Pelvic Vertical Shear Injuries and Sacroiliac Joint Disruptions

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Background

Pelvic ring injuries in the young patient commonly involve a high-energy mechanism and can be associated with severe orthopedic and nonorthopedic injuries [1–3]. In these patients, the ATLS protocol must be initiated, and swift action must occur to reduce mortality as these patients can require massive fluid resuscitation [3]. The purpose of this chapter is not to cover the ATLS protocol, epidemiology, or classification of these injuries, but rather to provide basic surgical principles to consider while operatively treating such patients in the damage control setting and while planning for definitive fixation. Despite the mechanism of injury (anterior posterior compression, lateral compression, or vertical shear (respectively, PC, LC, or VS)), all type C pelvic ring injuries are vertically and rotationally unstable [4]. This focus of instability must occur in both the anterior and posterior ring through bony or ligamentous structures or both. The chapter provides preoperative considerations and intraoperative tips and tricks that will focus on reduction maneuvers, treatment decision-making, potential complications, and a typical case presentation highlighting the discussion.

Obstacles in the Treatment Concept

Injury Severity

Type C pelvic ring injuries are the result of tremendous deforming forces that lead to bony and ligamentous disruptions. In APCIII and vertical shear injuries, the pelvis experiences extraordinary rotationally and vertically translated forces, which can lead to shear of vascular structures and hemodynamic instability [1]. In LCIII-type injures, the hemipelvis is recipient of a lateral blow that causes an internal rotation moment to the hemipelvis and an external rotation moment to the contralateral hemipelvis. The most common cause of death in lateral compression injury is from brain injury [5].

Those associated potentially fatal injuries highlight the importance of protocol-driven, multidisciplinary culture of teamwork to save the patients' life. This concept requires a dedicated fully staffed operating room; a close collaboration between trauma surgery, orthopedic, and neurosurgery; as well as a strong knowledge of institutional protocols to correct hemodynamic instability [6–8].

Hemodynamic Instability and Initial Stabilization

Patients who present in hemodynamic shock with an associated high-energy pelvic ring fractures must be aggressively resuscitated. Several strategies exist

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that we have summarized in a recently published paper [6]. In addition to blood product transfusion, the goal of initial resuscitation is to decrease the intrapelvic volume. In the trauma bay, application of a well-positioned sheet should be performed as expeditiously as possible. The sheet must be positioned at the level of the greater trochanters. A second person internally rotates the legs while the sheet is being applied. The ankles and knees can be taped together to help hold the legs internally rotating, which helps decrease the pelvic volume (Fig. 6.1). Commercially available pelvic binders can replace the sheet successfully. In the scenario of a vertical shear fracture, in addition to internally rotating the

legs and applying a sheet, gentle longitudinal traction can be applied to the affected hemipelvis through the ipsilateral leg (through distal femoral traction pin when feasible).

The treatment algorithm following placement of a sheet in the emergency department remains controversial. The strength of our institution is an evidence-based protocol-driven approach, which includes application of a pelvic external fixator and pre-peritoneal pelvic packing within 30 min from arrival to the emergency room in patients not responding to blood product transfusion (Fig. 6.2). The addition of resuscitative endovascular balloon occlusion of the aorta (REBOA) early in the

Fig. 6.1 A resuscitative pelvic sheet must be placed over the greater trochanters and secured
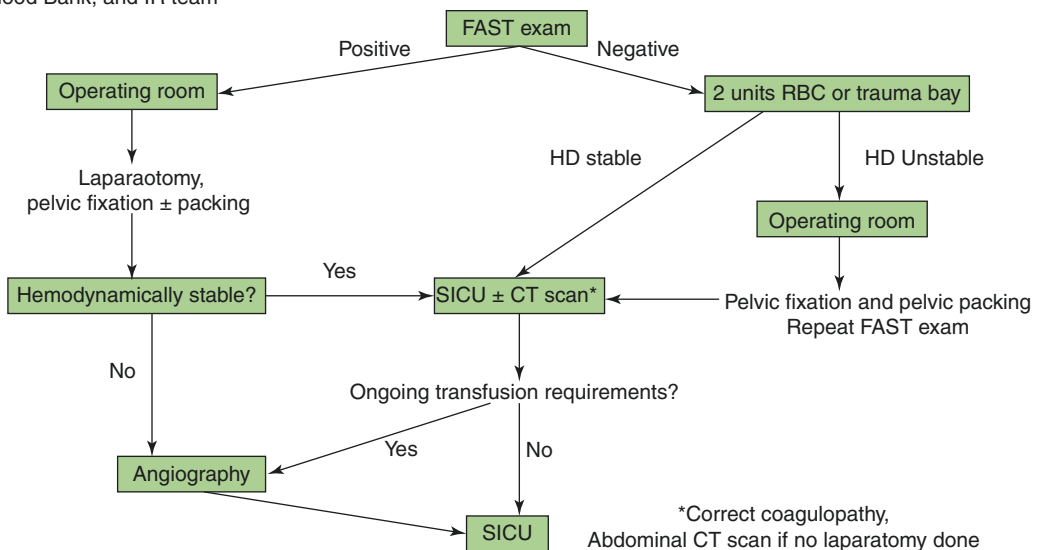

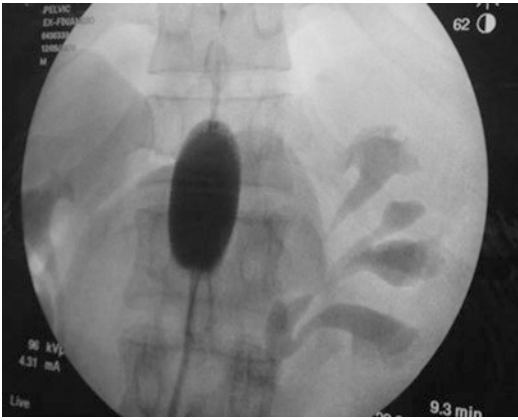**Fig. 6.2** Denver Health institutional algorithm for unstable patients with pelvic ring injuries

Fig. 6.3 Resuscitative endovascular balloon occlusion of the aorta (REBOA) in place for an unstable pelvic ring injury

Fig. 6.4 AP pelvis X-ray with combined APC3 with VS component. *1* Line showing superior migration of the left hemipelvis. *2* Incongruent left sacroiliac joint. *3* Displaced and widened pubic symphysis. *4* Note that the left hemipelvis is externally rotated compared to the right

resuscitation process is currently under investigation and is being used in our institution (Fig. 6.3). In well-trained hands and appropriate indications, it allows control of hemodynamic shock during placement of pelvic external fixation and packing [9, 10]. Such a damage control orthopedic approach requires a well-organized trauma system and a culture of trauma within the institution with adequate resources. Our recent papers have highlighted that with a protocol-driven approach, adequate resources, and a well-organized system, the mortality of patients with unstable pelvic ring injuries treated expeditiously is significantly reduced [7, 8].

Radiographic Analysis: Making Sense of the Injury

The initial AP pelvis X-ray obtained prior to placement of a sheet or external fixator can provide important information in the definitive treatment strategy; however, this X-ray may not always be available due to hemodynamic instability of the patient (Fig. 6.4). The timing of CT scan is controversial and the decision usually made by our trauma colleagues. In general, in the setting of severe shock, the CT scan is obtained post pelvic packing and pelvic external fixator application. One must always keep in mind that both CT and pelvic X-rays are dynamic injuries
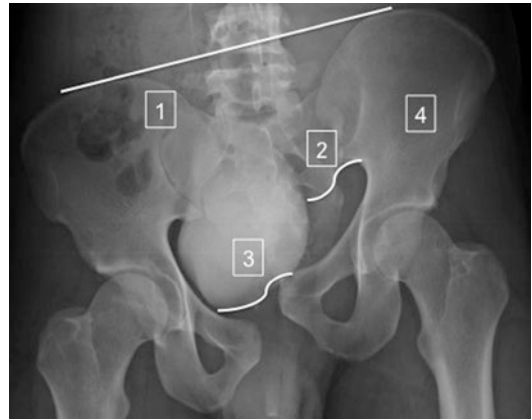
being assessed with a static imaging modality. The injury may appear subtle on X-ray and may not represent the significant degree of displacement at the time of injury. In addition, a well-positioned pelvic external fixators, pelvic sheets, binders, or even CT gantry in obese patients can mask a pelvic ring injury on a CT scan as seen in Fig. 6.5 [12].

Surgical Treatment Decision-Making

Acute Management: External Fixation and Pelvic Packing

In patients presenting with a hemodynamically unstable pelvic ring injury, they are initially managed based on the ATLS protocol.

Our protocol, highlighted in Fig. 6.2, recommends emergent pelvic external fixation and pre-peritoneal pelvic packing for patients not responding to resuscitative measures independently on the pelvic fracture type. This point can be controversial, but in the emergent setting, avoidance of interobserver variability in the decision-making process is crucial.

We prefer supra-acetabular external fixation pin placement for multiple reasons [11]:
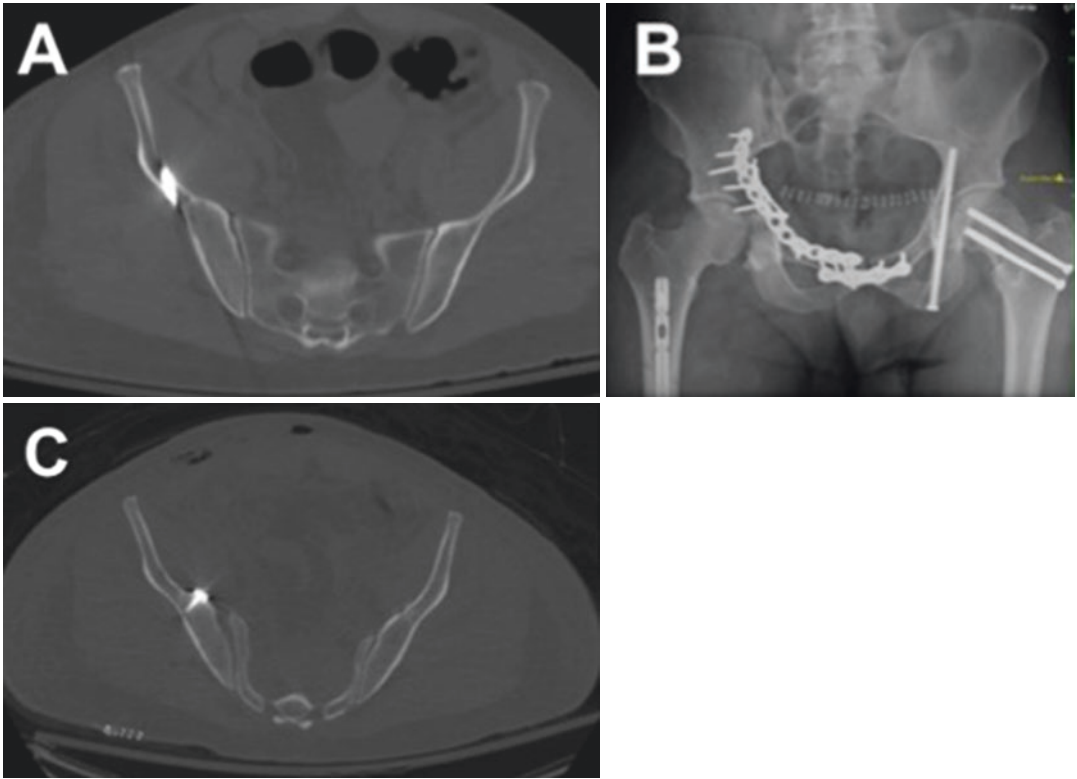
Fig. 6.5 Example of obese patient with a combined acetabular and pelvic ring injury that was masked by placement of external fixator. (**a**) Note that no posterior ring injury is visualized on the preoperative CT scan. (**b**) Postoperative X-ray shows satisfactory reduction of the acetabulum fractures. (**c**) However, postoperative CT scan shows residual widening of the right sacroiliac joint, which was missed due to reduction with the external fixator.

The bony corridor that extends from the anterior inferior iliac spine along the sciatic buttress back to the posterior superior iliac spine is a dense solid pathway that is larger and stronger than the iliac crest equivalent.

This corridor provides a biomechanically superior construct in contrast to iliac crest external fixator pins.

Finally, supra-acetabular pins represent our workhorse reduction tool during definitive fixation.

However, these pins require an experienced surgeon and the use of X-ray imaging to verify safe placement. These obstacles can deter some surgeons from this technique and may push them to use iliac wing corridors [13, 14].

- The patient is positioned supine on a radiolucent flattop operating table. The patient's pelvis is prepped and draped in the usual sterile fashion making sure to leave the umbilicus exposed which represents the only reliable landmark for midline.
- Incision for the supra-acetabular pins is marked 2 fingerbreadths distal and 1 fingerbreadth medial to the ASIS. A small 1 cm incision is made at this location.
- A tonsil is first used after incision to dissect the deep tissues and feel for the AIIS, making sure to understand the medial and lateral extent of this bony prominence. At this time, a 200 mm × 5 mm partially threaded Steinman pin is positioned on the AIIS. The pin is aimed 40° cephalad and 40° medial. A common pitfall is to not aim medial enough. The pin is lightly tapped and held in position.
- At this time, an obturator outlet oblique X-ray is obtained. To get this view, we ask the X-ray
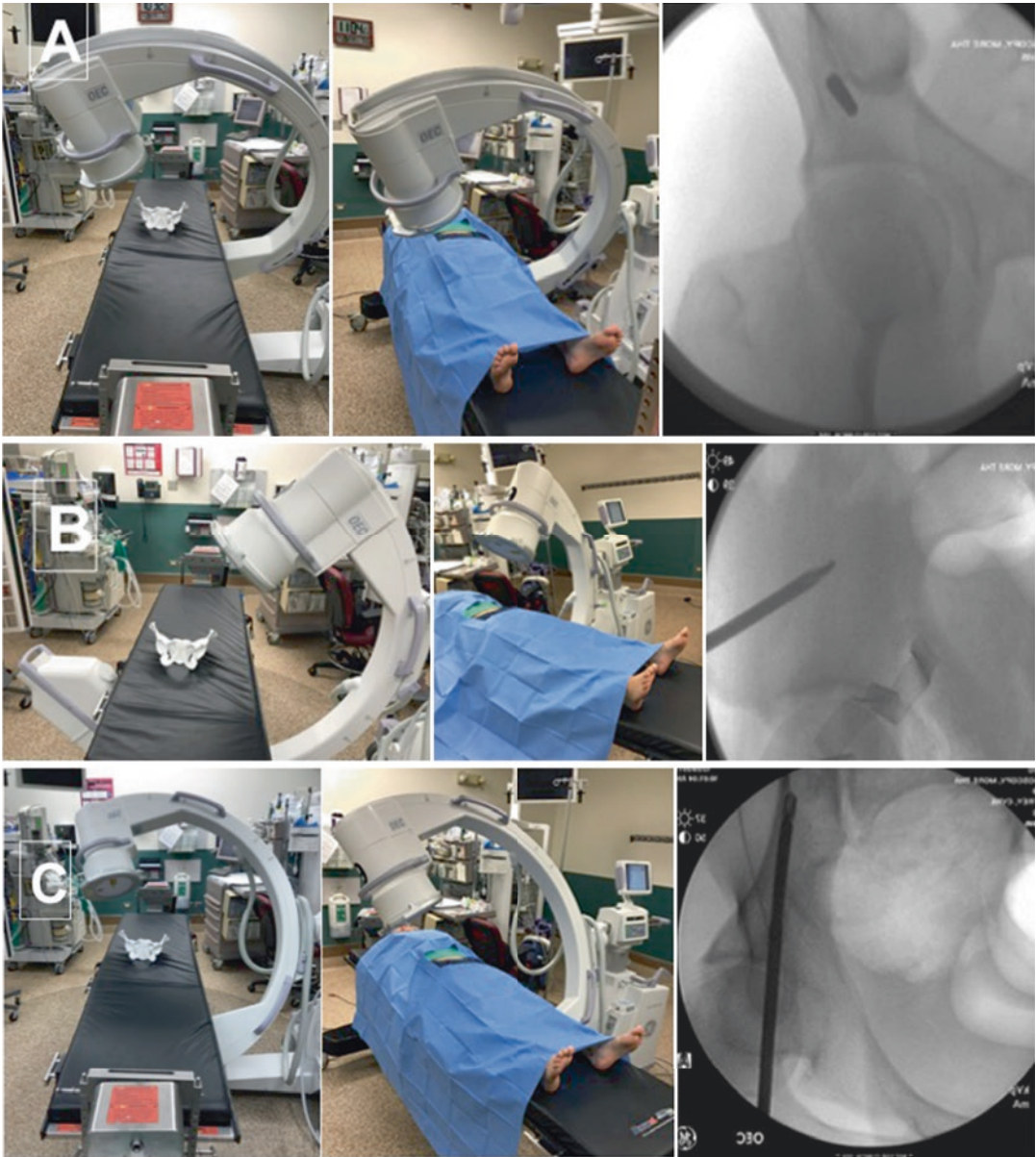
Fig. 6.6 Clinical and radiographic images of the views needed for supra-acetabular external fixator placement. (**a**) Obturator outlet oblique. (**b**) Iliac oblique. (**c**) Obturator inlet oblique

technician to place their column in line with the vector of the pin. The corridor of bone extending from the AIIS to the PSIS can be seen on this view. The pin should be within this corridor of bone (Fig. 6.6a–c).

- The pin is held in position and an iliac oblique X-ray is obtained. The pin trajectory should be just cephalad to the sciatic notch in the dense sciatic buttress bone.

- The final view is an obturator inlet oblique to verify that the trajectory of the pin is aiming between the inner and outer table of the ilium.
- Once all views have been obtained and the trajectory of the pin is satisfactory, the pin is advanced on the obturator inlet oblique image. The pin is advance just anterior to the SI joint. The same technique is performed on the contralateral side. An A frame external fixator
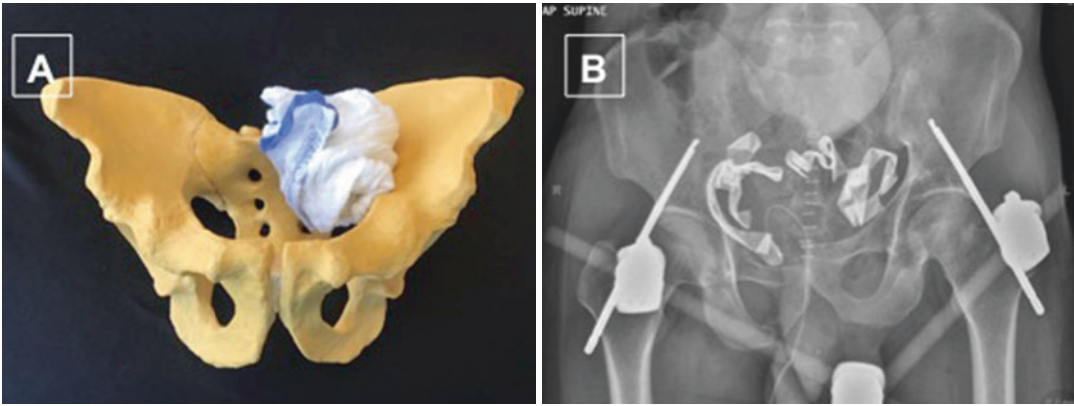
Fig. 6.7 (**a**) Pre-peritoneal packing on a model that demonstrates location of the pack along the pelvic brim. (**b**) Postoperative X-ray showing packs and external fixator in place

construct is built with the aim to stabilize the ring based on the deforming forces. For APC injuries, the hemipelvises are internally rotated, and for lateral compression injuries, the hemipelvises are externally rotated. For the more frequent combined mechanisms, we aim to recreate a solid ring upon which to pack, without too much attention to the initial reduction.

Pre-peritoneal pelvic packing can then be performed using a 5 cm vertical midline incision ensuring that a Foley catheter is in place [7]. The pelvis is then packed with a total of six lap sponges. Three of the lap sponges are placed along the pelvic brim on each side of the pelvis. The most posterior sponge is at the level of the SI joint (Fig. 6.7a, b). The sponges are removed at 24 h.

Preoperative Planning for Definitive Fixation: Imaging

Once the patient is hemodynamically stabilized and the inflammatory response has improved (day 3–6), if associated injuries allow, the patient can be considered for pelvic ring fixation. A pelvic CT scan will help assess the injury and understand the causative mechanism. However, an initial plain pelvic X-ray can add a tremendous amount of quality information to the preoperative

planning strategy and the reduction maneuvers required. For the most part, we prefer, when feasible (injury type, comminution, patient's anatomy), to treat type C pelvic fractures using percutaneous means posteriorly and open reduction internal fixation anteriorly. Such percutaneous method may be challenged in cases of:

- Significant comminution and displacement in transforaminal sacral fracture
- H- or U-type sacral fractures although those injuries can successfully be treated with transsacral screw fixation [15]
- Sacral dysmorphism where an S1 trans-sacral screw cannot safely be positioned
- Inability to obtain an adequate reduction with closed means

In those cases, modalities such as trans-iliac screws or bolts, lumbopelvic fixation, or posterior pelvic ring plating remain valid options of treatment [16]. Each surgical methods have inherent pros and cons, and it is important to weight those cautiously and adapt strategies to level of comfort, training, skills/expertise, and available resources.

Steps involved in the preoperative planning of trans-sacral screw fixation include (Fig. 6.8a, b):

- Split the X-ray viewing screen into two windows with the axial cut on one side and the sagittal cut on the other side. On the sagittal
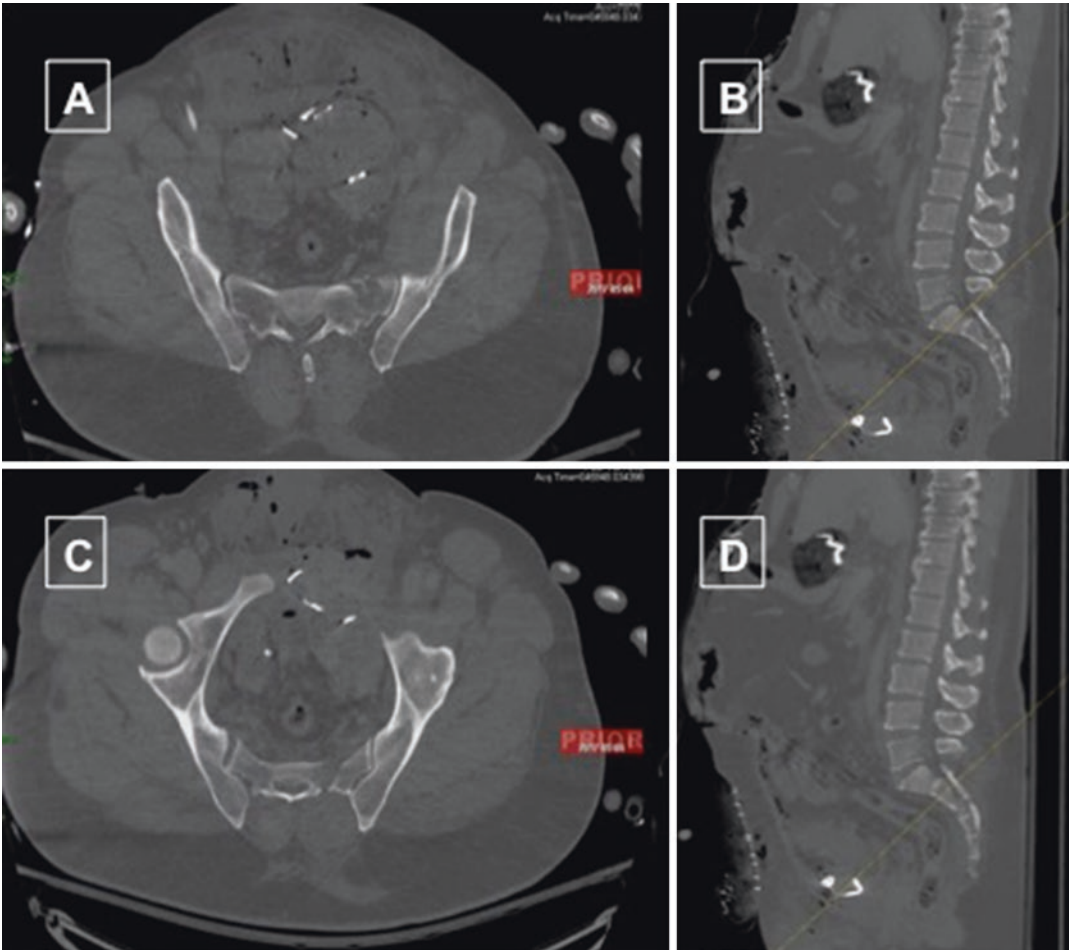
Fig. 6.8 A preoperative CT scan is obtained for planning. A reconstruction of the corridor for safe trans-sacral screw is performed by adjusting the axis of the coronal image for S1 (**b**) and S2 (**d**) to visualize the actual corridor on the axial cut S1 (**a**) and S2 (**c**)

image, the cursor is positioned to obtain an axial cut in the plane of the superior surface of the S1 body. This image will provide a true inlet image on the axial CT identifying the presence or absence of sacral dysmorphism and the AP size of S1 and S1 trans-sacral corridors.

- Measure distance between S1 and S2 on an outlet reconstruction view. This information is useful when the S2 foramen is not well identified during the surgery (gas bubbles, contrast, fecal material, radiolucent objects). In such cases and when the distance between S1 and S2 foramen is sufficient, the screw can be placed just beneath S1 foramina.

- Sagittal cut can help determine the inlet and outlet angles required for adequate fluoroscopy views (inlet and outlet).

Positioning and Operating Room Setup

Patient is positioned supine on a radiolucent flat-top table. The arms are positioned away from the chest abducted to allow for adequate anterior pelvic inlet view. Prepare and drape wide around the pelvis to include the umbilicus for orientation purposes and in case a lateral window is needed for open reduction. In cases of more chronic injuries

Fig. 6.9 Distal femoral traction setup for a left-sided vertical shear pelvic injury with sterile rope and a bucket with 40 lb of weight for traction
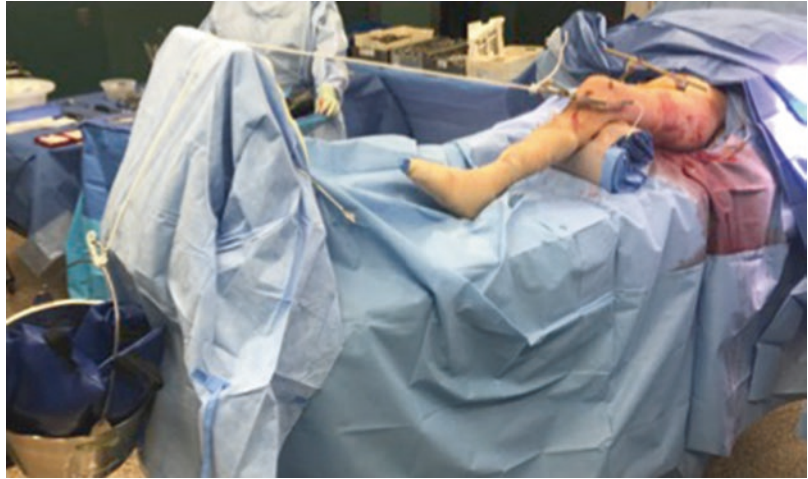

Fig. 6.10 In chronic VS injuries, the patient's pelvis must be bolted to the operating table for stabilization

and/or vertical shear component to the injuries, the vertically translated hemipelvis leg is prepped into the field. Prepping the leg into the field allows for placement of a distal femoral traction pin. A sterile bump is placed under the knee of the affected hemipelvis (Fig. 6.9). In some cases, the contralateral hemipelvis must be attached to the operating table by way of a supra-acetabular external fixator pin (Fig. 6.10).

Intraoperative Imaging

Required intraoperative fluoroscopic views include lateral of sacrum, inlet and outlet views of both the anterior and posterior rings, AP of pelvis, and obturator inlet and outlet oblique images. Once the appropriate angles are obtained, the X-ray technician should mark them for future reference.

Helpful Instrumentation

Several tools/techniques can be helpful to achieve reduction of an unstable pelvic ring injury. Supra-acetabular external fixator pins can be extremely powerful to help correct the posterior translation and external rotation of the affected hemipelvis. The distal femoral traction remains the hallmark of reduction of vertical translation. A drill-tip guide wire and a ball spike pusher are an essential part of our armamentarium. Ensure that 6.5 or 7.3 mm partially threaded cannulated screws are available in the room in all length (up to 170 mm for trans-sacral screws). The use of a drill-tip guide wire as opposed to a threaded-tip guide wire cannot be overemphasized (Fig. 6.11). Unlike the threaded-tip guide wire, the drill-tip guide wire provides the surgeon with proprioceptive feedback verifying the guide wire is within the bone rather than soft tissue

and allows for change of trajectory of the wire. The use of a second guide wire to provide a different trajectory or starting point should not be ignored as a useful technique intraoperatively.

For the anterior pelvic ring displacement, the supra-acetabular external fixator pin is again our workhorse, correcting most internal or external rotational deformity. The final reduction maneuver is achieved using Weber or Jungbluth clamps.

We do not have a GI preparation protocol for our patients preoperatively. Especially in the case of posterior pelvic ring fixation with percutaneous screws, it is important to obtain the appropriate X-rays prior to prepping and draping the patient to ensure that the S1 and S2 neural foramen can be visualized. If the bowel gas does not allow for adequate visualization of the bony landmarks and safe surgery cannot be performed, it is

prudent that the surgeon has a low threshold to reschedule the patient for a different date so that safe surgery can be performed. This occurrence is extremely rare and questions the benefit of bowel preparation prior to pelvic ring fixation.

Definitive Fixation and Reduction: Intraoperative Tips and Tricks

Prior to prepping/draping and reduction, obtain fluoroscopic views of the pelvis. The outlet will help visualize the vertical displacement of the hemipelvis, and the inlet will provide visualization of the A to P displacement.

Vertical shear pelvic ring injuries are rotationally and vertically unstable. The affected hemipelvis routinely assumes a posterior-superior (cephalad) position plus or minus external rotation. The operating surgeon must keep these deformities in mind to allow for adequate reduction and fixation.

We start with a Pfannenstiel incision. The aim is to achieve reduction and temporary fixation. Reduction maneuvers include the use of supra-acetabular external fixation pins that are internally rotated for APC injuries and/or Jungbluth clamp after drilling and placing two 3.5 mm cortical screws on the anterior brim of the pubic symphysis to avoid the area of plate placement. Provisional fixation can be achieved using two 2.0 mm k-wires in a crossing fashion through the symphysis (Fig. 6.12). The reduction achieved is
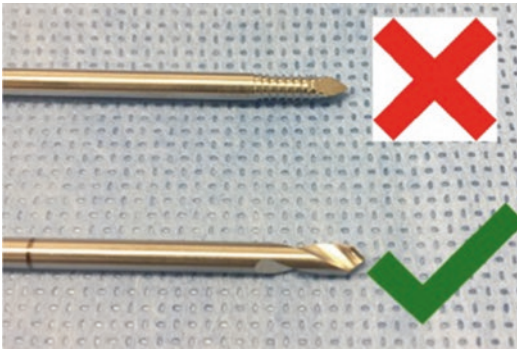

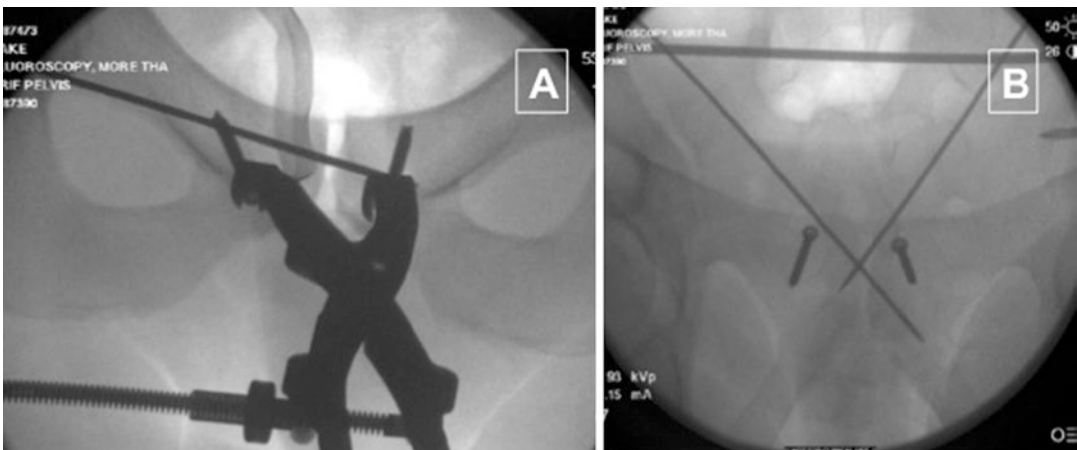**Fig. 6.11** Threaded-tip guide wire (top) and drill-tip guide wire (bottom)

Fig. 6.12 Panel (**a**) demonstrates the use of two screws and a Jungbluth clamp to reduce a widened pubic symphysis. Panel (**b**) shows provisional fixation of the pubic symphysis with two k-wires
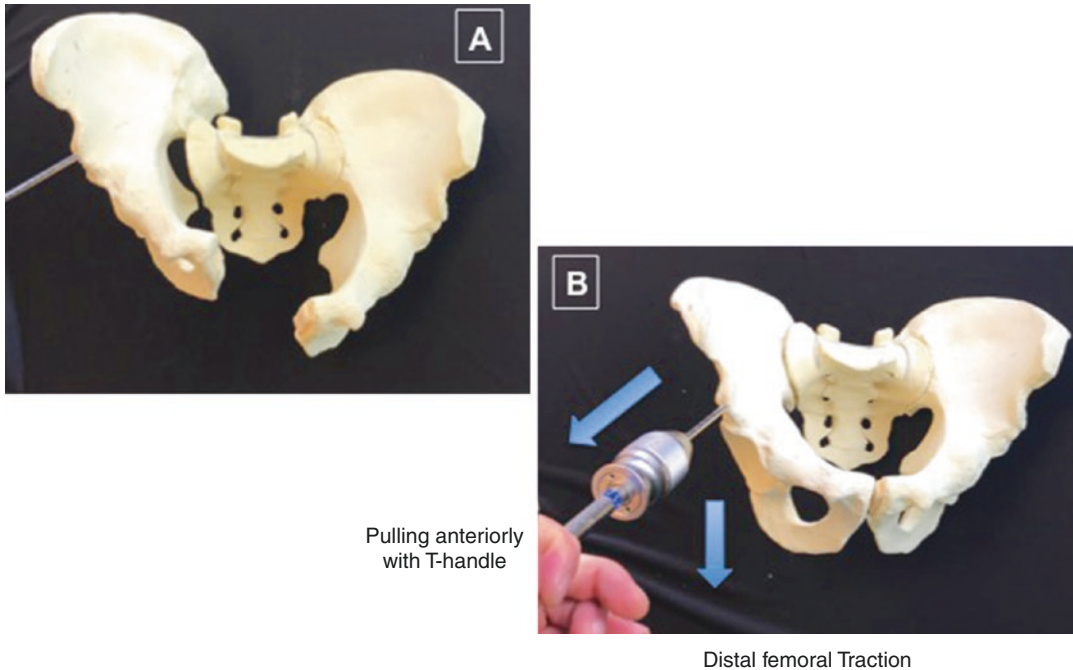
Pulling anteriorly
with T-handle

Distal femoral Traction

Fig. 6.13 Pelvis model showing the typical displacement pattern for a vertical shear pelvic ring injury. In (**a**), the right hemipelvis is vertically and posteriorly translated. Panel (**b**) shows the reduction maneuver with a T-handle chuck pulling anteriorly through the supra-acetabular external fixator pin and distal femoral traction pulling inferiorly on the hemipelvis

often imperfect at this point and only temporary. We then address the posterior ring.

In the case of vertically displaced fractures, a distal femoral traction can be helpful for reduction of the superior (cephalad) component. The distal femoral traction pin is placed on the ipsilateral-sided leg as the affected hemipelvis. The traction pin and Kirschner bow are applied sterilely, and sterile rope is used to attach the Kirschner bow to a bucket hanging off the end of the bed with sandbag weight and/or saline bags. The weight required for reduction can be up to 50 lb in order to overcome the vertically translated forces (Fig. 6.9). The hemipelvis also assumes posterior displacement. The hemipelvis must be translated anteriorly in order to get an accurate reduction. This can be performed by placing a supra-acetabular Steinman pin (if not already in place through a pelvic external fixator) and using a T-handle chuck to anteriorly translate the pelvis (Fig. 6.13a, b). The correction of vertical and posterior translation can be

temporarily held using a drill-tip guide wire inserted through the posterior ring in the S1 body. The diastasis that remains across the SI joint or the posterior ring fracture will be corrected using the force of two sequentially inserted partially threaded trans-sacral screws based on the preoperative planning.

Those maneuvers and screw insertion are often done with assistant hands holding the supra-acetabular pin in place to keep the newly reduced hemipelvis in place. This is not easy. We start with a lateral X-ray of the sacrum (overlap of the greater sciatic notches). The iliocortical density (ICD) is identified for the S1 corridor (Fig. 6.14). An entry point proximal to the ICD would damage the L5 nerve root and leave the patient with dramatic and potentially permanent nerve injury. A drill-tip guide wire is used to mark the appropriate starting position on the skin. This should be just distal to the ICD and cephalad to the S1 neural foramen. A small skin incision is made, and the wire is inserted against the bone. The wire is positioned in the safe
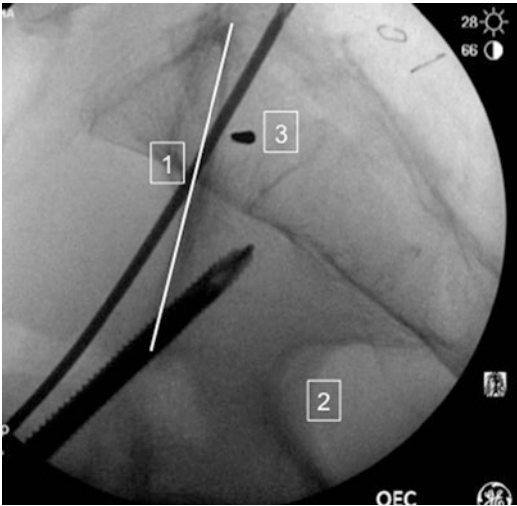
Fig. 6.14 Radiographic lateral of the sacrum utilized for placement of trans-sacral or iliosacral screws. Number 1 demonstrates the iliocortical density (ICD). Number 2 shows overlap of the greater sciatic notches. Number 3 indicates a guide wire positioned appropriately for a trans-sacral screw trajectory

corridor of bone, and a mallet is used to gently tap the wire. When the lateral sacral view confirms adequacy of entry point, inlet and outlet X-rays are obtained to verify the trajectory of the wire in both the cephalad and caudal planes and the anterior and posterior planes (Figs. 6.15 and 6.16). We routinely do not advance the wire until our trajectory is perfect. Proprioception and X-ray will guide the wire through the lateral iliac cortex of the oppos-

ing pelvis. An outlet obturator oblique view of the contralateral hemipelvis can confirm wire penetration of the lateral cortex (Fig. 6.17). When placing an S2 screw, the inlet view is not as reliable since it is impossible to differentiate the anterior edge of S2 body and S1 body. The lateral view remains the guide to appropriate starting point of an S2 trans-sacral screw followed by an inlet (not as reliable) and an outlet view. The wire should aim just distal to the S1 guide wire. We typically place the S1 and S2 wires and then place a 7.3 or 6.5 mm cannulated partially threaded screw over the guide wires. The screws are sequentially tightened ensuring closure of the diastasis.

We then perform definitive fixation of the anterior pelvic ring. A pubic symphysis plate is applied, and screws are placed on either side of the pubic symphysis for definitive fixation.

In lateral compression variant pelvic ring injuries, the challenge is to reduce the iliac wing to the posteriorly based crescent fracture. This can be accomplished with a variety of maneuvers. Obtain an obturator outlet oblique image to visualize the crescent fragment. Utilizing a supra-acetabular pin with a T-handle chuck, the iliac wing is externally rotated and pulled anteriorly to bring the iliac wing to the crescent fracture. Then a small incision is made laterally in the area where an SI screw would be placed and a ball spike pusher is inserted onto the posterior aspect of the iliac wing to allow for medialization of the iliac wing to the

Fig. 6.15 Clinical and radiographic example of an outlet view of the pelvis for placement of a trans-sacral screw

Fig. 6.16 Clinical and radiographic example of an inlet view of the pelvis for placement of a trans-sacral screw
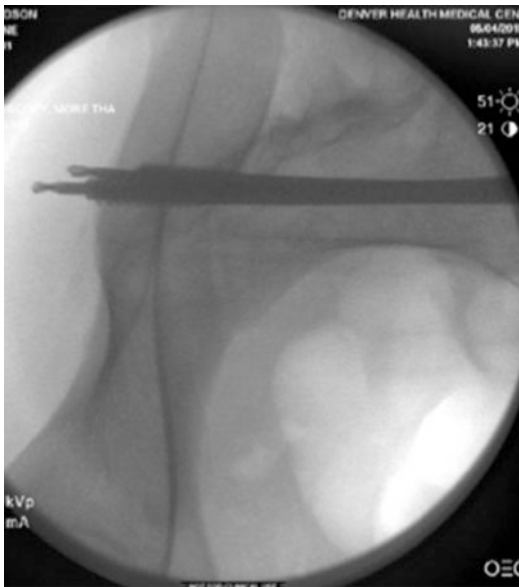

Fig. 6.17 An obturator inlet oblique is used to assess the length and amount of protrusion of trans-sacral screws

crescent fracture posteriorly. The third vector of reduction is through the longitudinal distal femoral traction. Finally, a drill-tip guide wire is inserted from anterior to posterior just cephalad to the supra-acetabular Steinman pin in the same corridor of bone (LC2 screw) through the iliac wing posteriorly to the crescent fragment (Fig. 6.18a–c). This reduces the iliac wing to the crescent fragment and allows for placement of a cannulated 6.5 mm screw from anterior to posterior as an additional point of fixation in addition to well-placed trans-sacral screws.

Postoperative Protocol

With the patient still intubated and in the operating room, we obtain pelvic flat plates AP, inlet, and outlet views to ensure adequacy of reduction and fixation (Fig. 6.19). We then obtain a postoperative CT scan to ensure adequate placement of hardware (Fig. 6.20).

Take-Home Messages

- Poly-trauma patients with hemodynamic instability should be evaluated for an unstable pelvic ring injury.
- Following the ATLS protocol in these patients is critical.
- Emergent placement of a sheet or pelvic binder in the emergency room is a lifesaving procedure.
- Critical assessment of the first AP pelvis (when available) provides the surgeon with essential preoperative planning information often more valuable than the CT scan itself.
- The use of institution protocols for the management of hemodynamically unstable pelvic fractures has been shown to reduce mortality.
- Preoperative planning before definitive fixation will improve outcomes.
- Our preferred method of reduction for most type C pelvic fractures is the use of distal femoral traction and a supra-acetabular Schanz
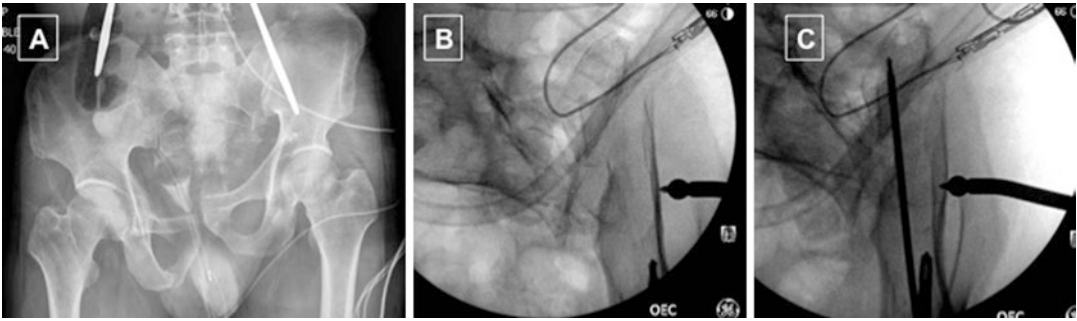
Fig. 6.18 In cases of an LC3 pelvic ring injury with a large crescent fracture, the supra-acetabular ex-fix pin with a T-handle chuck pulling anteriorly and a ball spike applying force laterally can allow for placement of a wire and screw from anteriorly to posteriorly, reducing the iliac wing to the crescent fracture
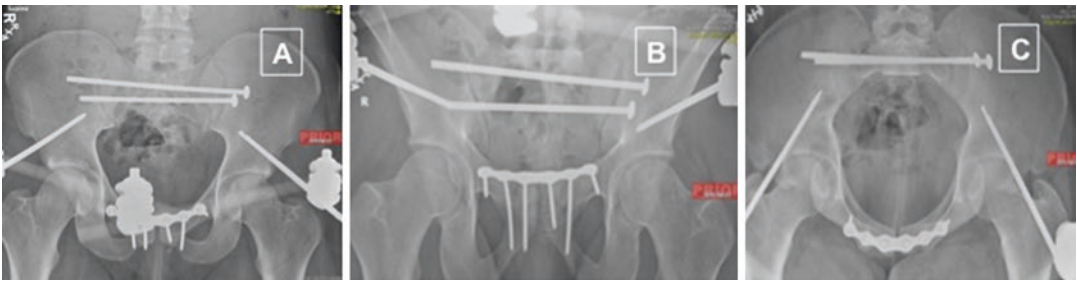

Fig. 6.19 Postoperative X-rays after anterior and posterior fixation of an unstable pelvic ring injury with external fixator left in place for 6 weeks to supplement the fixation. (**a**) AP. (**b**) Outlet. (**c**) Inlet
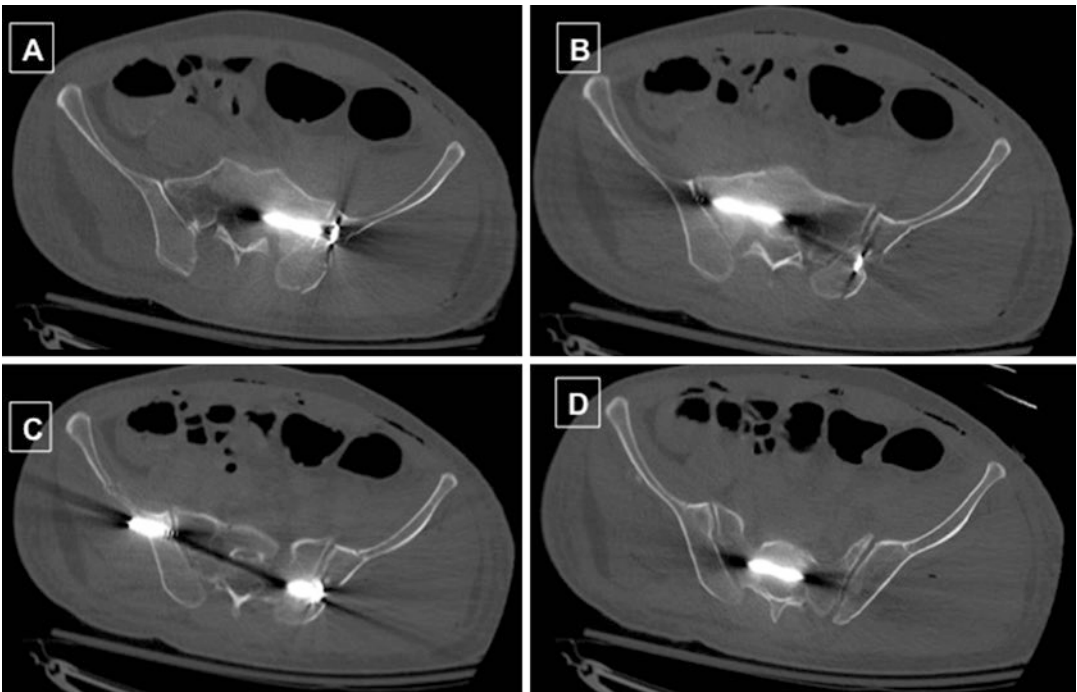

Fig. 6.20 A postoperative CT scan is obtained after fixation of the pelvic ring. Panels (**a**, **b**) show the course of the S1 trans-sacral screw, and (**c**, **d**) show the course of the S2 trans-sacral screw

pin. The former achieves vertical displacement reduction, while the latter corrects rotational deformity.

- We prefer percutaneous fixation for the posterior ring with the use of trans-sacral screws in S1 and S2 when feasible.
- The order of fixation in our hands is temporary fixation anteriorly, definitive fixation posteriorly, and definitive fixation anteriorly.
- Flat plate X-rays with the patient still asleep are important.
- Postoperative CT scan is essential to critically appraise quality of reduction and safe placement of hardware.

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