■ REVIEW ARTICLE

Fractures of the pelvis

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High energy fractures of the pelvis are a challenging problem both in the immediate post-injury phase and later when definitive fixation is undertaken. No single management algorithm can be applied because of associated injuries and the wide variety of trauma systems that have evolved around the world.

Initial management is aimed at saving life and this is most likely to be achieved with an approach that seeks to identify and treat life-threatening injuries in order of priority. Early mortality after a pelvic fracture is most commonly due to major haemorrhage or catastrophic brain injury. In this article we review the role of pelvic binders, angiographic embolisation, pelvic packing, early internal fixation and blood transfusion with regard to controlling haemorrhage.

Definitive fixation seeks to prevent deformity and reduce complications. We believe this should be undertaken by specialist surgeons in a hospital resourced, equipped and staffed to manage the whole spectrum of major trauma. We describe the most common modes of internal fixation by injury type and review the factors that influence delayed mortality, adverse functional outcome, sexual dysfunction and venous thrombo-embolism.

Fractures of the pelvis encompass a broad spectrum of injuries, from low-energy osteoporotic fractures to high-energy disruptions of the pelvic ring. In this article we focus on high energy injuries as they pose a different challenge to low-energy injuries.

Patients who sustain these injuries fall into two categories, survivors and non-survivors. In non-survivors, mortality is a bimodal distribution. Early death is commonly because of haemorrhage or associated brain injury. Late death is usually because of overwhelming sepsis and multi-organ failure. Survivors frequently experience long-term medical and socio-economic implications of fractures of the pelvis. These include mental health issues, chronic pain, pelvic obliquity, leg length or rotational discrepancy, abnormalities of gait, urological and sexual dysfunction and long-term unemployment.

Conceptual anatomy. The bony and ligamentous anatomy of the pelvis is relatively straightforward and well described elsewhere.¹ It is the content and role of the pelvis that makes this anatomical region unique. An intact pelvis provides protection for its visceral content and traversing neurovascular structures. It is the site of load transfer between the axial skeleton and the lower extremities; its main ligamentous

and muscle attachments are finely balanced to allow load transfer to take place when standing, sitting and during locomotion. The bony pelvis is turned into a basin by the pelvic floor – a complex network of ligaments, tendons and muscles that is pierced by the urethra, anus and vagina. When the pelvic floor is torn, huge amounts of blood can escape into the thighs and retroperitoneal space.

It is useful to think of the pelvis as the crossroads of the lower body. It is where forces, innervation, blood supply and perhaps surgical specialties all come together. It is not possible to treat injuries to the bony and ligamentous pelvis successfully without suspecting, identifying and managing associated soft tissue, visceral, and neurovascular injuries.

Classification. We recommend using the Young and Burgess classification (Table I, Fig. 1) which is derived from the initial anteroposterior (AP) radiograph and is predominantly based on the mechanism of injury and severity of fracture.² Fractures are divided into four categories based on the mechanism of injury, two of which are subdivided according to the severity of injury.

Anterior posterior compression. These fractures are secondary to a direct or indirect force in an AP direction leading to diastasis of the

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Table I. Young and Burgess classification²

Category of fracture	Grade		
	I	II	III
Anterior posterior compression	Symphyseal diastasis - slight widening $\pm$ sacroiliac joint. Intact anterior and posterior ligaments	Symphyseal diastasis - widening of sacroiliac joint, anterior ligaments disrupted, posterior ligaments intact	Complete hemipelvis separation without vertical displacement. Symphyseal disruption and complete disruption of sacroiliac joint, anterior and posterior ligaments
Lateral compression	Anterior transverse fracture of pubic rami plus ipsilateral sacral compression	Plus - crescent (iliac wing) fracture	Plus - contralateral anterior posterior compression injury
Vertical shear	Vertical displacement, anterior and posterior through sacroiliac joint		
Combined mechanical injuries	Combination of other injury patterns: lateral compression/vertical shear or lateral compression/anteroposterior compression		

symphysis pubis, with or without obvious diastasis of the sacroiliac joint or fracture of the iliac bone.

Lateral compression. A lateral compression force, which causes rotation of the pelvis inwards, leads to fractures in the sacroiliac region and pubic rami.

Vertical shear. An axial shear force causes disruption of the iliac or sacroiliac junction, combined with cephalic displacement of the fracture component from the main pelvis.

Combined mechanism. A combination of two of the above vectors leads to a characteristic pattern of pelvic fracture.

Within their classification system they aimed “to define the relationship of the mechanism of force delivery and magnitude and direction of the impact forces on the pattern of associated organ injuries which occurs in conjunction with a particular form of pelvic fracture”. In a study reviewing 343 multiple trauma patients with pelvic ring disruption, Dalal et al³ demonstrated a correlation between fracture mechanism, resuscitation requirements and patterns of associated injuries.

The Tile classification⁴ is more complex and we will not discuss it here. However, in his book entitled *Fractures of the pelvis and acetabulum*, Tile eloquently describes where each injury may be placed on a stability scale and how accurate clinical and radiological assessment may determine the degree of stability of any pelvic injury.⁴

There will be clues from the patient history about the level of energy transferred. High-velocity road traffic accidents, crush injuries and falls from a great height are all predictors of pelvic and haemodynamic instability.

On examination, severe displacement of the pelvis and marked posterior disruption are poor prognostic signs. Palpation may reveal gross pelvic instability. The presence of severe neurological and vascular injury is another indicator of instability. The possibility of open fracture and genitourinary injury must also be actively excluded as their presence is not only suggestive of greater energy and instability but also has consequences for surgical management.

A plain AP radiograph is essential and will demonstrate most injuries. Instability is suggested by displacement of the posterior sacroiliac complex by a fracture, dislocation or both. Another radiological abnormality suggestive of instability is an avulsion fracture of the transverse processes of the lower lumbar vertebrae. While rami fractures and diastasis of the pubic symphysis are more easily seen on a radiograph than posterior displacement, it is the latter which is more crucial in the initial stages. The widespread use of pelvic binders by pre-hospital care providers can make the initial radiograph appear normal.

Systems. The treatment received and outcome of patients with high-energy pelvic injuries will be influenced by the sophistication of the available healthcare system. There is evidence that immediate management of these patients within specialised facilities with access to multidisciplinary teams, early senior input and pelvic reconstructive expertise, results in improved rates of survival.^{2,5} Those injured in a developing world health system, with no resources and little specialist expertise, may have different outcomes and receive different treatment than those injured near a specialist trauma centre.

In healthcare systems where patients are treated first at their nearest hospital and then transferred, there may be compromised care because of delays in referral and prolonged transfer times.⁶ In the United Kingdom (but initially only within London) there is now recognition that trauma care can be improved; patients will begin to bypass local hospitals to be taken straight to designated specialist centres with specific expertise. This may again change the approach to trauma care and bring the United Kingdom into alignment with Germany and North America, where this approach has been successfully in place for many years.

Initial management

Saving life. Fractures of the pelvis are frequently only part of the overall injury burden and it is, therefore, essential

Fig. 1a

Fig. 1b

Fig. 1c

Figure 1a – lateral compression (grades I to III). Figure 1b – anterior posterior compression (grades I to III). Figure 1c – vertical shear.

that an Advanced Trauma Life Support approach⁷ is used to identify and treat life-threatening injuries in order of priority. Appropriate attention must be paid to airway management, spinal immobilisation, adequacy of ventilation and provision of supplementary oxygenation.

Haemorrhage is a major cause of death from displaced fractures of the pelvic ring and most commonly occurs from unstable fractures and from disruption of the presacral and paravesical venous plexuses. In less than 20% of patients internal arterial injury is responsible for haemodynamic compromise; associated thoracic, abdominal, extremity and external haemorrhage may also be present.

Methods of haemorrhage control include the use of pelvic binders/slings, external or internal fracture fixation,

pelvic tamponade/packing and angiographic embolisation. Despite these, there is still a mortality rate of approximately 10% for patients with haemodynamic compromise as a result of an unstable fracture of the pelvis. There is no international consensus regarding a treatment algorithm as resources, expertise and trauma systems vary widely between hospitals, regions and nations.

Predictors of major haemorrhage in patients with a fracture of the pelvis are: an emergency department haemocrit value of $\leq 30\%$; pulse rate of 130 beats/min; a displaced fracture of the obturator ring; and a wide pubic symphyseal diastasis.⁸

Binders. Although not a modern invention, pelvic binders and slings have largely replaced external fixation

and anti-shock trousers as the best initial means of controlling the haemorrhage associated with unstable fractures of the pelvis.^{9,10}

Three-dimensional modelling using CT has demonstrated that the pelvis is a hemi-elliptical sphere and that its absolute volume does not increase dramatically with changes in the radius and diameter of the pelvis which occur when it is fractured.¹¹ Therefore it is reasonable to assume that pelvic binders control bleeding by compressing and stabilising fractures, rather than by reducing pelvic volume. Binders may be used in all fracture patterns and not just open-book injuries.

Angiography. One retrospective study¹² of over a hundred patients with major fractures of the pelvis defined as an Abbreviated Injury Score (AIS) ≥ 3 , found that an ongoing rate of blood transfusion of > 0.5 units/hour is a reliable indicator for early angiography. Analysis also revealed that patients with a higher pelvis AIS and lower level of base excess were also more likely to require angiographic embolisation.¹²

Angiographic embolisation is not without its consequences. Peri-pelvic soft-tissue necrosis and subsequent infection can cause overwhelming sepsis, multiple organ failure and death, despite drainage of abscesses, debridement of necrotic tissue and intravenous antibiotics.¹³

The impact of on-site mobile angiography in the emergency department has recently been published.¹⁴ The authors concluded that this was safe and effective and described resuscitation intervals, including a median interval from diagnosis of haemodynamic instability to completion of angiographic embolisation of only 107 minutes. Specialist trauma centres should be able to provide angiographic embolisation on a 24-hour basis.¹⁵

Packing. In many other hospitals, angiographic embolisation may be more time-consuming or delayed and surgical haemostasis may be available more rapidly. Pelvic packing requires surgical facilities and expertise and aims to directly tamponade sources of bleeding within the pelvis. Packs can be placed in the preperitoneal and retroperitoneal spaces. The method is invasive and the packs must be subsequently removed, usually 48 hours after insertion. Packing may be combined with concurrent external fixation.¹⁶ It may be necessary to combine surgical haemostasis and angiographic methods.

Internal fixation. Internal fixation may be appropriate early in the management of a multiply injured patient with an unstable fracture of the pelvis. For example, a patient undergoing a post-traumatic laparotomy for another reason may benefit from an acute open reduction and internal fixation of a wide symphyseal diastasis rather than the application of an external fixator.

Transfusion. Aggressive volume replacement, including the early transfusion of packed red blood cells, is essential. Resuscitation targets vary. We would advocate using fresh-frozen plasma and platelets to support clot formation and prevent disseminated intravascular coagulation in patients

with major haemorrhage who require massive transfusion. The use of activated Factor VII as an adjuvant to massive transfusion and direct surgical haemostasis in a military patient with an unstable fracture of the pelvis has also been described.¹⁷

Open fractures. Open fractures of the pelvis are particularly dangerous. This is defined as a fracture where there is direct communication between the bony injury and overlying skin, rectum or vagina. It is vital that these injuries are recognised early. Wounds must be adequately debrided and irrigated. Treatment includes urgent bladder drainage by a cystostomy tube and bowel diversion and washout with a colostomy. The colostomy should be sited away from potential pelvic surgical fixation approaches.¹⁸ These are high-energy injuries with an increased incidence of intra-abdominal injuries and higher mortality rates.¹⁹⁻²² Survival has improved from 50% to almost 80% but these fractures still demand respect.

Genitourinary injury. A similar indicator of a high energy injury is an associated bladder or urethral injury. The overall incidence of genitourinary injury associated with a fracture of the pelvis is 4.6%; injury to the bladder alone is most common. Men and women are equally likely to sustain an injury to the bladder but damage to the male urethra is more common than to the female urethra.²³ Widening of the symphysis pubis and sacroiliac joint may predict an injury to the bladder while fractures of the inferior and superior pubic rami are more commonly associated with urethral injuries.²⁴ Clinical examination may reveal bleeding from the urethral meatus. Where there is suspicion of a urethral or bladder injury a cystourethrogram should be performed. Traumatic urethral injuries also result in strictures, recurrent infection, erectile dysfunction and infertility.

Definitive fixation: prevent deformity and reduce complications

Definitive fixation is not normally undertaken at the time of injury although exceptions could include management of open fractures of the pelvis and when the patient is undergoing a resuscitative laparotomy.

The aim of sophisticated reconstruction of the pelvis is the prevention of deformity. Deformity may be present because of fracture displacement at the time of injury or can develop over time because of loading through unstable fracture patterns or disrupted ligaments. Leg-length inequality, rotational inequality of the legs and asymmetry of the ischial tuberosities resulting in a sitting deformity, can occur as a result of malunited fractures of the pelvis.

Displacement of the fracture can be assessed through plain radiographs and CT scanning. Instability can be determined from the mechanism of injury, appearance on imaging and clinical assessment. We recommend that if there is doubt about stability, patients should undergo examination under anaesthesia. With the patient anaesthetised and on a radiolucent table, the pelvis is subjected

Fig. 2

Radiological inlet view after open reduction and internal fixation of the pubic symphysis and percutaneous sacroiliac screws, performed for an anterior posterior compression grade III fracture (sacroiliac joint disruption on right with contralateral sacral fracture and anterior symphyseal diastasis).

Fig. 3

Anteroposterior radiological view of percutaneous anterior column and sacroiliac screws.

Fig. 4

Anteroposterior view of external fixator and percutaneous sacroiliac screw. Note the supra-acetabular position of the lower half-pins.

Fig. 5

External fixator *in situ* – the lower transverse bars have been removed to facilitate sitting.

to AP and lateral compressive forces in order to assess rotational stability; alternate axial loading of both limbs is also applied in order to assess vertical stability. An image intensifier is used to assess the radiological appearance. Inlet views are most useful for assessing rotational displacement/instability and outlet views for vertical displacement/instability.

Displaced or unstable fractures require reduction and fixation. The condition of the soft tissues may limit the surgical options available especially in the presence of significant closed degloving or the Morel-Lavallée lesion.²⁵

Anterior ring. Injuries of the anterior ring are best treated by open reduction and internal fixation. The type of fixation used will be determined by the pattern of injury although the options available include plate fixation and column screws.

Anterior plating (Fig. 2) for a symphyseal diastasis normally only requires a Pfannenstiel-type incision and it

is common to discover that the insertion of the rectus abdominis muscles has been avulsed from the anterior aspect of the pubis, making dissection relatively straightforward.

Where injury to the anterior ring is complex and involves the pubic rami, additional access for longer plates may be required. Image-guided and/or navigated column screws (Fig. 3) may be used if the fracture is minimally displaced after closed reduction.

An external fixator (Figs 4 and 5) is a reasonable choice for definitive fixation in an unstable, multiply injured patient or when the soft tissues are badly damaged. A stable construct that we routinely use is a combination of supra-acetabular and iliac crest half-pins and a frame with low and high transverse bars. The higher bar can be removed if the patient requires a laparotomy and the lower bar can be removed when the patient is able to sit up.

Posterior ring. Injuries to the posterior ring include disruptions to the sacroiliac ligament, sacral fractures and iliac fractures in isolation or combination.

Disruptions to the sacroiliac ligament can be managed by closed reduction and percutaneous screw fixation (Figs 2 and 3), aiming the screw from posterior to anterior across the sacroiliac joint in order to reach the midline of the sacrum without emerging anteriorly. One or two screws can be used according to both preference and the assessment of stability. Percutaneous screws can also be placed bilaterally, although a posterior plate acting as a tension band through a two-incision approach can also be considered if the soft tissues are in a sufficiently good condition. Alternatively, one or two plates can be placed across the sacroiliac joint anteriorly, using the lateral window of an ilioinguinal approach.

Sacral fractures can be managed in a similar way if the fracture is acceptably positioned, although in this instance the screws should be positioned perpendicular to the fracture and of sufficient length (Fig. 2). Percutaneous screw fixation is hazardous because of the proximity of the nerve roots of the lumbosacral plexus; only surgeons with appropriate training and experience should undertake this technique. Open reduction and internal fixation may be required. The role of decompression is controversial. Anatomical reduction provides the best environment for nerve recovery but in order to reduce a sacral fracture adequately it is usually necessary to remove pieces of bone, thus decompression is achieved.

Iliac fractures are commonly associated with dislocations of the sacroiliac joint or the crescent fracture.²⁶ Depending on the subtype of crescent fracture, this situation can be managed either with percutaneous screws (Fig. 4) or by open reduction with fixation.²⁷

Outcome

Mortality. Early mortality in relation to fracture of the pelvis is due to associated injuries or catastrophic haemorrhage. About 10% of patients with haemodynamically unstable fractures of the pelvis will die.²⁸ For patients with pelvic and acetabular injury, two-thirds have other significant injuries to the skeleton or other body system.²⁹

An analysis of 63 033 trauma patients accepted that fractures of the pelvis is one of the many variables that contribute to the rise of mortality.³⁰ The odds ratio for mortality associated with fracture of the pelvis was approximately 2 and was similar to those associated with abdominal injury. However, haemodynamic shock, severe head injury and age ≥ 60 years had odds ratios for mortality greater than those associated with pelvic fracture.³⁰

A study of 102 patients with a bleeding fracture of the pelvis combined with severe associated injuries (AIS > 3)²⁹ revealed that 47 died within 24 hours of arrival and that 47% of deaths were because of haemorrhagic shock. Of the remainder, injury to the central nervous system was the next most common cause of death.³¹

Other recently published evidence suggests that the severity of associated injuries is a better predictor of mortality than the presence of an unstable fracture of the pelvis pattern.³²

Late mortality in relation to an unstable fracture of the pelvis is most commonly because of sepsis.¹³ One study of 830 fractures of the pelvis created by blunt trauma found five deaths from multiple organ failure in a group of 11 patients who developed sepsis; sepsis was defined as abscess formation in the subcutaneous tissues or muscle, diagnosed either by CT or at operation.¹³ These patients had multiple concomitant injuries and prolonged haemorrhagic shock, with a mean systolic blood pressure on arrival of 66 mmHg and a mean blood transfusion volume of 12.5 l in the first 20 hours.¹¹

Functional outcome. There is a significant discrepancy in the reporting of functional outcomes after fracture of the pelvis. Different authors have reported many factors associated with worse functional outcome including open fracture,²⁰ urological injury,²³ neurological injury,³³ fractures requiring open reduction and internal fixation,^{33,34} residual posterior displacement³⁵ and psychological problems.³⁶ Of these, the trauma surgeon can only influence the degree of residual displacement and the treatment method used. The aim is to reconstruct the pelvis to its pre-injury anatomical configuration where possible although there will be occasions when this is limited by the configuration of the fracture or by the physiology of the patient.

Suzuki et al³³ found that the Majeed score,³⁷ Iowa pelvic score³⁸ and Medical Outcomes Study Short Form 36-item Health Survey (SF-36)³⁹ are each altered after fracture of the pelvis and correlate closely with the presence of a neurological injury.

The Majeed score is a pelvic injury-specific functional assessment comprising seven items: pain, work, sitting, sexual intercourse, standing, unaided gait and walking distance. The Iowa pelvic score is also a pelvic injury-specific assessment comprising six items: activities of daily life, work history, pain, limping, visual pain line (visual analogue scale) and cosmesis. The SF-36 is a general health assessment survey with eight subscales including physical functioning, role physical, bodily pain and general health; these four make up the physical component.

The Majeed score and Iowa pelvic score both have a range between 0 and 100 in order of decreasing disability. In a study of 57 patients who had an unstable fracture of the pelvis, with a minimum follow-up of two years, the mean Majeed score was 79.7 and the mean Iowa pelvic score was 80.7.³³ The mean physical component of the SF-36 was 65.2 compared with a population norm of 78.6. The Majeed score and physical component of the SF-36 correlated with the presence of a neurological injury. The Iowa pelvic score correlated with the presence of a mental disorder, posterior displacement and neurological injury. In this study³³ there was no association found between long-term functional outcome and ISS, fracture location or fracture type.

Sexual dysfunction. Sexual dysfunction occurs in 61% of men after fracture of the pelvis. Disruption of the pubic symphysis is frequently associated with temporary erectile dysfunction. Metze, Tiemann and Josten⁴⁰ found that 19% had persistent erectile dysfunction. This appeared to be associated with higher energy injuries, such as distraction rather than compressive injuries, as well as in posterior ring disruptions.

Urological injury. Commonly associated urological injuries include urethral, corpus cavernosa, bladder and bladder neck injuries. Bladder injuries are usually extraperitoneal because of shearing forces, or as a result of direct laceration by a bone spicule. Complications of urethral injury are stricture, incontinence and impotence. The acute management of urethral injury depends on local expertise but early re-alignment may be possible and urological opinion should be sought as early as possible.⁴¹

Venous thromboembolism. High-risk trauma patients have an increased risk of deep-vein thrombosis (DVT) and pulmonary embolism. In a large series published in 2007,⁴² serial venous duplex scans were performed on 507 trauma patients with at least one risk factor for venous thromboembolism. Of 16 identified risk factors, only four had a higher incidence of DVT, with or without other risk factors: these were fracture of the pelvis, previous venous thromboembolism, spinal cord injury and significant head injury (AIS > 2). In 68% of patients DVT is asymptomatic and in 63% pulmonary embolism is silent.⁴²

Patients should commence low-molecular-weight-heparin (LWMH) without delay. This strategy reduced the incidence of proximal DVT to 10% in a cohort of 103 consecutive patients who were screened for this condition at ten to 14 days after surgery.⁴³ The incidence of DVT was only 3% where LWMH was started within 24 hours of injury.⁴³

A systematic review of thromboprophylaxis for fractures of the pelvis and acetabulum concluded that clinicians have limited data to guide their decisions about prophylaxis and suggested that well-designed clinical trials are still needed to prevent and detect venous thromboembolism in pelvic and acetabular trauma.⁴⁴

Our current practice is to use LMWH and compression stockings pre- and post-operatively until oral anticoagulation with warfarin reaches therapeutic levels. Patients are advised to remain on warfarin for three months.

The future

Nothing stands still in medicine or in the wider world. Trauma systems evolve, individual experience and corporate knowledge increases, legislation changes the behaviour of the population at risk and imaging, instrumentation and materials improve as technology advances. Pelvic anatomy will not change, and the challenges of first saving a life and then preventing deformity will remain.

Trauma centres may already have high speed, high-resolution CT scanners in the emergency department, as well as immediate access to angiographic embolisation. Recent

advances in critical care mean that patients are in better physiological condition at the time of surgery and can withstand longer operating times. However, these advances also mean that patients are surviving despite an injury burden that would previously have been considered fatal. This group will have more complications and a poorer functional outcome which will have both medical and economic implications.

Minimally invasive pelvic surgery is becoming more accurate through the use of computer navigation systems.⁴⁵ Both minimally invasive and open surgery might benefit from in-theatre CT devices in order to confirm the quality of fracture reduction and the position of implants.

Trauma systems vary according to trauma workload, financial resources, population density, the quantity and expertise of trauma personnel in the pre-hospital and hospital environments, distances to trauma units/centres, available modes of travel and numerous other medical, political, economic and social factors. The challenge for trauma surgeons is to understand, evolve and improve the ever-changing local environment in which they work, in order to maximise the benefits that can be offered to patients.

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