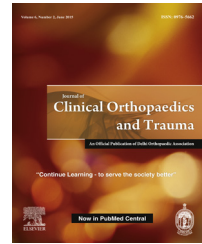


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Review Article

Pelvic ring injuries: Surgical management and long-term outcomes

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ABSTRACT

Pelvic ring injuries present a therapeutic challenge to the orthopedic surgeon. Management is based on the patient's physiological status, fracture classification, and associated injuries. Surgical stabilization is indicated in unstable injury patterns and those that fail nonsurgical management. The optimal timing for definitive fixation is not clearly defined, but early stabilization is recommended. Surgical techniques include external fixation, open reduction and internal fixation, and minimally invasive percutaneous osteosynthesis. Special considerations are required for concomitant acetabular fractures, sacral fractures, and those occurring in skeletally immature patients. Long-term outcomes are limited by lack of pelvis-specific outcome measures and burden of associated injuries.

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1. Introduction

Pelvic ring disruptions make up 3% of all skeletal fractures¹ and are associated with significant morbidity and mortality. Fractures of the ischiopubic bones, SI joint, and sacrum are the most common bony injuries² while lacerations to the urinary tract, retroperitoneal hematoma, and injuries to the lumbosacral plexus are the most common associated soft tissue injuries.³ The two most commonly used classification systems for pelvic ring injuries are those described by Tile⁴ and Young-Burgess⁵ (Tables 1 and 2). Careful examination of the fracture pattern is essential for surgical decision-making.

1.1. Indications

Type I anteroposterior compression (APC) and lateral compression (LC) injuries are generally stable patterns (i.e., able to

withstand physiologic stress) and therefore are managed nonoperatively. Four relative indications for surgical stabilization in this group have been reported: (1) substantial displacement, (2) associated abdominal injury requiring laparotomy, (3) tilt fracture protruding into the perineum, and (4) refractory pain.⁶ Olson and Pollack defined significant displacement as presence of a leg length discrepancy greater than 1.5 cm or a rotational deformity resulting in loss of all internal or external rotation in the lower extremity.⁶ APC and LC types II and III, on the other hand, are rotationally unstable patterns often associated with substantial displacement and are generally indications for surgical stabilization. Treatment of associated pubic rami fractures is often not necessary, as the risks of surgical dissection to fix these fractures outweigh the benefits.⁴ Similarly, the vertical shear (VS) pattern is both rotationally and vertically unstable, and requires fixation. However, due to often associated massive hemorrhage, VS pattern is usually treated with external fixation with or

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Table 1 – Simplified Tile classification of pelvic ring injuries.⁴

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, lateral compression fractures, and bucket-handle fractures.
C	Rotationally and vertically unstable	Vertical shear injuries.

Table 2 – Young–Burgess classification of pelvic ring injuries.⁵

Pattern	Characteristics	Incidence
Lateral compression (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%
Anterior-posterior compression (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%
Vertical shear (VS)	Vertical displacement of one or both hemipelvises.	5.6%
Combined	A combination of the above injuries.	6.8%

without skeletal traction as a temporizing measure until definitive fixation can be safely performed. Traction can prevent shortening of the hemipelvis, thus facilitating staged open reduction and internal fixation.

1.2. Timing

The optimal timing for definitive surgical stabilization is not clearly defined. While there is an emerging trend toward early fixation, the term “early” has been variably used in the literature and ranged from less than 8 h⁷ to less than 1 week.⁸ Advantages of early fixation include pain relief, improved fracture reduction, early mobilization, easier nursing care, better positioning for respiratory care, and bleeding control.^{9–11} Disadvantages of early definitive fixation, on the other hand, are increased risk of bleeding and the potential of introducing a second hit in patients who are not fully resuscitated.

Vallier et al. retrospectively reviewed 645 patients with unstable pelvic and acetabular fractures treated surgically and found early fixation (≤ 24 h) to be associated with lower morbidity (pulmonary complications and multi-organ failure) and length of ICU stay.⁹ However, the mean ISS for the early treatment group was statistically lower than the late treatment group. Similarly, Enninghorst et al. retrospectively reviewed 286 consecutive patients with unstable pelvic ring injuries who had either early (<24 h) or late (>24 h) fixation. Complex fractures requiring extensive open surgery were excluded. The authors found a trend toward less transfusion requirements, less complications (pneumonia and deep vein thrombosis), and shorter LOS in the early fixation group despite significantly worse preoperative resuscitation parameters in this group.¹⁰ Recently, Katsoulis and Giannoudis performed a systematic review on the timing of definitive pelvic fixation and found that late fixation was associated with increased risk of nosocomial infections, thromboembolism, and pressure ulcers, and inability to achieve anatomic reduction leading to more extensile approaches.¹² The authors

pointed that the most important factors to influence the timing of surgery were hemodynamic status and response to resuscitation, fracture pattern, associated injuries, and inflammatory status of the patient. Fluids and blood products should be immediately administered to hemodynamically unstable patients and the source of bleeding should be identified as soon as possible. Definitive fixation in the emergency phase is primarily indicated for hemodynamic instability associated with open fractures. Otherwise, unstable fractures can be temporarily stabilized by external techniques until systemic inflammation has decreased, especially in patients with high injury severity scores who are prone to multi-organ failure or patients with brain, thoracic, abdominal, or perineal injuries that should be addressed first.¹³

1.3. Surgical options

1.3.1. External fixation

External fixation with either a pelvic clamp or traditional frames can provide provisional stabilization (1) in hemodynamically unstable patients, (2) in cases of symphyseal widening with fecal or urinary contamination that may be prone to infection with internal fixation, or (3) as a definitive treatment.⁴ External fixation permits upright position, which may improve ventilation, especially in patients with chest injuries. The pelvic clamp and external fixators have equivalent effectiveness against displacement in rotationally unstable injuries, but none are sufficient to stabilize combined rotationally and vertically unstable injuries to allow the patient to get out of bed.¹¹

Several external fixator configurations have been described. While more sophisticated configurations may offer slightly better biomechanical stability over a simple rectangular configuration, they are not rigid enough to allow ambulation and hence the additional time needed to apply these frames is not justified.⁴ When used as a definitive treatment for APC II pattern, the external fixator is generally applied for

8–12 weeks to allow healing, with the patient permitted to ambulate during this time.¹¹

Careful placement of the external fixator with the connecting bar out of the field of the abdomen is important, especially if a laparotomy is planned. Timing of external fixator placement relative to laparotomy is generally made in consultation with the general surgeon, but can also be subject to institutional protocols. In our level 1 trauma center, most general surgeons prefer to do the laparotomy first with the orthopedic surgeon on standby if hemodynamic stability cannot be restored or if the pelvic ring injury is too unstable. 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.¹⁴ 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.

Two locations for pin placement in external fixators have been described: anterosuperior (into the iliac crest) and anteroinferior (into the supraacetabular dense bone). Kim et al. performed a biomechanical cadaveric study comparing the two types of fixation in Tile B1 (open book) and C (rotationally and vertically unstable) injuries.¹⁵ Stability of the sacroiliac (SI) joint was significantly higher, when the pins were placed in the dense supraacetabular bone. However, this technique requires fluoroscopic guidance, which may not be immediately available in emergency situations with exsanguinating hemorrhage. Pin site infection and injury to the lateral femoral cutaneous nerve can occur with both techniques, although the risk is higher with supraacetabular pins given the increased soft tissue depth and proximity to the nerve respectively.¹⁶

The pelvic C-clamp is another emergency stabilization instrument for unstable pelvic ring injuries. It provides rapid reduction of anterior pubic diastasis and the posterior disruption of the SI joint.¹⁷ The pins can be applied anteriorly at the greater trochanters¹⁷ or posteriorly on the lateral cortex of the ileum.¹⁸ Lastly, a modified external fixator with a second anterior articulation (X-frame) was recently described for the use of APC III pelvic injuries, where traditional frames cannot provide posterior compressive forces. In a biomechanical study using a Sawbones model, Sellei et al. demonstrated that the X-frame provided greater anterior compressive loads than a single-pin supraacetabular external fixator or C-clamp, and nearly half the posterior compressive load of the C-clamp.¹⁹

1.3.2. Open reduction and internal fixation

Compared to external fixation, open reduction and internal fixation (ORIF) provides better fracture reduction together with superior biomechanical stability, and allows earlier ambulation. Indications for ORIF are symphyseal widening >2.5 cm, tilt fracture that is difficult to close reduce, SI joint dislocation, iliac fracture, unstable acetabular fracture, and in

conjunction with laparotomy in the absence of fecal or urinary contamination.⁴ Patient positioning on the operative table depends on the approach used. Supine position is appropriate for anterior approach and prone position for posterior approach. For cases requiring dual anterior and posterior fixation, a lateral position is used. Posterior approach is rarely indicated and is reserved for cases of inadequate reduction of the SI joint or concomitant fracture of the sacrum.^{4,11} This approach is associated with significant wound breakdown and is contraindicated in cases of posterior crush injuries.

Anterior structures can be accessed with the Pfannenstiel, Stoppa, or ilioinguinal approaches depending on the extent of injuries and exposure needed. Care must be taken to avoid injury to the corona mortis, which is an anastomosis between the external iliac and obturator arteries. In a cadaveric study by Tornetta et al., the corona mortis was found in 84% of the specimens.²⁰ 34% had an arterial connection, 70% had a venous connection, and 20% had both. The average distance from the symphysis laterally to the corona mortis was 6.2 cm.

1.3.3. Percutaneous fixation

Percutaneous iliosacral fixation for posterior ring instability has gained popularity in recent years. This technique is particularly indicated in cases of traumatized posterior skin that are prone to breakdown with open reduction.¹¹ In a retrospective review of 32 patients with posterior pelvic ring instability treated with either percutaneous iliosacral screws or conservative means, Chen et al. found significantly less residual displacement, better pain relief, and improved functional and general health outcomes in the percutaneous fixation group at one year follow-up.²¹ In another series of 71 patients with Tile B1 and C fractures treated with posterior screw fixation, Schweitzer et al. found 86% of patients were able to return to pre-injury occupation and recreational activities.²² In a cohort of 25 patients with LC1 and II fractures treated with percutaneous iliosacral screw fixation, Osterhoff et al. found this technique alone provided sufficient stabilization with only 2 patients (8%) requiring additional anterior stabilization.²³ Most commonly reported complications with percutaneous fixation are nerve root injury, screw misplacement, and loss of reduction.²³

1.4. Special considerations

1.4.1. Associated acetabular fractures

The incidence of combined acetabular and pelvic ring fractures has been reported to be as high as 15.7%.²⁴ This combined injury can occur with any pelvic fracture pattern and is associated with higher ISS, hemodynamic instability, and transfusion requirements compared to isolated acetabular fractures.²⁴ Transverse and both-column fractures of the acetabulum are common in this combined injury. Halvorson et al. summarized the surgical indications for combined pelvic and acetabular fractures as follows: (1) joint incongruity with >2 mm displacement, (2) hip joint subluxation or instability, (3) posterior wall fracture with hip instability, (4) presence of intra-articular fragments, (5) roof-arc measurement <45° on any plain radiograph, (6) progressive neurologic deficit, or (7) irreducible hip dislocation.

The presence of an acetabular fracture can make the management of pelvic ring injuries more challenging. For example, closed reduction of a fracture-dislocation of the acetabulum may be difficult to achieve in an unstable pelvic ring, which may necessitate emergent open reduction and possibly early definitive fixation. In addition, the application of pelvic binders and external fixators may result in malreduction of the acetabular fracture, particularly in a transverse pattern. The external fixator pins may also increase the risk of infection after delayed definitive fixation.²⁴ Unlike posterior ring reductions where up to 1 cm displacement may be acceptable, anatomic reduction of the acetabulum is critical with >2 mm residual displacement is associated with poor outcomes.²⁴ Therefore, acetabular fractures require careful preoperative planning and internal reduction, which may need to be staged until the patient's physiological status allows. Accurate reduction of the posterior pelvic displacement is necessary for optimal reduction of the acetabulum.²⁵

1.4.2. Associated sacral fractures

Sacral fractures rarely occur in isolation and are often associated with spinal or pelvic ring injuries. Indications for surgery are zone 3 fractures, neurologic injuries, displacement greater than 10 mm, and complete fractures combined with bilateral rami fractures.^{26,27} Percutaneous iliosacral screw fixation is the treatment of choice unless spinopelvic dissociation is present, in which case spinopelvic fixation should be performed.

1.4.3. Skeletally immature patients

Pelvic ring injuries in skeletally immature patients are rare, accounting for less than 0.2% of all fractures in this patient population.²⁸ While these injuries were traditionally treated nonoperatively owing to the bone remodeling capacity, several authors have questioned this approach, especially when pelvic asymmetry exceeds 1.1 cm, as this is unlikely to correct with growth.²⁸ Guimaraes et al. published on a cohort of 14 skeletally immature patients with unstable pelvic fractures who underwent surgical fixation.²⁸ The mean age was 9.3 years. 12 patients were treated with combined external fixation/posterior SI screw(s), 1 with an external fixator only, and 1 with combined symphyseal plate/posterior SI screw. Surgical stabilization was associated with significant improvement in pelvic asymmetry and degree of deformity. At final follow-up, none of the patients had residual pain or altered gait. The authors recommended surgical management in skeletally immature patients with pelvic asymmetry greater than 5 mm, especially if there is dislocation of the SI joint.

2. Outcomes

Outcome measurement in pelvic ring injuries is difficult given the confounding effects of associated injuries, diversity of treatment modalities and outcome instruments used, and lack of validated pelvis-specific outcome measures.

Papakostidis et al. performed a systematic review of literature on the outcomes of pelvic ring injuries after treatment with (1) conservative means, (2) anterior stabilization, or (3) posterior stabilization.²⁹ There was no difference

among the three groups in regards to incidence of severe pain, return to previous employment, functional scoring systems, or general health and well being outcomes. Surgical stabilization was only associated with significantly better walking capacity. Additionally, internal fixation of the posterior pelvis correlated with better quality of reduction and malunion rates, although the relationship between quality of reduction and long-term functional outcomes remains unresolved. The authors concluded that "current literature is insufficient to provide clear evidence for clinical decision making in regards to the optimal treatment of unstable pelvic ring injuries."

Dienstknecht et al. retrospectively reviewed 109 patients with pelvic ring injuries with a minimum follow-up of 10 years.³⁰ Patients <3 years of >60 years were excluded. 33 patients had isolated anterior injuries, 33 had isolated posterior injuries, and 43 had combined anterior/posterior (A/P) injuries. The authors found the A/P group was associated with worst physical function and rehabilitation as measured by the SF-12 physical component summary and the Hannover Score for Polytrauma Outcome respectively. No significant differences were found in the mental and hip functions as measured by the SF-12 mental component summary and the Merle D'Aubigne score respectively. However, the validity, reliability, and most importantly the responsiveness of these outcome instruments to treatment have not been established. In a recent systematic review on functional outcomes after surgical treatment of pelvic ring injuries, Lefavre et al. cautioned of several limitations with currently used outcome measures, such as lack of responsiveness, reliability, or ceiling/floor effects, which prevent a well informed discussion on the functional outcomes after surgical fixation.³¹

The effect of fracture pattern on outcomes was explored in a number of studies with variable results depending on the outcome measured. Gerbershagen et al. reviewed 69 patients with pelvic and acetabular fractures, 70% of whom had ORIF.³² At a median follow-up of 52 months, 63.8% of patients reported chronic posttraumatic pelvic pain, with highest prevalence in Tile B and C patterns (67% and 90% respectively). Chronic pain was associated with psychosocial distress, such as anxiety and depression. In another retrospective review of 111 patients with Tile B and C pelvic ring fractures, Gabbe et al. found the ISS, and not fracture type or management, to be associated with odds of return to work or independent living.³³

The difficulty in assessing the outcomes of pelvic ring disruptions can also be attributed to the impact of associated extra-skeletal pelvic trauma including genitourinary, gastrointestinal, and nerve injuries. Urogenital injuries affect both men and women and can occur in any fracture pattern.¹⁶ Sexual dysfunction is common and presents with a spectrum that includes erectile dysfunction (ED), dyspareunia, loss of sensation, ejaculatory dysfunction, and restricted motion during intercourse.³⁴ In one study, the prevalence of sexual dysfunction in men was 61% with ED being the most common complaint.³⁴ Sexual dysfunction was significantly associated with widening or displacement of the pelvic ring (either anterior or posterior) compared to LC. In another study, dyspareunia was present in 56% of women with Tile B and C patterns.³⁵ Women experiencing pain with intercourse were

also significantly less likely to have intercourse or experience orgasm. Interestingly, when compared to an uninjured control group with similar ages and ethnicity, the rate of dyspareunia was not different although the symptoms were more debilitating in the pelvic trauma group. In another study by the same authors, women with pelvic trauma were found to have a significantly higher rate of cesarean delivery.³⁶ All these studies were limited by small sample sizes and high loss to follow-up, which limit their generalizability.

The incidence of neurologic deficits in pelvic ring fractures is variable and ranges from 0.75% to 50%.¹¹ The lumbosacral trunk and the superior gluteal nerve are the most common sites of injury.³⁷ While there is no significant correlation between the extent of pelvic instability and neurologic damage, several trends were observed. For example, injury to the lumbosacral plexus, which is located anterior to the SI joint, often occurs from stretching when the SI joint is displaced. Displacement of the hemipelvis can also cause a traction injury of the superior gluteal nerve due to its short course within the gluteal musculature.³⁷

3. Conclusion

The timing of definitive fixation is dictated by hemodynamic status, associated injuries, and experienced surgeon availability. Discussion among involved surgeons is important for planning of optimal surgical approach. With certain exceptions, Type I APC and LC injury patterns are generally stable and are treated nonoperatively. The remaining injury patterns are unstable and associated with significant displacement, necessitating anterior and/or posterior fixation. The assessment of long-term outcomes is challenging given the confounding effect of associated injuries, diversity of treatment modalities and outcome instruments used, and lack of validated pelvis-specific outcome measures.

Conflicts of interest

The author has none to declare.

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