



Sacral fractures: issues, challenges, solutions

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- Sacral fractures are a heterogeneous group of fractures occurring in young people following road traffic accidents and falls from height, or in the elderly with osteoporosis following trivial trauma.
- This heterogeneity, combined with the low incidence of sacral fractures, determines a lack of experience amongst physicians, often leading to misdiagnosis, underestimation and inadequate treatment. The diagnosis should be made by assessing specific features during the clinical presentation, while computed tomography (CT) scan continues to be the choice of investigation.
- Sacral fractures can be treated non-operatively or surgically. Non-operative treatment is based on rest, pain relief therapy and early mobilization as tolerated. Surgical techniques can be split into two main groups: posterior pelvic fixation techniques and lumbopelvic fixation techniques. Anterior pelvic fixation techniques should be considered when sacral fractures are associated with anterior pelvic ring injuries, in order to increase stability and reduce the risk of posterior implant failure. To improve fracture reduction, different solutions could be adopted, including special positioning of the patient, manipulation techniques and use of specific reduction tools. Patients suffering from spinopelvic dissociation with associated neurologic lesions hardly ever recover completely, with residual lower-limb neurologic sequelae, urinary problems and sexual dysfunction.
- Herein, we present issues, challenges and solutions related to the management of sacral fractures.

Keywords: fixation; lumbopelvic fixation; neurological lesion; sacral fracture

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Introduction

The os sacrum is the hinge between the vertebral column and the pelvic ring, supporting the upper body weight

and playing a fundamental role in giving stability to the pelvic ring during load-bearing.¹ It is in contact with several critical structures such as nerves, blood vessels, urogenital and other pelvic organs. A fracture of the sacrum is therefore troublesome as it determines an impairment in ambulation and it may present various associated lesions.

Sacral fractures are a heterogeneous group of fractures occurring in young people following road accidents and falls from height or in the elderly with osteoporosis following trivial trauma. The incidence of non-osteoporotic sacral fractures has been reported as 2.1 cases per 100,000 people, while osteoporotic fractures have been reported to have an incidence of 1–5% in elderly patients at risk.^{2–4} Both fracture groups are reported to be increasing: non-osteoporotic has tripled in the decade between 2002 and 2011 and the incidence of osteoporotic fractures is also increasing because of the aging of the population, with the prospect of continuing to further increase in the coming years.^{1,2,5} However, the reported growth must also be attributed to the greater and more widespread use of computed tomography (CT) scan, which allows a higher rate of diagnosis.⁶ This heterogeneity, combined with the low incidence of sacral fractures, determines a lack of experience amongst physicians, often leading to misdiagnosis, underestimation and inadequate treatment.⁷ Good knowledge of sacral fractures and their characteristics is therefore essential to correctly diagnose and manage these patients, in order to competently deal with both simple and complex fractures.

This review aims to highlight recent advances in diagnosis, management and treatment of this challenging fracture group.

Classification

Many classifications have been proposed to describe sacral fractures; however, being a heterogeneous group of injuries, none of these is really able to take into account all the possible variables that could characterize a sacral fracture.⁸ Current classification systems can be presented in terms of:

- a) The energy of trauma sustained: high-energy (young patients) or low-energy fractures (elderly);⁷ insufficiency fractures (secondary to radiation or frailty)⁹ and stress fractures (young athletes).¹⁰
- b) Association with pelvic ring injuries (isolated accounting for up to 10–13% of all sacral fractures^{11,12} or associated with pelvic injury (up to 80–90%).¹³ The classification systems broadly utilized to describe sacral fractures in the context of pelvic ring injuries are the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopaedic Trauma Association (AO/OTA) modified Tile (AO/OTA) classification¹³ and Young–Burgess (YB) classification,¹⁴ for high-energy fractures, and the Fragility Fracture of Pelvic ring (FFP) classification,¹⁵ for low-energy fractures. The AO/OTA classification classifies the fracture according to pelvic ring stability, while the YB takes into account the fracture resulting from the different displacing vectors: anterior-posterior compression (APC), lateral compression (LC), vertical shear (VS). FFP classification divides fractures according to morphology and instability.
- c) Morphology describes the orientation of the fracture lines with regard to the sacral bone (longitudinal, transverse or combined as H-, U-, lambda- or T-shaped). Longitudinal fractures are the most common (90%),¹¹ transverse fractures represent only 3–5% (divided into high or low),¹⁶ combined fractures such as U-, H-, lambda- or T-shaped (3–6%)^{17,18} characterize a specific condition known as spinopelvic dissociation, also described in cases of bilateral longitudinal fractures (Fig. 1).¹⁹ Normally the transverse fracture line is high and the longitudinal is transforaminal or medial to the foramina.^{18,20} Occasionally fractures can result from low-energy trauma, causing a U- or H-shaped insufficiency fracture still with a high level of intrinsic instability.²¹ Recently, a new classification for insufficiency fractures of the sacrum has been proposed, which divides fractures according to morphology, in order to predict the risk of cement leakage during sacroplasty.²²
- d) Location of fracture: Denis classification,²³ divides the sacrum into three zones. Zone I includes the

sacral ala lateral to the foramina, zone II the foramina and zone III the sacral canal medial to the neural foramina (Fig. 2). Zone I fractures (most common location for low-energy fractures)²⁴ have a 6% risk of neurologic injury (L5 radiculopathy). Zone II fractures (can be haemodynamically unstable because of the damage to the lateral and medial sacral arteries)²⁵ have a 28% risk of neurologic injury. Zone III fractures have a 56% risk of neurologic injury (cauda equina syndrome).²³ The modified Roy-Camille classification²⁶ describes transverse fractures of the upper sacrum above S4 and divides them according to their displacement. These fractures have been typically considered to affect Zone III.¹⁶ Modified Roy-Camille includes four different types of fractures with different risks of neurologic lesions, types I and II being the most common (93%), types III and IV less common (7%) (Fig. 3).²⁷ Isler also classified sacral fractures following the location criteria, in particular with respect to the L5–S1 facet, which together with lumbosacral posterior ligaments and sacroiliac joints, determines spondilopelvic stability.²⁸ He identified longitudinal transforaminal fractures and divided them into three types: type I stable lateral to the facet, type II unstable at the level of the facet, and type III highly unstable medial to the facet constituting a sort of spinopelvic dissociation.²⁹

Diagnosis

Clinical

Sacral fracture diagnosis is often troublesome, with a rate of missed or delayed diagnosis ranging from 25% to 70%.^{30,31} Overall the diagnosis should be made by assessing specific features during the clinical presentation particularly after high-energy trauma (buttock pain, bruising, swelling and laceration over the sacral area, perineal and genitalia sensibility, sphincter tone malfunction, neurological deficit of lower extremities, presence of Morel-Lavallée lesion). Patients suffering from a sacral low-energy fracture are characterized by an unspecific clinical presentation (complain about ambiguous low back pain,

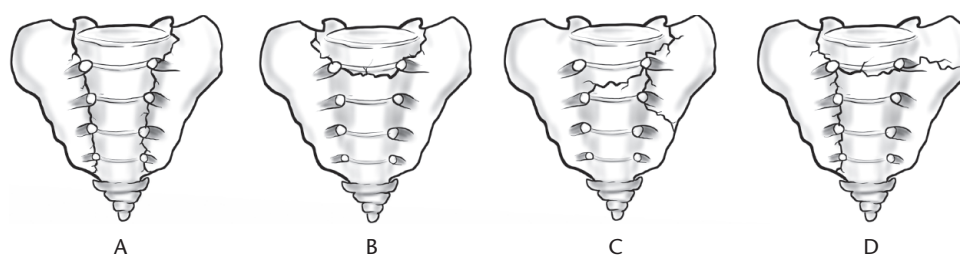


Fig. 1 The four combined sacral fracture types: (A) H-shaped; (B) U-shaped; (C) Lambda-shaped (λ); (D) T-shaped.

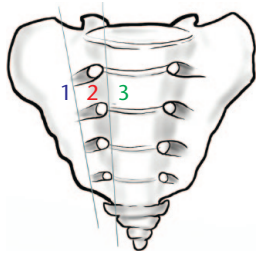


Fig. 2 The Denis classification: zone I fracture involves the sacral ala lateral to the foramina; zone II fracture at the level of the foramina; zone III fracture affects the sacral canal medial to the neural foramina.

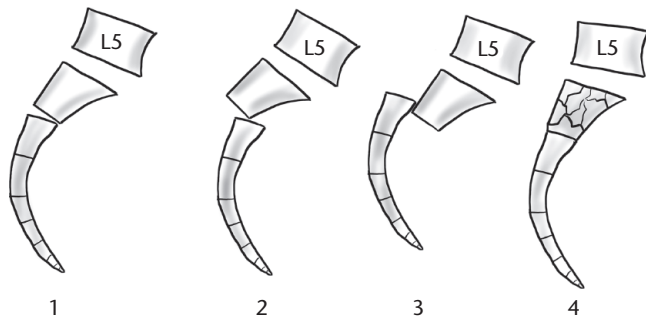


Fig. 3 The Roy-Camille classification: type I fractures show kyphotic angulation only; type II fractures demonstrate both kyphosis and retrolisthesis; type III fractures have complete anteriorlisthesis; type IV fractures characterized by severe comminution of the S1 body.

which increases with axial load or activities, mimicking the pain from lumbar stenosis or metastasis, generally without radiculopathy).^{32,33} Sacral stress fractures are typically seen in athletes reporting low back pain in absence of trauma.³⁴

Active bleeding must be promptly identified and addressed (derives from medial and lateral sacral arteries, presacral venous plexus, superior gluteal artery and iliac arteries).^{25,35} Pelvic stabilization with a pelvic binder, a sheet or an external fixator is essential if bleeding is related to pelvic instability. In the case of persistent haemodynamic instability or bleeding from isolated sacral fractures, pelvic packing or embolization must be considered.³⁶

Of note is that 62% of transverse fractures are associated with spine lesions, 25% with thoracolumbar lesions, and 11% with lumbosacral lesions, particularly related to high-energy trauma, able to disrupt the robust lumbosacral ligaments.³¹ Insufficiency fractures could be associated with vertebral compression fracture.³⁷

Radiological

Plain radiographs (anteroposterior [AP] pelvis, inlet/outlet views) are the first line of investigation, but could miss up to 50% of sacral fractures. Inlet and outlet views could be combined with standard AP view in order to improve the

X-ray sensitivity. Both direct and indirect signs of sacral fractures must be looked for on X-rays, such as paradoxical sign, an AP view resembling an inlet view due to an inclination of the proximal sacrum following a transverse fracture, and fracture of the L5 transverse process, indicative of pelvic instability, respectively.³⁸ If the X-ray is negative, and pain persists, a CT scan should always be performed, or a magnetic resonance imaging (MRI) scan. Nowadays in our institution the first line of investigation in patients presenting with fractures of the anterior elements of the pelvic ring is a CT scan, which is able to detect sacral fractures with a reported sensitivity of 68–88%.^{39,40} MRI has the highest sensitivity (98%).^{40,41} It is able to diagnose occult fractures missed by CT because of intact cortices.³⁴ It can detect bone edema of the cancellous bone, bone-bruise and fracture line as a line of hypointensity.^{33,42} Furthermore, sacral insufficiency fractures could be associated with malignancy, in some series in up to 45% of cases.⁴³ MRI could help in differential diagnosis by detecting the bone edema which is sign of infection or tumour which must be excluded.⁴⁴ When a stress fracture is suspected, MRI is the indicated exam, followed by a bone scan and CT scan respectively.⁴⁵ Bone scintigraphy can help in the diagnosis of low-energy sacral fractures, having high sensitivity but lower specificity than MRI.⁴⁶ Single Photon Emission Computed Tomography (SPECT/CT) allows not only identification of the fracture but also diagnosis of its age.^{47–49}

Principles of management

Presence of instability, displacement, association with pelvic ring damage and neurologic injury determine the need for operative treatment.^{30,50} Non-displaced isolated high transverse fractures, or fractures below the sacroiliac joint level (S3/S4–S5) are normally considered stable, along with longitudinal incomplete fractures. Complete longitudinal fractures and displaced transverse fractures are considered unstable and require surgical fixation.⁷ The same is true for U-shaped fractures characterized by spinopelvic instability, and U-shaped insufficiency fractures, which would usually require surgical fixation as they present an intrinsic instability which could lead to a progressive kyphotic deviation and delayed neurological sequelae.^{21,51} A displacement greater than 10 mm indicates surgical treatment.³⁶ As for association with high-energy pelvic ring injury, AO/OTA type A injuries, and some non-displaced cases of LC injuries are considered stable and should be managed conservatively.^{52,53} AO/OTA type B displaced and type C injuries, however, require surgical fixation since they are unstable.³⁶ In the elderly, according to the FFP classification, FFP II injuries could be conservatively treated as the fractures are usually stable enough to permit early mobilization of the patient, while FFP III and

IV are unstable and should be surgically stabilized.⁵ Surgical treatment of neurologic injury is controversial. A lesion above S4 presenting with cauda equina syndrome, often owing to zone III fractures, would call for direct or indirect surgical decompression, even if diagnosed late. Indeed, when faced with fracture fragments encroaching onto the sacral canal or compressing neural roots, responsible for neurologic deficit, surgical reduction is indicated. However, with regard to other neurologic lesions, a surgical decompression is not guaranteed to produce a better outcome than non-surgical treatment.^{36,54}

Recently, a lumbosacral injury classification system (LSICS) has been developed to help clinical decision. It focusses particularly on complex injuries, giving each fracture a score ranging from 0 to 10, based on fracture morphology, ligament injury and neurologic injury, where less than 4 indicates conservative treatment and above 4 indicates surgical stabilization.⁵⁵

Treatment

Sacral fractures can be treated non-operatively or surgically. Non-operative treatment is based on rest, pain relief therapy and early mobilization as tolerated. In high-energy fractures, it is indicated in the case of low transverse fractures, marginal avulsions or stable non-displaced

longitudinal fractures of the sacral ala, isolated or associated with stable LC pelvic injuries.^{52,53} Nonetheless, some authors have proposed the surgical treatment of anteriorly displaced low transverse fractures associated with neurologic injury.⁵⁶ Conservative treatment of insufficiency fractures is considered for stable non-displaced or incomplete fractures, isolated or associated with anterior pubic rami fractures in the context of FFP II. If conservative treatment fails, surgical treatment must be considered.⁵ The use of calcium and vitamin D drug supply, bisphosphonates, and teriparatide enhances the healing process and improves pain relief.^{5,42,57}

Treatment of stress fractures consists of rest for around six weeks from high-impact sports or activities and benefits from medical therapy such calcium or vitamin D intake in some cases associated with Parathyroid hormone (PTH) over a period of 3–6 months.⁵⁸

Surgical techniques can be split into two main groups: posterior pelvic fixation techniques and lumbopelvic fixation techniques (Figs 4, 5, 6, 7 and 8).⁵⁹ If the fracture is associated with pelvic ring injury, anterior pelvic fixation techniques can be performed.⁶⁰ Posterior pelvic fixation techniques connect the ilium to the sacrum. They can be performed either percutaneously or in an open manner. Among the percutaneous techniques, iliosacral screw fixation is the most common technique used.⁶¹ It is

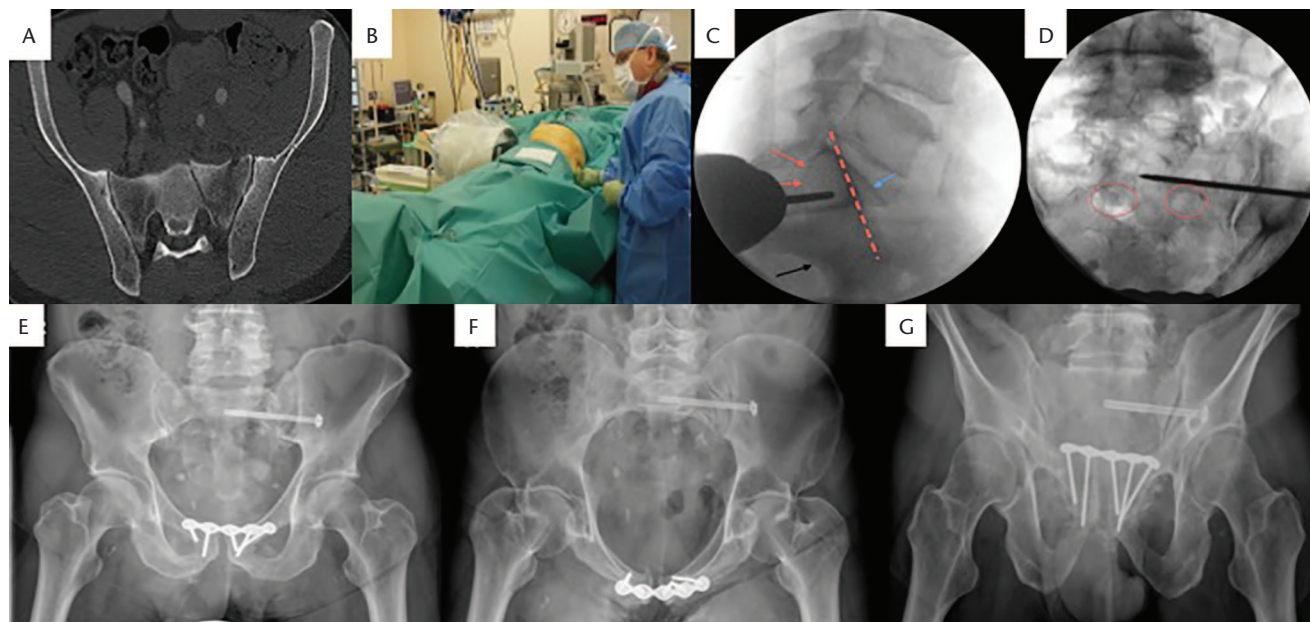


Fig. 4 (A) Axial CT scan showing Dennis I fracture over left sacral ala; (B) Patient in supine position, under fluoroscopic control and left buttock stab incision, surgeon tries to identify correct position of guide wire for sacral body 1 screw insertion; (C) Lateral fluoroscopic image demonstrating upper end of the first sacral vertebra (blue arrow), the iliac cortical density (red line), the greater sciatic notch (black arrow) and the upper nerve root tunnel (red arrows); (D) S1 sacral foramina are demonstrated by red circles. Guide wire for screw insertion is positioned above left S1 foramen; (E) Postoperative anteroposterior (AP) pelvic radiograph; (F) inlet and (G) outlet views demonstrating fixation of the pelvic ring (injury to pubis symphysis was addressed with a plate).

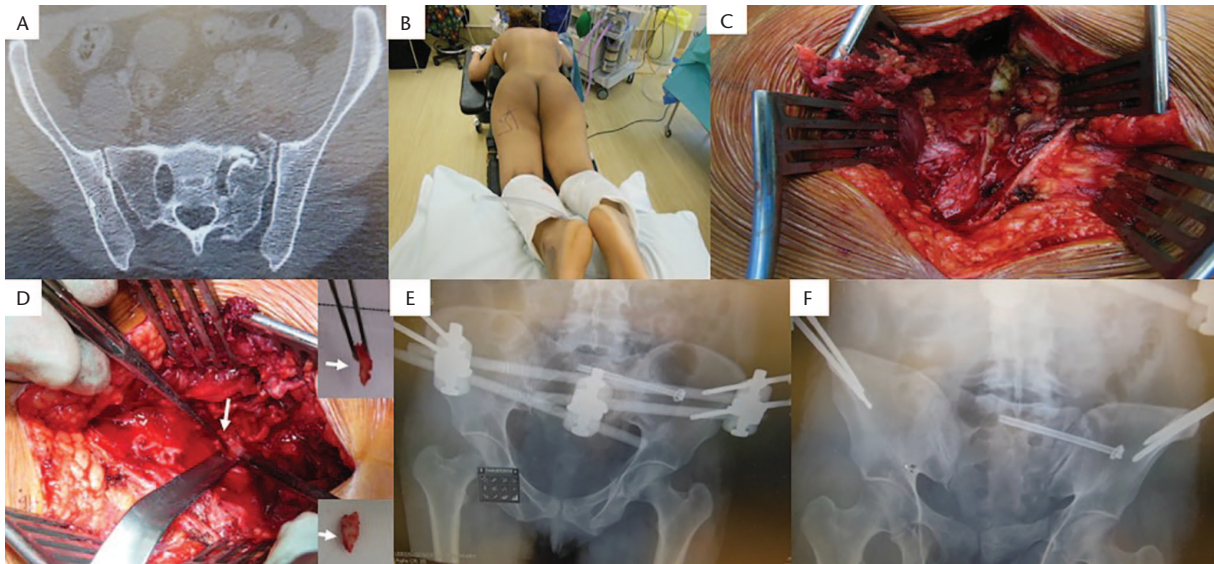


Fig. 5 (A) Axial computed tomography (CT) pelvic slice showing Denis II fracture with a small bone fragment in the Sacral 1 (S1) foramen causing S1 nerve root compression. (B) Patient positioned in prone position. (C) Midline exposure and for decompression of the nerve root. (D) Bony fragment removal (arrows). (E and F) Pelvic ring fracture was fixed with left S1 sacroiliac screw and an anterior external fixator frame for the pubic rami fracture.

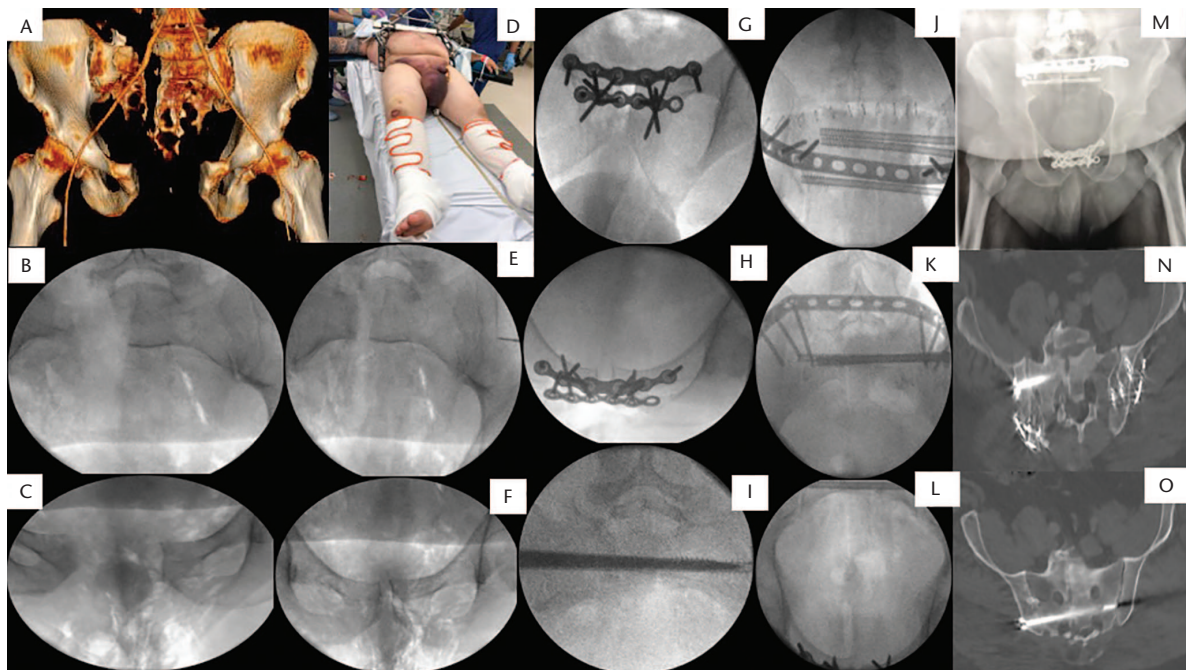


Fig. 6 (A) Three-dimensional pelvic image of a male patient sustaining after motorcycle accident an anteroposterior (AP) III injury with sacral fracture through body of S1 (Dennis III sacral fracture). (B) Fluoroscopic inlet view showing sacral fracture displacement. (C) Fluoroscopic AP pelvic view showing pubis diastasis anteriorly. (D) Intraoperative picture showing application of C-clamp and anterior external fixator for initial temporarily stabilization of the pelvic ring. (E) Fluoroscopic pelvic inlet view showing reduction of the sacral fracture. (F) Fluoroscopic AP pelvic view showing reduction of the pubic diastasis anteriorly. (G) Fluoroscopic AP view showing fixation of the pubis symphysis with two plates. (H) Fluoroscopic inlet pelvic view showing fixation of pubis symphysis with two plates. (I) Fluoroscopic inlet pelvic view showing insertion of S1 sacroiliac (SI) screws. (J) Fluoroscopic pelvic outlet view showing fixation of the sacrum with two SI screws and one S2 screw and a tension band plate. (K) Fluoroscopic pelvic inlet view showing fixation of the sacrum with two SI screws and one S2 screw and a tension band plate. (L) Fluoroscopic pelvic inlet view showing symmetric pelvic ring. (M) AP postoperative pelvic radiograph showing reconstruction of the ring anteriorly and posteriorly. (N) Axial cut of pelvic computed tomography (CT) scan showing reduction of the sacral fracture and safe placement of S1 screws. (O) Axial cut of pelvic CT scan showing safe placement of S2 screw.

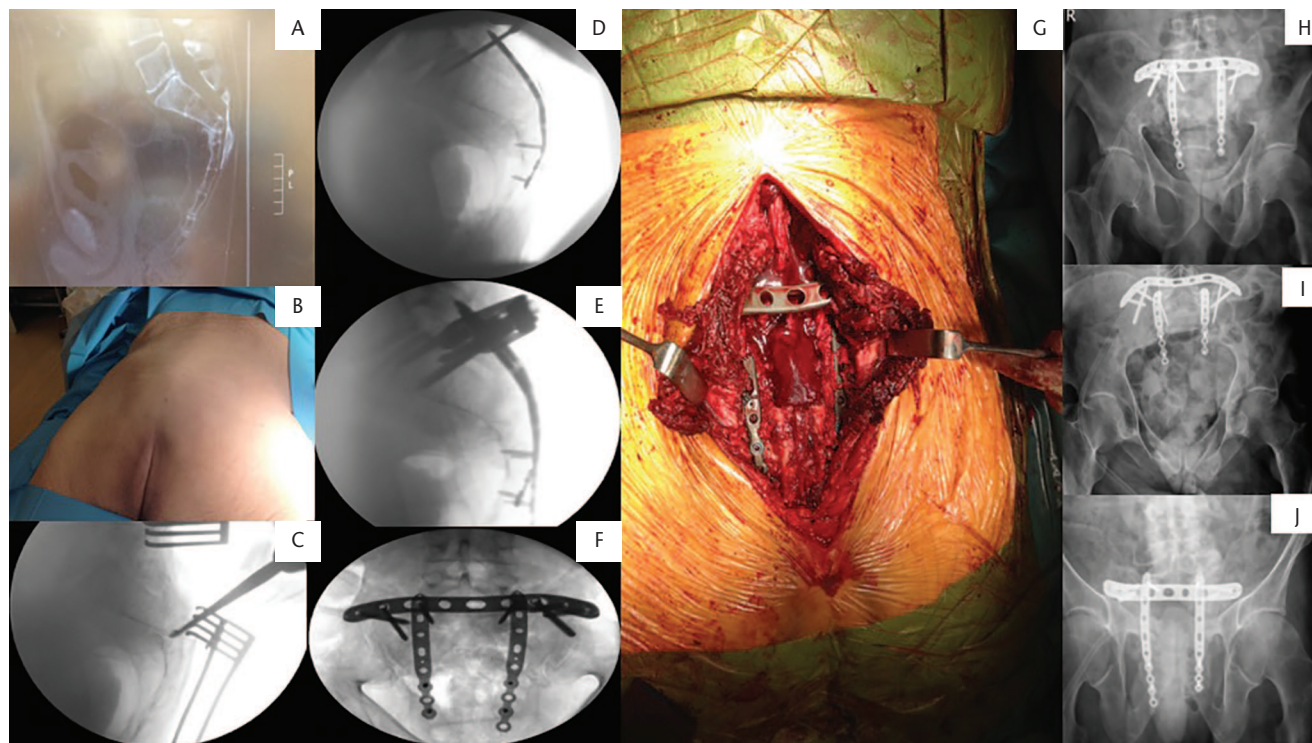


Fig. 7 (A) Lateral sacral radiograph showing a U-type fracture. Patient presented with full sacral plexus neurological symptoms, incontinence. Underwent diverting stoma post decompression of spinal canal and orif with tension band plate and bilateral sacral wing locking plates to address vertical fracture plane at levels of S1–S3. (B) Prone position of patient. (C) Fluoroscopic image for identification of the fracture level and decompression. (D) Lateral fluoroscopic image showing application of sacral wing plates and insertion of sacroiliac (SI) body screw. (E) Lateral fluoroscopic view showing fixation of sacral fracture with tension band plate and bilateral sacral wing locking plates. (F) Fluoroscopic outlet view showing fixation of fracture. (G) Intraoperative picture showing midline incision and application of plates. (H) Anteroposterior, (I) inlet, and (J) outlet pelvic postoperative radiographs showing stabilization of the ring posteriorly.

characterized by cannulated screw insertion through the safe corridor of S1 or S2 body, the latter being associated with higher malpositioning rates.⁶² In some cases, where required, the use of the S3 corridor has been described.⁶³ In osteoporotic fractures, iliosacral screws can be augmented with cement to increase the stability of the implant.^{1,64,65} Sacroplasty is an alternative to iliosacral screw for sacral ala incomplete insufficiency fractures and consists of percutaneous cement injection into the fracture site for pain relief and stability restoration.⁶⁶

Transsacral implants, such as transiliac-transsacral screws or transsacral bars, are alternative percutaneous techniques in which a long-threaded implant passes all the way across the S1 or S2 corridor to the contralateral ilium.⁶⁷ Transiliac bridging systems are minimally invasive techniques which connect the back side of the left and right ilium with a plate fixed with screws or a bar fixed with pedicle screws and introduced subcutaneously behind the sacrum by bilateral limited incisions, acting as transiliac internal fixators.^{68–71} The addition of an S1 pedicle screw in direct contact with the fracture has recently

been proposed in the ‘within ring’-based sacroiliac rod fixation system.⁷² In addition, other minimally invasive surgical techniques, such as tension band plate, and adjustable plate, have been described to address some of the drawbacks of iliosacral screws.⁷³ Other posterior sacroiliac open techniques that have been described include Beaujon’s sacroiliac assembly, and the Pitiè-Salpetriere shortening osteotomy.^{74,75}

Lumbopelvic fixation techniques connect the lumbar spine to the ilium. The lumbar-iliac technique is performed in an open manner and links the lower vertebral bodies with the ilium using bilateral pedicle screws connected with bars. In cases of high degree of instability, a more stable construct is obtainable connecting both L4 and L5 to the ilium; alternatively fixation from L5 to the ilium could be sufficient.⁷⁶ Similarly, the iliac screws are usually single but have also been known to be double.⁷⁷ If the above-mentioned lumbar-iliac technique is combined with iliosacral screws or transiliac plate, it makes up the triangular osteosynthesis assembly, originally proposed as unilateral but also described as bilateral with greater

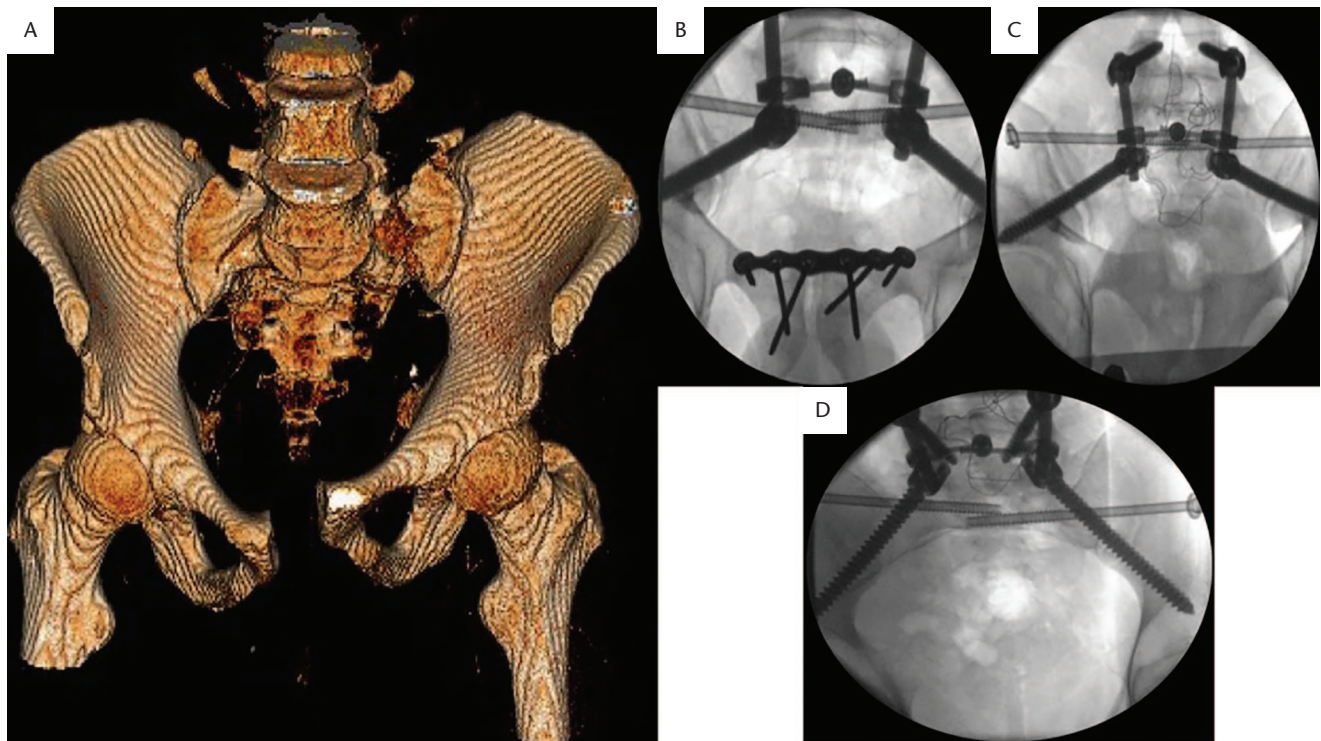


Fig. 8 (A) Three-dimensional pelvic model showing bilateral sacral fractures and pubis diastasis anteriorly. (B) Anteroposterior, (C) outlet, and (D) inlet fluoroscopic views showing stabilization of the fracture with spinopelvic fixation and sacroiliac screws to S1 body (triangular configuration). Pubis symphysis was stabilized with plating anteriorly.

stability, representing the most stable technique for the stabilization of the dorsal pelvic ring, especially in osteoporotic bone.^{78–81}

Anterior pelvic fixation techniques should be considered when sacral fractures are associated with anterior pelvic ring injuries, in order to increase stability and reduce the risk of posterior implant failure. They include retrograde transpubic screw, anterior internal fixator, or plate and screws.^{17,82}

Overall, indications and aims of surgical treatment are different depending on the energy of the fracture. In high-energy fractures, the objective of surgery is anatomic reduction and restoration of stability by rigid fixation, while in low-energy ones the objective is restoration of stability with a rigid fixation as minimally invasive as possible, with reduction becoming less relevant.⁵

Following high-energy trauma, longitudinal sacral fractures isolated or most commonly associated with a rotationally unstable AO/OTA B pelvic ring injury, if successfully reduced with external manoeuvres, can be treated using uni- or bilateral iliosacral screw, or transiliac bridging system in cases where iliosacral screw is not feasible.^{83,84} When the obtained closed reduction is not sufficient, open reduction and internal fixation is required. When longitudinal fractures are associated with vertically unstable AO/OTA C injuries, although different fixation methods have

been proposed, lumbopelvic implants, associated with anterior fixation, are those which provide the highest stability to counteract shear forces.^{85,86} High transverse sacral fractures (U- or H-shaped) can be treated with bilateral ileosacral or transsacral-transiliac screw in the case of a transverse component classifiable as Roy-Camille type I. In Roy-Camille II or III injuries, open reduction and decompression is required if neurologic injury is present.

In low-energy fractures, sacral ala fractures are treated with iliosacral screw fixation, feasible in both the S1 and S2 corridor.^{87,88} Sacroplasty is indicated as an alternative to iliosacral screw in incomplete sacral ala fractures without the interruption of bone cortices.⁶⁶ In the case of displaced transverse fracture or association with neurologic injury, on the other hand, treatment should be performed in an open manner using lumbopelvic fixation, triangular osteosynthesis having shown the highest stability.^{5,81,89}

Complications

Treatment of sacral fractures is challenging as it presents a wide range of complications with reported rates of up to 40–50% of cases in certain fracture types.⁹⁰ Perioperative complications include implant malpositioning (15%),^{91,92} neural lesions of L4–L5, S1 roots (2–15%),⁹² blood loss in

open approaches,⁹³ superior gluteal artery damage (1.2%), and ureteral damage and bowel lesion, which is a rare scenario.^{75,94} Postoperative complications include infection (low with minimally invasive or percutaneous techniques^{60,73,86} but rising to up to 50% with open lumbopelvic fixation, and up to 20% if treated with plates);^{74,95} wound healing problems;^{93,96,97} instrumentation failure (11–17%);⁸⁵ soft tissue irritation requiring implant removal;^{74,98,99} cement leakage after sacroplasty^{100,101} and cerebrospinal fluid leakage.⁷⁵

Outcomes

Functional outcome

The clinical outcome of high-energy fractures is related to the severity of initial trauma. Series of patients after spinopelvic dissociation have shown poor clinical outcome in up to 42% of cases, directly related to the degree of initial displacement and bad long-term outcomes with a patient-reported health score lower than that of the general population, with no improvement from the one-year to 10-year follow-up.^{102–104} Similarly, chronic residual pain is especially frequent after vertical unstable fractures or spinopelvic dissociation, where it has been found to persist in up to 100% of patients, also in long-term follow-up.^{96,102,103} However, after 10 years, patients have shown a significant recovery in independence of daily activities compared with at one-year follow-up.¹⁰³ Regarding the fixation technique, iliosacral screws have better results in terms of early return to everyday activities compared to posterior plates, and satisfactory surgical outcomes even when treating AO/OTA type B or C unstable injuries, without the advantage of the use of a second screw.^{69,105} Low-energy fractures are related to high mortality rates, with a 12-month mortality of 28% and loss of pre-morbidity abilities in 34% of cases.^{106,107} Patients suffering from sacral insufficiency fractures, if operated, present a higher rate of return to pre-injury level than conservatively treated patients, with a significant reduction of postoperative pain.^{88,108} Isolated insufficiency fractures, if treated with a posterior transiliac-transsacral screw, have shown a 75% rate of returning home compared to 20% of conservatively treated patients, and a 100% ability to ambulate compared to 70% of non-operated patients.¹⁰⁹

Fracture healing

A sacral fracture takes 8–12 weeks to heal and fusion rates following sacral fractures have been reported to be 85–90%.^{6,105} Malunion can occur after delayed treatment or insufficient reduction, with a consequent alteration of pelvic incidence. This is more frequent with Roy-Camille II and III fractures and in the case of spinopelvic dissociation.^{102,104} After spinopelvic dissociation injuries, the restoration of

the lumbosacral orientation is crucial, otherwise a sagittal imbalance will occur, with a deterioration of functional outcome and chronic back pain.^{110,111}

Neurologic recovery

As for clinical outcome, prognosis of neurologic injury is strictly related to the severity of the sacral fracture. It has recently been shown how in a sacral fracture combined with lumbar plexus injury, the higher the instability, the poorer the neurological recovery will be, with an impact on gait outcomes.¹¹² Accordingly, patients suffering from spinopelvic dissociation with associated neurologic lesions hardly ever recover completely, with residual lower-limb neurologic sequelae, urinary problems and sexual dysfunction.^{96,102} Here, with regard to clinical outcome, the degree of the initial displacement of the transverse component was found to be closely linked to the neurological recovery rate.¹⁰⁴ Another factor found to be associated with neurologic deficits is postoperative reduction with more than 10 mm residual displacement and fragment encroachment into canal and post foramen.¹¹³

Regardless of the treatment, neurologic injuries often recover with time, although a complete recovery is seen in less than half of patients. Recovery is better when surgical decompression is associated, even if this is controversial.⁵⁴ In the case of cauda equina syndrome, surgical decompression improves neurologic recovery.¹¹⁴ Indirect decompression by fracture reduction has shown better results compared to direct laminectomy.¹¹⁵ Also the decompression timing (< 72 h) does not have a clear influence. Although some authors state that it does not seem to influence the outcome, others say that an early decompression would improve the outcome, but it is often not feasible because of the severe condition of the patients during the acute phase.^{18,115}

Discussion/conclusions

Sacral fractures are complex fractures as the sacrum is considered the keystone of the pelvic girdle and thus is subjected to high stresses, being responsible for around 60% of pelvic stability. This highlights the utmost importance of restoring its anatomy and mechanics with the highest possible accuracy after a fracture, making its management extremely challenging.¹¹⁶

The first major issue related to sacral fracture management is the characteristics of the patients who suffer from this condition. They could be young people suffering from a high-energy trauma or elderly patients suffering from low-energy trauma. Both conditions, if not well managed, present high mortality rates. Another issue is related to fracture classification. In order to correctly identify the clinical situation, fracture characteristics and its

implications, a surgeon could usually take advantage of fracture classifications. However, given the heterogeneity of sacral fractures, none of the available classifications is comprehensive of all possible aspects related to these fractures, as they are unable to really help the user better understand the fracture. For this purpose, a survey has been conducted among AOSpine/Trauma members to identify the main controversies of sacral fractures. They submitted queries to surgeons about their perceptions of different topics such as severity of different fracture patterns, risk of neurologic injury following disparate fracture location, involvement of S1–L5 facet and insufficiency fractures. Based on the variety of the answers, they concluded the need for a new comprehensive and accepted classification which is able to take into account all the relevant factors associated with this complex fracture group.⁸

Furthermore, the diagnosis of sacral fractures is challenging, with high rates of mis- or delayed diagnosis.³⁰ The origin of this problem is multifactorial: first of all the low incidence of sacral fractures results in the majority of surgeons having little experience when dealing with them; the variability of clinical presentation, which differs according to the energy of fracture and associated lesions and is often arduous because of altered mental status, both in the case of high-energy trauma due to associated life-threatening conditions and in the case of insufficiency fractures due to the general impairment of the fragile patient; the variety of available imaging techniques which do not have the same diagnostic power, notably in relation to X-rays which often, being the first-line exam, are not powerful enough to detect the fracture, also because of intercurrent difficulties such as air in the bowel, non-compliance of the patient, sclerotic degeneration or arthritis of pelvic bones overlapping the sacrum. A solution to this issue could be to use more X-ray views (inlet, outlet) and to set the mandatory indication to always deepen the diagnostic process with at least a CT scan in case of X-rays showing indirect signs of sacral fractures or high clinical suspicion after a careful evaluation.^{7,96}

Management of sacral fractures is also troublesome, since common accepted standards able to drive the treatment strategy are missing and the few that do exist, such as the stability of the fracture, are not easy to interpret. In order to address this issue, and to help the surgeon facing a sacral fracture give an indication whether to operate or not, the lumbosacral injury classification system (LSICS) has recently been proposed. It is a scoring system, which, similar to what has been done for the cervical and thoracolumbar spine, guides surgical management, recommending surgical treatment for each fracture with a score higher than 4, on the basis of morphology, ligament integrity and neurologic status.⁵⁵

Surgical treatment represents another big challenge for surgeons facing sacral fractures, because it is related to high complication rates and poor outcomes, either related to percutaneous or closed techniques, both being characterized by benefits and drawbacks. Percutaneous and minimally invasive techniques present perioperative complications but fewer postoperative complications compared to open techniques. Furthermore, it is generally difficult to obtain a good reduction with these techniques.⁹³ Open techniques are burdened by some perioperative complications such as a higher quantity of blood loss and longer surgical time, but their principal limitations are related to higher correlation with postoperative complications. However, they allow a more easily achievable and more accurate reduction. Therefore, to reduce complications and improve outcomes, except for cases of high vertical instability or spinopelvic dissociation in which open lumbopelvic fixation implants ensure better stability, the use of percutaneous or minimally invasive techniques should always be attempted. However, to do so, their drawbacks, such as perioperative complications and difficulty to obtain reduction, must be addressed.

Perioperative complications of percutaneous techniques such as malpositioning, consequent neural lesions and radiation exposure are typically related to the iliosacral screw technique. Accurate preoperative planning and the aid given by modern instrumentation to control positioning could reduce malpositioning rate, radiation exposure and surgical time.^{73,83,92,117,118}

To improve fracture reduction, different solutions could be adopted: special positioning of the patient i.e. ‘hyperextended’ supine position in case of transverse fractures; manipulation techniques, especially useful in cases of sacral fractures associated with pelvic ring injuries, such as manipulating the iliac wings together with controlling rotations of the lower limbs when facing a type B pelvic injury; the use of specific aids such as transcondylar traction, indicated in case of impacted transverse fracture, Schanz pin, useful as a percutaneous aid to perform reduction manouevres and to maintain the obtained reduction until the definitive fixation, or frames such as the ‘Starr frame’, able to apply controlled forces to reduce the fracture on different planes simultaneously.^{75,119–121}

Finally, minimally invasive lumbopelvic fixation has also recently been proposed, with promising results,^{60,76,122,123} thus, it could minimize the high rate of complications related to such an invasive technique.

In conclusion, sacral fractures represent unique injuries with a variety of fracture patterns. They can be associated with shock, intrapelvic solid organ injuries and neurologic sequelae. Their treatment possesses many challenges and requires input from a multidisciplinary team for an optimum outcome.

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ICMJE CONFLICT OF INTEREST STATEMENT

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