DOI: 10.1111/papr.13338

EVIDENCE-BASED REVIEW

Update of Evidence-Based Interventional Pain Medicine According to Clinical Diagnoses

5. Sacroiliac joint pain

Karolina Szadek MD, PhD, FIPP[1] | Steven P. Cohen MD, FIPP[2,3] | Javier de Andrès Ares MD, PhD, FIPP[4] | Monique Steegers MD, PhD, FIPP[1] | Jan Van Zundert MD, PhD, FIPP[5,6] | Jan Willem Kallewaard MD, PhD, FIPP[7,8]

[1]Department of Anesthesiology and Pain Medicine, Amsterdam University Medical Centers, Amsterdam, The Netherlands

[2]Department of Anesthesiology, Neurology, Physical Medicine & Rehabilitation and Psychiatry and Behavioral Sciences, Northwestern University Feinberg School of Medicine, Chicago, Illinois, USA

[3]Department of Anesthesiology and Physical Medicine & Rehabilitation, Walter Reed National Military Medical Center, Uniformed Services University of the Health Sciences, Bethesda, Maryland, USA

[4]Pain Unit Hospital Universitario La Paz-(Anesthesiology), Madrid, Spain

[5]Department of Anesthesiology, Intensive Care, Emergency Medicine and Multidisciplinary Pain Center, Ziekenhuis Oost-Limburg, Genk/Lanaken, Belgium

[6]Department of Anesthesiology and Pain Medicine, Maastricht University Medical Center, Maastricht, The Netherlands

[7]Department of Anesthesiology and Pain Medicine, Rijnstate Ziekenhuis, Velp, The Netherlands

[8]Department of Anesthesiology and Pain Medicine, Amsterdam University Medical Centers, Amsterdam, The Netherlands

Correspondence
Jan Van Zundert, Department of Anesthesiology, Intensive Care, Emergency Medicine and Multidisciplinary Pain Center, Ziekenhuis Oost-Limburg, Bessemersstraat, Genk/Lanaken 478 3620, Belgium.
Email: jan.vanzundert@zol.be

Abstract

Introduction: Sacroiliac (SI) joint pain is defined as pain localized in the anatomical region of the SI joint. The reported prevalence of SI joint pain among patients with mechanical low back pain varies between 15% and 30%.

Methods: In this narrative review, the literature on the diagnosis and treatment of SI joint pain was updated and summarized.

Results: Patient's history provides clues on the source of pain. The specificity and sensitivity of provocative maneuvers are relatively high when three or more tests are positive, though recent studies have questioned the predictive value of single or even batteries of provocative tests. Medical imaging is indicated only to rule out *red flags* for potentially serious conditions. The diagnostic value of SI joint infiltration with local anesthetic remains controversial due to the potential for false-positive and false-negative results. Treatment of SI joint pain ideally consists of a multidisciplinary approach that includes conservative measures as first-line therapies (eg, pharmacological treatment, cognitive-behavioral therapy, manual medicine, exercise therapy and rehabilitation treatment, and if necessary, psychological support). Intra- and extra-articular corticosteroid injections have been documented to produce pain relief for over 3 months in some people. Radiofrequency ablation (RFA) of the L5 dorsal ramus and S1-3 (or 4) lateral branches has been shown to be efficacious in numerous studies, with extensive lesioning strategies (eg, cooled RFA) demonstrating the strongest evidence. The reported rate of complications for SI joint treatments is low.

Conclusions: SI joint pain should ideally be managed in a multidisciplinary and multimodal manner. When conservative treatment fails, corticosteroid injections and radiofrequency treatment can be considered.

KEYWORDS
cooled radiofrequency, evidence-based medicine, low back pain, radiofrequency ablation, sacroiliac joint

INTRODUCTION

This narrative review on sacroiliac (SI) joint pain is an update of the article published in the series "Evidence-based Interventional Pain Medicine According to Clinical Diagnoses."[1] The SI joint has long been considered an important source of low back pain due to the nociceptive innervation of the joint and empirical findings that treatments targeting the SI joint can relieve pain. The International Association for the Study

of Pain (IASP) has formulated criteria for the diagnosis of SI joint pain.[2] According to these criteria SI joint pain is defined as pain localized in the anatomical region of the SI joint, reproducible by performing specific SI joint provocation tests, or reliably relieved by selective infiltration of the symptomatic SI joint with a local anesthetic. Depending on the diagnostic criteria employed (clinical examination, intra-articular test blocks, medical imaging), the reported prevalence of SI joint pain among patients with axial low back pain varies between 15% and 30%.[3–5]

The SI joint is a diarthrodial synovial joint, that connects the sacrum to the iliac bone. The antero-caudal part of the SI joint is a true synovial joint, whereby the facies auricularis of the sacrum is connected bilaterally to the facies auricularis of the iliac bones. Strong ligaments support the joint, limiting its movement. These ligaments can be divided into the ligamentum sacroilacum interosseum, posterius, and anterius, and three accessory ligaments—ligamentum sacrotuberale, sacrospinale, and iliolumbale. The SI joint is encompassed by some of the most powerful muscles in the body, including the erector spinae, psoas, quadratus lumborum, piriformis, and gluteus. Yet, there are no muscles explicitly intended for the active manipulation of the SI joint.

The SI joint cannot function independently because these muscles, together with the musculus piriformis, are shared with the hip joint, and the erector spinae and psoas muscles interact with the lumbar spine. The ligaments and the muscles support and influence the stability of the SI joint. The anterior part of the SI joint is innervated by branches arising from the anterior ramus of L4 and L5,[6] or the lumbosacral trunk.[7,8] Although one detailed anatomical study describes the dorsal part of the SI joint receiving innervation from the posterior sacral network (PSN) formed by the lateral branches of the posterior rami of S1–S3 (with variable contributions from L5 and S4),[9] findings from another study suggest that these nerves innervate the posterior SI joint ligaments but do not reach the synovial part of the joint posteriorly.[10]

SI joint pain can be divided into intra-articular causes (infection, arthritis, spondyloarthropathies, malignancies) and extra-articular causes (enthesopathy, fractures, ligamentous injuries, and myofascial injuries). Frequently, no specific cause can be identified. Unidirectional pelvic shear stress, repetitive torsional forces, and inflammation can all cause pain. Risk factors include leg length discrepancy, abnormal gait pattern, trauma, scoliosis, lumbar fusion surgery with fixation to the sacrum, heavy physical exertion, obesity, and pregnancy.[11–17] In patients suffering from persistent low back pain after a technically successful lumbar arthrodesis, a prevalence rate of SI joint pain between 30% and 40% has been demonstrated by means of diagnostic intra-articular blocks, with the sole study that utilized double-blocks reporting a true-positive rate of 40% and a false-positive rate of 26%.[14,18,19] However, it remains unclear what percentage of these patients developed post-fusion SI joint pain (eg, adjacent segment disease) due to increased post-fusion stress on the SI joints[20] versus individuals with presurgical SI joint pain who underwent unnecessary fusion.

METHODOLOGY

This narrative review is based on the article "SI joint pain" published in 2010.[1] In 2015, an independent company, Kleijnen Systematic Reviews (KSR) performed a systematic review of the literature for the period 2009–2015 based on existing systematic reviews (SRs) and randomized controlled trials (RCTs).[21,22]

For the current article, an updated search was conducted for the period 2015–2023 using the terms "sacroiliac" and "joint" and "pain" in combination with specific interventional pain management techniques, in this case, "corticosteroid" or "steroid" and "injections"; "radiofrequency" or "cooled radiofrequency." Additionally, authors selected relevant missing articles based on reference lists and precision literature reviews (eg, complications, arthrodesis).

DIAGNOSIS

History

Pain from the SI joint is generally localized in the gluteal region, below the L5 spinal level, where the posterior elements of the SI joint are situated (94%).[23] Referred pain from the intra-articular part of the joint may also be perceived in the lower lumbar region (72%), groin (14%), upper lumbar region (6%), or abdomen (2%). According to one study, pain referred to the lower limb occurs in 28% of patients, with 12% reporting pain in the foot.[23] (Figure 1). The posterior extra-articular ligaments may also result in pain that is referred into the lumbar area, lower extremity, and into the groin. In one study, between 10% and 20% of extra-articular SI joint pain was referred to the lower extremity, with between 5% and 10% extending below the knee.[24] Upper extra-articular SI joint pain may be more likely to extend into the groin, while middle and lower extra-articular pathology may radiate into the lower leg more than upper ligamentous pathology.[24] Groin pain and anterior thigh pain may also occur in individuals with ventral and occasionally even dorsal SI ligamentous pathology, though epidemiological data on this are lacking. If the pain is felt in the anatomical region of the ischial tuberosity, it is less probable that the patient suffers from SI joint pain.[25]

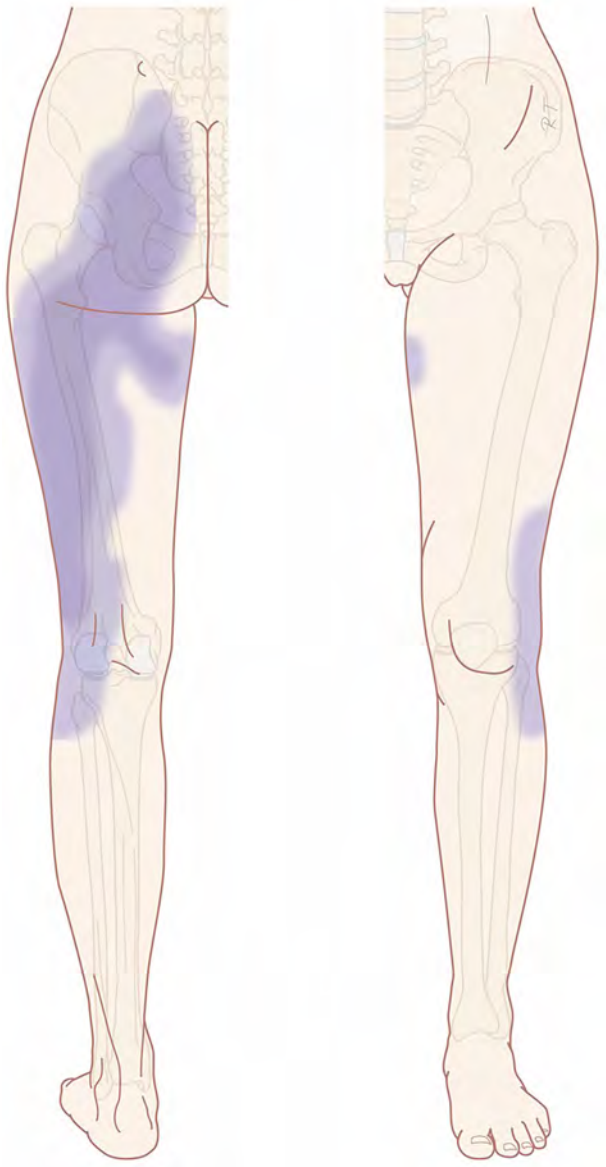

FIGURE 1 Typical pain referral pattern of sacroiliac joint pain (illustration: Rogier Trompert Medical Art http://www.medicalart.eu).

Many investigators have emphasized that medical history is important for correct diagnosis.[20] Several investigators have found that radiation into the groin can distinguish SI joint pain from other sources,[4,24,26] while others reported that proximity of the area of maximal pain and/or tenderness to the posterior superior iliac spine is predictive to response to injections.[27,28] Young et al.[29] found positive correlations between SI joint pain and worsening of symptoms when rising from a sitting position, when symptoms are unilateral (particularly in younger individuals with traumatic, extra-articular SI joint pain), and with three or more positive pain provocation tests. Yet, other investigators have found no aggravating or relieving factors to be helpful in identifying a painful SI joint.[30]

Physical examination

Although solitary pain provocation maneuvers have no pathognomonic value in identifying a painful SI joint, two individual pain provocation tests- the compression and thigh thrust test- may be helpful in diagnosing SI joint pain.[31] Patients with a positive thigh thrust test or compression test may be more likely to suffer from intra-articular SI joint pain [sensitivity 0.907 (0.78–0.97), specificity 0.662 (0.53–0.77), diagnostic odds ratio 18.461 (5.82–58.53)]. Due to the size and the immobility of the SI interface, large forces are needed to stress the joint, which can be a source of false negatives. In addition, if forces are applied incorrectly, pain can be provoked in neighboring structures, resulting in false-positive tests. Both the sensitivity and specificity of the clinical examination increases as a direct function of the number of positive tests. Two studies found that three or more positive provocative tests resulted in a specificity and sensitivity of 79% and 85%, and 78% and 94%, respectively.[32,33] This was confirmed by a meta-analysis which showed that 3 or more positive stress tests have discriminative power for diagnosing SI joint pain.[31] However, three recent studies call into question the diagnostic value of individual or a battery of provocative tests.[34–36] In a systematic review involving five studies and 422 patients, Saueressig et al. found that a battery of positive provocative SI joint maneuvers had only a 35% certainty of identifying the SI joint as the primary pain generator, but that a negative cluster of tests is associated with a non-painful joint in 92% of cases. {Saueressig, 2021 #12827}.

There is scant research on the association of historical and physical exam findings to predict response to extra-articular injections, with one study finding an association between a positive block and the patient identifying the most painful point as being within 2 cm of the posterior superior iliac spine. {Murakami, 2008 #12828} More research needs to be done on tests to identify extra-articular pathology and distinguish between pathology involving different aspects of the SI joint complex.

There are several clinical tests described in the literature: palpation tests to assess mobility and alignment, and provocation tests to reproduce a patient's typical pain. Herein we describe several of the more popular and well-studied tests, with purported diagnostic validity.[31]

1. Fortin's finger test: The patient localizes the pain with one finger, in the area immediately inferomedial to the posterior iliac spine (within 1 cm), and consistently points to the same area.[37]
2. A combination of five provocation tests for SI joint pain with a threshold of three or more positive tests, including the compression, thigh thrust, distraction, Gaenslen's, and Patrick's tests. Each of these purports to reproduce a patient's typical pain.

a. Compression test (Approximation test): The patient lies on his/her side with the affected side up; the patient's hips and knees are flexed approximately 45° and 90°, respectively. The examiner stands behind the patient and places both hands on the front side of the iliac crest and then exerts downward pressure.[38]
b. Thigh thrust test (POSH-Posterior Shear test, Femoral Shear test): The patient lies supine with the unaffected leg extended. The examiner stands next to the affected side, then bends the leg at the hip to an angle of approximately 90° with slight adduction while applying light pressure to the bent knee, causing anterior-to-posterior shear in the affected SI joint.[38]
c. Distraction test (Gapping test): The examiner stands on the affected side of the patient who is in the supine position with their arms crossed and hands on the spinae iliaca anterior superior (SIAS). The examiner applies pressure in the dorso-lateral direction.[38]
d. Patrick's sign (FABER-Flexion Abduction External Rotation test): The patient lies in the supine position with the examiner standing on the affected side. The leg of the affected side is bent at the hip and knee, with the foot positioned under the opposite knee. The examiner fixes the contralateral SIAS to prevent movement in the lower back. Downward pressure is then applied to the knee of the affected side.[38]
e. Gaenslen's test (Pelvic torsion test): The patient lies in a supine position with the affected side on the edge of the examination table. The unaffected leg is bent at both the hip and knee, and maximally flexed until the knee is pushed against the abdomen. The leg on the affected side is brought into hyperextension whereby light pressure is applied to the knee.[38]

3. The Gillet test, also known as the Stork test, is one of the tests used in the assessment of SI and hip joint mobility and alignment.[39] The patient stands upright in a comfortable posture, with both feet flat on the floor. The examiner stands behind the patient to observe their back and pelvis. Pelvic Movement Assessment: Instruct the patient to lift one leg while flexing the knee toward their chest, as if they were marching in place. They can choose either leg for the initial assessment. While the patient lifts their leg, palpate, and closely observe the position of the iliac crest on the side of the lifted leg (the ASIS—Anterior Superior Iliac Spine). During normal hip flexion, the ASIS on the side of the lifted leg should rise slightly or move upward symmetrically compared to the stationary ASIS on the opposite side. This is because the hip joint is flexing, and the pelvis on the lifted side should rotate forward. If, during the leg lift, the ASIS on the side of the lifted leg does not move upward or moves downward compared to the opposite side, it may indicate a lack of mobility or dysfunction in the SI joint on that side. This can suggest SI joint pathology or immobility. After assessing one leg, repeat the test on the other leg to compare mobility and symmetry.

Additional tests

Medical imaging is indicated only to rule out *red flags* for potentially serious conditions.[40]

The choice of imaging depends on the patient's clinical presentation. In various studies, the use of radiography, computed tomography, single photon emission computed tomography (SPECT), bone scans, and other nuclear imaging techniques have been used to identify specific disorders of the SI joint. As a sole diagnostic tool, computed tomography (CT) is not helpful in diagnosing SI joint pain because of the high prevalence of degenerative changes among asymptomatic individuals.[41] This prevalence increases with age, whereby >85% of asymptomatic patients over the age of 60 have radiological evidence of SI joint degeneration. Degenerative changes on the sacral surface generally lag years behind the occurrence on the iliac side, with the correlation between clinical symptoms and imaging being poor.[42] Similar to CT scans, SI joint abnormalities are commonly observed on magnetic resonance imaging (MRI) of asymptomatic individuals and include bone marrow edema, erosions, and sclerosis, with erosions being more specific in patients with low back pain.[43]

According to the Assessment of Spondyloarthritis International Society (ASAS), MRI is the most adequate imaging modality to detect sacroiliitis,[44] but care must be taken to distinguish between inflammatory SI joint pathology and non-inflammatory changes which may resemble sacroiliitis.[45,46] (see Table 1).

Diagnostic blocks

According to the 3rd IASP criterion, SI joint pain should be completely relieved by selective infiltration of local anesthetics into the symptomatic SI joint,[2] whereby a local anesthetic is injected in the joint cavity. Yet, this approach fails to consider both concomitant pain generators and failure to achieve spread throughout the entire SI joint complex. Several authors used a single diagnostic block in clinical studies.[4,23,47] Others have used confirmatory (double) diagnostic blocks on two separate occasions,[5,25,32,33,48–50] ideally using local anesthetics of different durations of action, though the sensitivity of the "comparative local anesthetic" paradigm has been reported to be low in other contexts.[51,52] In six studies, corticosteroids were used in combination with local anesthetics.[30,33,48,53,54] Although the volume of local anesthetic used for infiltration has

TABLE 1 Differential diagnosis for spondyloarthropathy and the major findings in MRI.

Conditions that resemble sacroiliac joint pain	MRI findings in SI joints[46]
Anatomical variations involving the cartilaginous or ligamentous part of the joint, including an accessory SI joint, transitional vertebrae, hemisacralization	Small vessels located in transitional cartilaginous-ligamentous portions which may simulate bone marrow edema (BMO).
Osteoarthritis/degenerative changes of the SI joints and lower lumbar spine	Young (sports-active) individuals: (BMO) in the SI joints, minor erosions, osteophytes, and sclerosis. Elderly with SI joint osteoarthritis: BMO (often in the antero-superior part of the SIJs), minor erosions.
Osteitis condensans ilii (OCI)	Triangular-shaped, well-circumscribed, subchondral sclerosis (anteriorly located, iliac side > sacral) without gross erosions or SI joint narrowing. BMO surrounding sclerosis. If there is BMO surrounding fat metaplasia, this suggests SpA may coexist with OCI.
Infectious sacroiliitis	Anatomic boundaries are not respected (involvement can be unilateral or bilateral), usually with large erosions, joint effusion, and more extensive BMO; soft tissue involvement, often with abscess(es).
Tumors/pseudotumors	Usually a straightforward imaging diagnosis
Diffuse idiopathic skeletal hyperostosis	Evident, coarse bony/ossified bridges over the anterior and posterior SI joint articular margins and entheseal bridging. Intra-articular ankylosis.
Hyperparathyroidism	Subchondral resorption with irregularity, gross erosions, and pseudo-widening of the SI joints (more pronounced on the iliac side).
Synovitis, acne, pustulosis, hyperostosis, osteitis syndrome, and chronic recurrent multifocal osteomyelitis	Osteitis/BMO (on either side of the SI joints) precedes erosive changes, sclerosis, and hyperostosis in the SI joints (more marked on the iliac side). Unilateral or bilateral asymmetric involvement of the SI joints mainly involving the iliac side, with extensive osteosclerosis.
Gout	Tophi may form in SI joints (juxta-articular, intra-articular and subchondral).
Paget's disease	Must have other Pagetic changes in the pelvis. Fusion of the SI joints is occasionally observed in Paget's disease with coexisting sacroiliitis.
Sarcoidosis	May mimic SpA in radiographs. In the presence of known clinical sarcoidosis, the diagnosis of bone sarcoidosis should be considered if there is concomitant involvement of the SI joints.

Abbreviations: BMO, bone marrow edema; OCI, Osteitis condensans ilii; SpA, spondyloarthropathy.

varied between 1 mL[4] and 4 mL,[55] the capacity of the intra-articular portion of the SI joint typically does not exceed 2.7 mL[27]; hence, volumes too low can result in false-negative blocks while excessive volumes can lead to rupture of the joint capsule or extravasation outside of the joint and false-positives. In individuals in whom posterior extra-articular pathology is suspected (eg, young individuals with unilateral pain after trauma and prominent tenderness in the absence of significant radiographic findings), either extra-articular injections or lateral branch blocks may be employed, with the latter also being used as a prognostic tool before sacral lateral branch RFA.[56–58]

The diagnostic value of SI joint infiltration with local anesthetic remains controversial and difficult to calculate due to the potential for false-positive and false-negative results.[59] Possible causes of inaccurate blocks include dispersal of the local anesthetic to adjacent pain-generating structures, (muscles, ligaments, nerve roots through connections between the SI joint and upper sacral foramina),[60] the overzealous use of superficial anesthesia or sedation, and failure to achieve infiltration throughout the entire SI joint complex, with the latter being a potential cause of a false-negative diagnosis. In one study, three communication pathways between the SI joint and adjacent neural structures were observed that could increase the risk of a false-positive block: posterior extravasation into the first dorsal sacral foramina, superior recess extravasation at the sacral ala extending to the fifth lumbar spinal nerve, and ventral extravasation reaching the lumbosacral plexus.[60] The use of fluoroscopy or other imaging to guide needle placement during SI joint blocks is strongly recommended. In studies evaluating the ability of blind injections to spread inside the joint, the accuracy has varied between 8% and 22%.[56,61,62] CT-guided injections can be useful when the SI joint cannot be accessed using fluoroscopy.[63]

Differential diagnosis

Spondyloarthropathy or axial spondyloarthritis is an inflammatory disease of the spine. It usually presents as chronic low back pain before the age of 45 years, with involvement of other joints and inflammation observed on imaging studies. Possible accompanying symptoms

include uveitis, psoriasis, and inflammatory bowel disease. Patients frequently carry the gene for human leukocyte antigen (HLA)-B27, and those with active inflammatory disease often have evidence of elevated acute phase reactants, including erythrocyte sedimentation rate and C-reactive protein (CRP).[64]

See also chapters on lumbosacral radicular syndrome and lumbar facet joint pain.[65,66]

Hip pain is usually secondary to arthritis of the joint. Patients usually present with pain in groin area but also frequently have pain in the buttock and lateral hip which can extend below the knee.[67,68] Activity makes the pain worse, and it may interfere with sleep. Plain radiography is indicated.

Endometriosis[69] is a common cause of pelvic, abdominal, and low back pain caused by the implantation of normal uterine endometrial mucosa in abnormal locations including the bowel, diaphragm, and pleural cavity. The pain in endometriosis can be associated with other symptoms such as dysmenorrhea, dyspareunia, and dysuria.

Myofascial pain.[70] is a relatively common source of chronic pain caused by the presence of trigger points, spasm or increased myoelectric tone, or even atrophy within muscles. In addition to pain, it is associated with restricted active movement in the affected area.[71]

Piriformis[72] syndrome is associated with pain in the buttock, hip, and lower limb. Sciatic-like symptoms may accompany piriformis syndrome and can be caused by irritation of the sciatic nerve if the nerve passes through the muscle or adjacent to the piriformis or neighboring (eg, gemelli, obturator internis) muscle(s) anteriorly. Entrapment of the sciatic nerve may develop following excessive muscle strain, spasm or trauma to the buttocks in patients with anatomical variations in which the sciatic nerve passes through or next to the piriformis muscle (20%). Pathology involving the adjacent musculature of the lateral rotator group (superior and inferior gemelli, obturator internus) can also mimic SI joint pain.

Cluneal nerve entrapment syndrome is a medical condition characterized by the compression or irritation of the superior, middle and/or inferior cluneal nerves.[73] In all three categories of nerve involvement, individuals typically experience pain in the lower back or buttocks, along with dysesthesia or paresthesia. Symptoms are typically exacerbated by lumbar movements or shifts in posture, with numbness or radiating pain provoked when pressure is applied over the relevant trigger point(s). Symptomatic relief achieved through nerve blocks is considered a diagnostic hallmark.

TREATMENT OPTIONS

Optimal treatment of SI joint pain consists of an interdisciplinary approach and should include conservative (pharmacological treatment, cognitive-behavioral therapy, manual medicine, exercise therapy, and rehabilitation treatment, and if necessary, psychological evaluation and management) as well as interventional pain management techniques.

A conservative management

Physical therapies primarily address the underlying cause. In SI joint pain attributed to postural and gait disturbances, targeted exercise therapy and manipulation can reduce pain and improve mobility. There are numerous randomized trials showing efficacy for muscle relaxants, non-steroidal anti-inflammatory drugs, and antidepressants for back pain, but none have specifically addressed individuals with SI joint involvement. Although anecdotal evidence supports spinal manipulation, one study found that individuals with positive SI joint provocation tests did not fare better than other patients with chronic low back pain.[74] In patients with true leg length discrepancies, partial correction with shoe inserts may provide benefit.[75] One randomized study, performed to evaluate whether radiofrequency denervation added to a standardized exercise program and psychological support if indicated is more effective than only standardized exercise and psychological support alone, showed a statistically significant but clinically questionable improvement in pain intensity 3 months after the intervention for the SI joint treatment arm.[76]

Ankylosing spondylitis (M. Bechterew) is an inflammatory rheumatological disorder that affects the vertebral column and the SI joint. Controlled studies have demonstrated analgesic efficacy for immunomodulating agents in ankylosing spondylitis and other spondylarthropathies. However, no conclusions can be drawn with respect to their specific efficacy for SI joint pain.[76]

Interventional management

Patients with SI joint pain resistant to conservative treatment are eligible for interventional management such as intra- and peri-articular injections or radiofrequency ablation (RFA) treatment.

Corticosteroid injections

Intra-articular injections

Randomized controlled trials evaluating intra-articular injections report good pain relief for up to 6 months.[77–79] Maugars et al.[78] treated 13 SI joints in 10 patients: 6 joints with intra-articular corticosteroids, and seven joints with physiological saline solution. After 1 month, pain reduction of >70% was noted for five of the six SI joints treated with corticosteroid, whereas no benefit was noted in the placebo group.

Subsequently, all control group patients and two in the treatment group who had short-term pain relief received a repeat injection with corticosteroid. After 1, 3, and 6 months, significant pain reduction was observed in 86%, 62%, and 58% of patients, respectively. In a study by Visser et al.[79] Fifty-one patients with SI joint-related leg pain were randomized to treatment with intra-articular corticosteroid injections ($N=18$), physiotherapy ($N=15$), or manual therapy ($N=18$). The effect of the treatment was evaluated after 6 and 12 weeks. Overall, 56% experienced a successful treatment, with physiotherapy achieving success in 20% of 15 patients, manual therapy resulting in a 72% success rate in 18 patients, and intra-articular injection yielding a positive outcome in 50% of 18 patients. However, in those treated with steroid injections, only 28% ($N=5$) of patients experienced clinically relevant pain relief after 12 weeks. Chen et al.[77] compared intra-articular SI joint platelet-rich plasma (PRP) injections with intra-articular corticosteroids. Although pain scores decreased over time for both the corticosteroid and PRP groups, the corticosteroid group showed statistically significantly greater improvements in pain than did the PRP group during the 6-month follow-up. At 1 month, 80%, of participants in the corticosteroid group reported ≥50% pain relief, and 70% at 3-month follow-up.

Extra-articular and combination injections

There is similar, if not stronger evidence supporting peri-articular corticosteroid infiltrations.[28,80–82] Luukkainen et al.[80] randomized 24 patients to receive either peri-articular corticosteroid with local anesthetic ($n=13$) or local anesthetic and saline ($n=11$). One month after the intervention, VAS pain scores decreased significantly in the corticosteroid group compared to the control patients. In an earlier double-blind study, Luukkainen and colleagues demonstrated superiority of periarticular SI joint injections to saline 2-month post-injection in 20 patients with spondyloarthropathy.[81] In a large, double-blind comparative-effectiveness study comparing landmark-guided to fluoroscopically guided intra-articular injections, Cohen et al.[56] reported comparable benefit between subjects with intra-articular and extra-articular spread at 1-month, though on some outcome measures individuals in whom intra-articular spread was noted fared better at 3 months. In this study, only 8% of landmark-guided injections were intra-articular.

There have been several non-randomized trials comparing intra-articular to peri-articular injections. In an observational study performed in 50 patients, Murakami et al.[83] reported superiority for peri-articular lidocaine injections compared to intra-articular injections immediately post-procedure. A quasi-randomized study (via laterality) by Khalil et al.[84] performed in 96 patients reported superiority for peri-articular over intra-articular injections through 3-month follow-up. Two studies that included one small observational study and a retrospective analysis, reported comparable benefit for SI joint injections administered within and outside of the joint cavity.[85,86] Two other studies showed superiority for combination intra- and extra-articular SI joint injections with corticosteroid and local anesthetic compared to intra-articular injections alone.[82,87]

Radiofrequency ablation (RFA) treatment of the SI joint

The efficacy of RFA treatments of the SI joint is demonstrated by numerous observational,[88–90] retrospective,[91–93] and randomized controlled studies.[58,94–100] However, the selection criteria, definitions of success, RFA techniques (conventional monopolar, bipolar, multielectrode combination mono- and bipolar, and monopolar cooled), and parameters (ie, temperature, duration, and location of RFA treatment), and imaging techniques (fluoroscopy, CT, ultrasound) have varied widely between studies.

In one of the earliest attempts at SI joint denervation, Ferrante et al.[91] performed multiple bipolar intra-articular lesions at 90°C, reporting poor outcomes with a technique that targets only the postero-inferior part of the joint. A few years later, Gevargez et al.[89] performed three 90°C monopolar lesions in the ligamentum sacroiliacum posterior and one targeting the L5 ramus dorsalis, which again resulted in poor outcomes. In the first iteration of an extensive lesioning strategy targeting the extrinsic nerve supply, Cohen and Abdi[92] performed single 80°C lesions of the L4-L5 rami dorsalis and the S1–S3 (or S4) rami lateralis of the rami dorsalis. Despite obtaining excellent results in this small observational study, this technique would currently be considered inadequate for severing most of the nociceptive input. Several months later, Yin et al.[57] published the description of a similar technique except that they excluded the L4 ramus dorsalis and selected more caudal levels based solely on concordant sensory stimulation. Burnham and Yasui[88] performed paraneuroforaminal bipolar RF strip lesions at the level of S1–S3, and a monopolar RF treatment at the level of the L5 ramus dorsalis. Two authors described[90,93] the effectiveness of a single strip lesion utilizing a combination of both monopolar and bipolar current transfer with the Simplicity III electrode positioned lateral to S1, S2, S3, and S4 neuroforamina, whereby lesions were created at a temperature of 80–85°C for 60 s,[93] and 85°C for 90 s.[90] Cohen et al.[101] investigated which demographic and clinical variables could be used to predict SI joint RFA outcome. In multivariate analysis, pre-procedure pain intensity, age 65 years or older and pain referral below the knee were all statistically significant predictors of failure, with a trend toward cooled RFA to provide better outcomes than conventional denervation.

Younger patients may be more likely to benefit from L5 dorsal ramus and sacral lateral branch RF treatment because they are more likely than older patients to have an extra-articular, ligamentous source of SI joint pain, which are innervated by the nerves being lesioned.

There are some reports on the use of pulsed radiofrequency (PRF) therapy for the treatment of SI joint pain.[98,102,103] In study of Vallejo[102] the L4, L5 rami mediales and the S1, S2 rami laterales of the rami dorsales were treated with PRF using the parameters 45 V, temperature of 42°C, for 120 s and temperature not exceeding 42°C. Although Dutta et al.[103] treated the same levels, they performed 3 PRF treatments on levels S1–S3 and two at L4 and L5, with the time extended to 180 s per cycle based on studies suggesting that longer heating times may be more effective for neuropathic pain.[104] AboElafdl et al.[98] used yet another approach, intraarticular PRF, whereby 5 cycles of pulsed radiofrequency for 120 s each were applied. Despite these uncontrolled studies, randomized studies for lumbar facet joint pain have consistently failed to demonstrate equivalence to RFA treatment.[105,106]

To circumvent anatomical variations in innervations, some investigators have employed internally cooled RF electrodes, which increase the ablative area by minimizing the effect of tissue charring that limits lesion expansion. An extensive lesioning strategy is particularly important for SI joint pain given the widespread variability in the number and location of nerves receiving and conveying nociceptive input. In the first study to demonstrate efficacy with cooled RFA, Cohen et al.[95] performed a randomized placebo-controlled study in which a "classic" RFA procedure was performed on the L4 and L5 dorsal rami and cooled RFA was applied to the S1 to S3 or four lateral branches, with S4 being targeted in individuals where the foramen was located level with, below, or just above the bottom of the SI joint. One, 3- and 6 months post-treatment, 79%, 64%, and 57% of patients reported ≥50% pain relief, respectively. In the placebo group, only 14% experienced significant improvement at 1-month follow-up, and none experienced significant benefit 3 months post-procedure. Patel et al.[58] randomized 51 patients in a 2:1 ratio who responded to two prognostic lateral branch blocks to receive either cooled RFA or sham RFA of L5 dorsal ramus and S1-3 lateral branches. At the 3-month primary endpoint, 47% of patients in the RFA group experienced a positive outcome, defined as ≥50% reduction in average pain coupled with significant improvement in either the SF-36 bodily pain score or functional capacity measured by Oswestry disability index, versus 12% in the control group. In their most recent multi-center randomized controlled study involving 210 patients who responded with short-term relief to SI joint injections and experienced significant benefit with prognostic lateral branch blocks, Cohen et al.[100] reported the superiority of the cooled RFA over standard medical management, with 52% of patients in the RFA group experiencing a positive categorical outcome at the 3-month endpoint versus only 4% in the control group.

A detailed overview of RCTs evaluating RF techniques and their effectiveness is provided in Table 2.

Surgery

The use of SI joint fusion has increased dramatically over the past 15 years. Older retrospective and observational studies of SI joint fusion reported good, equivocal, and poor results for a variety of indications including instability, malalignment, and degenerative changes, but these studies were characterized by serious methodological flaws including an incomplete description of diagnosis, including the parameters of diagnostic blocks.[107–109] Many earlier studies did not even use blocks for diagnosis.[110–112]

One rationale for the recent growth of minimally invasive SI joint arthrodesis techniques is that while fusion may benefit degenerative conditions, the trauma of surgery in many cases outweighs the benefit. In one systematic review that evaluated 40 studies (including 2 randomized controlled trials that compared iFUSE to conservative management), Chang et al.[113] reported significant improvement across multiple domains lasting greater than 1 year, with the 2 RCTs resulting in large improvements in pain (mean difference − 40.5 mm, 95% CI, −50.1 to −30.9; −38.1 mm) and function (mean difference in Oswestry Disability Index −25.4 points, 95% CI, −32.5 to −18.3; −19.8 points). However, the 2 RCTs contained multiple sources of bias and methodological flaws including industry sponsorship, non-blinding of patients (with most of the patients allocated to conservative management receiving treatments they already failed), and non-standardization of the diagnostic injections, many of which were performed with high volumes that exceeded the joint capacity.[114] In another systematic review that included six studies, five of which were industry-sponsored, Abbas et al.[115] reported more modest differences in 6-month pain scores [standardized mean difference − 1.5 (95% CI −1.8, −1.1)] and Oswestry disability index [standardized mean difference − 1.1 (95% CI −1.6, −0.5)] between SI joint arthrodesis and conservative management.

Complications of interventional management

Although potential complications of intra-articular injections and RF procedures include infection, hematoma formation, neural damage, trauma to the sciatic nerve during intra-articular injections or sacral spinal nerve roots during the placement of "finder" needles during RFA, vasovagal reactions, weakness secondary to extra-articular extravasation to neural structures, and

TABLE 2 Summary of the evidence on efficacy of the RFA treatments according to RCTs results.

Author, Reference, Goal	Diagnostic/prognostic block technique, Positive outcome	RF technique	Effect
Juch[94] Efficacy of physiotherapy versus RFA and physiotherapy. Psychotherapy provided to both groups as indicated.	25G needle inserted 3–10 mm lateral to the S1–S3 sacral foramina under fluoroscopic guidance. After confirmation of the needle position in lateral view, 0.5 mL of 2% lidocaine was injected. The dorsal ramus of L5 was blocked using 0.5 mL of 2% lidocaine. ≥50% pain reduction within 30 to 90 min after the block.	Cooled RFA; 17G electrode; 3 lesions were created next to the S1, S2, and S3 neuroforamina; 3 lesions were made for S1 and S2 and 2 lesions at S3. Temperature of 60°C for 2.5 min per lesion. Simplicity; SIMPLICITY III probe: was inserted at the lateral, inferior border of the sacrum, 10 mm below the S4 foramen under fluoroscopic guidance. The electrode probe was advanced in a cephalad direction along the sacrum, lateral to the sacral neuroforamina, medial to the sacroiliac joint and ventral to the ileum. The correct position of the electrodes was checked and RF lesions (85°C for 90 s per step) were created. Bipolar palisade RFA: six 20G electrodes with 10 mm active tips were placed parallel to each other 10 mm apart and perpendicular to the sacrum. Then eight lesions (90°C, 180 s per lesion) were made using adjacent pairings of cannulas. With all three techniques, RF lesion of the ramus dorsalis of L5 was carried out with a conventional monopolar electrode.	The mean difference for the primary outcome, pain intensity at 3 months, was −0.71 (95% CI, −1.35 to −0.06) favoring the RFA group. No significant differences between the groups were found when success was defined as greater than 30% or a 2-point reduction in pain at 3 months. 48 patients (49.48%) had >30% pain reduction at 12 months. 57 patients (58.76%) had 2-point or greater pain reduction at 12 months.
Salman[96] Randomized, crossover study comparing RFA and intra-articular steroid injection.	Intra-articular SI joint block with 3 mL solution containing 2 mL of lidocaine 2% and 1 mL bupivacaine 0.5%. ≥75% pain relief for at least 3 h post-block	RFA of the L4–5 primary dorsal rami and S1–S3 lateral sacral rami was accomplished using a 20G electrode with a 10 mm active tip, with sensory electro-stimulation at 50 Hz. RFA lesion of 90 s at 80°C. For S1 down to S3 lateral branch RFA, 22G electrodes with 5 mm active tips, placed 3-5 mm from the lateral border of the foramina were used. For S1 and S2, 3 monopolar thermal lesions were created, with 2 created at S3. Sensory stimulation at each level was performed for the first lesion, eliciting concordant sensation at 0.5 V. 90 s 80°C lesions.	At 1-, 3-, and 6-month post-intervention, 73%, 60% and 53% of patients, respectively, experienced ≥50% pain relief in the RFA group. In the steroid group, at 1-month post-intervention, only 20% experienced ≥50% pain relief, with no one having improvement at 3- and 6-month follow-ups.
Zheng[97] Randomized, open-label study performed in SA patients with significant SI joint pain using PSRN under computed tomography guidance versus celecoxib treatment.	Intra-articular injection verified using arthrography. Triamcinolone (40 mg) in 3 mL 0.5% bupivacaine was injected. ≥50% pain relief on VAS pain scale 6 h after diagnostic block	CT-guided strip bipolar lesions were created with a 20G electrodes containing 5 mm active tips spaced 10 mm apart. Electrodes were leapfrogged between adjacent pairs of cannulas, with lesions created at 90°C for 3-min.	At week 12, pain reduction from baseline was 65.3% versus 36.2% in the PSRN and celecoxib arms, respectively. At 24 weeks, pain reduction was 61.1% versus 27.5% in the PSRN and celecoxib arms, respectively.
Cohen[95] Randomized, placebo-controlled comparing cooled RF versus sham procedure.	SI joint injection with 3 mL solution containing 2 mL of bupivacaine 0.5% and 1 mL of 40 mg/mL of depo-methylprednisolone. ≥75% pain relief lasting at least 3 h after diagnostic block	L4 and L5 dorsal rami were treated with 22G SMK-C10 cannula with 5-mm active tips. Sensory stim <0.5 V, with 90 s 80°C lesions created. For S1–S3 lateral rami procedures, 17G 75 mm internally cooled electrodes with 4 mm active tips were inserted between 3 and 5 mm from the lateral border of the foramina at pre-designated positions. Three peri-foraminal lesions were created at S1 and S2, 2 at S3, and 1 at S4 (when treated). Sensory stimulation at ≤0.5 V. 2.5- min lesions were created at 60°C with the target tissue heated to >75°C, resulting in a lesion diameter ranging between 8 and 10 mm.	One, 3-, and 6-month post-procedure, 11 (79%), 9 (64%), and 8 (57%) of radiofrequency treated patients experienced ≥50% pain relief and significant functional improvement versus 14% who experienced a positive 1-month outcome in the sham group.

(Continues)

TABLE 2 (Continued)

Author, Reference, Goal	Diagnostic/prognostic block technique, Positive outcome	RF technique	Effect
Patel 2012 and 2016[58,129] Cooled RF versus sham intervention for SI joint pain.	Lateral branches of S1–S3 were targeted with 25G spinal needles, advanced to the surface of the sacrum 3–10 mm lateral to the posterior sacral foramina of S1–S3; 0.5 mL of 0.5% bupivacaine was injected at each level. The dorsal ramus of L5 was blocked with 0.5 mL of bupivacaine 0.5%. This block protocol was repeated on a separate day, after return to baseline pain. Subjects achieving ≥75% relief of their index pain after both blocks were eligible for enrollment.	The L5 dorsal ramus was targeted between the sacral ala and articular process. For S1 and S2, 3 lesions were created, for S3, 2 lesions were created. For reference, right-sided S1 and S2 lesions corresponded to 2:30, 4:00, and 5:30 positions on the face of a clock; for S3, right-sided lesions corresponded to 1:30 and 3:00 on a clock face; left-sided lesions were mirror images. 17G, 75 mm cooled electrode with 4-mm active tips were used to create lesions at all levels for 150 s at 60°C. Position confirmed using epsilon marker.	Improvement in NRS pain score at the 3-month time-point for the treatment group was significantly greater than that for the sham group. At 3-month follow-up, 47% of treated patients and 12% of sham subjects achieved pre-defined treatment success, defined as ≥50% pain relief with significant improvement in SF-36 bodily pain or ODI. At 6 and 9 months, 38% and 59% of treated subjects, respectively achieved treatment success.
Mehta[99] Randomized double-blind, sham-controlled trial evaluating the effectiveness of RFA using a strip lesioning device for SI joint pain	Double intra-articular, fluoroscopy-guided blocks with 2 mL of lidocaine. Patients were determined to have SI joint pain if they reported greater than 80% pain relief immediately following the diagnostic block on both occasions.	RFA of the L5 primary dorsal ramus was performed using a 22G 10 cm electrode with a 10 mm active tip after sensory stimulation at <0.5 V. Simplicity strip lesioning of the lateral branches of the S1, S2, and S3 was performed using an electrode that creates mono- and bipolar lesions. The sham procedure was identical to RFA except no RF energy was applied.	At 3 months post-RFA, patients in the active group reported a reduction in the mean NRS pain score from 8.1 ± 0.8 to 3.4 ± 2.0. In the sham group, the pre-randomization mean pain score decreased from 7.3 ± 0.8 to 6.5 ± 2.0.
Cohen[100] Randomized, Comparative-effectiveness study comparing cooled RF vs. standard medical management	In patients with short-term relief from SI joint injections, fluoroscopically guided lateral branch blocks at S1–S3 (S4) and L5 dorsal ramus block with local anesthetic using a total volume <2 mL were performed. Subjects with bilateral pain had bilateral blocks. Positive response was ≥50% pain relief.	*N* = 105: Fluoroscopically guided paraforaminal lesions at the L5 dorsal ramus and the S1–S3 (S4) lateral branches. Cooled RF ablation was performed using 17G electrodes which were inserted at 1:30, 3:30, and 5:30 o'clock for right-sided lesions at S1 and S2, and at 1:00 and 3:00 o'clock at S3, with mirror image positions for left-sided lesions. L5 was targeted in the groove lateral to the sacral articular process. The 150 s lesions were created at a temperature of 60°C, resulting in a target tissue temperature ≥ 80°C. Subjects with bilateral pain received cooled RF ablation treatment on both sides on the same occasion. *N* = 105: Standard treatment included pharmacotherapy, physical and chiropractic therapy, lifestyle changes, acupuncture, yoga, and therapeutic injections into the sacroiliac ligaments or joint cavity.	At 3 months, the mean NRS pain score for the cooled RF ablation group was 3.8 ± 2.4 with a mean reduction in average NRS pain score of 2.5 ± 2.5. In the control group the mean NRS pain score at 3 month was 5.9 ± 1.7 with a 0.4 ± 1.7 reduction.
van Tilburg[122] Randomized, sham-controlled trial evaluating the efficacy of RFA using a strip lesion device	60 patients who experienced ≥2-point reduction in pain after an intra-articular injection with 3 cc of 2% lidocaine.	RFA of the L5 primary dorsal ramus was accomplished using an electrode (size not noted) with a 10 mm active tip. Simplicity strip lesioning of the lateral branches of the S1, S2, and S3 was performed using an electrode that creates mono- and bipolar lesions. Each step was 85°C for 90 s, with a total of five steps. Sham group received an identical procedure except with no RF lesioning.	No significant differences found for pain reduction, positive outcome, or satisfaction between groups 1-month post-treatment.

Abbreviations: CI, confidence interval; NRS, numeric rating scale; ODI, Oswestry Disability Index; PSRN, palisade sacroiliac radiofrequency neurotomy; RFA, radiofrequency ablation; SA, spondyloarthrosis; VAS, visual analog scale.

complications related to drug administration such as intravascular uptake, the reported rate of these complications in SI joint treatment is low.[116]

Luukkainen et al.[80,81] reported no complications from periarticular SI joint injections. For intra-articular injections, Maugars et al.[78] reported only transient perineal anesthesia lasting a few hours and mild sciatica lasting 3 weeks, but no information was given as to the number of patients who reported these side effects. In the largest randomized trial evaluating SI joint injections, Cohen et al.[56] reported a 6% adverse event rate in the fluoroscopically guided injection group and a 12% adverse event rate in the landmark-guided group. These included a 6.4% incidence of temporary neurological symptoms (eg, weakness) attributed to sciatic nerve blockade.

For RF treatment of the SI joint, Cohen et al.[95] noted that the majority of 28 patients experienced temporary worsening of pain 5–10 days after the procedure which was attributed to procedure-related tissue trauma and temporary neuritis. In a follow-up study, Cohen et al.[101] reported five complications out of 77 treated patients. These included three cases of temporary paresthesia, one superficial skin infection that resolved with antibiotics and one case of hyperglycemia in a diabetic patient requiring increased insulin use for 3 days. The latter was caused by the corticoid used to prevent procedure-related neuritis, which is a relatively common practice recommended in the lumbar and cervical facet guidelines.[117,118] In their study evaluating pulsed RF of the SI joint, Vallejo et al.[102] observed no complications or worsening of pain. Transient buttock dys- or hypoesthesia and temporary worsening of pain have been frequently reported in other studies evaluating heat radiofrequency of the sacral lateral branches and is likely related to denervation of branches to the skin.[57,88,89,94] In one uncontrolled study evaluating cooled RF treatment, post procedural hip pain lasting up to 5 days was reported in most treated patients ($N=21$).[119] In another study, several patients reported soreness or numbness at the introducer sites for up to 2 weeks after cooled RF and one subject developed shingles at the introducer site, though this complication was probably not directly related to treatment.[58]

Minimally invasive SI joint arthrodesis is considered safer than open fusion, but still carries risks. In a systematic review evaluating 14 studies and 819 minimally invasive fusions, Shamrock et al.[120] reported an 11.1% complication rate, with wound infection being the most common. There was a 1.6% incidence of nerve entrapment, and a revision rate of 2.6%.

In a large database review involving 469 patients, Schoell et al.[121] reported an overall complication rate of 16.4% at 6 months, which did not include the 5.3% of patients who developed novel lumbar pathology within 6 months of surgery.

EVIDENCE FOR INTERVENTIAONAL MANAGEMENT

A summary of the available evidence for interventional treatment of SIJ pain is provided in Table 3.

RECOMMENDATIONS IN 2023

The evidence evaluated in this review supports RFA as an intervention to provide pain relief and functional benefit in patients with chronic SIJ pain for periods ranging between 3 months and 1-year post-treatment. Among 16 RCTs, 15 showed positive results. The only unequivocally negative study was a small study by van Tilburg et al.[88] that enrolled over 75% of individuals screened and inexplicably included patients with radiculopathy. Whereas the largest randomized trial reached significance for the primary outcome measure, the benefits at other points were small, and 76% of patients had a positive "diagnostic" block.[94,122] In one recent systematic review by Chappell et al.,[123] the authors reported a mean difference favoring RFA in both all randomized trials [$n=5$, (five trials, mean difference −1.53, 95% CI −2.62 to 0.45)] and in just sham-controlled studies ($n=4$, mean difference −1.89, 95% CI −3.45 to 0.34).

TABLE 3 Evidence of interventional pain management for SI joint pain.[21]

Technique	Recommendations in 2010	GRADE level of evidence in 2015	Recommendations in 2018
Intra-articular corticosteroid injections	1B+	Low	Weak
Radiofrequency treatment of rami dorsalis and lateralis (palisade)	2C+	Very low	Very weak
Radiofrequency treatment of rami dorsalis and lateralis (palisade) SI joint pain secondary to ankylosing spondylitis		Moderate	Moderate
Radiofrequency treatment of rami dorsalis and lateralis (simplicity)		Not graded	Moderate against
Pulsed radiofrequency treatment of rami dorsalis and lateralis	2C+	Not graded	Very weak
Radiofrequency treatment of ramus dorsalis at L4–L5 and cooled radiofrequency of the ramus lateralis	2B+	Low	Weak
Cooled radiofrequency treatment of ramus dorsalis at L4–L5 and ramus lateralis		Moderate	Moderate

The evidence supporting SI joint injections is less robust. In one systematic review evaluating 15 studies, only two of which were randomized, Kennedy et al.[124] concluded the evidence supporting intra-articular SI joint injections was moderate for short-term benefit. In a narrative review that separated out intra- and extra-articular injections, Gartenberg et al.[125] recommended consideration of extra-articular injections in individuals who fail more conservative measures.

Although there are no guidelines on the use of minimally invasive SI joint fusion, systematic reviews recommend consideration of arthrodesis in individuals with refractory SI joint pain secondary to degeneration, instability, or malalignment.[113,115]

In summary, in patients with chronic low back complaints possibly originating from the SI joint complex, intra- and extra-articular injections with a local anesthetic and corticosteroids can be recommended. If this fails or produces only short-term effects, radiofrequency/palisade or cooled radiofrequency treatment of the lateral branches of S1 to S3, (S4) can be considered in those whose pain emanates primarily from extra-articular sources. For individuals with SI joint degeneration or instability, minimally invasive SI joint arthrodesis should be considered.

Clinical practice algorithm

The practice algorithm is illustrated in Figure 2.

TECHNIQUES

SI-joint infiltration technique[126]

The patient lies in a prone position. Using an AP fluoroscopic projection, the medial SI-joint line is formed by the posterior joint articulation while the lateral opening represents the anterior joint. Next, the C-arm is rotated contralaterally until the medial cortical line of the posterior articulation aligns with the lateral (ventral) opening, thereby providing a clear soft-tissue trajectory for the needle to penetrate ventrally. Tilting the C-arm longitudinally in relation to the patient (cephalocaudally) can sometimes help the clinician distinguish between the anterior and posterior articulations. Skin puncture is 1–3 cm cranially from the lower edge of the SI joint at the level of the zone of maximal radiographic translucency. Penetration of the SI joint is characterized by a change in resistance and sometimes increased procedure-related pain. The tip of the needle may appear to be slightly bent between the os sacrum and the os ilium from needle distortion that occurs while traversing the bony structures. On a lateral view, the needle tip should appear anterior to the dorsal edge of the sacrum. Injection of contrast agent shows dispersal along the articulation and a filling of the caudal joint capsule. Use only 0.25–0.5 mL contrast agent. If this technique is not successful, then approaching the joint from a more rostral puncture point, or using computed tomography, may facilitate penetration.

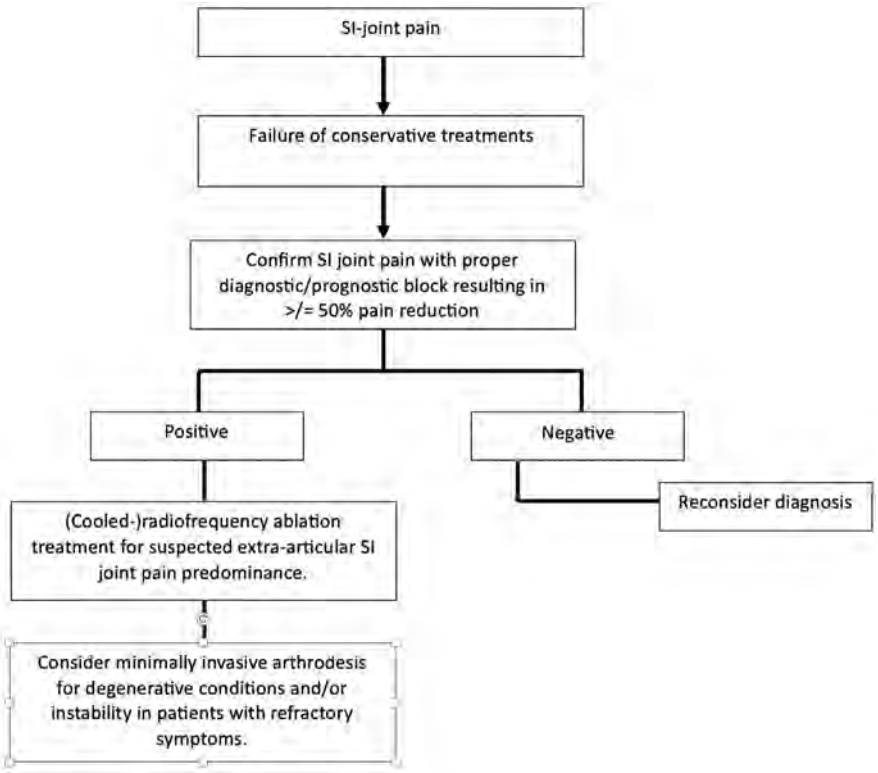

FIGURE 2 Algorithm for the treatment of SI joint pain.

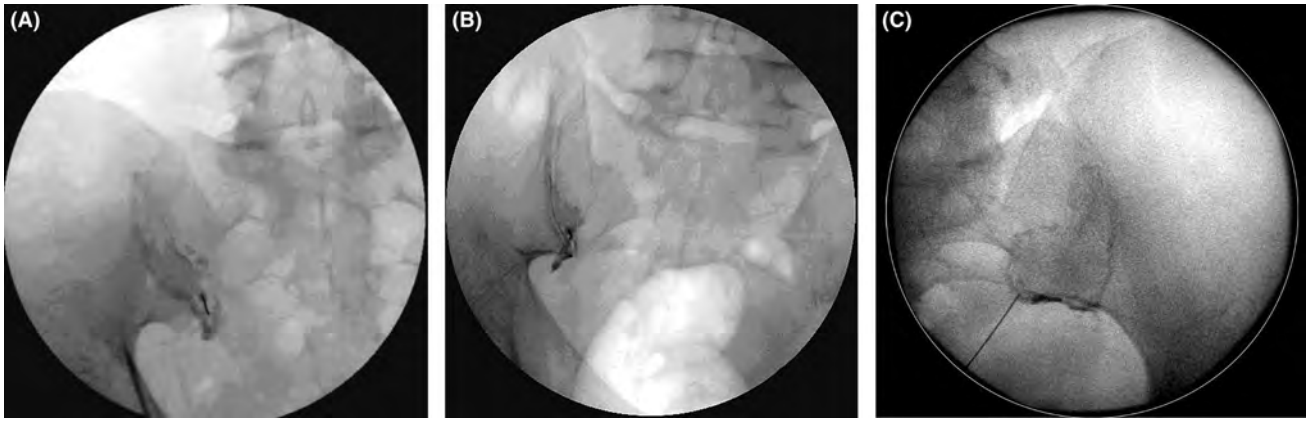

FIGURE 3 (A, B) Intra-articular injection of SI joint with contrast in anterior–posterior view. (c) Intra-articular injection of SI joint with contrast shown in an oblique view.

For peri-articular injections, the area(s) of maximal pain and tenderness is targeted. Since the posterior ligaments are targets, there is no need to align the posterior and ventral openings by obliquing the image intensifier. Generally, higher volumes (up to 5 mL) are injected, with contrast spread outlining ligamentous structures on both the sacral and iliac sides.

Needle positioning for intra-articular SI joint injection is illustrated in Figure 3A–C.

Lateral rami of S1–S3 (4) and dorsal ramus L5 (4) (LBBs)

Since lateral branches innervate the posterior ligaments supporting the SI joint complex but not the capsule or ventral soft tissue elements, they are sometimes used as prognostic tests, but are not diagnostic. Some, but not all randomized trials have used prognostic lumbar dorsal rami and sacral lateral branch blocks as predictive tools before RFA.[58,94,100]

For the lateral rami of S1–S3, the image intensifier may need to be angled cephalad so that it is perpendicular to the posterior foramina, the targets for the finder needles. For S1, further angling the image intensifier ipslaterally often improves visualization of the posterior opening. Since the ventral and dorsal foraminal openings may be difficult to align, 25- or 22G finder needles are placed into the S1–S3 foramina and withdrawn to the posterior cortex, thereby forming an orienting landmark. Since S4 provides innervation to the joint in some people as described in a majority of the anatomical studies, and others have found L4 innervation to the upper SI ligaments in some individuals, the lateral branches at S4 and the dorsal ramus at L4 may be targeted depending on presentation (eg, when the S4 foramina lies at or above the level of the lower margin of the joint).[127,128] The relevant areas should be marked on the skin, ideally somewhere between 7 and 10 mm from the lateral edge of the foramina. On the face of a clock, levels may correspond to 2:00–2:30 and 5:00–5:30 at S1, 1:30 and 4:30 at S2, and 1:00–3:00 at S3 depending on foramen's opening relative to the inferior SI joint margin. Thereafter a lateral image should be obtained to confirm appropriate depth of needle placement on the sacral surface, followed by infiltration of between 0.5 and <2 mL of a local anesthetic at each level.

For the dorsal ramus of L5 and possibly L4, place the needle in the notch between the sacral ala and the S1 articular process, and at the junction between the upper border of the transverse process where it intersects with the superior articular process at L5, respectively, and inject 0.5 mL of local anesthetic.

Various studies have defined different thresholds for a prognostic block to be considered positive which vary from ≥2 points.[122] to ≥75% pain reduction on NRS pain.[58,129] As reductions in chronic pain intensity of at least 50% are indicative of substantial improvements,[130] we recommend at least 50% pain relief following the prognostic blocks for a duration equal or longer than the length of action of the local anesthetic.

Radiofrequency treatment technique of the SI joint

RF treatment of the SI joint is performed with fluoroscopic imaging after a positive diagnostic/prognostic block. The patient may be lightly sedated. The C-arm is positioned in a similar fashion to that for lateral branch blocks, with the same considerations for the nerves targeted. For S1, slight ipsilateral oblique angulation can often increase visualization of the posterior foramen. Larger gauge electrodes are associated with increased capture rates, which is important given the variability in the location of lateral branches. Although sensory electrostimulation at 50 Hz is often performed, because there may be up to four lateral branches converging on the sacral foramina, many physicians forego sensory

stimulation and opt for an extensive lesioning strategy that seeks to encompass the entire lateral margin of the foraminal opening, as injecting local anesthetic before lesioning at one area may prevent stimulation at other areas. This may involve inserting RF cannulas at a caudad-cephalad (longitudinal) angle so that the 10 mm active tip envelops more of the lateral foraminal border. Right S1 rami laterales are usually found between the "2 o'clock and 5:30 o'clock" positions on the lateral side of the posterior neuroforamen, right S2 between 1:30 and 5:30, and right S3 rami laterals between 1:00 and 3:30. For S4, the nerve target is generally high on the foraminal border, for example, between 12:30 and 2:00. In view of the small lesion size created by conventional electrodes, and the widespread variability in the location and number of nerves converging on each foramen, multiple lesions are usually necessary. Before performing the RF treatment, motor stimulation should be performed to ensure the absence of leg or sphincter contraction. If present, the needle position is too close to the spinal nerve root and repositioning is necessary. After correct positioning of the electrode, the RF probe is inserted and a 120 s RF treatment at 80°C is made.[92]

The bipolar RF palisade technique[131]

The palisade technique is performed after a positive diagnostic/prognostic block. In an AP fluoroscopic view, a cranio-caudal line is marked on the skin between the lateral aspect of the sacral foramina and the SI joint line. In a lateral fluoroscopic view, six 20G electrodes with 10 mm active tips are placed parallel to each other perpendicular to the sacrum, approximately 10 mm apart. If different needle sizes and dimensions are used, the distance between the needles may be adjusted accordingly (ie, closer for smaller lesions and active tips). The electrode position is checked in an AP view to confirm placement of the needles lateral to the sacral foramina, but close enough to capture the afferent input (around 10 mm from the lateral edge). Motor stimulation up to 2.0 V can be used to confirm an absent motor response. Thereafter, five bipolar lesions (90°C, 180 s per lesion) are created using adjacent electrode pairings. The needle positioning is illustrated in Figure 4A,B.

Cooled RF of the SI joint[132,133]

Cooled RF treatment of the SI joint is performed after a positive diagnostic/prognostic block. The patient can be lightly sedated. C-arm fluoroscopy is used to visualize the sacrum in a manner similar to that used for lateral branch blocks and conventional RFA. The target nerves are the same as those outlined for conventional RFA, except that the morphology of the lesion (ie, circular instead of elliptical, extending past the distal tip of electrode) dictates a perpendicular approach. The RF electrode, which is subsequently inserted via the same introducer, is 2 mm shorter than the stylet, but extends 2 mm beyond the tip of the cannula which has implications for sensory (if performed) and motor stimulation and allows the lesion, which projects distal to the active tip, to encompass a larger area down to bone. To maximize encasement of the lateral branches of the S1 to S3 (S4) dorsal rami and prevent inadvertent injury to spinal nerves, the electrode is placed 8–10 mm from the lateral edge of the posterior sacral foramina. Thereafter, three lesions are created at S1 and S2, 2 lesions at S3 and if applicable, a single lesion at S4. Typically, these lesions are spaced about 1 cm apart from one another, creating a continuous strip of ablated tissue lateral to each

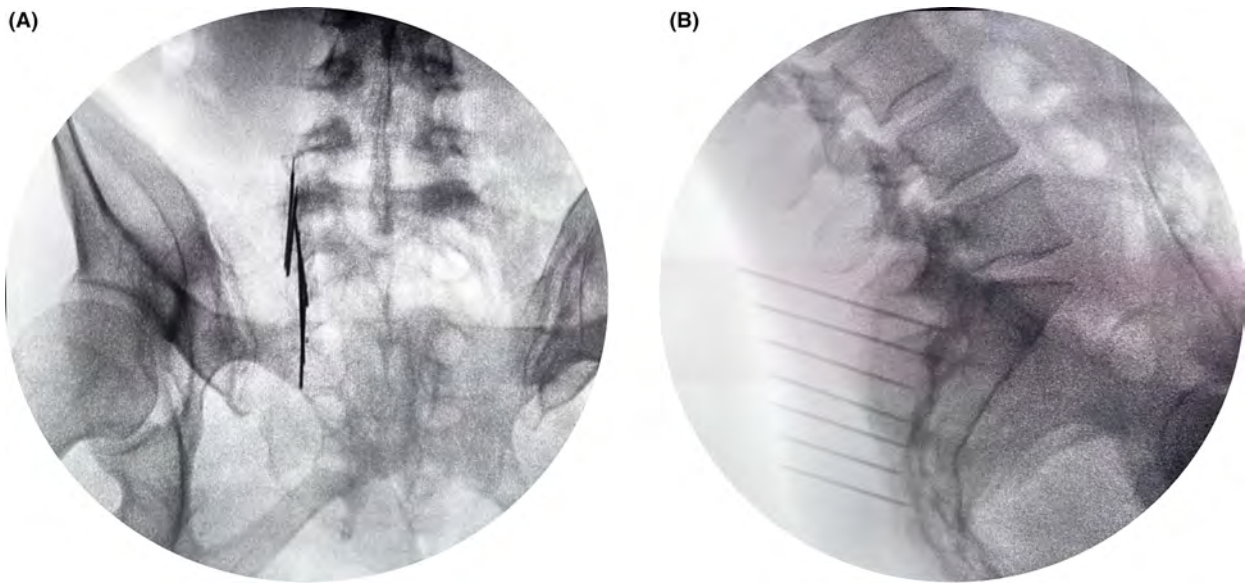

FIGURE 4 (A) AP view of the palisade technique. (B) Lateral view of the palisade technique.

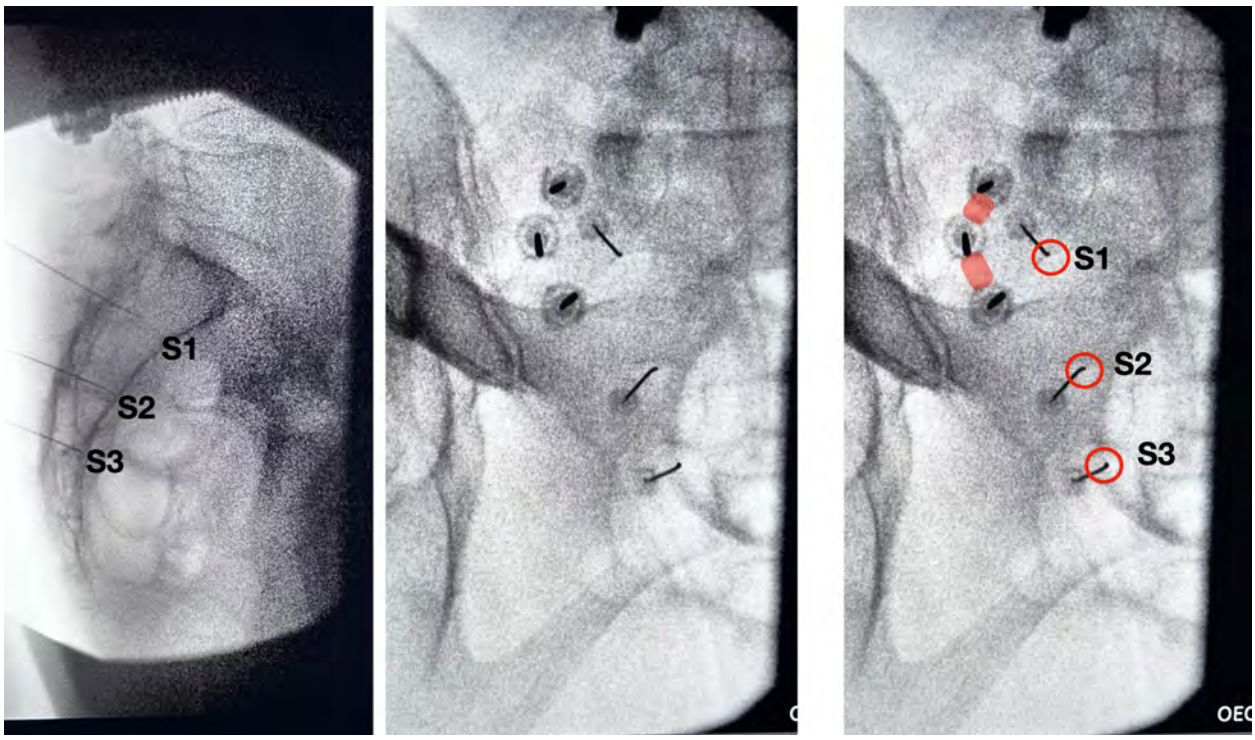

FIGURE 5 (A–C) Cooled RF with finder needles, cooled RF probe, and bipolar cooled RF lesions.

foramen. The dorsal rami of the L5 and L4 spinal nerves may be targeted in a classical manner with traditional electrodes or using cooled RFA.

Figures 5 and 6 illustrate the performance of cooled RF lesions at S1, S2, and S3.

Images from left to right A: Lateral fluoroscopic view demonstrating "finder" needles in the S1, S2, and S3 foramina. B: Antero-posterior fluoroscopic view demonstrating finder (thin) needles in the S1–S3 foramina with cooled RF electrodes positioned at the 10:30, 9:00, and 7:00 positions on the face of a clock around the S1 foramen. C: Depiction of bipolar cooled RF lesions in red at the 9–11 o'clock and 7–9 o'clock positions around S1 left foramen. The thin needles are spinal "finder" needles while RF cannulas are thicker.

Images from left to right A: Depiction of bipolar cooled RF lesions around the S1, S2, and S3 foramina in red (anteroposterior view). B: Lateral view of SI joint bipolar cooled RF. The finder needles at the S1, S2, and S3 foramina appear thin and traverse each foramen, while the thicker needs are RF cannulas. C: Photograph of SI joint bipolar cooled RF of the left sacral lateral branches. Notice the bipolar lesioning forming between the first two needles at the 9–11 o'clock positions around the S1 foramen and the black hub of the finder needles.

Note

According to recent changes in local coverage determination (LCD), the diagnosis of SI joint pain is contingent on clinical evaluation and positive provocative maneuvers, with diagnostic injections recommended for confirmation due to inconsistencies in diagnostic criteria. Many payers require a cutoff of 75% or higher for pain improvement, although there is ongoing debate about the ideal threshold and the IMMPACT guidelines and responder analyses in U.S. Food and Drug Administration and European Medicines Agency studies use thresholds ranging from 30% to 50%.[130] The long-term effectiveness of therapeutic SI joint injections remains unclear, with repetitive corticosteroid injections posing cumulative risks. Guidelines recommend a multidisciplinary approach for long-term management and suggest consideration of controlled injections when used to guide invasive treatment, emphasizing the importance of accurate diagnosis.

The frequency and duration between treatments lack clarity in the literature, with guidelines suggesting injections at a minimum of 2–3 months apart and a maximum of four injections over a 12-month period. Intra-articular injections may not be optimal for selecting candidates for radiofrequency ablation (RFA) with lateral sacral branch blocks suggested as an alternative, though this recommendation lacks validation in studies.

Although there is clear evidence supporting RFA for SI joint pain, the literature faces challenges in meta-analysis and other evidence-based reviews due to small sample sizes, high heterogeneity, and methodological flaws in existing studies. Overall, the evidence for RFA compared to placebo for SIJ pain is deemed to be

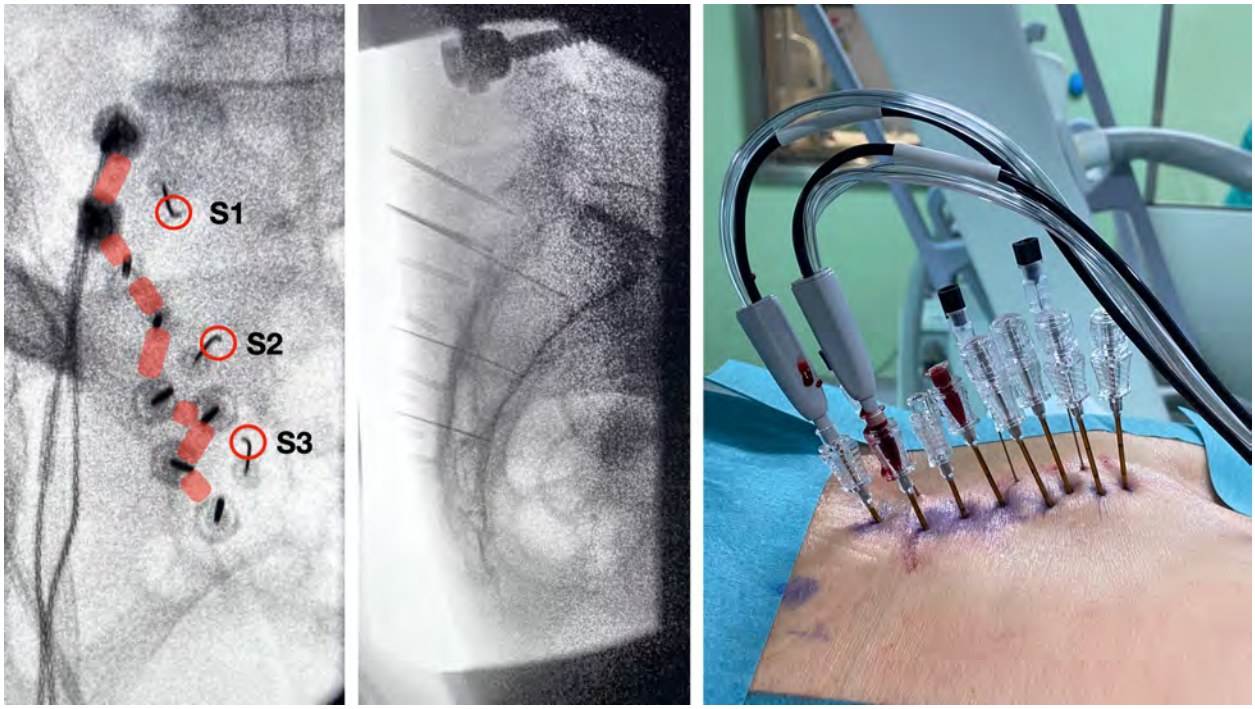

FIGURE 6 (A–C) Bipolar cooled RF around S1, S2, and S3.

low-quality, highlighting the need for further research with improved study designs and larger sample sizes. It is noteworthy that the U.S. Centers for Medicare & Medicaid Services no longer considers SI joint denervation essential as a treatment option despite the advent of unique Current Procedural Technology (CPT) codes for lateral branch blocks and RFA in 2020. These changes are specific to the United States and may not be globally relevant. More information can be found at the following link: https://www.cms.gov/medicare-coverage-database/view/lcd.aspx?lcdId=39383&ver=9.

SUMMARY

The SI joint is responsible for 15%–30% of axial low back complaints predominantly below L5 and can be difficult to distinguish from other forms of low back pain which often co-exist. The results of clinical examination and radiological imaging are of limited diagnostic value. Several studies demonstrate that having at least three positive SI joint pain provocation tests is associated with high sensitivity and specificity (≥ 75%) for diagnostic intra-articular blocks, though some recent studies question this. Furthermore, there is scant evidence on the ability of provocative maneuvers to identify extra-articular pathology, which appears to be similar in prevalence to intra-articular etiologies of SI joint pain. Given the high incidence of false-positive and false-negative results, the outcome of diagnostic blocks should be interpreted with caution. There is evidence for both intra- and peri-articular SI joint injections to provide >1 month of pain relief, with some studies suggesting that combination injections are more effective than either stand-alone procedure. In individuals who fail conservative treatment, L5 dorsal rami and sacral lateral branch RFA can be considered, particularly in individuals with a prominent component of extra-articular joint pain. For refractory patients with degenerative changes and/or instability, minimally invasive SI joint arthrodesis has potential, but further research is warranted.

AUTHOR CONTRIBUTIONS

Karolina Szadek performed the literature search and review and wrote the article. Steven P. Cohen provided additional references and comments and also edited the paper. Javier de Andrès Ares provided additional comments and also edited the paper. Jan Willem Kallewaard provided additional references and comments and also edited the paper. Jan Van Zundert controlled the paper, provided comments, and had full responsibility for the end product. Monique Steegers assisted Karolina Szadek and edited the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

This narrative review is based on the existing literature, therefore data on the used publications are available through PubMed and libraries.

ORCID

Monique Steegers https://orcid.org/0000-0003-0812-5089
Jan Van Zundert https://orcid.org/0000-0002-5389-2036
Jan Willem Kallewaard https://orcid.org/0000-0002-7681-1796

REFERENCES

1. Vanelderen P, Szadek K, Cohen SP, de Witte J, Lataster A, Patijn J, et al. 13. Sacroiliac joint pain. Pain Pract. 2010;10:470–8. https://doi.org/10.1111/j.1533-2500.2010.00394.x
2. Merskey H, Bogduk N. Classification of chronic pain: descriptions of chronic pain syndromes and definitions of pain terms. 2nd ed. Seattle, Washington: IASP Press; 1994.
3. Bernard TN Jr, Kirkaldy-Willis WH. Recognizing specific characteristics of nonspecific low back pain. Clin Orthop Relat Res. 1987;217:266–80.
4. Schwarzer AC, Aprill CN, Bogduk N. The sacroiliac joint in chronic low back pain. Spine. 1995;20:31–7.
5. Maigne JY, Aivaliklis A, Pfefer F. Results of sacroiliac joint double block and value of sacroiliac pain provocation tests in 54 patients with low back pain. Spine. 1996;21:1889–92.
6. Cox M, Ng G, Mashriqi F, Iwanaga J, Alonso F, Tubbs K, et al. Innervation of the anterior sacroiliac joint. World Neurosurg. 2017;107:750–2. https://doi.org/10.1016/j.wneu.2017.08.062
7. Ikeda R. Innervation of the sacroiliac joint. macroscopical and histological studies. Nihon Ika Daigaku Zasshi. 1991;58:587–96. https://doi.org/10.1272/jnms1923.58.587
8. Szadek KM, Hoogland PV, Zuurmond WW, de Lange JJ, Perez RS. Nociceptive nerve fibers in the sacroiliac joint in humans. Reg Anesth Pain Med. 2008;33:36–43. https://doi.org/10.1016/j.rapm.2007.07.011
9. Roberts SL, Burnham RS, Ravichandiran K, Agur AM, Loh EY. Cadaveric study of sacroiliac joint innervation: implications for diagnostic blocks and radiofrequency ablation. Reg Anesth Pain Med. 2014;39:456–64. https://doi.org/10.1097/aap.0000000000000156
10. Steinke H, Saito T, Kuehner J, Reibetanz U, Heyde CE, Itoh M, et al. Sacroiliac innervation. Eur Spine J. 2022;31:2831–43. https://doi.org/10.1007/s00586-022-07353-1
11. Schuit D, McPoil TG, Mulesa P. Incidence of sacroiliac joint malalignment in leg length discrepancies. J Am Podiatr Med Assoc. 1989;79:380–3.
12. Herzog W, Conway PJ. Gait analysis of sacroiliac joint patients. J Manip Physiol Ther. 1994;17:124–7.
13. Schoenberger M, Hellmich K. Sacroiliac dislocation and scoliosis. Hippokrates. 1964;35:476–9.
14. Katz V, Schofferman J, Reynolds J. The sacroiliac joint: a potential cause of pain after lumbar fusion to the sacrum. J Spinal Disord Tech. 2003;16:96–9.
15. Marymont JV, Lynch MA, Henning CE. Exercise-related stress reaction of the sacroiliac joint. an unusual cause of low back pain in athletes. Am J Sports Med. 1986;14:320–3.
16. Albert H, Godskesen M, Westergaard J. Prognosis in four syndromes of pregnancy-related pelvic pain. Acta Obstet Gynecol Scand. 2001;80:505–10.
17. Faflia CP, Prassopoulos PK, Daskalogiannaki ME, Gourtsoyiannis NC. Variation in the appearance of the normal sacroiliac joint on pelvic CT. Clin Radiol. 1998;53:742–6. https://doi.org/10.1016/s0009-9260(98)80316-4
18. Liliang PC, Lu K, Liang CL, Tsai YD, Wang KW, Chen HJ. Sacroiliac joint pain after lumbar and lumbosacral fusion: findings using dual sacroiliac joint blocks. Pain Med. 2011;12:565–70. https://doi.org/10.1111/j.1526-4637.2011.01087.x
19. Maigne JY, Planchon CA. Sacroiliac joint pain after lumbar fusion. A study with anesthetic blocks. Eur Spine J. 2005;14:654–8.
20. Ha KY, Lee JS, Kim KW. Degeneration of sacroiliac joint after instrumented lumbar or lumbosacral fusion: a prospective cohort study over five-year follow-up. Spine (Phila Pa 1976). 2008;33:1192–8. https://doi.org/10.1097/BRS.0b013e318170fd35
21. Huygen F, Kallewaard JW, van Tulder M, van Boxem K, Vissers K, van Kleef M, et al. "Evidence-based interventional pain medicine according to clinical diagnoses": update 2018. Pain Pract. 2019;19:664–75. https://doi.org/10.1111/papr.12786
22. Huygen F, Kallewaard JW, van Tulder M, Van Boxem K, Vissers K, van Kleef M, et al. Evidence based interventional pain practice: according to clinical diagnoses. 2018. [cited 2019 November 16]. Available from: https://richtlijnendatabase.nl/gerelateerde_documenten/f/20783/Evidence%20based%20interventional%20pain%20practice.pdf
23. Slipman CW, Jackson HB, Lipetz JS, Chan KT, Lenrow D, Vresilovic EJ. Sacroiliac joint pain referral zones. Arch Phys Med Rehabil. 2000;81:334–8.
24. Kurosawa D, Murakami E, Aizawa T. Referred pain location depends on the affected section of the sacroiliac joint. Eur Spine J. 2015;24:521–7. https://doi.org/10.1007/s00586-014-3604-4
25. van der Wurff P, Buijs EJ, Groen GJ. Intensity mapping of pain referral areas in sacroiliac joint pain patients. J Manip Physiol Ther. 2006;29:190–5.
26. Jung JH, Kim HI, Shin DA, Shin DG, Lee JO, Kim HJ, et al. Usefulness of pain distribution pattern assessment in decision-making for the patients with lumbar zygapophyseal and sacroiliac joint arthropathy. J Korean Med Sci. 2007;22:1048–54.
27. Fortin JD, Aprill CN, Ponthieux B, Pier J. Sacroiliac joint: pain referral maps upon applying a new injection/arthrography technique. part II: clinical evaluation. Spine (Phila Pa 1976). 1994;19:1483–9.
28. Murakami E, Kurosawa D, Aizawa T. Treatment strategy for sacroiliac joint-related pain at or around the posterior superior iliac spine. Clin Neurol Neurosurg. 2018;165:43–6. https://doi.org/10.1016/j.clineuro.2017.12.017
29. Young S, Aprill C, Laslett M. Correlation of clinical examination characteristics with three sources of chronic low back pain. Spine J. 2003;3:460–5.
30. Dreyfuss P, Michaelsen M, Pauza K, McLarty J, Bogduk N. The value of medical history and physical examination in diagnosing sacroiliac joint pain. Spine (Phila Pa 1976). 1996;21:2594–602. https://doi.org/10.1097/00007632-199611150-00009
31. Szadek KM, van der Wurff P, van Tulder MW, Zuurmond WW, Perez RS. Diagnostic validity of criteria for sacroiliac joint pain: a systematic review. J Pain. 2009;10:354–68.
32. van der Wurff P, Buijs EJ, Groen GJ. A multitest regimen of pain provocation tests as an aid to reduce unnecessary minimally invasive sacroiliac joint procedures. Arch Phys Med Rehabil. 2006;87:10–4.
33. Laslett M, Aprill CN, McDonald B, Young SB. Diagnosis of sacroiliac joint pain: validity of individual provocation tests and composites of tests. Man Ther. 2005;10:207–18.
34. Schneider BJ, Ehsanian R, Rosati R, Huynh L, Levin J, Kennedy DJ. Validity of physical exam maneuvers in the diagnosis of sacroiliac joint pathology. Pain Med. 2020;21:255–60. https://doi.org/10.1093/pm/pnz183
35. Mekhail N, Saweris Y, Sue Mehanny D, Makarova N, Guirguis M, Costandi S. Diagnosis of sacroiliac joint pain: predictive value of three diagnostic clinical tests. Pain Pract. 2021;21:204–14. https://doi.org/10.1111/papr.12950
36. Cohen SP, Doshi TL, Kurihara C, Reece D, Dolomisiewicz E, Phillips CR, et al. Multicenter study evaluating factors associated with treatment outcome for low back pain injections. Reg Anesth Pain Med. 2022;47:89–99. https://doi.org/10.1136/rapm-2021-103247

37. Fortin JD, Falco FJ. The Fortin finger test: an indicator of sacroiliac pain. Am J Orthop (Belle Mead NJ). 1997;26:477–80.
38. Kokmeyer DJ, van der Wurff P, Aufdemkampe G, Fickenscher TC. The reliability of multitest regimens with sacroiliac pain provocation tests. J Manip Physiol Ther. 2002;25:42–8.
39. Meijne W, van Neerbos K, Aufdemkampe G, van der Wurff P. Intraexaminer and interexaminer reliability of the Gillet test. J Manip Physiol Ther. 1999;22:4–9. https://doi.org/10.1016/s0161-4754(99)70098-9
40. McGavin JC. Scientific application of sports medicine principles for acute low back problems. J Orthop Sports Phys Ther. 1997;26:105–8.
41. Eno JJ, Boone CR, Bellino MJ, Bishop JA. The prevalence of sacroiliac joint degeneration in asymptomatic adults. J Bone Joint Surg Am. 2015;97:932–6. https://doi.org/10.2106/jbjs.N.01101
42. Williamson L, Dockerty JL, Dalbeth N, McNally E, Ostlere S, Wordsworth BP. Clinical assessment of sacroiliitis and HLA-B27 are poor predictors of sacroiliitis diagnosed by magnetic resonance imaging in psoriatic arthritis. Rheumatology (Oxford). 2004;43:85–8. https://doi.org/10.1093/rheumatology/keg475
43. Barnsley L, Paiva J, Barnsley L. Frequency of pertinent MRI abnormalities of the sacroiliac joints of patients without spondyloarthropathies: a systematic review of the literature. Skelet Radiol. 2021;50:1741–8. https://doi.org/10.1007/s00256-021-03719-6
44. Rudwaleit M, Jurik AG, Hermann KG, Landewé R, van der Heijde D, Baraliakos X, et al. Defining active sacroiliitis on magnetic resonance imaging (MRI) for classification of axial spondyloarthritis: a consensual approach by the ASAS/OMERACT MRI group. Ann Rheum Dis. 2009;68:1520–7. https://doi.org/10.1136/ard.2009.110767
45. Østergaard M. MRI of the sacroiliac joints: what is and what is not sacroiliitis? Curr Opin Rheumatol. 2020;32:357–64. https://doi.org/10.1097/bor.0000000000000718
46. Campos-Correia D, Sudoł-Szopińska I, Diana Afonso P. Are we overcalling Sacroillitis on MRI? Differential diagnosis that every rheumatologist should know—part II. Acta Reumatol Port. 2019;44:42–56.
47. Fortin JD, Kissling RO, O'Connor BL, Vilensky JA. Sacroiliac joint innervation and pain. Am J Orthop. 1999;28:687–90.
48. Laslett M, Young SB, Aprill CN, McDonald B. Diagnosing painful sacroiliac joints: A validity study of a McKenzie evaluation and sacroiliac provocation tests. Aust J Physiother. 2003;49:89–97.
49. Maigne JY, Boulahdour H, Chatellier G. Value of quantitative radionuclide bone scanning in the diagnosis of sacroiliac joint syndrome in 32 patients with low back pain. Eur Spine J. 1998;7:328–31.
50. Manchikanti L, Singh V, Pampati V, Damron KS, Barnhill RC, Beyer C, et al. Evaluation of the relative contributions of various structures in chronic low back pain. Pain Physician. 2001;4:308–16.
51. Lord SM, Barnsley L, Bogduk N. The utility of comparative local anesthetic blocks versus placebo-controlled blocks for the diagnosis of cervical zygapophysial joint pain. Clin J Pain. 1995;11:208–13.
52. Schneider B, Joshi M, Ehsanian R, McCormick ZL, Patel J, Zheng P, et al. Patient-perceived duration of effect of lidocaine and bupivacaine following diagnostic medial branch blocks; a multicenter study. Interventional Pain Med. 2022;1:100083.
53. Slipman CW, Sterenfeld EB, Chou LH, Herzog R, Vresilovic E. The value of radionuclide imaging in the diagnosis of sacroiliac joint syndrome. Spine (Phila Pa 1976). 1996;21:2251–4. https://doi.org/10.1097/00007632-199610010-00013
54. Fukui S, Nosaka S. Pain patterns originating from the sacroiliac joints. J Anesth. 2002;16:245–7. https://doi.org/10.1007/s005400200033
55. Broadhurst NA, Bond MJ. Pain provocation tests for the assessment of sacroiliac joint dysfunction. J Spinal Disord. 1998;11:341–5.
56. Cohen SP, Bicket MC, Kurihara C, Griffith SR, Fowler IM, Jacobs MB, et al. Fluoroscopically guided vs landmark-guided sacroiliac joint injections: A randomized controlled study. Mayo Clin Proc. 2019;94:628–42. https://doi.org/10.1016/j.mayocp.2018.08.038
57. Yin W, Willard F, Carreiro J, Dreyfuss P. Sensory stimulation-guided sacroiliac joint radiofrequency neurotomy: technique based on neuroanatomy of the dorsal sacral plexus. Spine (Phila Pa 1976). 2003;28:2419–25. https://doi.org/10.1097/01.Brs.0000085360.03758.C3
58. Patel N, Gross A, Brown L, Gekht G. A randomized, placebo-controlled study to assess the efficacy of lateral branch neurotomy for chronic sacroiliac joint pain. Pain Med. 2012;13:383–98. https://doi.org/10.1111/j.1526-4637.2012.01328.x
59. Berthelot JM, Labat JJ, Le Goff B, Gouin F, Maugars Y. Provocative sacroiliac joint maneuvers and sacroiliac joint block are unreliable for diagnosing sacroiliac joint pain. Joint Bone Spine. 2006;73:17–23. https://doi.org/10.1016/j.jbspin.2004.08.003
60. Fortin JD, Washington WJ, Falco FJ. Three pathways between the sacroiliac joint and neural structures. AJNR Am J Neuroradiol. 1999;20:1429–34.
61. Hansen HC. Is fluoroscopy necessary for sacroiliac joint injections? Pain Physician. 2003;6:155–8.
62. Rosenberg JM, Quint TJ, de Rosayro AM. Computerized tomographic localization of clinically-guided sacroiliac joint injections. Clin J Pain. 2000;16:18–21. https://doi.org/10.1097/00002508-200003000-00004
63. Bollow M, Braun J, Taupitz M, Häberle J, Reihauer BH, Paris S, et al. CT-guided intraarticular corticosteroid injection into the sacroiliac joints in patients with spondyloarthropathy: indication and follow-up with contrast-enhanced MRI. J Comput Assist Tomogr. 1996;20:512–21.
64. van den Berg R, de Hooge M, Rudwaleit M, Sieper J, van Gaalen F, Reijnierse M, et al. ASAS modification of the Berlin algorithm for diagnosing axial spondyloarthritis: results from the SPondyloArthritis caught early (SPACE)-cohort and from the assessment of SpondyloArthritis international society (ASAS)-cohort. Ann Rheum Dis. 2013;72:1646–53. https://doi.org/10.1136/annrheumdis-2012-201884
65. Van den Heuvel SAS, Cohen SPC, de Andrès AJ, Van Boxem K, Kallewaard JW, Van Zundert J. 3. Pain originating from the lumbar facet joints. Pain Pract. 2023. https://doi.org/10.1111/papr.13287. Online ahead of print.
66. Peene L, Cohen SP, Kallewaard JW, Wolff A, Huygen F, Gaag A, et al. 1. Lumbosacral radicular pain. Pain Pract. 2023. https://doi.org/10.1111/papr.13317. Online ahead of print.
67. Lesher JM, Dreyfuss P, Hager N, Kaplan M, Furman M. Hip joint pain referral patterns: a descriptive study. Pain Med. 2008;9:22–5. https://doi.org/10.1111/j.1526-4637.2006.00153.x
68. Arnold DR, Keene JS, Blankenbaker DG, Desmet AA. Hip pain referral patterns in patients with labral tears: analysis based on intra-articular anesthetic injections, hip arthroscopy, and a new pain "circle" diagram. Phys Sportsmed. 2011;39:29–35. https://doi.org/10.3810/psm.2011.02.1859
69. Benson WF, Ivins JC, Soule EH, Faber JE. Endometrioma as the cause of pubic and sacroiliac pain. JAMA. 1965;193:234–5. https://doi.org/10.1001/jama.1965.03090030056022
70. Simons DG, Travell JG. Myofascial origins of low back pain. 3. Pelvic and lower extremity muscles. Postgrad Med. 1983;73:99–105, 108. https://doi.org/10.1080/00325481.1983.11697758
71. Plaut S. Scoping review and interpretation of myofascial pain/fibromyalgia syndrome: an attempt to assemble a medical puzzle. PLoS One. 2022;17:e0263087. https://doi.org/10.1371/journal.pone.0263087
72. Probst D, Stout A, Hunt D. Piriformis syndrome: A narrative review of the anatomy, diagnosis, and treatment. PM R. 2019;11(Suppl 1):S54–63. https://doi.org/10.1002/pmrj.12189
73. Karri J, Singh M, Orhurhu V, Joshi M, Abd-Elsayed A. Pain syndromes secondary to Cluneal nerve entrapment. Curr Pain

Headache Rep. 2020;24:61. https://doi.org/10.1007/s11916-020-00891-7
74. Flynn T, Fritz J, Whitman J, Wainner R, Magel J, Rendeiro D, et al. A clinical prediction rule for classifying patients with low back pain who demonstrate short-term improvement with spinal manipulation. Spine (Phila Pa 1976). 2002;27:2835–43. https://doi.org/10.1097/00007632-200212150-00021
75. Cho BY, Yoon JG. The effect of gait training with shoe inserts on the improvement of pain and gait in sacroiliac joint patients. J Phys Ther Sci. 2015;27:2469–71. https://doi.org/10.1589/jpts.27.2469
76. Cohen SP. Sacroiliac joint pain: a comprehensive review of anatomy, diagnosis, and treatment. Anesth Analg. 2005;101:1440–53.
77. Chen AS, Solberg J, Smith C, Chi M, Lowder R, Christolias G, et al. Intra-articular platelet rich plasma vs corticosteroid injections for sacroiliac joint pain: A double-blinded, randomized clinical trial. Pain Med. 2022;23:1266–71. https://doi.org/10.1093/pm/pnab332
78. Maugars Y, Mathis C, Berthelot JM, Charlier C, Prost A. Assessment of the efficacy of sacroiliac corticosteroid injections in spondylarthropathies: a double-blind study. Br J Rheumatol. 1996;35:767–70.
79. Visser LH, Woudenberg NP, de Bont J, van Eijs F, Verwer K, Jenniskens H, et al. Treatment of the sacroiliac joint in patients with leg pain: a randomized-controlled trial. Eur Spine J. 2013;22:2310–7. https://doi.org/10.1007/s00586-013-2833-2
80. Luukkainen RK, Wennerstrand PV, Kautiainen HH, Sanila MT, Asikainen EL. Efficacy of periarticular corticosteroid treatment of the sacroiliac joint in non-spondylarthropathic patients with chronic low back pain in the region of the sacroiliac joint. Clin Exp Rheumatol. 2002;20:52–4.
81. Luukkainen R, Nissila M, Asikainen E, Sanila M, Lehtinen K, Alanaatu A, et al. Periarticular corticosteroid treatment of the sacroiliac joint in patients with seronegative spondylarthropathy. Clin Exp Rheumatol. 1999;17:88–90.
82. Borowsky CD, Fagen G. Sources of sacroiliac region pain: insights gained from a study comparing standard intra-articular injection with a technique combining intra- and peri-articular injection. Arch Phys Med Rehabil. 2008;89:2048–56. https://doi.org/10.1016/j.apmr.2008.06.006
83. Murakami E, Tanaka Y, Aizawa T, Ishizuka M, Kokubun S. Effect of periarticular and intraarticular lidocaine injections for sacroiliac joint pain: prospective comparative study. J Orthop Sci. 2007;12:274–80. https://doi.org/10.1007/s00776-007-1126-1
84. Khalil I, Horn P, Kanaan A, Ababneh A, Hammo B, Shawahna A, et al. Efficacy of peri-articular versus intra-articular sacroiliac joint blocks under fluoroscopic guidance: a multi-center study. Chronic Pain Manag. 2022;6:141.
85. Hartung W, Ross CJ, Straub R, Feuerbach S, Scholmerich J, Fleck M, et al. Ultrasound-guided sacroiliac joint injection in patients with established sacroiliitis: precise IA injection verified by MRI scanning does not predict clinical outcome. Rheumatology (Oxford). 2010;49:1479–82. https://doi.org/10.1093/rheumatology/kep424
86. Nacey NC, Patrie JT, Fox MG. Fluoroscopically guided sacroiliac joint injections: comparison of the effects of intraarticular and periarticular injections on immediate and short-term pain relief. AJR Am J Roentgenol. 2016;207:1055–61. https://doi.org/10.2214/ajr.15.15779
87. Tantawy MF, Nazim WM. Comparison between intraarticular and combined intra and periarticular sacroiliac injection: a prospective randomized controlled clinical trial. J Neurosurg Sci. 2022. https://doi.org/10.23736/s0390-5616.22.05581-3. Online ahead of print.
88. Burnham RS, Yasui Y. An alternate method of radiofrequency neurotomy of the sacroiliac joint: a pilot study of the effect on pain, function, and satisfaction. Reg Anesth Pain Med. 2007;32:12–9. https://doi.org/10.1016/j.rapm.2006.08.008
89. Gevargez A, Groenemeyer D, Schirp S, Braun M. CT-guided percutaneous radiofrequency denervation of the sacroiliac joint. Eur Radiol. 2002;12:1360–5.
90. Bellini M, Barbieri M. Single strip lesions radiofrequency denervation for treatment of sacroiliac joint pain: two years' results. Anaesthesiol Intensive Ther. 2016;48:19–22. https://doi.org/10.5603/ait.2016.0004
91. Ferrante FM, King LF, Roche EA, Kim PS, Aranda M, Delaney LR, et al. Radiofrequency sacroiliac joint denervation for sacroiliac syndrome. Reg Anesth Pain Med. 2001;26:137–42.
92. Cohen SP, Abdi S. Lateral branch blocks as a treatment for sacroiliac joint pain: A pilot study. Reg Anesth Pain Med. 2003;28:113–9.
93. Bayerl SH, Finger T, Heiden P, Esfahani-Bayerl N, Topar C, Prinz V, et al. Radiofrequency denervation for treatment of sacroiliac joint pain-comparison of two different ablation techniques. Neurosurg Rev. 2020;43:101–7. https://doi.org/10.1007/s10143-018-1016-3
94. Juch JNS, Maas ET, Ostelo R, Groeneweg JG, Kallewaard JW, Koes BW, et al. Effect of radiofrequency denervation on pain intensity among patients with chronic low Back pain: the mint randomized clinical trials. JAMA. 2017;318:68–81. https://doi.org/10.1001/jama.2017.7918
95. Cohen SP, Hurley RW, Buckenmaier CC 3rd, Kurihara C, Morlando B, Dragovich A. Randomized placebo-controlled study evaluating lateral branch radiofrequency denervation for sacroiliac joint pain. Anesthesiology. 2008;109:279–88.
96. Salman OH, Gad GS, Mohamed AA, Rafae HH, Abdelfatah AM. Randomized, controlled blind study comparing sacroiliac intra-articular steroid injection to radiofrequency denervation for sacroiliac joint pain. Egypt J Anaesth. 2016;32:219–25.
97. Zheng Y, Gu M, Shi D, Li M, Ye L, Wang X. Tomography-guided palisade sacroiliac joint radiofrequency neurotomy versus celecoxib for ankylosing spondylitis: a open-label, randomized, and controlled trial. Rheumatol Int. 2014;34:1195–202. https://doi.org/10.1007/s00296-014-2959-5
98. AboElfadl GM, Ali WN, Askar FJE, Osman AM, Daghash NH, AbdelRady MM. Intra-articular pulsed radiofrequency with methyl prednisolone injection in chronic sacroiliac joint arthritis: A randomized clinical trial. Egypt J Anaesth. 2022;38:85–93.
99. Mehta V, Poply K, Husband M, Anwar S, Langford R. The effects of radiofrequency neurotomy using a strip-lesioning device on patients with sacroiliac joint pain: results from a single-center, randomized, sham-controlled trial. Pain Physician. 2018;21:607–18.
100. Cohen SP, Kapural L, Kohan L, Li S, Hurley RW, Vallejo R, et al. Cooled radiofrequency ablation versus standard medical management for chronic sacroiliac joint pain: a multicenter, randomized comparative effectiveness study. Reg Anesth Pain Med. 2023;rapm-2023-104568. https://doi.org/10.1136/rapm-2023-104568. Online ahead of print.
101. Cohen SP, Strassels SA, Kurihara C, Crooks MT, Erdek MA, Forsythe A, et al. Outcome predictors for sacroiliac joint (lateral branch) radiofrequency denervation. Reg Anesth Pain Med. 2009;34:206–14.
102. Vallejo R, Benyamin RM, Kramer J, Stanton G, Joseph NJ. Pulsed radiofrequency denervation for the treatment of sacroiliac joint syndrome. Pain Med. 2006;7:429–34.
103. Dutta K, Dey S, Bhattacharyya P, Agarwal S, Dev P. Comparison of efficacy of lateral branch pulsed radiofrequency denervation and intraarticular depot methylprednisolone injection for sacroiliac joint pain. Pain Physician. 2018;21:489–96.
104. Huang JH, Galvagno SM Jr, Hameed M, Wilkinson I, Erdek MA, Patel A, et al. Occipital nerve pulsed radiofrequency treatment: a multi-center study evaluating predictors of outcome. Pain Med. 2012;13:489–97. https://doi.org/10.1111/j.1526-4637.2012.01348.x
105. Tekin I, Mirzai H, Ok G, Erbuyun K, Vatansever D. A comparison of conventional and pulsed radiofrequency denervation in the treatment of chronic facet joint pain. Clin J Pain. 2007;23:524–9.

106. Kroll HR, Kim D, Danic MJ, Sankey SS, Gariwala M, Brown M. A randomized, double-blind, prospective study comparing the efficacy of continuous versus pulsed radiofrequency in the treatment of lumbar facet syndrome. J Clin Anesth. 2008;20:534–7.
107. Waisbrod H, Krainick JU, Gerbershagen HU. Sacroiliac joint arthrodesis for chronic lower back pain. Arch Orthop Trauma Surg (1978). 1987;106:238–40. https://doi.org/10.1007/bf00450461
108. Buchowski JM, Kebaish KM, Sinkov V, Cohen DB, Sieber AN, Kostuik JP. Functional and radiographic outcome of sacroiliac arthrodesis for the disorders of the sacroiliac joint. Spine J. 2005;5:520–8; discussion 529. https://doi.org/10.1016/j.spinee.2005.02.022
109. Schütz U, Grob D. Poor outcome following bilateral sacroiliac joint fusion for degenerative sacroiliac joint syndrome. Acta Orthop Belg. 2006;72:296–308.
110. Smith-Petersen MN, Rogers WA. End-result study of arthrodesis of sacroiliac joint for arthritis–traumatic and nontraumatic. J Bone Joint Surg Am. 1926;8:118–36.
111. Campbell W. Operative measures in the treatment of affections of the lumbosacral and sacroiliac articulation. Surg Gynecol Obstet. 1930;51:381–6.
112. Dabezies EJ, Millet CW, Murphy CP, Acker JH, Robicheaux RE, D'Ambrosia RD. Stabilization of sacroiliac joint disruption with threaded compression rods. Clin Orthop Relat Res. 1989;246:165–71.
113. Chang E, Rains C, Ali R, Wines RC, Kahwati LC. Minimally invasive sacroiliac joint fusion for chronic sacroiliac joint pain: a systematic review. Spine J. 2022;22:1240–53. https://doi.org/10.1016/j.spinee.2022.01.005
114. Whang P, Cher D, Polly D, Frank C, Lockstadt H, Glaser J, et al. Sacroiliac joint fusion using triangular titanium implants vs. non-surgical management: six-month outcomes from a prospective randomized controlled trial. Int J Spine Surg. 2015;9:6.
115. Abbas A, Du JT, Toor J, Versteeg A, Finkelstein JA. The efficacy of primary sacroiliac joint fusion for low back pain caused by sacroiliac joint pathology: a systematic review and meta-analysis. Eur Spine J. 2022;31:2461–72. https://doi.org/10.1007/s00586-022-07291-y
116. Manchikanti L, Boswell MV, Singh V, Benyamin RM, Fellows B, Abdi S, et al. Comprehensive evidence-based guidelines for interventional techniques in the management of chronic spinal pain. Pain Physician. 2009;12:699–802.
117. Cohen SP, Bhaskar A, Bhatia A, Buvanendran A, Deer T, Garg S, et al. Consensus practice guidelines on interventions for lumbar facet joint pain from a multispecialty, international working group. Reg Anesth Pain Med. 2020;45:424–67. https://doi.org/10.1136/rapm-2019-101243
118. Hurley RW, Adams MCB, Barad M, Bhaskar A, Bhatia A, Chadwick A, et al. Consensus practice guidelines on interventions for cervical spine (facet) joint pain from a multispecialty international working group. Reg Anesth Pain Med. 2022;47:3–59. https://doi.org/10.1136/rapm-2021-103031
119. Karaman H, Kavak GO, Tüfek A, Çelik F, Yildirim ZB, Akdemir MS, et al. Cooled radiofrequency application for treatment of sacroiliac joint pain. Acta Neurochir. 2011;153:1461–8. https://doi.org/10.1007/s00701-011-1003-8
120. Shamrock AG, Patel A, Alam M, Shamrock KH, Al MM. The safety profile of percutaneous minimally invasive sacroiliac joint fusion. Global Spine J. 2019;9:874–80. https://doi.org/10.1177/2192568218816981
121. Schoell K, Buser Z, Jakoi A, Pham M, Patel NN, Hsieh PC, et al. Postoperative complications in patients undergoing minimally invasive sacroiliac fusion. Spine J. 2016;16:1324–32. https://doi.org/10.1016/j.spinee.2016.06.016
122. van Tilburg CW, Schuurmans FA, Stronks DL, Groeneweg JG, Huygen FJ. Randomized sham-controlled double-blind multicenter clinical trial to ascertain the effect of percutaneous radiofrequency treatment for sacroiliac joint pain: three-month results. Clin J Pain. 2016;32:921–6. https://doi.org/10.1097/ajp.0000000000000351
123. Chappell ME, Lakshman R, Trotter P, Abrahams M, Lee M. Radiofrequency denervation for chronic back pain: a systematic review and meta-analysis. BMJ Open. 2020;10:e035540. https://doi.org/10.1136/bmjopen-2019-035540
124. Kennedy DJ, Engel A, Kreiner DS, Nampiaparampil D, Duszynski B, MacVicar J. Fluoroscopically guided diagnostic and therapeutic intra-articular sacroiliac joint injections: A systematic review. Pain Med. 2015;16:1500–18. https://doi.org/10.1111/pme.12833
125. Gartenberg A, Nessim A, Cho W. Sacroiliac joint dysfunction: pathophysiology, diagnosis, and treatment. Eur Spine J. 2021;30:2936–43. https://doi.org/10.1007/s00586-021-06927-9
126. Boody B, Caballero J, Macadaeg C, Funk R, Macadaeg K. Intra-articular sacroiliac joint injection: technical guide. Clin Spine Surg. 2021;34:14–6. https://doi.org/10.1097/bsd.0000000000001010
127. Zhu W, Zhao Q, Ma R, Liu Z, Zhao J, Liu Z, et al. Anatomical study of the innervation of different parts of the posterior ligamentous region of the sacroiliac joint. Reg Anesth Pain Med. 2021;46:410–5. https://doi.org/10.1136/rapm-2020-102366
128. Poilliot AJ, Zwirner J, Doyle T, Hammer N. A systematic review of the Normal sacroiliac joint anatomy and adjacent tissues for pain physicians. Pain Physician. 2019;22:E247–74.
129. Patel N. Twelve-month follow-up of a randomized trial assessing cooled radiofrequency denervation as a treatment for sacroiliac region pain. Pain Pract. 2016;16:154–67. https://doi.org/10.1111/papr.12269
130. Dworkin RH, Turk DC, Wyrwich KW, Beaton D, Cleeland CS, Farrar JT, et al. Interpreting the clinical importance of treatment outcomes in chronic pain clinical trials: IMMPACT recommendations. J Pain. 2008;9:105–21.
131. Cosman ER Jr, Gonzalez CD. Bipolar radiofrequency lesion geometry: implications for palisade treatment of sacroiliac joint pain. Pain Pract. 2011;11:3–22. https://doi.org/10.1111/j.1533-2500.2010.00400.x
132. Kapural L, Nageeb F, Kapural M, Cata JP, Narouze S, Mekhail N. Cooled radiofrequency system for the treatment of chronic pain from sacroiliitis: the first case-series. Pain Pract. 2008;8:348–54.
133. Stelzer W, Aiglesberger M, Stelzer D, Stelzer V. Use of cooled radiofrequency lateral branch neurotomy for the treatment of sacroiliac joint-mediated low back pain: a large case series. Pain Med. 2013;14:29–35. https://doi.org/10.1111/pme.12014

How to cite this article: Szadek K, Cohen SP, de Andrès Ares J, Steegers M, Van Zundert J, Kallewaard JW. 5. Sacroiliac joint pain. Pain Pract. 2024;24:627–646. https://doi.org/10.1111/papr.13338