Outcome Predictors for Sacroiliac Joint (Lateral Branch) Radiofrequency Denervation

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Background and Objective: Sacroiliac (SI) joint pain is a challenging condition characterized by limited treatment options. Recently, numerous studies have reported excellent intermediate-term outcomes after lateral-branch radiofrequency (RF) denervation, but these studies are characterized by wide variability in technique, selection criteria, and patient characteristics. The purpose of this study was to determine whether any demographic or clinical variables can be used to predict SI joint RF denervation outcome.

Methods: Seventy-seven patients with refractory, injection-confirmed SI joint pain underwent SI joint denervation at 2 academic institutions. A composite binary variable "successful" outcome was predefined as greater than 50% reduction in pain lasting at least 6 months coupled with a positive global perceived effect. Secondary outcome measures included Oswestry Disability Index scores, medication reduction, and retention on active duty for soldiers. Factors retrospectively evaluated for their association with outcome included demographic variables, duration of pain, opioid usage, pain referral pattern, physical examination signs, number of blocks and percentage of pain relief after SI joint injection, prognostic lateral-branch blocks, previous surgery, levels lesioned, RF technique, disability status, and coexisting medical conditions.

Results: Forty patients (52%) obtained a positive outcome. In multivariate analysis, preprocedure pain intensity, age older than 65 years, and pain radiating below the knee were significant predictors of failure. A trend was noted whereby patients receiving regular opioid therapy were more likely to experience a negative outcome. The use of cooled, rather than conventional RF, was associated with a higher percentage of positive outcomes.

Conclusions: Whereas several factors were found to influence outcome, no single clinical variable reliably predicted treatment results. The use of more stringent selection criteria was not associated with better outcomes.

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Sacroiliac (SI) joint pain represents one of the more common causes of axial low-back pain (LBP), comprising between 15% to 25% of cases.[1,2] In addition to its frequency, 2 other aspects that make it particularly challenging for clinicians are its diagnostic ambiguity and lack of therapeutic options for long-term improvement. Whereas some investigators advocate complex examination algorithms as a means to diagnose a painful SI joint,[3–5] most experts maintain low-volume intra-articular anesthetic injections to be the only reliable diagnostic modality.[1,2,6]

The treatment of SI joint pain treatment is a difficult task with no easy solution. In addition to injections and pharmacotherapy, other interventions that have been used with mixed results include surgical fixation, viscosupplementation, prolotherapy, and chiropractic manipulation.[7–12] In recent years, 1 new treatment that has spawned intense interest in the pain management community is lateral-branch radiofrequency (RF) denervation. First described 5 years ago,[13,14] numerous uncontrolled[15–17] and controlled[18] studies have since been published on this procedure, reporting unwaveringly auspicious results. However, these studies are characterized by wide disparities in technique, selection criteria, and standards of success.

Selecting appropriate candidates is important for any interventional pain management procedure,[19–24] but is essential for new innovations, whereby negative results threaten to undermine the very concept behind treatment. In light of its size, variable pain referral zones, and the controversy regarding innervation, one might reasonably argue that proper selection criteria are even more critical for SI joint denervation.[25,26]

To illustrate, there is considerable variability in the pain radiation patterns from the largest spinal joint in the body. In uncontrolled studies evaluating SI joint denervation, various investigators have used different referral maps in their inclusion criteria.[13,27,28] Because lateral-branch denervation does not interrupt the afferent input from the entire SI joint, and different aspects of the joint indubitably possess different referral zones, identifying those radiation patterns most amenable to RF lesioning could save many patients an unnecessary procedure. Considering that certain inciting events may also be associated with specific injury patterns, attempting to distinguish which inciting events best correlate with outcome is also a worthwhile endeavor.

In view of this quandary, some investigators have used "prognostic" lateral-branch blocks (LBBs) done with local anesthetic to screen RF candidates,[13,16] whereas others have used confirmatory SI joint injections because of the high false-positive rate associated with uncontrolled blocks.[29,30] Yet, most studies have not used any confirmatory or prognostic procedure before proceeding to definitive treatment.[15,18,27,28] Similar discrepancies exist for the nerves targeted and pain relief cut-off thresholds for designating a diagnostic block as positive. In an attempt to improve selection criteria for SI joint denervation,

we performed a dual-center study whose aim was to identify those demographic and clinical variables associated with outcome.

PATIENTS AND METHODS

Permission to conduct this study was granted by the internal review boards of the Johns Hopkins Medical Institutions (JHMI) and Walter Reed Army Medical Center (WRAMC). The medical records of 86 consecutive patients who underwent lower lumbar primary dorsal rami and S1-S3 lateral-branch RF denervation between 2002 and 2007 were examined for inclusion. These records were selected from among approximately 340 patients who underwent intra-articular SI joint injections during that period. The 2 most common reasons for not performing denervation on patients with suspected SI joint pain were failure to obtain adequate relief from the SI joint injection and prolonged relief from the block. Nine patients who did undergo the denervation procedure with ambiguous records and incomplete outcome documentation, or who failed to meet designated inclusion criteria, were excluded from consideration, leaving 77 subjects for data analysis.

Inclusion criteria were age 18 years or older, chronic LBP of 3 months' duration or longer, absence of focal neurologic signs or symptoms, and 50% or greater pain relief after at least 1 low-volume (≤2 mL) local anesthetic intra-articular SI joint block. Excluded from the study were patients with a known, specific cause of LBP (eg, spondylolisthesis or significant spinal stenosis), untreated coagulopathy, less than 50% pain relief after either SI joint or LBB, and concomitant medical (eg, poorly controlled cardiac condition) or psychiatric illness (eg, untreated depression) likely to endanger the patient or compromise treatment outcome.

Diagnostic SI 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 slightly oblique or anteroposterior view. Placement within the joint capsule was ascertained in all cases by an SI joint arthrogram. After confirmation of placement, a solution containing 2 mL or less of bupivacaine 0.5% mixed with 40 to 60 mg of 40 mg/mL depomethylprednisolone was administered. After the injection, patients were instructed to engage in normal activities and fill out 0-to-10 numerical rating scale (NRS) pain diaries every half-hour over the ensuing 6 hours. Only those patients who experienced 50% or greater pain relief while performing their normal activities of daily living, but whose pain returned to near baseline within 6 months, were considered for SI joint denervation.

Thirty-five patients underwent a second SI joint injection at the discretion of the attending physician. Reasons for performing subsequent SI joint injection(s) included purportedly better diagnostic/prognostic utility, intermediate or prolonged (≥3 months) pain relief, and patient preference. The number of injections in these patients ranged from 2 to 5, with the latter occurring in 1 woman who initially experienced long-term benefit from the blocks that diminished over time. The interval between blocks ranged from 3 weeks to slightly more than 8 months. In those patients who underwent multiple SI joint blocks, the percentage of pain relief was calculated based on all available pain diaries. Patients who received an SI joint injection(s) in the remote past with no documentation of block parameters or analgesic response were categorized separately.

Lateral-Branch Blocks

Twenty-four subjects underwent prognostic LBB at the discretion of the attending physician. Aside from logistical reasons (ie, extensive travel time involved) and/or physician preference, no set criteria were used to select patients for LBB. For L4 and L5 primary dorsal rami blocks, 22-gauge needles were placed at the junction of the L5 superior articular and transverse processes (L4), and sacral ala (L5), respectively, as per our previously described technique.[19] For S1-S3 LBB, 22-gauge spinal needles were placed approximately 5 mm from the lateral edge of the foramen in either the 3-o'clock position for right-sided blocks, or the 9-o'clock position for left-sided blocks, using our previously described technique (Fig. 1).[13] Once correct needle position was determined by fluoroscopy and contrast injection, 0.5 mL of 0.5% bupivacaine was injected at each level. After a brief stay (≤20min) in the recovery area, patients were instructed to engage in normal activities and fill out 0- to 10-point NRS pain diaries every half-hour. A positive block was designated as 50% or greater pain relief during performance of normal activities of daily living over the 6 hours after discharge. No patient received intravenous sedation for either the diagnostic SI joint or prognostic LBB.

Radiofrequency Denervation

Radiofrequency denervation was performed as an ambulatory procedure using superficial anesthesia and, if necessary, intravenous sedation. Lesioning of the L4 and L5 primary dorsal rami was accomplished by inserting 22-gauge SMK-C10 (Radionics, Burlington, Mass) cannulas with 5-mm active tips parallel to the course of the nerves until bone was contacted at the junction between the superior border of the transverse and superior articular processes for L4, and in the groove of the sacral ala for L5, as per previously published studies.[18,19] At each level, correct placement of the electrode in proximity to the target nerve was confirmed using electrostimulation at 50 Hz, with concordant sensation achieved at 0.5 V or less. Before

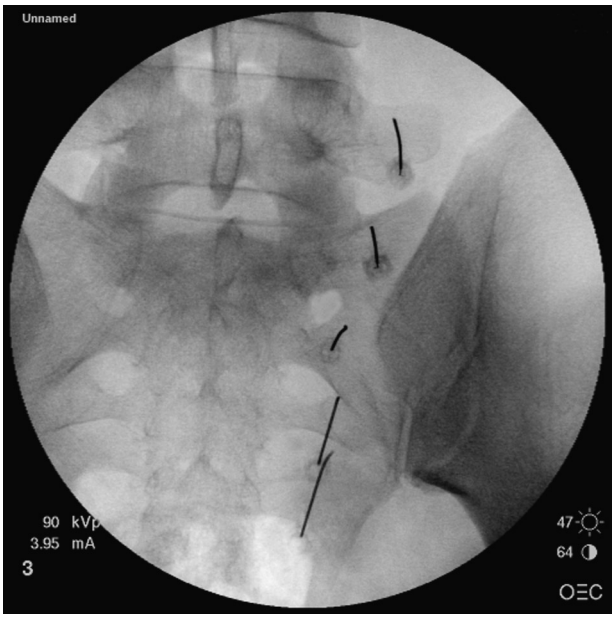

FIGURE 1. Anteroposterior fluoroscopic image demonstrating needle placement for diagnostic L4 and L5 primary dorsal rami and S1-S3 LBBs.

lesioning, the absence of leg contractions was verified with electrostimulation at 2 Hz. After satisfactory electrode placement, 0.5 mL of lidocaine 2% mixed with 5 mg of methylprednisolone was injected through each cannula to reduce thermal pain and prevent neuritis. The RF probe was then reinserted, and a 90-second, 80°C lesion was made using an RF generator (Electrothermal 20S Spine System; Smith and Nephew, Andover, Mass; or Radionics RF Lesion Generator System, model RFG-3C, Radionics, Valleylab, Boulder, Colo). Six patients did not undergo L4 denervation because of physician preference. The outcomes for these patients are noted separately.

For S1-S3 lateral-branch denervation, either 22-gauge SMK-C10 or 17-gauge cooled electrodes with 4-mm active tips (Baylis Medical, Montreal, Quebec, Canada) were inserted perpendicular to the bone between 3 and 5 mm from the perimeter of the foramina in a semicircumferential pattern. In approximately 10% of cases, 22-gauge "finder" needles were inserted into indiscernible foramen, usually at S1, to facilitate electrode placement. In 1 obese patient on high-dose opioids, a bowel preparation was used to reduce bowel gas, which may camouflage foramina in certain contexts.

At S1 and S2, 2 lesions were created; at S3, 2 lesions were always made. For right-sided S1 and S2 procedures, lesion sites varied between the 1:00 and 5:30 positions on the face of a clock; on the left, the target sites were located between 6:30 and 11:00 (Figs. 2, 3). The cutoff for sensory stimulation was 0.5 V or less and was done only for the first needle placement at each foramen. Before lesioning, 0.5 mL of lidocaine 2% mixed with 5 mg of methylprednisolone was administered at each 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. Once adequate needle position was confirmed, the electrodes were sequentially reinserted into the cannulas. When SMK electrodes were used, 90-second, 80°C lesions were created. For cases involving the large-bore, 75-mm electrodes, 2.5-minute lesions were made using a water-cooled heating system (Pain Management SInergy System; Baylis Medical). The internally cooled electrodes created a lesion 8 to 10 mm in diameter, with the depth extending distal to the electrode tip, compared with 3- to 4-mm lesions that do not extend much past the tip when conventional needles are used. The decision regarding which system to use was based on availability, physician preference, and reimbursement considerations.

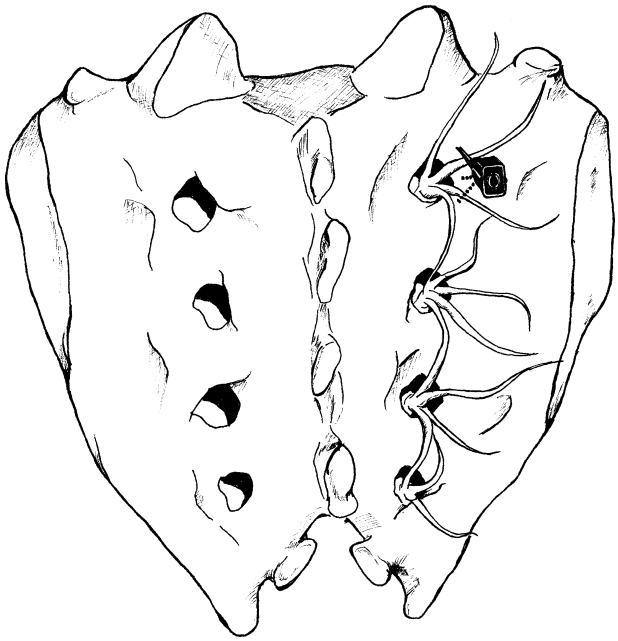

FIGURE 2. Schematic drawing demonstrating needle placement at approximately 1:00, 3:00, and 5:30 positions on the face of a clock for right S1 lateral-branch RF denervation. Drawing by Cherry Crooks.

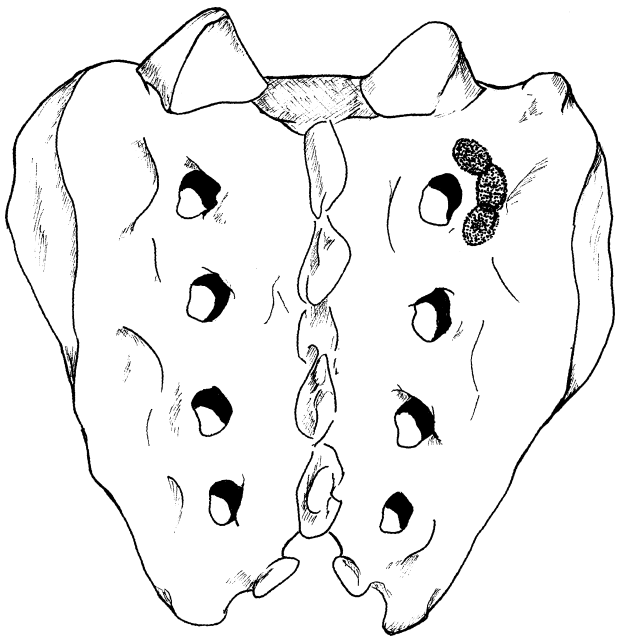

FIGURE 3. Schematic drawing showing the anticipated continuous strip lesion from right-sided S1 lateral-branch RF denervation. Drawing by Cherry Crooks.

Outcome Measures and Statistical Analysis

All pain scores were measured using 0- to 10-point NRS. A successful treatment was defined as a 50% or greater average reduction in preprocedure NRS pain score that persisted at least 6 months after the procedure, coupled with a positive satisfaction rating. Secondary outcome measures included Oswestry Disability Index (ODI, version 2.0) scores, medication reduction (defined as a 20% reduction in opioid use or complete cessation of a nonopioid analgesic),[31] and patient satisfaction. When noted, continuous outcome measures (eg, NRS and ODI scores) reflect 6-month scores in patients with successful outcomes and scores recorded at the visit in which the subject exited the study for unsuccessful outcomes (ie, 3-month scores in subjects whose pain relief lasted between 2 and 3 months). In addition to treatment outcome, the other demographic and clinical variables recorded for analysis were age, sex, duration of pain, opioid usage, referral pattern (ie, exclusively axial, radiating above the knee, or extending below the knee), presence of groin pain, presence of SI joint tenderness, response to provocative maneuvers (Patrick and Gaenslen tests), percentage of relief with SI joint blocks (≥50% or ≥80%), use of prognostic LBBs, number of SI joint blocks, etiology, smoking history, history of diabetes, obesity (body mass index ≥30 kg/m^2), prior and type of back surgery, workers' compensation or disability status (or pending medical evaluation board for soldiers),

TABLE 1. Patient Characteristics by Study Center

	JHMI (n = 40)	WRAMC (n = 37)	*P*
Positive outcome (≥ 50% decrease in pain)	22 (55.0)	18 (48.7, n = 36)	0.50
Mean numeric rating scale pain intensity			
Preprocedure (median, SD, 95% CI, range)	6.9 (7, 1.9, 6.3–7.5, 3–10)	5.8 (6, 1.9, 5.2–6.5, 3–9)	0.02
Postprocedure (median, SD, 95% CI, range)	4.5 (4.5, 2.8, 3.6–5.4, 0–10)	4.6 (5.0, 2.2, 3.9–5.4, 1–9; n = 36)	0.88
Mean ODI score	n = 28	n = 17	
Preprocedure (mean, median, SD, 95% CI, range)	45.7 (47.5, 10.5, 41.6–49.8, 24–64)	37.5 (40.0, 14.3, 30.2–44.9, 16–74)	0.03
Postprocedure (mean, median, SD, 95% CI, range)	33.9 (32, 18.1, 26.9–41.0, 0–70)	24.6 (22, 10.6, 19.2–30.0, 10–40)	0.06
Patient satisfaction	31 (77.5)	25 (83.3)	0.55
Medication reduction*	13 (34.2; n = 38)	4 (11.1; n = 34)	0.03
Mean age (median, SD, range), y	54.5 (55.5, 17.0, 27–89)	53.6 (52.0, 14.7, 31–84)	0.81
Age ≥65 y	11 (27.5)	11 (29.7)	0.83
Sex			0.79
Female	27 (50.9)	26 (70.3)	
Male	13 (32.5)	11 (29.7)	
Duration of symptoms, mean (median, SD, 95% CI, range), y	8.2 (5.5, 7.6, 5.8–10.6, 1–35; n = 40)	8.1 (4, 9.3, 0.2–40, 4.7–11.5; n = 31)	0.98
Etiology			0.05
Motor vehicle accident	5 (12.5)	4 (10.8)	
Fall	11 (27.5)	3 (8.1)	
Repetitive strain	4 (10.0)	1 (2.7)	
Pregnancy	2 (5.0)	1 (2.7)	
Unknown	18 (45.0)	28 (75.7)	
Referral pattern†			0.19
Axial back pain only	17 (42.5)	23 (62.2)	
Above knee	14 (35.0)	7 (18.9)	
Below knee	9 (22.5)	7 (18.9)	
Groin	8 (20.0)	0 (0.0)	0.005
SI joint tenderness	33 (84.6, n = 39)	34 (94.4, n = 36)	0.27
Positive Patrick test	17 (53.1, n = 32)	24 (80.0, n = 30)	0.03
Positive Gaenslen test	2 (20.0, n = 10)	9 (60.0, n = 15)	0.10
Diabetes	7 (17.5)	7 (18.9)	0.87
Obesity (≥30 kg/m^2)	15 (37.5)	11 (29.7)	0.47
Smoker	11 (27.5)	6 (16.7, n = 36)	0.26
Prior surgery			0.12
None	28 (70.0)	25 (67.6)	
Fusion	9 (22.5)	4 (10.8)	
Decompression procedure	3 (7.5)	8 (21.6)	
Regular opioid use‡	26 (65.0)	12 (32.4)	0.004
No. diagnostic SI joint injections			<0.0001
Undocumented§	4 (10.0)	1 (2.7)	
1	26 (65.0)	11 (29.7)	
>2	10 (25.0)	25 (67.6)	
Prognostic LBBs performed	7 (17.5)	17 (46.0)	0.0007
Percent relief from SI joint block	n = 35	n = 31	0.65
50%–79%	20 (57.1)	16 (51.6)	
≥ 80%	15 (42.9)	15 (48.4)	
Workers' compensation or disability claim	19 (47.5)	11 (29.7)	0.11
Bilateral procedure	3 (7.5)	0 (0.0)	0.24
RF technique			
Conventional lesions	29 (72.5)	28 (75.7)	0.751

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TABLE 1. *(Continued)*

	JHMI (n = 40)	WRAMC (n = 37)	*P*
Cooled lesions	11 (27.5)	9 (24.3)	
Vertebral levels treated			0.68
L4-S3	36 (90.0)	35 (94.6)	
L5-S3	4 (10.0)	2 (5.4)	

Values are presented as n (%), unless specified otherwise.

*Cessation of nonopioid analgesic or >20% reduction in opioid.

†Referral patterns are mutually exclusive except to groin.

‡Fifteen milligrams or greater oral morphine equivalents per day.

§Injection done in the remote past without documentation.

retention on active duty for service members, number of levels lesioned (L4-S3 or L5-S3), RF technique (ie, cooled or conventional), and, for procedures done at WRAMC, active-duty status.

Statistical analyses were performed using Stata 9.2 (Stata Statistical Software: release 9; StataCorp 2005, College Station, Tex). Statistical significance was assessed using *t* tests for continuous variables, and Pearson χ^2 and Fisher exact tests for categorical variables. $P \leq 0.05$ or a 95% confidence interval (CI) for the odds ratio that did not include 1.0 was considered statistically significant. Univariate and multivariate regression analyses were used to quantify the relation between a successful outcome and the patient's clinical and demographic characteristics. Because the outcome variable was binary, logistic regression techniques were used. All variables were included in the multivariate model, and the explanatory variables modeled were chosen based on hypothesized relation to outcome. Consequently, all terms were retained in the model regardless of statistical significance, except those that were collinear with other terms or that perfectly predicted outcome. The baseline set of covariates was as follows: preprocedure pain of new onset and mild intensity (NRS 1-3), age younger than 65 years, nondiabetic, nonobese, nonsmoker, female, pain located only in axial back/buttock, absence of SI joint tenderness, no prior surgery, no regular opioid use, no prior SI joint injections or LBB, conventional RF technology, and no workers' compensation or disability claim(s).

RESULTS

The clinical and demographic characteristics of the study subjects, stratified by institution and outcome, are shown in Tables 1 and 2. With the exceptions of regular opioid use and disability claims, which were lower in the WRAMC cohort, there were no significant differences between the study subjects at each institution; thus, the data were combined. The mean age of patients was 54.1 years (SD, 15.8 years; range, 27–89 years), 69% were female, and the average duration of pain was 8.2 years (SD, 08.3 years; range, 0.3–40 years). Preprocedure NRS and ODI scores demonstrated moderate pain and functional limitation, averaging 6.4 (SD, 2.0; range, 3–10) and 42.6 (SD, 12.6; range, 16–74), respectively. Forty percent of the patients could identify a specific inciting event, the 2 most common of which were falls (n = 14) and motor vehicle accidents (n = 9). A slight majority of patients (n = 40) reported pain localized to their back and/or buttock, with the second most frequent pain referral pattern being back pain extending into the thigh. Eighty-nine percent of the patients experienced SI joint tenderness, and 66% had a positive Patrick test. Diabetes, obesity, smoking, and prior surgery were relatively uncommon. Whereas 65% of the JHMI group reported regular opioid use, only 32% of the WRAMC group used these drugs. Bilateral procedures were done in 5% of the cohort, and 92% of the patients had lesions done at the L4-S3 levels (8% had lesions limited to L5-S3).

Statistically significant reductions in NRS and ODI scores were noted collectively and at each institution. Among the entire study cohort, both NRS ($P < 0.0001$) and ODI ($P = 0.0001$) scores declined an average of 40%. At JHMI, reductions in NRS and ODI scores averaged 53% ($P < 0.0001$) and 35% ($P = 0.005$), respectively. At WRAMC, the respective improvements in pain and functional indices were 27% ($P = 0.01$) and 53% ($P = 0.005$). Although 80% of patients were satisfied with their results, only 23% reduced their opioid intake or completely stopped a nonopioid analgesic. All 11 active-duty service members were retained on active duty. Overall, 52% of subjects reported 50% or greater pain relief.

Broken down by outcome, the mean preprocedure pain score was 6.0 in patients with a successful procedure versus 6.8 in those with an unsuccessful outcome ($P = 0.09$). The duration of symptoms was more than 2 years less in patients whose treatment was successful ($P = 0.2$), and patients older than 65 years were more likely to have a negative outcome ($P = 0.08$). Fifty-seven percent of patients who had a negative outcome used opioid analgesics regularly, compared with 44% of successfully treated patients ($P = 0.2$). Whereas the percentage of pain relief (ie, >80% or <80%) from LBB and SI joint injections were positively and statistically significantly correlated ($r = 0.64$, $P = 0.01$), the percentage of relief from LBB negatively correlated with treatment success ($r = -0.36$, $P = 0.11$). Sixty-five percent of the 20 patients who underwent the cooled RF procedure experienced a positive outcome versus 47% in the conventional group ($P = 0.18$). Neither physical examination signs, previous surgery, etiology, concomitant medical illness (eg, diabetes), disability claims, number of SI joint blocks, nor previous prognostic LBB were predictive of outcome.

The results of the logistic regression model estimating the relation between demographic and clinical characteristics and outcome are shown in Table 3. This model accounted for 31% of the variability in the dependent variable (ie, outcome). In the univariate analyses, none of the terms were statistically significant. In multivariate analysis, preprocedure pain intensity, age 65 years or older, and pain referral below the knee were each statistically significant predictors of failure. Specifically, each unit increase in preprocedure pain intensity increased the odds of failure by 0.65; being older than 65 years was associated with a 90% increase in the odds of failure, and pain radiating below the knee pain with an 89% increase. The only variable that successfully predicted success in multivariate analysis was the use of cooled RF technology.

TABLE 2. Patient Characteristics by Outcome

	Negative Outcome (n = 37)	Positive Outcome (n = 40)	*P*
Numeric rating scale pain intensity			
Preprocedure, mean (median, SD, 95% CI, range)	6.8 (7.0, 2.0, 6.1–7.4, 3–10)	6.0 (6.0, 1.9, 5.4–6.6, 3–10)	0.09
Postprocedure, mean (median, SD, 95% CI, range)	6.5 (6.0, 1.7, 5.9–7.1, 4–10)	2.7 (3.0, 1.6, 2.2–3.3, 0–7; n = 39)	<0.0001
ODI score			
Preprocedure, mean (median, SD, 95% CI, range)	43.8 (45.0, 13.5, 37.1–50.5, 18–64; n = 18)	41.8 (44.0, 12.2, 37.0–46.6, 16–74; n = 27)	0.60
Postprocedure, mean (median, SD, 95% CI, range)	41.5 (38.0, 16.0, 33.5–49.5, 22–70)	23.0 (20.0, 11.7, 18.4–27.6, 0–56)	0.0001
Patient satisfaction	17 (54.8, n = 31)	39 (100.0, n = 39)	<0.0001
Medication reduction*	4 (10.8, n = 37)	13 (35.1, n = 37)	0.03
Age ≥65 y	14 (37.8)	8 (20.0)	0.08
Sex			0.79
Female	26 (70.3)	26 (66.7)	
Male	11 (29.7)	13 (32.5)	
Duration of symptoms, mean (median, SD, 95% CI, range), y	9.4 (5.0, 9.0, 6.3–12.4, 1–40; n = 35)	7.0 (4.5, 7.5, 4.4–9.5, 0.2–35; n = 36)	0.23
Etiology			0.45
Motor vehicle accident	6 (16.2)	3 (7.5)	
Fall	7 (18.9)	7 (17.5)	
Repetitive strain	2 (5.4)	3 (7.5)	
Pregnancy	0 (0.0)	3 (7.5)	
Unknown	22 (59.4)	24 (60.0)	
Referral pattern†			0.42
Axial back pain only	18 (48.7)	22 (55.0)	
Above knee	9 (24.3)	12 (30.0)	
Below knee	10 (27.0)	6 (15.0)	
Groin	5 (13.5)	3 (7.5)	0.47
SI joint tenderness	32 (88.9, n = 36)	35 (89.7, n = 39)	1.00
Positive Patrick test	21 (70.0, n = 30)	20 (62.5, n = 32)	0.53
Positive Gaenslen test	6 (46.2, n = 13)	5 (41.7, n = 12)	0.82
Diabetes	8 (21.6)	6 (15.0)	0.45
Obesity (≥30 kg/m^2)	13 (35.1)	13 (32.5)	0.81
Smoker	9 (24.3)	8 (20.5, n = 39)	0.69
Prior surgery			0.69
None	27 (73.0)	26 (65.0)	
Fusion	6 (16.2)	7 (17.5)	
Decompression procedure	4 (10.8)	7 (17.5)	
Regular opioid use‡	21 (56.8)	17 (42.5)	0.21
No. diagnostic SI joint injections			0.72
Undocumented§	3 (8.1)	2 (5.0)	
1	16 (43.2)	21 (52.5)	
>2	18 (48.7)	17 (42.5)	
Prognostic LBBs performed	12 (32.4)	12 (30.0)	0.82
Percent relief from SI joint block	n = 31	n = 35	0.59
50%–79%	18 (58.1)	18 (51.4)	
≥80%	13 (41.9)	17 (48.6)	
Workers' compensation or disability claim	15 (40.5)	15 (37.5)	0.79
Institution			0.58
JHMI	18 (48.7)	22 (55.0)	
WRAMC	19 (51.4)	18 (45.0)	
Active-duty military	5 (26.3, n = 19)	6 (33.3, n = 18)	0.64
Bilateral procedure	1 (2.7, n = 37)	2 (5.0, n = 40)	1.00

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TABLE 2. *(Continued)*

	Negative Outcome (n = 37)	Positive Outcome (n = 40)	*P*
RF technique			
Conventional lesions	30 (81.1)	27 (67.5)	0.18
Cooled lesions	7 (18.9)	13 (32.5)	
Vertebral levels treated			
L4-S3	34 (91.9)	37 (92.5)	1.00
L5-S3	3 (8.1)	3 (7.5)	

Values are presented as n (%), unless specified otherwise.

*Cessation of nonopioid analgesic or >20% reduction in opioid.

†Referral patterns are mutually exclusive except to groin.

‡>15 mg oral morphine equivalents/d.

§Injection done in remote past resulting in "good reported relief" without documentation.

TABLE 3. Association of Factors With Successful Outcome (Multivariate r^2 = 0.3077; n = 68)

	Unadjusted Odds Ratio	*P*	95% CI	Adjusted Odds Ratio	*P*	95% CI
Preprocedure pain intensity	0.82	0.09	0.64–1.04	0.59	0.03	0.44–1.02
Preprocedure ODI score	0.99	0.60	0.94–1.04	—	—	—
Age ≥65 y	0.41	0.09	0.15–1.14	0.07	0.02	0.01–0.66
Male sex	1.14	0.79	0.43–2.99	0.34	0.23	0.06–2.01
Duration of symptoms, y	0.96	0.23	0.91–1.02	0.99	0.86	0.90–1.09
Etiology						
Motor vehicle accident	0.46	0.31	0.10–2.06	—	—	—
Fall	0.92	0.89	0.28–3.03	—	—	—
Repetitive strain	1.38	0.74	0.21–9.01	—	—	—
Pregnancy (predicted success perfectly)	—	—	—	—	—	—
Referral pattern						
Above knee	1.10	0.87	0.38–3.17	0.85	0.83	0.18–3.89
Below knee	0.49	0.24	0.15–1.61	0.14	0.06	0.02–1.09
Groin	0.52	0.39	0.11–2.34	0.21	0.16	0.02–1.84
SI joint tenderness	1.09	0.91	0.25–4.74	1.23	0.87	0.10–14.73
Positive Patrick test	0.71	0.53	0.25–2.06	—	—	—
Positive Gaenslen test	0.83	0.82	0.17–4.06	—	—	—
Diabetes	0.64	0.45	0.20–2.06	1.55	0.66	0.22–11.06
Obesity (≥30 kg/m^2)	0.89	0.81	0.35–2.29	1.19	0.84	0.22–6.30
Smoker	0.80	0.69	0.27–2.37	0.84	0.83	0.17–4.25
Prior surgery						
Fusion	1.21	0.76	0.36–4.09	7.12	0.13	0.55–92.69
Decompression procedure	1.82	0.38	0.48–6.95	3.41	0.29	0.35–33.03
Regular opioid use (≥15 mg oral morphine equivalents per day)	0.56	0.21	0.23–1.39	0.26	0.09	0.05–1.22
No. diagnostic SI joint injections						
1	1.97	0.49	0.29–13.2	2.32	0.64	0.07–77.51
≥2	1.42	0.72	0.21–9.55	2.43	0.63	0.06–91.08
Prognostic LBBs performed	0.89	0.82	0.34–2.34	7.22	0.06	0.94–55.21
≥80% relief from SI joint block	1.30	0.59	0.49–3.46	—	—	—
Active-duty military	1.40	0.64	0.34–5.76	—	—	—
Levels treated	0.92	0.92	0.17–4.87	—	—	—
Bilateral procedure	1.89	0.61	0.16–21.81	—	—	—
RF technique	2.06	0.179	0.72–5.93	8.28	0.02	1.33–51.49

Baseline reference characteristics: mild pain intensity (NRS 1-3); younger than 65 years; female; duration = 0 years; pain in axial back/buttock only; pain not referred to groin; no SI joint tenderness; patient was not diabetic, obese, or a smoker; no prior surgery; no regular opioid use; any prior diagnostic SI joint injections were done in remote past without pain diary or documentation; no prognostic LBBs performed; conventional RF; and no workers' compensation or disability claim.

Analysis was controlled for treatment center. Etiology (including pregnancy), Gaenslen test, and levels treated were dropped from the multivariate model due to perfect prediction of outcome.

Five complications were noted in the study. These included 3 cases of temporary, self-limiting (<14 days) paresthesias; 1 case of hyperglycemia requiring increased insulin use for 3 days in a diabetic patient; and 1 superficial skin infection that resolved with antibiotics.

DISCUSSION

The main purpose of this study was to identify factors associated with SI joint RF denervation outcomes. This is a laudable endeavor considering the time, expense, and inherent risks involved in lateral-branch lesioning. The observation that no single variable strongly predicted outcome suggests that most patients with SI joint pain, irrespective of cause, can potentially benefit from the procedure. Nonetheless, several trends did emerge that warrant attention.

The 2 most notable trends were the negative associations found between age and duration of symptoms, and outcome. An inverse correlation between duration of symptoms and pain reduction has been previously described not only for RF denervation,[19] but also for other therapeutic interventions.[32–34] This may reflect the extent of neuroplasticity that develops secondary to persistent pain, a greater degree of intractability, or a higher prevalence of concomitant psychosocial issues.[35,36] With respect to age, prior studies have not identified a reliable independent relationship with outcome.[19,22,33,34] One plausible explanation for this association is that elderly patients are more likely to experience progressive arthritic SI joint pain rather than the extra-articular causes that show a predilection toward younger patients and tend to be self-limiting. Support for this hypothesis stems from the observation that a smaller percentage of elderly patients attributed their symptoms to a specific traumatic event (31.8%, $P = 0.03$). In another unsurprising finding, opioid use was found to be a weak predictor of negative outcome. This result is consistent with other studies examining predictive variables for denervation outcomes.[19,22] Possible reasons for this finding include subclinical nociceptor sensitization, a higher incidence of overlying psychopathology, and secondary gain issues.[37–40]

The only positive predictor of a successful outcome was the use of cooled RF technology. Although this study was not designed to detect a difference between cooled and conventional RF lesioning, this finding is not surprising. The lateral branches supplying afferent information from pain-generating SI joints form a complex arcade of small nerve fibers anastomosing with multiple dorsal rami at each foramen. The location of these branches is unpredictable, varying from patient to patient, side to side, and level to level.[14] Using small conventional lesions, some of this nociceptive input is likely to be missed. But cooled-probe technology, which more than doubles the lesion diameter to approximately 10 mm, may be more likely to sever all nociceptive input converging on the sacral foramen. Because of the lesion size created by this aggressive approach, we did not attempt to use it at L4 or L5 and risk heat injury to the ventral rami. In the absence of a head-to-head randomized comparison between techniques, no definitive conclusions should be drawn regarding the superiority of cooled electrodes.

One unexpected finding was the lack of association between a successful outcome and factors that might logically seem to correlate with treatment prognosis including positive LBB, multiple positive SI joint blocks, and the percentage of pain relief resulting from the diagnostic block(s). Yet, these findings are consistent with a prior study demonstrating no significant association between the degree of pain relief after a single local anesthetic medial branch block and lumbar facet RF outcomes[41] and the uniformly high success rates reported in previous SI joint denervation studies regardless of the use of multiple prognostic blocks.[13,15,17] When the risks, costs, and possibility of a false-negative result are taken into account, these findings suggest that a single diagnostic SI joint anesthetic block is the most cost-effective screening method.

Another interesting observation was the higher percentage of unsuccessful outcomes in patients with referred pain radiating below the knee. This trend is consistent with a study by Slipman et al,[25] revealing that less than 30% of SI joint cases produce pain distal to the knee, and suggests that a least some of these patients may have been misdiagnosed. Previous studies have revealed a high false-positive rate associated with uncontrolled SI joint blocks.[29,30] An alternative explanation is that distal leg pain is transmitted by a portion of the SI joint not amenable to lateral-branch lesioning. However, the absence of any relationship between LBB and outcome mitigates against this hypothesis.

Finally, some may question our aggressive lesioning strategy involving L4. The innervation of the SI joint is a subject of great controversy. Whereas some investigators cite old literature describing sensory input stemming from levels as high as the L4 dorsal ramus,[42] others have failed to corroborate these findings.[43,44] In clinical studies, whereas some investigators have denervated L4,[13,15,17,18] others have not endeavored to do so.[14,15] The downside of targeting superfluous nerves includes not only additional time and expense, but also undermining the procedural specificity by denervating the lowest and most frequently affected facet joint. Future studies should attempt to determine whether a less invasive procedure has comparable efficacy.

There are several study limitations that deserve mention. The most prominent ones center on the retrospective nature of this analysis and all the inherent flaws this entails, including post hoc selection of study variables, no predetermined sample size, expectation bias, and missing data. In addition, because the attending physician for each case decided whether follow-up SI joint and/or prognostic LBBs should be done, and which RF technique to use, the resultant unequal number of patients in each category was not ideal to detect outcome differences. Other limitations include the variability in techniques used for denervation and the inclusion of active-duty soldiers in the study sample, who may be subjects to different injury mechanisms, psychosocial stressors, and potential confounding factors (eg, overseas deployments) than a purely civilian cohort.

In conclusion, the results of this study demonstrated that although certain demographic and clinical variables may influence outcome, no single factor strongly and reliably predicted treatment results. These preliminary data do not support the routine use of more stringent selection criteria, such as multiple SI joint local anesthetic blocks, near-complete pain relief from diagnostic blocks, or prognostic LBB. It must be emphasized that although outcomes are noted here, this study was not intended to be an outcome study. Hence, caution must be heeded when interpreting our results. More research is needed to refine the technique of SI joint denervation, better assess long-term outcomes, and determine whether combinations of variables can be used to improve candidate screening. This can best be accomplished by head-to-head trials comparing cooled and conventional RF lesioning, and denervation involving various treatment levels (ie, L4-S3 vs L5 or S1-S3); randomized trials allocating denervation candidates to uncontrolled SI joint blocks, double blocks, or SI joint injections followed by LBB; and prospective studies stratifying outcomes based on a wide range of demographic and clinical variables.

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