MINI-SYMPOSIUM: PELVIC FRACTURES

(v) Delayed reconstruction of pelvic fractures

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Summary
Unstable pelvic fractures are usually the result of high energy trauma and 70% of patients have other significant injuries. The initial priorities are to identify all injuries and stabilise the patient. Delayed reconstruction should be considered in patients with unstable fracture patterns (lateral compression, anteroposterior compression or vertical shear) that are displaced. Open reduction and internal fixation with plating techniques remains the most commonly used surgical technique. However, combinations of internal fixation, percutaneous fixation and external fixation are also possible and have a role to play. The ilioinguinal and Pfannestiel approaches are the most frequently employed. Posterior approaches are generally reserved for displaced sacral fractures. Percutaneous fixation can be used for fractures where closed reduction has been achieved. Sacroiliac screws and the medullary ramus screw are the two common techniques. Anatomical results are superior with internal fixation compared to non-operative treatment or external fixation. Late morbidity rates remain high due to persistent pelvic pain and associated visceral injury.

Introduction
Pelvic ring disruptions are rare injuries but present a significant challenge for the treating orthopaedic surgeon. The majority of pelvic ring disruptions occur as a result of high energy trauma and 70% of patients have other serious injuries. The management of associated injuries may have a significant influence on the emergency and definitive management of the pelvic fracture. Patients who are haemodynamically unstable with other life-threatening injuries at the time of admission may be too unfit to undergo definitive internal fixation of the pelvic ring disruption. Application of pelvic external fixation has been the most commonly employed urgent orthopaedic intervention in the acute setting. However, there are drawbacks to use of external fixation as definitive mode of treatment. They are cumbersome, poorly tolerated by patients and are associated with a high rate of malunion, particularly with more unstable fracture patterns. Once the patient is stabilised there is therefore a need to consider delayed reconstruction. This article reviews the current indications for pelvic reconstruction, the techniques available and aspects of outcome, including complications and function.
Clinical assessment

Initial clinical assessment should be in accordance with ATLS guidelines. This facilitates a thorough evaluation of the patient and identification of those with other injuries. As part of the secondary survey a careful examination of the perineum, rectum and vagina is required to identify wounds that communicate with the fracture. Open pelvic fractures are found in 5–10% of cases. Although rare they are associated with a significantly higher morbidity and mortality and early identification of open wounds is essential to institute early appropriate treatment, which may include a defunctioning colostomy.

Once the patient is stabilised some other clinical aspects need to be taken into account when considering definitive fixation. A careful assessment of the skin condition of the pelvis is necessary to determine if a surgical approach can be safely undertaken. Skin in the lateral and posterior aspect of the pelvis may be extensively contused and degloved and surgical incisions in these circumstances have an increased risk of infection and wound breakdown. Contamination of external fixation pin-tracks or supra-pubic catheter sites may necessitate altered planning of incisions or consideration of alternative approaches.

A careful neurological assessment should be undertaken before definitive fixation if possible. This will allow the surgeon to document any pre-existing neurological deficit which might otherwise be attributed to the surgical procedure. The status of the bladder and urethra should have been established as part of the initial assessment but if there is any doubt a retrograde urethrogram and cystogram should be performed. The presence and extent of any apparent leg-length discrepancy should be documented, as this may influence the decision to operate or not. Rectal, vaginal and perineal examinations should have been carried out in the acute phase of treatment but may need to be repeated if there is any clinical doubt regarding the findings. Ideally definitive fixation should be undertaken in a haemodynamically stable patient, with urethral catheter drainage of the bladder and with no other adjacent contaminated wounds. This is not always possible in practice and therefore surgical decisions may have to be modified depending on the clinical situation.

Radiographic assessment

Plain AP radiographs will identify most pelvic fractures and allow classification of the injury. Additional imaging helps more accurate classification and detection of the pathology in more detail. The inlet and outlet views allow identification of subtle degrees of superior and posterior migration that may not be evident on the AP view (Fig. 1). The outlet view also shows the sacral foramina more clearly and may help identify sacral fractures in the transforamenal region which may be difficult to detect on the AP view. Patients with associated acetabular fractures should have additional iliac oblique and obturator oblique views if possible. In patients who are haemodynamically unstable at the time of presentation, these additional views may have to be deferred until the patient is stabilised.

The CT scan is the most useful additional investigation in these patients. The majority of patients will require imaging from the head down to the level of the pubic symphysis. This is the most accurate way of identifying associated head, thoracic and intra-abdominal trauma. The scan will also define accurately the extent of the posterior pelvic ring disruption. It is particularly useful in

Figure 1 (a) Inlet view of pelvic fracture showing posterior displacement of right hemipelvis with disruption of pubic symphysis; (b) outlet view showing sacral foramina. Note the superior displacement of the right hemipelvis with incongruity of the symphysis and a fracture through the iliac wing.
showing the morphology of sacral fractures, which may be difficult to discern on plain radiographs (Fig. 2). More sophisticated imaging, including two-dimensional and three-dimensional reconstructions, is most useful for imaging acetabular fractures but is not mandatory for most pelvic fractures.

Some additional views of the pelvis are useful during surgical reconstruction and can be obtained with image intensification. For percutaneous fixation of sacroiliac dislocation or sacral fractures, a true lateral view of the sacrum is required during surgery to ensure correct screw placement in a safe zone. For insertion of the medullary ramus screw combination views of the iliac oblique and inlet view and the obturator oblique and the outlet view are required.

**Classification**

The most commonly used classification systems are the AO system\(^1\) and the mechanistic classification of Young and Burgess.\(^2\)–\(^4\) The AO classification patterns comprise stable patterns (type A), rotationally unstable (type B) or vertically unstable patterns (type C). Rotationally unstable patterns are divided into unilateral open book patterns (B1), unilateral lateral compression (B2) or combinations involving both sides of the pelvic ring (B3). Type C vertically unstable injuries may involve one side of the pelvis (type C1), or both sides (C2 and C3). The C2 pattern is a vertical unstable hemipelvis on one side with the contralateral side rotationally unstable. Type C3 injuries are bilateral vertically unstable injuries.

The mechanistic classification is less comprehensive but relates the mechanism of injury to the fracture pattern and the likely associated soft tissue injuries. The main categories are lateral compression (LC), anteroposterior compression (APC, “open book” pattern) and vertical shear (VS). Fractures with mixed patterns of injuries are classified as combined mechanical injuries (CMI). LC injuries are associated with visceral injuries. APC patterns increase pelvic volume and hypotension is common due to pelvic haemorrhage. Vertical shear injuries are the most unstable pattern and are associated with visceral trauma, hypotension and pelvic neurological injury.

**Options for reconstruction**

**Non-operative management**

Many pelvic ring fractures do not require surgical reconstruction. Lateral compression fractures are the most common variety of pelvic ring disruption. In many of these fractures there is minimal distortion of the pelvic ring. In addition, this pattern of injury does not disrupt the internal pelvic ligaments (sacrospinous and sacrotuberous) or the posterior ligaments so late displacement is rare. APC (open book) injuries with less than 2.5 cm symphyseal diastasis are also inherently stable since this degree of distraction is not associated with any significant posterior or internal pelvic ligament injury. These injuries can be treated non-operatively. If other injuries allow, patients can be mobilised weight-bearing as tolerated, often with crutches. Patients with stable unilateral pelvic fractures can be allowed mobilise with crutches fully weight-bearing on the intact side. If non-operative treatment is chosen repeat radiographs on two occasions within a month of injury are advisable to detect any loss of position that might warrant consideration of operative intervention. Progression to full-weight bearing can usually begin at 6–8 weeks assuming there is on radiographic evidence of callus formation.

**Operative management**

There are several options available for definitive surgical management of an unstable pelvis. These include external fixation alone, combined external fixation and internal fixation, sequential external fixation followed by internal fixation or definitive...
internal fixation, sometimes by percutaneous techniques. The indications for operative treatment are summarised in Table 1. Fixation needs to be considered for any pelvic ring disruption with significant displacement. The degree of displacement considered acceptable depends to a large extent on the pattern of injury.

As already indicated most lateral compression patterns can be treated non-operatively. However, some variations of this injury do occur that merit surgical intervention. Lateral compression fractures may be associated with considerable rotation of one hemipelvis in relation to the other and this may result in the development of an apparent leg-length discrepancy. Although the anterior lesion in most lateral compression disruptions is an isolated or multiple pubic ramus fractures, disruption of the pubic symphysis with overlapping of the symphysis (a “locked symphysis”) can occur (Fig. 3). Displacement of the ramus fractures in lateral compression injuries is normally not severe enough to merit fixation but a tilt fracture of the pubic ramus is occasionally seen. These fractures involve a fracture of the superior and inferior pubic ramus laterally with disruption of the symphysis medially (Fig. 4). The symphyseal-ramus fragment then protrudes into the perineum. This is a particular problem in female patients where it will lead to late pain and dyspareunia later. Finally the iliac wing component of a lateral compression fracture may displace considerably with a risk of non-union (Fig. 5). In any of these situations internal fixation of the fracture is preferable to non-operative treatment.

For APC (open book) injuries, most pelvic surgeons consider internal or external fixation when the degree of diastasis exceeds 2.5 cm. With this degree of displacement, there is usually a significant disruption of the anterior sacroiliac ligaments and the internal ligaments, allowing for rotational instability. Vertical shear injuries are often associated with marked anterior and posterior displacement. In general displacement in any plane exceeding 1 cm is considered an indication for fixation. These injuries are very variable in morphology. Occasionally there may be anterior ramus fractures and a posterior transforaminal sacral fracture with limited displacement. Non-operative treatment can be considered in this situation. Vertical shear patterns with symphyseal disruption and/or sacroiliac dislocation are highly unstable patterns and are not suitable for non-operative management.
Acute management

Approximately 50% of patients with unstable pelvic ring disruptions are haemodynamically unstable at the time of presentation. Internal fixation at this stage is often impractical. The most common mode of pelvic stabilisation is application of external fixation. The rationale for use of external fixation is a reduction in the volume of the pelvic cavity to tamponade haemorrhage and to achieve reduction of the pelvic ring conferring some skeletal stability. The use of external fixation has been reported to improve survival rates but its use remains controversial and there are some drawbacks associated with application of a frame on the pelvis. Technical errors in frame application are common, particularly in surgeons with limited experience of pelvic ring disruptions. The commonest error is imperfect pin placement in the iliac wing, which may result in early loosening and loss of reduction. More seriously application of a frame to the anterior pelvis may actually increase the extent of posterior displacement in vertical shear patterns.

In general acute external fixation is best avoided if the patient is haemodynamically stable, irrespective of the fracture pattern. Pin track infection may compromise surgical exposures required for delayed reconstruction. There are other drawbacks to the use of external fixation for definitive management. External fixation is biomechanically inferior to rigid internal fixation. The devices are cumbersome and mobilisation of the patient with a pelvic external fixator in situ is difficult. External fixation alone for vertical shear fractures is associated with malunion rates of up to 95% and if possible should not be used as the definitive treatment. However, in a proportion of patients the circumstances favouring successful internal fixation may never occur. In patients with open fractures contaminating the perineum with the presence of a colostomy the risk of undertaking fixation may be too high. Some patients remain too ill to withstand major open surgery and in elderly patients osteoporosis is associated with an increased risk of fixation failure.

Timing of surgery

The timing of definitive pelvic fixation depends on achieving haemodynamic stability, treatment of other life-threatening injury and correction of any associated coagulopathy. This frequently occupies the first 24–48 h following admission. At that stage definitive reconstruction can be considered, assuming the haematological indices are normal and coagulopathy is reversed. Ideally definitive stabilisation of the pelvic ring should be achieved within 5–7 days. Delay beyond this time frame increases the technical difficulty of the surgery. Closed reduction and percutaneous fixation becomes less feasible as the delay to surgery increases. While awaiting an appropriate window of opportunity to perform definitive fixation, traction or external fixation (or both) can be used to maintain reduction. However, as already indicated, external

Figure 4 Vertical shear injury with sacroiliac disruption and pubic symphysis disruption. There was an additional fracture of the superior and inferior pubic ramus on the right side with displacement of the right symphyseal segment into the perineum—a tilt fracture.

Figure 5 Lateral compression injury shown in Fig. 3. This fracture was associated with a displaced crescent fracture of the iliac wing and a disruption of the pubic symphysis. Nonoperative treatment would have been associated with a poor outcome and a significant risk of non-union. Position after internal fixation with plate fixation of iliac wing and symphysis.
fixation may compromise subsequent surgical access by pin track infection and should be avoided unless there is persistent haemodynamic instability during the acute phase of treatment.

**Surgical approaches**

Prior to surgery a urinary catheter should be inserted in all patients to minimise the risk of bladder injury and to monitor urinary output. Anterior and posterior lesions may be present and the approach chosen depends on the pattern of injury and fixation techniques selected.

Pubic symphyseal disruptions are approached using the Pfannenstiel incision. A horizontal incision is made 2 cm above the level of the pubic symphysis. After division of subcutaneous tissue the rectus sheath is identified. In most symphyseal disruptions, the rectus abdominis on one side is avulsed with extensive stripping of the symphysis, which simplifies the surgical exposure.

Fractures of the pubic ramus are not accessible for plate fixation using the Pfannenstiel incision and an iliourginal approach is required. Although this is a more extensive surgical procedure it allows simultaneous access to the iliac wing and sacroiliac joint which is an advantage if anterior and posterior elements of pelvic disruption need to be addressed. The approach will allow fixation of pubic ramus fractures, iliac wing fractures and sacroiliac dislocations. Sacral fractures are too medial to be fixed via this exposure.

The pelvis is approached via an incision along the iliac wing extending medially to the pubic symphysis. The inner table of the iliac wing is exposed by subperisteal elevation of the iliopsoas muscle. The external oblique aponeurosis is divided in line with the incision and the inguinal ligament is split along its length. Access to the pelvis is gained via three surgical “windows”. In the lateral window the iliac wing is accessible. A second interval is developed between the iliopsoas and femoral vessels giving access to the iliopectineal eminence, the pelvic brim and quadrilateral plate. The femoral nerve remains on the surface of the iliopsoas. Between the iliopsoas and femoral vessels is the iliopsectineal fascia which runs down onto the brim of the pelvis and must be divided to make full use of this interval. The third and most medial window is developed between the femoral vessels and spermatic cord. This allows access to the superior pubic ramus and symphysis.

Additional exposures may be required for posterior ring disruptions, particularly for sacral fractures. These can be approached via posterior longitudinal incisions situated adjacent to the posterior superior iliac spine. The incision can be made medial to the spine if the lesion is a sacral fracture but lateral if the lesion involves the iliac wing. A subperisteal exposure can be made of the iliac wing or the posterior aspect of sacrum. Bilateral incisions can be used for bilateral posterior disruptions. This approach has a number of advantages—sacroiliac dislocations and sacral fractures can be accessed via this exposure. For patients with sacral nerve root injury, decompression is possible although the benefit of this latter procedure remains uncertain. The main drawback is the requirement for prone or lateral positioning of the patient. Simultaneous access to the anterior lesion is therefore not possible with prone positioning and obviously external fixation has to be removed. The other problems with these incisions are soft tissue complications. Degloving and extensive bruising of the posterior pelvic skin is a common accompaniment of these major injuries and increases the risk of open surgery, with attendant risks of wound breakdown and infection.

Percutaneous fixation has become popular for fixation of some types of pelvic ring disruption. These techniques have some particular advantages for these patients. It avoids the need for extensive exposures, which is an advantage in patients who may have other major injuries. Blood loss is minimal and the risk of wound infection is negligible. Percutaneous iliosacral screws and the medullary ramus screw are the most common techniques used.

Percutaneous iliosacral screws can be used for sacral fractures and sacroiliac dislocations. They can be used for patients with bilateral posterior disruptions, which greatly limits the degree of soft tissue dissection. The supine position is preferred if possible, since simultaneous anterior access to the pelvis is possible. The patient is placed on a radiolucent table in order to obtain inlet, outlet and lateral sacral views. The procedure is facilitated by a small midline support behind the sacrum to elevate the pelvis slightly which makes the entry point easier to obtain. The starting point is chosen with the lateral sacral view to identify the body of S1. A curved sclerotic line denotes the slope of the ala and care must be taken to remain below this to avoid penetration above the ala and the risk of L5 root injury. A guide wire is introduced and advanced with the use of the inlet and outlet views to ensure correct placement into the body of S1, avoiding the S1 formen and anterior or posterior malposition of the screw.

The medullary ramus screw may be inserted from the antegrade approach via the iliac wing or the
A retrograde approach with an entry point adjacent to the pubic ramus. Two views are necessary to guide placement of this screw. One is a combination of the outlet and obturator oblique view and the other is a combination of the inlet and iliac oblique view. These two views allow visualisation of the superior pubic ramus in two different planes to ensure the screw remains within the medullary canal. The main practical limitations of this type of surgery are the difficulty in achieving a satisfactory closed reduction and the need for high quality imaging to minimise the risk of neurovascular injury.

Computer CT guided pelvic surgery is currently being developed. Current systems are evolving but at the moment remain expensive and time consuming to use. There is no widely available system at present. In the future improved methods of closed reduction using percutaneous clamps and traction with more user-friendly imaging technology may increase the applicability of this approach.

Reduction and fixation techniques

Most procedures are performed with the patient in the supine position. Intraoperative screening is essential in all cases to verify fracture reduction and guide implant placement. The patient therefore needs to be placed on a table that allows visualisation of the pelvic using intraoperative radiography. Some tables have the advantage of allowing application of skeletal traction, which may facilitate reduction.

For rotationally unstable patterns it may be sufficient to stabilise the anterior disruption alone but in vertical shear injuries with displacement anterior and posterior stabilisation is necessary. Posterior approaches to the sacrum or sacroiliac joint require the patient to be positioned prone.

Pubic symphysis disruption

Surgical treatment of pubic symphysis diastasis can be achieved by internal or external fixation. Internal fixation has a number of advantages. Biomechanically it is stronger than external fixation. The use of an external frame is associated with a less precise reduction and the frame has to be maintained for at least 6–8 weeks. Pin track infection is almost invariable and patients find the frame cumbersome. Mobilisation is difficult and risks loss of reduction. Plating of pubic symphysial disruption is usually straightforward in rotationally unstable injuries. Reduction requires closure of the symphysis which can usually be achieved by use of a pointed reduction clamp applied on either side of the pelvis in the obturator ring (Fig. 6).

In vertical shear injuries achieving reduction can be much more difficult—one hemipelvis is shifted in a superior and posterior direction, with associated rotation in many of these cases, and the reduction requires correction of this multiplanar deformity. Techniques of reduction include use of traction on the leg and pointed reduction clamps applied to the obturator foramen on either side. Application of the plates may be needed to achieve the final reduction.

There is no consensus about the configuration of plating. Most surgeons use at least one 4.5 mm (or equivalent) plate applied to the superior aspect of the symphysis with two screws on either side of the symphysis. The use of a second anterior plate increases the stability of the construct and is worth considering, particularly in vertical shear injuries (Fig. 7). Alternatives such as the two hole plate or tension band wiring systems are now less popular as they are less rigid and the risk of loss of reduction with fixation failure is higher.

Figure 6 (a) APC (open book) injury with pubic symphysial disruption (b) after plating of pubic symphysis.
Pubic ramus fractures are most commonly found in association with lateral compression vertical shear patterns. If the fracture configuration is a lateral compression injury then the pelvic ligaments are usually intact and fixation is often not required.

With more significant degrees of displacement fixation may need to be considered. The ilioinguinal exposure is the usual surgical approach. In order to make full use of this exposure, a range of specialised pelvic clamps and the ball spike pusher are necessary (Fig. 8). The fracture is reduced either indirectly with traction or directly using pelvic clamps. The fracture is usually fixed with application of a 3.5 mm pelvic reconstruction plate extending from the iliac wing across the superior pubic ramus fracture to the pubic symphysis.

An alternative to plating is the use of retrograde or antegrade pubic ramus screws. Reduction must be achieved by closed or open methods, after which a medullary ramus screw is inserted retrograde from the symphysis or antegrade from the iliac wing. The retrograde screw is difficult to insert in obese patients or if there is a lot of perineal or scrotal swelling. The antegrade screw may be a better choice in these patients but obesity or marked gluteal swelling will increase the technical difficulty. Closed reduction must be achieved to allow safe insertion of these screws.

Posterior fixation

Fixation of the posterior component of the injury is not always required. In APC injuries, there is usually opening of the SI joint on one or both sides but reduction of the anterior disruption will reduce the posterior component of the injury. Fixation of the posterior lesion is indicated principally for vertical shear patterns with sacroiliac dislocations or sacral fractures. Lateral compression injuries with displacement of crescent iliac wing fractures
may also require posterior fixation. In vertical shear injuries fixation of both anterior and posterior lesions is required to achieve and maintain an acceptable reduction. Fixation of the anterior lesion alone is not adequate.

The surgical approach is determined by the anatomy of the posterior disruption and other considerations including the state of the posterior skin and soft tissues. Crescent iliac wing fractures and sacroiliac dislocations can be accessed using the ilioungual approach. This has the advantage of allowing simultaneous anterior and posterior access which greatly facilitates fracture reduction. In patients with sacroiliac dislocation the precision of reduction is more easily judged from the anterior approach. However, the L5 nerve root lies on the ala of the sacrum and is vulnerable to injury. It also limits medial access for plating. In obese patients or those with marked abdominal swelling access may be very difficult.

Reduction of sacroiliac dislocation is usually achieved with a combination of direct and indirect manipulation. Application of longitudinal traction on the leg is usually needed. Pelvic clamps can then be applied to the iliac wing to internally rotate the bone and close the SI joint. Anterior fixation by one or two plates is then carried out. Specially designed plates have been used for this purpose but 3.5 mm plates are the usual implants employed. The limited space on the medial side limits fixation in each plate to one screw in the sacral ala (Fig. 7).

Sacral fractures are commonly classified by location. Type I are lateral to the sacral foramena, type II are transforamenal and type III are medial to the sacral foramena. The risk of neurological injury increases with more medial patterns. Sacral fractures are too medial to be accessed using the ilioungual exposure. There are three options for fixation: transiliac bars, plate fixation or percutaneous fixation. Fixation may be percutaneous or by a direct open posterior approach. The posterior exposure allows plate fixation of sacral fractures and sacral nerve root decompression. However, there is no possibility of simultaneous anterior access and clearly any external fixator frame cannot be left in situ during the procedure. Skin in this area is also quite frequently extensively contused and there may be degloving. If these features are present the risk of wound breakdown and infection increases considerably.

In posterior approaches plate fixation is usually employed although iliosacral screws can be inserted via this approach. Reduction is generally achieved by use of pelvic clamps. The sciatic notch can be accessed and palpation of the anterior sacroiliac joint is possible to verify reduction in sacroiliac dislocations. In sacral fractures direct visualisation of the two sides of the fracture is possible after subperiosteal dissection. If bony impingement caused by loose fragments has been indentified on preoperative CT scans then a posterior nerve root decompression is possible via this exposure. A laminar spreader can be used to distract the fracture to allow this to be carried out. Once this is achieved the fracture is reduced with clamps. Plate fixation may be achieved with large plates applied across the sacrum to each iliac wing or with small fragment plates applied across the fracture line between sacral foramena.

Percutaneous fixation of posterior pelvic disruptions is an alternative surgical option. It can be utilised for sacral fractures and sacroiliac dislocation. However, it is only an option in situations where adequate closed reduction can be achieved. This sometimes requires traction or application of an external frame. Excellent quality image intensification is mandatory to safely insert percutaneous screws with inlet, outlet and lateral sacral views being required. The main risk of procedure is nerve injury to the L5 or sacral roots from misplaced screws. If the reduction cannot be obtained and verified with good quality imaging, then an alternative method of fixation must be chosen. The one exception to this rule is a sacroiliac dislocation where the level of the iliac wing is restored but residual widening of the joint is present. A percutaneous screw in this situation may be used to close the joint and complete the reduction. In sacral fractures, percutaneous screw fixation can be used but care must be taken in transforamenal injuries not to overcompress the fracture, which may inflict a neurological injury.

**Sequence of reconstruction**

The sequence of reconstruction will vary with the pattern of injury. Rotationally unstable APC injuries with symphysis disruption only require anterior plating. Lateral compression and vertical shear injuries may have anterior and posterior disruption to deal with. In this situation the ilioungual exposure allows access to both. Temporary reduction of the anterior lesion is first achieved with clamps and traction. The posterior lesion can then be reduced. Fine tuning the quality of reduction is then carried out if required. Fixation of the anterior lesion and then the posterior lesion is carried out.
Complications

Early

Major pelvic disruptions are severe injuries and there is considerable risk of complications associated with the injury and the subsequent treatment. Associated visceral trauma is not uncommon. The incidence of these injuries varies with the type of disruption. Urological injuries to the bladder or urethra are present in 15–25% of unstable pelvic fractures. Open book patterns in particular are associated with a high risk of urethral and bladder injury. Lateral compression patterns of injury are associated with blunt force delivered to the abdomen and chest. These patients often have lung contusions and liver or spleen injury. Vertical shear injuries are the most violent pattern of disruption and any combination of visceral injury may be associated. Neurological injury is the highest in this group and is present in 30–50% of cases.

Infection rates following surgery are generally low (<5%) with anterior plating procedures. Access via posterior skin incisions has been associated with higher rates of sepsis due to the associated soft tissue damage in that area. Neurological injury as a consequence of surgery should be kept to a minimum with modern imaging and reduction techniques. The lateral cutaneous nerve is frequently subjected to traction forces during the ilioinguinal exposure and some disturbance of nerve function is common. Sacral roots and the L5 nerve root are vulnerable to injury during reduction and implant placement. Percutaneous fixation carries particular hazards. Adequate imaging, a satisfactory reduction and awareness of the relevant surgical anatomy will minimise this risk. Iatrogenic visceral injury is much less common but can occur. Bladder damage is the main risk but can be minimised by use of a urinary catheter and avoiding over penetration of drills during anterior plating procedures.

Deep venous thrombosis and pulmonary embolus are particular problems in this group of patients. Prevention is controversial. Many patients are coagulopathic due to blood loss in the early stages of treatment and preventative measures may be inappropriate. I generally commence DVT prophylaxis with enoxoparin (or another suitable pharmacological prophylactic agent) when haematological parameters are normal and any coagulopathy has been reversed.

Late

Malunion was common when external fixation alone was used as definitive treatment. More widespread use of internal fixation has been associated with superior anatomical results. However, loss of fixation leading to malunion still occurs and is more common in vertical shear patterns of fracture. Rigid anterior and posterior plating minimises this risk. Patients with bladder and urethral injury often have long-term problems including urinary incontinence, urethral stricture and impotence in men. Malunion in female patients may be associated with dyspareunia and problems in labour following pregnancy.

Functional outcome

There are a number of advantages associated with internal fixation of unstable pelvic fractures. Patients can mobilise more easily, pain control is better and the anatomical result is superior to non-operative treatment or external fixation alone. Published studies of outcome suggest that results after internal fixation are superior to other methods. Improvements in imaging and instrumentation have been associated with better anatomical results, but poor functional results with chronic disability are still common. Patients with with APC and LC patterns of injury do better since the anatomical results of fixation are better and the incidence of severe soft tissue injury is lower. Although anatomical reductions are easier to achieve in APC (open book) patterns, these fractures tend to have a poorer functional outcome than the LC patients probably because they have a higher incidence of urethral and bladder trauma with late sexual dysfunction.

In general more severe degrees of disruption with associated visceral or neurological injury are associated with poorer outcomes, as might be expected. Most published studies identify vertical shear patterns with a poorer prognosis since these injuries have a higher incidence of associated injury. Chronic posterior pelvic pain is common and has been reported in 30–70% of cases. Sacroiliac dislocations and sacral fractures are both associated with this problem. Although up to 70% of patients will have pelvic pain, about two-thirds return to some type of occupational and recreational activity. However 30% never return to work or recreation and remain chronically disabled due to the combined effects of pain, visceral and neurological injury.

Malunion and non-unions of the pelvis after fracture can be corrected surgically. However, the surgery is technically demanding, although satisfactory outcomes have been reported in the hands of experienced surgeons. Union rates after
surgical correction are >90%, but anatomical reductions are possible in only 50% of cases. However, Mears reported 71% of patients had very little or no pain and 64% were very satisfied with the outcome. United malunions appear to have a better prognosis than unstable ununited malalignments which had a higher risk of a poor outcome and neurological complications.

The future

Modern methods of pelvic reconstruction have contributed to a significant improvement in the quality of anatomical results of pelvic reconstruction compared to older methods of non-operative treatment or reliance of external fixation as definitive treatment. The late morbidity of these injuries remains high. As motor vehicle safety improves and traffic speeds gradually reduce there may be a reduction in the proportion of more severe patterns of pelvic disruption. Computer assisted surgery systems are becoming more sophisticated and may eventually have an integral role in fixation of these injuries. This may assist in achieving better quality reductions and will minimise risk of iatrogenic injury. However, the violence required to disrupt the pelvis means that these patients will continue to represent the more severe end of the spectrum of orthopaedic trauma. A residual degree of significant morbidity can therefore be expected even with the best reconstructive treatment.

Practice points—delayed reconstruction

- Consider fractures with significant displacement for fixation (> 1 cm any plane)
- Definitive fixation easier within first 7 days
- Ilioinguinal and Pfannenstiel approaches most common
- Fixation of both anterior and posterior lesions required in vertical shear patterns
- Percutaneous fixation an option only if closed reduction can be achieved
- Anatomical results better with anterior and posterior internal fixation
- Late morbidity significant due to pelvic pain and visceral/nerve injury

References