SURGICAL TECHNIQUES

Percutaneous ilio-sacral screw insertion. Fluoroscopic techniques

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Introduction

Unstable pelvic ring fractures raise treatment challenges in severely injured patients. Ilio-sacral screw fixation is an elegant option for stabilising the posterior lesion, which is a common source of residual pain. This technique provides secure fixation. The first description can be found in a 1913 treatise by Lambotte [1]. In 1978, Letournel reported the treatment of sacro-iliac joint dislocation by open ilio-sacral screw placement with the patient in the prone position and direct digital control [2]. A decade later, Matta et al. [3] extended the indications to sacral lesions by using the inlet, outlet, and antero-posterior views described by Pen nal et al. [4]. Ebraheim et al. in 1987 then Routt et al. in 1993 described strictly percutaneous ilio-sacral screw insertion with the patient in the supine position [5,6] to allow the use of this technique in fragile multiply injured patients while eliminating the risk of surgical site infection. Routt et al. improved the fluoroscopic technique by analysing the features of the lateral sacral view [7]. Prior reduction of the posterior lesion using an external method is a prerequisite to ilio-sacral screw fixation. Thorough familiarity with the anatomic features of the lumbo-pelvic junction and neighbouring vessels and nerves is crucial [8]. A high level of expertise with the surgical procedure is necessary to avoid iatrogenic complications and to minimise radiation exposure of the patient and surgeon [9,10].

Prior reduction of the displacement

Reduction to restore the normal pelvic ring anatomy is a prerequisite to percutaneous ilio-sacral screw fixation. The posterior bone and ligament lesions must be reduced using indirect methods.

Reduction of posterior Tile type B lesions opened into the anterior ring lesion involves approximation of the two coxal bones. There is no vertical instability. When the anterior lesion consists in symphyseal dislocation, plate fixation

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of the pubic symphysis is an effective and simple means of achieving coaxial bone reduction in the supine position. Fixation of the obturator rim is not performed in everyday practice, as preservation of the obturator membrane and inguinal ligament limits the instability of this lesion. Reduction can then be achieved by simple compression to approximate the two antero-superior iliac spines. The assistant usually maintains the compression while the surgeon inserts a pin into the sacro-iliac joint. A sheet wrapped around the two iliac wings may be needed. An opening is fashioned in the sheet at the screw insertion site in the skin. After ilio-sacral implantation an anterior simple external fixator could be placed with a pin in each antero-superior iliac spine. This could help to stabilize the horizontal stability until obturator rim(s) healed.

Posterior Tile type C lesions combine horizontal and vertical instability and must be reduced within 48 hours of the injury. After this interval, organisation of the haematoma at this highly vascularized site precludes manipulative reduction. Transcondylar femoral traction with an initial weight of up to 20% of the patient’s body weight is used to correct the ascension of the detached hemi-pelvis. Subsequently, the weight is decreased to 10% of the patient’s body weight. In haemodynamically unstable patients, a clamp must be placed after traction is complete. Combined traction and clamping ensures the full reduction of complete Tile type C posterior lesions. Inlet, outlet, and lateral views as described below are used to check that reduction has been achieved before percutaneous screw insertion. Even when reduction in the horizontal plane is less than perfect, the patient can wait in the position ensuring reduction in the vertical plane. Definitive reduction in the horizontal plane can then be achieved on the operating table as described above for Tile type B lesions.

Sacro-iliac dislocation may require additional manipulations to achieve full reduction. Two hard pads (folded sheets) placed under the posterior iliac spines and ischial tuberosities may facilitate re-positioning of the coaxial bone relative to the sacrum, as the sacrum is usually displaced anteriorly. Pins inserted into the anterior iliac crest serve to displace the coaxial bone anteriorly or posteriorly in order to seat the sacrum into the auricular surface. Ilio-sacral screw placement should not be relied on to reduce the dislocation. At the most, compression serves to close the joint space, but anatomic approximation of the two bones must be obtained first. An external fixation system can be used to secure the intact contra-lateral hemi-pelvis and femur to the traction table. This method increases the effectiveness and strength of the transcondylar traction on the detached hemi-pelvis, while preventing ipsilateral tilting. Finally, neuromuscular blockade of the abdominal and ilio-psosas muscles is required to facilitate this closed reduction procedure.

When closed reduction is suboptimal, the sacro-iliac joint should be approached either anteriorly via the middle portion of the ilio-inguinal approach, with the same installation, or posteriorly with the patient in the prone position. Severely displaced sacral wing fractures, i.e., with more than 10 mm of upwards displacement on the anteroposterior radiograph, require a posterior approach in the prone position. Upwards displacement of less than 10 mm has no functional impact and can therefore be tolerated. The screws are then inserted percutaneously, under direct visual guidance via the open surgical approach used for the reduction.

**Preparation of the material**

We prefer screws with large diameters, either 7 mm for steel screws or 7.3 mm for titanium screws. These screws are cannulated, which simplifies the procedure, as the only requirement is optimal positioning of the guide-wire. A skin suture kit is needed and a mallet may be useful. The table should have a transparent top, an intra-operative traction system, and an image amplifier with image persistence that can be rotated and translated along the 6 degrees of freedom in space (Fig. 1).

**Installation**

The patient is in the supine position. Unilateral or bilateral transcondylar traction is left in place during the procedure, depending on the extent of the displacement (Fig. 1). The table should be inclined towards the head to compensate for the traction. The pelvis is elevated from the table top to increase the obliquity of the screw trajectory in the posterior-to-anterior and lateral-to-medial directions. General anaesthesia and neuromuscular blockade are used.
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Fluoroscopic feasibility check

Before clamping, all the radiographic manipulations must be repeated to check their feasibility. The X-ray captor is positioned above the patient to minimise magnification and allow for greater amplitude relative to the support column of the operating table. The Jackson table with supports on both ends is ideal for this procedure. Patients in critical condition may have large amounts of intra-pelvic faecal material or intestinal gas; poor visibility of the skeleton contra-indicates percutaneous ilio-sacral screw fixation. The operator must check that the views required during the procedure can be obtained:

1. inlet view as described by Pennal et al. [4] (Fig. 1): visibility of the sacral canal and S1 vertebral body indicate good image quality;
2. outlet view described by Pennal et al. [4] (Fig. 2), which should provide a vertically symmetrical view of the first two sacral foramina on both sides. The pubic symphysis should project over the S3 vertebral body. A crucial step is evaluation of this view for signs of lumbo-sacral junction dysplasia, which alters the screw placement landmarks;
3. strict lateral view, known as the Routt view [7] (Fig. 3), which should show the antero-superior part of the S1 vertebral body, on which the iliac cortical density on each side projects as two lines directed obliquely from posterior to anterior and from cephalad to caudad [7]. These lines run along the anterior edge of the sacro-iliac joint and serve as landmarks when advancing the wire. Perfect superimposition of the two greater sciatic notches is the quality criterion for this view. Superimposition of the femoral heads is not sought as it would induce a parallax compared to a strict lateral view centred on the first sacral vertebra.

Note on lumbo-sacral dysplasia

Lumbo-sacral dysplasia consists in sacralisation of L5 and must be identified to avoid attempts at screw insertion into an S1 vertebra that is too small to accommodate an ilio-lumbar fixation screw. In addition, screw placement would require a degree of anterior obliquity too great to be achieved in the supine position. In patients with lumbo-sacral dysplasia, the screws should be inserted into the second vertebra below the caudal-most mobile disk. The diagnostic criteria for lumbo-sacral dysplasia are outlined below:

1. three simple criteria on the antero-posterior pelvic radiograph and outlet view: the caudal-most mobile disk is near the bi-iliac line; the sacral mammillary processes are hypertrophied; and the first anterior sacral foramina are abnormally large;
2. other signs visible on sagittal computed tomography (CT) reformations: between the first and second sacral vertebrae, a disc remnant is visible and the lordosis is very marked;
3. transverse CT reformations show mortise-and-tenon fitting of the sacro-iliac joints;
4. finally, on the lateral radiograph with superimposition of the greater sciatic notches, the iliac cortical densities are vertical.

In addition, a careful analysis of transverse sections though S1 is always valuable before ilio-sacral screw insertion, to assess the position of the S1 body relative to the skin insertion site. The screw pathway should be tailored to the anatomical characteristics of each patient. Spines with large curvatures and marked pelvic incidence usually have an S1 body that projects anterior to the line connecting the two sacro-iliac joints.

Identification of the S1 body

Once the feasibility of the three views has been established, the installation is considered satisfactory. Before preparing the skin, the surgeon determines the site of projection onto the skin of the S1 body, which is the target of the screw trajectory. On the antero-posterior view, a metallic rod transversal to the axis of the patient’s body is positioned over the projection of the S1 body to materialise a transversal abdominal line, which is then traced on the skin using an indelible marker. This line is extended laterally on the side where the screw will be inserted; this extension visible on the patient’s side is
vertical. On the strict lateral view (superimposition of the two greater sciatic notches), a metallic rod is placed horizontally along the patient’s body, over the projection of the S1 body. The longitudinal line along this second rod is then traced using a marker on the skin on the side of screw insertion (Fig. 3); this line is horizontal on the patient’s side. The intersection of the two lines delimits four quadrants: dorso-cranial, dorso-caudal, ventro-cranial, and ventro-caudal.

The skin is then prepared and draped. Adhesive plastic film should not be used in the area of the line intersection where the guide-wire will be introduced, as there would be a risk of the plastic film winding around the guide-wire.

**Principle and topography of the screw pathway**

The principle of the procedure is to connect the coxal bone to the S1 body using a screw. The pathway is therefore a straight line that successively crosses the outer table of the coxal bone (hard tissue), the cancellous bone of the iliac wing, the sacro-iliac joint with the bone of the two coxal and sacral joint surfaces (hard), the sacral wing corridor filled with fatty tissue, and the S1 body composed of compact cancellous bone (fairly hard).

The screw must travel through the narrow zone of the sacral wing (Fig. 4). This zone is seen on sagittal sections as an oval with a mean long axis of about 23 mm and a mean short axis of about 12 mm [11]. Major nerves course near this zone. Superiorly and anteriorly, the lumbo-sacral trunk courses downwards against the sacral wing as a flat cord containing the L4 and L5 fibres for the sciatic nerve. Posteriorly and inferiorly, the anterior branch of the S1 spinal nerve travels without tension into the anterior S1-S2 foramen. Thus, an extra-osseous pathway in the sacral wing region has a potential for causing nerve injury. Medial to this region, the common iliac vein is near the skeleton at the site where the sacral wing connects with the vertebral body. On the right side, this vein may be in close contact with the bone.

Although the screw must travel through a point centred on the narrow zone of the sacral wing, the direction of the pathway differs depending on whether the lesion involves the sacrum or the sacro-iliac joint. For sacral lesions, the screw follows the axis of the sacral wing (Fig. 5). The desired effect is not compression but instead a nailing effect that counteracts the vertical shear forces in the sacrum. For sacro-iliac lesions, in contrast, the screw is perpendicular to the joint surface (Fig. 6) and the desired effect is compression of the coxal bone (which must be intact) against the S1 body. Screw fixation of an unstable sacro-iliac joint along the sacral wing axis carries a risk of overlap between the sacral and coxal sides of the joint. It is worth noting here that crescent fractures of the posterior iliac wing that involve the joint surface should not be managed by ilio-sacral screw fixation, as the head of the screw would not be supported by the outer table of the coxal bone.

**Guide-wire insertion**

The guide-wire can be inserted either at the intersection of the two lines traced on the skin on the side of the fracture or in the dorso-cranial quadrant (Fig. 7). The guide-wire in the cannulated screw ancillary kit is introduced manually through the skin with no prior incision. When the guide-wire contacts the outer table of the coxal bone, it is driven into the outer cortex using a mallet to stabilise its position while
inlet and outlet views are obtained (Figs. 8 and 9). On these views, the direction of the guide-wire must remain strictly within the bone. If this is not the case, the guide-wire is left in place and a second guide-wire is inserted using the first one as a reference.

Once the appropriate direction is identified, a power driver can be used to advance the guide-wire along half of its pathway, i.e., into the sacral wing. The crossing of the outer coxal-bone table and of the sacro-iliac joint is easily perceived by the operator. Once the guide-wire is

**Figure 4**  Narrow zone and neurological landmarks.

**Figure 5**  Sacro-iliaque screws. Thread is discontinuous. The direction is perpendicular to the ilio-sacral articulation.

**Figure 6**  Sacral screw. Thread is continuous. Direction is closed to a perpendicular line to the sagittal plan.
in the sacral wing there is no further resistance to its progression. At the level of the sacral foramen, a lateral view must be obtained to check the pathway of the guide-wire, whose tip should be located behind the two iliac cortical densities and directed towards the sacral promontory (Fig. 10). If at this level the guide-wire has already crossed the iliac cortical densities, then continuing along the same line would result in an extra-osseous pathway anterior to the sacral wing and, therefore, in a risk of injury to the lumbo-sacral trunk. On this view, it is important to check that the direction is neither excessively cranial towards the L5-S1 disc nor excessively posterior towards the sacral canal containing the cauda equina roots, including S1. In either case, the entire procedure must be started over. The guide-wire is left in place as a reference and another guide-wire is inserted. Thus, inlet, outlet, and lateral views should be obtained repeatedly until the correct position is achieved. The guide-wire is then advanced under guidance from an antero-posterior view until about 1 cm beyond the midline in the S1 body. In this way, the screw threading is anchored into the total volume of available cancellous bone. When the guide-wire is being pushed through the sacral wing, the assistant can place a hand on the patient’s ipsilateral foot to check the absence of nerve irritation. This functional assessment is only useful if the neuromuscular block has been lifted. Motor evoked potential recording has been suggested but has not been proved reliable.

Another option consists in using the lateral view for the initial position checks. This requires a C-arm with a large radius of curvature, as before being advanced the guide-wire is near the ipsilateral fluoroscope captor.

**Screw insertion**

A short incision is made along the guide-wire. A tool in the ancillary kit is used to determine the required screw length, by subtraction. The cannulated bit in the kit serves to drill a tunnel along the guide-wire. Again, the passage of the cortices is easily felt and provides information on the position of the bit: if a hard area is felt about mid-way through the sacral wing, then an extra-osseous trajectory is being created.

The tap is then used to cross the coxal bone and the sacroiliac joint. The screw is inserted manually, with a washer under the screw head if a compression effect is desired (Fig. 11).

Screw fixation of a sacral fracture does not require compression of the fragments, which carries a risk of injury to the nerve roots near the fracture site. A screw with a continuous thread should therefore be used. Sacro-iliac joint dislocation, in contrast, requires compression. A washer is
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Criteria for successful ilio-sacral screw fixation

The main criterion for success of the procedure is strictly intra-osseous screw implantation as assessed on transverse CT images along the axis of the screw. In addition, the muscles and dermatomes served by the L4, L5, and S1 roots should be tested before and after the procedure. Transverse CT images are used to check compression of a dislocated sacro-iliac joint. On the plain antero-posterior pelvic radiograph, the heights of the two iliac crests should be within 5 mm of each other.

Postoperative care

The patient is allowed to sit at about 45° for the first 45 days. Gradual weight-bearing is then started in a pool. Single-leg weight-bearing is allowed on either side between 1.5 and 3 months after the injury.

Learning curve

This procedure requires in-depth familiarity with the anatomy of the lumbo-sacral junction bones and ligaments and of the neighbouring vessels and nerves. Electronic simulation tools can help to identify three-dimensional positions from two-dimensional fluoroscopy images [10].

Personal clinical experience

We have collected longitudinal data on 134 lesions managed by ilio-sacral screw fixation in 120 patients with a mean follow-up of 14 months. There were 96 males and 24 females with a mean age of 38 years (range, 14–75 years). The mean Injury Severity Score was 26/75 and 94% of the lesions were Tile type C. Emergency continuous traction was used in all patients and a pelvic clamp in 23 patients. Mean time from injury to screw insertion was 2 days. Open reduction was performed in 10 cases, via the anterior ilio-inguinal approach in seven and the posterior sacral approach in...
three. Anterior internal fixation was used also in 39% of patients. Sacral dysplasia was present in 5% of patients.

Extra-osseous trajectories occurred in 19.8% of cases. The neurological status worsened in 12 patients, i.e., 16.7% of the patients whose preoperative neurological status was known. Local infection occurred in four cases and disassembly in 10. Mean time to weight-bearing was 70 days. After the mean follow-up of 14 months (range, 6–50 months), the mean Majeed score was 76/100 (range, 22–100), the mean visual analogue scale score (VAS) was 5/10, and the mean WHO analgesic use score was 1/3. Non-union was noted in only seven cases. Mean posterior vertical misalignment was 4 mm (range, 0–20 mm) and mean anterior horizontal malalignment was 1 mm (range, 0–32 mm). Anterior and posterior extra-osseous trajectories showed weak correlations with posterior vertical misalignment. Neurological injuries affected the functional Majeed score, WHO score and visual analogue scale score.

Conclusion

The results in our clinical case-series highlight the challenges raised by percutaneous ilio-sacral screw fixation. Nevertheless, in severely injured patients, this technique provides valuable benefits including absence of non-union and of highly incapacitating sacro-iliac pain. As with all image-guided percutaneous techniques, strong three-dimensional conceptualisation is required before the procedure. A period of cautious training under close supervision is mandatory.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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