19 Sacral Insufficiency Fractures

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Key Points

1. SIF are increasingly recognized in elderly patients with atraumatic low back pain or following low-energy trauma.
2. A high degree of suspicion for SIF is needed given frequently negative initial workup and imaging.
3. Management of SIF consists of conservative therapies with emphasis on analgesia and early mobilization.
4. Operative therapy including screw fixation or sacroplasty may be indicated in patients with displaced fracture or with persistent intractable pain and morbidity.

Introduction

Sacral insufficiency fractures (SIF) are a common cause of low back pain in the elderly. First described by Lourie in 1982, SIF are increasingly recognized as a source of morbidity in older patients [1]. These fractures may occur spontaneously or following low-energy trauma in patients with risk factors such as osteoporosis, malignancy, or prior radiation. SIF can be classified as a type of stress fractures, in which repetitive loading exceeds the mechanical resistance of bone. The two primary types of stress fractures include insufficiency and fatigue fractures, which are differentiated based on underlying bone physiology and mechanism of injury. Specifically, an insufficiency fracture occurs when normal or physiologic stress is applied to abnormal bone with decreased elastic resistance. This differs from fatigue fractures, which result when abnormal stresses are applied to normal bone [2]. This strict classification of SIF is difficult, as they can occur when osteoporotic bone is subjected to minor trauma. Therefore, some authors have preferred to define these osteoporotic fractures as fragility fractures of the pelvis [3].

Incidence

The true incidence of SIF is difficult to estimate given its subtle presentation and diagnosis. Compared to other types of osteoporotic fractures, especially those involving the axial spine, the relative incidence is still low [4]. However, with an aging population, the prevalence of osteoporotic fractures including SIF is expected

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to increase over the next 20 years. The most frequent sites include fractures of the vertebra (27%), wrist (19%), hip (14%), pelvis (7%), and other locations (33%) [5].

With increasing awareness, SIF are being more commonly recognized and diagnosed with a reported incidence of 1% to 20% in at-risk populations [4, 6–9]. Early reports by Weber et al. noted an incidence of 1.8% in 1015 female patients older than 55 years admitted to their institution for low back pain [9]. This was lower than those rates reported by Hatzl-Griesenhofer et al. who found 102 sacral fractures on bone scintigraphy in elderly patients with acute-onset low back pain following incidental trauma with negative radiographs over a 2-year period [7]. In another single-center retrospective review of 1017 bone scans in patients over 70 years, 194 (19%) SIF were identified [8]. Recently, a review of 250 patients with atraumatic acute back pain presenting to the emergency room identified 11 (4.4%) sacral fractures diagnosed via CT or MRI [10].

SIF often go unrecognized due to nonspecific symptoms and negative initial imaging. A high level of suspicion is needed in high-risk patients, particularly elderly females with a preexisting history of osteoporosis or osteopenia. Given these difficulties, there is frequently a delay between clinical presentation and the use of appropriate sacral imaging that may identify previously missed or misdiagnosed SIF. Various reports have found an average delay in the accurate diagnosis of SIF between 24 and 55 days, emphasizing the need for a high index of suspicion during the initial evaluation [10, 11].

Anatomy and Biomechanics

The sacrum is a triangular or wedge-shaped bone formed by the fusion of five vertebral segments. Important articulations include the ilium along its lateral border, fifth lumbar vertebra along its cranial border and coccyx at its caudal extension. While there is no classification specific to SIF, the sacrum and associated fractures have been characterized by Denis and consists of three zones (Fig. 19.1) [12]. Zone 1, which includes the sacral ala and falls lateral to the neural foramina, is the most common site for SIF [13]. Zone 2 includes the sacral foramina without extension into the spinal canal. Zone 3 involves the sacral body and central spinal canal. Given its relationship to the sacral nerve roots and central canal, SIF are rarely associated with neurologic symptoms, which differ from fractures in zones 2 and 3 that are commonly traumatic in nature and may have neurologic deficits on initial presentation [12, 14, 15].

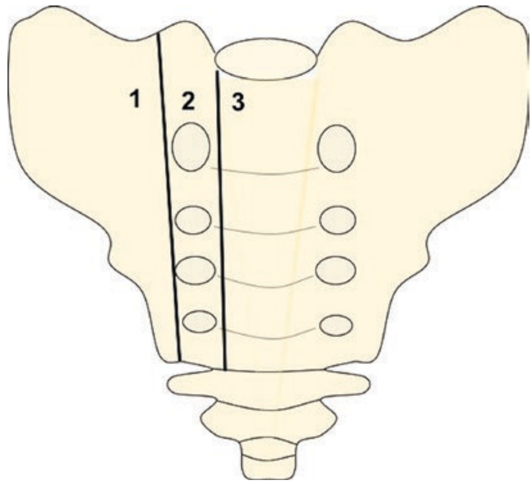

Fig. 19.1 Denis classification. Zone 1 falls lateral to sacral foramina. Zone 2 includes the sacral foramina without extension into the central canal. Zone 3 consists of the sacral body and central canal

SIF classically consist of an H-type fracture that runs vertically along both sacral ala and is connected by a horizontal component through the sacral body (Fig. 19.2) [1]. However, each of these segments may be absent, and instead an isolated unilateral or bilateral vertical fracture or unilateral vertical fracture with horizontal component may predominate. While bilateral fractures are thought to be most common, studies examining fracture morphology have failed to identify a predominant type [16, 17]. In one review of 102 SIF diagnosed with bone scan, only 19.6% exhibited typical H-type pattern versus 32.4% unilateral vertical, 6.9% bilateral vertical, 27.4% horizontal, and 13.7% half H-type fractures [7]. This differed from analysis of 85

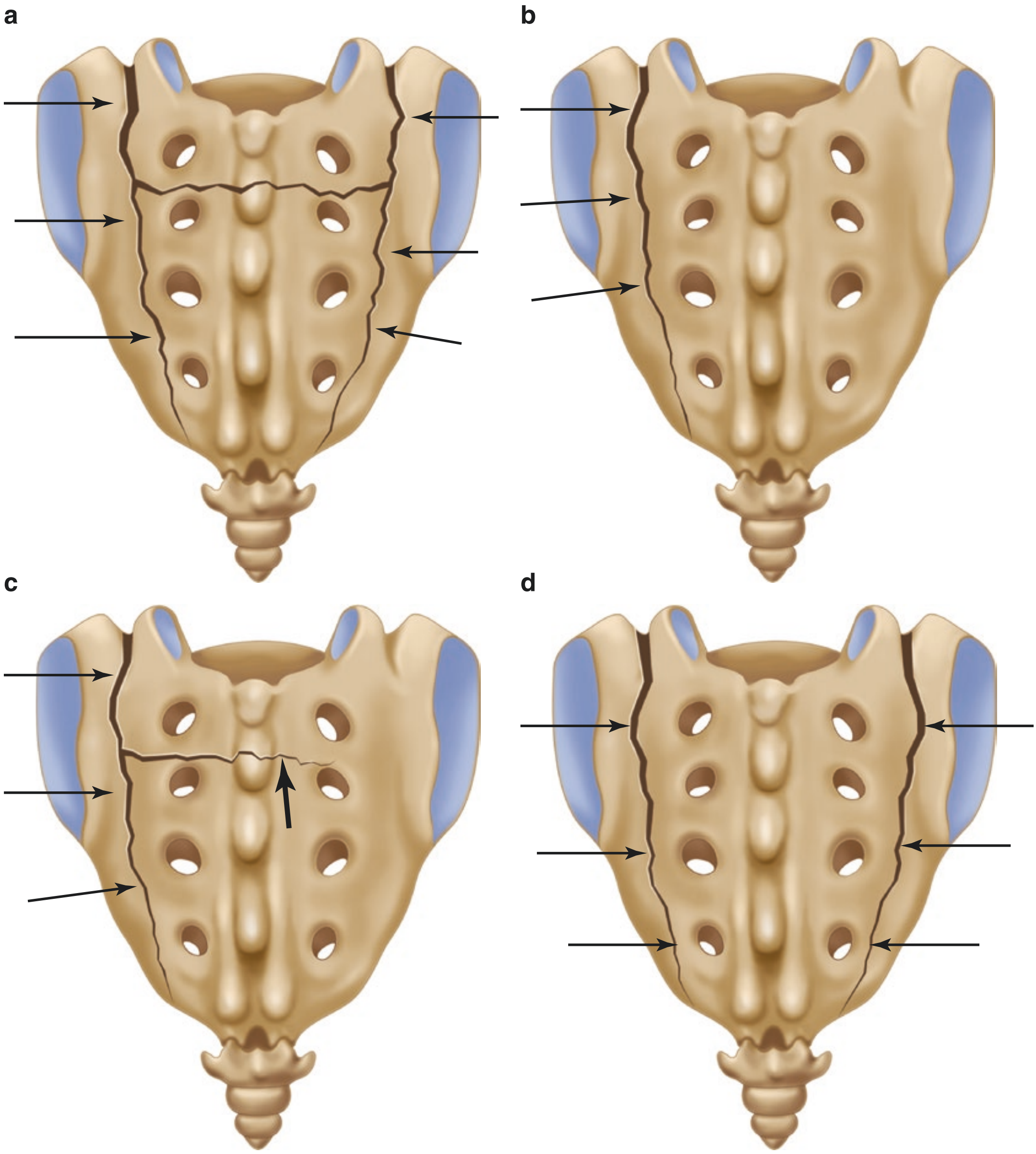

Fig. 19.2 Characteristic SIF fracture patterns (**a**) depict classical H-type fracture consisting of bilateral vertical fractures with horizontal segment, (**b**) unilateral vertical fracture, (**c**) unilateral vertical fracture with horizontal component, and (**d**) bilateral isolated vertical fractures

osteoporotic fractures, which had 61.2% H-type, 19.8% unilateral vertical only, 11.8% bilateral vertical only, and 8.2% unilateral vertical plus horizontal component [18].

Fracture morphology is likely related to the underlying osteoporosis, which preferentially affects trabecular rather than cortical bone. The ala, which has a high ratio of trabecular to cortical bone compared to the sacral body and neural foraminal region, is therefore particularly susceptible. As hypothesized by Cooper, when a bilateral vertical fracture occurs, the sagittal support provided by the sacral ala may be compromised leading to increased stresses along the central portion of the sacrum. With sustained axial stress in conjunction with natural lumbar lordosis, compression of the anterior sacral bodies may result in a horizontal fracture component [19]. Anatomic pelvic models of stress during ambulation support this theory and have demonstrated little to no transverse stress across the central portion of the sacrum if the sacrum is intact. A potential exception is patients with excessive lumbar lordosis, atypical stress patterns, or advanced osteoporosis [18].

Risk Factors

Multiple metabolic and mechanical risk factors have been associated with SIF (Table 19.1). The most common presentation occurs in elderly postmenopausal females with osteoporosis [2, 6, 20]. Age has been found to be a separate risk factor, with the average age of SIF ranging from 65 to 71 years old [13, 21, 22]. In their systematic review, Yoder et al. analyzed 101 cases of SIF and found that 75 patients were elderly females with an average age of 70.5 years, and 36 had a preexisting diagnosis of osteoporosis [21]. This was similar to the meta-analysis conducted by Finiels et al. who analyzed 493 SIF in the literature and 15 from the author's institution. They found that most fractures occurred in patients over 60 years of age and over two-thirds were insidious in onset without a history of trauma [22].

Other common risk factors involve processes that compromise the mechanical strength of bone. This includes metabolic conditions and medical therapy that either temporarily or permanently affect bone density. Corticosteroid therapy, which can lead to steroid-induced osteopenia with long-term use, is a well-established risk factor for SIF [21]. Similarly, rheumatoid arthritis and its treatment with long-term steroid suppression has been show to increase the risk for insufficiency fractures. These patients are also likely to have a mechanical component due to their impaired functional demand and resultant stress applied to the bone [23–26]. Additional causes of secondary osteoporosis reported in the literature include hyperparathyroidism [27], renal osteodystrophy [28], and Paget's disease [29]. Transplant patients including the liver, kidney, and lung are also at increased risk due to a combination of the required medical therapy and metabolic derangements that may result from solid-organ transplantation [30–32].

A history of pelvic irradiation is another important consideration in patients with potential SIF. Its association with impaired bone strength and insufficiency fractures in oncologic patients is well documented; however, delays in diagnosis often occur due to complicated symptomology and high suspicion for tumor recurrence or metastases [28, 33–36]. Ikushima et al. reviewed 158 patients with gynecologic malignancies who underwent pelvic irradiation and noted an 11.4% incidence of insufficiency fractures, the majority of which occurred within 12 months. In cases of SIF following irradiation, the typical symmetric bilateral vertical fracture pattern occurred, which can help to differentiate between SIF and metastases [36]. Blomile et al. noted even higher rates (89%) of insufficiency fractures in 18 patients with cervical cancer who underwent pelvic irradiation, 7 of whom were premenopausal [33]. Males are also at increased risk following radiation for conditions such as prostate cancer. One review of 134 males with prostate cancer who had pelvic radiation as part of their definitive treatment found a 6.8% 5-year incidence of SIF [35].

Prior spinal surgery and instrumentation may also impact the structural integrity of the spinal column and sacrum, thereby increasing the risk for sacral stress fractures especially in patients

Tables 19.1 Metabolic and mechanical risk factors for SIF

SIF risk factors	
Osteoporosis	Radiation therapy
Rheumatoid arthritis	Corticosteroid therapy
Organ transplant (lung, liver, kidney)	Anorexia nervosa
Paget's disease	Prior spinal instrumentation
Renal osteodystrophy	

with preexisting osteoporosis. In these instances, the primary cause is due to the abnormal distribution of force along the spinal column and sacrum following fusion and instrumentation, which is more consistent with a fatigue-type fracture [37]. When noted, sacral stress fractures frequently occur at or the level below instrumentation and may be an isolated horizontal fracture [38]. The exact timing of presentation is variable but occurs on average 5 months following the index procedure [39]. Meredith et al. analyzed 394 patients who underwent spinopelvic fusion from L5-S1 and found 24 (6.1%) sacral fractures at a mean of 4.3 months. Females over 67 years who had instrumentation of three or more levels were at the highest risk [40].

Clinical Presentation and Evaluation

Patients with SIF often have a vague and nonspecific presentation, which makes it difficult to obtain the appropriate imaging and diagnosis. A thorough history is necessary to identify possible risk factors that may predispose to stress fractures and any history of trauma. The most common presenting symptoms are diffuse, intractable low back and buttock pain, though patients may also present with pelvic, hip, or groin discomfort with or without radiation to the thigh [9, 13, 21]. Tamaki et al. noted that low back pain (36.4%), gluteal pain (63.6%), and coxalgia (19.2%) were the most frequent complaints in patients with traumatic SIF presenting to the emergency room [10].

Antecedent trauma typically consists of a low-energy mechanism, e.g., a mechanical trip and fall from standing height or a seated position. Cadaveric studies have shown that as little force as 3200 ± 1200 N is required to reproduce SIF in an osteoporotic sacrum [41]. Minor trauma preceding the onset of symptoms may occur in only one-third of cases, as many SIF occur spontaneously with the acute onset of sudden pain that is exacerbated by weight-bearing and restricted functional mobility [22, 42]. Neurologic symptoms are rare and if present can be indicative of concomitant pathology of the central cord, lumbar spine, or pelvis. Case reports of SIF associated with cauda equina have been reported but are exceedingly rare [43].

On examination, point tenderness over the distal aspect of the lumbar spine and sacrum may be present, though it is not frequently encountered [44]. Stability of the pelvic ring must be assessed given the frequent association between SIF and additional pelvic fractures. Provocative testing of the sacrum and sacroiliac joints including flexion-abduction-external rotation (FABER) and simultaneous maximal hip flexion and contralateral hip extension while supine (Gaenslen' test) will often illicit significant pain but are poorly tolerated in the acute setting and have poor specificity for SIF. If the patient is able to ambulate, gait testing will be significant for a slowed, antalgic gait with poor overall mobility [13].

Imaging

Given the nonspecific presentation of SIF and its association with low back pain, initial imaging is frequently focused on the lumbar spine and/or pelvis. This may lead to delayed recognition and diagnosis [10, 45]. Imaging techniques useful in the diagnosis of SIF include radiographs, MRI, bone scintigraphy, and CT scans.

Plain Radiographs

The initial diagnostic workup includes plain film radiographs, which consists of anterior posterior (AP) views of the pelvis and possibly AP and lateral views of the lumbar spine depending on symptomology. Supplemental radiographs including pelvic inlet and outlet views may be ordered to better assess the pelvic ring. However, insufficiency fractures are difficult to detect on radiograph, and frequently plain X-rays are not sensitive and inadequate [11]. This is particularly true in the acute setting prior to calcification at the fracture site. Additionally, overlying bowel gas, calcified iliac arteries, demineralization of the surrounding bone, and SI joint arthritis can obscure visualization making diagnosis difficult

[46]. Less than 15–20% of injuries are detected on initial evaluation, and after retrospective review of patients with SIF confirmed on CT or bone scintigraphy, only 30–50% of injuries can be detected on plain radiographs [16, 47].

When present, SIF usually present as vertical lines of sclerosis lateral to the neural foramina (Fig. 19.3) [11] . This is best appreciated in subacute or chronic injuries after the initiation of fracture healing. Typically, there are no distinct fracture lines, but subtle anterior cortical disruptions can be detected (Fig. 19.4) [48]. A review of 20 patients with SIF found that that fracture lines were evident in 12.5% of cases, and sclerosis was only noted in 57% of cases [6]. The onset and resolution of sclerosis at the fracture site is variable and ranges from 1 to 13 months after initial presentation [49].

Computed Tomography (CT)

Following plain radiographs, CT is often the next step in the diagnostic workup for possible SIF and is a useful adjunct to advance imaging such as MRI or bone scintigraphy. Compared to X-rays, CT has a greater sensitivity with reported rates of 60–75% [50, 51]. Characteristic findings include cortical disruption over the anterior sacral cortex in Zone 1 of the sacrum consistent with vertical fractures (Figs. 19.5 and 19.6). Additionally, compression of the sacral ala medial to the SI joint may be appreciated. In these instances, CT relies on the presence of cortical irregularities for appropriate diagnosis, but in cases of occult fracture especially in an atraumatic setting, CT may be negative. Given these subtle findings, SIF are often overlooked or misinterpreted on the initial reading [47].

Magnetic Resonance Imaging (MRI)

Magnetic resonance imaging (MRI) is the most sensitive imaging technique for SIF with reported sensitivities of 98–100% [48]. Its application in

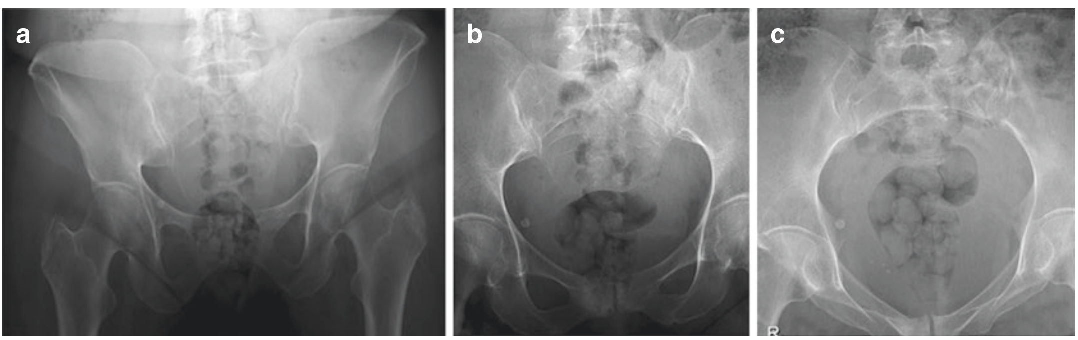

Fig. 19.3 Plain radiographs including (**a**) AP pelvis and (**b**, **c**) pelvic views demonstrating sclerosis in the left sacral ala suggestive of SIF

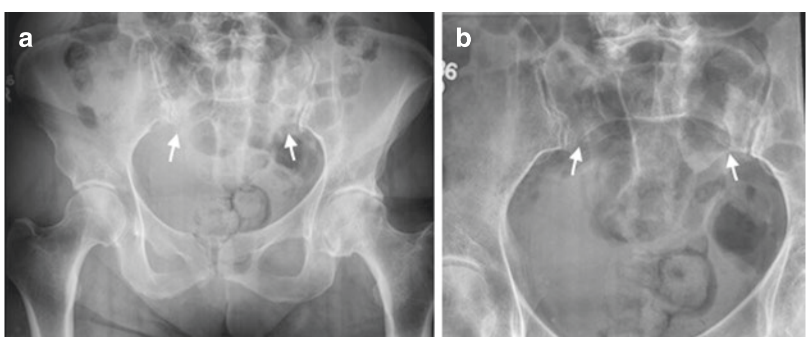

Fig. 19.4 Plain radiographs including (**a**) AP pelvis and (**b**) sacral view demonstrating bilateral anterior cortical disruption (arrows) indicative of bilateral vertical SIF

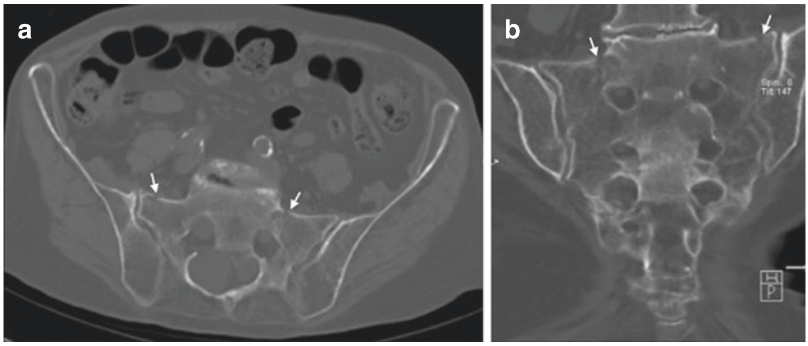

Fig. 19.5 Computed tomography (CT) including (**a**) axial and (**b**) coronal views demonstrating bilateral vertical SIF (arrows)

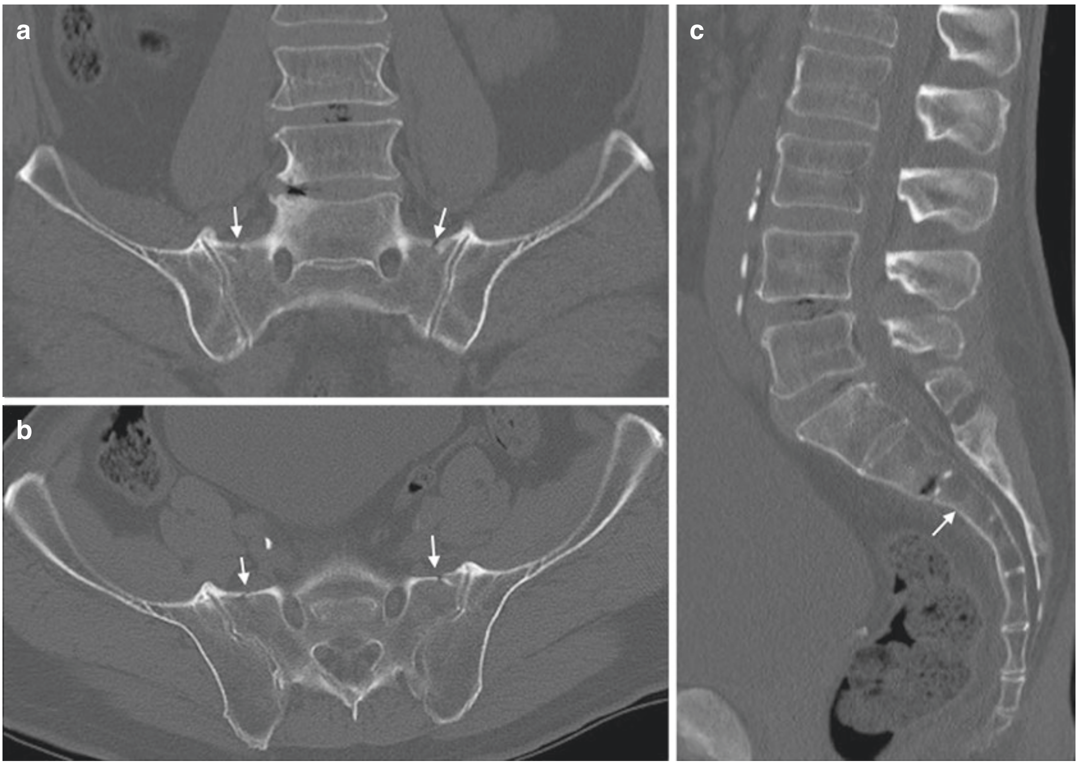

Fig. 19.6 CT including (**a**, **b**) coronal and (**c**) sagittal views demonstrating bilateral vertical SIF with horizontal component at S2 (arrows)

early injuries can detect marrow edema representative of post-traumatic bone hemorrhage related to SIF as early as 18 days after the initial symptoms. Case reports have described the presence of SIF on CT with negative MRI; however, this imaging was conducted in the acute setting possibly prior to the onset of early signal changes [52]. The marrow edema associated with SIF appears as low signal intensity on T1-weighted imaging and increased signal intensity on T2-weighted or short tau inversion recovery (STIR) series (Figs. 19.7 and 19.8) [51, 53]. Patterns of signal change will often mimic the fracture morphology as bands of abnormal signal paralleling the SI joint. These signal changes are also associated with other pathologic and non-pathologic processes including stress reactions, malignancy, nutrient vessels, and hyperplastic

Fig. 19.7 MRI including (**a**) T1 axial, (**b**) T2 axial, (**c**) STIR axial, and (**d**) T2 sagittal series demonstrating bilateral SIF with horizontal component at S2 (arrows)

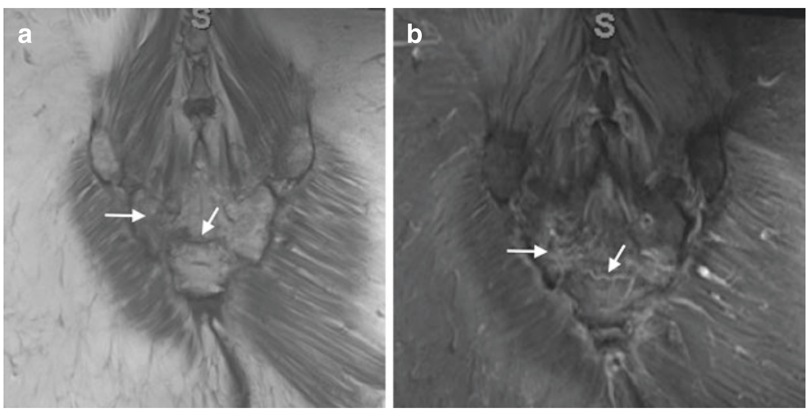

Fig. 19.8 MRI including sagittal (**a**) T1 and (**b**) T2 series demonstrating right vertical SIF with horizontal component

bone marrow [54]. This is of particular importance with SIF given their association with malignancy and pelvic irradiation, which can sometimes mislead the diagnosis.

In addition to signal changes within the sacral ala, a distinct fracture line may be present but is not required for diagnosis. Cabbarus et al. noted that in at least 7% of SIF, there was not a clearly discernable fracture. Adjacent soft tissue edema was present in approximately one-third of cases compared to 65% of pubic rami fractures [51]. When present, fracture lines can be seen as hypo-intense signal changes on T1-weighted imaging.

Bone Scintigraphy

Bone scintigraphy with technetium-99 m medronate methylene diphosphonate (MDP) is considered an important diagnostic tool for SIF given its high sensitivity; however, with increasing accessibility to MRI and inability to discern SIF from possible metastases, this imaging modality is now uncommonly used. For select patients, it has a sensitivity and positive predictive value of 96% and 92%, respectively [17]. The classical pattern of radiotracer uptake consists of the "H-type" pattern or a "Honda" sign (Fig. 19.9) [55]. When correlated to clinical symptoms consistent with SIF, this pattern is considered to be diagnostic. However, "H-type" fractures may not always be present and have been reported on bone scan in only 40–60% of cases [17, 22]. Radiotracer uptake may also be obscured by surrounding structures including the pubic bone, spine, and SI joints [17].

Fig. 19.9 Bone scintigraphy demonstrating bilateral vertical sacral fractures with horizontal component characteristic of the "H" or Honda sign

Treatment Options

Conservative Management

Initial management for the vast majority of SIF consists of conservative measures including limited rest, analgesia, and weight-bearing as pain allows using ambulation aides (cane, walker) with an emphasis on early mobilization as pain allows. Previously, some authors advocated for strict bed rest for pain control until symptom improvement. More recently, others have reported the importance of early mobilization and activity modification in a supervised environment to stimulate osteoblastic activity and prevent deconditioning [6, 9, 13, 56–58]. Assistive devices such as walkers, canes, or crutches can be used to offload weight-bearing on the affected sacrum allowing for early rehabilitation [13].

Symptom resolution with conservative therapy can take up to 1 year, though reported rates of recovery have varied from 4 to 15 months [11]. During this period, immobilization can be morbid, especially in an elderly population with SIF who may have preexisting comorbidities limiting their functional reserve. One particular concern is thromboembolic disease, with reported rates of deep vein thrombosis ranging from 29% to 61% and pulmonary embolism from 2% to 12% in patients with pelvic insufficiency fractures [58]. Additional well-known consequences include deleterious effects on muscle conditioning, the cardiopulmonary system, decubitus ulcers, and pneumonia [11].

Functional outcomes following SIF treated with conservative therapy are variable. However, these fractures are often a significant source of morbidity. Compared to displaced fractures of the pelvis, insufficiency fractures in the elderly have similar short-term and 2-year outcomes [59]. One series reviewed 60 patients aged 65 years or older found to have pelvic insufficiency fractures including 16 SIF who were managed with conservative therapy. They noted an overall mortality rate of 14.3%, with 25% of patients being institutionalized following the injury and 50% never returning to their former level of self-sufficiency [60]. In another smaller series of 20 patients with SIF, 17 were noted to have complete symptom resolution within 9 months with no patients reporting decreased independence in their daily activities [6].

Medical Management

Medical therapy in patients with SIF focuses on the underlying primary or secondary osteoporosis that predisposes to insufficiency fractures. While oral calcium and vitamin D supplements remain a mainstay of osteoporosis prevention, there is limited data to support their use in preexisting SIF, and additional supplementation may have limited efficacy in the setting of advanced osteoporosis [16]. Similarly, bisphosphonates are a common treatment of osteoporosis that act by inhibiting bone resorption and have been found to increase bone mineral density of the spine and hip [61, 62]. However, longtime use may negatively affect bone metabolism by inhibiting normal bone turnover, thereby predisposing to insufficiency fractures [63]. Once an insufficiency fracture has been identified, continuation of bisphosphonates remains controversial [42].

Newer anabolic agents are also being used in the setting of osteoporotic fractures. Teriparatide or recombinant human PTH has been used for insufficiency fractures, atypical fractures, and nonunions with promising results [64–66]. Its effect may increase bone mineral density and trabecular and cortical thickness thereby aiding fracture healing and preventing subsequent pathology [42]. Yoo et al. compared 21 patients with SIF who received daily teriparatide injections to 20 patients with SIF who did not receive additional medical therapies. They found that those treated with teriparatide had earlier time to mobilization (1.2 weeks vs 2.0 weeks) and faster bony healing with all patients receiving teriparatide demonstrating healed fractures by 8 weeks [67]. This is consistent with smaller case series that have shown improved SIF healing following the administration of teriparatide [68]. Alternatively, the use of PTH has also shown to have benefits in the setting of SIF. In one series five patients with SIF were treated with PTH and compared to ten cases of SIF without the use PTH. The treatment group receiving PTH was found to have shorter duration until bony union and improved VAS scores [69].

Surgical Management

Given the potential morbidity associated with immobility from intractable pain, operative stabilization has gained increasing popularity in the treatment of SIF in patients with displaced fractures or who have failed conservative therapy. The mainstay of surgical intervention previously consisted of screw fixation either via a minimally invasive or percutaneous approach. However, in recent years minimally invasive augmentation with cement, or sacroplasty, has gained wider spread use. While vertebroplasty has been well described for osteoporotic fractures of the vertebral column, this analogous procedure involving injection of bone cement into the pathologic sacrum is now being used to treat patients with persistent symptoms and/or disability [70–72].

Screw Fixation

Operative fixation of sacral fractures has evolved significantly over time with a shift away from open exposures toward minimally invasive techniques. However, in significantly displaced fractures, open reduction may be required with the use of spinopelvic fixation. Various methods of fixation have been described including iliosacral screws, transsacral bars, and posterior tension banding [73–76]. Regardless, fracture morphology, displacement, and areas of instability dictate the appropriate method of fixation.

Iliosacral screw fixation has been well described in the treatment of posterior ring injuries and is a useful method of osteosynthesis in the setting of SIF. Done in either a prone or supine position, one or two screws can be inserted percutaneously into the S1 and/or S2 body [77, 78]. The use of two screws may help to prevent rotational instability; however, variability in sacral anatomy may limit screw placement [79]. Another consideration is bone quality, which is likely to be poor in elderly patients with insufficiency fractures. In order to optimize screw purchase, iliosacral screws can be advanced to the midline of the vertebral body where the density of cancellous bone is higher relative to the sacral ala [80]. Additional augmentation with washers or PMMA (polymethylmethacrylate) cement has also been described to improve fixation [81, 82].

Another percutaneous approach is transsacral-transiliac screw fixation. This technique is useful in the setting of bilateral posterior ring injuries with poor bone quality and may help to overcome weak screw purchase if used in the sacrum alone [83]. These constructs consist of a partially threaded 6.5 or 7.3 mm single or double transsacral-transiliac screw that traverses the sacrum through either the S1 or S2 body [84]. Screw size and location are dictated by the sacral anatomy and therefore require careful preoperative planning. When passing the screws, the goal is to insert them through safe anatomic pathways in the sacrum called transsacral corridors, which vary in size and location [79]. Sanders et al. recently reported on 11 patients who underwent transsacral-transiliac screw fixation for SIF following failed non-operative management. They found all patients went onto fracture healing with significant improvements in VAS and Oswestry Low Back Disability Index scores following surgery, with no surgical complications [84].

Sacroplasty

First described by Garant, sacroplasty has evolved from the principles of vertebroplasty used for insufficiency fractures in the thoracic and lumbar spine [85]. Early attempts at cement injection into the sacrum were used for painful metastases, and since then the technique has evolved for use with SIF. It has gained increased popularity, especially in cases of nondisplaced SIF refractory to non-operative management. This percutaneous procedure involves the forceful injection of PMMA cement into the fractures site, which is then distributed throughout the area of injury. Once hardened, the cement acts to stabilize the fracture allowing for pain relief and early mobilization. Various percutaneous methods have been described and will be detailed below, including the use of CT with or without fluoroscopic guidance.

The biomechanical principles of sacroplasty have not been well elucidated. Compared to vertebroplasty, where cement acts to resist compressive forces along the axis of the spine, sacroplasty must counteract shear forces along vertically oriented fracture lines in the sacrum [50]. The proposed advantage of this technique is that injecting cement stabilizes the fracture and prevents continued micromotion, thereby improving pain. This has been supported by finite element analysis (FEA) in cadaveric models that have demonstrated that PMMA injection with sacroplasty decreases fracture propagation by 93% and micromotion at the fracture site by 48% [86]. This stabilization may only occur locally at the fracture site, as additional FEA models have showed increases in overall sacral stiffness by only 1–4% vs 40–60% at the site of cement-bone interface [87]. However, cadaveric testing has failed to show restoration of strength or stiffness following cement injection, regardless of the volume injected or the approach used [88, 89].

Multiple basic approaches have been described for needle introduction into the fracture site and include a posterior or short-axis, long-axis, and midline approach. The two primary approaches consist of a posterior (short-axis) or long-axis approach, while a midline approach is typically used if additional injections are needed into a horizontal fracture component [11]. In the short-axis approach, the needle is placed in the posterior-to-anterior direction versus a long-axis approach where the needle is introduced in the caudal-cephalad direction [90]. The long-axis approach has the potential benefit of using a single cannula, injecting cement directly along a vertically oriented fracture line, and decreased risk of ventral perforation/extravasation [91]. In either case there is the potential risk of perforating the anterior or superior cortex and entering the sacral foramen [92].

Posterior (Short-Axis) Technique

The patient is positioned prone in a radiologic suite and a lateral scout CT, or fluoroscopic imaging is taken for localization. The choice of posterior puncture site is dependent on fracture

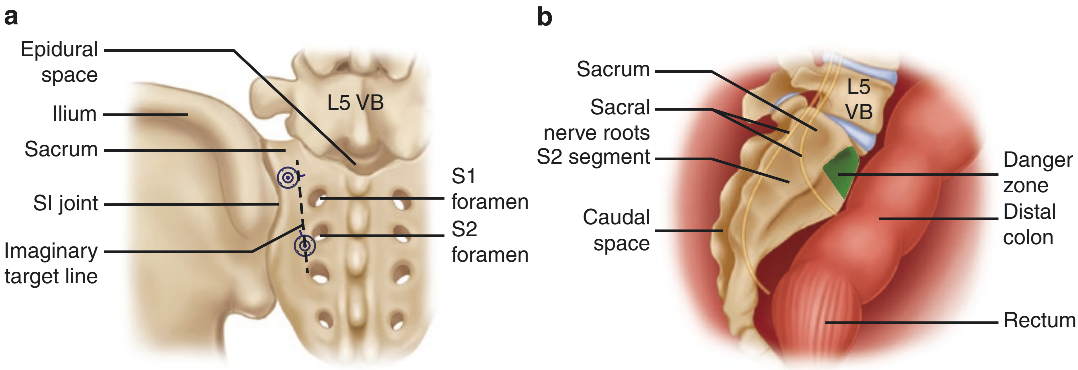

Fig. 19.10 Short-axis technique for percutaneous sacroplasty. (**a**) Appropriate start point in coronal plane lateral to sacral foramina at S1 and S2 and (**b**) needle position in the sagittal plane. Tip should not extend into anterior 1/3 of S1 body to prevent anterior perforation

location and morphology. Traditionally a posterolateral approach is used, which begins at a point centered on the S1 or S2 vertebral body, halfway between the dorsal aspect of the sacral foramina and SI joint (Fig. 19.10). Alternatively, an oblique central posterior approach can be used, which is centered over the sacral ala but angles medially between the spinal canal and sacral foramina. Once the appropriate approach has been determined, a small incision is made, and the needle is introduced into the posterior cortex of the sacrum and advanced 2–3 mm. Location is confirmed with CT or fluoroscopic imaging. After necessary adjustments are made, the needle is advance in small 5–10 mm intervals with manual pressure or with a mallet, checking position with localizing images. Final position of the needle should be within 10 mm to the anterior sacral cortex; however, care must be taken not to penetrate the anterior cortex. If using fluoroscopy, optimal needle position on lateral films will be within the anterior aspect of the middle third of the vertebral body. On AP imaging, confirmation of needle placement lateral to the sacral foramina must be achieved.

Once the needle is in appropriate position, the cement is prepared. When choosing cement, it should preferentially contain opacifiers to allow for visualization and have a long setting time. Cement is then injected in 0.5 mL aliquots, with repeat imaging after each injection. Between injections, the needle is removed along the fracture line in 1 cm intervals, but if cement extravasation is noted, injection through that needle should cease. The total volume of cement injected ranges from 3 to 8 mL per side and varies on fracture pattern, location, and morphology. Once the cement has hardened, the needles can be removed and surgical site is dressed. Postoperatively, patients are monitored for neurologic change. They are made weight-bearing as tolerated, given appropriate analgesia, and can be discharged on the same day.

Long-Axis Technique [90]

The patient is positioned prone on the radiologic procedure table, and the imaging beam is canted cephalad to align the image with the L5-S1 disk space and is oriented perpendicular to the long-axis of the sacrum. Localization is used to mark the starting point at the midpoint between the inferior aspect of the SI joint and lateral aspect of S3 foramen. A spinal needle is inserted, and positioning is checked on AP and lateral images. On lateral imaging, the needle is pointed toward the center of S1. Once the needle position is confirmed, the cannula is advanced into the posterior cortex approximately 1 cm. Position is confirmed on AP and lateral imaging. The cannula is advanced in 5–10 mm intervals, checking with localizing imaging at each interval. The final position should demonstrate the cannula tip 1 cm inferior to the geometric center of the S1 body. If the needle has advanced past this point, it should be withdrawn given the high risk of cephalad perforation.

After confirming the cannula position, cement is mixed and injected into the sacrum under fluoroscopic visualization. As the S1 body is filled, the cannula is withdrawn in 1 cm increments along the fracture line. Once the needle approaches the inferior aspect of the SI joint, cement injection is stopped. Approximately 3–8 mL of cement is injected. After the injection is completed, final imaging is done to confirm cement filling and evaluate for extravasation. The cannula sites are dressed and the patient is monitored for neurologic changes, made weight-bearing as tolerated with expected same-day discharge.

Long-term outcome data following sacroplasty is limited; early reports from multiple cases series have demonstrated favorable results with pain improvement. Dougherty et al. reported on 57 patients undergoing percutaneous sacroplasty and found that 76% of patients experienced at least 30% decrease in pain scores and 60% endorsed decrease opioid usage [93]. These improvements occur almost immediately following the procedure and persist at 1-year follow-up [94]. Another series by Gupta et al. consisting of 53 patients undergoing sacroplasty found significant improvements in VAS, Functional Mobility Scale, and Analgesic Scale scores with 93% reporting complete resolution or improvement in overall pain [95]. The largest series to date consists of 243 patients undergoing sacroplasty for SIF or sacral lesions. Preoperative VAS scores improved significantly from 9.2 ± 1.1 points to 1.9 ± 1.7 following CT-guided percutaneous sacroplasty [96]. By improving pain, the procedure may also allow for improved mobilization and decreased disability. Onen et al. found a decrease in ODI scores from 44 [38–46] preoperatively to 14 [11–22] postoperatively in patients undergoing sacroplasty [97]. Similarly, significant improvements in clinical mobility scale scores have been reported at 4, 24, and 48 weeks postoperatively [98].

While sacroplasty is considered a safe procedure, complications can result from extravasation of cement outside of the sacrum with neurologic compromise being the most concerning. Few reported cases of cement leakage into the sacral foramina have been reported with an overall frequency of PMMA extravasation of 7.4% [92, 94, 96, 98, 99]. The most commonly affected location is the S1 foramen resulting in S1 neuritis, which may improve with targeted epidural steroid injections [94]. However, in cases where the neuritis is refractory to conservative therapy, surgical decompression may be required to remove the cement and allow for nerve root decompression [99]. Additional potential complications include extravasation into the spinal canal, pulmonary emboli, and infection though no cases have been reported in the literature to date.

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