Pelvic fractures

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Abstract

Pelvic injuries have been increasing in incidence over the past 30 years carrying with them a significant risk of morbidity and also mortality. Patient survival from these injuries is increasing due to improved standards of care both pre-hospital and in hospital. They tend to occur in two distinct populations: young patients in high-energy road traffic collisions and older patients in low-energy injuries. Differentiating those that can be treated conservatively from those that would benefit from surgical stabilization, is based upon good clinical examination, appropriate radiological investigations and knowledge of classification systems. Stabilization for these patients may allow for earlier mobilization and less pain. In displaced or unstable injuries, surgical stabilization is essential to reduce and prevent mal-union, which is associated with poor patient outcome. Due to the significant bony displacement at the time of injury, the severe soft tissue injuries that accompany the bony injuries are often associated with non/mal-union and neurological and urogenital injuries. High-energy pelvic injuries, often have significant associated injures, and are at high risk of chronic pain and disability, thus present a significant challenge, and hence are best cared for in specialist centres, with a multi-disciplinary team approach.

Keywords Pelvic ring; trauma

Epidemiology and aetiology

Pelvic ring injuries are showing an increase in incidence over the past 30 years. This is due to increasing numbers of polytrauma patients that survive, and in particular improved patient survival from road traffic collisions (RTCs). This has translated into increased numbers of patients undergoing operative intervention for such injuries. The prevalence is reported to be between 20 and 37 per 100,000, and account for 3–8% of all skeletal fractures.[1] Data collected from the Trauma Audit Research Network (TARN) in the UK showed >54,000 pelvic ring injuries had been recorded for the past 6 years, 2013–19, which represents a significant burden on healthcare systems. The majority of these high-level trauma pelvic injuries are sustained in RTCs (62.9%), followed by falls (30.6%). They are the third most common cause of death in RTC, behind brain and thoracic injuries.

Anatomy

The pelvic ring is made up of the two innominate bones, joined anteriorly by the pubic symphysis, with sacrum interposing posteriorly. The articular surface of the sacrum is propeller like and slots into the opposing ilium. The sacroiliac joints are divided into two parts, with the lower portion used for articulation, covered in a thin layer of cartilage and then upper tuberosities. These joints allow for only a small amount of movement, which is limited due to the extensive and strong ligamentous structures. The bones themselves do not maintain the stability of the pelvic ring and rely on the surrounding soft tissue structures for this (Figure 1).

The pelvic ring can be divided into anterior and posterior with a line drawn through the acetabulum. The anterior component – pubic rami and pubis—gives 40% of the pelvic stiffness, with the pubic symphysis being made of opposing rami united by fibrocartilage and fibrous tissue. The other 60% comes from the posterior ligamentous complex and is made up of the anterior sacroiliac ligament (ASIL), posterior sacroiliac ligament (PSIL) and the interosseous sacroiliac ligament (ISIL) – which is the strongest in the human body. They get further stability from the iliolumbar ligament which attaches L5 to the lumbar crest.

Some additional strength may be gained from the sacrotuberous and sacrospinous ligaments, which make up the pelvic floor. This has been brought into question in recent years with cadaveric studies sectioning these and assessing horizontal and vertical instability. Sectioning these pelvic floor ligaments contributed little importance to the pelvic structure stability.[2] As well as axial stability and connection of the lower limbs to the spine, the pelvis provides protection to vital visceral and neurovascular structures.

Disruption of the pelvic ring must be thought of in the same way all fractures, as a broken bone within a soft tissue injury, with both needing consideration. In the pelvic ring, like any ring object, a break in one area should heighten suspicion of a further injury at another part. The inner anatomy confined by the bony and ligamentous architecture creates a cylindrical space. Blood loss into this space when the ring is intact, in theory, will tamponade as the pressure in the space rises above the pressure in the vessel bleeding. Blood loss, however, can increase dramatically when the ring is fractured, increasing pressure increases the volume and the tamponade effect is lost. When the ring is fractured, as illustrated in Figure 1, the radius of the pelvic ring will increase secondary to displacement, and massively increase the cross sectional area of the pelvis and therefore space to haemorrhage into (volume = area × depth of pelvic cavity).

Initial assessment and resuscitation

Pre-hospital protocols are essential to ensure the patient rapidly arrives at a hospital with the correct resources, for example the major trauma centre (MTC) system in UK. Interventions such as tranexamic acid within the first hour by the emergency response team and pelvic immobilization by application of a pelvic binder are essential to reduce the pelvic volume and cause a tamponade and thus coagulating effect. Closing the pelvis with these aids has been shown to decrease the overall mortality from 31% to 15%, and rate of death from exsanguination from 9% to 1%.[3]

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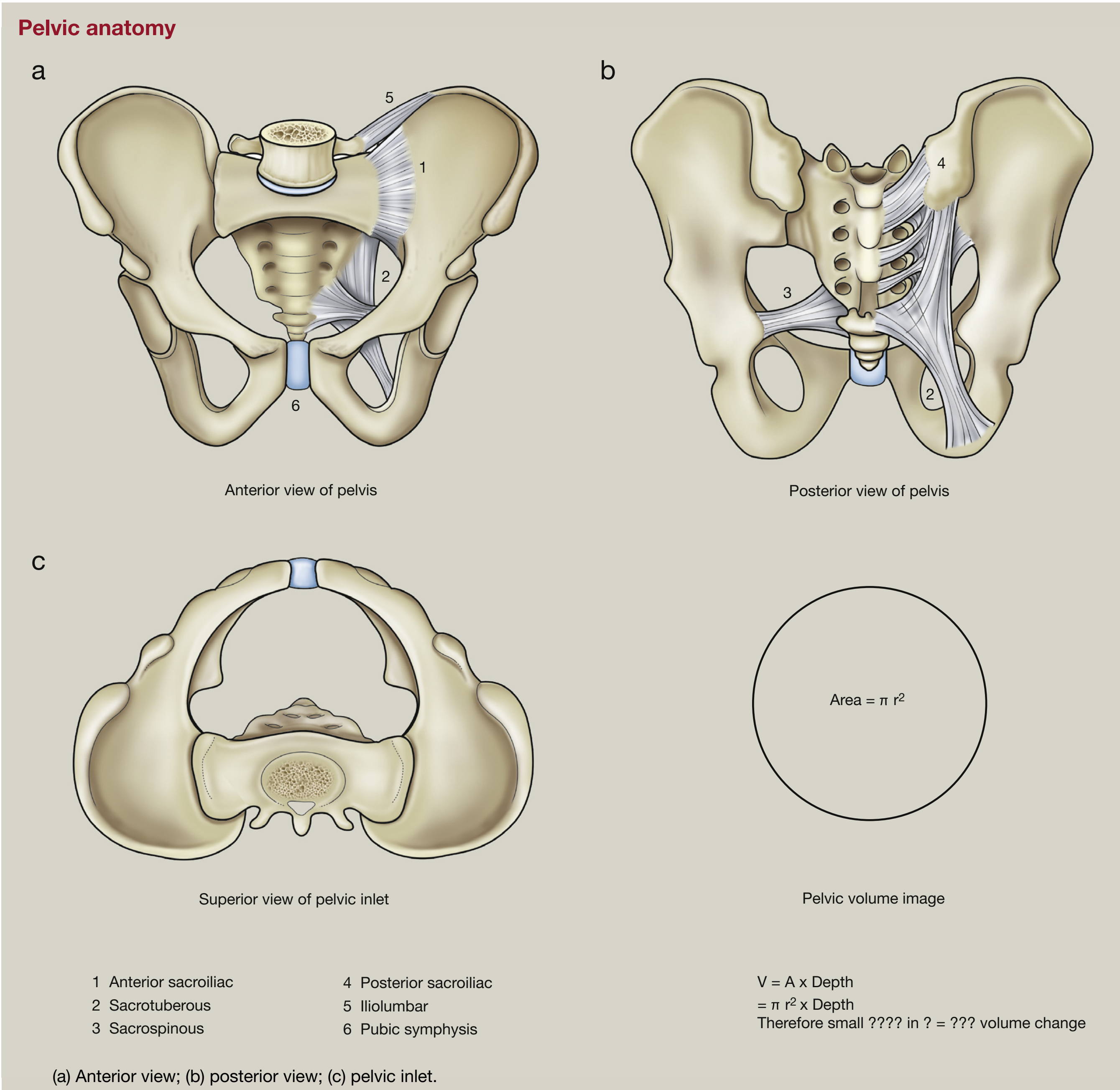

Figure 1 (**a**) Anterior view; (**b**) posterior view; (**c**) pelvic inlet.

Information gathered at the scene is also essential in helping assess biomechanics of injury for classification.

All patients with a history of trauma should be assessed following the ATLS protocol covering both primary and secondary survey, with attention being paid to the haemodynamic stability. This will help identify patients who are at risk of death and allows rapid assessment and intervention to be carried out sequentially. In the haemodynamically unstable patient the source of bleeding should be ascertained, looking for sources of overt catastrophic haemorrhage commonly following the concept of one on the floor, and four more – chest/abdomen/long bones and the pelvis. The retroperitoneum may hold up to 4 L of blood and will continue to fill until the intravascular pressure is overcome and tamponade occurs.

Part of the work up for the patients after initial assessment and intervention is whole body CT/pan scan for trauma patients. Within MTCs in the UK, the target is often set at 15 minutes from arrival at the emergency department (ED) to scanner. Injuries identified at the time of the initial assessment should also be imaged at this time, with this approach showing improved survival rates.[8] This imaging is used both to identify bleeding source and associated injuries. Something to keep in mind is that this imaging will show the resting position of the pelvis (often held within a binder) and not the position at the point of maximal

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A seven-point assessment

1. Does the patient have pelvic pain? Where?
2. Is there a leg length difference or is the resting position of one leg different from the other?
3. Are there neurological deficits involving sciatic, femoral, obturator or sacral nerves?
4. Is there bruising of the scrotum or perineum?
5. Is there blood at the urethral meatus?
6. A PR exam must be clearly documented. Is there blood around/in the rectum and is the prostate normal? Is anal tone and sensation intact?
7. Are there open wounds of the groin, buttock, lower back or perineum?

Box 1

impact/displacement. If a binder is on it may mask injuries to the pelvic ring, so there must be further images taken of the pelvis with the binder removed, once the patient is haemodynamically stable. It is estimated that a binder-off AP pelvis X-ray will identify an unstable pelvic ring injury in as many as 7% of those with initial normal reports of their trauma CT with the binder on (Figure 2).[15]

Associated injuries

After a primary survey and initiation of interventions, a secondary survey and concurrent assessment of the patient's response is started immediately. Studies have reported 12–62% of patients with pelvic fractures also have additional injuries to the chest/head/abdomen/axial skeleton/spine and perineum.[4] One study found 42% of patients had neurological injuries on initial presentation.[9]

Along with the systematic process of an ATLS secondary survey, we would recommend full assessment and documentation of all patients with suspected pelvic injuries in a systematic way (e.g. a seven-point assessment process for suspected pelvic injury — Box 1).

Imaging

Imaging is essential for diagnosis, classification and planning intervention for pelvic ring injuries. An AP pelvis X-ray should give a view of the bony pelvis from the superior iliac crest to the proximal femur, centred over the midpoint of the pubic symphysis and the ASIS.

Additional views are the inlet and outlet views of the pelvis. The inlet view will allow assessment in disruption of the true pelvis, as well as displacement of the pubic rami. This inlet view also allows assessment of AP translation, rotational widening or internal rotation deformity of any posterior disruption. It is captured with the patient supine, with the central ray angled 25–40 degrees caudal to the pelvic inlet, centred over the ASIS. When inserting sacroiliac (SI) screws, this inlet view is used to

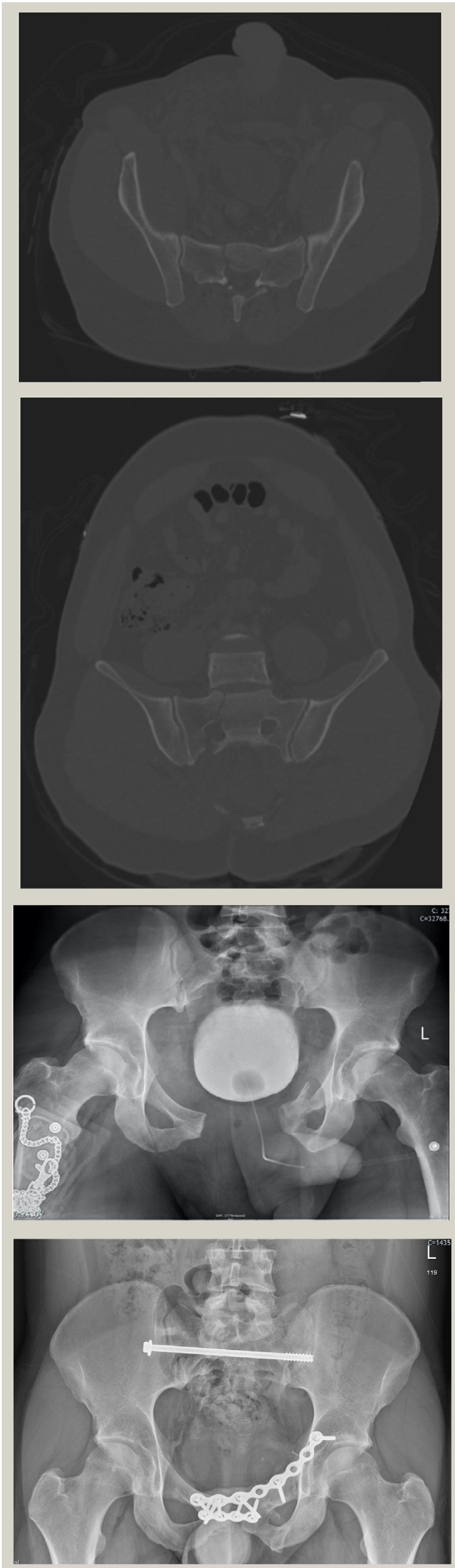

Figure 2 CT images of inlet and outlet views of pelvis, with binder on and X-ray with binder off for a LC3 injury post RTC, and image at one year post intervention with anterior ORIF and posterior SI screw.

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Young-Burgess Classification system and Tile Classification

Fracture type	Common characteristic	Differentiating characteristic
LC1	Transverse pubic rami fracture	Sacral compression on side of the impact
LC2	Transverse pubic rami fracture	Crescent fracture
LC3	Transverse pubic rami fracture	Contralateral open book
APC1	Symphyseal diastasis	Intact ASIL and PSIL
APC2	Symphyseal diastasis, or vertical pubic rami fracture	ASIL ruptured, but PSIL intact
APC3	Symphyseal diastasis, or vertical pubic rami fracture	Complete hemipelvis separation
VS	Symphyseal diastasis, or vertical pubic rami fracture	Vertical hemipelvis displacement either through SIJ, sacrum or ileum
CM	Vertical or transverse fracture of pubic rami	Combination of the above

Tile classification

Type A — stable
A1 — fractures not involving the ring — iliac wing, avulsions.
A2 — stable minimally displaced fractures of the ring
Type B — Rotationally unstable but vertically stable
B1 — open book
B2 — lateral compression, ipsilateral
B3 — Lateral compression, contralateral or bucket handle-type injury
Type C — Rotationally and vertically instable
C1 — unilateral
C2 — bilateral
C3 — associated with acetabular fracture

Table 1

guide anterior and posterior positioning through the sacral alar and sacral bodies.

Outlet views are used to assess both the rami and any vertical migration/instability of the hemipelvis. During SI screw insertion the outlet view of sacral foramina, ensures they can be avoided and allows superior/inferior positioning in the sacral alar and sacral bodies. It is performed with the patient supine and the X-ray centred over the pubic symphysis and angled cephalic 20—45 degrees, or whatever angle necessary to achieve a clear view of the sacral foramen.

For intraoperative pelvic imaging, it is also essential to have a true lateral image centred over S1. This will give an outline of the sacral promontory and the iliac cortical densities marking the anterosuperior surface of the ala. A true lateral is acquired when the sciatic notches and iliac cortical densities of either side superimpose on each other. A perfect view on this lateral will show the 'acorn sign', indicating the ideal corridor for trans-sacral screw insertion. This view can be used to get the starting point for insertion of the SI screw.[16]

Imaging should be examined closely preoperatively to assess for screw corridors and identify patients with sacral dysmorphism, as this will increase risk of iatrogenic injury if not accounted for. There are a number of variations to look out for in dysmorphism, each adding to the complexity of SI screw insertion:

- The lumbosacral disc is more caudal.
- The superior alar slope is steeper from posterior to anterior and medial to lateral.
- There is an indentation on the upper sacral alar cortical limit, compared to the second sacral segment.
- The upper most anterior sacral foramina are not round.

Injury classification

Two main systems are used to classify these injuries, which came from the work of Young and Burgess and Tile/Pennal.

The Young and Burgess classification is an anatomical classification based on the direction of the force applied to the pelvis to cause the injury. It is focused on pattern recognition and is good for visualization of the injury for the surgeon. It is broken into categories by the three plane forces which can be applied to the pelvis, anterior—posterior compression (APC), lateral compression (LC) and vertical shear (VS) (Table 1).

APC will force the pelvis into external rotation of either one or both iliac wings.

Lateral compression forces will cause internal rotation of the hemipelvis. Most injuries are due to lateral impact (can be as high as 80%). Lateral compression injuries are associated with higher rates of head injuries, whereas APC fractures are associated with intra-abdominal injuries.[7]

Vertical shear mechanism of injury is usually caused by a fall from height and usually landing on one leg. The vertical

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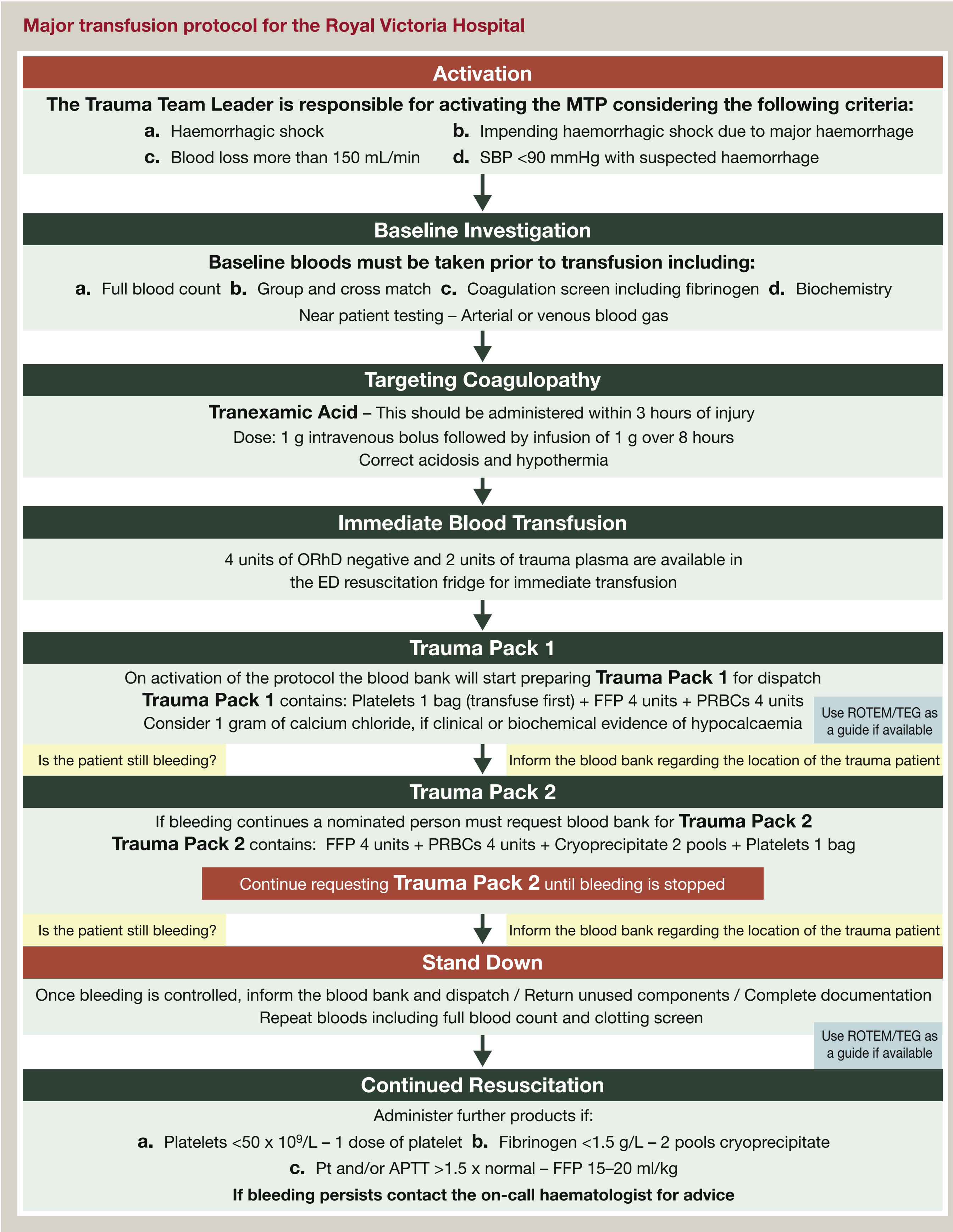

Figure 3

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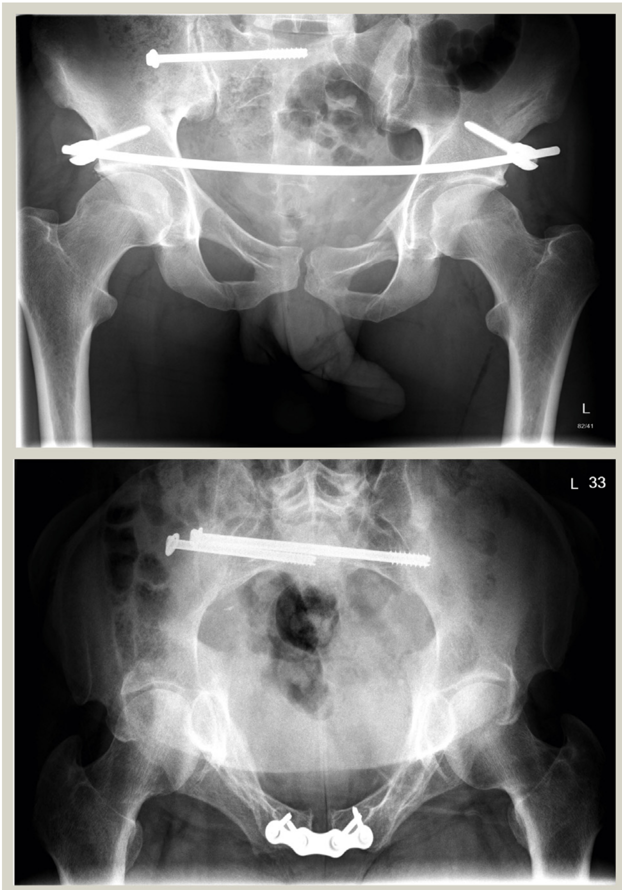

Figure 4 Use of anterior in-fix and posterior SI screw, and ORIF anteriorly with posterior trans-sacral screw.

displacement of the fracture is best appreciated on outlet and AP views of the pelvis.

This classification system has been shown to be useful in predicting the need for blood transfusion, with APC requiring more than LC and with the higher severity in each of the groups, i.e. LC3/APC3 requiring more than LC1/APC1. However, it has not been shown to be useful for prediction of mortality.

The Tile Classification system is useful for surgeons when deciding on whether and which surgical intervention is necessary for a particular pelvic injury. The classification focuses on whether the broken pelvis is stable to withstand forces if they were applied in either a rotational or vertical orientation.

Tile described that a type A injury to the pelvis could be stable to both rotational and vertical forces. A type B injury would be partially stable, in that it could withstand vertical forces but was susceptible to rotational forces. A type C pelvic injury was completely unstable to both rotational and vertical forces. Type A and B make up a majority of pelvic injuries.

The Denis classification is also used for sacral fractures and breaks the sacrum into three zones dependant on vertical fracture position in relation to the sacral foramina (zone 1 – lateral to; zone 2 – through; zone 3 – medial to). Neurological injury risk increases from zone 1 to 3. Bilateral vertically orientated sacral fractures can also be associated with transverse fractures, resulting in 'U'- or 'H'-shaped patterns, reflecting dissociation between the pelvis and the spine (lumbar–pelvic instability). This is a highly unstable fracture pattern which often requires fixation. It is most easily appreciated by assessing the sagittal reconstructions of a CT scan. A high suspicion is required to look for these when bilateral sacral fractures are identified.

Treatments

Haemorrhage control

Bleeding in pelvic fractures is usually venous (>90%), but can be multifactorial, from the cancellous bone, retroperitoneal venous plexus and intra-pelvic arterial system. Damage to the internal iliac artery accounts for up to 25% of haemodynamically unstable pelvic injuries.[13] Assessment and determination of the bleeding point is essential as a significant proportion of mortality in pelvic trauma is attributed to persistent bleeding.

Assessment of haemodynamic stability is achieved through identifying physiological parameters, allowing grading of shock, with assessment of patient cerebration/end organ perfusion and ability to respond will give ques on blood loss and need for initiation of the major transfusion protocol. Predictors of significant bleeding are a haematocrit of less than 30, heart rate over 130 (grade 3 shock – blood loss of 1.5–2 L), displaced obturator ring fractures and symphyseal diastasis greater than 1 cm.[13]

Knowledge of classification systems is essential to guiding assessment in relation to risk of significant bleeding, with APC and VS injuries having higher risk of significant blood loss.

Reassessment after any intervention is needed to identify the type of 'responder'. Responders who normalize rapidly with administration of a crystalloid bolus of 20 ml/kg will usually be in grade 1 or 2 shock; however, in grade 3 or 4 patients who are haemodynamically unstable in the ED, 'like-for-like' replacement is advocated with the major transfusion protocol and a typical ratio of 1:1:1 blood products. Time-limited permissive hypotension, meaning avoidance of artificial systolic BP >100 mmHg, is now advocated to allow clot formation and reduce overall blood volume loss. Figure 3 shows an example of the major transfusion protocol for the Royal Victoria Hospital Major Trauma Centre in Northern Ireland.

Polytraumatized patients presenting with haemodynamic instability are at risk of developing 'triad of death', of being coagulopathic, hypothermic and acidotic. Presence of these clinical parameters carries with it an overall mortality of around 50%. Coagulopathy carries the most significant weight in this.

Algorithms should be in place to identify and address patients who do not respond to the above measures. Such protocols fall under the remit of damage control surgery (DCS), the aim of which is to enable resuscitation of the patient for survival and delay definitive care until the patient is stable. The four main components of this are.

- haemorrhage control – either by angiography or pelvic packing
- decompression of compartments
- decontamination of wounds and ruptured viscera
- fracture splintage.

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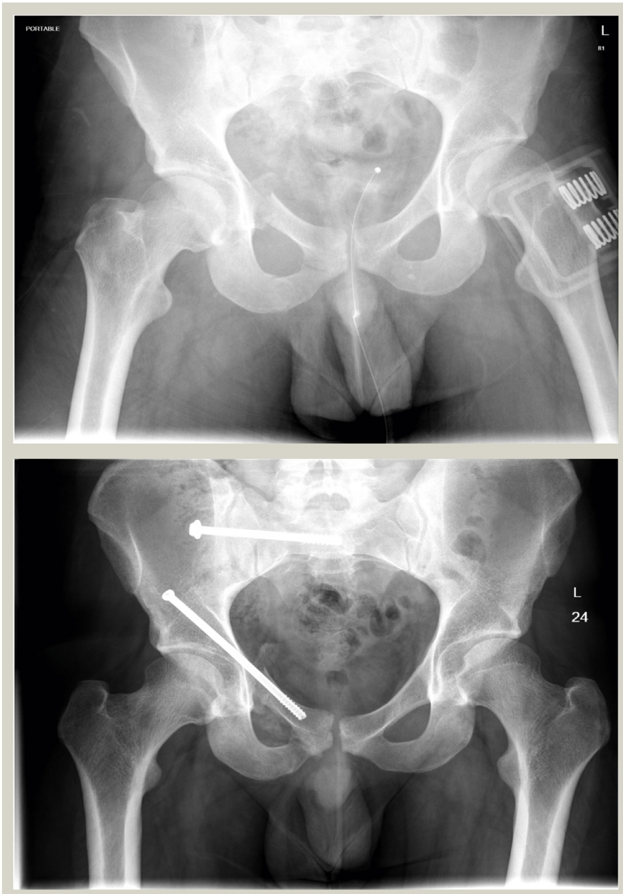

Figure 5 Percutaneous screw fixation of superior pubic rami and SI screw.

The decision between angiography and pelvic packing is often debated at international trauma meetings, and each unit needs to take into consideration the resources available and have an algorithm for management of non-responding haemodynamically unstable pelvic fractures. Pelvic packing may be the choice over angiography if the patient needs to attend theatre for other interventions or the patient is in extremis. This should be quick and be performed through a lower abdominal laparotomy wound. Sound application of stabilization device is necessary prior to packing, so packing is into a closed space and will therefore be effective. Angiography may be chosen if resuscitation and temporary pelvic stabilization measures failed or the patient becomes haemodynamically unstable within hours of initial successful resuscitation, local guidelines should be followed for this.

Temporary fixation in patients with pelvic fractures is essential for haemorrhage control and pain relief of the patient. They act by reducing the pelvic volume and allowing tamponade of blood. Folded bed sheets, binders, c-clamps (placed on the trochanters), resuscitation SI screws, and external fixators can all be used to achieve this. They all act to medialize the displaced hemipelvis. Sheets and binders compress indirectly via the greater trochanters and the addition of internally rotating the legs will help with closing an 'open book' pelvis.

Definitive intervention

For definitive pelvic ring fixation, there are three basic caveats:

- With complete instability of the posterior ring, anterior fixation alone is not enough.
- With posterior rotational and vertical instability, posterior fixation should be augmented with anterior stabilization.
- With partial (rotational) instability – posterior SI ligaments intact, anterior fixation alone may be sufficient.[7]

Long-term outcomes are improved when anatomical reduction of the displacement of the posterior ring is achieved, following SI complex disruption.

The mantra of always fixing the back first has now been relaxed in some instances. However, fixation of the anterior pelvis should only be undertaken prior to posterior, when it is confirmed that the anterior reduction is associated with anatomical posterior alignment/reduction, as it has been shown that rigid anterior fixation may limit later posterior reduction.[14]

Recent studies have shown occult injuries not diagnosed from CT and initial imaging can lead to poor functional outcomes for patients. The true role for examination under anaesthesia (EUA) of pelvic ring injuries to identify instability is still evolving. In a recent study, patients with previously presumed potentially stable pelvic fractures, were taken to theatre for examination under anaesthetic and dynamic stress fluoroscopy. This revealed radiographic instability in 50% of APC-1 injuries, 39% in APC-2 and 37% of LC-1 injuries.[14] This suggests that there may be a role for EUA and dynamic fluoroscopy in patients with potentially stable injures that are a concern for conservative management due to pain or the risk of fracture displacement.

Anterior fixation can be achieved in one of four ways:

- open reduction and internal fixation (ORIF)
- percutaneous screws
- external fixation
- internal fixator (Infix) (Figure 4).

Studies have shown no difference in these augments. 'Infix' frames, tend to be uncomfortable for patients with a low BMI, and there is also the issue of needing a further intervention to remove the device. They do have a lower risk of infection and are easy to tolerate for the majority of patients.

Percutaneous fixation of the pubic rami (Figure 5) carries the benefit of lower intraoperative blood loss and less tissue damage; however, the fracture must be amenable to closed or percutaneous reduction. A high level of knowledge of intraoperative fluoroscopy is needed to safely place guidewires for cannulated screws. This is ideally done within the first 5 days, and waiting longer than this increases the need for open reduction, due to difficulty with fracture reduction.

Posterior fixation: Percutaneous screws are used in a majority of cases when adequate reduction is achieved. Open reduction is still, however, required when anatomy cannot be restored or nerve injury is present and decompression required. Lumbar–pelvic fixation is reserved for cases where severe vertical

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instability is present initially and or in revision cases where there has been failure and migration of initial posterior fixation.

Careful documentation of neurological status is required preoperatively and postoperatively for all sacral fractures. It is possible in highly comminuted sacral fractures, in Dennis zone 2, to over-compress the fracture site over the exiting nerve roots when using partially threaded screws. It is our preference to watch screw insertion and compression of these fractures on the inlet fluoroscopy view and aim to recreate the contour of the contralateral sacral alar anatomy and not over compress.

Outcomes

Deaths associated with trauma patients occur in a bimodal distribution now more so than trimodal due to improved resuscitation and critical care.[6] Pelvic ring injuries have a mortality rate ranging between 3% and 50%. Mortality is mainly attributed to associated injuries and high Injury Severity Score (ISS).[1] The presence of head and neck injuries as well as hypotension/shock are key associations with increasing risk of mortality. These associated injuries, along with higher ISS, are shown to have a linear correlation with days of hospitalization, outcome and the number of operative interventions required.[4] There is also a direct correlation drawn between mortality rate and injury severity score, age and transfusion requirement.[5]

In the younger population there is a preponderance of male patients, mostly due to high-energy blunt force trauma. The opposite is true in the older population, with a preponderance for low-energy falls in female patients. The mortality rate in these groups is similar, with most deaths happening prehospital, and for both groups being attributed to major haemorrhage.

Mortality rate is up to 50% in some studies for compound pelvic injuries. Thankfully these account only for 2–4% of the overall number for pelvic fractures.[4] Improved mortality rates for this group of patients has been associated with standardization and centralization of the treatment of major trauma and trauma protocols written in BOAST guidelines. These focus on early detection from modern imaging techniques and careful examination, including documented PR examination for all patients and faecal diversion when appropriate.

Outcomes from fixation directly correlated with the quality of reduction achieved, with adverse outcomes also being associated with lumbosacral plexus or associated injuries. Fractures of the posterior ring tend to do better than SI dislocations as it is thought that bone healing will restore the initial strength and stability faster than ligamentous healing. In patients with chronic pain post SI screw, removal of hardware improved the pain in 88% of the patients.[17] Even with these interventions, chronic pelvic pain and disability is a significant issue and is multifactorial. The early contact for polytrauma patients with psychology and rehabilitation support services in multidisciplinary team (MDT) approach is a new aim in MTCs across the UK.

Genitourinary injuries

Any displacement of the pelvic ring will risk damage to the genitourinary system, with every 1 mm in pubic diastasis or inferomedial pubic bone fracture fragment displacement being associated with a 10% increase in urethral injury.[10]

Bladder trauma with pelvic injuries is common and can occur in up to 25% of pelvic fractures. The mortality rate associated with bladder rupture being around 16%, which is in turn often due to the multiplicity of other associated injuries.[11] Assessment and management of this should be carried out in accordance with the BOAST guidelines for urological trauma, with Urology input for confirmed injuries.

With more patients surviving following severe pelvic trauma with the improvements in all aspects of acute care, the persistent disabilities that a patient has to live with are now becoming a focus for research and treatment. Sexual dysfunction post pelvic trauma is significantly debilitating and the reported prevalence ranges from 5% to 44%.[12] The aetiology of this can be multifactorial, but has been associated with greater displacement and instability. This may be due to nerve damage or neuropraxia of the sympathetic truck and lumbosacral plexus. Patients with an associated transverse process fracture of the fifth lumbar vertebrae had a higher risk of sexual dysfunction. This dysfunction includes erectile dysfunction, pelvic pain, ejaculatory dysfunction and sensory problems. All having both physical and psychological effects on the patient and family, necessitating the need for early counselling, patient information and again an MDT approach.[12]

Functional outcomes scores

How we measure the outcome for pelvic trauma patients is now the subject of much interest. Patient function post trauma can be assessed using a number of both general and injury-specific quality-of-life indicators. General quality-of-life scoring systems like the SF 36, EQ-5D-5L, and PROMIS scoring systems are examples often used. Pelvic-specific scoring systems such as IOWA, MAJEED and ORLANDO are common, but not as reliable in capturing the psychosocial aspect of the trauma as well as physical disabilities.

Future research

Future work will have to acknowledge the limitations of existing pelvic specific outcome measures, and develop and validate new scores to test treatment.

Regarding best treatments for specific injuries, some studies are currently underway in the UK looking at outcomes of LC1 injuries in two different population groups. The L1FE trial is a multicentre randomized controlled trial (RCT) which will assess outcomes in patients over 60 years sustaining injury from a low-energy fall. They will be randomized to either operative intervention (Anterior INFIX) or non-operative treatment groups, with primary outcome being patient focused and based on quality of life scores.

TULIP is a UK MTC-based RCT studying the outcome for LC1 injuries sustained from high-energy injuries in patients over 16 years of age. This study will again assess the functional outcome for those patients treated surgically compared to conservatively.

Conclusion

Pelvic fractures are low in prevalence but are associated with polytraumatized patients who are potentially unstable and at risk of death and disability. Major trauma protocols in place across

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the UK to transport these patients to specialized centres for assessment, and concurrent resuscitation by teams specialized in these injuries, have significantly improved survival rates. Protocols should be in place for haemodynamically unstable patients who do not respond to primary resuscitation measures. Surgical stabilization for these patients may allow for earlier mobilization and less pain. Surgical reduction of deformity and preventing mal-union has also been shown to improve outcome. As more of these patients survive to discharge from hospital, they have ongoing complex care needs requiring input from all aspects of the physical and psychosocial model. ◆

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