REVIEW ARTICLE

Sacroiliac Joint Pain: A Comprehensive Review of Anatomy, Diagnosis, and Treatment

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Sacroiliac (SI) joint pain is a challenging condition affecting 15% to 25% of patients with axial low back pain, for which there is no standard long-term treatment. Recent studies have demonstrated that historical and physical examination findings and radiological imaging are insufficient to diagnose SI joint pain. The most commonly used method to diagnose the SI joint as a pain generator is with small-volume local anesthetic blocks, although the validity of this practice remains unproven. In the present review I provide a comprehensive review of the anatomy, function, and mechanisms of injury of the SI joint, along with a systematic assessment of its diagnosis and treatment.

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Anatomy

The sacroiliac (SI) joint is the largest axial joint in the body, with an average surface area of 17.5 cm^2 (1). There is wide variability in the adult SI joint, encompassing size, shape, and surface contour. Large disparities may even exist within the same individual (2,3). The SI joint is most often characterized as a large, auricular-shaped, diarthrodial synovial joint. In reality, only the anterior third of the interface between the sacrum and ilium is a true synovial joint; the rest of the junction is comprised of an intricate set of ligamentous connections. Because of an absent or rudimentary posterior capsule, the SI ligamentous structure is more extensive dorsally, functioning as a connecting band between the sacrum and ilia (4). The main function of this ligamentous system is to limit motion in all planes of movement. In women the ligaments are weaker, allowing the mobility necessary for parturition (Figs. 1 and 2).

The SI joint is also supported by a network of muscles that help to deliver regional muscular forces to the pelvic bones. Some of these muscles, such as the gluteus maximus, piriformis and biceps femoris, are functionally connected to SI joint ligaments, so their actions can affect joint mobility. The potential for vertical shearing is present in approximately 30% of SI joints, owing to the more acute angulation of the short, horizontal articular component (5).

Age-related changes in the SI joint begin in puberty and continue throughout life. During adolescence, the iliac surface becomes rougher, duller, and coated in some areas with fibrous plaques. These senescent changes accelerate during the third and fourth decades of life and are manifested by surface irregularities, crevice formation, fibrillation and the clumping of chondrocytes. Degenerative changes on the sacral side generally lag 10–20 yr behind those affecting the iliac surface. In the sixth decade, motion at the joint may become markedly restricted as the capsule becomes increasingly collagenous and fibrous ankylosis occurs. By the eighth decade of life, erosions and plaque formation are inevitable and ubiquitous (4).

Innervation

The innervation of the SI joint remains a subject of much debate. The lateral branches of the L4-S3 dorsal rami are cited by some experts as composing the major innervation to the posterior SI joint (1). Other investigators claim that L3 and S4 contribute to the posterior nerve supply (6,7). The innervation of the anterior joint is similarly ambiguous. Early 20th century German literature asserts the anterior SI joint is supplied by the obturator nerve, superior gluteal nerve and the lumbosacral trunk (8). More recent literature suggests the anterior joint is innervated by L2-S2 (1), L4-S2 (9), and the L5-S2 ventral rami (10). Some authors have even suggested that the anterior SI joint is devoid of nervous tissue (7,11). In a study testing the ability of L5 dorsal ramus and S1-4

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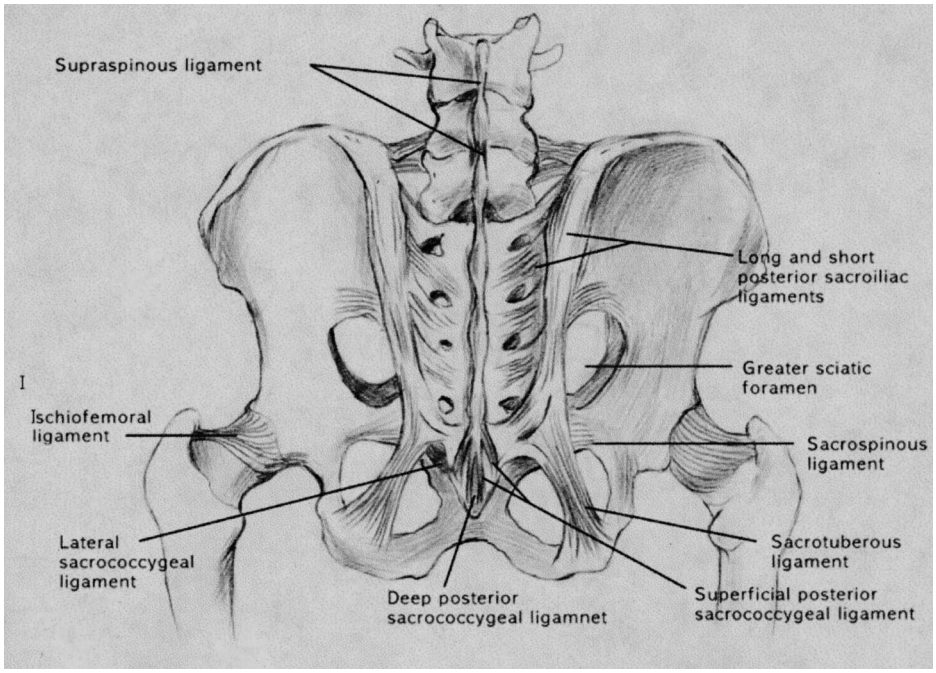

Figure 1. Posterior view of the articulations and associated ligaments of the sacroiliac joint and surrounding structures. Drawing by Jee Hyun Kim.

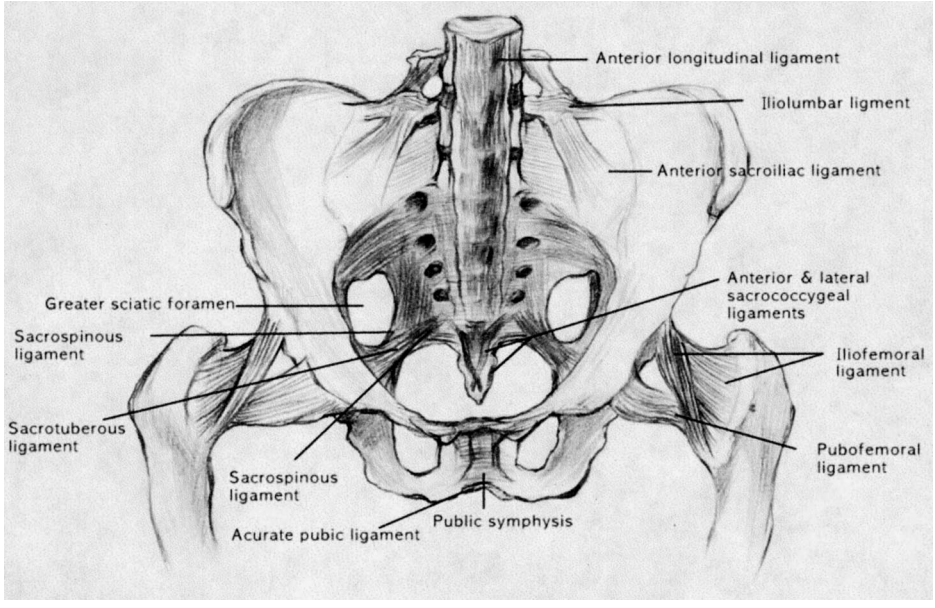

Figure 2. Anterior view of the articulations and associated ligaments of the sacroiliac joint and surrounding structures. Drawing by Jee Hyun Kim.

lateral branch blocks to protect the SI joint from an experimental stimulus, 6 of 10 subjects retained the ability to perceive ligamentous probing (12).

A neurophysiologic study conducted in cats identified 29 mechanosensitive afferent units, 26 of which were found in the joint capsule and 3 in adjacent muscles (13). Twenty-eight of these units were classified as nociceptive and 1 as proprioceptive. Among these 29 receptive fields, 16 were located in the proximal third of the posterior SI joint and 11 in the middle third. The average mechanical threshold of an SI joint nociceptive unit was 70 g, as compared to the 6 g mean mechanical threshold for lumbar facet joint nociceptive units and the 241 g threshold for units residing in the anterior lumbar disk (14–16). This indicates that the pain sensitivity of the SI joints may be lower than that of the lumbar facet joints but higher than the anterior portions of lumbar discs. As all animals underwent posterior midline incisions, somatosensory units in the anterior SI joint were not stimulated.

Function and Biomechanics

The SI joints are designed primarily for stability. Their functions include the transmission and dissipation of truncal loads to the lower extremities, limiting x-axis rotation, and facilitating parturition. Compared to the lumbar spine, the SI joints can withstand a medially directed force 6 times greater but only half the torsion and $1/20^{th}$ of the axial compression load (17). These last 2 motions may preferentially strain and injure the weaker anterior joint capsule (18).

There have been numerous attempts to discern the biomechanics of the SI joint. These motion studies can be summarized as follows: the SI joint rotates about all 3 axes, although the movements are very small and difficult to measure (19,20). Miller et al. (21) studied the load-displacement behavior of single and paired SI joints in 8 elderly cadavers. Various static test loads were applied in the superior, lateral, anterior and posterior directions, and rotations about all 3 axes were measured. These tests were conducted with one and both ilia fixed. The authors found that with 1 leg immobile, movements in all planes ranged from between 2 to 7.8 times more than that measured with both legs fixed. In a series of cadaveric studies, Vleeming et al. (22,23) found that the total range of motion during flexion and extension at the SI joint rarely exceeded 2 degrees, with 4 degrees being the upper limit during sagittal rotation. In another cadaver study, Brunner et al. (24) found that the main motion in male specimens tended to be translation, whereas in female specimens it was rotational. The maximum range of motion in this study was 1.2 degrees in men and 2.8 degrees in women. In a study by Egund et al. (25) examining SI joint movements in 4 volunteers using radiographic stereophotogrammetry, the authors found the maximal rotations and translations to be 2.0 degrees and 2.0 mm, respectively. A larger study ($n = 24$) by Jacob and Kissling (26) conducted in healthy young and middle-aged men and women found similarly small limits on rotation (1.7 degrees) and translation (0.7 mm). However, one individual with a history of SI joint pain exhibited more than 6 degrees of rotation about the y-axis. Finally, Sturesson et al. (27) measured multiple SI joint movements in 25 patients diagnosed with SI joint pain. Movements in all planes were found to be small, with translations never exceeding 1.6 mm, and rotations being limited to 3 degrees. No differences were found between symptomatic and asymptomatic joints, leading the authors to conclude that 3-dimensional motion analysis was not useful for identifying painful SI joints in most patients. Possible exceptions to the finding that hypermobility is not a typical cause of SI joint pain include traumatic instability, multiparity, muscular atrophy, and lower motor neuron disease (28).

Prevalence

Although it is widely acknowledged that dysfunctional SI joints may cause low back pain (LBP), the prevalence of this condition has not been well studied. Prevalence studies are further compromised by the fact that most have used either physical examination findings and/or radiological imaging techniques to make the diagnosis of SI joint pain. The largest of these is a retrospective study by Bernard and Kirkaldy-Willis (29), who found a 22.5% prevalence rate in 1293 adult patients presenting with LBP. Diagnoses in this series were based predominantly on physical examination.

Schwarzer et al. (30) conducted a prevalence study involving 43 consecutive patients with chronic LBP principally below L5-S1 using fluoroscopically guided SI joint injections. Fifty-seven other patients with LBP were excluded on the basis of more rostral symptoms. Three criteria were used to diagnose SI joint pain: analgesic response to local anesthetic (LA), abnormalities on post-arthrography computed tomography (CT) scanning, and concordant pain provocation during joint distension. Using significant pain relief after LA injection as the sole criterion for diagnosis, the prevalence of SI joint pain in the 43 subjects was determined to be 30% (95% confidence interval [CI], 16%–44%), with 4 patients obtaining complete pain relief. Using analgesic response combined with a ventral capsular tear (the most common radiologic finding) as the criteria, the prevalence decreased to 21% (95% CI, 9%–33%). Only 7 patients satisfied all 3 diagnostic criteria, for a lower limit prevalence rate of 16% (95% CI, 5%–27%). The presence of groin pain was the only referral pattern found to distinguish patients with SI joint pain from those with LBP of non-SI joint origin.

Maigne et al. (31) conducted a prevalence study in 54 patients with unilateral LBP using a series of blocks done with different LA based on International Spinal Injection Society guidelines (32). Nineteen patients had a positive response (≥75% pain relief) to the lidocaine screening block. Among these patients, 10 (18.5%) responded with >2 h pain relief after the confirmatory block with bupivacaine and were considered to have true SI joint pain (95% CI, 9%–29%). Based on these studies, the prevalence of SI joint pain in carefully screened LBP patients appears to be in the 15%–25% range.

Mechanism of Injury

The mechanism of SI joint injury has previously been described as a combination of axial loading and abrupt rotation (18). On an anatomic level, pathologic changes affecting many different SI joint structures can lead to nociception. These include capsular or synovial disruption,

Table 1. Sacroiliac Joint Involvement and Other Characteristics of the Adult Spondylarthropathies

Clinical characteristic	Ankylosing spondylitis	Reactive arthritis (Reiter's syndrome)	Psoriatic arthritis	Enteropathic arthritis
Clinical Sacroiliitis	Almost universal	20%–30%	20%–30%	15%–25%
Symmetry of SI Joint Involvement	Symmetric or alternating	Mostly asymmetric	Mostly asymmetric	Mostly asymmetric
Onset	< 35 years	Young to middle-aged	Young to middle-aged	Young to middle-aged
Peripheral Joint Involvement	20%–30%	Approximately 90%	Almost universal	15%–30%
Sex Ratio	M:F = 3:1	M:F = 5:1	Males = females	Males = females

SI = sacroiliac.

capsular and ligamentous tension, hypomobility or hypermobility, extraneous compression or shearing forces, abnormal joint mechanics, microfractures or macrofractures, chondromalacia, soft tissue injury, and inflammation. Mechanistically, there are numerous reported etiologies for SI joint pain. To simplify matters, these causes can be divided into intraarticular and extra-articular sources. Arthritis and infection are two examples of intraarticular causes of SI joint pain. Extra-articular sources are the more common of the two and include enthesopathy, fractures, ligamentous injury, and myofascial pain. Clinical studies have demonstrated significant pain relief after both intraarticular and periarticular SI joint injections (33–36).

In addition to etiologic sources, there are numerous factors that can predispose a person to gradually develop SI joint pain. Risk factors that operate by increasing the stress borne by the SI joints include true and apparent leg length discrepancy (37), gait abnormalities (38), prolonged vigorous exercise (39), scoliosis (40), and spinal fusion to the sacrum (41). Whereas increased SI joint uptake using scintigraphy has been demonstrated after lumbar spine fusion (42), at least one study examining the long-term effects of spinal fusion on SI joint function concluded that neither biomechanical nor anatomical changes were more common in fusion patients than in those who underwent decompression procedures (43). Lumbar spine surgery has also been purported to trigger SI joint pain for reasons unrelated to increased force transmission. These factors include SI ligament weakening and/or surgical violation of the joint cavity during iliac graft bone harvest (44) and postsurgical hypermobility (45).

Pregnancy predisposes women to SI joint pain via the combination of increased weight gain, exaggerated lordotic posture, the mechanical trauma of parturition, and hormone-induced ligamental laxity (46,47). The laxity associated with pregnancy is attributable to increased levels of estrogen and relaxin, and it predisposes parturients to sprains of the SI joint ligaments. SI subluxation has also been reported to cause back pain in pregnancy (48).

Inflammation of one or both SI joints is considered to be an early and prominent symptom in all seronegative and HLA-B27-associated spondylarthropathies (49). Although the precise etiology of spondylarthropathy remains unknown in most patients, the strong association with HLA-B27 supports the view that these conditions are attributable to a genetically determined immune response to environmental factors in susceptible individuals. In a subset of patients with Reiter's syndrome/reactive arthritis, the disease is clearly induced by infection (50) (Table 1).

The specific etiologies that can result in SI joint pain are widespread and protean. Potential causes range from rare events such as pyogenic infection (51) and malignancy (52), to more mundane occurrences such as bracing one's legs in a motor vehicle accident (53), falls (53), athletic injuries (54), prolonged lifting and bending (55), and torsional strain (55). In a retrospective study by Chou et al. (56) assessing the inciting events in 54 patients with injection-confirmed SI joint pain, the authors found trauma was the cause in 44% of patients, 35% were idiopathic, and 21% were attributed to the cumulative effects of repeated stress. In the 24 patients who cited trauma as the source of their pain, the most common events were motor vehicle accidents ($n = 13$), falls onto the buttock ($n = 6$), and childbirth ($n = 3$).

Diagnosis and Presentation

History and Physical Examination

One of the most challenging aspects of treating SI joint pain is the complexity of diagnosis. Literally dozens of physical examination tests have been advocated as diagnostic aids in patients with presumed SI joint pain (57). Many involve distraction of the SI joints, with 2 of the most common ones being Patrick's test and Gaenslen's test. Despite the plethora of diagnostic tests, clinical studies have for the most part demonstrated that neither medical history nor physical examination findings are consistently capable of identifying dysfunctional SI joints as pain generators (30, 58, 59) (Table 2). In addition, Dreyfuss et al. (60) found 20% of asymptomatic

Table 2. Studies Assessing Accuracy of History and Physical Examination in the Diagnosis of Injection-Confirmed Sacroiliac (SI) Joint Pain

Author, year	Study type	Number and type of patients	Diagnostic standard	Results	Comments
Schwarzer et al., 1995 (30)	Cross-sectional, analytic study	43 pts with chronic axial LBP principally below L5–S1	Used ≥ 75% pain relief to a single block as dx criteria.	No PE test was of predictive value in predicting subsequent response to block. Only groin pain found to be more common in pts with (+) dx block.	30% of pts dxed with SI jt pain based on dx block, 21% based on response to block and ventral capsular tear on CT scanning, and 16% based on response to block, capsular tear and pain provocation.
Dreyfuss et al., 1996 (59)	Prospective study assessing value of hx and 12 PE tests in diagnosing SI joint pain	85 pts with axial LBP principally below L5	Used ≥ 90% pain relief to a single SI joint block as criteria for dx.	45 pts had a (+) block, 40 a (−) block. No historical or PE finding predicted response to block.	Response to previous therapy not indicative of SI joint pain. Pts with negative response slightly more likely to have pain above L5.
Maigne et al., 1996 (31)	Prospective study assessing the prevalence of SI joint pain using double blocks and the accuracy of pain provocation tests to dx the disorder.	67 pts with chronic unilateral LBP without extension below the knee.	Criteria for dx was ≥ 75% pain relief after lidocaine screening block followed by similar pain relief lasting > 2 hours after confirmatory bupivacaine block.	Of 54 pts completing the study, 19 experienced good pain relief with the screening block, and 10 of these (18.5%) rec'd > 2 hours pain relief after the confirmatory block. There was no association between any clinical variable or pain provocation test and a (+) response to both blocks.	7 pts excluded b/c SI jt could not be entered, 3 b/c of sciatic palsy after screening block and 3 b/c they remained pain-free after screening block.
Broadhurst and Bond, 1998 (105)	Double-blind study determining the value of Patrick's (FABER) test, posterior shear test and resisted abduction in the dx of SI jt pain.	40 pts with LBP and pain reproduction using the 3 PE tests.	All pts had either saline or 1% lidocaine injected into 1 SI jt. Dx based on ≥ 70% pain reduction when provocative test performed after SI jt block.	Patrick's test found to have 77% sensitivity and 100% specificity; posterior shear test had 80% sensitivity and 100% specificity; resisted abduction had 87% sensitivity and 100% specificity.	No pt had ≥ 70% pain reduction after saline injection.
Slipman et al., 1998 (58)	Prospective cohort study assessing predictive value of provocative tests in dx SI joint pain.	50 pts without spondylarthropathy who had (+) response to 3 dx PE tests.	Used ≥ 80% pain relief to a single block as criteria for dx.	SI jt blocks were (+) in 30 pts for a positive predictive value of 60%.	2 of 3 (+) dx tests had to be Patrick's test and sacral sulcus tenderness. Steroid added to dx block, with average symptom reduction being 30.5%.
Young et al., 2003 (106)	Prospective validity study to identify association between PE & facet, discogenic, and SI jt pain.	55 of 102 pts with chronic axial LBP underwent SI joint blocks.	Used not only pain relief (≥ 80%) to a single block as dx criteria, but also concordant pain provocation.	22 of 57 injected joints had (+) response to SI jt block. Pts with SI jt pain rarely had midline LBP or pain above L5. Positive correlation noted between SI jt pain and increased pain when rising from sitting, unilateral pain and ≥ 3 positive pain provocation tests.	5 provocation tests used to examine the SI joint. Clinical evaluation done by physical therapists. Also sought to identify clinical determinates of discogenic LBP and lumbar facet pain.

Dx = diagnosis, diagnostic; Hx = history; Jt = joint; PE = physical examination; LBP = low back pain; pts = patients; CT = computed tomography; b/c = because.

adults had positive findings on 3 commonly performed SI joint provocation tests.

The reliability of provocative SI joint maneuvers and alignment/mobility tests has also been questioned, with most studies conducted by chiropractors and physical therapists. Whereas some of these studies have found moderate to high inter-examiner reliability (61–63), most have not (64–68). Generally, reproducibility has been found to be greater for provocative tests than for mobility and alignment assessments. In the Dreyfuss et al. study (59) conducted in 85 patients with injection-confirmed SI joint pain, there was moderate agreement (kappa = 0.6) between chiropractors and medical doctors with regard to provocative maneuvers of painful joints. Even when agreement was perfect, the maneuvers were still found to lack diagnostic utility.

Radiological Studies

Results of studies examining radiologic findings in patients with SI joint pain have been similarly disappointing. In studies by Maigne et al. (69) and Slipman

et al. (70), the investigators found sensitivities of 46% and 13%, respectively, for the use of radionuclide bone scanning in the identification of SI joint pain. Despite the high specificites in these studies (89.5% for Maigne et al. and 100% for Slipman et al.), the low sensitivies indicate bone scanning is a poor screening test for SI joint pain. Poor correlation with diagnostic injections and symptoms have also been found for CT and radiographic stereophotogrammetry (71,27). In a retrospective analysis by Elgafy et al. (71), CT imaging was found to be 57.5% sensitive and 69% specific in diagnosing SI joint pain.

Pain Referral Patterns

There have been several attempts to identify pain referral patterns from SI joints. In one of the earliest studies conducted in 10 asymptomatic volunteers, Fortin et al. (72) performed provocative SI joint injections using contrast and lidocaine. Sensory changes were localized to the ipsilateral medial buttock inferior to the posterior superior iliac spine in 6 of the 10 subjects. In 2 subjects, the area of hyperesthesia extended to the superior aspect of the greater trochanter. The last 2 subjects experienced sensory changes radiating into the upper thigh. In a follow-up study, independent examiners selected 16 individuals among 54 with chronic LBP whose pain diagrams most closely resembled the pain referral patterns obtained in the first study (73). These 16 patients proceeded to undergo provocative SI joint injections with contrast and LA. All 16 experienced concordant pain during the injection, with 14 obtaining pain relief after deposition of LA. Ten patients reported $\geq$50% pain reduction. Six of the 16 patients had ventral capsular tears revealed during arthrography. After the SI joint injections, provocative discography and lumbar facet joint injections were performed in 9 patients each. In none of the patients was either test positive.

Slipman et al. (74) conducted a retrospective study to determine the pain referral patterns in 50 patients with injection-confirmed SI joint pain. In contrast to the findings by Fortin et al. (72) and Schwarzer et al. (30), the authors found the most common referral patterns for SI joint pain to be radiation into the buttock (94%), lower lumbar region (72%), lower extremity (50%), groin area (14%), upper lumbar region (6%), and abdomen (2%). Twenty-eight percent of patients experienced pain radiating below their knee, with 12% reporting foot pain. Based on the existing data, the most consistent factor for identifying patients with SI joint pain is unilateral pain (unless both joints are affected) localized predominantly below the L5 spinous process (30,59,72–74).

Diagnostic Blocks

It is often assumed that an analgesic response to a properly performed diagnostic block is the most reliable method to diagnose SI joint pain. Although this may seem to be self-evident, the validity of intraarticular SI joint blocks remains unproven. There are many factors that can impact on the sensitivity and specificity of diagnostic blocks. These include the placebo effect, convergence and referred pain, neuroplasticity and central sensitization, expectation bias, unintentional sympathetic blockade, systemic absorption of LA, and psychosocial issues (75). In addition, SI joint block can be one of the most challenging spinal injection procedures. Extravasation of LA to surrounding pain-generating structures such as muscles, ligaments, and lumbosacral nerve roots can lead to false-positive blocks. Conversely, failure to obtain adequate LA spread to the anterior and cephalad portions of the SI joint can result in false-negative blocks. In a classic study by North et al. (76) examining the specificity and sensitivity of a battery of lumbosacral LA blocks in 33 patients with a chief complaint of sciatica, the authors found the specificity of all blocks to be exceedingly low. SI joint blocks were not performed in this study.

In a pilot study by Fortin et al. (72) mapping SI joint referral patterns in asymptomatic volunteers, extravasation of contrast (mean 1.6 mL injected) occurred in 9 of 10 subjects during SI joint injection, with half having at least moderate spread outside the joint. After the injection of LA, 40% of subjects noted lower extremity numbness, indicating inadvertent anesthetization of the lumbosacral nerve roots. In the Maigne et al. (31) study, 3 of the initial 67 patients were excluded because of "sciatic palsy" after the screening block and another 7 were excluded because penetration of the SI joint was impossible. Other investigators have reported much less frequent (<5%) failure rates with fluoroscopically guided SI joint injections (30,59,77). Technical difficulties may be more frequently encountered in elderly patients and those with spondylarthropathies, in whom degenerative changes are more pronounced. If persistent difficulties entering the SI joint are encountered using fluoroscopy, the 3-dimensional imaging capabilities of CT may facilitate entry into the joint (34, 78) (Fig. 3).

Regardless of the imaging modality used to confirm intraarticular injection, SI joint injections should never be performed blindly. Rosenberg et al. (79) performed a double-blind study in 37 patients (39 joints) to determine the accuracy of clinically guided SI joint injections using CT imaging as the standard. The authors found that intraarticular injection was accomplished in only 22% of patients, whereas sacral foraminal spread occurred 44% of the time. In 3 patients, no contrast was seen on CT scanning, indicating probable vascular uptake. In 24% of injections, contrast extended into the epidural space.

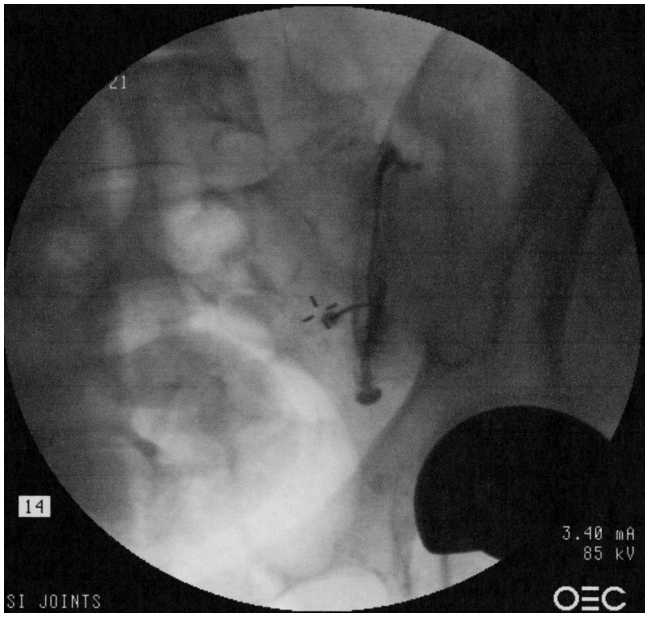

Figure 3. Anteroposterior fluoroscopic image demonstrating a right-sided sacroiliac joint block with minimal extra-articular extravasation of contrast.

As for facet blocks, some experts have advocated using a series of SI joint blocks to reduce the incidence of false-positives. In a prospective study involving 67 patients with unilateral LBP, SI joint-compatible referral patterns and joint tenderness, Maigne et al. (31) sought to determine the prevalence of SI joint pain using a series of blocks with 2 different LA. In the 54 patients who completed the study, 19 obtained ≥75% pain relief with the lidocaine screening block. After the bupivacaine confirmatory block, only 10 of the 19 patients achieved ≥75% pain relief lasting 2 or more hours, for a prevalence rate of 18.5%. The false-positive rate of 17% in this study is less than that previously reported for lumbar facet blocks (80). Yet without a diagnostic "gold standard," there is no way of determining how many true positives were false positives and how many false positives were actually true positives. In clinical practice confirmatory SI joint blocks are almost never performed because a) the block itself is considered to be definitive treatment; b) double-blocks are not cost-effective (81); and c) the negative consequences of obtaining a false false-positive block (misdiagnosing true SI joint pain) outweigh the ramifications of overdiagnosing the condition. In summary, there is no infallible, universally accepted method for diagnosing pain originating in the SI joint(s).

Treatment

The treatment of SI joint pain is widely acknowledged to be one of the most challenging problems confronting pain physicians. Evidence supporting this statement can be seen by the plethora of different therapies that have been advocated for this disorder. Generally, these treatments can be divided into 2 categories: those directed at correcting the underlining pathology and those aimed at alleviating symptoms. For both of these categories, the evidence supporting any one therapy is limited by the lack of controlled outcome studies.

Psychosocial Issues

Recent studies have provided incontrovertible evidence that psychopathology and other psychosocial factors can influence both the development of chronic pain conditions and the response to treatment. In a study by Polatin et al. (82) conducted in 200 chronic LBP patients, the authors found that 77% met lifetime criteria and 59% demonstrated current symptoms for at least one psychiatric diagnosis, with the most common being depression, substance abuse, and anxiety disorders. Notably, more than 50% of those with depression and more than 90% of patients with substance abuse or an anxiety disorder experienced symptoms before the onset of LBP. Most, but not all, studies have shown untreated psychopathology to negatively affect LBP treatment outcomes (83).

In addition to psychiatric illness, social factors have been demonstrated to impact the prognosis of LBP. These include return-to-work issues, secondary gain, catastrophizing, poor role models, codependency behavior, inadequate coping mechanisms, and attitudes, beliefs, and expectations (84). To optimize outcomes, the identification and treatment of concomitant psychosocial issues is of paramount importance. This is best accomplished via a multidisciplinary approach.

Conservative Management

The non-interventional management of SI joint pain should ideally address the underlining pathology. In patients with true or apparent leg length discrepancy, this might include the use of shoe inserts to more equitably distribute the load borne by the SI joints. Because leg length discrepancies are frequently found in asymptomatic individuals (37) and many patients already compensate for their lower extremity length difference by altering their gait or posture, most experts recommend starting out cautiously with inserts that correct only half the incongruity. For SI joint pain resulting from altered gait mechanics and spine malalignment, physical therapy and osteopathic or chiropractic manipulation have been reported to reduce pain and improve mobility (85,86). However, there are no prospective, controlled studies supporting these modalities.

Nonsurgical stabilization programs have been advocated for SI joint pain. These range from the application of pelvic belts that reduce the sagittal rotation of incompetent SI joints in pregnant women (87,88) to

Table 3. Evidence Supporting Various Pharmacologic Therapies in Spondylarthropathies

Drug class/name	Conditions studied	Evidence for efficacy
Antibiotics	Re spA	Moderate evidence when a triggering organism such as Yersinia or Chlamydia is suspected. No evidence otherwise.
Anti-tumor necrosis factor-alpha	AS, Ps spA, Undifferentiated spA	Strong evidence for infliximab and etanercept in AS, weak evidence for other agents in AS. Weak evidence for Ps spA and undifferentiated spA.
Sulfasalazine	All types	Most studied in Ps spA and AS, whereby effects on peripheral arthritis may be > for axial symptoms. For axial symptoms evidence is very weak. Mixed evidence for Re spA and juvenile onset spA. Weak evidence for Ps spA.
Cyclosporine	Ps spA	Moderate evidence
D-Penicillinamine	AS	Mixed evidence
Quinine and its derivatives	AS, Ps spA, seronegative spA	Mixed evidence for AS. Weak evidence Ps spA. No evidence for other anti-malarial drugs.
Oral corticosteroids	AS	Moderate evidence
Tricyclic antidepressants	AS	Only placebo-controlled trial showed reduction in pain for amitriptyline.
Methotrexate	AS and Ps spA	Strong evidence of Ps spA. Moderate evidence only for peripheral symptoms in AS. Efficacy may be better for IV than oral treatment.
Nonsteroidal anti-inflammatory drugs	All, but mostly AS and Ps spA	Strong evidence
Gold salts	Ps spA	Moderate-strong evidence
Levamisole	Seronegative spA	Moderate-strong evidence
Leflunomide	Ps spA, AS	Moderate-strong evidence for Ps spA. In AS, effects on peripheral arthritis > for axial symptoms.
Azathioprine	Re spA, Ps spA, seronegative spA	Moderate evidence
Bisphosphonates	Mostly AS	Moderate evidence. Effect on axial symptoms may be > for peripheral arthritis.
Bromocriptine	All types	No evidence for re spA. Weak evidence for PsA and other seronegative spA.
Heat-killed Mycobacterium vaccae	Ps spA	No evidence
Interleukin 1 antagonists	AS	Weak evidence
Monoclonal antibodies	Ps spA	Weak evidence

Strong evidence = one or more placebo-controlled trials coupled with evidence from other studies; moderate evidence = 1 placebo-controlled study with moderate support from comparative or open-label studies, or strong support from comparative or open-label studies; weak evidence = some support from open-label or comparative studies, or mixed evidence from placebo-controlled studies; no evidence = the evidence against outweighs the evidence supporting efficacy; AS = ankylosing spondylitis; SpA = spondylarthropathy; Re spA = reactive spondylarthropathy/Reiter's syndrome; Ps spA = Psoriatic spondylarthropathy.

exercise-induced pelvic stabilization programs (89). In a study by Mooney et al. (89), the authors found that 5 women with injection-confirmed SI joint pain had electromyographic-documented hyperactivity of the ipsilateral gluteus muscles and contralateral latissimus muscle compared with 15 asymptomatic control patients. After a 2-1/2 month exercise program, all 5 patients achieved a significant reduction in pain and a return of myoelectric activity to normal patterns.

Ankylosing spondylitis (AS), the most well known and studied spondylarthropathy, is an inflammatory rheumatic disease characterized by spine and SI joint involvement that manifests as spondylitis and sacroiliitis. There are numerous studies assessing the efficacy of various pharmacologic treatment modalities in AS and other spondylarthropathies, but the conclusions that can be drawn from these studies are limited by several factors. These include the protean nature of rheumatic involvement, the systemic manifestations accompanying the disorders, and the fact that although the outcome measures generally include changes in pain complaints and mobility, most do not specifically address SI joint pain. Table 3 lists the evidence supporting various pharmacotherapies for AS and other spondylarthropathies.

Intraarticular Injections

Intraarticular injections with steroid and LA often serve the dual function of being therapeutic and aiding in diagnosis. To summarize these studies, most but not all investigators have found radiologically guided SI joint injections to provide good to excellent pain relief lasting from 6 mo to 1 yr (Table 4). Along

Table 4. Clinical Studies Evaluating Corticosteroid Injections for Sacroiliac (SI) Joint Pain

Author, year	Study type	Number and type of patients	Treatment	Primary outcome	Comments
Maugars et al., 1992 (107)	Prospective observational	24 patients w/sero-negative spondylarthropathy	42 corticosteroid injections without LA. Eighteen pts underwent bilateral injections, 6 unilateral.	67% of joints experienced ≥ 80% pain relief, 19% 50%–80% improvement and 14% had < 50% pain relief. Mean duration of improvement 8.4 +/−4.2 months.	Dx made by PE and radiologic studies. Fluoroscopy used to guide injections. Good pain relief was correlated with shorter duration of symptoms.
Bollow et al., 1996 (78)	Prospective observational	66 patients with spondylarthropathy	103 corticosteroid injections without LA. Used an average of 10 ml of superficial LA per joint before during procedure.	92.5% of patients had significant improvement of pain after a mean of 1.7 wks. Mean duration of pain relief 10 +/− 5 months.	Dx made by PE. CT used to guide injections. No difference in Schober's sign or range of motion before and after treatment. ESR and CRP decreased after rx.
Braun et al., 1996 (34)	Prospective, observational	30 patients with spondylarthropathy	54 corticosteroid injections without LA.	Clear improvement in pain and MRI demonstrated inflammation in 83% of patients, lasting 8.9 +/−5 months.	Dx made by PE and contrast enhancement on dynamic MRI. CT used to guide injections. No difference in Schober's sign before and after rx. Both ESR and CRP decreased after rx.
Maugars et al., 1996 (33)	Placebo-controlled double-blind	10 patients with spondylarthropathy, 13 joints. Pts with degenerative SI joints and complete ankylosis excluded.	13 total joints injected. 6 were injected with corticosteroid without LA and 7 with normal saline. 6 of 7 placebo pts were re-injected with steroid at 1 month.	5 steroid joints had good or very good pain relief at 1 month vs. 1 in placebo group. Overall, 12/14 SI joints had good or very good results at 1 month, 8/13 at 3 months and 7/12 at 6 months.	Dx made by PE and radiologic studies. Fluoroscopy used to guide injections. One pt developed radicular pain that lasted 3 weeks.
Luuk-kainen et al., 1999 (35)	Randomized, controlled study	20 pts with sero-negative spondylarthropathy rec'd steroid and LA; 10 pts rec'd saline and LA. All pts had unilateral blocks.	All pts underwent unilateral, periarticular injections. 10 rec'd corticosteroid without LA; 10 rec'd normal saline with LA.	At 2-month follow-up, VAS pain scores decreased significantly in the steroid but not saline group.	Injections were periarticular, not intra-articular. Dx made by PE and radiologic studies. Fluoroscopy used to guide injections.
Dussault et al., 2000 (77)	Retrospective chart review	24 pts with pain overlying the SI jt (n = 11), LBP (n = 10) or hip pain (n = 3), 31 joints. Data evaluated on 28 joints.	Total of 31 joints injected with corticosteroid and LA. 4 subjects underwent bilateral injections, 3 repeat injections.	Pain decreased by ≥ 80% in 7 joints, by 50%–70% in 11 joints and < 50% in 10 joints. More than 50% relief was obtained in 55% of joints with normal radiographs, in 62% of joints with degenerative joint disease, and in the only pt with ankylosing spondylitis.	Injections done by radiologists with fluoroscopic guidance. In 1 pt the joint could not be penetrated and 2 pts developed lower extremity weakness.
Gunaydin et al., 2000 (108)	Prospective observational	9 pts with spondylarthropathy.	16 joints injected with corticosteroid without LA.	7 of 9 pts reported improvement (mean decrease in VAS scores 49%, mean duration of pain relief 10.8 +/− 5.6 months).	Dx by PE and radiographic studies. MRI used to guide injections. CRP but not ESR decreased after rx.
Hanly et al., 2000 (109)	Prospective, single-blind (evaluators)	19 pts with spondylarthropathy. 13 had radiologic evidence of sacroiliitis and 6 had normal imaging studies.	All pts underwent bilateral injections with corticosteroid without LA.	Both groups experienced significant pain relief 1 month after injections, with no difference between groups. 6 months postinjection, there was no difference in pain or stiffness compared to baseline in either group.	CT used to guide injections. Pts randomized by radiologic imaging, not PE. Spinal mobility was not changed in either group over the study period. Main fault of this trial is that radiological studies have been shown to be insensitive as a screening tool for SI joint pain.

Continued

Table 4. Continued

Author, year	Study type	Number and type of patients	Treatment	Primary outcome	Comments
Pereira et al., 2000 (110)	Prospective observational	12 patients with spondylarthropathy (3 with ankylosing spondylitis) and buttock pain	24 injections with corticosteroid without LA. 9 pts had bilateral injections.	Clinical improvement noted in 10 patients, with a mean pain-free period of 9.6 months.	MRI used to guide injections. In 1 pt adequate needle position was not obtained due to software failure. Three months after injection there was a significant decrease in marrow edema in 2 pts, a marked decrease in 5 pts and a moderate decrease in 3 pts.
Pereira et al., 2000 (111)	Prospective observational	10 patients with sacroiliitis (9 bilateral)	21 injections with corticosteroid without LA. 9 pts had bilateral injections.	Good to excellent pain relief in 8 of 10 pts lasting a mean of 13.5 months. The 2 non-responders suffered from fibromyalgia and reactive depression.	MRI used to guide injections. Subchondral marrow edema resolved on follow-up MRI minimally in 3 pts, partially in 3 pts and completely in 3 pts.
Ojala et al., 2001 (112)	Prospective observational	20 patients with low back pain	Total number of injections not noted. Used corticosteroid with LA.	60% of patients had significant short-term pain reduction after injections.	Dx made by history and PE. All pts had normal imaging studies. MRI used to guide SI joint injections.
Karabacakoglu et al., 2002 (113)	Prospective observational	17 patients with ankylosing spondylitis.	5 pts underwent bilateral injections. Used corticosteroid without LA.	15 of 17 patients reported good relief 1 month after injection, with 2 reporting fair relief.	CT used to determine needle puncture point and angle of intervention. Fluoroscopy used to guide injections.
Luuk-kainen et al., 2002 (36)	Randomized, controlled study	24 pts without spondylarthropathy.	All pts underwent unilateral, periarticular injections. 13 pts rec'd corticosteroid and LA, with 11 pts receiving normal saline and LA.	At 1-month follow-up, VAS pain scores decreased significantly more in the steroid group than in the saline group.	Injections were periarticular, not intraarticular. Dx made by PE. No pt had radiologic evidence of sacroiliitis. Fluoroscopy used to guide injections.
Katz et al., 2003 (41)	Retrospective chart review	34 pts with low back pain after lumbar spinal fusion to the sacrum.	Total number of injections not noted. Used corticosteroid with LA.	59% (n = 20) of pts had > 75% pain relief 15–45 minutes after injections and were thus diagnosed with SI joint pain. 11 of the 20 experienced > 75% relief lasting > 2 wks, while 6 had moderate pain relief.	Dx considered based on history and PE. Fluoroscopy used to guide injections. 10 pts excluded because they had multiple injections at the same visit.
Fischer et al., 2003 (114)	Randomized, controlled	89 children with juvenile spondyarthropathy. 56 were responders to NSAIDs (control group) and 33 were non-responders (treatment group).	Treatment group rec'd corticosteroid without LA injections plus NSAIDs (27 bilateral injections). The control group was continued on NSAIDs without injections.	87.5% of children who rec'd injections reported significant decrease in their pain complaints over the 20-month follow-up period (mean VAS pain score decreased from 6.9 to 1.8). The control group showed similar improvement in pain scores, with no difference between groups.	Dx made clinically and by MRI evidence of sacroiliitis. CT used to guide injections. One-third of patients who rec'd injections demonstrated continued joint destruction despite absence of subjective complaints.

Dx = diagnosis; CT = computed tomography; Rx = treatment; PE = physical examination; ESR = erythrocyte sedimentation rate; CRP = C-reactive protein; LA = local anesthetic; pts = patients; MRI = magnetic resonance imaging; VAS = visual analog scale; LBP = low back pain; NSAIDs = nonsteroidal antiinflammatory drugs.

with a multitude of studies demonstrating prolonged pain relief after intraarticular SI joint steroid injections, double-blind studies have shown a beneficial effect for periarticular corticosteroid treatment as well (35,36).

Radiofrequency Denervation Procedures

Several investigators have performed radiofrequency (RF) denervation procedures in an attempt to provide prolonged pain relief to patients suffering SI joint pain. The techniques used have ranged from denervating the nerves supplying the SI joint (90–92) to creating lesions in the joint itself (93), with one study using a combination of the two (94). The success rates of studies targeting the nerve supply are higher than those focusing on the joint itself, with approximately two thirds of patients reporting significant pain relief. The major drawback to percutaneous RF denervation procedures is that they should not be expected to alleviate pain emanating from the ventral SI joint. In the study by Schwarzer et al. (30), ventral capsular pathology was shown to account for 69% of all CT pathology in the 13 patients with a positive response to diagnostic SI joint blocks. Complicating matters

Table 5. Clinical Studies Evaluating Radiofrequency Procedures in the Treatment of Sacroiliac Joint Pain

Author, year	Study type	Number of patients	Treatment	Primary outcome	Comments
Ferrante et al., 2001 (93)	Retrospective study	33 pts, 50 joints	Multiple, 90°C, 90 second lesions made at < 1 cm intervals as high in the postero-inferior joint as possible.	36.4% of pts obtained ≥ 50% pain relief 6-months post-procedure. Average duration of pain relief was 12.0 ± 1.2 months.	Did not specify % pain relief required during diagnostic SI joint injections for inclusion. Only postero-inferior joint denervated.
Gevargez et al., 2002 (94)	Prospective observational study	38 patients, including 13 who underwent bilateral treatment	Three 90°C, 90 second lesions in the posterior interosseous SI ligaments and 1 lesion of the L5 dorsal ramus.	Three months after treatment, 34.2% were pain-free, 31.6% reported a substantial decrease in pain, 18.4% obtained a slight decrease in pain and 7.9% reported no pain reduction.	Did not specify % pain relief required during diagnostic SI joint injections for inclusion.
Cohen and Abdi, 2003 (90)	Retrospective study	18 patients	80°C, 90 second lesions of the L4 and L5 dorsal rami and S1–3 lateral branches.	13 of 18 pts with SI joint pain obtained 50% pain relief with L4 and L5 dorsal rami and S1–3 lateral branch blocks, with 2 deriving long-term relief. 8 of 9 pts who underwent RF denervation obtained ≥ 50% pain relief 9-months post-procedure.	Inclusion criteria was ≥ 50% pain relief with SI joint blocks. In 6 pts, empirical lesions were made at the S3 lateral branch because of failure to obtain concordant stimulation.
Yin et al., 2003 (92)	Retrospective study	14 patients, including 4 who underwent previous spine surgery	80°C, 60 second lesions of the L5 dorsal ramus sensory branch and S1–S3 dorsal rami lateral branches depending on stimulation results. All pts had L5 and S1 branches lesioned. 11 pts had a lateral branch at S2 and 6 at S3 that were lesioned.	64% of patients obtained > 50% consistent pain relief at 6 months, with 36% obtaining complete relief. 5 patients reported < 50% pain relief, and 2 reported no relief whatsoever.	Inclusion criteria was > 70% pain relief after 2 separate SI joint deep interosseous ligament injections.
Buijs et al., 2004 (91)	Prospective observational study	38 patients, 43 joints	80°C 60 second lesions of the S1–3 dorsal rami in all pts and L4–L5 dorsal rami in about half the pts.	At 12-week follow-up, 34.9% of procedures (26.3% of pts) resulted in complete pain relief and another 32.6% (34.2% of pts) reported > 50% pain relief.	Inclusion criteria included > 50% pain relief with SI joint blocks. Outcomes of pts receiving additional L4–5 dorsal rami denervation not compared to pts undergoing only S1–3 denervation.

pts = patients; RF = radiofrequency.

further are that the nerves lesioned during RF procedures innervate other pain-generating structures besides the SI joint, and the SI joint is likely innervated by other nerves inaccessible for denervation (Table 5).

Surgical and Other Invasive Interventions

In 1999, Srejic et al. (95) reported 12–16 mo of significant pain relief in 4 patients with SI joint pain who received a series of 3 intraarticular injections with hyaluronic acid. Three of these patients had postsurgical SI joint pain and one suffered from severe osteoarthritis of the spine. The rationale for this treatment stems from studies demonstrating long-term pain relief with hyaluronic acid injections in degenerative joint disease of the knee (96). However, one meta-analysis found only scant evidence for the use of viscosupplementation in knee osteoarthritis, especially when lower molecular weight hyaluronate formulations are used (97). In addition to questionable efficacy, another factor that mitigates against intraarticular hyaluronic acid injections for SI pain is that degenerative joint disease accounts for only a small percentage of cases.

Proliferative therapy (a.k.a. "prolotherapy") has been advocated as a treatment for nonspecific LBP and SI joint pain (98). The rationale behind the use of "prolotherapy" is that the ligaments and other soft tissue structures are of primary importance in the development of LBP. Thus, the injection of a drug promoting fibroblast hyperplasia should theoretically increase the strength and reduce sensitization of these structures. In a double-blind study, Ongley et al. (99) found that LBP patients who received 6 wk of proliferant therapy had lower pain scores and disability indices at their 6-mo follow-up than "control" patients who received saline injections. Despite these

findings, the lack of specific diagnoses, the numerous other treatment differences between groups, and the targeting of pain generators outside the SI joints limit the relevance of this study.

In patients with SI joint pain unresponsive to more conservative measures, several investigators have advocated surgical stabilization. Unfortunately, all published reports on SI joint fusion have been small case series or retrospective studies. Whereas the primary indications for SI joint fixation are either joint instability or fractures (100,101), successful arthrodesis has also been reported for degenerative joint disease (102). In some patients, successful stabilization can be done percutaneously using CT guidance (103). Regardless of the underlying etiology, based on the existing studies the long-term success rate for SI joint fusion appears to be in the range of 70% (100–102). Neuroaugmentation of the third sacral nerve root has also been reported to provide adequate pain relief in 2 patients with severe SI joint pain unresponsive to conventional therapy (104).

Conclusions

The SI joint is a real yet underappreciated pain generator in an estimated 15% to 25% of patients with axial LBP. Whereas historical and physical examination findings have been previously advocated as useful tools in identifying patients with SI joint pain, more recent studies have demonstrated they have limited diagnostic value. Presently, small-volume diagnostic blocks remain the most commonly used method for diagnosing this disorder, although their validity remains unproven. Owing to the complexity of the joint, the mechanisms of SI pain are numerous and ill-defined. When a pathological condition such as leg length discrepancy or altered gait mechanics is present, correcting the underlying defect is the safest and most reliable treatment option. Intraarticular and periarticular corticosteroid injections have been shown in most, but not all, studies to provide good to excellent pain relief lasting up to 10 mo in patients with and without spondylarthropathy. One promising area in the treatment of SI joint pain is RF denervation, although the conclusions that can be drawn are limited by the heterogeneous methods used and the lack of controlled studies.

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