

Randomized Placebo-controlled Study Evaluating Lateral Branch Radiofrequency Denervation for Sacroiliac Joint Pain

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Background: Sacroiliac joint pain is a challenging condition accounting for approximately 20% of cases of chronic low back pain. Currently, there are no effective long-term treatment options for sacroiliac joint pain.

Methods: A randomized placebo-controlled study was conducted in 28 patients with injection-diagnosed sacroiliac joint pain. Fourteen patients received L4–L5 primary dorsal rami and S1–S3 lateral branch radiofrequency denervation using cooling-probe technology after a local anesthetic block, and 14 patients received the local anesthetic block followed by placebo denervation. Patients who did not respond to placebo injections crossed over and were treated with radiofrequency denervation using conventional technology.

Results: One, 3, and 6 months after the procedure, 11 (79%), 9 (64%), and 8 (57%) radiofrequency-treated patients experienced pain relief of 50% or greater and significant functional improvement. In contrast, only 2 patients (14%) in the placebo group experienced significant improvement at their 1-month follow-up, and none experienced benefit 3 months after the procedure. In the crossover group (n = 11), 7 (64%), 6 (55%), and 4 (36%) experienced improvement 1, 3, and 6 months after the procedure. One year after treatment, only 2 patients (14%)

in the treatment group continued to demonstrate persistent pain relief.

Conclusions: These results provide preliminary evidence that L4 and L5 primary dorsal rami and S1–S3 lateral branch radiofrequency denervation may provide intermediate-term pain relief and functional benefit in selected patients with suspected sacroiliac joint pain. Larger studies are needed to confirm these results and to determine the optimal candidates and treatment parameters for this poorly understood disorder.

SACROILIAC joint pain is a challenging condition estimated to account for between 15% and 20% of chronic axial low back pain cases.^{1,2} Currently, there is no reliably effective treatment for sacroiliac pain. In randomized studies evaluating periarticular and intraarticular corticosteroid injections in patients suspected of having sacroiliac joint pain, the results are divided as to whether or not they afford any long-term benefit.^{3–7} Studies evaluating conservative therapies are flawed by the lack of adequate control subjects and inappropriate diagnostic workups.¹

In the past several years, radiofrequency denervation has emerged as a promising treatment alternative for refractory cases of sacroiliac joint pain.⁸ The concept of disrupting the nerve supply to pain-generating spinal structures was extrapolated from more than 30 yr of experience using radiofrequency lesioning for zygapophysial (facet) joint pain.⁹ In four studies evaluating different variants of lower lumbar primary dorsal rami and sacral lateral branch radiofrequency denervation, all reported success rates ranging between 64% and 89%.^{10–13} However, none of these studies were controlled, which raises questions regarding their validity and applicability. To determine whether sacroiliac joint denervation is a viable treatment for patients with chronic, intractable, injection-diagnosed sacroiliac joint pain, we conducted a placebo-controlled study evaluating L4 and L5 primary dorsal rami and S1–S3 lateral branch radiofrequency lesioning.

Materials and Methods

Permission to conduct this study was granted by the internal review boards at Johns Hopkins Medical Institutions, Baltimore, Maryland, and Walter Reed Army Medical Center, Washington, D.C., and all study participants who provided informed consent. The standardized protocol was performed at both institutions, with recruit-

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ment and all procedures occurring between May 2005 and August 2006. A two-tailed power analysis determined a sample size of 14 in each group had 80% power (β of 0.2) to detect a 2-point difference in the 0–10 numeric rating scale (NRS) between groups with a significance level (α) of 0.05.

All procedures were performed in an outpatient setting using local anesthesia and, for radiofrequency denervation, intravenous sedation. Subjects were recruited from the regular pain clinic populations at the participating institutions. Inclusion criteria included age older than 18 yr; axial low back or buttock pain of 6 months or longer; tenderness overlying the sacroiliac joint(s); failure to respond to conservative therapy (*e.g.*, physical therapy and pharmacotherapy), including long-term (> 2 months) pain relief with sacroiliac joint corticosteroid injections; and pain relief of 75% or greater as calculated from a 6-h postblock pain diary after a single diagnostic sacroiliac joint injection. Exclusion criteria were focal neurologic signs or symptoms; radiologic evidence of a

symptomatic herniated disc; spondyloarthropathy; untreated coagulopathy; and unstable medical (*e.g.*, unstable angina) or psychiatric illness (*e.g.*, untreated depression) that might preclude an optimal treatment response. Before enrollment, all patients underwent magnetic resonance imaging to rule out other possible sources for their back pain. Six patients, three in each group, underwent previous diagnostic spinal procedures. These included four discograms and four medial branch (facet joint nerve) blocks, all of which were negative. Throughout the recruitment phase, 62 patients were excluded for a variety of reasons, of which the most common was failure to achieve documented pain relief of 75% or greater from the diagnostic sacroiliac joint block ($n = 38$; fig. 1).

Screening Sacroiliac Joint Injections

Sacroiliac joint injections were performed using 22-gauge spinal needles inserted into the bottom one third of the joint using fluoroscopic guidance in either a

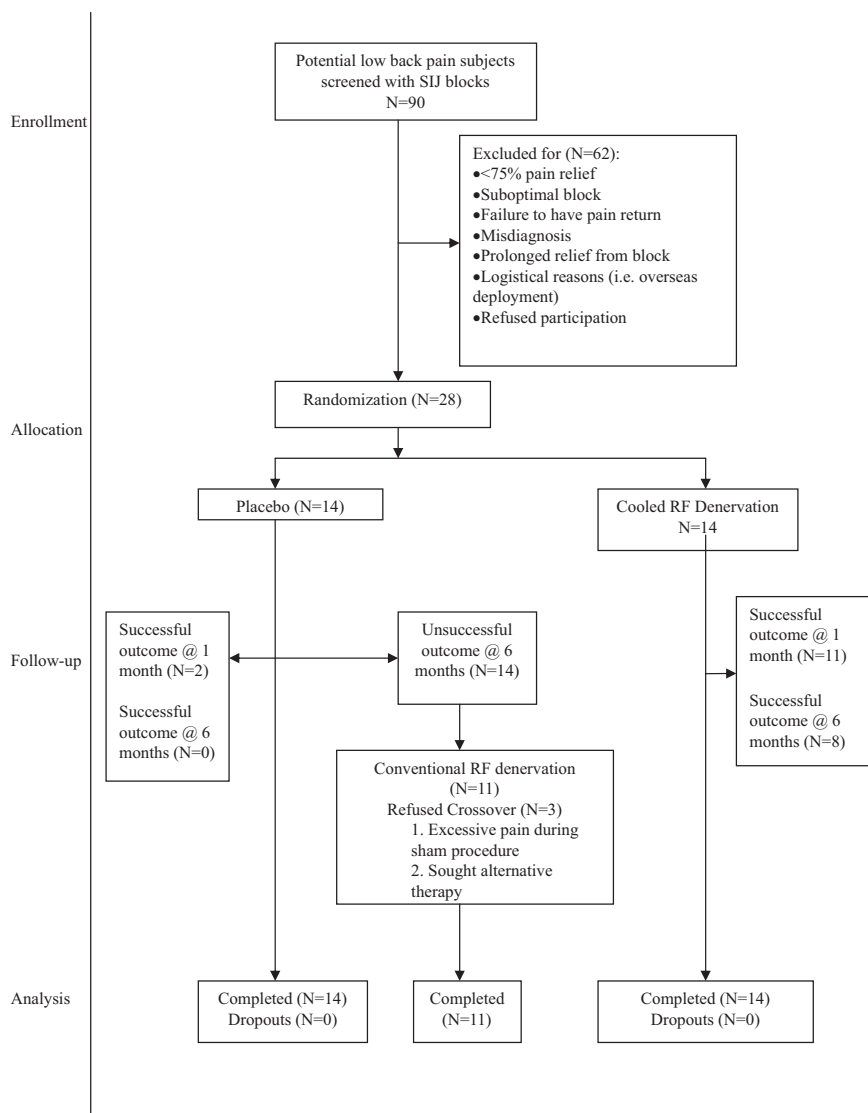


Fig. 1. Consolidated Standards of Reporting Trials (CONSORT) chart showing progression of subjects in study arms. N = number of patients; RF = radiofrequency; SIJ = sacroiliac joint.

slightly oblique or an anteroposterior view. Correct placement was ascertained in all cases by a sacroiliac joint arthrogram. After confirmation of joint penetration, a 3-ml solution containing 2 ml bupivacaine, 0.5%, and 1 ml depo-methylprednisolone 40 mg/ml (Pharmacia and Upjohn, Kalamazoo, MI), was administered. After the injection, patients were instructed to engage in normal activities and fill out 0–10 numerical rating scale (NRS) pain diaries every half hour over the ensuing 6 h. Only those patients who experienced pain relief of 75% or greater for at least 3 h while performing their normal activities of daily living, but whose pain returned to near baseline within 2 months, were eligible for enrollment.

Randomization and Primary Treatment

All subjects were treated by a physician not involved in randomization. Study patients were randomized in a 1:1 ratio to receive either true or placebo denervation. A research nurse not involved in patient care performed randomization in blocks of four *via* presealed envelopes at each institution. Under sterile conditions with the patient positioned prone, a C-arm intensifier was used to optimize visualization of the target sites. For blockade and lesioning of the L4 and L5 dorsal rami, 22-gauge SMK-C10 cannulae (Radionics, Burlington, MA) with 5-mm active tips were inserted parallel to the course of the nerve until bone was 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.^{14,15} Because it is not possible to discern electrostimulation between the various branches of the L4 primary dorsal ramus (it is the lateral branch that may innervate the sacroiliac joint), 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 was confirmed using electrostimulation at 50 Hz, with concordant sensation achieved at 0.5 V or less. Before lesioning, the absence of leg contractions was verified with stimulation at 2 Hz up to 2 V. After satisfactory electrode placement, 0.5 ml lidocaine, 2%, was injected through each cannula to reduce thermal pain and ensure blinding. The radiofrequency probe was then reinserted, and a 90-s, 80°C lesion was made using a radiofrequency generator set to the lowest audible volume to blend in with ambient noise (Electrothermal 20S Spine System; Smith and Nephew, Andover, MA, or Radionics RF Lesion Generator System, model RFG-3C; Radionics, Valleylab, Boulder, CO).

For S1–S3 lateral branch procedures, 17-gauge, 75-mm cooled electrodes with 4-mm active tips (Baylis Medical, Montreal, Quebec, Canada) were inserted between 3 and 5 mm from the lateral border of the foramina at predesignated positions. For right-sided S1 and S2 procedures, these corresponded approximately to the 1:00, 3:00, and 5:30 positions on the face of a clock; on the left, the target sites were at 6:30, 9:00, and 11:00 (fig. 2). At S3, needles were placed at 1:30 and 4:30 on the right side and at 7:30 and 10:30 on the left side. In 10 patients in whom the S4 foramen was located level with or just below the inferior portion of the sacroiliac joint, one upper lesion was also done at S4. Sensory stimulation was performed at each level only for the first needle placement, revealing concordant sensation at 0.5 V or less. Before lesioning, 0.5 ml lidocaine, 2%, was administered per spinal level. To ensure that anesthetic spread to adjacent foramina did not impede sensory testing, electrodes were placed and stimulated at contiguous levels before denervation commenced. When the needles were properly positioned, monopolar electrodes were sequentially inserted into the cannulae, and 2.5-min lesions were made using a water-cooled radiofrequency heating system (Pain Management SIenergy Sys-

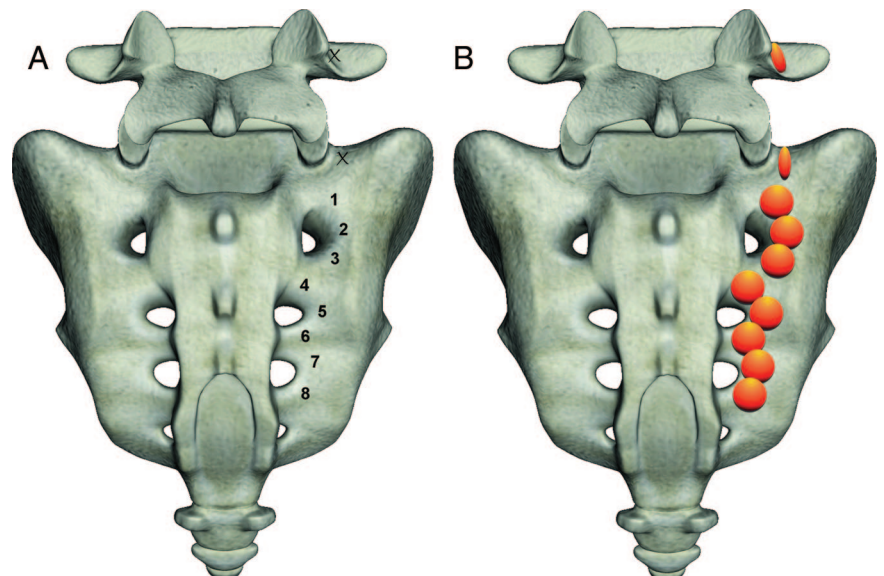


Fig. 2. Schematic diagram illustrating: (A) Target points for right-sided conventional (L4 and L5) and cooled (S1–S3) radiofrequency denervation at the junction of the L5 superior articular and transverse processes (L4 primary dorsal ramus), the sacral ala (L5 primary dorsal ramus), and S1–S3 foramina (lateral branches). (B) Anticipated lesions at each of the target points.

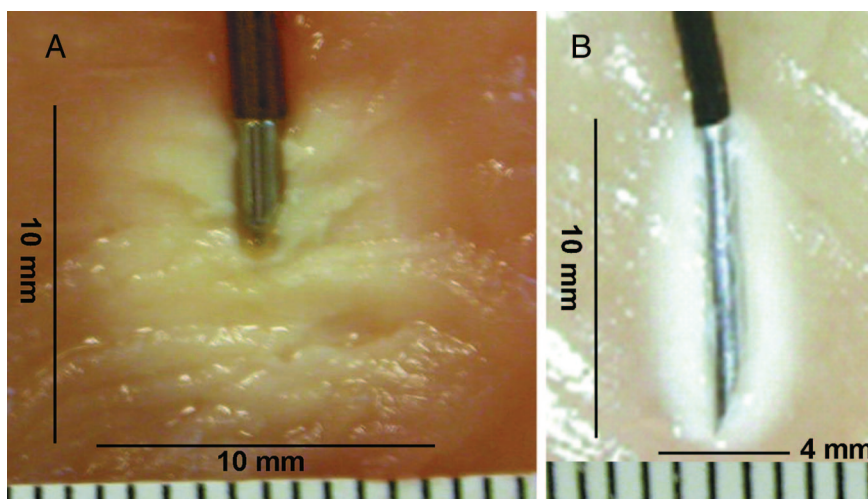


Fig. 3. Adjacent photographs demonstrating the difference in lesion size between cooled (A) and conventional (B) radiofrequency probes in chicken meat. Each *small line* represents a distance of 1 mm.

tem; Baylis Medical) and generator (PMG-115-TD, V2.0A; Baylis Medical). 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 (fig. 3). For safety reasons, this aggressive lesioning precludes using cooling-probe technology for lumbar primary dorsal rami.

In the control group, electrodes were similarly positioned, electrostimulation was performed in an identical manner, and 0.5 ml lidocaine, 2%, was administered, but no current was administered. The average time it took to perform the radiofrequency and placebo procedures were comparable (mean of 61 *vs.* 54 min, respectively, for the first 5 people in each group).

Outcome Measures, Crossover Group Treatment, and Follow-up

A physician unaware of the patient's study group assignment obtained all outcome data during scheduled follow-up visits. Between the procedure and first follow-up, no contact was permitted between any patient and investigator except for emergencies. All patients were seen in the treating clinic 1 month after the procedure. If a patient obtained a positive global perceived effect (GPE) and significant ($\geq 50\%$) pain relief obviating the need for further therapy, he or she was reevaluated 3 and 6 months after treatment. Abridged follow-up interviews were done by e-mail or telephone every 2 months after the 6-month follow-up in patients who reported persistent relief to determine the duration of benefit. Patients who did not obtain adequate symptomatic improvement were unblinded at follow-up. For those who obtained significant relief 1 month after the procedure, unblinding was done 3 months after treatment.

Patients in the initial radiofrequency denervation (cooled electrode) group who did not obtain a positive outcome were recorded as a treatment failure and offered alternative treatment. All placebo patients who did

not achieve a positive outcome were offered the opportunity to cross over and receive sacroiliac joint denervation using conventional (noncooled) technology in an open-label parallel arm. The reason for using conventional equipment was based on availability (*i.e.*, cooled equipment was not ordered for patients in whom the outcome and hence treatment plan was not known beforehand). In these patients, 22-gauge SMK-C10 (Radionics) cannulas with 5-mm active tips were placed in an identical fashion to that described for the treatment group. When concordant sensory stimulation was obtained and 1% lidocaine was administered at each level, the monopolar radiofrequency probe was reinserted, and a 90-s, 80°C lesion was made using a different generator (Electrothermal 20S Spine System; Smith and Nephew, or Radionics RF Lesion Generator System, model RFG-3C; Radionics). Data from the crossover group were analyzed separately from those of the initial experimental group.

The primary outcome measure was a 0–10 NRS pain score, which reflected the average pain experienced by the patient for 10 days before follow-up. Secondary outcome measures included Oswestry disability index score (ODI version 2.0; MODEMS, Des Plaines, IL; reflecting the 10 days before follow-up), reduction in analgesic medications (defined as a 20% reduction in opioid use or complete cessation of a nonopioid analgesic),¹⁶ GPE, and a composite successful outcome. A positive GPE was defined as an affirmative response to the following three questions:

1. My pain has improved/worsened/stayed the same since my last visit.
2. The treatment I received improved/did not improve my ability to perform daily activities.
3. I am satisfied/not satisfied with the treatment I received and would recommend it to others.

The composite binary variable “successful outcome” was predefined before initiation of the study as a

Table 1. Demographic and Clinical Characteristics of Study Patients

	Placebo (n = 14)	Lateral Branch Denervation (n = 14)
Sex		
Male (n = 11)	6 (43%)	5 (36%)
Female (n = 17)	8 (57%)	9 (64%)
Age, mean (SD, range), yr	51.8 (13.1, 31–74)	51.9 (13.6, 27–75)
Active duty (n = 6)	3 (21%)	3 (21%)
Opioid use (n = 13)	7 (50%)	6 (43%)
Dosage in morphine equivalents per day, mean (SD, range)	46.4 (43.1, 7.5–130)	60 (50.0, 7.5–150)
Worker's compensation, disability, or military medical board claim (n = 9)	3 (21%)	6 (43%)*
Failed back surgery syndrome (n = 6)†	4 (29%)	2 (14%)
Baseline numerical rating scale score		
Mean (SD, range)	6.5 (1.9, 3.5–10)	6.1 (1.8, 3–8)
Median (interquartile range)	6 (5.5–7)	6 (5–8)
Baseline Oswestry disability index score		
Mean (SD, range)	47.9 (9.3, 28–58)	37.1 (10.6, 18–49)
Median (interquartile range)	50.5 (44–56)	41 (26–46)

Continuous data are listed as mean (SD, range) and median (interquartile range [25–75%]); categorical data are listed as number (%).

* Includes 3 active duty soldiers undergoing a medical board. † Includes 5 patients with spinal fusion and 1 status post laminectomy.

reduction of 50% or greater in numerical pain score, a positive GPE, and either a 10-point decrease in ODI or a 4-point decrease coupled with a reduction in medication usage.^{17,18}

Statistical Measures

Statistical analyses were performed using STATA version 10.0 (Statcorp, College Station, TX). The Shapiro-Wilk W test for normal data was performed on continuous outcome measures. The distribution of categorical variables in each group was compared using the Fisher exact test. Continuous variables are reported as mean and SD or median and interquartile range. Categorical data are reported by number of subjects and percentage. Comparisons between the initial radiofrequency treatment group and the placebo group were made with unpaired *t* tests or the Mann-Whitney U test. Because the continuous data in each group had a normal distribution, comparisons between and within the initial radiofrequency and crossover treatment groups were made with two-way analysis of variance. For multiple significance testing, a *post hoc* Bonferroni correction was used. Because baseline ODI differences were a potential confounding factor, an adjusted multiple linear and logistic regression analysis was performed for each continuous and categorical outcome measure, respectively.

Results

Demographics

Data were analyzed on 28 patients. Demographic (including active duty status) and clinical characteristics were balanced between the radiofrequency denervation treatment and control group. Two patients, one each in the control and treatment groups, received bilateral procedures. Thirteen patients were taking opioids, and 24 were taking nonopioid analgesics. There were no differ-

ences with regard to treatment location with the exception of military duty status, which was not present in those subjects treated at Johns Hopkins. Preprocedure NRS scores did not seem to differ between the radiofrequency treatment and placebo groups (6.5 ± 1.9 and 6.1 ± 1.8 , respectively). However, preprocedural ODI scores did differ between the treatment and placebo groups (37.1 ± 10.6 and 47.9 ± 9.3 , respectively; table 1).

Three patients in the placebo group declined to cross over to the radiofrequency denervation treatment group. Among these three patients, one elected not to receive the true procedure because the placebo treatment was "too painful," and two sought alternative care. Based on the demographic and clinical characteristics, there seemed to be no difference between these patients and those who elected to cross over.

Primary Outcome Measure

A significant difference in the primary outcome, NRS pain score, was detected between the treatment and placebo groups at follow-up (table 2). One month after the procedure, the treatment group had significantly lower NRS scores than the placebo group (2.4 ± 2.0 ; range, 0–8 *vs.* 6.3 ± 2.4 ; range, 2–10; $P < 0.001$). In the placebo group, only two patients at 1 month and no patients at 3 months reported a positive outcome. The primary outcome remained significantly different between the two groups when baseline ODI scores were analyzed as a covariate (coefficient of variation, -3.8 ; 95% confidence interval, -5.8 to -1.8 ; $P < 0.001$). At 3- and 6-month follow-up visits, eight and four patients in the treatment group, respectively, reported NRS pain scores of 2 or less.

In a within-groups analysis, subjects who received radiofrequency treatment reported significantly lower NRS scores at 1, 3, and 6 months after the procedure compared with baseline scores ($P < 0.001$). Patients' pain

Table 2. Numerical Rating Pain Scores Stratified by Treatment Group and Time Point

Time Point	Placebo (n = 14)	Lateral Branch Denervation (n = 14)	Lateral Branch Denervation Crossover (n = 11)
Baseline			
Mean (SD, range)	6.5 (1.9, 3.5–10)	6.1 (1.8, 3–8)	6.3 (2.4, 2–10)
Median (interquartile range)	6 (5.5–7)	6 (5–8)	6 (4–7)
1 Month		*†	*†
Mean (SD, range)	6.3 (2.4, 2–10)	2.4 (2.0, 0–8)	3.6 (2.6, 0–10)
Median (interquartile range)	7 (4–7)	2 (1–3)	3 (2–5)
3 Months	(n = 2)	†	†
Mean (SD, range)	6 (0, 6–6)	2.4 (2.3, 0–7)	2.1 (2.4, 0–7)
Median (interquartile range)	6 (6–6)	1.5 (1–4.5)	1.5 (0.5–3)
6 Months	No data	†	†
Mean (SD, range)		2.6 (2.2, 0–7)	3.1 (2.1, 0–6)
Median (interquartile range)		2 (1.5–2.5)	3.5 (1.5–4)

* $P < 0.05$ as compared with placebo group. † $P < 0.05$ as compared with baseline of the respective group.

scores were reduced by 60, 60, and 57% at 1, 3, and 6 months, respectively. In contrast, the 1-month NRS scores of subjects who received the placebo treatment were unchanged from baseline (6.4 ± 1.9 and 6.3 ± 2.4 , respectively; $P > 0.9$). No further within-groups analysis was performed because of insufficient patients remaining in the placebo group at the 3-month ($n = 2$) and 6-month ($n = 0$) time points.

Eleven subjects in the placebo arm crossed over to the radiofrequency treatment; nine crossed over at 1 month and two crossed over at 3 months. In the crossover phase of this trial, the NRS scores of the placebo group after conventional radiofrequency treatment did not significantly differ from those of the initial radiofrequency group (3.6 ± 2.6 vs. 2.4 ± 2.0 , respectively). Similar to the initial treatment group, the placebo crossover group experienced a significant decrease in NRS scores 1 month (44%), 3 months (67%), and 6 months (52%) after denervation when compared with baseline ($P < 0.001$; table 2).

Secondary Outcome Measures

Oswestry Disability Index. A significant difference in ODI was detected between treatment and placebo groups. One month after the procedure, the treatment

group had lower ODI scores than the placebo group (20.9 ± 10.9 ; range, 4–38 vs. 43.6 ± 14.0 ; range, 16–70; $P < 0.03$). In a within-group analysis, subjects who received radiofrequency treatment reported significantly lower ODI scores at 1, 3, and 6 months when compared with their baseline scores ($P < 0.001$; table 3). Subjects' ODI scores were reduced by 44, 50, and 39% at 1, 3, and 6 months, respectively. In contrast, the mean 1-month ODI score of subjects who received the placebo treatment was unchanged from baseline (43.6 vs. 47.9 ± 9.3 ; range, 28–59, respectively).

In the crossover phase, the placebo group's ODI scores after radiofrequency treatment were reduced by 28, 59, and 49% at 1, 3, and 6 months after the procedure, respectively. ODI scores in the crossover group did not significantly differ from those of the initial treatment group 3 or 6 months after the procedure. However, the initial radiofrequency treatment group had significantly lower ODI scores at 1 month compared with the placebo/crossover group (20.9 vs. 34.3 ± 16.3 ; range, 4–58; $P < 0.03$). The difference between baseline and postprocedure ODI scores in the crossover group was statistically significant 3 and 6 months after the conventional radiofrequency procedure ($P < 0.02$) but not 1 month after denervation.

Table 3. Oswestry Disability Index Score (%) Stratified by Treatment Group and Time Point

Time Point	Placebo (n = 14)	Lateral Branch Denervation (n = 14)	Lateral Branch Denervation Crossover (n = 11)
Baseline			
Mean (SD, range)	47.9 (9.3, 28–59)	37.1 (10.6, 18–49)	43.6 (14, 16–70)
Median (interquartile range)	50.5 (44–56)	41 (26–46)	41 (34–56)
1 Month		*†‡	
Mean (SD, range)	43.6 (14, 16–70)	20.9 (10.9, 4–38)	34.3 (16.2, 4–58)
Median (interquartile range)	41 (34–56)	19 (14–29)	33 (24–46)
3 Months	(n = 2)	‡	‡
Mean (SD, range)	24 (8.5, 18–30)	18.5 (11.6, 0–36)	19.4 (18.1, 0–44)
Median (interquartile range)	24 (18–30)	20 (9.5–27)	16 (4–44)
6 Months	No data	‡	‡
Mean (SD, range)		22.6 (10.6, 7–40)	24.3 (21.0, 0–56)
Median (interquartile range)		20 (16–24)	20 (8–42)

* $P < 0.05$ as compared with placebo group. † $P < 0.05$ as compared with lateral branch denervation crossover group. ‡ $P < 0.05$ as compared with baseline of the respective group.

Table 4. Percent Positive Global Perceived Effect Stratified by Treatment Group and Time Point

Time Point	Placebo (n = 14)	Lateral Branch Denervation (n = 14)	Lateral Branch Denervation Crossover (n = 11)
1 Month		*	
% (95% CI)	21 (2–45)	93 (78–100)	73 (41–100)
3 Months	(n = 2)		
% (95% CI)	0	83 (59–100)	86 (51–100)
6 Months			
% (95% CI)	No data	89 (63–100)	83 (63–100)

* *P* < 0.05 as compared with placebo group.
CI = confidence interval.

Global Perceived Effect. Subjects who received radiofrequency treatment reported a significantly higher proportion of positive GPE responses at 1 month compared with subjects who received placebo treatment (93% vs. 21%; *P* < 0.001). The percentages of subjects remaining in the treatment group at any given time point with a positive GPE were 93% (n = 13), 71% (n = 10), and 89% (n = 8) at 1, 3, and 6 months respectively (table 4). In the crossover phase, the percentages of subjects who underwent conventional denervation (n = 11) remaining in the treatment group at any given time point with a positive GPE were 73% (n = 8), 86% (n = 6), and 83% (n = 5) at 1, 3, and 6 months after the procedure, respectively. The crossover group’s GPE proportion after treatment did not significantly differ from that of the initial radiofrequency group.

Medication Reduction. The radiofrequency treatment group had a significantly higher proportion of patients able to reduce their analgesic medications after the procedure at 1 month compared with subjects who received placebo treatment (77%, 10/14 vs. 8%, 1/11; *P* < 0.001). The percentages of subjects in the radiofrequency group who were able to reduce their analgesic intake were 77% (n = 10), 82% (n = 9), and 67% (n = 5) at 1, 3, and 6 months, respectively (table 5). In the crossover phase (n = 11), the percentages of subjects who reported a decrease in medication requirements were 78% (n = 7), 83% (n = 5), and 60% (n = 3) at 1, 3,

Table 5. Positive Percent Medication Reduction Stratified by Treatment Group and Time Point

Time Point	Placebo (n = 14)	Lateral Branch Denervation (n = 14)	Lateral Branch Denervation Crossover (n = 11)
1 Month		*	*
% (95% CI)	8 (0–25)	77 (52–100)	78 (44–100)
3 Months	(n = 2)		
% (95% CI)	0	82 (55–100)	83 (55–100)
6 Months			
% (95% CI)	No data	67 (28–100)	60 (0–100)

* *P* < 0.05 as compared with placebo group.
CI = confidence interval.

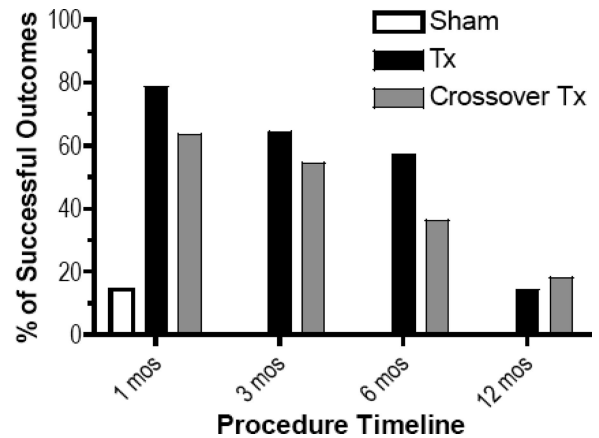


Fig. 4. Bar graph demonstrating the percentage of patients with a successful treatment outcome at various time points. A positive outcome is defined as a reduction of 50% or greater in numerical pain score, a positive global perceived effect, and either a 10-point decrease in Oswestry disability index score or a 4-point decrease coupled with a reduction in medication usage. Tx = treatment.

and 6 months, respectively. The reduction in analgesic intake between the original and crossover radiofrequency groups was not statistically different.

Percent Successful Treatment. The proportion of subjects who experienced a “positive outcome” was significantly higher in the denervation group than in the control group (*P* < 0.001). This success rate persisted at 3- and 6-month follow-up visits (fig. 4). In contrast, only two subjects (14.3%) in the placebo group experienced a positive composite outcome 1 month after the procedure, and none obtained relief at 3 months.

Placebo subjects who crossed over to conventional radiofrequency treatment (n = 11) experienced slightly lower success rates than the original treatment group (7 [64%] vs. 11 [79%] at 1 month, 6 [55%] vs. 9 [64%] at 3 months, and 4 [36%] vs. 8 [57%] at 6 months). However, the proportion of successful procedures in the crossover group was not statistically different than in the initial radiofrequency treatment group.

Duration of Pain Relief. Subjects in the treatment group had a mean duration of pain relief of 5.8 (± 4.2; range, 0–12) months versus 0.7 (± 1.6; range, 0–1) months in the placebo group. The mean duration of relief in the radiofrequency crossover group did not significantly differ from that of the initial treatment group (4.6 ± 4.6; range, 0–12 vs. 5.8 ± 4.2 months, respectively). Two patients each in the cooled and conventional radiofrequency groups continued to experience significant pain relief 1 yr after treatment. Among patients with a successful outcome at any time point, the mean duration of pain relief was 7.9 ± 4.7 months.

Adequacy of Blinding. A disinterested observer querying patients before discharge from their procedure assessed the adequacy of blinding. In the 14 patients in the radiofrequency group, 9 thought they received denervation, 2 thought they received placebo treatment,

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and 3 were unable to guess which group they were randomized to despite prodding. Of the 14 placebo patients, 8 believed they received radiofrequency denervation, 3 thought they received the placebo treatment, and 3 were unsure which group they were randomized to. In the radiofrequency group, the 11 successful outcomes at 1 month were comprised of 8 patients who thought they received denervation, 1 who thought he received placebo treatment, and 2 patients who were unsure which group they were allocated to. Both successful outcomes in the placebo arm at 1 month thought they received denervation.

Complications. A majority of patients reported temporary worsening pain typically lasting between 5 and 10 days after the procedure, which was attributed to procedure-related pain and/or temporary neuritis; the latter may be attenuated by preemptive corticosteroid administration.¹⁹ However, there were no serious complications reported for either the 14 placebo or the 25 radiofrequency treatments. In the radiofrequency treatment group, one patient reported transient nonpainful buttock paresthesias that resolved without therapy.

Discussion

The results of this placebo-controlled study provide preliminary evidence that radiofrequency denervation of the L4 and L5 primary dorsal rami and S1–S3 lateral branches may provide significant pain relief and functional improvement in carefully selected patients with suspected sacroiliac joint pain. At 1, 3, and 6 months after the procedure, 79, 64, and 57% of patients, respectively, obtained pain relief of 50% or greater and clinically relevant functional improvement.

The high success rate in this study may be partially explained by the combination of stringent inclusion criteria used and several innovations over previously described sacroiliac joint denervation techniques. First, rather than targeting individual nerves, this technique endeavored to lesion a continuous volume of tissue lateral to the S1–S3 foramina. The rationale for this approach is based on a recent cadaveric study demonstrating a complex arcade of small nerve fibers anastomosing with multiple primary dorsal rami around each foramina.¹² While individual branch location was shown to vary from level to level and specimen to specimen, they all course through a finite volume of tissue between the lateral edge of the foramen and the joint. By placing electrodes strategically around the foramen, this finite volume of tissue can be heated to neuroablative temperatures, thus severing all nociceptive input converging on the primary dorsal ramus. If single lesions had been used as in previously published studies,^{10–12} some of the afferent input from the sacroiliac joint would likely have remained intact. Creating strip lesions has been previ-

ously advocated for sacroiliac joint lesioning,¹³ but was described using smaller electrodes. Because there is a direct correlation between lesion size and electrode diameter,²⁰ the use of small electrodes increases the likelihood of inadvertently sparing neural input. The probability of three geometrically configured lesions failing to coalesce was further reduced by the use of a water-cooled electrode. Internal cooling enhances lesion size by removing the constraint of high-temperature charring in tissue adjacent to the electrode, thus allowing effective ionic heating at a greater distance.²¹

This study was not powered or designed to detect a difference between outcomes or duration of benefit in patients who underwent denervation with the 17-gauge water-cooled system and those who were treated with the conventional 22-gauge needles, but the slightly higher success rate in the former group (albeit in a nonrandomized comparison), despite a lower inferred placebo response, is consistent with preclinical and clinical data supporting larger lesions for radiofrequency denervation.²² Typically, reported success rates in open-label studies tend to be higher than in controlled studies using similar techniques. This issue needs to be examined in a subsequent randomized trial to determine whether lesion size is an important factor in the success after SI joint radiofrequency denervation.

Because we elected for ethical reasons to treat our placebo-controlled patients with conventional denervation at their 1-month follow-up, one can only speculate about any long-term differences between the treatment and placebo arms. The rationale for this decision was based on pilot data examined before embarking on this study that determined the chances of someone obtaining long-term benefit if none was experienced 1 month after the procedure to be exceedingly low.

Finally, our main inclusion criterion, pain relief of 75% or greater after a single diagnostic SI joint injection, was stricter than that used in some previous studies.^{10–13} This relatively high inclusion threshold may have contributed to our high success rate. Therefore, caution must be heeded when extrapolating these results to conditions wherein less rigorous selection criteria are used. In a prevalence study conducted in 43 patients with low back pain below L5–S1, Schwarzer *et al.*²³ found that 30% obtained pain relief of 75% or greater after low-volume sacroiliac joint infiltration. Because the intent of this trial was to examine the therapeutic benefit of this technique, the use of strict inclusion criteria was deemed justified to limit the number of patients who did not have true sacroiliac joint-related pain (*i.e.*, “false positives”), thereby enhancing the internal validity of the trial. When the beneficial effects of treatment are established, subsequent trials can be conducted under less rigorous conditions to better assess external validity.

Five of 14 patients (36%) in the treatment arm and 5 of 11 (45%) in the open-label crossover group did not

obtain significant improvement 3 months after the procedure. There are several explanations for this, including a short-lived placebo response to the diagnostic block but not the definitive treatment, the high false-positive rate associated with single sacroiliac joint blocks,²⁴ and the fact that the L4–S3 primary dorsal rami do not supply all the innervation to the sacroiliac joint.⁸ In the first two scenarios, the use of double confirmatory diagnostic sacroiliac blocks performed with two different local anesthetics might reduce the failure rate. In the latter case, performing prognostic lateral branch blocks might screen out those patients whose pain emanates from a part of the sacroiliac joint not innervated by the targeted dorsal rami branches. In the two studies whereby both sacroiliac joint and lateral branch blocks were used to screen radiofrequency treatment candidates, the authors reported identical 9-month success rates of 89%.^{10,13}

One disappointing finding is that the high success rate and more aggressive lesion size realized with cooled radiofrequency did not translate into a longer duration of pain relief. Similar to studies conducted with conventional radiofrequency technology,^{1,9,25} the duration of benefit seems to be constrained by nerve regeneration to between 6 months and 1 yr. Future studies should address whether refinements in technique (*e.g.*, creating bipolar lesions) and/or selection criteria (*e.g.*, examining pain referral patterns; the use of controlled sacroiliac joint or prognostic lateral branch blocks) can influence the success rate or duration of pain relief, and what the long-term consequences of repeat denervations are.

One criticism that might be levied against this study is our decision to target five levels for lesioning. The innervation of the sacroiliac joint is a subject of great contention. Whereas some experts have cited contributions to the superior aspect of the joint from as high as L4,^{1,26} other investigators have not confirmed these findings.²⁷ Branches derived from the L4 and L5 dorsal rami may ostensibly innervate not only the sacroiliac joint and surrounding ligaments, but also paraspinal muscles, the L5–S1 zygapophysial joint, and the inferior pole of the L4–L5 zygapophysial joints as well.⁹ Although screening sacroiliac joint blocks were performed on all our patients, the specificity of diagnostic spinal injections is inherently low.^{28,29} In particular, uncontrolled sacroiliac joint blocks are associated with a high false-positive rate.^{24,30} Whether a less aggressive lesioning scheme targeting fewer levels would yield similar results is something that should be addressed in future clinical trials.

There are several flaws in this study that must be addressed. First, although the power analysis designed to detect significant differences between the groups was borne out by positive results, the small number of patients enrolled in this study had the unintended consequence of creating two groups of patients with potentially clinically significant differences in several variables known to influence outcome, including baseline func-

tionality (*i.e.*, ODI scores), previous spine surgery, and disability or worker's compensation cases.^{15,31,32} Recruiting more patients in a bicenter pilot study to redress these inequities when a beneficial effect for the studied treatment has purportedly been proved would undermine the goodwill of subjects who were paid nothing for their participation. Large multicenter studies, which are needed to confirm our preliminary results, should be adequately powered to address these issues.

The small numbers of patients enrolled also leaves unresolved questions regarding the safety of cooled radiofrequency. Fourteen patients is an insufficient number to detect the small but clinically significant risk of a neurologic complication, which may be magnified by the more ambitious lesioning scheme used here. Caution should thus be taken until large numbers of patients are safely treated by multiple clinicians.

A second flaw revolves around our testing of blinding adequacy. The effectiveness of blinding in this study was evaluated shortly after the conclusion of the procedure, when the effects of the local anesthetic were still active. A more valid indicator of the adequacy of blinding might have been to query patients several days after the procedure, when the cues of actual treatment (*e.g.*, procedure-related pain) were more manifest.

In summary, the results of this placebo-controlled study provide preliminary support for the use of radiofrequency denervation to treat presumptive sacroiliac joint pain. Larger, multicenter studies with long-term follow-up and comprehensive outcome measures are needed to confirm our findings, further establish safety, and determine how best to identify candidates for this treatment.

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