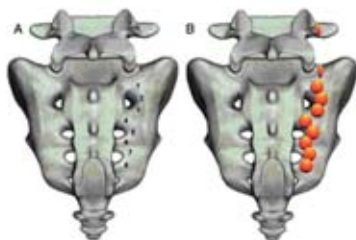
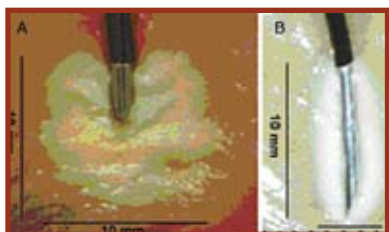
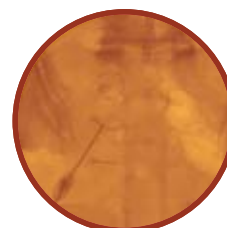




# Evidence-based Review of Radiofrequency Ablation Techniques for Chronic Sacroiliac Joint Pain

**ANITA GUPTA, DO, PHARM D**

*Assistant Professor  
Department of Anesthesiology and Critical Care  
Division of Pain Medicine, University of Pennsylvania  
Philadelphia, Pennsylvania*



The largest axial joint in the body is the sacroiliac (SI) joint. The average surface area is approximately 17.5 cm<sup>2</sup>,<sup>1</sup> with variability in size, shape, and surface contour among individuals.<sup>2,3</sup> A complex ligamentous network supports the synovial joint anteriorly and posteriorly.<sup>4</sup>

The primary function of this ligamentous system is to bolster stability while allowing for adequate range of motion in multiple planes of movement. The SI joint is further supported by a network of muscles that generate stabilizing forces across the pelvic bones. These muscles include the gluteus maximus, piriformis, and biceps femoris. Their connection to the SI joint ligaments enables effective joint mobility. In 30% of SI joints, there

exists a potential for shearing that contributes to the acute angulation of the short horizontal articulating component.<sup>5</sup>

The SI joint is perhaps best conceptualized as complex, with both intra- and extraarticular elements. Injury to either of these components can produce the clinical picture of “SI joint pain.” Animal and human cadaveric studies have demonstrated nociceptors both within the joint capsule and in the surrounding

*Dr. Gupta has no relevant financial conflicts to disclose*

ligaments.<sup>6,7</sup> Additionally, clinical studies performed in asymptomatic volunteers and patients with low back pain have documented pain provocation with both capsular distension and ligamentous stimulation.<sup>8-11</sup>

Understanding the innervation of the SI joint is essential when contemplating denervation procedures. The lateral branches of the S1-S3 dorsal rami comprise the primary innervation to the posterior SI joint in humans, with contribution from the L5 dorsal ramus in most individuals.<sup>12-16</sup> In a cadaveric study, McGrath reported afferent input from S4 to the long posterior sacroiliac ligament in more than 50% of SI joints.<sup>17</sup> Although some literature refers to contributions from L4—the obturator nerve—and the superior gluteal nerve, the sources for these references are older and ambiguous.

The posterior lateral branch nerves are inconsistent in their anatomic locations, varying in number and location from patient to patient, side to side, and level to level. The nerves also run their anatomic courses at different depths, with some situated on bone and others embedded in soft tissue. These wide and unpredictable anatomical variations have significant implications when contemplating denervation treatments because small, single-plane lesions are unlikely to interrupt all afferent nociceptive information.<sup>13-18</sup>

The innervation of the ventral aspect of the SI joint complex similarly has not been well illuminated. However, because the nerve supply is not amenable to denervation, the ambiguity is less clinically relevant. The ventral rami of L4-S2 are cited most frequently as the main innervation to the ventral aspect of the joint,<sup>15,19-22</sup> although some sources report contributions from cephalad at L2.<sup>1</sup>

## Diagnosis and Clinical Presentation

Pain generated in the SI joint or surrounding structures can present as low back pain, leg pain, sacral pain, pelvic pain, or gluteal pain. Patterns of somatically referred SI joint pain have been identified and can vary significantly.<sup>23</sup> Numbness, popping, clicking, or groin pain<sup>24</sup> can occur.<sup>25</sup> Unilateral pain is more common than bilateral by a ratio as high as 4 to 1 ratio.<sup>1</sup>

## Radiofrequency Treatments

In randomized studies evaluating periarticular and intraarticular corticosteroid injections in patients suspected of having SI joint pain, the results are divided regarding affording any long-term benefit.<sup>26-29</sup> Studies evaluating conservative therapies are flawed by the lack of adequate control subjects and inappropriate diagnostic workups.<sup>12</sup>

Radiofrequency (RF) denervation has emerged as a promising treatment alternative for refractory cases of SI joint pain.<sup>30,31</sup> Since lateral branch RF denervation was first described in the early 2000s,<sup>13,30</sup> numerous uncontrolled<sup>32-34</sup> and controlled<sup>31</sup> studies have universally reported positive results. However, these studies are characterized by wide variations in technique, selection criteria, and standards of success.

## PATIENT SELECTION

Patient selection is critical for any interventional spine procedure,<sup>18,35-39</sup> especially in the application of new innovations, as negative results may threaten to undermine the very concept behind treatment. In view of the wide variability in pain referral zones, the ambiguity of innervation, and the overriding controversy surrounding RF denervation in general, one might reasonably argue that proper patient selection criteria is even more critical for SI joint denervation.<sup>40-42</sup> There are considerable differences in the reported pain referral patterns from the SI joint. In uncontrolled studies evaluating SI joint denervation, investigators have used disparate referral maps in their selection criteria.<sup>30,43,44</sup>

## PULSED RADIOFREQUENCY

Pulsed RF is a novel technique in which a relatively high voltage is applied near neural tissue in short pulses, which avoids a significant rise in temperature to neurolytic thresholds (45°C). Hence, pulsed RF ablation is essentially a non-neurolytic procedure. Due to the large electromagnetic field created, the affected target area may be greater in scope than that associated with conventional RF. However, there is limited evidence supporting the efficacy of this procedure, and the evidence that does exist suggests that the benefit may be shorter in duration than that obtained with conventional RF. In the only published study on pulsed RF for SI joint pain, Vallejo and colleagues reported the results of a prospective case series conducted in patients with intractable SI joint dysfunction who were treated with pulsed RF denervation of the lateral branches from L4-S2. One hundred and twenty-six patients with presumptive SI joint dysfunction based on history and physical examination underwent fluoroscopically guided intraarticular SI joint injections. Among the 52 patients with a positive response (41.3%), 22 failed to obtain long-term relief and proceeded to pulsed RF. Sixteen (73%) of these individuals experienced either “good” or “excellent” pain relief lasting at least 6 months. In positive responders, the mean duration of analgesia was 20 weeks. In addition to pain scores, quality-of-life scores also improved in all measured categories.<sup>34</sup>

## Approaches to Radiofrequency Ablation And Technique

The principal purpose for RF denervation procedures is to provide prolonged pain relief compared with more conservative measures in patients suffering from injection-confirmed SI joint pain. For SI joint pain, the most common indication is significant but transient relief with diagnostic SI joint injections. The RF techniques used have ranged from ablating the nerves supplying the SI joint,<sup>13,30,32</sup> creating lesions in the joint itself,<sup>43</sup> and using a combination of ligamentous and neural RF ablation.<sup>44</sup> Few previous studies have described RF lesion within the SI (or other) joint(s). Among these, the results have been inconsistent and mostly disappointing.<sup>43,45</sup>

In contrast, the success rates in studies targeting the nerve supply are higher than in those focusing on the

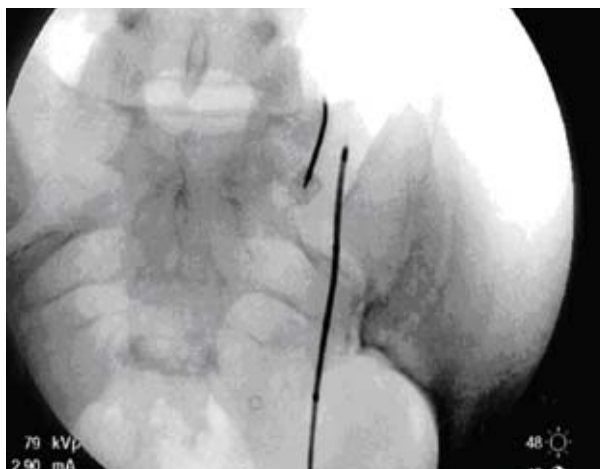
joint itself, with approximately two-thirds of patients reporting significant pain relief. Following is a review of the various approaches to RF ablation, including intraarticular approach, extraarticular approach, cooled RF ablation, bipolar RF ablation, and a combination of ligamentous and neural RF ablation.

### **INTRARTICULAR APPROACH**

In 2001, Ferrante et al described the intraarticular approach for RF ablation for SI joint pain (Figure 1).<sup>43</sup> The authors reported the results of a series of 50 SI joint RF denervations performed in 33 patients with SI joint



**Figure 1.** Leapfrog technique of sacroiliac joint radiofrequency denervation<sup>43</sup>



**Figure 2.** Radiograph demonstrating single electrode placement for S1-S3 lateral branch radiofrequency denervation. Also pictured is a separate electrode for L5 dorsal ramus lesioning.

pain. All patients underwent diagnostic SI joint injections with local anesthetic before denervation. Changes in visual analog scale (VAS) scores, pain diagrams, physical examination (eg, palpation tenderness over the joint, myofascial trigger points overlying the joint, SI joint pain provocation tests, and range of motion of the lumbar spine), and opioid use were assessed pre- and post-denervation. The criterion for a successful procedure was at least a 50% decrease in VAS scores for no less than 6 months; 36.4% of patients (12 of 33) met this criterion. This study demonstrated that intraarticular RF lesioning of the SI joint can significantly reduce pain in only a minority of patients with SI syndrome. The main disadvantage of this approach is that it only denervates the posterior-inferior one-third of the joint.

As with all interventional techniques, lateral branch RF ablation must be performed under sterile conditions, with the patient positioned prone and a C-arm present to optimize visualization of the target sites. For lesioning of the L5 and L4 dorsal rami (if targeted), RF cannula with active tips are inserted parallel to the course of the nerve until bone is contacted just superior and medial to the junction between the superior border of the transverse and superior articular processes for procedures done at L4, and at the junction of the ala and articular process of the sacrum for L5 procedures, similar to previously published studies (Figure 2).<sup>18,46</sup> Inserting the electrode parallel to the course of the nerve has been shown to increase lesion size, minimizing the chance of inadvertently missing the target nerve.<sup>47</sup> Because it is not possible to discern electrostimulation between the various (eg, medial, lateral, and intermediate) branches of the primary dorsal rami, the targeted nerve at this level is referred to as the parent branch. At each level, placement of the electrode in close proximity to the nerve is confirmed using electrostimulation at 50 Hz, with concordant sensation achieved at 0.5 V or less. Before lesioning, the absence of leg contractions is verified with stimulation at 2 Hz up to 2 V. After satisfactory electrode placement, 0.5 mL lidocaine, 2% mixed with corticosteroid, can be injected through each cannula to reduce procedure-related pain and the subsequent risk for neuritis.<sup>48</sup> By enhancing electrical conductivity, the preablation injection of local anesthetic also may increase lesion size. Once sufficient time has elapsed for the local anesthetic to take effect, the RF probe is reinserted, and a 90-second, 80°C lesion is made using an RF generator.

For S1-S3 lateral branch procedures, conventional electrodes may be inserted between 3 and 5 mm from the lateral border of the foramina at predesignated positions (Figure 3).

Generally a pure antero-posterior view is used to optimize visualization of S2-S4, although occasionally the image intensifier must be angled cephalad to properly visualize the posterior opening. For S1, either slight cephalad or ipsilateral oblique angulation often is needed to discern the foramen. In certain patients, it may not be possible to definitively visualize all of the



**Figure 3.** Antero-posterior radiograph depicting electrode placement for L4 and L5 primary dorsal ramus, and S1-S3 lateral branch blocks.

foramina, in which case inserting a 25-gauge needle into the obscured foramina may be helpful to conceptualize the anatomy. In obese patients on high-dose opioids, a bowel prep can be used to maximize visualization.<sup>49</sup>

For right-sided S1 and S2 procedures, the electrode target sites correspond approximately to the 1, 3, and 5:30 positions on the face of a clock; on the left, the target sites were at 7, 9, and 10:30 (Figures 3-5). At S3, needles are placed at 1:30 and 4:30 on the right side, and 7:30 and 10:30 on the left side. We currently target S4 only when the foramen is at a level parallel or cephalad to the inferior border of the SI joint.

It is our practice to perform sensory stimulation at each level only for the first needle placement, provided concordant sensation is elicited at 0.5 V or less. Before lesioning, 0.5 mL lidocaine, 2%, is administered per spinal level. To ensure that anesthetic spread to adjacent foramina does not impede sensory testing, electrodes are generally placed and stimulated at contiguous levels before denervation is commenced. When all needles are properly positioned, monopolar electrodes are sequentially inserted into the cannulae, and 90-second lesions are created.<sup>13</sup>

#### **COOLED-PROBE RADIOFREQUENCY ABLATION**

Cooled-probe RF ablation is a new modality of treatment for SI joint pain. Using cooling-probe technology, the tissue temperature immediately adjacent to the cooled electrode is maintained at 60°C, while the target tissue is heated to 75°C, resulting in a lesion diameter ranging between 8 and 10 mm (Figures 7-8).<sup>51</sup> The main advantages of cooled-tip probes are the larger heating distance (up to 3 cm from the active tip), and greater depth of lesioning, which should theoretically improve success rates. In contrast, conventional RF ablation creates lesions approximately 3 to 4 mm in diameter, which is less likely to interrupt all afferent nociceptive input from the SI joint. This is an important consideration in light of the individual anatomic variations in location and quantity of nerves. When using cooled-probe technology, inserting the electrodes at least 5 mm from the foramen is necessary to ensure that the temperature



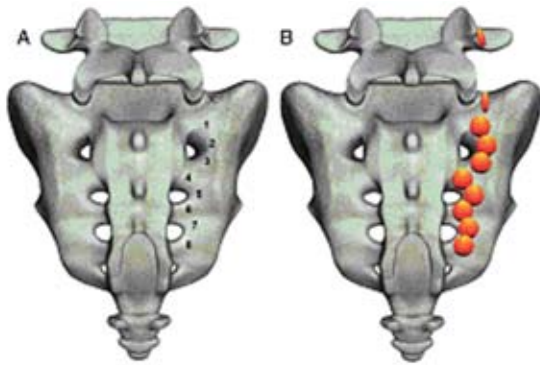
**Figure 4.** Antero-posterior radiograph demonstrating S1 electrode placement at 7 on the face of a clock. The smaller needles delineate the location of the foramina.



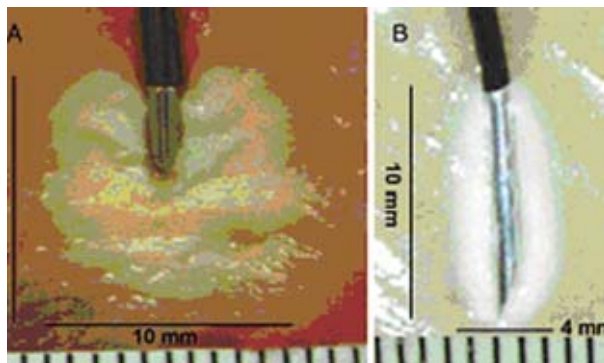
**Figure 5.** Antero-posterior radiograph demonstrating S2 electrode placement at 10 on the face of a clock. The smaller needles delineate the location of the foramina.

within the foramen does not exceed 45°C. Because of the 8-fold increase in lesion volume, most clinicians choose not to perform sensory stimulation provided the locations of the foramina are clearly demarcated. An additional advantage of cooled RF is that the needles are placed using a perpendicular rather than parallel trajectory, which is technically easier and causes less tissue trauma.

In the only placebo-controlled study evaluating SI joint denervation, Cohen et al<sup>51</sup> compared sham and cooled RF denervation of the L4-S3 lateral branches in 28 subjects with injection-confirmed pathology. For 6 months postprocedure, the treatment group obtained significant improvement in pain scores, functional capacity, and medication usage compared with the control group. Of patients in the RF group, 57%



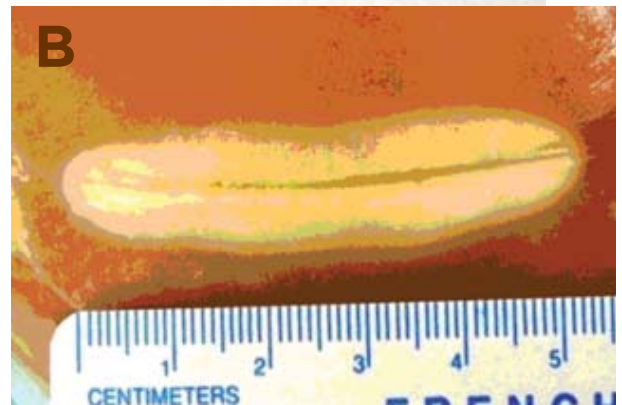
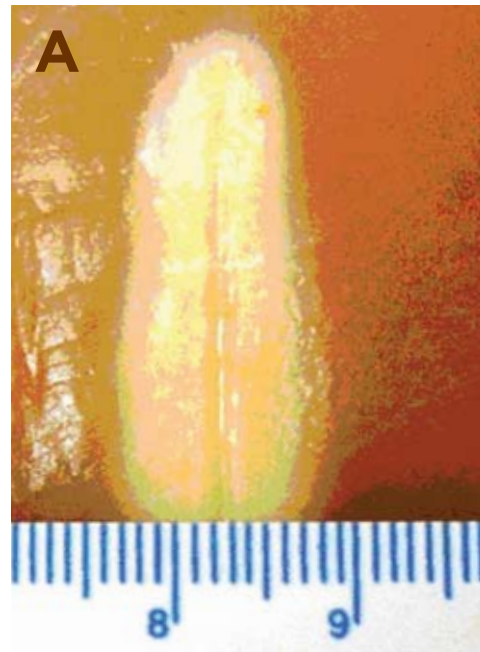
**Figure 6.** Schematic diagram illustrating: (A) Target points for right-sided conventional (L4 and L5) and cooled (S1-S3) radiofrequency denervation at the junction of the L5 superior articular and transverse processes (L4 primary dorsal ramus), the sacral ala (L5 primary dorsal ramus), and S1-S3 foramina (lateral branches). (B) Anticipated lesions at each of the target points.<sup>31</sup>



**Figure 7.** Adjacent photographs demonstrating the difference in lesion size between cooled (A) and conventional (B) radiofrequency probes in chicken meat. Each small line represents a distance of 1 mm.<sup>31</sup>

continued to report pain relief 6 months after treatment, compared with none in the placebo group. In those patients with a successful procedure, the median duration of relief was 7.9 months.

The main disadvantages of cooled RF are the greater electrode diameter, which may increase the risk for bleeding, and the longer lesioning time (2.5 minutes vs. 60-90 seconds for conventional RF). For safety reasons, the aggressive lesion size may increase the risk for motor nerve injury when targeting lumbar dorsal rami, and at present cannot be recommended at these levels (Figures 8-10).<sup>31</sup>



**Figure 8.** Depiction of lesion dimensions for single electrode sacral lateral branch radiofrequency technique. A 10-minute, 90°C lesion measures (A) 13 mm in diameter and (B) 52 mm in length.

#### **BIPOLAR RADIOFREQUENCY ABLATION**

In 2007, Burham and Yasui<sup>33</sup> performed a prospective, open-label study evaluating the effectiveness of bipolar RF ablation on pain, analgesic usage, and disability in 9 patients with injection-confirmed chronic, mechanical SI joint pain. Subjects were treated with a series of bipolar RF strip lesions performed adjacent to the lateral dorsal foraminal aperture plus conventional monopolar lesioning at the L5 dorsal ramus. Overall, 8 of 9 subjects were satisfied with the procedure, with two-thirds experiencing significant pain relief 1 year after treatment. The primary concern with this approach is that tissue impedances are highly variable in the SI joint complex, which may result in asymmetrical, nonconfluent lesions, or even technical failure.

**Table. Summary of Clinical Studies Evaluating Radiofrequency Procedures in Treatment of Sacroiliac Joint Pain**

Author, Year	Study Design	N	Treatment	Primary Outcomes	Comments
Cohen et al, 2009 <sup>49</sup>	Retro-spective	77	Multiple, 80°C, 90-s lesions of the L4 and L5 dorsal rami and S1-S3 lateral branches	Forty patients (52%) obtained a positive outcome. Among the entire study cohort, both NRS and ODI scores declined an average of 40%.	Patients had ≥50% pain relief after at least 1 low-volume (<2 mL) local anesthetic intraarticular SI joint block. Age >65, high pre-procedure pain score, opioid use, and pain below knee were associated with negative outcome. Cooled RF weakly associated with positive outcome.
Cohen et al, 2008 <sup>31</sup>	Randomized placebo-controlled	28	Single conventional lesions at L4 and L5; 3 cooled-probe lesions at S1 and S2 and 2 at S3 and sometimes S4.	In the treatment group, pain scores were reduced by 60%, 60%, and 57% at 1, 3, and 6 mo, respectively	Pain relief of ≥75% calculated from a pain diary after a single SI joint injection required for inclusion.
Kapural et al, 2008 <sup>51</sup>	Retro-spective case series	26	1 cooled-probe lesion at L5 and 2 to 3 cooled-probe lesions at S1-S3.	3 to 4 mo after treatment, 50% of patients had achieved the primary outcome of ≥50% reduction in VAS pain scores	Patients included in study had 2 diagnostic SI joint blocks with ≥50% of pain relief.
Burnham and Yasui, 2007 <sup>33</sup>	Prospective	9	3 conventional lesions at L5 and 3 bipolar strip lesions at S1-S3.	The percentages of those very satisfied at 1, 3, 6, 9, and 12 mo postprocedure were 78%, 67%, 67%, 89%, and 67%, respectively.	Patients included had ≥50% relief of index pain on at least 1 SI joint block and 1 prognostic lateral branch block.
Vallejo et al, 2006 <sup>34</sup>	Prospective	22	Multiple, 39°C to 42°C, 120-s pulsed RF lesions of the L4 and L5 medial branches and S1-S2 lateral branches	16 patients (73%) experienced >50% reduction in pain. Duration of pain relief range was 6 to 9 wk in 4 patients, 10 to 16 wk in 5 patients, and 17 to 32 wk in 7 patients.	Confirmation of SI joint pain required ≥75% pain relief following >2 SI joint injections
Buijs et al, 2004 <sup>32</sup>	Prospective observational	38 (43 joints)	80°C 60-s lesions of the S1-S3 dorsal-rami in all patients and L4-L5 dorsal rami in about half of patients	At 12-wk follow-up, 34.9% of procedures (26.3% of patients) resulted in complete pain relief and another 32.6% (34.2% of patients) reported ≥50% pain relief.	Inclusion criteria included ≥50% pain relief with SI joint blocks. Outcomes of patients receiving additional L4-L5 dorsal rami lesions no different than those undergoing only S1-S3 denervation.
Yin et al, 2003 <sup>13</sup>	Retro-spective	14 (4 underwent previous spine-surgery)	80°C, 60-s lesions of the L5 dorsal ramus sensory branch and S1-S3 dorsal rami lateral branches depending on stimulation results. All patients had L5 and S1 branches lesioned; 11 had a lateral branch at S2 and 6 at S3 that were lesioned.	Of patients, 64% obtained >50% consistent pain relief at 6 mo, 36% obtained complete relief; 5 patients reported <50% pain relief, and 2 reported no relief.	Inclusion criteria was >70% pain relief after 2 separate SI joint deep interosseous ligament injections.

**Table. Summary of Clinical Studies Evaluating Radiofrequency Procedures in Treatment of Sacroiliac Joint Pain (continued)**

Author, Year	Study Design	N	Treatment	Primary Outcomes	Comments
Gevargez et al, 2002 <sup>44</sup>	Prospective observational	38 patients (13 who underwent bilateral treatment)	Three 90°C, 90-s lesions in the posterior interosseous SI ligaments and 1 lesion of the L5 dorsal ramus.	3 mo after treatment, 34.2% of patients were pain-free, 31.6% reported a substantial decrease in pain, 18.4% obtained a slight decrease in pain, and 7.9% reported no pain reduction.	Did not specify % pain relief required during diagnostic SI joint injections for inclusion.
Cohen and Abdi, 2003 <sup>30</sup>	Retro-spective	18	80°C, 90-s lesions of the L4 and L5 dorsal rami and S1-S3 lateral branches.	Of 18 patients with SI joint pain, 13 obtained 50% pain relief with L4 and L5 dorsal rami and S1-S3 lateral-branch blocks, with 2 deriving long-term relief; 8 of 9 patients who underwent RF denervation obtained >50% pain relief 9 mo postprocedure.	Inclusion criteria was >50% pain relief with SI joint blocks. In 6 patients, empirical lesions were made at the S3 lateral branch because of failure to obtain concordant stimulation.
Ferrante et al, 2001 <sup>43</sup>	Retro-spective	33 (50 joints)	Multiple, 90°C, 90-s lesions made at <1 cm intervals as high in the postero-inferior joint as possible.	Of patients, 36.4% obtained >50% pain relief 6 mo postprocedure. Average duration of pain relief was 12 ± 1.2 mo.	Did not specify % pain relief required during diagnostic SI joint injections for inclusion. Only postero-inferior joint denervated.

NRS, numerical rating scale; ODI, Oswestry Disability Index; RF, radiofrequency; SI, sacroiliac; VAS, visual analog scale

#### COMBINATION OF LIGAMENTOUS AND NEURAL RF ABLATION

Gevargez et al<sup>44</sup> performed a study to evaluate computed tomography (CT)-guided percutaneous RF denervation of the SI joint in patients with low back pain. The procedure was performed on 38 patients who only temporarily responded to CT-guided SI joint blocks. The RF lesioning was performed in 3 locations in the posterior interosseous SI ligaments, and once on the dorsal ramus of the fifth spinal nerve. Three months after therapy, 13 patients (34.2%) were completely free of pain. Twelve patients (31.6%) also reported substantial pain reduction, 7 (18.4%) obtained slight benefit, and 3 (7.9%) reported no pain relief. The principal drawback of this procedure is that it targets only a small portion of the ligamentous connections of the SI joint, and leaves most of the nerve supply intact.

#### Conclusions and Future Research

SI joint pain is a common cause of axial low back pain, affecting between 15% and 25% of people.<sup>50</sup> In patients who obtain significant but short-term benefit from diagnostic blocks, RF denervation may provide a reasonable treatment alternative. Based on preclinical and clinical studies, the ideal candidates for RF denervation may be younger patients with suspected extraarticular pathology. Several techniques have thus far been described (Table), but current evidence favors lateral branch RF lesioning as the most effective treatment option. When selecting patients, neither double comparative blocks,

nor prognostic lateral branch blocks have proved to enhance outcomes. Studies conducted in cadavers have demonstrated that the L5-S3 levels should be targeted in most people, although some individuals may benefit from lesioning L4 and S4 as well. Indirect evidence has shown that cooled-probe technology can enhance lesion size, and may thus improve treatment outcomes. However, randomized comparative trials are needed to definitively establish superiority.

#### References

- Bernard TN, Cassidy JD. The sacroiliac syndrome. Pathophysiology, diagnosis and management. In: Frymoyer JW, ed. *The Adult Spine: Principles and Practice*. New York: Raven; 1991: 2107-2130.
- Dijkstra PF, Vleeming A, Stoeckart R. Complex motion tomography of the sacroiliac joint: an anatomical and roentgenological study [in German]. *Rofo*. 1989;150:635-642.
- Ruch WJ. *Atlas of Common Subluxations of the Human Spine and Pelvis*. Boca Raton, FL: CRC Press; 1997.
- Bowen V, Cassidy JD. Macroscopic and microscopic anatomy of the sacroiliac joint from embryonic life until the eighth decade. *Spine*. 1981;6:620-628.
- Mitchell FL Jr. *The muscle energy manual*. Vol. 1. East Lansing, MI: MET Press; 1995.
- Sakamoto N, Yamashita T, Takebayashi T, et al. An electrophysiologic study of mechanoreceptors in the sacroiliac joint and adjacent tissues. *Spine*. 2001;26: E468-E471.
- Szadek KM, van der Wurff P, van Tulder MW, Zuurmond WW, Perez RR. Diagnostic validity of criteria for sacroiliac joint pain: A systematic review. *J Pain*. 2009; 10:354-368.

8. 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*. 1994;19:1483-1489.
9. Fortin JD, Dwyer AP, West S, Pier J. Sacroiliac joint: pain referral maps upon applying a new injection/arthrography technique. Part I: asymptomatic volunteers. *Spine*. 1994;19:1475-1482.
10. Dreyfuss P, Snyder BD, Park K, Willard F, Carreiro J, Bogduk N. The ability of single site, single depth sacral lateral branch blocks to anesthetize the sacroiliac joint complex. *Pain Med*. 2008;9:844-850.
11. Dreyfuss P, Michaelsen M, Pauza K, et al. The value of medical history and physical examination in diagnosing sacroiliac joint pain. *Spine*. 1996;21:2594-2602.
12. Cohen SP. Sacroiliac joint pain: a comprehensive review of anatomy, diagnosis, and treatment. *Anesth Analg*. 2005;101:1440-1453.
13. 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*. 2003;28:2419-2425.
14. Grob KR, Neuhuber WL, Kissling RO. Innervation of the sacroiliac joint in humans [in German]. *Z Rheumatol*. 1995;54:117-122.
15. Ikeda R. Innervation of the sacroiliac joint: macroscopic and histological studies. *J Nippon Med Sch*. 1991;58:587-596.
16. Fortin JD, Kissling RO, O'Connor BL, Vilensky JA. Sacroiliac joint innervation and pain. *Am J Orthop*. 1999;28:68-90.
17. McGrath MC, Zhang M. Lateral branches of dorsal sacral nerve plexus and the long posterior sacroiliac ligament. *Surg Radiol Anat*. 2005; 27: 327-330.
18. Cohen SP, Hurley RW, Christo PJ, Winkley J, Mohiuddin MM, Stojanovic MP. Clinical predictors of success and failure for lumbar facet radiofrequency denervation. *Clin J Pain*. 2007;23:45-52.
19. Nakagawa T. A study on the distribution of the nerve filaments of the iliosacral joint and its adjacent region in the Japanese. *J Jap Orthop Assoc*. 1966; 40:419-30.
20. Dreyfuss P, Dreyer SJ, Cole A, Mayo K. Sacroiliac joint pain. *J Am Acad Orthop Surg*. 2004;12:255-265.
21. Rupert MP, Lee M, Manchikanti L, Datta S, Cohen SP. Evaluation of sacroiliac joint interventions: a systematic appraisal of the literature. *Pain Physician*. 2009;12:399-418.
22. Hansen HC, McKenzie-Brown AM, Cohen SP, Swicegood JR, Colson JD, Manchikanti L. Sacroiliac joint interventions: a systematic review. *Pain Physician*. 2007;10:165-184.
23. Norman GF. Sacroiliac disease and its relationship to lower abdominal pain. *Am J Surg*. 1968;116:54-56.
24. Schwarzer AC, Aprill CN, Bogduk N. The sacroiliac joint in chronic low back pain. *Spine*. 1995;20:31-37.
25. Prather H, Hunt D. Conservative management of low back pain, part I. Sacroiliac joint pain. *Dis Mon*. 2004;50:670-683.
26. Luukkainen R, Nissila M, Asikainen E, et al. Periarticular corticosteroid treatment of the sacroiliac joint in patients with seronegative spondyloarthritis. *Clin Exp Rheumatol*. 1999;17:88-90.
27. Luukkainen R, Wennerstrand PV, Kautiainen HH, Sanila MT, Asikainen EL. Efficacy of periarticular corticosteroid treatment of the sacroiliac joint in nonspondyloarthropathic patients with chronic low back pain in the region of the sacroiliac joint. *Clin Exp Rheumatol*. 2002;20:52-54.
28. Maugars Y, Mathis C, Vilon P, Prost A. Corticosteroid injection of the sacroiliac joint in patients with seronegative spondyloarthritis. *Arthritis Rheum*. 1992;35:564-568.
29. Hanly JG, Mitchell M, MacMillan L, Mosher D, Sutton E. Efficacy of sacroiliac corticosteroid injections in patients with inflammatory spondyloarthritis: Results of a 6 month controlled study. *J Rheumatol*. 2000;27:719-722.
30. Cohen SP, Abdi S. Lateral branch blocks as a treatment for sacroiliac joint pain: a pilot study. *Reg Anesth Pain Med*. 2003;28:113-119.
31. 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;109:279-288.
32. Buijs EJ, Kamphuis ET, Groen GJ. Radiofrequency treatment of sacroiliac joint-related pain aimed at the first three sacral dorsal rami: a minimal approach. *Pain Clinic*. 2004;16:139-146.
33. 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; 32:12-19.
34. Vallejo R, Benyamin RM, Kramer J, Stanton G, Joseph NJ. Pulsed radiofrequency denervation for the treatment of sacroiliac joint syndrome. *Pain Med*. 2006;7:429-434.
35. Benzon HT. Epidural steroid injections for low back pain and lumbosacral radiculopathy. *Pain*. 1986;24:277-295.
36. Ferrante FM, Wilson SP, Iacobo C, Orav EJ, Rocco AG, Lipson S. Clinical classification as a predictor of therapeutic outcome after cervical epidural steroid injection. *Spine*. 1993;18:730-736.
37. Cohen SP, Bajwa Z, Kraemer J, Dragovich A, Williams K, Hurley RW. Clinical predictors of success and failure for cervical facet radiofrequency denervation. *Reg Anesth Pain Med*. 2007;32:495-503.
38. Airaksinen O, Herno A, Turunen V, Saari T, Suomlainen O. Surgical outcome of 438 patients treated surgically for lumbar spinal stenosis. *Spine*. 1997;22:2278-2282.
39. Cohen SP, Larkin T, Abdi S, Chang A, Stojanovic M. Risk factors for failure and complications of intradiscal electrothermal therapy: A pilot study. *Spine*. 2003;28:1142-1147.
40. Slipman CW, Jackson HB, Lipetz JS, Chan KT, Lenrow D, Vresilovic EJ. Sacroiliac joint pain referral zones. *Arch Phys Med Rehabil*. 2000; 81:334-338.
41. Cohen SP, Rowlingson J, Abdi S. Low back pain. In: Warfield CA, Bajwa ZA, eds. *Principles and Practice of Pain Medicine*. 2nd ed. New York: McGraw-Hill, 2004: 273-284.
42. Staal JB, de Bie RA, de Vet HC, Hildebrandt J, Nelemans P. Injection therapy for subacute and chronic low back pain: an updated Cochrane review. *Spine*. 2009;34:49-59.
43. Ferrante FM, King LF, Roche EA, et al. Radiofrequency sacroiliac joint denervation for sacroiliac syndrome. *Reg Anesth Pain Med*. 2001;26:137-142.
44. Gevargze A, Groenemeyer D, Schirp S, Braun M. CT-guided percutaneous radiofrequency denervation of the sacroiliac joint. *Eur Radiol*. 2002;12:1360-1365.
45. Sanders M, Zuurmond WW. Percutaneous intra-articular lumbar facet joint denervation in the treatment of low back pain: a comparison with percutaneous extra-articular lumbar facet denervation. *Pain Clinic*. 1999;11:329-335.
46. van Kleef M, Barendse GA, Kessels A, Voets HM, Weber WE, de Lange S. Randomized trial of radiofrequency lumbar facet denervation for chronic low back pain. *Spine*. 1999;24:1937-1942.
47. Lau P, Mercer S, Govind J, Bogduk N. The surgical anatomy of lumbar medial branch neurotomy (facet denervation). *Pain Med*. 2004;5:289-298.
48. Dobrogowski J, Wrzosek A, Wordliczek J. Radiofrequency denervation with or without addition of pentoxifylline or methylprednisolone for chronic lumbar zygapophysial joint pain. *Pharmacol Rep*. 2005;57:475-480.
49. Cohen SP, Strassels SA, Kurihara C, et al. Outcome predictors for sacroiliac joint (lateral branch) radiofrequency denervation. *Reg Anesth Pain Med*. 2009;34:206-214.
50. Cohen SP. Epidemics, evolution and sacroiliac joint pain. *Reg Anesth Pain Med*. 2007;32:3-6.
51. 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 Practice*. 2008;5:348-354.