to the stability of the pelvis.[4] Posteriorly, there are the much stronger posterior SI, sacrospinous, and sacrotuberous ligaments. These posterior ligaments form a suspension bridge that maintains the position of the sacrum within the pelvic ring.[6] Additional stability is provided by the iliolumbar and lumbosacral ligaments.[7] Collectively, the aforementioned

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ligaments stabilize the pelvic ring by resisting rotationally and vertically applied deforming forces. The transversely oriented anterior SI and sacrospinous ligaments more effectively resist rotation, whereas the vertically oriented sacrotuberous ligaments help prevent vertical displacement.[8] The posterior SI ligaments, on the other hand, consist of short transverse and long vertical fibers, and therefore resist both rotational and vertical deforming forces.[9]

3. Classification

The two most commonly used classification systems for pelvic ring injuries are those described by Tile[6] and Young-Burgess.[7] The Tile system, which is the basis of the AO/OTA classification of pelvic ring fractures, is divided into three categories based on stability of the posterior SI complex (Table 1): type A injuries that can withstand physiologic forces without deformation, type B injuries that are rotationally unstable, and type C injuries that are rotationally and vertically unstable.[6] The Young-Burgess system, on the other hand, is based on the vector of force applied to the pelvic ring.[8] Three injury patterns are described: lateral compression (LC), anteroposterior compression (APC), and vertical shear (VS; Table 2).

LC injuries, the most common pattern, are caused by a laterally applied force to the pelvis leading to compression of the SI joint and internal rotation of the hemipelvis on the side of injury.[9] In LCII pattern, there is a characteristic avulsion fracture of the iliac wing (crescent fracture), which remains attached to the sacrum by the strong posterior SI ligaments. Alternatively, there may be disruption of the posterior SI ligaments without a crescent fracture, especially in young patients.[9] In LCIII pattern, also known as windswept pelvis, there is concomitant opening (external rotation) of the contralateral hemipelvis caused by a secondary crush injury.

APC injuries, also referred to as open book injuries, occur from an anteriorly or posteriorly applied force resulting in opening or external rotation of hemipelvices. Depending on the magnitude of the force applied, the spectrum of injury can range from pubic symphysis diastasis (APCI), to disruption of the anterior SI ligaments (APCII), to complete hemipelvis separation (APCIII). APCIII can be differentiated from VS injury by the absence of vertical displacement of the hemipelvis.

Koo et al. examined the interobserver reliability of the Tile and Young-Burgess classification systems among surgeons with variable levels of expertise: two senior orthopedic trainees, two orthopedic traumatologists, and two pelvic and acetabular specialists.[10] Thirty patients, each with three radiographs (AP, inlet, and outlet) and a pelvic CT scan were reviewed. The authors found substantially higher interobserver reliability using the Young-Burgess system among trainees and orthopedic traumatologists, but not pelvic and acetabular specialists. The addition of CT scan did not improve the overall reliability of either system although it significantly improved the determination of pelvic stability.[10]

Osterhoff et al. compared the Tile and Young-Burgess classification systems with regard to their predictive value on mortality, resuscitation requirements, and associated injuries.[11] 285 consecutive patients with pelvic ring fractures were retrospectively reviewed. The authors found no relationship between mortality and fracture pattern for both systems. However, a subgroup analysis showed unstable Young-Burgess fractures (LC II/III, APC II/III, VS, and combined patterns) to carry a significant risk of mortality. In both classification systems, the severity of the fracture pattern significantly correlated with blood transfusion and total fluid resuscitation requirements.[11] Furthermore, while there was no significant relationship between fracture pattern and concomitant head and chest injuries, open book fractures were associated with more severe injuries of the abdomen, spine, and extremities in both classification systems.

Table 2 – Young-Burgess classification of pelvic ring injuries.[8]

Pattern	Characteristics	Incidence
LC	I. Rami fracture and ipsilateral sacral compression.	48.7%
	II. Rami fracture and ipsilateral crescent fracture.	7.4%
	III. Rami fracture and contralateral APC injury.	9.3%
APC	I. Symphysis diastasis < 2 cm; SI joints intact.	0%
	II. Symphysis diastasis with disruption of the anterior SI ligaments.	11.1%
	III. Symphysis diastasis with disruption of the anterior and posterior SI ligaments.	4.3%
VS	Vertical displacement of one or both hemipelvices.	5.6%
Combined	A combination of the above injuries.	6.8%

Table 1 – Simplified Tile classification of pelvic ring injuries.[6]

Type	Stability	Examples
A	Stable	Isolated iliac wing fractures, avulsion fractures of the iliac spines or ischial tuberosity, nondisplaced pelvic ring fractures.
B	Rotationally unstable; vertically stable	Open book fractures, LC fractures, and bucket-handle fractures.
C	Rotationally and vertically unstable	VS injuries.

4. Initial evaluation

A systematic approach is important to quickly identify injuries, treat life-threatening complications, and reduce morbidity and mortality. The approach should start by inquiring about the mechanism of injury, which can provide insight into the pelvic disruption pattern and potential associated injuries. Burgess et al. reviewed 162 consecutive patients with pelvic fractures (excluding acetabular fractures) and found that each patient had an average of 1 additional orthopedic injury and 1.6 non-orthopedic injuries.[8] In their series, closed head injury was the most common non-orthopedic injury with highest incidence in LC pattern. This was followed by visceral injury, which had highest incidence in APC pattern.[8] In addition, overall transfusion requirements and mortality were highest in APC injuries (14.8 units of packed red blood cells and 20%, respectively).

The perineum, posterior SI region, rectum, and vagina should be inspected for wounds that can indicate open fractures. Blood at the penile meatus may suggest urethral injury in men and occult open fractures in women.[3] Urological injury is common in all injury patterns with incidence as high as 25%.[12] Limb shortening or rotational abnormalities may suggest long bone fractures and/or pelvic ring disruptions.

5. Physical examination

Examination of the pelvis may show pelvic tenderness, deformity, or gross motion. A neurologic exam is also important to rule out injury to the lumbosacral plexus.[9] Shlamovitz et al. retrospectively reviewed 115 patients with pelvic fractures to evaluate the utility of physical examination in detecting unstable pelvic ring injuries.[13] The study excluded patients who had penetrating trauma, were transferred from outside hospitals, did not meet criteria for trauma team activation, had no pelvic imaging, or died in the ED before complete workup. Pelvic stability was assessed by applying rotational, anteroposterior, and superoinferior stress to the pelvis with both hands on the iliac crests. A gross motion in any direction was considered abnormal. The study found that presence of pelvic deformity or instability had poor sensitivity and specificity for detecting unstable injuries.[13] Pelvic pain was the only reliable finding in unstable pelvic injuries with sensitivity and specificity at 97% and 93%, respectively. Table 3 provides a summary of the sensitivity and specificity of the different exam findings.

Table 3 – Sensitivity and specificity of physical exam findings in pelvic ring injuries.[13]

Finding	Sensitivity		Specificity	
	Stable	Unstable	Stable	Unstable
Pelvic pain or tenderness	74%	100%	97%	93%
Pelvic deformity	30%	55%	98%	97%
Unstable pelvic ring	8%	26%	99%	99.9%

6. Radiographic assessment

6.1. *Plain radiographs*

Plain radiographs consisting of AP, inlet, and outlet views allow rapid and inexpensive evaluation of pelvic ring.[7] The portable AP view is often obtained as part of the initial trauma workup. This screening radiograph is helpful for assessing the integrity of the anterior pelvis and overall pelvic symmetry. It may show symphysis diastasis or fractures of the pubic rami, iliac wing, and acetabulum. The addition of the inlet view may demonstrate anterior/posterior translation of the hemipelvis and provide better visualization of the iliac wings and sacral ala. The outlet view, on the other hand, may demonstrate superior/inferior translation of the hemipelvis and provide good visualization of the sacrum and its neural foramina.

The significance of pubic rami fractures as a marker of posterior pelvic injury has been demonstrated in several studies.[14,15] Hill et al. found that the 5-year survival after pubic rami fractures was equivalent to that of hip fractures at 45.6%, thereby questioning the "benign" nature of these injuries.[16] Because the pelvis is a ring structure, an isolated pubic ramus fracture without disruption at another site within the ring is unusual—an association that is often poorly recognized.[4] Scheyerer et al. retrospectively reviewed a consecutive cohort of 233 patients with pubic rami fractures who had no obvious posterior pelvic injuries on initial radiographs. Excluding patients with acetabular fractures, 96.8% (171/177) had involvement of the posterior ring on CT scans. The authors concluded that isolated rami fractures associated with prolonged pain and immobility should be further investigated with CT scans to rule out occult posterior ring injuries.[14] Similarly, Courtney et al. retrospectively reviewed a cohort of 155 patients with displaced inferior ramus fractures on AP radiographs. Excluding patients with acetabular fractures, 68% (63/93) were found to have concomitant posterior ring injury, particularly those with parasymphyseal involvement and fractures of the superior ramus.[15]

Pubic rami may be fractured in vertical or horizontal orientation. Vertical fracture patterns are characteristic of APC and VS injuries, whereas horizontal fractures are characteristic of LC pattern.[7,9] Several methods for measuring displacement on pelvic X-rays have been described including the cross measurement technique by Keshishyan, inlet and outlet ratio by Sagi, the absolute displacement method by Lefaivre, and the posterior iliac offset by Ton.[17,18] However, none of these methods has been validated and they are limited by variable interobserver reliability.[17,18]

6.2. *Computed tomography*

Computed tomography (CT) is the best imaging technique in the trauma setting to detect injuries to the pelvic ring.[3] CT scans can detect injuries to the posterior ring that may be missed on plain radiographs including disruptions of the neural foramina. They can also detect soft tissue injury and free peritoneal fluid (FPF), which could indicate life-threatening hemorrhage. Verbeek et al. showed that the amount of FPF on CT scan was highly predictive for the need for abdominal hemorrhage control and requirement for blood transfusion.[19] Furthermore, the advent of three-dimensional reconstructions using CT scans now allows the visualization of the whole pelvic ring, providing detailed morphological information on the extent of injury.

6.3. *Ultrasound*

Ultrasound (US) is often performed to detect FPF in the setting of trauma. Tayal et al. retrospectively reviewed 87 patients with pelvic fractures using US and found the sensitivity and specificity for detecting FPF only 80.8% and 86.9%, respectively.[20] The authors theorized that the relatively lower predictive value of US in pelvic ring injuries compared to the general trauma population was due to the distorted architecture of the pelvis and high proportion of intraperitoneal bladder rupture. Among those patients with true-positive results in their study, urine was the FPF in 19% of patients.[20] With the routine of chest/abdomen/pelvis CT scan as part of the emergency screening for patients with severe trauma, CT has largely replaced US for detection of FPF.

6.4. *Magnetic resonance imaging*

The use of magnetic resonance imaging (MRI) for the evaluation of pelvic ring fractures in the acute is limited. Nüchtern et al. prospectively reviewed 60 patients with anterior pelvic ring injury on AP radiographs but without obvious fractures posteriorly.[21] Patients underwent CT scan on the day of admission and 1.5 Tesla MRI within 7 days from admission. In addition, patients had clinical examination of the posterior pelvis. The exam was considered positive if there was 1) tenderness to palpation over the sacrum or SI joint or 2) posterior ring pain with LC or pressure over the pubic symphysis. The group found CT and clinical examination to be equally effective in detecting posterior ring injuries (sensitivity and specificity 0.83/0.67 and 0.83/0.92, respectively). In the cases where the posterior injury was missed by either CT or clinical examination, MRI was able to detect them. The authors concluded that MRI was the superior imaging modality for pelvic fractures in patients with osteoporosis.

7. Hemodynamic instability

Hemodynamic instability occurs in about 10% of pelvic ring injuries.[22] Bleeding usually originates from cancellous bone, presacral venous plexus, and/or iliac vessels.[23,24] Extra-pelvic hemorrhage can also occur due to the often high-energy trauma required to disrupt the pelvis, with long bones and abdominal viscera being the most common sites.[25] The incidence of associated long bone fractures in unstable pelvic ring injuries has been reported to be over 80%.[25] While the severity of the injury pattern correlates with blood transfusion and fluid resuscitation requirements,[11] hemorrhagic shock can occur in both stable and unstable patterns,[25] and is the most common cause of death in the first 24 h.[22] Immediate recognition and treatment of this life-threatening complication is the most important factor for survival.

The criteria for hemorrhagic shock are variable, but are often based on presence of either a systolic blood pressure $<$90 mmHg or an acid base deficit <-6 mmol/L.[22] Additionally, hemoglobin level $\leq$10 g/dL within the first 30 min of arrival may indicate significant bleeding.[26] Aggressive resuscitation is required in these circumstances in accordance with the Advanced Trauma Life Support (ATLS) protocol. Porter et al. reviewed the optimal end points of complete resuscitation from shock in trauma patients and concluded that serum lactate, base deficit, and gastric intramucosal pH were the most reliable indicators.[27] However, given the acid/base disturbances in older patients with medical comorbidities, some authors argued that serum lactate level was the most reliable indicator of peripheral end-organ perfusion.[28]

The optimal transfusion protocol in patients with hemorrhagic shock is the subject of ongoing research. These patients often require massive transfusion, which can further compound initial coagulopathy. Together with acidosis and hypothermia, coagulopathy forms the so-called deadly triad in trauma and has high incidence early in the post-injury period.[29] However, unlike hypothermia and acidosis, coagulopathy is more difficult to treat and is associated with decreased survival.[30] This has led to emergence of transfusion protocols emphasizing early administrating of fresh frozen plasma (FFP) and platelets along with packed red blood cell (PRBC) in 1:1:1 ratio. While this protocol is thought to closely resemble whole blood and reduce coagulopathy, it is largely based on retrospective studies and confounded by survivorship bias.[31] Recently, Holcomb et al. performed a multicenter, randomized clinical trial comparing FFP, platelets, and PRBC transfusion in 1:1:1 ratio to 1:1:2 ratio.[32] The authors found no differences between the two protocols in 24-h and 30-day all-cause mortality. There was also no difference in the incidence of complications, such as sepsis, acute respiratory distress syndrome, and multi-organ failure. However, the 1:1:1 group had significantly lower rates of exsanguination in the first 24 h.

In addition to aggressive resuscitation measures and correction of coagulopathy, hemodynamically unstable patients with pelvic ring injuries may require additional interventions including the application of circumferential wrapping, external fixation, angiographic embolization, and laparotomy with pelvic packing.

7.1. *Circumferential wrapping*

Pelvic stabilization with non-invasive techniques (a folded bed sheet or a commercially available binder) is the fastest way to provide immediate stabilization for hemodynamic instability secondary to pelvic ring disruption. Croce et al. found that the use of pelvic binders was associated with significant reduction in transfusion requirements and length of study (LOS) compared to external fixation.[33] Interestingly, in a cadaveric study using 3-D analysis to compare intact and post-fracture pelvic volumes, Stover et al. found only small changes, suggesting that pelvic binders reduce bleeding by minimizing clot disruption.[34] The binder should be applied at the level of the greater trochanters as soon as possible, ideally on the scene of injury, in any patient with signs of hemodynamic compromise and suspected pelvic ring injury.[35] Application of the binder above the level of the greater trochanter is a common mistake and results in poor reduction of the pelvic diastasis and inadequate hemodynamic control. Bonner et al. retrospectively reviewed 167 radiographs with pelvic binders and found only 50% were appropriately positioned, while 39% were above and 11% below the level of the greater trochanters.[36] Circumferential wrapping should be continued until hemodynamic stability is restored or an alternative stabilization technique is applied. Recently, Pizanis et al. compared the outcomes of pelvic fracture patients after sheet wrapping, binder, and C-clamp treatment in 207 patients in the German Pelvic Trauma Registry.[37] The authors found sheet wrapping to be associated with a significantly higher incidence of fatal pelvic bleeding, prompting them to recommend binders and C-clamps for emergency stabilization of the pelvic ring.

Despite being part of the ATLS protocol, compliance with the use of pelvic binders for hemodynamically unstable pelvic ring injuries has been poor. Toth et al. retrospectively reviewed 115 patients with hemorrhagic shock secondary to unstable pelvic ring injuries and found the utilization of pelvic binders to be only 50%.[22] Among those who had pelvic binders, there were no reported cases of nerve injury or pressure necrosis although these complications have been reported in other studies. It is important to remember that the use of a correctly applied circumferential wrapping is the fastest and least invasive intervention to help control bleeding; and its immediate application in hemodynamically unstable patients may be lifesaving.

7.2. *Angiographic embolization*

Arterial hemorrhage has been reported to occur in up to 15% of hemodynamically unstable pelvic ring injuries.[23] It usually presents with hypotension refractory to resuscitation and mechanical stabilization.[38] Arterial injury carries poor prognosis, especially when larger arteries are involved.[24] There is currently no clear association between fracture pattern and vascular injury or need for angiographic embolization.[39] Indications for angiography are hemodynamic instability refractory to resuscitation, partially responsive patients with contrast extravasation on CT scan, and progressive decline in hemoglobin level requiring ≥ 4 units of blood within 8 h.[23] El-Haj et al. retrospectively reviewed 61 patients who underwent angiography for hemodynamic instability, 38 of whom (62%) required embolization.[23] Among those patients, 27 (71%) had embolization of a single vessel and 11 (29%) required embolization of multiple vessels. The internal iliac artery was the commonly injured vessel. Arterial embolization was associated with higher injury severity score (ISS), transfusion requirements, and mortality. In another study, Lindahl et al. retrospectively reviewed 49 patients with pelvic and acetabular fractures who had angiographic embolization.[24] The internal iliac artery was the most common source of bleeding (86%) with the vast majority of lesions occurring at the main branch.

The optimal timing to angiography is not clearly defined. The sources of pelvic bleeding are of venous origin in the vast majority of cases, which cannot be addressed with embolization.[40] In addition, the door to angiography time and the time spent in the angiography suite can be several hours,[24] which may not be appropriate for patients with exsanguinating hemorrhage. The use of angiography as a first-line intervention in these cases can therefore result in delaying the time to hemodynamic stabilization. In one study, the time to angiography was nearly three-fold the time for operative pelvic packing (130 min vs. 45 min respectively).[40] However, both groups had similar blood pressure and laboratory values during the first 24 h post intervention. There was also no difference in mortality, complications, or hospital LOS including time spent in the intensive care unit (ICU).

7.3. *Pelvic packing*

Patients with exsanguinating hemorrhage who have a positive FAST scan (Focused Assessment with Sonography for Trauma)[38] or those where angiography is not available[41] are generally taken to the operating room for emergent laparotomy. This allows a tamponade effect for venous and bony bleeding by packing with large sponges.[38] While this technique may provide rapid hemodynamic stabilization, it often fails to identify the exact source of bleeding.[42] Pelvic packing also requires another operation to remove the padding material, does not control arterial bleeding, and may compromise future surgical incisions for definitive fixation.[42] Papakostidis and Giannoudis performed a systematic review of literature on the efficacy of pelvic packing for pelvic ring injuries with hemodynamic instability.[1] Three studies were included in the review, one involved transperitoneal pelvic packing and two used direct retroperitoneal packing. No clear advantage for pelvic packing was demonstrated in regards to mortality, infection rates, or multiple organ failure.

7.4. *External fixation*

External fixation with either a pelvic clamp or traditional frames can provide provisional stabilization in hemodynamically unstable patients. Abrassart retrospectively reviewed 60 patients with unstable pelvic fracture pattern who presented with hemodynamic instability and who were treated with one of the following: 1) external fixation only, 2) external fixation followed by angiography, 3) external fixation followed by laparotomy ± angiography, or 4) laparotomy or angiography before external fixation.[42] The survival rate was 100% in group 1, 91% in group 2, 82% in group 3, and 0% in group 4. The authors recommended the application of external fixation prior to any other hemostatic procedure. However, the study was limited by variable ISS among the different groups and was not adequately powered to draw conclusions.

8. Summary

Due to the high energy required to disrupt the pelvis, pelvic ring injuries are only part of a spectrum of polytrauma with significant morbidity and mortality. The anatomy of the pelvis as a ring structure makes an isolated disruption in one part of the ring unusual. Classifications systems can help predict associated injuries and resuscitation requirements. The utility of physical examination is limited with pain on palpation being the most reliable finding. While CT scan is the gold standard for detecting injuries to the posterior ring, plain radiographs consisting of AP, inlet, and outlet views allow rapid and inexpensive evaluation of pelvic ring. Early recognition and treatment of hemorrhagic shock is the most important factor for survival after unstable pelvic ring injuries. A pelvic binder should be applied at the level of the greater trochanters as soon as possible, ideally on the scene of injury, in any patient with signs of hemodynamic compromise and suspected pelvic disruption. External fixation, angiographic embolization, and pelvic packing can also provide additional hemodynamic stabilization.

Conflicts of interest

The author has none to declare.

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