The Role of Radiofrequency Ablation for Sacroiliac Joint Pain: A Meta-Analysis

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Radiofrequency ablation (RFA) has become an option for those with chronic or refractory sacroiliac (SI) joint pain. The purpose of this critical review is to assess the existing literature and conduct a meta-analysis to assess the effectiveness of RFA of the SI joint for pain relief at 3 and 6 months' after an RFA procedure. An electronic search of PubMed, OVID, Medline, and CINAHL were conducted with keywords; sacroiliac joint, sacroiliac pain, sacroiliac syndrome, sacroiliac radiofrequency ablation, sacroiliac neurolysis, sacroiliac injection, and low back pain. Articles that addressed RFA of the SI joint were reviewed. Ten articles ranging from inception to January 1, 2010, were found. The main outcome measure was a reduction of pain by ≥50% post-RFA procedure. At 3 months, 7 groups met the criteria and at 6 months, 6 groups met the criteria. A meta-analysis with a forest plot was done at the 3- and 6-month patient follow-up intervals. The associated standard error was calculated for each study group. An overall weighted average with respective standard error was also obtained. A calculation of 95% confidence intervals (95% CI) was then derived. A test for heterogeneity, publication bias, and file drawer effect was also done at the 3- and 6-month intervals. At 3 months, a range of 0.538-0.693 was found to have a 95% CI, with a pooled mean of 0.616. At 6 months, a 95% CI of 0.423-0.576 was found, with a pooled mean of 0.499. The meta-analysis demonstrated that RFA is an effective treatment for SI joint pain at 3 months and 6 months. This study is limited by the available literature and lack of randomized controlled trials. Further standardization of RFA lesion techniques needs to be established, coupled with prospective randomized controlled trials.

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INTRODUCTION

Sacroiliac (SI) joint pain was first described by Goldthwaite and Osgood in 1905 as an independent pain generator [1]. SI joint syndrome is described as mechanical pain generated at the SI joint with or without appreciable lesions on imaging [2]. It is regarded as a challenging disorder to correctly diagnose and patients often present with the common complaint of low back and buttock pain. The pain generated from the SI joint can be the result of joint sprain injury, fracture, diastasis, pyogenic or crystal arthropathy, and spondyloarthropathy [1,3].

It has been believed that the most frequent causes of pain attributable to the SI joint are traumatic events such as motor vehicle collisions, falls onto the buttocks, and repetitive motion. In patients without a history of trauma, it is more common in athletes and pregnant women [4,5]. Diagnosis can often be difficult and misleading based on physical examination, and some studies have postulated that a diagnostic injection of local anesthetic into the joint may be the only way to accurately diagnose this problem [6]. The innervation patterns for sensory perception of pain from the SI joint are not well-defined except that innervation is multisegmental from different nerve root sources (Figure 1) [4,7]. In contrast, lumbar facet joint innervation patterns have been well-defined as involving dual-level medial branches of the dorsal rami and radiofrequency ablation (RFA) for facet-mediated pain is more widely used [8].

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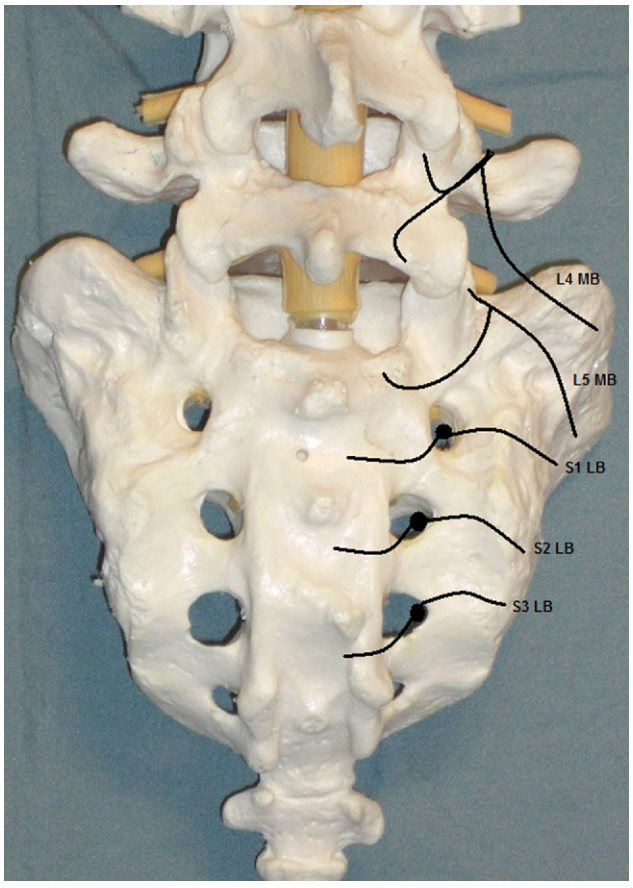

Figure 1. Proposed innervation to the sacroiliac joint. The innervation is believed to have segmental supply from the medial branches (MB) from L4 and L5 dorsal rami, as well as lateral branches (LB) from the dorsal rami of S1, S2, and S3. Note that cadaveric studies have shown variability of the nerve's course (17,26).

RFA is becoming a more popular and accepted treatment for SI joint pain. It has been proposed as a way to provide longer lasting relief from a painful SI joint. RFA offers the ability to denervate the sensory fibers of the nerves transmitting pain from the SI joint region [1,9-13] and is a treatment that is generally employed after more conservative measures have failed [12]. The effectiveness of RFA for SI joint pain remains unclear [14] in part perhaps because of what is believed to be a complex innervation pattern, as mentioned earlier [15]. The purpose of this article is to review the literature regarding efficacy of RFA for SI joint pain and to determine statistically via meta-analysis if it is an effective treatment for SI pain.

Anatomy and Innervation

The SI joint is formed by the articulation of the lateral aspects of the sacrum with the medial surface of the ilium [16] and is the largest axial joint in the human body, consisting of an auricular shaped diarthrodial synovial joint [12]. Only a limited portion of the sacral surfaces make contact with the ilium, whereas multiple ligaments and a matrix of muscles provide connections and support for this articulation [12,16].

To date, the sensory innervation of the SI joint has not been defined as definitively as that of the lumbar facet joints [8]. The majority of the posterior sensory innervation is believed to be transmitted from the S1, S2, and S3 dorsal rami via the lateral branches, as well as medial branches from the L4 and L5 dorsal rami (Figure 1) [17]. This innervation consists of both large- and small-diameter fibers. The small demyelinated fibers function to provide thermal and nociceptive information to the central nervous system [5]. The larger diameter fibers function to provide proprioceptive and mechanical information to the central nervous system [5,12,18]. The anterior portion of the SI joint is believed to derive sensory innervation from the lumbosacral plexus [5]. Some have speculated that contributions from the superior gluteal nerves and obturator nerve also occur [12,16]. There are also published studies that claim that certain areas of the SI joint are devoid of innervation altogether [12].

Diagnostic Blocks

Because of inconsistent information obtained from history, physical examination, and imaging-guided intra-articular SI joint corticosteroid injection, the diagnostic local anesthetic injection has become a common procedure to help with the diagnosis of SI joint pain [6,19]. The injection should be image-guided to allow for validation of entry into the joint [12]. SI joint anesthetic injections are widely accepted as a diagnostic tool to identify the SI joint as a primary source of pain [7,9,10,13].

Diagnostic SI injections are performed under fluoroscopic guidance [8]. Computed tomography (CT) can also be used to identify the SI joint and guide an injection [20,21]. Ultrasound guidance has been used in cases in which there is a concern about radiation exposure. In a case series done by Pekkafali et al, intra-articular injection was accomplished 76% of the time with ultrasound. When studied more closely, the successful intra-articular injection rate was 60% in the first 30 injections and improved to 93.5% in the last 30 injections, which may represent a learning effect [16,22,23]. There is also literature that notes that SI joint injection can be done without imaging, by using proper positioning and landmarks; however, this technique has only shown 22% successful intra-articular injection [24,25].

An alternative to anesthetizing the joint with an intra-articular block has more recently been postulated [17]. Anesthetizing the neural branches that transmit pain sensation to the central nervous system by applying aliquots of local anesthetic over the anatomical sites where the afferent fibers

Table 1. *Each study was paired with the specific intervention done to the SI joint after diagnostic criteria were met*

Author	Lesion Location	Radiofrequency	Needle
Buijs et al (11)	S1, S2, S3 dorsal sacral foramina	80°C for 60 seconds/site, continuous RFA	22-gauge, 10 cm, 5-mm tip
Yin et al (26)	L5 posterior sensory branch; S1, S2, S3 dorsal sacral foramina	80°C for 60 seconds/site, continuous RFA	20-gauge, 10 cm, curved tip
Gevargez et al (21)	Posterior interosseous sacroiliac ligament, L5 and S1 dorsal branches	90°C for 90 seconds/site, continuous RFA	23-gauge, 10 cm or 15 cm, 5-mm tip
Cohen et al (32)	L4-L5 dorsal rami, lateral foramina of S1-S3	80°C for 90 seconds/site L4-L5, continuous RFA 60°C for 90 seconds/site S1-S3, cooled RFA	22-gauge, 10 cm, 5-mm tip; 17-gauge, 75 cm, 4-mm cooled tip
Cohen et al, crossover group (32)	L4-L5 dorsal rami, lateral to S1-S3	80°C for 90 seconds/site, continuous RFA	22-gauge, 10 cm, 5-mm tip
Ferrante et al (1)	Strip lesion along the SI joint line	90°C for 90 seconds/site, bipolar continuous RFA	N/A
Kapural et al (33)	Sacral lateral branches, L5 dorsal rami	60°C for 150 seconds/site, cooled RFA	27-gauge, 3.5 inches
Cohen and Abdi (13)	L4-L5 dorsal rami, S1-S3 lateral branches	80°C for 90 seconds/site, continuous RFA	22-gauge, 10 cm, 5-mm tip
Burnham and Yasui (15)	S1-S3 dorsal sacral foramina	80°C for 90 seconds/site, bipolar continuous RFA	22-gauge, 10 cm, 5-mm tip
Cohen et al, June 2009 (34)	L4-L5 dorsal rami, lateral foramina of S1-S3	80°C for 90 seconds/site L4-L5, continuous RFA; 60°C for 90-150 seconds/site S1-S3, cooled RFA	22-gauge, 10 cm, 5-mm tip; 17-gauge or 22-gauge, 75 cm, 4-mm cooled tip

SI = sacroiliac; RFA = radiofrequency ablation.

reside proximally is a technique employed to diagnose lumbar facet joint pain via medial branch blocks [8]. Similarly, blocking the lateral branches of the dorsal rami at the S1-S3, as well as the medial branches of the L4-L5 dorsal rami have been reported to be of diagnostic value for SI joint pain, without actually injecting into the SI joint (Figure 1) [13,16]. This technique has shown to be helpful in determining posterior SI joint pain and pain mediating from the posterior ligaments stabilizing the SI joint [17]. However, Yin et al have shown inconsistent lateral branch anatomy from the sacral dorsi rami, suggesting a lack of precision in diagnosing SI joint–mediated pain [26].

RFA Mechanism

RFA has come into use over the past few decades as an interventional treatment for pain. RFA was first developed in the 1920s, when it was used for cutting and coagulation of tissue. In 1975, RFA was first described in the literature for the treatment of back pain [27].

RFA is done with the following elements: a radiofrequency generator, cannulas with active tips, and a thermocoupler that serves to sense body temperature and transmit radiofrequency energy. A grounding pad is used if a unipolar lesion is performed; 2 cannulas are used without a grounding pad for bipolar lesions. The body serves as a resistor between the active tip and the grounding pad for unipolar lesions. When the current enters the body from the active tip, it generates an electromagnetic field and produces a spherical lesion around the active tip. The current then travels through the body and eventually reaches the grounding pad to disperse out of the body [27,28].

At the active tip, the formation of a static electric field results in heat generation. A frequency range of 0.5-1 MHz is used. The tissue directly in contact with the needle tip acts as the reservoir for the current being generated. Those tissues that are better insulated (ie, bone) can maintain the higher temperatures and have less of a heat washout [29]. Washout occurs in tissues with poor insulation or high blood circulation; the moisture or blood flow allows the heat to be carried away from the area the probe is in contact with. The heat reaches a temperature of about 60°C–80°C, and is subsequently conducted to the surrounding tissues [27,29,30]. Smith et al demonstrated that axonal injury of myelinated and unmyelinated fibers occurs at 45°C [29,30]. The heat, produced from the electrical fields, causes ionic agitation and friction, which then results in protein denaturing, cellular membrane disruptions, increased membrane permeability, and finally tissue necrosis or lysis [31]. This is applied over a period of 90 to 150 seconds [27,32,33].

There are 3 main types of RFA; low-intensity RFA, cooled RFA, and pulsed RFA. Low-intensity RFA is administered constantly for 60-90 seconds at a specific temperature. Cooled RFA involves the use of a cannula needle that has saline running through it to cool the tip. Pulsed RFA is done with signal interruption every half second, creating temperatures of 42°C [4].

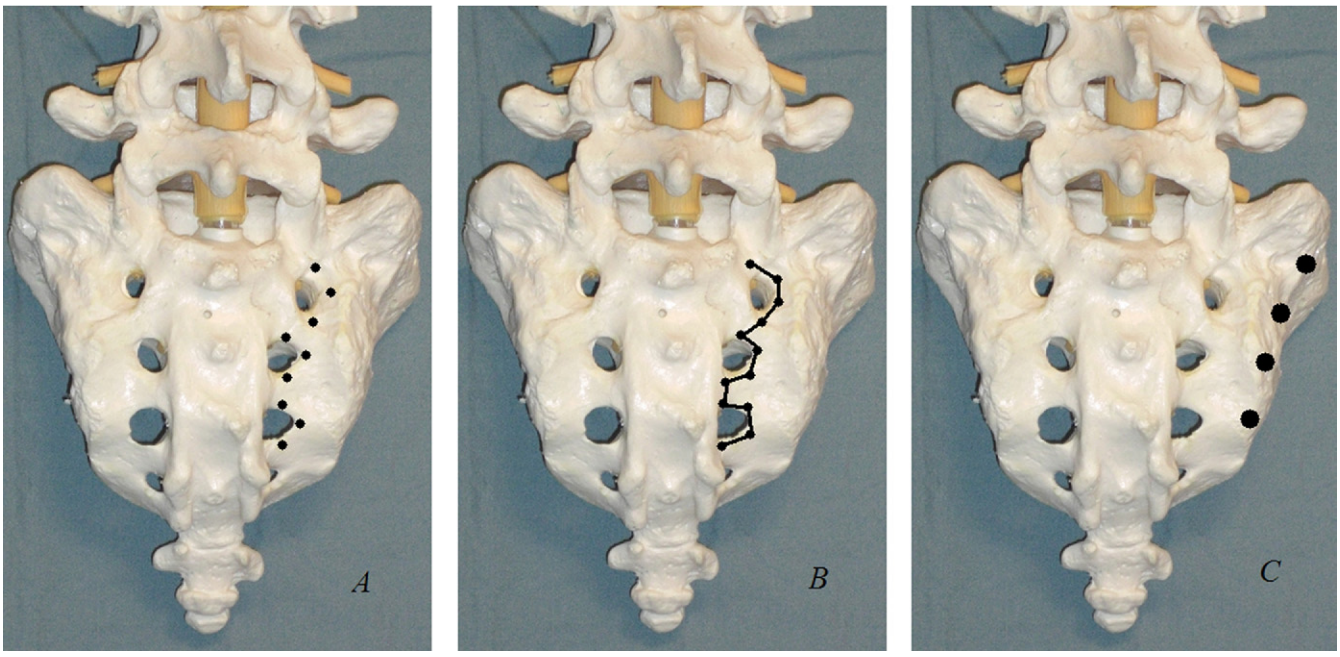

Figure 2. The 3 main types of lesion techniques described in the literature. **(A)** Three-puncture technique: 3 separate probes are placed at the periphery of the sacral foramen at each level (11,13). **(B)** Strip-lesion technique: a bipolar radiofrequency ablation technique. The lesion is done in a continuous pattern from the first lesion site to the inferior border of the S3 foramen (15). **(C)** Leap-frog technique: a bipolar radiofrequency ablation technique which is done along the actual sacroiliac joint. The 2 probes are placed alongside one another; after the first lesion is completed, the lead probe is moved to the other side of the second probe and the next lesion is completed. The second probe now the lead probe and leaps over the other probe to the next position. This is repeated until completion (1).

In the studies reviewed for this meta-analysis, different techniques, as well as combinations of different nerve lesions have been described. No standards have been established for the specific nerves to ablate, type of technique, or type of RFA (Table 1) [1,4,11,13,15,21,26,32-34].

The 3 main types of techniques described in the literature include the 3-puncture, the strip-lesion, and the leapfrog techniques (Figure 2). Buijs et al and Cohen et al describe the use of the 3-puncture technique, in which 3 RFA probes are placed near the dorsal sacral foramina to target the S1-S3 lateral branches [11,13]. Burnham et al described the strip-lesion technique, which focuses on the continuous lesion pattern from the L4-L5 dorsal rami region to the S1-S3 dorsal lateral foraminal apertures [15]. Ferrante et al described the leapfrog technique, which involves using multiple probes (up to 3) close together to allow for the production of a more

Table 2. *Shows the different studies matched with the lesion locations and RFA technique used*

Author	Intervention
Buijs et al (11)	"3-puncture" technique directed at the lateral upper quadrant of S1-S3 dorsal foramina, targeted to dorsal rami of L4-L5, and S1-S3 nerves
Burnham and Yasui (15)	"Leap frogging" and "strip lesion" technique done to the L5 posterior ramus and dorsal lateral foraminal aperture of S1-S3
Cohen and Abdi (13)	RFA to L4-L5 dorsal rami, and S1-S3 lateral branches
Cohen et al (32)	RFA to L4-L5 dorsal rami, and cooled RFA to the S1-S3 lateral branches. The crossover group received RFA to the L4-L5 dorsal rami, lateral to S1-S3.
Cohen et al, June 2009 (34)	RFA to L4-L5 dorsal rami, and cooled RFA to the S1-S3 lateral branches
Ferrante et al (1)	"Leapfrog" technique done to the superior aspect of the joint with multiple lesions around the posterior joint
Gevargez et al (21)	Regional RFA to the posterior interosseous sacroiliac ligaments and dorsal branches of L5 spinal nerves
Kapural et al (33)	Cooled RFA to lateral edge of the S1, S2, and S3 posterior sacral foramina
Yin et al (26)	RFA directed at the lateral branches of the S1-S3 lateral spinal nerves

RFA = radiofrequency ablation.

Table 3. *Author and the study type.*

Author	Study Type Conducted
Buijs et al (11)	Prospective observational study
Burnham and Yasui (15)	Prospective observational study
Cohen and Abdi (13)	Retrospective study
Cohen et al (32)	Randomized placebo-controlled trial study
Cohen et al, June 2009 (34)	Retrospective study
Ferrante et al (1)	Retrospective study
Gevargez et al (21)	Prospective observational study
Vallejo et al (4)	Prospective observational study*
Kapural et al (33)	Retrospective study
Yin et al (26)	Retrospective study

*Study was excluded due to use of pulsed radiofrequency ablation.

consistent and larger thermal lesion [1]. These techniques have been applied alone, or in combination, to different regions of the SI joint and neuroanatomy (Table 2) [1,4,11,13,15,21,26,32-34].

Methodology

An electronic search of PubMed, OVID, Medline, and CINAHL was conducted. Articles that addressed RFA for SI joint pain were examined. Keywords included sacroiliac joint, sacroiliac pain, sacroiliac syndrome, sacroiliac radiofrequency ablation, sacroiliac joint neurolysis, sacroiliac joint injection, and low back pain. Ten articles were found from inception to January 1, 2010. Each article was examined and data were collected by 1 reviewer [1,4,11,13,15,21,26,32-34].

Of the 10 studies found, 5 were retrospective, 4 were prospective observational studies, and 1 was a randomized placebo control study. The randomized, placebo-controlled study did have a crossover group, which was considered a separate group when the data were collected for the meta-analysis (Table 3) [1,4,11,13,15,21,26,32-34]. Nine of the studies used conventional RFA, whereas 1 study used pulsed radiofrequency technique; this study by Vallejo et al was excluded [4].

Each of the 9 studies was assessed for patient results after RFA of the SI joint at 3-, 6-, 9-, and 12-month follow-ups. The data extracted were placed into an Excel (Microsoft Inc, Redmond, WA) spreadsheet and examined. Specific attention was paid to the number of patients versus the number of procedures done in each study, as well as the follow-up intervals in each study. Each study used several outcome measures to determine a positive result from the procedure (Table 4). The main outcome measure used in the meta-analysis, which was preset and common in each study, was an improvement of ≥50% in pain post-RFA treatment.

The greatest number of patients was followed at 3 months and 6 months after RFA. These were the 2 points at which the meta-analysis was conducted. Statistical analysis at 3 months was done on 7 groups from 6 studies. At 6 months, the meta-analysis was done on 6 groups obtained from 5 studies.

Statistical Analysis

Nine articles were found and reviewed; each study used a ≥50% in pain reduction as a positive outcome post-RFA as a positive result. The studies consisted of retrospective chart analysis, prospective observational studies, and a randomized placebo controlled study [1,4,11,13,15,21,26,32-34]. The data were tabulated and analyzed from each study (Table 5).

Given the limited data supplied by each study, the effective size for the meta-analysis was represented by the associated proportions. The associated proportions were calculated for each study group that met the established criteria. This was done by obtaining the number of patients that received the RFA treatment in each study. The proportion was then calculated by dividing the number of patients that had reported pain relief of ≥50% on the pain scale used in the study, by the total number of patients who received the RFA procedure. The associated standard error was then calculated. The results were then used to calculate the weighted

Table 4. *Each study is matched with the pain scale and outcome measured used for that specific study*

Author	Pain Scale
Buijs et al (11)	Subjective percent of relief; favorable result was >50% pain reduction
Burnham and Yasui (15)	>50% reduction in numeric rating scale pre- vs postprocedure was a favorable result
Cohen and Abdi (13)	Visual analog scale, >50% reduction in pain was a favorable result
Cohen et al (32)	Numeric rating scale (0 = least; 10 = most), ≥50% reduction of pain score for both the interventional and crossover groups was a favorable result
Cohen et al, June 2009 (34)	Numeric rating scale (0 = least; 10 = most), ≥50% reduction of pain score for both the groups that were present in the study were considered a favorable result
Ferrante et al (1)	Visual analog scale; ≥50% reduction of pain scale was a favorable result
Gevargez et al (21)	Number scale choice; 1 = no pain, 2 = substantial pain reduction, 3 = slight pain reduction, 4 = no pain reduction; favorable outcomes were responders with 1 or 2
Kapural et al (33)	Visual analog scale, >50% reduction was favorable
Yin et al (26)	VIPS at 3 months; ≥50% reduction in VIPS, at 6 months a ≥50% reduction in VIPS, and ≥60% reduction in subjective pain perception was favorable

VIPS = visual integer pain scale.

Table 5. *Outcomes of the Nine RFA studies*

Author	Outcome
Buijs et al (11)	63.2% of the patients had a greater than 50% reduction in their pain at 12 weeks post-RFA
Burnham and Yasui (15)	67% of the patients indicated a "very satisfied" response postprocedure at 12 weeks post-RFA
Cohen and Abdi (13)	100% of patients had a greater than 40% improvement in pain at 9 months post-RFA.
Cohen et al (32)	RFA group showed a reduction of pain of 60% at 1 month, 60% at 3 months, and 57% at 6 months. Crossover group showed pain reduction of 28% at 1 month, 59% at 3 months, and 49% at 6 months
Cohen et al, June 2009 (34)	1.9% of patients in group 1 showed a greater than 50% reduction in pain at 6 months
Ferrante et al (1)	34.6% of patients had a 50% decrease of pain at 6 months post-RFA
Gevargez et al (21)	65.8% of patients had "a substantial relief" in pain at 3 months post-RFA
Kapural et al (33)	13 patients had ≥50% relief at 3 months post-cooled RFA
Yin et al (26)	64% of patients had a reduction in pain of 50% at 6 months post-RFA

RFA = radiofrequency ablation.

averages. The meta-analysis and forest plot were computed with statistical software, STATA version 10 (StataCorp, College Station, TX). This was performed at the 3-month and 6-month study intervals. Calculations for heterogeneity and the 95% confidence interval were also performed.

Calculations for publication bias were done at the 3-month and 6-month data collections. Given the limited number of published studies available in the literature, this was done to help determine if only those studies with positive outcomes made it to publication. This was done using STATA version 10, and a funnel plot was generated for the 3- and 6-month follow-ups, with Egger's and Begg's *P* values.

To further assess publication type bias, a file drawer effect (also known as fail-safe N) calculation was done. The file drawer effect (K_0 = number of negative publications needed to negate current published studies) was determined at the 3-month and 6-month intervals, with the equation: $K_0 > -k + (\sum zi)2/(Z_x/2)^2$.

The number of patients in each study was evaluated. Specific attention was given to the outcome of ≥50% pain reduction of each patient in the studies post-RFA procedure. The follow-up periods that had the greatest number of patients were the 3-month and 6-month intervals.

Buijs et al showed 24 of 38 patients with pain improvement of ≥50% at 3 months [11]. In Yin et al, no narrative description was given regarding the improvement at the 3-month period; however, a graph was presented with pain score changes plotted for each patient denoting 9 of 24 patients with improvement of ≥50% at both the 3-month and 6-month intervals [26]. Gevargez et al noted 25 of 38 patients who met criteria of ≥50% reduction in pain at only the 3-month follow-up interval [21].

Cohen et al conducted a randomized placebo control study. The placebo group was offered RFA treatment 1 month after sham treatment. At 3 months, the placebo group was found to have no improvement in their pain and was offered treatment, and was designated the crossover group in the study. The treatment group and crossover group were considered separate study groups in the meta-analysis for both the 3-month and 6-month follow-up intervals. In the treatment group, 9 of 14 patients showed improvement of pain ≥50% at 3 months; at 6 months, 8 of 14 showed an improvement of pain ≥50%. The crossover group showed 6 of 11 patients at 3 months, and 4 of 11 patients at 6 months, with a reduction of pain ≥50% [32].

Table 6. *Each study group matched with the number of patients found to have a positive result after RFA at the 3-, 6-, 9-, and 12-month follow-up intervals*

Author	Patients at 3 Months' Follow-up with ≥50% Relief	Patients at 6 Months' Follow-up with ≥50% Relief	Patients at 9 Months' Follow-up with ≥50% Relief	Patients at 1 Year Follow-up with ≥50% Relief
Buijs et al (11)	24	NA	No data available	No data available
Yin et al (26)	9	9	No data available	No data available
Gevargez et al (21)	25	No data available	No data available	No data available
Cohen et al (32)	9	0	No data available	No data available
Cohen et al, crossover group (32)	6	4	No data available	No data available
Ferrante et al (1)	No data available	12	No data available	No data available
Kapural et al (33)	13	No data available	No data available	No data available
Cohen and Abdi (13)	No data available	No data available	8	No data available
Burnham and Yasui (15)	6	6	8	6
Cohen et al, June 2009 (34)	No data available	40	No data available	No data available

Table 7. *Proportion of patients with positive results 3 months after RFA*

Author	Total Number of Patients	Patients at 3 Months' Follow-up with ≥50% Relief	Calculated Proportion
Buijs et al (11)	38	24	0.6316
Yin et al (26)	14	9	0.6429
Gevargez et al (21)	38	25	0.6579
Cohen et al (32)	14	9	0.6429
Cohen et al, crossover group (32)	11	6	0.5454
Ferrante et al (1)	33	No data available	N/A
Kapural et al (33)	26	13	0.5000
Cohen and Abdi (13)	9	No data available	N/A
Burnham and Yasui (15)	9	6	0.6667
Cohen et al, June 2009 (34)	77	No data available	N/A

The calculated proportion is also indicated.

Ferrante et al noted 12 of 33 patients with a reduction of pain ≥50% at the 6-month interval; no data were available at the 3-month interval [1]. Kapural et al showed 13 of 26 patients to have a ≥50% reduction in pain at the 3-month follow-up interval; no data were found for the 6-month interval [33].

Cohen and Abdi did not indicate results at 3- or 6-month follow-ups, but did have a 9-month follow-up [13]. Burnham and Yasui did follow-up evaluations at 3-, 6-, 9-, and 12-month intervals. At the 3- and 6-month interval, they noted 6 of 9 patients with a reduction of pain ≥50% [15]. In June 2009, Cohen et al conducted a 2-site retrospective study, which evaluated patients at 6 months. Forty of 77 patients were noted to have a pain reduction of ≥50% at the 6-month interval [34]. Tables 6, 7, and 8 show each study matched with the respective data collected.

RESULTS

The meta-analysis and forest plots were completed. The meta-analysis at 3 months showed a 95% confidence interval of 0.538-0.693 and a pooled estimated average of 0.616. Analysis was conducted on 7 groups from 6 studies. The degree of heterogeneity was calculated and found to have a *P* value of .906, showing similarity between the study groups (Figure 3).

The meta-analysis at 6 months was also conducted, which revealed a pooled estimated average of 0.499, and a 95% confidence interval of 0.423-0.576. This was done for 6 groups from 5 studies. The degree of heterogeneity was calculated, and found to have a *P* value of .277, which shows higher evidence of heterogeneity between the different study groups (Figure 4).

The meta-analysis was done with the literature reported in this review; to represent effective size, the associated proportion was used. One of the major limitations with meta-analyses is the quality of the studies available in the literature to compute and calculate averages; those of best statistical value are randomized controlled trial studies. However, given the lack of more than 1 randomized controlled trial in the literature, the use of retrospective and prospective observational studies were included, with established criteria common to each study available to determine a standardized positive outcome.

At both the 3- and 6-month follow-ups, it was determined that half or greater of the patients that received an RFA procedure to the SI joint showed a reduction in their pain by ≥50%. These results are based on studies that used a continuous RFA technique to the SI joint region. The studies compared did have similar pre-RFA treatments, with SI joint

Table 8. *Proportion of patients with positive results 6 months after RFA*

Author	Total Number of Patients	Patients at 6 Months Follow-up with ≥50% Relief	Calculated Proportion
Buijs et al (11)	38	No data available	N/A
Yin et al (26)	14	9	0.6429
Gevargez et al (21)	38	No data available	N/A
Cohen et al (32)	14	8	0.5714
Cohen et al, crossover group (32)	11	4	0.3636
Ferrante et al (1)	33	12	0.3636
Kapural et al (33)	26	No data available	N/A
Cohen and Abdi (13)	9	No data available	N/A
Burnham and Yasui (15)	9	6	0.6667
Cohen et al, June 2009 (34)	77	40	0.5195

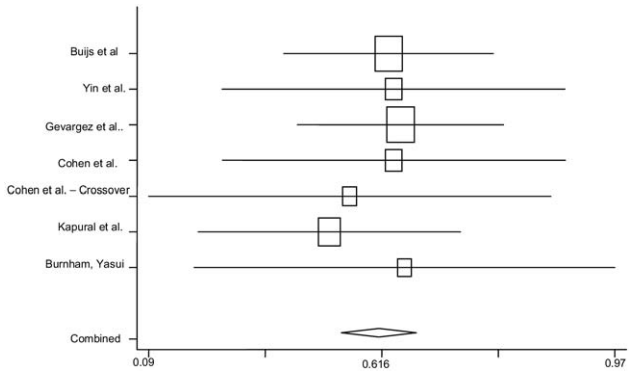

Figure 3. Forest plot of the 3-month meta-analysis. Seven groups from 6 studies were evaluated. Pooled mean was calculated to 0.616, with a 95% CI of 0.538-0.693.

region injections with local anesthetic, to determine if RFA was indicated for the patient. Variation was also noted among the radiofrequency technique, location, and duration of lesion (Table 1).

Calculations for heterogeneity were also conducted in STATA version 10 to help determine if the studies available were similar to each other for this analysis. At the 3-month interval, the *P* value was found to be closer to 1, which showed little evidence of heterogeneity. At the 6-month follow-up, however, the *P* value was closer to 0, and showed more heterogeneity among the studies.

The funnel plots for the 3-month and 6-month follow up groups were calculated. The 3-month funnel plot *P* value for Egger's test was .770; the *P* value for Begg's test was .649 (Figure 5). The funnel plot at 6 months showed a *P* value for Egger's test of .669; the *P* value for Begg's test was .707 (Figure 6). The 3-month and 6-month *P* values for Begg's and Egger's were similar to one another and represent little publication bias. The 3- and 6-month funnel plots, determined

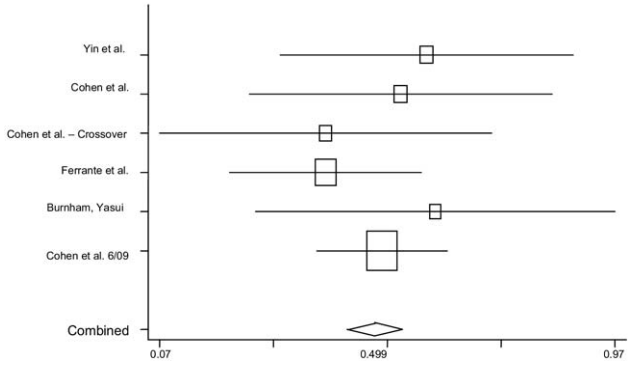

Figure 4. Forest plot of the 6-month meta-analysis. Six groups from 5 studies were evaluated. The pooled mean was found to be 0.499, with a 95% CI of 0.423-0.576.

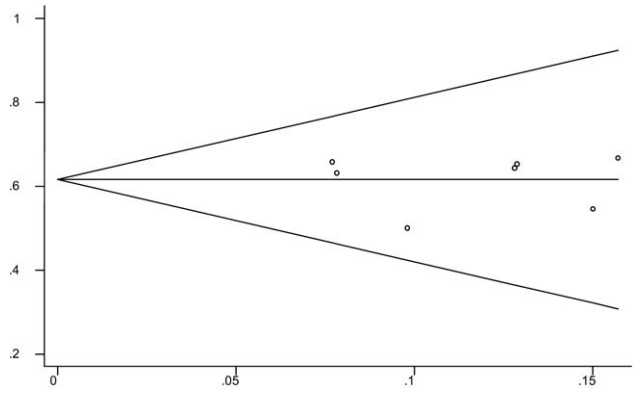

Figure 5. Funnel plot to assess for publication bias at the 3-month meta-analysis. The x axis represents the standard error, and the y axis represents the associated proportion. The Begg's *P* value was .649, and the Egger's *P* value was .77.

by a limited number of studies, show a scattered distribution which appears symmetric.

To further assess for publication bias, the file drawer affect (or fail-safe N) was calculated for both the 3-month and 6-month follow-up groups. This was done to determine the number of negative studies needed to be done and published to contradict the current published literature. The 3-month file drawer calculation for K_0 was greater than 401.9 negative studies. At 6 months, the file drawer calculation for K_0 was greater than 228.5 negative studies.

DISCUSSION

Each study involved patients with a history of low back pain. Physical examination coupled with diagnostic injection was used to confirm SI joint syndrome. The major limitation seen when looking at all the studies is the inconsistency between

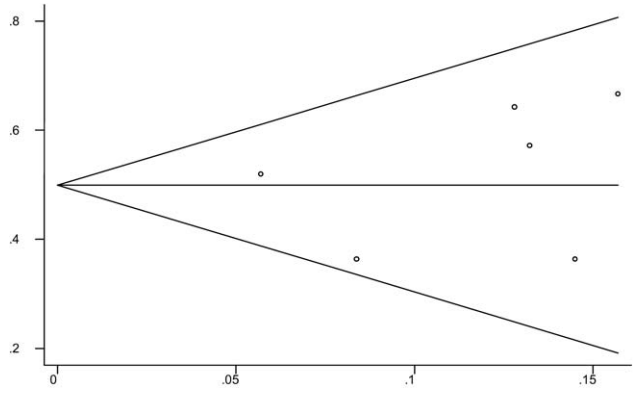

Figure 6. Funnel plot to assess for publication bias at the 6-month meta-analysis. The x axis represents the standard error, and the y axis represents the associated proportion. The Begg's *P* value was .707, and the Egger's *P* value was .669.

Table 9. *Breakdown of individual studies with the diagnostic criteria for patients to advance to RFA procedure of the SI joint*

Author	Injection Location	Injectate	Positive Outcome Needed to Progress to RFA
Buijs et al (11)	Intra-articular SI joint injection with fluoroscopic use	Only local anesthetic, specific type not indicated	>50% reduction of pain
Burnham and Yasui (15)	Intra-articular SI joint, with L5 medial branch block, and lateral branch blocks of S1-S3 with fluoroscopic use	N/A	>50% reduction in pain
Cohen and Abdi (13)	Intra-articular SI joint, with L4 and L5 dorsal rami block, and lateral branch blocks of S1-S3 with fluoroscopic use	SI joint intra-articular injection not available. Nerve blocks were done with 0.3 mL of 0.5% ropivacaine or 0.5% bupivacaine; second series was done with 2% lidocaine	>80% reduction in pain immediately; >50% reduction after second series
Cohen et al (32)	Intra-articular SI joint injection with fluoroscopic use	2 mL of 0.5% bupivacaine and 40 mg of depomethylprednisolone	>75% reduction in pain
Cohen et al, June 2009 (34)	Intra-articular SI joint injection with fluoroscopic use	2 mL of 0.5% bupivacaine and 40-60 mg of depomethyl-prednisolone	>50% reduction in pain
Ferrante et al (1)	Intra-articular SI joint injection with fluoroscopic use	2 mL of 0.25% bupivacaine and 12 mg of betamethasone	Subjective patient not of immediate pain relief after injection
Gevargez et al (21)	Intra-articular SI joint injection with CT scan	2 mL of 0.5% bupivacaine and 40 mg methylprednisolone	Subjective temporary relief of concordant symptoms
Kapural et al (33)	Intra-articular SI joint injection with fluoroscopic use	3 mL of bupivacaine 0.5% with 40 mg of triamcinolone	>50% reduction in pain
Yin et al (26)	2 separate deep interosseous ligament injections of the SI joint with fluoroscopic use	5 mL solution of bupivacaine 0.5% with triamcinolone 4 mg/mL	>70% reduction of concordant pain on 2 separate occasions

RFA = radiofrequency ablation; SI = sacroiliac; CT = computed tomography.

the RFA techniques and the anatomical sites targeted. This may be related to the lack of certainty over the neuroanatomy in the SI joint and the difficulty of determining the innervation of the SI joint pain [5,17,26].

Patients in each study were treated with a diagnostic and therapeutic injection to the SI joint region done under fluoroscopic or CT guidance. However, diagnostic injection done to evaluate for SI joint pain relief was also variable among the studies. There was variation with the type of anesthetic, the percentage of relief that was considered a positive result, and whether or not steroid was used (Table 9). Yin et al used a 70% reduction in pain as a positive outcome and determination for RFA. Ferrante et al determined that immediate relief after injection would determine progression to RFA. Gevargez et al used an intra-articular injection with a temporary subjective relief noted by the patient. Cohen and Abdi noted a progression to RFA with 80% reduction of pain with intra-articular injection. Cohen et al in 2008 used a 75% reduction in pain after injection. Cohen et al in 2009 used the greater than 50% reduction in pain after injection. Burnham et al, Kapural et al, and Buijs et al also noted a greater than 50% reduction in pain after injection. All cases were done with either fluoroscopic visualization or CT guidance with iodinated contrast confirmation [1,11,13,15,21,26,32-34]. More recently, there is support in the literature that local anesthetics to the lateral branches of the sacrum can be used alone, without intra-articular injection, to determine good response with RFA to the SI joint [17].

Each study used a specific pain scale to assess the improvement of pain after a diagnostic injection and post-RFA procedure. Some studies used functional scores, whereas others used a combination of visual analog scale, numerical rating scale, or percentage of pain relief. All studies used a 0-10 numerical rating scale that could quantify a percentage of improvement, and the marker of ≥50% improvement of the pain was considered a positive outcome after the RFA treatment [1,11,13,15,21,26,32-34].

The techniques for RFA, the pain assessment, follow-up intervals, and sites for RFA in the SI joint varied from study to study. One cannot conclude any sort of standardization of technique from this review. No technique was found to be more beneficial than another.

The majority of the studies concluded that RFA for SI joint–mediated pain is a treatment in those patients who have had transient improvements of their pain with more conservative measures. Each study did indicate further need for more randomized placebo-controlled studies to assess the usefulness and successfulness of RFA of the SI joint. There was 1 randomized-controlled study found in the literature, which noted no improvement in pain for the placebo-controlled group at the 1-month follow-up, and allowed for a crossover group.

CONCLUSION

RFA of the SI joint does appear to have a place in treating those patients with SI joint pain refractory to more conservative measures. The findings from the meta-analysis at 3 months suggest effective control of pain with ≥50% relief. A total of 60.1% of the patients at 3 months did show an improvement of pain by ≥50%. At the 6-month evaluation, 49.9% of the patients showed >50% reduction. The diminished outcomes at 6 months may be related to the natural course of nerve regeneration and regrowth.

This study is limited by the available literature and lack of more than 1 published randomized control trial. Statistical measures were taken to evaluate for heterogeneity, publication bias, and file drawer effect. Significant variability existed between each study done; however, similar outcome measures were used to assess post-RFA procedure pain relief, as well as similar selection criteria for patients with SI joint pain before receiving RFA to the SI joint.

The success of RFA for SI joint pain is dependent on further investigative work on 2 fronts. The value of accurate anatomical delineation of the joint innervation cannot be underestimated because it forms the basis of RFA needle localization. Furthermore, outcomes with different types of RFA modalities need to be looked at prospectively in a randomized placebo-controlled or comparative fashion to help improve outcomes in patients experiencing SI joint pain.

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