REVIEW ARTICLE

PELVIC RING FRACTURES: SHOULD THEY BE FIXED?

MARVIN TILE

From the Sunnybrook Medical Centre, Toronto

The management of traumatic disruption of the pelvic ring has become a focus of interest, the main question being whether such disruptions should be stabilised at operation. Stabilisation may be important for the survival of the patient, as has been suggested for femoral fractures, and it may also be desirable to improve the long-term functional results of such injuries. It is therefore necessary to study both survival and the natural history of the various types of pelvic trauma.

Survival studies

The mortality of major pelvic fractures, despite improvements in management, continues to be about 10% (McMurtry et al. 1980; Hesp et al. 1985; Goldstein et al. 1986). This results mainly from associated injuries, especially to the head, and from massive pelvic bleeding. In our study of 494 pelvic fractures over five years we have found a direct correlation between the mortality and the Injury Severity Score (ISS). Despite early, more aggressive resuscitation including the early application of external fixators, this 10% mortality rate has remained unchanged.

Several studies have shown that early open reduction and stable internal fixation of long- bone fractures is safe, and improves the chance of survival (LaDuca et al. 1980; Goris et al. 1982; Johnson, Cadambi and Seibert 1985; Seibel et al. 1985). Two recent studies have favoured early open reduction and internal fixation of unstable pelvic fractures for this reason. Hesp et al. (1985) reported 111 cases treated for unstable fracture of the pelvic ring with an average ISS of 53 and an overall mortality of 19%. The mortality in non-operated patients was 21.8%; in the operated patients it was 8.3%, though the ISS was the same in each group. Goldstein et al. (1986) compared early and late open reduction and internal fixation in 15 multiply-injured patients. The early group, treated at a mean time of 38 hours had an ISS of 41 (range 14 to 68), while the late group had a lower mean ISS score of 27 (range 11 to 50). There were fewer complications in the patients treated early, but the infection rate was very high, 27% in the late group and 18% in the early.

These reports suggest that early open reduction and internal fixation is safe and may reduce mortality, but as yet there is no final answer. Early operation should only be undertaken in well-staffed and well-equipped trauma centres and then only as part of a prospective trial.

Natural history

Conventional orthopaedic wisdom is that patients who survive disruption of the pelvic ring eventually have few late musculoskeletal problems. However, the literature has been concerned more with life-threatening problems than with the natural history of such injuries.

Holdsworth in 1948 reported that 15 of 27 patients with a sacroiliac dislocation were unable to return to their regular work because of continuing disability; but 23 patients with sacral or iliac fractures had more satisfactory results. In 1958, Pennal studied 359 cases, and reported to the Canadian Orthopaedic Association (unpublished) that patients with unstable vertical shear injuries had many late complications including non-union. Räf (1966) reported that after pelvic fractures some 33% of patients complained of moderate to severe discomfort, but that of those suffering a sacral fracture or a sacroiliac dislocation 52% had severe symptoms. Slätis and Huittinen (1972) and Monahan and Taylor (1974–5) also found a significant percentage of late musculoskeletal problems in patients after unstable pelvic injuries.

In an attempt to clarify the natural history we (Tile et al. 1982; Tile 1984) have reviewed 248 patients after pelvic ring disruptions. Each patient was interviewed and examined, and inlet, outlet and anteroposterior radiographs were taken. Injuries were classified according to the degree of instability and severity, that is, they were divided into those which were vertically stable (the open book and lateral compression types) and those which were vertically unstable.

At a mean follow-up of 5.6 years (range, 2 to 18 years), 30 patients were excluded because of major acetabular involvement, leaving 218 patients whose results are given in Tables I and II. Of the total, 118 had been treated in community hospitals with traditional methods of traction and bed rest, and 100 cases were the first consecutive group treated at the Sunnybrook Trauma Unit, 21 of them with external fixation.

M. Tile, MD, BSc, FRCS(C) Surgeon-in-Chief
Sunnybrook Medical Centre, 2075 Bayview Avenue, Toronto, Ontario, Canada M4N 3M5.

0301-620X/88/1053 $2.00
J Bone Joint Surg [Br] 1988;70-B:1-12.

Table I. Unsatisfactory results in 218 patients with displaced ring fractures of the pelvis

	Number	*Per cent*
Leg length discrepancy > 2.5 cm	9	*4*
Non-union	8	*3.5*
Pain	88	*40*
Anterior	9	*4*
Posterior	79	*36*

The conclusions were that stable injuries gave few major long-term problems, and that pain, if any, was usually mild or moderate. In contrast, patients with vertically unstable disruption had many problems, with 60% continuing to suffer pain. This pain was usually in the posterior sacroiliac area or the lower lumbar spine and was most often associated with an unreduced sacroiliac dislocation or a non-union. Non-union occurred in 3.5% of patients and malunion with a leg length discrepancy of more than 2.5 cm was seen in 4%. In addition, 12 patients (5.5%) had a permanent nerve injury and six (2.5%) had permanent urethral damage.

The natural history of a pelvic fracture was seen to depend upon the degree of violence, the stability of the injury, the treatment, and the presence of complications such as permanent nerve damage, urethral tear, malunion, or non-union.

Since the type of injury is paramount in determining prognosis, this must be classified according to instability, and the case mix of stable and unstable injuries in each reported series must be closely examined so that fractures of a similar type and prognosis are being compared. Unstable vertical shear injuries treated by conventional means often result in significant disability, often with posterior pain, whereas stable fractures usually achieve good results with simple treatment. Therefore, most energy should be directed to the management of the unstable vertical shear fracture, especially if this is associated with a sacroiliac dislocation. Attempts at internal fixation should be limited to this group, unless there is an associated acetabular fracture. Even at major trauma centres, more than 60% of all pelvic injuries are stable and do not require stabilisation. Of the 494 cases of pelvic disruption managed at Sunnybrook Medical Centre in the past five years, only 68 required external fixation and 24 had internal fixation (Kellam et al. 1987).

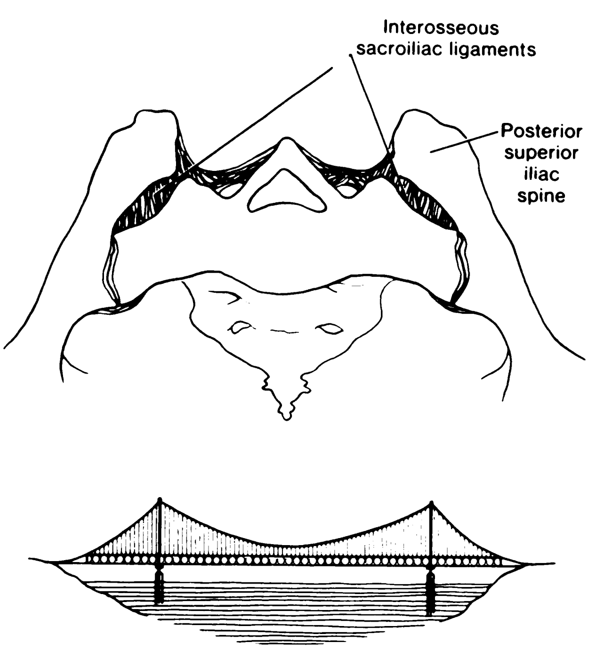


Fig. 1

The ligaments binding the posterior sacroiliac complex. The interosseous sacroiliac ligaments, the strongest in the body, are aligned vertically. The transverse components act as the tension members in a suspension bridge, and join the pillars of the posterior superior iliac spines to the sacrum (from Tile M, *Fractures of the pelvis and acetabulum*, Williams & Wilkins, 1984).

PELVIC BIOMECHANICS

1. The pelvis is a *ring structure*, and if the ring is broken in one area and the fragments displaced, then there must be a fracture or dislocation in another portion of the ring.
2. The *stability* of the pelvic ring depends upon the integrity of the posterior weight-bearing sacroiliac complex, with the major sacroiliac, sacrotuberous and sacrospinous ligaments. The extremely strong posterior sacroiliac ligaments maintain the normal position of the sacrum in the pelvic ring and the entire complex has the appearance of a suspension bridge (Fig. 1). The sacrospinous ligaments join the lateral edge of the sacrum to the ischial spine and resist external rotation of the hemipelvis, whereas the sacrotuberous ligaments resist both rotational forces and shearing forces in the vertical plane.
3. The major *forces acting upon a hemi-pelvis* are external rotation, internal rotation (compression from the lateral side) and vertical shear (Figs 2 and 3). In some complex high energy injuries, the forces may defy detailed description.

External rotation is caused by a direct blow on the posterior iliac spines or more commonly by forced external rotation of the legs, and produces an open-book type of injury. This is characterised by disruption of the symphysis pubis, and as the force continues, by rupture of the anterior sacroiliac and sacrospinous ligaments. An end point is reached when the posterior ilium abuts against the sacrum, but if the force continues the hemipelvis may be sheared off, resulting in gross instability.

Internal rotation (lateral compression) may be caused by a direct blow on the lateral aspect of the iliac crest or an indirect force through the femoral head. This produces compression fractures of the posterior complex, and fractures of the rami anteriorly. The posterior and anterior lesions may either be on the same side of the pelvis (ipsilateral type) or on opposite sides (bucket

Table II. Incidence of late pain related to type of fracture in 218 patients

				Pain		
		Number	*Per cent*	Nil	Moderate	Severe
Type B1	Open book	29	*13*	17	11	1
Type B2/B3	Lateral compression	155	*71*	100	51	4
Type C	Vertically unstable	34	*16*	13	15	6

handle type). This latter type is associated with major rotational deformities and may result in malunion. In some instances, a lateral compression force may stop short of rupture of the posterior structures, but in others, rupture will occur.

Vertical shearing forces act across the main trabecular pattern of the pelvis, causing marked displacement of bone with disruption of soft tissues. There is generally no end point to damage by this force and even a traumatic hemipelvectomy may result (Tile 1984).

CLASSIFICATION

Fractures of the pelvis may be divided into three types (Table III). Excluding those that are minimally displaced and stable (Type A), most clinically relevant disruptions will show rotatory instability, either alone (Type B) (Fig. 2), or in association with vertical instability (Type C) (Fig. 3). The intact bony pelvis withstands physiological forces without deformation, but this must be understood in relative rather than absolute terms; all pelvic injuries may be placed on a scale of stability. Thus, displacement in the vertical plane with posterior and cephalad migration of the hemi-pelvis is only possible if the posterior sacroiliac complex is disrupted (see Fig. 3)

Table III. Classification of pelvic disruption

Type A	Stable A1 - Fractures of the pelvis not involving the ring A2 - Stable, minimally displaced fractures of the ring
Type B	Rotationally unstable, vertically stable B1 - Open book B2 - Lateral compression: ipsilateral B3 - Lateral compression: contralateral (bucket handle)
Type C	Rotationally and vertically unstable C1 - Unilateral C2 - Bilateral C3 - Associated with an acetabular fracture

An injury which is vertically stable cannot, by definition, be vertically displaced, but there may be rotation.

An *external rotatory force* applied to the hemi-pelvis may rupture the symphysis and the sacrospinous and anterior sacroiliac ligaments, allowing the pelvis to open like a book. Either one hemi-pelvis or both may have external rotational instability, but if the posterior ligaments remain intact, vertical stability is maintained (Fig. 2). Only if continuing force ruptures the posterior ligaments can vertical displacement occur.

Internal rotatory forces cause the rami to fracture and the posterior complex is crushed. However, if the posterior ligaments remain intact, there may be internal rotatory instability but no vertical displacement is

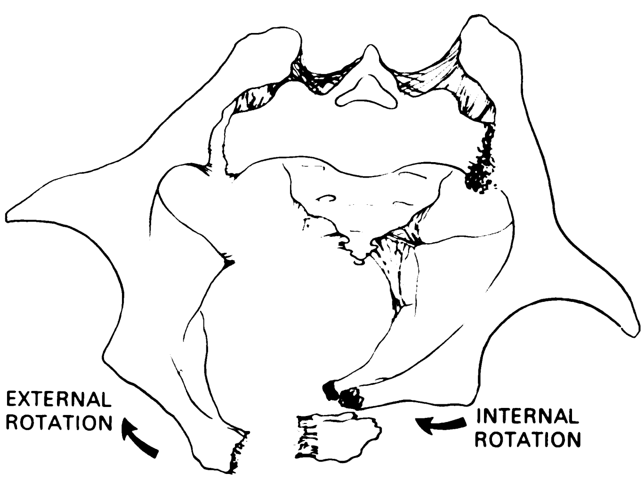


Fig. 2

Diagram to show rotational instability of the pelvis, with no vertical instability. On the left of the diagram external rotation has disrupted the symphysis and the sacrospinous and anterior sacroiliac ligaments, but the posterior ligaments remain intact. There is abutment of the posterior iliac spine against the sacrum. On the right of the diagram internal rotation has fractured the rami and crushed the posterior complex, but the posterior ligaments are intact.

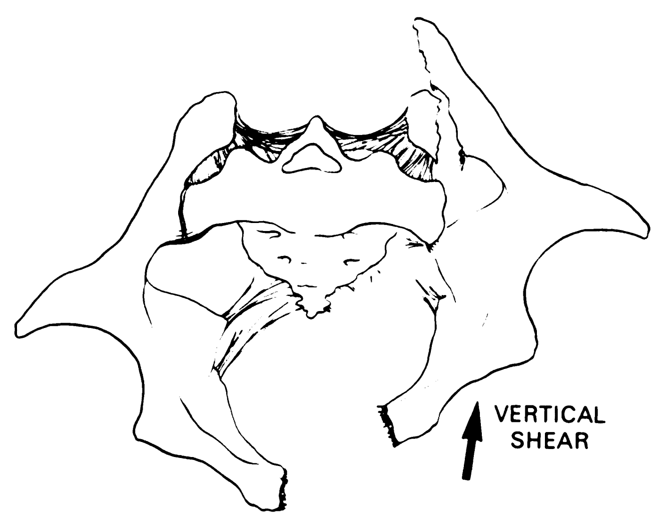


Fig. 3

Diagram to show vertical instability of the pelvis. A vertical shearing force has disrupted the symphysis and the sacrospinous ligament and caused a fracture-dislocation of the sacroiliac joint. The posterior sacroiliac complex has been disrupted.

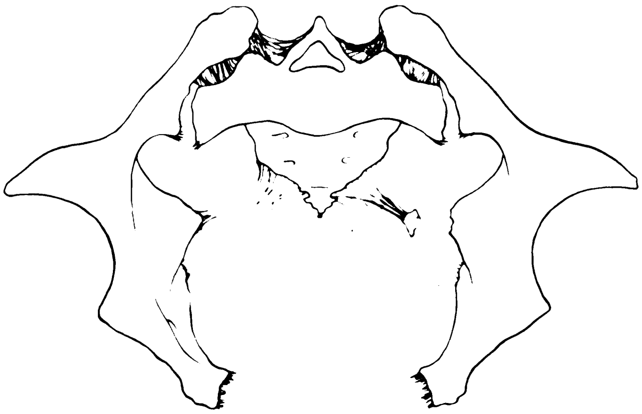


Fig. 4a

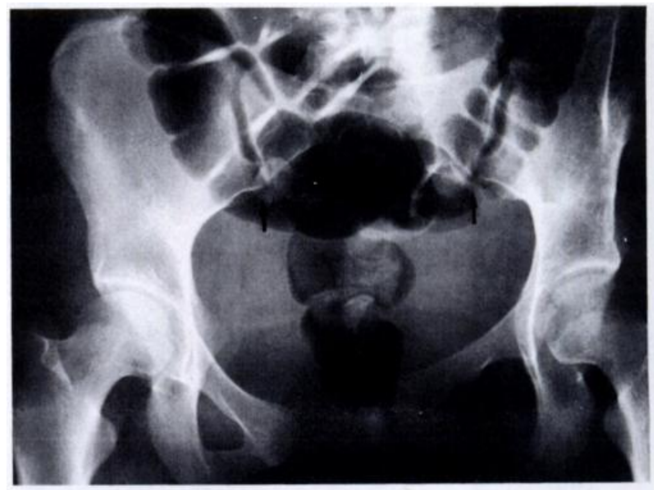


Fig. 4b

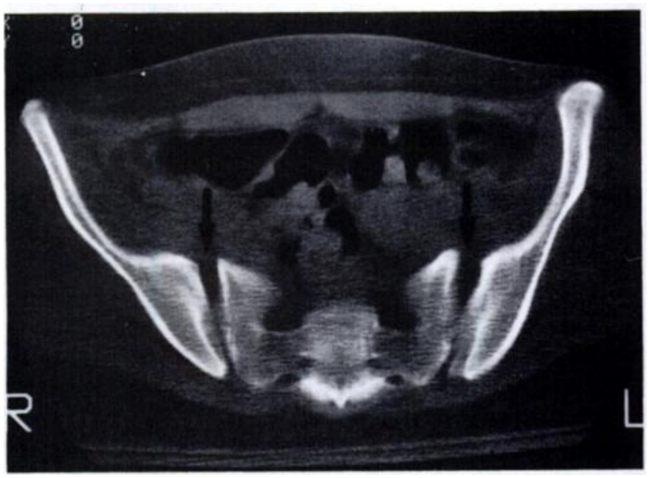


Fig. 4c

Open Book Injury – *Type B1*. The diagram shows wide separation of the symphysis, avulsion of the sacrospinous ligaments and disruption of the anterior sacroiliac ligaments. The intact posterior ligaments allow external rotational instability, but prevent vertical instability. The radiograph shows wide anterior opening of the sacroiliac joints with no posterior displacement and this is confirmed on the CT scan.

possible. Therefore, rotatory forces cause rotatory instability – either an open book injury or a lateral compression (closed book) injury – but these remain vertically stable when the posterior ligaments are intact. Table III summarises the types of fracture.

Type A – Stable, minimally displaced

The pelvic ring is stable and the amount of displacement is insignificant. In Type A1, the ring is not involved. Avulsion fractures of the iliac spines, the ischial tuberosity and isolated fractures of the iliac wing are included in this group. In Type A2, the pelvic ring is fractured, but is undisplaced and stable.

Type B – Rotationally unstable, vertically stable

Type B1 – Open book. This injury is caused by external rotatory forces resulting in a disruption of the symphysis pubis, but there is vertical stability (Fig. 4). The hemi-pelvis is unstable in external rotation, but can be made stable by internal rotation. Three stages are recognised. In *Stage 1* the disruption of the symphysis pubis is less than 2.5 cm and there is no posterior lesion. In *Stages 2 and 3* the separation at the symphysis pubis is greater than 2.5 cm. This implies disruption of the sacrospinous ligament and the anterior sacroiliac ligament (Fig. 4). This may occur on one side only (Stage 2) or be bilateral (Stage 3).

Types B2 and B3 – Lateral compression. The hemi-pelvis is unstable in internal rotation, and may rotate inwardly until it impacts with the opposite hemi-pelvis. The posterior sacroiliac complex is commonly impacted, so vertical displacement is not possible. The stages of lateral compression depend upon the sites of the anterior and posterior lesions. In *Type B2 – Ipsilateral* the rami are commonly fractured anteriorly and the posterior complex is crushed. Other varieties include those with an overlapped locked symphysis, or with a superior ramus fracture rotated around the disrupted symphysis. In the latter case a fragment may protrude into the perineum, the so-called a "tilt" fracture. In *Type B3 – Contralateral* (*bucket handle*) the cause is usually a direct blow on the iliac crest. The major anterior fracture is on the opposite side to the posterior lesion (Fig. 5), but all four rami may have fractured anteriorly. The affected hemi-pelvis rotates anteriorly and superiorly like the handle of a bucket so that, even if the posterior structures are relatively intact, the patients may have a major leg length discrepancy. Reduction requires derotation of the hemi-pelvis rather than traction in the vertical plane.

Type C – Rotationally and vertically unstable

There is rupture of the pelvic floor including the posterior sacroiliac complex, as well as the sacrospinous and sacrotuberous ligaments (Fig. 6). This injury may be

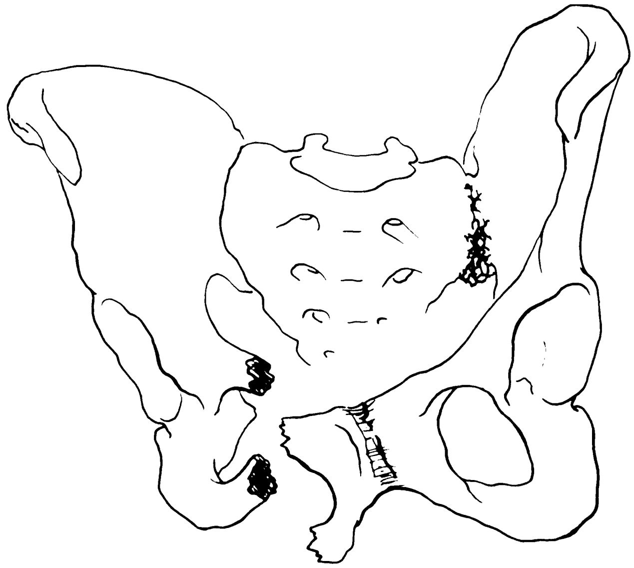


Fig. 5a

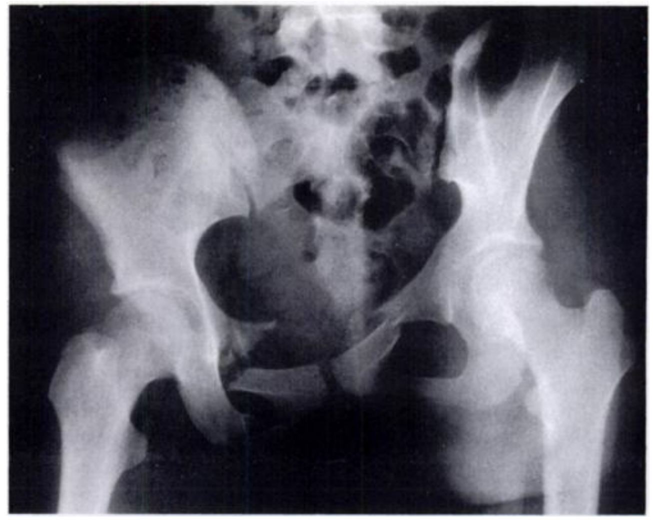


Fig. 5b

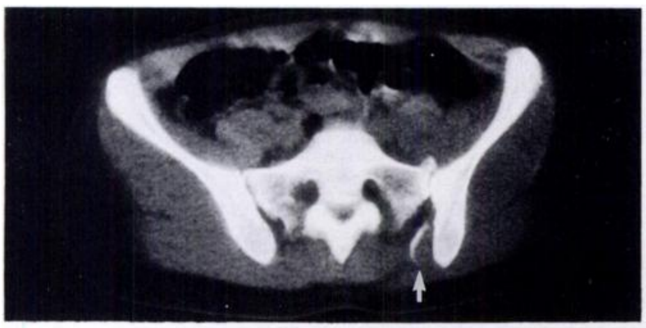


Fig. 5c

Bucket Handle Lateral Compression Injury - *Type B3*. The diagram shows the typical appearance of a bucket handle injury, with the left hemi-pelvis internally and superiorly rotated by 40°. The radiograph shows internal rotation of the left hemi-pelvis with fracture of all four pubic rami. The CT scan confirms the internal rotation of the hemi-pelvis and the crush injury of the anterior sacrum. It shows avulsion of the posterior iliac apophysis (arrow).

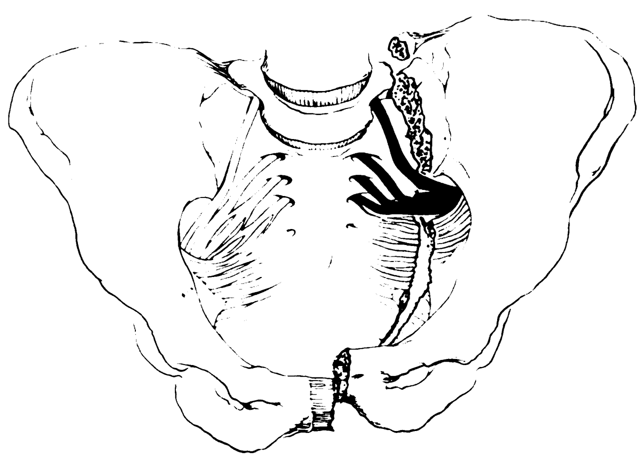


Fig. 6a

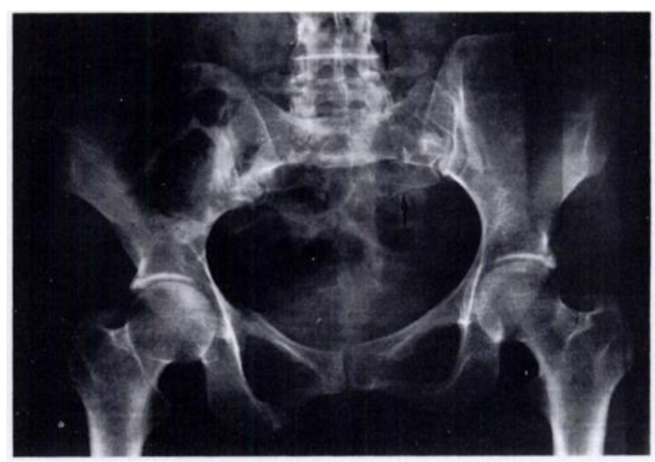


Fig. 6b

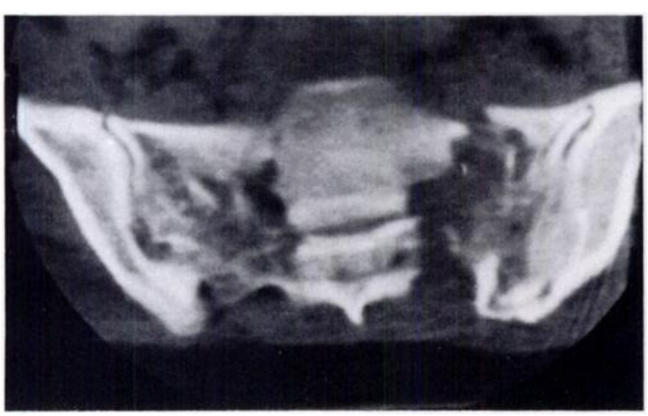


Fig. 6c

Unstable Vertical Shear Injury - *Type C*. The drawing shows an unstable vertical shear fracture. The shearing forces cause massive disruption of the pelvic ring, its soft tissues and surrounding structures. The radiograph shows the fracture line through the sacrum and avulsion of the tip of the transverse process of L5 (arrows). Displacement appears to be minimal, but the unstable nature of this injury is best shown on the CT scan by the wide displacement of the sacral fragments. (Modified from Tile M., *Fractures of the pelvis and acetabulum*, Williams & Wilkins, 1984) unilateral (Type C1) or bilateral (Type C2). The radiographic signs of instability include posterior displacement of the hemi-pelvis by more than 1 cm, avulsion of the transverse process of the fifth lumbar vertebra, and detachment of the bony insertion of the sacrospinous ligament from either the sacrum or the ischial spine. Diagnosis of the posterior changes associated with gross vertical instability is best made by computerised tomography (CT) (see Figs 5 and 6). In Type C3 there is an associated acetabular fracture. Pelvic ring disruptions associated with acetabular fractures should be considered separately, since the prognosis is more dependent on the result of treatment of the hip than upon that for the pelvic ring.

MANAGEMENT

Assessment. This article cannot deal with the intricacies of assessment and resuscitation of the patient with multiple injuries. Suffice it to say that these extremely ill patients require rapid general assessment, and the central theme of management should be simultaneous rather than sequential care. Haemodynamic stability or instability will greatly affect decisions.

The stability of the pelvic ring is determined by clinical and radiographic means. Direct manipulation of the pelvis in rotation will determine whether rotational instability is present, and manual traction will easily discover the presence of vertical instability. Other clinical signs of instability include severe displacement, marked posterior bruising, severe associated injuries to nerves or vessels, and the presence of an open wound.

Instability is confirmed on radiographic examination: the routine anteroposterior view is less important than the inlet view (see Fig. 12c), which clearly shows posterior displacement, and the outlet view which shows superior migration or rotation (Pennal et al. 1980; Tile and Pennal 1980; Tile 1984). Radiographic evidence of vertical instability includes posterior or superior displacement of the posterior complex by greater than 1 cm or the presence of a large posterior gap rather than impaction. The best single investigation for determining instability is a CT scan of the sacroiliac complex, while the recent refinement of three-dimensional CT allows clearer visualisation of the pattern of injury.

Careful assessment will allow the surgeon to determine the character of the pelvic injury, in particular whether it belongs at the stable or the unstable end of the stability scale. Patients with vertical instability are at much greater general risk, so their resuscitation must be immediate and precise.

Resuscitation. This may require massive fluid replacement, use of a pneumatic antishock garment, embolisation of the pelvic vessels for small bore artery bleeding and consideration of direct surgical intervention (McMurtry et al. 1980). There is a growing body of evidence that the application of an external skeletal frame will reduce venous and bony bleeding to the extent that other intervention is rarely required.

Provisional stabilisation. For pelvic fractures which result in an increase in pelvic volume, either an open book injury (Type B1), or an unstable vertical shear injury (Type C), stabilisation of the pelvic ring should be performed early, during the resuscitation phase of management (Table IV). This can be safely and quickly achieved with an external frame applied percutaneously or with a pelvic clamp which may be applied in the emergency room. An external skeletal frame can reduce the volume of the pelvis, restore tamponade and result in reduction of haemorrhage.

Table IV. Indications for external fixation of pelvic ring injuries

Type B	Vertically stable, rotationally unstable injuries B1 Open book – to provide definitive treatment B2/B3 Lateral compression – to aid and maintain reduction
Type C	Vertically unstable injuries – to produce partial stability in order to: Reduce bleeding Relieve pain Aid in nursing the patient

Since these patients are often very ill, a simple frame configuration is preferable. Two pins are placed percutaneously in the ilium, one at the anterior superior spine and the other at the iliac tubercle, angled at approximately 45° to each other. The frame is completed in the form of an anterior rectangle (Fig. 7). The more sophisticated external frames now recommended (Mears and Fu 1980), which require operative exposure of the anterior inferior spine, should not be used in the acute period. They have slight biomechanical advantages, but even these frames cannot produce enough stability to allow walking (Fig. 8), so the added risk of the operative procedure is not worthwhile (Tile and McBroom 1982).

The percutaneous insertion of a third pin into the area of the anterior inferior iliac spine under image intensifier control has been described by Behrens (personal communication 1987). This increases the stability of the frame because of the dense bone proximal to the acetabulum, but great care must be taken to avoid damaging neurovascular structures or entering the hip joint.

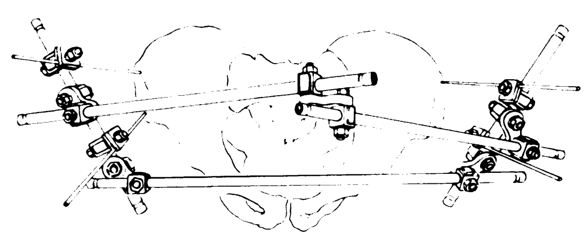


Fig. 7

Anterior external fixation of the pelvis.

Although a simple frame cannot fully stabilise the pelvic ring (Fig. 8), it will allow the patients to be placed with the trunk in the upright position for improved ventilation. Some redisplacement may occur, but this can be corrected when the general state of the patient has improved.

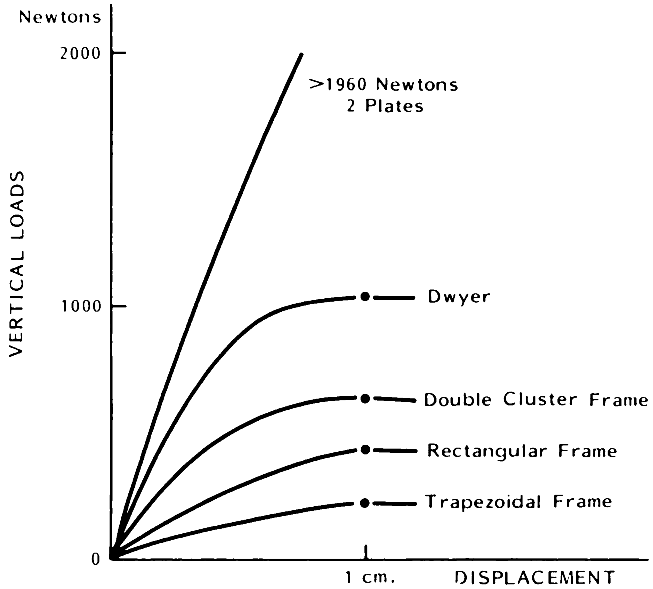


Fig. 8a

Results of biomechanical testing on a vertically stable open book injury produced by division of the symphysis pubis and the anterior sacroiliac ligaments. The external frames all gave adequate fixation for this type of injury, but two plates across the symphysis provided excellent stability.

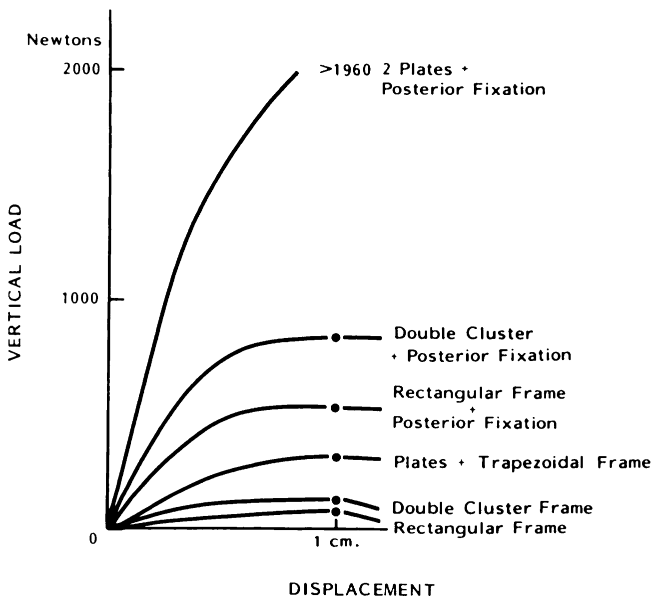


Fig. 8b

Results of fixation of an unstable vertical shear injury produced in the laboratory by division of the symphysis pubis, fracture of the ilium posteriorly, and division of the pelvic floor ligaments. All forms of anterior fixation failed under 20 kg load (1 kg = 10 newtons), posterior internal fixation proving far superior. Internal stabilisation of the unstable posterior injury and of the symphysis pubis produced excellent stability of the pelvic ring. (From Tile M., *Fractures of the pelvis and acetabulum*, Williams & Wilkins, 1984)

Definitive stabilisation. If the pelvic ring is stable and only minimally displaced (Type A2) symptomatic treatment only is necessary. These patients may be mobilised quickly and the pelvic fracture largely ignored. The definitive management of displaced fractures depends upon their stability and requires clear definition of the risks and benefits of stabilisation.

Type B1 – Open book. When the symphysis is open less than 2.5 cm (*Stage 1*), no specific stabilisation is usually required. A good result may be expected although in some cases pain at the symphysis may persist for months or even permanently. When the symphysis is open more than 2.5 cm in *Stage 2 or 3* the pelvic ring may be closed by placing the patient in the lateral position. The reduction may be maintained either by a simple external skeletal fixator or by a plate across the symphysis. Both methods are biomechanically sound and will allow the patient to stand and walk (Fig. 8). If the patient needs a laparotomy and there has been no faecal or urinary contamination, we favour plating; in other cases we prefer external fixation.

Types B2, B3 – Lateral compression injuries. These are the commonest group of pelvic ring fractures. In most cases of Type B2 (ipsilateral) injuries, the elastic recoil of the pelvis restores the anatomy to near normal, and no form of stabilisation is required.

In the *Type B3 – bucket handle injury*, the posterior complex is commonly compressed, rendering the ring stable. It may be impossible to reduce the displacement by closed manipulation under general anaesthesia, and in most cases, no stabilisation is required. It is usually preferable to accept a leg length discrepancy of up to 1.5 cm and some internal rotation of the hemi-pelvis rather than destabilising the pelvis and producing the need for an external frame or internal fixation.

If the leg length discrepancy is greater than 1.5 cm, or if the pelvic deformity is excessive, more aggressive management may be indicated, but only when the patient or his family have been informed of the possible risks and benefits. Reduction may then be obtained by external rotation of the hemi-pelvis by pins in the iliac crest (Tile 1984). When reduction has been achieved, the anterior frame is completed to hold the necessary external rotation. In the rare case of a "tilt" fracture where bone is protruding into the perineum, open reduction and internal fixation may be required.

Type C – Rotational and vertical instability. In these cases, the options for definitive fixation include external frames with or without skeletal traction, and open reduction with internal fixation. Complex frames have a biomechanical advantage over simple frames, but no frame can restore enough stability to allow the patient to walk without loss of position; since the use of these frames add risk to the procedure without substantial benefit, they are not indicated.

The combination of an anterior frame with skeletal traction provides the surgeon with a safe method of treatment which yields a high percentage of satisfactory results in the right cases. This is especially true when an adequate reduction of the posterior sacroiliac complex can be obtained and when the posterior injury is a fracture through the ilium rather than a fracture of the sacrum or a pure dislocation of the sacroiliac joint. The major disadvantage of this method is the long period of enforced bed rest with its inherent risks. To be successful, traction must be maintained for at least 8 to 12 weeks, depending on the rate of radiographic healing. We favour a supracondylar traction pin in the femur, and up to 20 kg of traction may be necessary to maintain the posterior sacroiliac complex in the reduced position.

Open reduction and internal fixation. The relatively high complication rate of Type C vertically unstable pelvic disruptions make open reduction and internal fixation seem desirable; it can restore excellent stability and allow early ambulation, a distinct advantage in cases of multiple injury. The large cancellous surfaces of the pelvis are amenable to interfragmental compression, and this will help prevent both malunion and non-union. However, the disadvantages are many and include bleeding, infection and nerve damage.

Opening the pelvis may cause loss of tamponade and increased bleeding. This will be worse if massive transfusion has interfered with the patient's clotting mechanism. The risks are so potentially devastating that some centres have recommended pre-operative angiography and selective embolisation for patients in whom early internal fixation is planned (Goldstein et al. 1986)

Posterior pelvic wounds are especially prone to necrosis. Kellam et al. (1987) report a 25% incidence of wound breakdown after crush injuries had been treated by posterior open reduction and internal fixation and Goldstein et al. (1986) reported very high infection rates. Causes of this high rate of posterior wound breakdown include crushing of the skin at the time of injury, and avulsion of the fascia of the gluteus maximus from its origin, leaving the overlying skin with an inadequate blood supply. Since skin breakdown may occur even

Fig. 9a

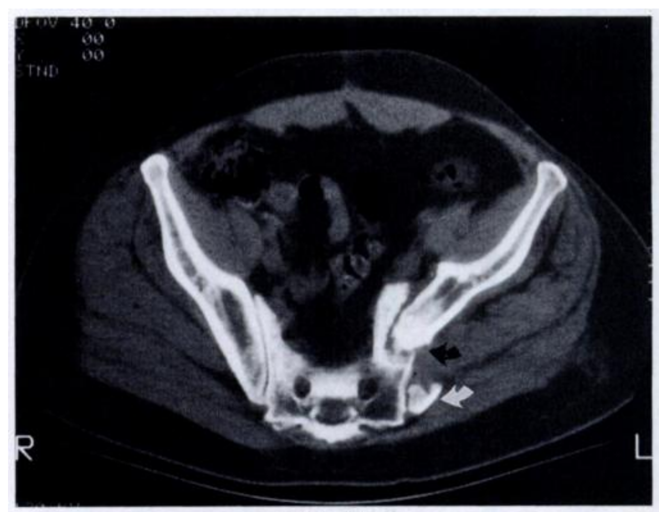


Fig. 9b

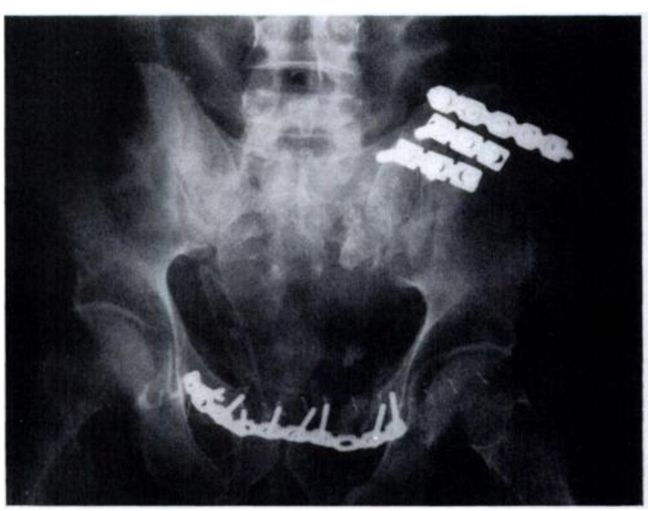


Fig. 9c

Reduction of the posterior sacroiliac complex. The radiograph shows marked external rotation of the left hemi-pelvis with fractures of all four pubic rami. The degree of displacement is best seen on the CT scan, which shows that the left hemi-pelvis has been externally rotated and driven to the anterior surface of the sacrum (black arrow), where it had caused a complete lumbosacral trunk injury. The remaining portion of the ilium is indicated by the white arrow. The second radiograph shows the result after open reduction and internal fixation with plates across the sacroiliac joint, the iliac fracture, and the rami.

Table V. Indications for open reduction and internal fixation of vertically unstable pelvic fractures

1.	**Anterior** for disruption of the symphysis pubis (fractures of the rami)
	To improve pelvic stability
	In association with a laparotomy
	For bone protruding into the perineum (tilt fracture)
	In association with an acetabular fracture which requires open reduction
2.	**Posterior**
	Inadequate reduction of the posterior injury (especially sacroiliac dislocation)
	Presence of an open posterior wound (never for perineal wound)
	In association with an acetabular fracture which requires open reduction

without surgery, the risks of operation are very high. Neurological damage is a major risk, especially in posterior approaches where a misplaced screw may enter a sacral nerve foramen or the spinal canal and damage the cauda equina (see Fig. 13).

These major risks may, in some patients, be outweighed by the benefits. The indications for either anterior or posterior open reduction and internal fixation of the pelvis are summarised in Table V.

Anterior internal fixation of an unstable disruption of the symphysis pubis will simplify the management of the patient. Biomechanical tests (Mears and Fu 1980; Tile and McBroom 1982; Tile 1984) show that adequate stability will be gained by plate fixation of the symphysis supported by an anterior external fixator. Full stability may be restored if these are associated with posterior internal fixation (see Fig. 8). The technique for anterior fixation is quick and relatively safe since the dissection has usually been performed by the injury. When abdominal or pelvic surgery have been needed for associated injuries, the symphysis should be fixed at the same time, provided that the wound is not contaminated, and no long-standing suprapubic drain is contemplated. Other indications include the rare tilt fracture, when bone protrudes into the perineum, and cases in which an associated anterior acetabular fracture requires open reduction and fixation.

The fixation of fractures of the pubic rami is much more difficult and may require an ilio-inguinal approach (Letournel 1980). The risks of this major dissection are usually greater than the benefits, so it is rarely indicated unless an anterior approach is needed for an associated acetabular fracture. In such unstable injuries it is better to fix the posterior lesion and control the rami with an anterior external frame.

Posterior internal fixation is indicated for inadequate reduction of the posterior sacroiliac complex, especially an unreduced sacroiliac *dislocation* or a gap of more than 1 cm between the fragments (Fig. 9). For posterior *fractures*, especially through the ilium, with a minimal gap, external frames and skeletal traction will suffice.

In the rare case with sacroiliac disruption and laceration of the posterior skin, posterior internal fixation may be indicated because the wound is already open. If, however, the wound is in the perineum, then internal fixation is contra-indicated. An open pelvic fracture should normally be treated by cleansing and careful wound toilet followed by stabilisation with an external skeletal frame. Both bowel and bladder diversion may be necessary to reduce sepsis.

OPERATION

Timing. It is usually better to wait until the patient's general state has improved, between five and seven days after injury. One exception to this rule is the case in which an early laparotomy gives access for plating the symphysis, another is when vascular repair of the femoral artery has given access to the superior pubic ramus, and a third is when a posterior open fracture exposes the sacroiliac area. Some trauma units are assessing the value of immediate open reduction and internal fixation, but this is certainly contra-indicated in the haemodynamically unstable patient. Prophylactic antibiotics are routinely given to cover these major operations.

Methods

The anterior pelvis. For disruption of the symphysis pubis in vertically stable, Type B1 open book injuries, a two to four-hole plate should be placed on the superior surface and fixed with fully threaded cancellous screws. For unstable Type C injuries, *where no posterior fixation is planned*, two plates at 90° to each other should be used (Fig. 10); if posterior fixation is planned, a single plate will suffice.

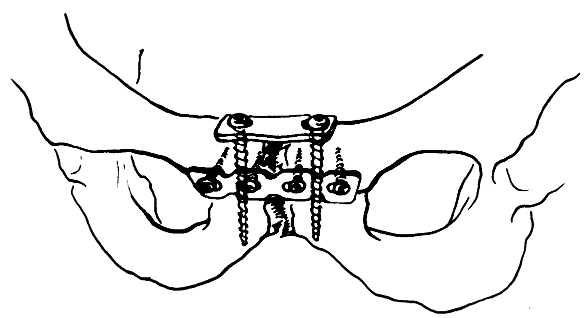


Fig. 10

Plating the symphysis pubis. For stable injuries, a superiorly placed two-hole plate may be used. For vertically-unstable injuries where posterior fixation will not be used, two plates at right angles to each other are recommended.

The posterior pelvis. The approach may be either anterior or posterior. An anterior approach has the advantage of good soft-tissue cover and is indicated if the posterior skin is crushed. The precise method used will depend upon the pattern of fracture or fracture-dislocation.

For *sacral fractures*, two sacral bars from one posterior iliac spine to the other will provide good stability and compression of the sacral fracture, at no risk to the neural

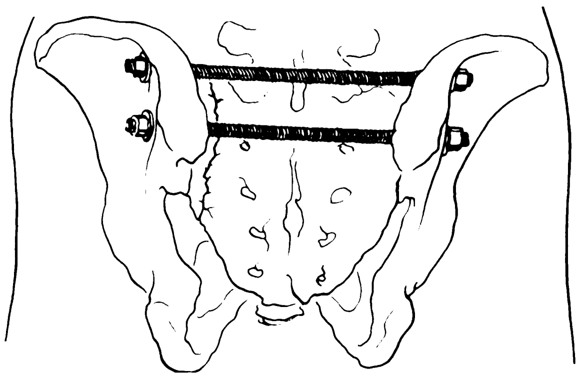


Fig. 11a

Sacral bars. For sacral fractures, two sacral bars provide good stability and compression.

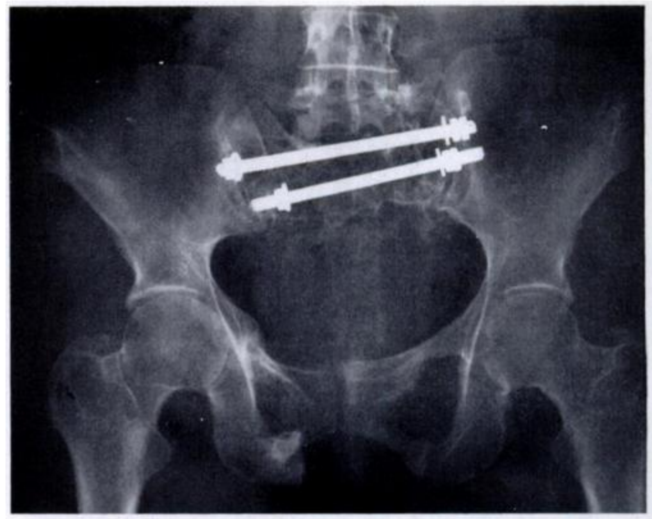


Fig. 11b

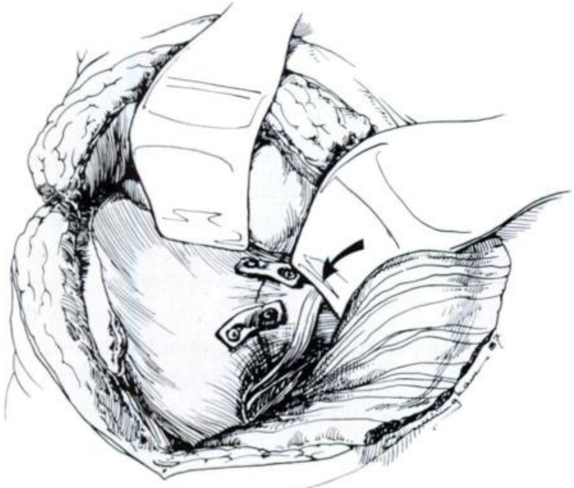
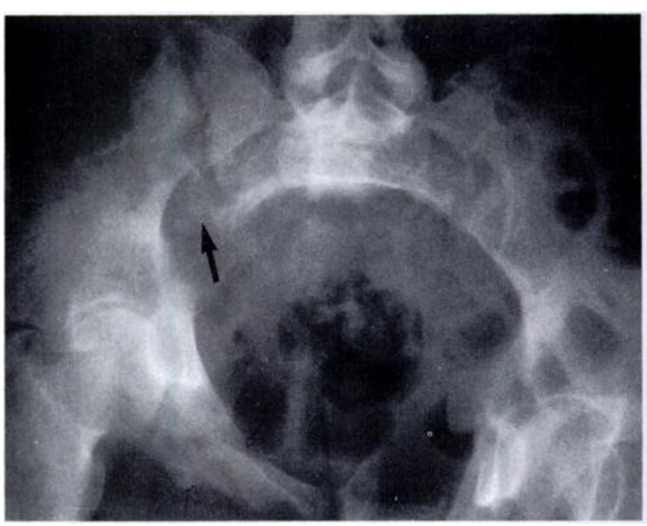


Fig. 12a



Fib. 12c

Anterior plating of the sacroiliac joint. The diagram shows two small plates across the sacroiliac joint, placed through an anterior approach after reflecting the iliopsoas. The lumbosacral nerve root is seen crossing the ala of the sacrum (arrow). Only one screw can be placed into the sacrum through this approach. The first radiographs show marked posterior displacement of the right sacroiliac complex, seen best on the inlet view (arrow). The CT scan shows the line of the fracture. Reduction was through an anterior approach, with fixation by three plates across both the sacroiliac joint and the iliac fracture.

Fig. 12b

Fig. 12d

Fig. 12e

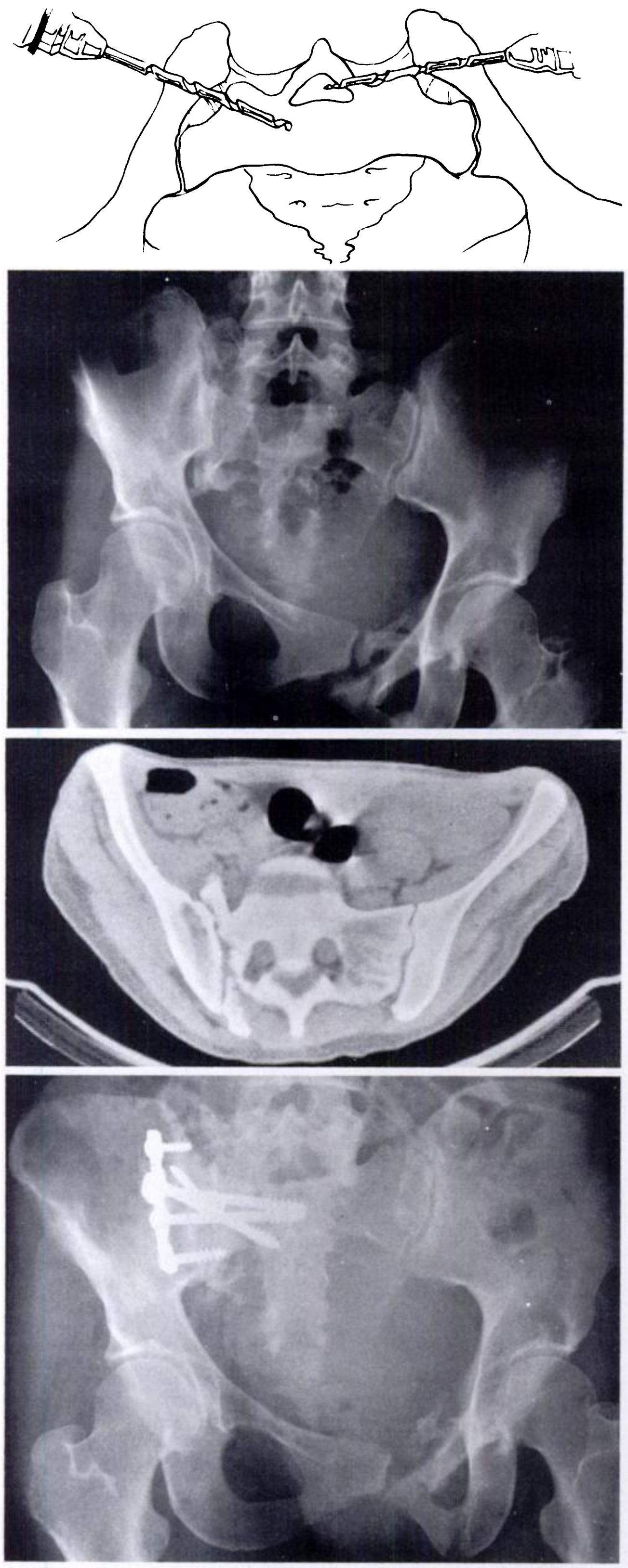


Fig. 13

Posterior screw techniques. The diagram shows on one side the correct line for the drill into the lateral mass and body of the sacrum. Slight error causes it to enter the spinal canal. The first radiograph shows displacement with marked internal rotation of the right hemi-pelvis and this is confirmed on the CT scan. Reduction of the pelvis, with its position held by posterior screws, is shown in the final radiograph.

structures (Fig. 11). Care must be taken to avoid overcompression. This technique is only possible when both posterior iliac spines are intact.

For *sacroiliac dislocations*, with or without an iliac fracture, we favour an anterior approach to the joint, with plates across the sacroiliac joint and any iliac fracture (Fig. 12). Care must be taken to avoid the lumbosacral trunk where it crosses the pelvic brim. The articular cartilage of the sacroiliac joint (which is usually damaged) may be curetted out and bone graft used to aid fusion. Posterior screw fixation may provide equally good stability, but there is the added risk of skin breakdown after a posterior approach. This method is safe when the screws penetrate only the lateral mass of the sacrum (Fig. 13), but if the technique is used in patients with a sacral fracture, the screws must enter the body of the sacrum, and there is a risk of damage to the cauda equina or the sacral nerves (Fig. 13).

Iliac fractures may be fixed by plates using standard techniques of interfragmental compression (Fig. 14). Pelvic reconstruction plates are more malleable and allow easier contouring. An anterior approach is preferred, especially if a sacroiliac dislocation is present.

Placing the patient in a lateral position allows a simultaneous approach to the anterior and posterior structures, otherwise the patient is placed in a supine position for anterior approaches, and a prone position for posterior approaches. Reduction may be extremely difficult and a variety of pelvic clamps are essential. A finger placed through the greater sciatic notch allows the surgeon to assess the adequacy of the reduction.

DISCUSSION

Disruption of the pelvic ring is a serious injury with a significant mortality and morbidity. Early general management is essential with a concomitant treatment of the musculoskeletal injury. The need for fixation of pelvic fractures depends on many factors, and there must be clear reasons for advocating operation. Stabilisation is only required for the uncommon Type C vertically unstable pelvic disruptions and occasionally for Type B rotational instability. In our series of 494 pelvic fractures over five years, only about 19% needed stabilisation and this was by internal fixation in only 5%.

In Type B1 open book injury, stabilisation may be indicated to reduce the pelvic volume in the acute phase, and in the rare Type B3 lateral compression injury, external fixation pins may aid in reduction. Only in unstable pelvic disruption can stabilisation reduce the mortality rate (Hesp et al. 1985; Goldstein et al. 1986).

Quickly applied, simple anterior external fixation has a major role in the acute phase of management of the patient with multiple injuries and either a Type C unstable vertical shear injury or a Type B1 open book injury (Table IV). Bleeding may be reduced by tamponade, the patients are more comfortable and breathing

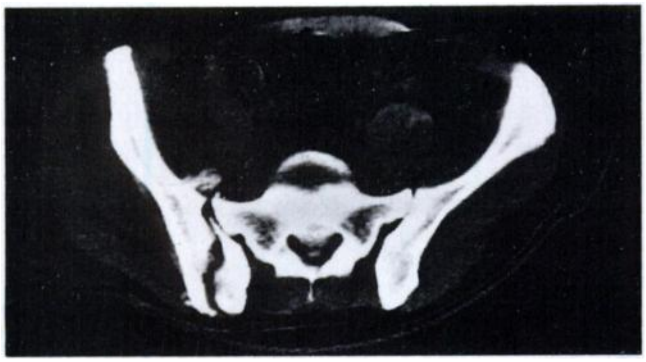


Fig. 14a

Fig. 14b

Plate fixation of iliac fractures. The iliac fracture seen in the CT scan was fixed by interfragmental compression through a 4.5 mm plate. The radiograph shows the final position.

may be helped by an upright position. External skeletal fixation may be the definitive treatment for a vertically stable open book fracture, or for the occasional lateral compression injury which requires reduction. In vertically unstable pelvic disruption it may be used in association with skeletal traction or with open reduction and internal fixation.

The role of internal fixation (Table V) is not as clear, since good results can be gained in most cases with external fixation and simple traction. However, there are relative indications, and to plate a separated symphysis is to simplify the management of the patient. This is recommended, especially if the abdomen is already open.

Since sacroiliac dislocations have a high morbidity, we favour open reduction if, as is often the case, it cannot be obtained by closed means. Fixation may be through either an anterior or posterior approach, but at present, we favour the anterior approach with the use of two plates. If the sacrum is grossly disrupted and cannot be reduced, sacral bars can be used to compress the fracture without danger to nerves. If an associated iliac fracture is present, direct plating may suffice.

These complex injuries often occur in very ill patients and need individual management. The techniques are difficult and should be performed only in centres with experience and expertise in this field and with anaesthetists and critical care specialists who are able to cope with general problems.

Most pelvic fractures, even those referred to major trauma units, are relatively stable and may be managed by simple techniques. Posterior internal fixation should be reserved for those cases with a difficult vertically unstable pelvis; this often does badly with traditional methods.

The author wishes to thank Dr Jim Kellam for his support and helpful ideas; Patsy Cunningham, Medical Artist, Sunnybrook Medical Centre, for the original artwork; Jim Atkinson, Director of Media Services, Sunnybrook Medical Centre, for the photography; and Shirley Fitzgerald, Carol Young and Ronda Klap for help in preparing the manuscript.

REFERENCES

Goldstein A, Phillips T, Sclafani SJA, et al. Early open reduction and internal fixation of the disrupted pelvic ring. *J Trauma* 1986;26:325–33.

Goris RJA, Gimbrère J, van Niekerk JLM, Schoots FJ, Booy LHD. Early osteosynthesis and prophylactic mechanical ventilation in the multitrauma patient. *J Trauma* 1982;22:895–903.

Hesp WL, van der Werken C, Keunen RW, Goris RJ. Unstable fractures and dislocations of the pelvic ring: results of treatment in relation to the severity of injury. *Neth J Surg* 1985;37:148–52.

Holdsworth FW. Dislocations and fracture-dislocation of the pelvis. *J Bone Joint Surg [Br]* 1948;30-B:461–6.

Johnson KD, Cadambi A, Seibert GB. Incidence of adult respiratory distress syndrome in patients with multiple musculoskeletal injuries: effect of early operative stabilization of fractures. *J Trauma* 1985;25:375–84.

Kellam JF, McMurtry RY, Paley D, Tile M. The unstable pelvic fracture: operative treatment. *Orthop Clin North Am* 1987;18:25–41.

LaDuca JN, Bone LL, Seibel RW, Border JR. Primary open reduction and internal fixation of open fractures. *J Trauma* 1980;20:580–6.

Letournel E. Acetabulum fractures: classification and management. *Clin Orthop* 1980;151:81–106.

McMurtry R, Walton D, Dickinson D, Kellam J, Tile M. Pelvic disruption in the polytraumatized patient: a management protocol. *Clin Orthop* 1980;151:22–30.

Mears DC, Fu FH. Modern concepts of external skeletal fixation of the pelvis. *Clin Orthop* 1980;151:65–72.

Monahan PRW, Taylor RG. Dislocation and fracture-dislocation of the pelvis. *Injury* 1974–5;6:325–33.

Pennal GF, Tile M, Waddell JP, Garside H. Pelvic disruption: assessment and classification. *Clin Orthop* 1980;151:12–21.

Räf L. Double vertical fractures of the pelvis. *Acta Chir Scand* 1966;131:298–305.

Seibel R, LaDuca J, Hassett JM, et al. Blunt multiple trauma (ISS36), femur traction and a pulmonary failure – septic state. *Ann Surg* 1985;202:283–95.

Slätis P, Huittinen V-M. Double vertical fractures of the pelvis: a report on 163 patients. *Acta Chir Scand* 1972;138:799–807.

Tile M. *Fractures of the pelvis and acetabulum.* Baltimore, etc: Williams & Wilkins, 1984.

Tile M, McBroom R. Disruption of the pelvic ring. *Orthop Trans* 1982;6(3):493.

Tile M, Pennal GF. Pelvic disruption: principles of management. *Clin Orthop* 1980;151:56–64.

Tile M, Lifeso R, Dickinson D, McBroom R. Disruptions of the pelvic ring. *Orthop Trans* 1982;6(3):324.