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The effectiveness and safety of sacral lateral branch radiofrequency neurotomy (SLBRFN): A systematic review

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ABSTRACT

Objective: To assess the effectiveness and safety of sacral lateral branch radiofrequency neurotomy (SLBRFN) in treating posterior sacroiliac joint complex (PSIJC) pain, stratifying results by patient selection criteria and technique.
Design: Systematic review.
Population: Adults over 18 years old with suspected PSIJC pain.
Intervention: SLBRFN with image guidance (including computed tomography, fluoroscopy, ultrasound).
Comparison: Any other treatment, sham, or no treatment.
Outcomes: The primary outcome was improvement in pain reported as continuous data or the proportion of patients obtaining ≥50% reduction in pain scores on either the visual analog scale (VAS) or numeric rating scale (NRS). Secondary outcomes included functional improvement, reported as continuous data or the proportion of patients obtaining ≥30% in function from baseline, and adverse events.
Methods: Six reviewers independently assessed publications prior to December 2022 in PubMed, EMBASE, Web of Science, and Google Scholar and utilized the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) framework to evaluate the overall quality of evidence.
Results: Of the 415 publications screened, 37 met the inclusion criteria, with 33 providing sufficient data regarding the effectiveness of SLBRFN. Of the included studies, there were four explanatory randomized controlled trials (RCTs), four pragmatic RCTs, 11 prospective cohort studies, 14 retrospective cohort studies, and four case reports describing adverse events. At 6 months, the proportion of patients with ≥50% pain relief ranged from 19 to 89%. Studies providing continuous data reported that patients achieved 40–60% pain relief sustained at 12 months. There was heterogeneity in reporting functional improvement, but most studies noted improvement. While all studies that reported categorical outcomes targeted the S1-3 sacral lateral branches, the majority also included RFN of the L5 dorsal ramus. Successful outcomes were reported in patients selected by the response to intra-articular blocks (single or dual) or sacral lateral branch blocks (single or dual). Twenty-nine total adverse events and three serious adverse events (SAE) were reported across 1367 patients. According to the GRADE system, there is moderate-quality evidence overall that SLBRFN effectively reduces pain and disability in a majority of patients with PSIJC pain at 1, 3, 6, and 12 months. When anatomically validated SLBRFN techniques are assessed, the level of evidence is upgraded to high quality.
Discussion/conclusion: Despite the variability in types of radiofrequency technology, technique, nerve targets, and study methodology, most studies found that substantial proportions of patients achieved ≥50% relief at 1, 3, 6, and 12 months following SLBRFN. When anatomically validated SLBRFN techniques are applied, there is a high level of confidence that the procedure effectively reduces pain and improves function in patients with PSIJC pain.

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Additional high-quality studies exploring the prognostic value of different block protocols and the relative effectiveness of the various SLBRFN procedure techniques are needed to further optimize the clinical outcomes of SLBRFN.

1. Introduction

The sacroiliac joint complex (SIJC) comprises intra-articular synovial and cartilaginous structures, the capsule, and the extensive network of ligaments that support intra- and extra-articular portions of the joint. The innervation of the SIJC is commonly divided into anterior and posterior elements. The anterior innervation has been described to include the lumbosacral trunk, obturator nerve, and gluteal nerve [1–5]. Posterior innervation includes lateral branches of the sacral dorsal rami from S1 to S3 and the fifth lumbar dorsal ramus [6]. Consequently, anesthesia of the posterior sacroiliac joint complex (PSIJC) does not fully anesthetize the SIJC, as demonstrated by persistent awareness of joint distension after anesthesia of the PSIJC [2].

An accurate prevalence of pain arising from the PSIJC is unknown. Despite this, radiofrequency neurotomy (RFN) of the PSIJC, also referred to as sacral lateral branch radiofrequency neurotomy (SLBRFN), has emerged as a viable treatment for those suffering from CLBP thought to originate from the PSIJC [1,3,5,6].

The present study is a systematic review of the published literature on the effectiveness and safety of SLBRFN to characterize patient selection, technique, and technology. The literature has been evaluated according to these factors to inform outcome optimization and to make recommendations on how to direct future research. This review is intended to facilitate understanding among patients, physicians, payors, and regulatory agencies regarding the expected therapeutic value of SLBRFN to address pain arising from the PSIJC.

2. Methods

The literature search aimed to identify data addressing the effectiveness and adverse events associated with SLBRFN.

2.1. Protocol and registration

This IRB-exempt study was registered on PROSPERO (ID:CRD42021249092, May 15, 2021).

2.2. Eligibility criteria

2.2.1. Population

Adults over 18 years old with suspected PSIJC pain.

2.2.2. Intervention

SLBRFN with image guidance [including computed tomography (CT), fluoroscopy, or ultrasound (US)].

2.2.3. Comparison

Any other treatment (active, sham, or placebo) or no treatment.

2.2.4. Outcome

The primary outcome of interest was improvement in pain, reported as mean/continuous data or the proportion of patients who experienced $\geq$50% reduction in pain scores on either the visual analog scale (VAS) or numeric rating scale (NRS). Secondary outcomes of interest included functional improvement, reported as mean/continuous data or the proportion of patients obtaining $\geq$30% in function from baseline. Analgesic use, subsequent need for surgery, other healthcare utilization, return to work, and adverse events were also evaluated. Outcome measures were recorded at follow-up points ranging from 1 month to 2 years.

2.2.5. Studies

This review was restricted to randomized controlled trials (RCTs) and observational studies addressing effectiveness. Case reports were included for adverse events only. RCTs were categorized as either explanatory or pragmatic. Explanatory RCTs compared SLBRFN to a treatment not expected to have a therapeutic effect (*i.e.,* sham), revealing the attributable effect of SLBRFN. Pragmatic RCTs compared SLBRFN to an alternative treatment(s), providing comparative effectiveness of SLBRFN relative to the alternative treatment(s). Expert opinion, non-English language articles, and case reports unrelated to adverse events were excluded. No publication date restrictions were applied.

2.3. Information sources and search

Clinical outcome studies addressing the effectiveness of SLBRFN were identified by searching the PubMed, EMBASE, Web of Science, and Google Scholar databases. The search strategies are presented in Appendix 1. The searches were designed by author DS in consultation with a medical research librarian at Vanderbilt University Medical Center and were performed in May 2021. Search results were uploaded to Covidence (Covidence Systematic Review Software, Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org), a screening and data extraction tool for conducting systematic reviews. The searches were again performed in late December 2022 and early January 2023 to identify any new publications meeting the inclusion criteria.

2.4. Study selection

Four authors (CC, DL, CCS, DS) with formal training in principles of evidence-based medicine independently assessed a subset of abstracts according to the screening criteria. Two reviewers independently evaluated each abstract for eligibility. A third reviewer resolved discrepancies to reach a final decision regarding study inclusion. Subsequently, the publications were independently reviewed by at least two authors (CC, BD, DL, DS, SW) and assessed for inclusion. A third reviewer again resolved discrepancies. Studies were included based on the criteria listed above.

2.5. Data items and collection

Using Covidence, reviewers extracted the following data from each study: (1) bibliographical details, including the year of publication and authors; (2) study design; (3) participant inclusion criteria related to diagnostic tests and imaging criteria; (4) technical details about the RFN procedure; (5) information about the comparator treatment, if applicable; and (6) any relevant author disclosures or study funding. Additionally, outcome measures were recorded for pain, function, subsequent surgery, other healthcare resource utilization, and return to work at follow-up points ranging from 1 month to 2 years; and all adverse events were recorded.

2.6. Risk of bias and methodological assessment

Reviewers evaluated studies for their intrinsic methodological rigor, assessing various factors critical in determining the quality of studies addressing treatments for pain conditions [7]. These considerations included the selection of a patient sample representative of a realistic clinical population, using validated outcome measures, <20% loss to follow-up, controlling for co-interventions, authors' potential conflicts of interest, and the validity of diagnostic criteria and assessment tools.

The body of evidence was evaluated using the Grades of Recommendation, Assessment, Development, and Evaluation (GRADE) system of appraisal to determine the levels of certainty of the evidence of the effectiveness of SLBRFN [8]. The GRADE system transparently evaluates the body of evidence in domains including limitations in study design or execution, imprecision, inconsistency, indirectness, and publication bias. GRADE provides an initial rating of quality based upon the best available evidence and allows for upgrading (*e.g.,* large magnitude of effect, dose-response gradient) or downgrading (*e.g.,* risk of bias, indirectness) of the evidence quality. Disagreements regarding GRADE evaluation were resolved by consensus decision among the reviewers.

Six authors (CC, DL, PM, CCS, DS, SW) independently assessed the included RCTs for risk of bias using the Cochrane Risk of Bias Tool [9]. Discrepancies were resolved by the lead author (DL).

2.7. Summary measures and synthesis of results

The primary outcome of interest was improvement in pain, reported as mean/continuous data or the proportion of patients who experienced a ≥50% reduction in pain scores on either the VAS or NRS. Secondary outcomes included the proportion of individuals with ≥30% functional improvement from baseline measured by the Oswestry Disability Index (ODI), mean changes in ODI or NRS/VAS scores, analgesic use, subsequent spinal surgery, utilization of healthcare, return to work, and adverse events. The GRADE system was applied to assess the quality of evidence related to the effectiveness of SLBRFN and its risk for adverse events [10].

3. Results

After the removal of duplicates, the literature search yielded 415 records. Thirty-seven studies or reports of complications met the inclusion criteria (Fig. 1): four explanatory RCTs, four pragmatic RCTs, 11 prospective observational studies, 14 retrospective observational studies, and four case reports. Due to significant heterogeneity in the evidence, a formal meta-analysis was not performed. Considerable variability was observed in study design (*e.g.*, inclusion criteria, patient selection), follow-up time points, procedural technique, and the types of neurotomy technology utilized.

Results were organized by study design and characteristics of individual studies, which are detailed in Table 1. Categorical and continuous data from these studies are described in Tables 2 and 3, respectively. There were four case reports of adverse events, which are not included in Table 1, but appear with the reports of adverse events listed in Table 4.

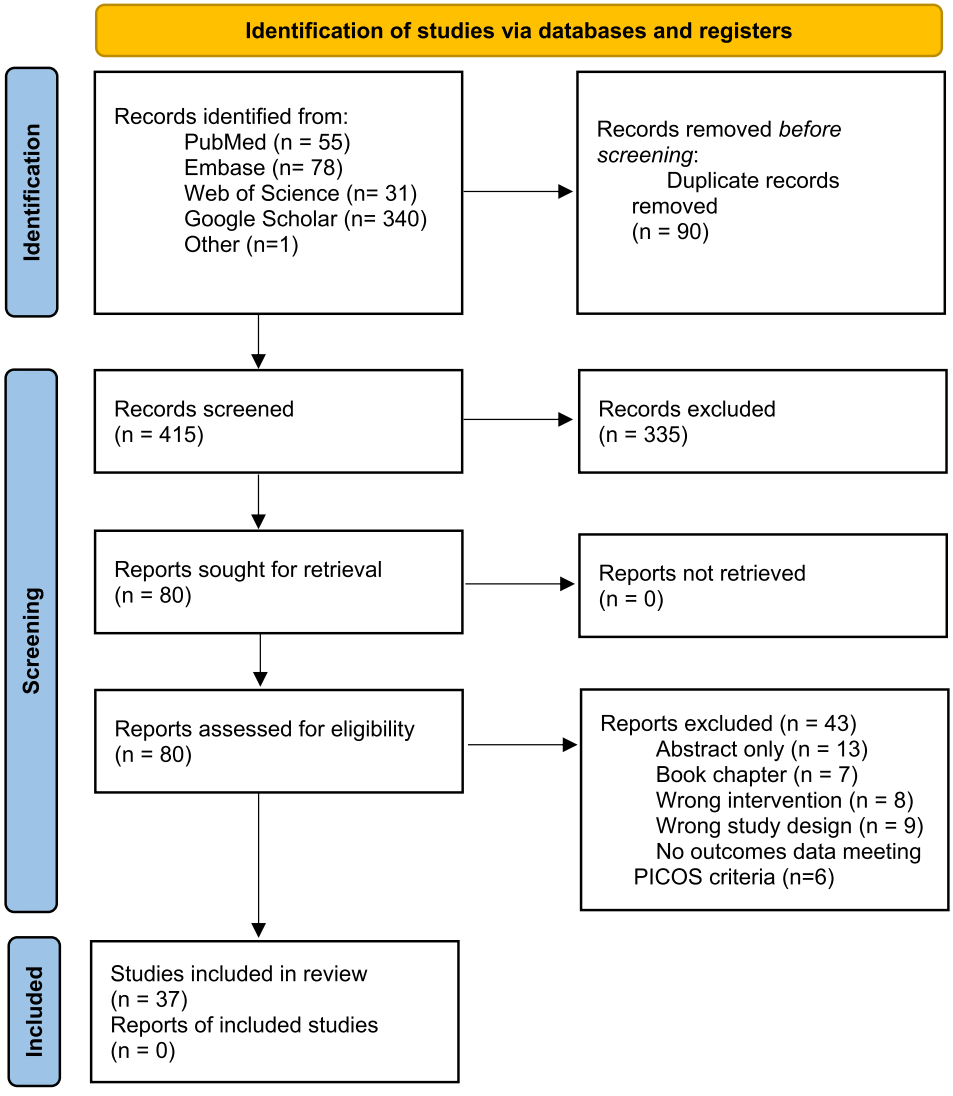

Fig. 1. PRISMA 2020 Flow Diagram.

Table 1
Study characteristics.

Study Info	Inclusion Criteria	SLBRFN Procedure						Comparator	
Author Year	Diagnostic Test	RF Type	Nerves/Structures Targeted	Cannula Details	Temp (°C)	Duration (seconds)	Patients Treated (N)	Description	Patients Treated (N)
EXPLANATORY RANDOMIZED CONTROLLED TRIALS									
Mehta 2018 [14]	DIB	Monopolar L5DR, Multipolar Strip Lesion S1-S3	L5DR, S1-S3	22G, 10 mm active tip; Multipolar Strip Lesion probe	Not listed	Not listed	11	Sham procedure	6
vanTiiburg 2016 [13]	SIB	Monopolar L5DR, Multipolar Strip Lesion S1-S3	L5DR, S1-S4	Sluijter-Mehta Kit (SMK) needle, Multipolar Strip Lesion probe	85	90	27	Sham procedure	33
Patel 2012 [12]	DLBB	Cooled	L5DR, S1-S3	Cooled probe	60	150	34	Sham procedure	17
Cohen 2008 [11]	SIB	Monopolar at L4MB, L5DR; Cooled at S1-S3	L4, L5DR, S1-3	Monopolar: 22G, 5 mm active tip; Cooled: 17G, 75 mm, 4 mm active tip	Monopolar: 80 Cooled: 60	Monopolar: 90 Cooled: 150	14	Placebo with crossover at 6 months to conventional RFN	14
PRAGMATIC RANDOMIZED CONTROLLED TRIALS									
Eissa 2022 [18]	SIB	Monopolar	L4, L5DR, S1-3	22G, 5 mm active tip	80	90	15	IA methyl-prednisolone	15
Martinez 2016 [17]	SIB	Bipolar	S1-S3	22G, 10 mm active tip	90	180	40 (20 Palisade, 20 modified Palisade)	two ultrasound-guided IA SIJ with 3 ml 5% levobupivacaine and 12 mg betamethasone sodium.	20
Salman 2016 [16]	SIB	Monopolar	L4MB, L5DR, S1-3	Not listed	90	80	15	LBB	15
Zheng 2014 [15]	SIB	Monopolar	L5DR, S1-S4	Not listed	90	180	82	Celebrex	73
OBSERVATIONAL STUDIES (PROSPECTIVE)									
Loh 2022 [24]	DLBB	Bipolar	S1-S3	multitined	80	120	32	N/A	N/A
Brennick 2021 [26]	DLBB	Multipolar Strip Lesion	L5DR, S1-S3	20G, 10 mm active tip	80	90	14	N/A	N/A
Abd El Barr 2019 [23]	SIB	Monopolar	L5DR, S1-S3	18G,10 mm active tip	70	90	30	N/A	N/A
Bellini 2016 [25]	SIB	Bipolar	S1-S4	Not listed	85	90	60	N/A	N/A
Cheng 2016 [29]	SIB	Cooled	L5DR, S1-S3	Cooled: 17G, 75 mm, 4 mm active tip; Strip: 20G, 10 mm active tip	85	150	62	Bipolar RF	31
Patel 2016 [28]	DLBB	Cooled	L5DR, S1-S3	Cooled System	60	150	41	N/A	N/A
Mitchell 2015 [21]	DIB	Monopolar	L5DR, S1-S3	18G, 10 mm active tip	90	90	215	N/A	N/A
Romero 2015 [22]	SIB	Monopolar	L5DR, S1-S3	18G, 10 mm active tip	80	90	32	N/A	N/A
Karaman 2011 [27]	DIB	Cooled	L5DR, S1-S3	Cooled System	60	150	15	N/A	N/A

(*continued on next page*)

Table 1 (*continued*)

Study Info	Inclusion Criteria	SLBRFN Procedure						Comparator	
Author Year	Diagnostic Test	RF Type	Nerves/Structures Targeted	Cannula Details	Temp (°C)	Duration (seconds)	Patients Treated (N)	Description	Patients Treated (N)
Buijs 2004 [20]	SIB	Monopolar	S1-S3	22G, 5 mm active tip	80	60	38 (43 procedures)	N/A	N/A
Gevargez 2002 [19]	SIB	Monopolar	L5DR, two locations within the intra-articular SIJ	23G, 5 mm active tip	90	270 (3 cycles of 90 s)	38	N/A	N/A
OBSERVATIONAL STUDIES (RETROSPECTIVE)									
Bayerl 2020 [43]	SIB	Multipolar Strip Lesion	L5DR, S1-S4	Not listed	85	60	64	N/A	N/A
	SIB	Monopolar	L5DR, S1-S4	18G,10 mm active tip	85	60	57	N/A	N/A
Kleinmann 2020 [35]	DIB	Cooled	L5DR, S1-S3	Cooled System	60	150	20	N/A	N/A
Speldewinde 2020 [42]	SIB	Multipolar Strip Lesion, Bipolar	L5DR, S1-S3	Multipolar Strip Lesion	80	90	32	Palisade	47
Tinnirello 2020 [36]	SIB	Cooled	S1-S3	Not listed	60	150	27	N/A	N/A
Vanaclocha 2018 [31]	SIB	Monopolar	L4, L5DR, S1-S3	Not listed	90	90	51	CMM/Fusion	101
Tinnirello 2017 [41]	SIB	Multipolar Strip Lesion	S1-S3	Not listed	60	150	21	Cooled	22
Anjana Reddy 2016 [39]	SIB	Multipolar Strip Lesion	L5DR,S1-S3	Not listed	80	60	26	N/A	N/A
Schmidt 2014 [38]	SIB	Multipolar Strip Lesion	L5DR, S1-S4	Not listed	80	90	60	N/A	N/A
Cheng 2013 [40]	DIB	Cooled	variable L5-S2; L5-S3; S1-S3; L4-S3	Cooled: 17G, 75 mm, 4 mm active tip	60	150	58	N/A	N/A
	DIB	Monopolar	variable L5-S2; L5-S3; S1-S3; L4-S3	Conventional: 22G, 5 mm active tip	80	150	30	N/A	N/A
Ho 2013 [34]	SIB	Cooled	L5DR, S1-S3	Cooled System	60	150	20	N/A	N/A
Stelzer 2013 [37]	SIB	Cooled	L5DR, S1-S3	Cooled System	60	150	105	N/A	N/A
Kapural 2008 [33]	DIB	Cooled	L5DR, S1-S3	Cooled System	60	150	27	N/A	N/A
Cohen 2003 [30]	SLBB	Monopolar	L4MB, L5DR, S1-S3	22G, 5 mm active tip	80	90	18	N/A	N/A
Yin 2003 [32]	DLBB	Monopolar	Variable depending on results of sensory stimulation	20G, 100 mm, 10 mm active tip	80	60	14	N/A	N/A

RF Type: water-cooled RF (cooled), bipolar RF (bipolar), monopolar RF (monopolar).
Nerves/Structures Targeted: L4, L5, S1, S2, S3, L5 Dorsal Ramus (L5DR).
Diagnostic Tests: Single LBB (SLBB), Dual LBB (DLBB), Single Intraarticular Block (SIB); Dual Intraarticular Block (DIB).
CMM: Conservative Medical Management; SIJ: Sacroiliac Joint.

None of the included studies reported data on the subsequent need for surgery or other healthcare utilization, and few provided data on return to work. These secondary outcomes are not presented in the tables but are reported in the narrative sections where applicable. Fig. 2 provides a visual representation of the responder rates defined by ≥50% relief at 1, 3, 6, and 12 months stratified by patient selection methods, procedural techniques, and nerve targets. At 1 month, all of the studies reporting categorical outcomes found that ≥50% of patients experienced ≥50% pain relief. At 3 months, 56% (9/16) of studies that reported categorical outcomes found that ≥50% of patients experienced ≥50% relief. At six months, 62% (13/21) of studies that reported categorical outcomes found that ≥50% of patients experienced ≥50% relief. At 12 months, 25% (4/16) of studies that reported categorical outcomes found that ≥50% of patients experienced ≥50% relief.

3.1. Explanatory studies

Cohen et al. (2008) published results from a sham-controlled, double-blind, randomized trial evaluating combined conventional RFN of the L4 medial branch and L5 dorsal ramus and cooled RF of the sacral lateral branches of S1-S3 compared to sham treatment [11]. Selection criteria consisted of a positive single intra-articular block. Patients who experienced ≥75% relief for at least 3 hours from the intra-articular block were enrolled. Of the 28 patients included in the study, 14 were randomized to cooled RFN and 14 to the sham group. The treatment group received conventional monopolar RFN at the L4 medial branch and L5 dorsal ramus (80 °C for 90 seconds), and cooled RFN (60 °C generator setting [>80 °C intralesional temperature] for 150 s) was used at the S1-S3 lateral branches. SLBRFN was conducted utilizing a periforaminal lesioning technique. In the sham arm, RF cannulae were placed, but the current was not activated. Outcome measures included NRS and ODI at 1, 3, 6, and 12-month intervals. Between-group analysis at 1 month revealed significantly lower mean NRS scores in the treatment group (2.4 ± 2.0; range, 0–8 vs. 6.3 ± 2.4; range, 2–10; $P < 0.001$). The percentage of patients in the treatment group reporting at least 50% pain relief was 79% [95% Confidence Interval (CI): 57–100%], 64% (95% CI: 39–89%), 57% (95% CI: 31–83%), and 14% (95% CI: 0–33%) at 1, 3, 6, and 12 months, respectively. One month after the procedure, the cooled RFN treatment group had lower ODI scores than the sham group (20.9 ± 10.9; range, 4–38 vs. 43.6 ± 14.0; range, 16–70; $P < 0.03$). Changes from baseline ODI scores in the cooled RFN treatment arm showed 44%, 50%, and 39% reductions at 1, 3, and 6 months, respectively.

All 14 patients in the placebo arm had an unsuccessful outcome at 6 months and were invited to cross over to conventional monopolar RFN treatment only using the same targets as the initial treatment group. Eleven of the 14 patients consented to participate in the crossover group (nine patients crossed over at 1 month and two crossed over at 3 months). The percentage of patients reporting at least 50% pain relief in the sham to monopolar RFN crossover group was 64% (95% CI: 35–92%), 55% (95% CI: 25–84%), 36% (95% CI: 8–65%), and 18% (95% CI: 0–41%) at 1, 3, 6, and 12 months, respectively. (These data points were excluded from Table 2, which includes only patients that were originally assigned to the RFN treatment group). NRS scores for the sham group 1 month after monopolar RFN treatment were not significantly different from the cooled RFN group (3.6 ± 2.6 vs. 2.4 ± 2.0, respectively). No further within-group analysis was performed because insufficient patients remained in the placebo group at the 3-month ($n = 2$) and 6-month ($n = 0$) time points.

Patel et al. (2012) conducted a sham-controlled, single-blind, randomized trial evaluating cooled RFN of the L5 dorsal ramus and S1-S3 lateral branches [12]. The study included patients with predominantly axial pain below the L5 vertebrae for longer than 6 months who failed to achieve adequate improvement with comprehensive non-operative treatments, including fluoroscopically-guided injections of steroids into the SIJ or sacroiliac ligaments. Single-depth, dual sacral lateral branch blocks were used to screen patients who met the inclusion criteria. A positive response to the block was defined as ≥75% pain reduction between 4 hours and 7 days following the injections. Thirty-four patients were randomized to the treatment group and 17 to the sham group. For the active treatment, the L5 dorsal ramus was targeted with monopolar RFN, followed by cooled RFN of the S1-S3 lateral branches utilizing a monopolar periforaminal technique. At 3 months, patients were unblinded, and the sham group participants were allowed to cross over to RFN. Differences in mean NRS scores for those that crossed over were not statistically significant at 1-month follow-up but were statistically significant at 3 months. The treatment group achieved a significantly greater improvement in the Short-form 36 Bodily Pain Score (SF-36BP) and ODI score at the 1- and 3-month time points. When determining the proportion of patients who achieved a clinically meaningful outcome, treatment success was defined as ≥50% NRS decrease along with one of the following: 1) a 10-point increase in SF-36BP or 2) a 10-point decrease in ODI. Sixteen of the 34 treatment patients (47%, 95% CI: 30–65%) and five of the 17 sham patients (29%, 95% CI: 8–51%) met the definition of treatment success at 3 months. At 6 months, 13 of the 34 treatment patients (38%, 95% CI: 22–56%) had a successful outcome according to the composite definition. Of the 16 patients who crossed over from the sham group to the RFN group, seven (44%, 95% CI: 19–68%) had a successful outcome at 3 and 6 months. Raw data from the original treatment group at 3 months showed ≥50% NRS improvement in 18/34 patients or 53% (95% CI: 36–70%). No raw data were available for other timepoints.

Two separate publications studied the use of a multipolar strip lesion technique of the sacral lateral branches combined with traditional RFN at L5 [13,14]. VanTilburg et al. (2016) published a sham-controlled, double-blind, randomized trial including 60 patients with a medical history and physical examination suggestive of SIJ pain [13]. Eligible participants reported a reduction of ≥2 on NRS after a single intra-articular SIJ injection. Percutaneous RF heat lesioning (85 °C, 90-s cycle, total of 5 cycles) was performed with a multielectrode RF probe that used a single percutaneous entry point. The RF probe was inserted along the inferior aspect of the sacrum and then advanced with continuous contact with the sacrum in a cephalad direction while remaining lateral to the sacral foramen, medial to the SIJ, and ventral to the ilium until the distal end of the probe contacted the sacral ala. The primary outcomes were NRS and Global Perceived Effect (GPE) at 1- and 3-month follow-ups. Patients in both groups reported a decrease in the NRS at 1 and 3 months, with no significant difference between the two groups. The baseline mean NRS in the treatment and sham groups were 7.2 and 7.5, respectively. At 1 month, the mean NRS were 5.4 and 5.4, respectively. At 3 months, the mean NRS was 3.3 and 3.2, respectively. Of the 33 patients in the sham group, 32 opted to crossover at 3 months, with 43% (95% CI: 25–62%) reporting a statistically significant reduction after the RF treatment. There was no statistically significant difference between the crossover group and the sham group results. GPE was not significantly different in any of the three groups.

In the second publication utilizing the multipolar strip lesion technique, Mehta et al. (2018) included patients who reported ≥80% reduction in pain following dual intra-articular SIJ injections [14]. Seventeen patients were randomly assigned to the active treatment ($n = 11$) or the sham treatment ($n = 6$). At 3 months, the mean NRS score for the active group had significantly decreased from 8.1 (±0.8) at baseline to 3.4 (±2.0), a mean NRS reduction of 58%. The sham group did not show a statistically or clinically meaningful decrease in mean NRS score from baseline (7.3 ± 0.8) to 3 months (6.5 ± 2.0). The mean difference between the treatment and sham groups at 3 months was statistically significant ($P < 0.001$). At the 6-month follow-up, the mean NRS score reported by all patients (active and crossover) was 4.2, a statistically significant mean reduction of 47% from baseline.

3.2. Pragmatic studies

Zheng et al. (2014) randomized patients to receive oral analgesia or CT-guided monopolar RFN at the L5 dorsal ramus and S1-S4 lateral

Table 2
Categorical Data: Responder rates for 50% pain relief reported in individual randomized controlled trials and observational studies.

Author Year	RF Type	Outcome Measures	Total N	# Patients Treated with RFN	Responder Rate [>50% Pain Relief (95% Confidence Intervals)]					
					1 mo	3 mo	6 mo	12 mo	18 mo	24 mo
EXPLANATORY RANDOMIZED CONTROLLED TRIALS										
vanTiiburg 2016 [13]	Multipolar Strip Lesion	NRS	45	27		43% (25–62%)				
Patel 2012 [12]	Cooled	NRS	51	34		53% (36–70%)				
Cohen 2008* [11]	Cooled	NRS	28	14	79% (57–100%)	64% (39–89%)	57% (31–83%)	14% (0–33%)		
PRAGMATIC RANDOMIZED CONTROLLED TRIALS										
Eissa 2022 [18]	Monopolar	NRS	30	15	60% (35–85%)	60% (35–85%)				
Salman 2016 [16]	Monopolar	NRS	30	15	73% (51–96%)	60% (35–85%)	53% (28–79%)			
OBSERVATIONAL STUDIES (PROSPECTIVE)										
Loh 2022 [24]	Bipolar	PDQQ-S (Pain Intensity Domain)	31	32	2 months: 61% (44–78%)		39% (22–56%)	23% (8–37%)		
Brennick 2021 [26]	Multipolar Strip Lesion	NRS	14	14		14% (0–33%)		7% (0–21%)		
Bellini 2016** [25]	Bipolar	ODI	60	60	92%	82%	59%	36%		
Cheng 2016 [29]	Bipolar	NRS	31	31		74% (52–96%)	68% (51–84%)	48% (31–66%)		
	Cooled	NRS	62	62		39% (27–51%)	19% (10–29%)	8% (1–15%)		
Patel 2016 [28] (follow-up study from Patel 2012)	Cooled	NRS	50	Originally Assigned to RFN: 34 Crossover to RFN: 16			Crossover Group: 56% (32–80%)	Original Group: 38% (22–55%)		
Romero 2015 [22]	Monopolar	NRS	32	32	78% (64–92%)		81% (68–95%)	72% (56–88%)	50% (33–67%)	
Karaman 2011 [27]	Cooled	VAS	15	15			80% (60–100%)			
Buijs 2004 [20]	Monopolar	NRS	38	38		63% (48–78%)				
OBSERVATIONAL STUDIES (RETROSPECTIVE)										
Bayerl 2020 [43]	Monopolar	NRS	121	57				39% (26–51%)		
	Multipolar Strip Lesion	NRS	121	64				72% (61–83%)		
Speldewinde 2020 [42]	Monopolar	NRS	73	41			47% (35–59%)			
	Multipolar Strip Lesion	NRS	73	32			71% (58–84%)			
Tinnirello 2020 [36]	Cooled	NRS	27	27	93% (83–100%)		63% (45–81%)	44% (25–63%)		
Tinnirello 2017 [41]	Multipolar Strip Lesion	NRS	22	22	95% (86–100%)	90% (81–100%)	38% (32–44%)	24% (19–29%)		
	Cooled	NRS	21	21	100% (91–100%)	91% (82–100%)	82% (74–90%)	73% (65–81%)		
Anjana Reddy 2016 [39]	Multipolar Strip Lesion	NRS	26	26			31% (13–49%)	27% (10–44%)		
Schmidt 2014 [38]		VAS	77	77			55% (43–66%)	16% (8–24%)		

(*continued on next page*)

Table 2 (*continued*)

Author Year	RF Type	Outcome Measures	Total N	# Patients Treated with RFN	Responder Rate [>50% Pain Relief (95% Confidence Intervals)]					
					1 mo	3 mo	6 mo	12 mo	18 mo	24 mo
	Multipolar Strip Lesion				6 weeks: 71% (61–81%)					
Cheng 2013 [40]	Monopolar	NRS	30	30	60% (42–78%)	40% (22–57%)	30% (14–46%)		17% (3–30%)	
	Cooled	NRS	58	58	50% (37–62%)	40% (27–52%)	28% (16–39%)		17% (7–27%)	
Ho 2013 [34]	Cooled	NRS	20	20	50% (28–72%)	75% (56–94%)	70% (50–90%)	75% (56–94%)		70% (50–90%)
Kapural 2008 [33]	Cooled	VAS	27	27		48% (29–67%)				
Cohen 2003 [30]	Monopolar	NRS	9	9			9 months: 89% (68–100%)			
Yin 2003 [32]	Monopolar	VIPS	14	14			64% (39–89%)			

RF Type: water-cooled RF (cooled), bipolar RF (bipolar), monopolar RF (monopolar).
Outcome Measures: Visual Analog Scale (VAS), Numeric Rating Scale (NRS), Oswestry Disability Index (ODI), Pain, Disability and Quality of Life Questionnaire - Spine (PDQQ-S), Visual Integer Pain Score (VIPS).
*Data for patients randomly assigned to cooled RFN; does not include crossover patients.
**Raw data not provided, cannot calculate 95% CI.

branches [15]. The patients were selected with a single intra-articular SIJ block. A positive response was defined as ≥50% pain relief on the VAS at 6 hours post-injection. Eighty-two treatment arm patients underwent a bipolar RFN procedure with four radiofrequency cannulae placed in a line between the involved SIJ and the lateral aspects of the ipsilateral dorsal sacral foramen, from superior to S1 to inferior to S3 at 10 mm intervals. Bipolar RFN was carried out by what the authors described as "leapfrogging" electrodes between adjacent pairs of cannulae to create a strip lesion lateral to the posterior sacral foramen. Seventy-three control arm patients received oral celecoxib (200 mg twice daily for 24 weeks) and acetaminophen (500 mg as needed, up to six tablets daily). At 12 weeks, the mean VAS reduction was 65% (95% CI: 55–76%) and 36% (95% CI: 26–47%) in the RFN and celecoxib arms, respectively. At 24 weeks, the mean VAS reduction was 61% (95% CI: 51–62%) and 28% in the RFN and celecoxib arms, respectively. The adjusted global pain intensity reduction was better in the RFN arm than in the control arm (1.9 and 2.2 cm at 12 and 24 weeks from the baseline, $P < 0.0001$).

A randomized, single-blind comparative study performed by Salman et al. (2016) enrolled 30 patients with SIJ pain selected by a single positive intra-articular SIJ block defined as ≥75% pain relief for at least 3 hours post-block [16]. Fifteen patients were treated with monopolar RFN of the L4 and L5 primary dorsal rami and the S1-S3 lateral branches, and 15 patients received a fluoroscopically-guided steroid injection. At 1-, 3-, and 6-months post-intervention, 73% (95% CI: 51–96%), 60% (95% CI: 35–85%), and 53% (95% CI: 28–79%) of patients, respectively, achieved ≥50% pain relief in the RFN group. In the steroid group, three of 15 patients (20%, 95% CI: 0–40%) reported ≥50% pain relief at 1-month follow-up. These three patients reported no significant improvement at 3-month and 6-month follow-ups. The remaining 12 patients crossed over to the RFN group at 1 month, with one additional patient crossing over at 3 months. Crossover data were not analyzed.

Martinez et al. (2016) conducted a prospective, randomized, non-blinded study on the efficacy of bipolar RFN of the sacral lateral branches compared to intra-articular SIJ corticosteroid injections [17]. Selection criteria included a positive response to three provocation tests (Gaenslen, Patrick, Gillet) and at least 50% pain relief from diagnostic intra-articular SIJ blocks. The patients were randomized into three groups ($n = 20$ each): ultrasound-guided intra-articular SIJ injections with corticosteroid (Group A), fluoroscopically-guided, bipolar Palisade RFN technique at 1 cm from S1-S3 (Group B), and a "modified" fluoroscopically-guided, bipolar Palisade RFN technique at S1-S3 (Group C). The "modified" bipolar Palisade RFN technique and lesion protocol was identical to that used in Group B, but the distance between the cannulae was >1 cm (±12 mm). The manuscript provided no raw data. The average VAS was calculated for all groups at baseline, 1-month, 3-month, and 12-month follow-ups. At the 1-month follow-up, there was a 53%, 42%, and 41% mean VAS reduction in groups A, B, and C, respectively. At 3-month and 12-month follow-ups, Group A patients reported no significant pain relief (15% and 9%). At the 3-month follow-up in Group B, patients reported 41% pain relief which dropped to 25% at 12 months, but the reduction in pain score remained statistically significant. In Group C, pain relief was reported as 52% over baseline at 3 months and 48% at 12-month follow-up. A comparison of all three groups showed that VAS scores at 12-month follow-up were significantly lower in the "modified" RFN Palisade group when compared with the other two groups.

Eissa et al. (2022) performed a prospective study of 30 patients who reported >50% relief with a diagnostic SIJ block [18]. The patients were randomized to receive either an intra-articular corticosteroid injection or conventional RFN of the L4 medial branch, L5 dorsal ramus, and S1-S3 lateral branches. The technique for SLBRFN was poorly described. The primary outcome measure was the change in NRS at 2 weeks, 1 month, and 3 months post-procedure. Secondary measures included ODI at 1 and 3 months and GPE after 3 months. At 2 weeks post-procedure, the mean NRS in both groups was significantly (<50%) lower than baseline. In the steroid group, patients reporting >50% reduction in NRS at 2 weeks, 1 month, and 3 months were 9/15 patients (60%, 95% CI: 35–85%), 7/15

Table 3
Continuous Data: Mean improvements in pain relief in individual randomized controlled trials and observational studies.

Author Year	RF Type	Outcome Measures	Total N	# Patients Treated with RFN	Mean Improvement - Pain Relief					
					1 mo	3 mo	6 mo	12 mo	18 mo	24 mo
EXPLANATORY RANDOMIZED CONTROLLED TRIALS										
Mehta 2018 [14]	Multipolar Strip Lesion	NRS	17	11		58%	47%			
Patel 2012 [12]	Cooled	NRS	51	34	44%	39%	41%			
Cohen 2008 [11]	Cooled	NRS	28	14	61%	61%	57%			
PRAGMATIC RANDOMIZED CONTROLLED TRIALS										
Eissa 2022 [18]	Monopolar	NRS	30	15	56%	55%				
Martinez 2016 [17]	Conventional Bipolar	VAS	60	20	42%	41%		25%		
	Modified Bipolar	VAS	60	20	41%	52%		48%		
Zheng 2014 [15]	Monopolar	VAS	155	82		65%	61%			
OBSERVATIONAL STUDIES (PROSPECTIVE)										
Loh 2022 [24]	Bipolar	PDQQ-S (Pain Intensity Domain)	31	32	2 months: 50%		41%	21%		
Abd El Barr 2019 [23]	Monopolar	VAS	30	30	50%	53%	53%	62%		
Patel 2016 [28]	Cooled	NRS	50	Originally Assigned to RFN: 34 Crossover to RFN: 16			Crossover Group: 43%	Original Group: 46%		
Romero 2015 [22]	Monopolar	NRS	32	32	64%		60%	56%	48%	
Karaman 2011 [27]	Cooled	VAS	15	15	63%	75%	63%			
OBSERVATIONAL STUDIES (RETROSPECTIVE)										
Ho 2013 [34]	Cooled	NRS	20	20	42%	62%	61%	59%		58%
Kapural 2008 [33]	Cooled	VAS	27	27		41%				

RF Type: water-cooled RF (cooled), bipolar RF (bipolar), monopolar RF (monopolar).
Outcome Measures: Visual Analog Scale (VAS); Numeric Rating Scale (NRS); Pain, Disability and Quality of Life Questionnaire - Spine (PDQQ-S).

patients (47%, 95% CI: 21–72%), and 6/15 patients (40%, 95% CI: 15–65%), respectively. Of the patients in the SLBRFN group, 9/15 (60%, 95% CI: 35–85%) experienced >50% reduction in NRS at 2 weeks, 1 month, and 3 months. Average NRS scores were reduced for both groups at all follow-up points. Between 1 and 3 months, NRS reduction was unchanged in the SLBRFN group, while in the steroid group, the NRS improvement diminished (3.30–4.40). Mean ODI scores and GPE, as calculated by the authors, were improved in both groups at all designated follow-up points. There were larger improvements in ODI and GPE in the SLBRFN compared to the steroid group, but the differences between the groups were not statistically significant.

3.3. Prospective observational studies

3.3.1. Monopolar RFN

Gevargez et al. (2002) published results of a single-arm prospective cohort study utilizing CT-guided monopolar RFN of the L5 dorsal ramus and the distal S1-S3 lateral branches [19]. From a cohort of 43 patients, 38 reported "definite" but only temporary relief at 2 weeks with a single intra-articular SIJ injection of corticosteroid and anesthetic. These patients subsequently underwent monopolar RFN, though denervation was carried out on two locations within the intra-articular recess of the SIJ, in addition to the L5 dorsal ramus. The RFN technique was inconsistent with standard techniques (*i.e.,* Palisade, periforaminal RF cannulae placement) for targeting the sacral lateral branches. At 1 month, 15 patients (39%, 95% CI: 24–55%) reported being pain-free, 12 (32%, 95% CI: 17–46%) experienced "substantial" pain reduction, seven (18%, 95% CI: 6–31%) reported a "slight" pain reduction, and two (5%; 95% CI: 0–12%) experienced no pain reduction. Data on two patients were missing. At 6 months, 13 patients (34%, 95% CI: 19–49%) reported being pain-free, 12 patients (31%, 95% CI: 17–46%) reported a "substantial" pain reduction, seven patients (18.%, 95% CI: 6–31%) reported a "slight" reduction, and three patients (8%, 95% CI: 0–16%) experienced no pain relief. Data on three patients were missing at the 6-month follow-up.

Buijs et al. (2004) performed a prospective, single-arm, cohort study of monopolar RFN of the sacral lateral branches that included 38 patients (in five patients, RFN was conducted bilaterally for a total of 43 procedures) [20]. The patients were included if they experienced ≥50% pain reduction after a single intra-articular SIJ block with anesthetic. RFN was performed at 80°C for 60 seconds with cannulae placed in the superolateral aspect of the S1, S2, and S3 dorsal foramen. At 3 months, 24 patients (63%, 95% CI: 48–78%) reported ≥50% relief. Outcomes beyond 3 months were not reported.

In a prospective, single-arm cohort study, Mitchell et al. (2015)

Table 4
Adverse events.

Author Year	RF Type	Adverse Event
Abbott 2007 [46]	Monopolar	L5 Radiculopathy
AnjanaReddy 2016 [39]	Strip Lesion	Increased Pain at 6 and 12 Months
Brennick 2021 [26]	Strip Lesion	Mechanical Fall Immediately Post-Procedure
Buijs 2004 [20]	Monopolar	Increased Pain at 12 Weeks
Cohen 2008 [11]	Cooled	Temporary Post-Procedure Pain Transient Buttock Paresthesia
Gevargez 2002 [19]	Monopolar	Temporary Post-Procedure Pain
Kapural 2010 [33]	Cooled	Temporary Post-Procedure Pain Transient Buttock Paresthesia Increased Lower Back Pain Prolonged Itching
Karaman 2011 [27]	Cooled	Temporary Post-Procedure Pain
Kleinmann 2020 [35]	Cooled	Temporary Post-Procedure Pain Temporary Skin Irritation at Entry Point Hematoma
Martinez 2016 [17]	Bipolar	Mild Hematoma Temporary Post-Procedure Pain
Mehta 2018 [14]	Conventional RFN + Strip Lesioning S1-S3	L5-S1 Disc Prolapse Temporary Post-Procedure Pain Inflammation at Injection Site
Rea 2011 [47]	Bipolar	Infective Sacroiliitis Temporary Post-Procedure Pain
Sulindro 2020 [48]	Cooled	Skin Burn
Tinnirello 2017 [41]	Cooled	Transient Neuritis
Tinnirello 2020 [36]	Cooled	Transient Neuritis
Yao 2016 [49]	Monopolar	Sexual Dysfunction/Anorgasmia (resolved at 6 weeks)
Zheng 2014 [15]	Bipolar	Epigastric Pain, Abdominal Pain, Nausea, Diarrhea Pruritis Hemorrhage and Infection at Treatment Site

RF Type: water-cooled RF (cooled), bipolar RF (bipolar), monopolar RF (monopolar), pulsed RF (pulsed).

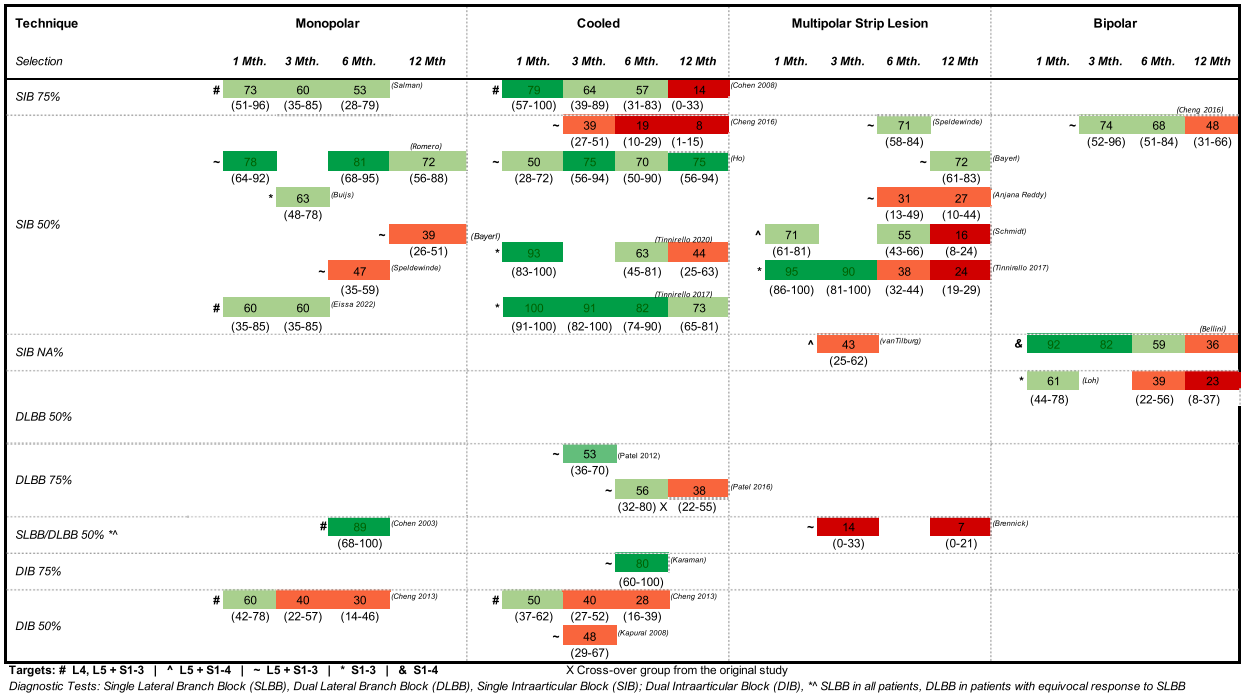

Fig. 2. Responder Rates Reported on VAS/NRS. ≥ 50% relief with 95% Confidence Intervals.

collected data over 5 years, including 215 patients who underwent fluoroscopically-guided monopolar RFN of the S1-S3 lateral branches and the L5 dorsal ramus [21]. RFN was conducted at 90°C for 90 s. A periforaminal RF technique was used to target the sacral lateral branches where a series of lesions were made along the posterior surface of the sacrum, from the inferolateral corner to the superolateral corner of the S1 to S3 foramen. Additionally, the dorsal ramus of L5 was targeted. The RFN cannulae were placed "horizontally, inferolaterally to the S1, S2, and S3 foramen, approximately 5–10 mm off the bone," where a second neurotomy cycle was performed. Patients were selected based on achieving at least 80% relief from dual intra-articular SIJ blocks with deep interosseous ligament injections. Outcome measures included NRS, a Likert scale to measure perceived changes in analgesic use (increased, no change, slight decrease, moderate decrease, extreme decrease), capacity for paid employment (decreased capacity, no change, increased capacity), and patient satisfaction with treatment outcome (unsatisfied, neutral, satisfied). The authors reported that 124/215 (58%, 95% CI: 51–64%) of patients experienced pain relief, with a mean NRS reduction of 33% at follow-up (baseline pain score of 6.9 ± 1.7 to a follow-up average of 4.6 ± 2.7 pain scale points; $p < 0.01$). At a follow-up range of 14.9 ± 10.9 months (range 6–49 months), 48% (95% CI: 40–56%) of patients reduced their analgesic use.

Romero et al. (2015) performed a prospective, single-arm cohort study of 32 patients to assess the effectiveness of monopolar RFN of the L5 dorsal ramus and S1-S3 lateral branches [22]. The cannulae tips were positioned approximately 10 mm from the lateral edge of the posterior

sacral foramina and suspended approximately 2 mm off the sacral surface. Radiofrequency lesioning was then carried out at 80 °C for 90 s. Radiofrequency of the L5 dorsal ramus was also performed with monopolar RFN. Patients were selected if they achieved ≥50% pain relief for at least 6 hours following a single intra-articular SIJ block. At 6-, 12-, and 18-month follow-ups, 81% (95% CI: 68–95%), 72% (95% CI: 56–88%), and 50% (95% CI: 33–67%) of patients reported at least 50% pain reduction, respectively. At 6-, 12-, and 18-month follow-ups, 19% (95% CI: 5–32%), 16% (95% CI: 3–28%), and 3% (95% CI: 0–9%) of patients reported at least 75% pain reduction, respectively. GPE was positive in 84% (95% CI: 72–97%) of patients. The Patient Global Impression of Change (PGIC) score was 1.3 ± 1.1.

Abd El Barr et al. (2019) conducted a prospective, single-arm cohort study of 30 patients who underwent monopolar RFN of the L5 dorsal ramus and S1-S3 lateral branches [23]. Selection criteria included unilateral or bilateral chronic SIJ pain for more than 6 months, failed conservative treatment with medications and physical therapy, and more than 50% pain relief after "local SIJ blocks." It was unclear whether the blocks were intra-articular or sacral lateral branch blocks. Under fluoroscopic guidance, 18-gauge, 1-cm active tip RFN cannulae were positioned at the lateral margin of the posterior sacral foramen targeting all lateral branches according to the Epsilon technique [2]. Three separate radiofrequency lesions were created along the superolateral, lateral, and inferolateral aspects of the S1, S2, and S3 foramina. The preoperative mean VAS was 8.43 ± 1.006, which decreased to 4.23 (50%), 3.966 (53%), 4.00 (53%), and 3.23 (62%) at 1, 3, 6, and 12 months, respectively. The Patient Satisfaction Index (PSI) improved by 0.033, 0.3, and 0.76 at 3, 6, and 12 months respectively.

3.3.2. Bipolar RFN

Loh et al. (2022) conducted a prospective, single-arm cohort study to evaluate the clinical outcomes of US-guided SLBRFN [24]. Thirty-two patients underwent two separate diagnostic blocks: the first was performed with fluoroscopic guidance, and the second with US guidance. Fluoroscopically-guided block techniques were varied; either using a periforaminal technique or anesthetizing in a strip lateral to the posterior sacral foramen. If patients reported ≥50% improvement with the fluoroscopically-guided block, a confirmatory block was performed utilizing ultrasound. This involved injecting 0.2–0.5 mL of 2% lidocaine along the lateral sacral crest from the first transverse sacral tubercle to the third transverse sacral tubercle at approximately 1 cm intervals as measured and marked along the skin surface. If patients reported ≥50% NRS improvement, a multitined RF cannula was used to produce bipolar lesions at 80 °C for 120 seconds for the S1-S3 lateral branches for US-guided SLBRFN. One patient was withdrawn from the study after developing a new onset lumbar radiculopathy and no longer met the study inclusion criteria. At 2 months post-RFN, 19/31 participants (61%, 95% CI: 44–78%) reported ≥50% pain reduction on the pain intensity domain of the Pain Disability Quality of Life Questionnaire-Spine (PDQQ-S). Greater than or equal to 50% pain reduction was noted at 6, 9, 12, and 16 months post-RFN in 12/31 participants (39%, 95% CI: 22–56%); 8/31 participants (26%, 95% CI: 10–41%), 7/31 participants (23%, 95% CI: 8–37%), and 4/31 participants (13%, 95% CI: 1–25%), respectively. At 2, 6, 9, 12, and 16 months there was a reduction of ≥50% in overall PDQQ-S scores in 17/31 participants (55%, 95% CI: 37–72%), 12/31 (39%, 95% CI: 22–56%), 8/31 (26%, 95% CI: 10–41%), 7/31 (23%, 95% CI: 8–37%), and 3/31 (10%, 95% CI: 0–20%), respectively. There was a subgroup analysis of 11 patients that had previously had fluoroscopically-guided SLBRFN. The authors reported that at 2 months, there was no statistically significant difference in mean post-RFN NRS and PDQQ-S between fluoroscopically-guided and US-guided SLBRFN.

3.3.3. Multipolar strip lesion RFN

Bellini et al. (2016) conducted a prospective, single-arm cohort study on 60 patients (102 sacral lateral branch RFN procedures) who underwent multipolar strip RFN of the sacral lateral branch nerves [25]. Patients were selected based on pain below the L5 level or buttock pain and an unreported level of relief achieved following a single intra-articular SIJ injection. Outcome measures included the ODI with assessment at 1, 3, 6, and 12 months. No raw data were made available in the study. Authors reported that ≥50% pain relief was achieved in 92% of the 102 treatments at 1 month, 82% at 3 months, 59% at 6 months, and 36% at 1 year. The ODI scores improved by 30% at 1 month after the procedure (45 ± 3.2) compared with the baseline scores (64 ± 4.3). This improvement continued by 80% at 6 months (13 ± 4.0) and 81% at 12 months (12 ± 3.5).

Brennick et al. (2021) performed a prospective, single-arm cohort study utilizing multipolar strip lesion RFN. Inclusion criteria required at least 50% pain reduction following dual lateral branch blocks [26]. Fourteen patients were enrolled and completed SLBRFN. The NRS and the Modified ODI (MODI) were used as outcome measures, with the primary measure being the proportion of patients with an NRS score reduction of 2.5 points and an improvement in MODI by 15%. Patients were followed at a 3-6-month interval and 12-month interval (an average of 88 and 352 days, respectively). Of the 14 patients included in the study, four had incomplete data. At 3–6 months, 2/14 patients (14%, 95% CI: 0–33%) had both reduction of NRS and an improvement in MODI. At 12 months, only 1/14 patients (7%, 95% CI: 0–21%) had both reduction of NRS and an improvement in MODI.

3.3.4. Cooled RFN

Karaman et al. (2011) conducted a prospective, single-arm cohort study of cooled RFN at the L5 dorsal ramus and the S1-3 lateral branches [27]. The study included 15 patients selected based on a positive response, defined as ≥75% pain relief, to dual intra-articular SIJ blocks. The median baseline VAS score was 8 (range: 7–9). At 1-month follow-up, the median VAS had decreased to 3 (range: 1–4). Furthermore, values for 3 and 6 months were 2 (range: 1–3) and 3 (range: 2–4), respectively. At the final 6-month follow-up, 80% (95% CI: 60–100%) of the patients reported a decrease in pain of at least 50%. All patients in the study reported a decline in pain scores of at least 2 points. At the 6-month follow-up, 87% (95% CI: 69–100%) of the patients reported improvement of at least 10 points in their ODI scores. At 1-, 3-, and 6-month follow-ups, improvements in ODI were 56%, 67%, and 61%, respectively.

From the aforementioned Patel et al. (2012) RCT, 51 patients were randomized 2:1 to receive monopolar RFN or sham intervention, respectively, with 34 patients assigned to RFN and 17 to sham [12]. Of the 17 patients assigned to the sham group, 16 opted to cross over after the primary endpoint of 3 months. The 2016 study reports the 12-month results for the original RFN group, of which 25 patients were available for 12-month follow-up, and 6-month results for the crossover group, for which all 16 patients were available for follow-up [28]. All study participants experienced at least 75% relief from dual lateral branch blocks. Pain evaluation scores at 12 months were significantly improved from baseline values, with a mean NRS score change of −2.7 points, while the mean SF36-BP increased by nearly 16 points. The average ODI score for the RFN group overall at 12 months was significantly less than at baseline (mean score change was 13.9 ± 20.8, $P = 0.0003$). The SF36-PF score for the RFN group at 12 months was statistically greater than it was at baseline (mean score change of 17.4 ± 22, $P < 0.0001$), but the Assessment of Quality of Life (AQoL) score was not (mean score change of 0.07 ± 0.15, $P = 0.021$). For the 6-month reported outcomes in the crossover group, nine of the 16 patients (56%, 95% CI: 32–80%) reported ≥50% pain reduction. A worst-case analysis was performed for the original RFN group at 12-month follow-up, accounting for the nine

dropouts as treatment failures, with 14/34 (41%, 95% CI: 25–58%) reporting ≥50% pain reduction.

3.3.5. Mixed studies

Cheng et al. (2016) used bipolar RFN to create a strip lesion from the lateral border of the base of the sacral superior articular process (L5-S1 facet joint) to the lateral border of the S3 sacral foramen [29]. The authors devised a guide block to facilitate the accurate placement of multiple electrodes to simultaneously ablate the L5 dorsal ramus and the S1-S3 lateral branches. This novel technique was used to treat 31 consecutive patients and compared directly to a historical cohort of 62 patients treated with cooled RFN. The patients were selected based on reporting ≥50% relief with a single intra-articular SIJ block. The bipolar RFN patients experienced a longer duration of >50% pain relief. At 3 months, 23/31 (74%, 95% CI: 52–96%) of bipolar RFN patients had >50% pain relief, compared to 24/62 (39%, 95% CI: 27–51%) of cooled RFN patients. At 6 months, 21/31 (68%, 95% CI: 51–84%) of bipolar RFN patients reported >50% pain relief compared to 12/62 (19%, 95% CI: 10–29%) of cooled RFN patients. At 12 months, 15/31 (48%, 95% CI: 31–66%) of bipolar RFN patients and 5/62 (8%, 95% CI: 1–15%) of cooled RFN patients had >50% pain relief. No patients with either treatment experienced any significant adverse events or serious complications.

3.4. Retrospective observational studies

3.4.1. Monopolar RFN

In 2003, Cohen et al. reported the results of a retrospective cohort study of 18 patients treated with monopolar periforaminal RFN [30]. Selection criteria included ≥80% immediate relief from intra-articular SIJ injection with steroid and anesthetic. Eighteen patients met the initial inclusion criteria and elected to undergo a diagnostic sacral lateral branch block with anesthetic alone. A second block was performed for patients with an "equivocal" response to the first diagnostic block. The reasons for a second block included changes in the patient's pain symptoms, inability to discount procedure-related pain, difficulty interpreting the pain diary, or failure to fill out the pain diary or accurately remember the effectiveness of the block. Of the 13 patients who reported ≥50% relief, two were lost to follow-up, and two reported sustained relief. Therefore, nine total patients underwent monopolar RFN. At 9-month follow-up, eight of the nine included patients reported ≥50% improvement. More specifically, 2/9 patients (22%, CI: 0–49%) reported 100% improvement, 3/9 patients (33%, CI: 3–64%) reported ≥80% improvement, 4/9 patients (44%, CI: 12–77%) reported ≥75% improvement, 5/9 patients (56%, CI: 23–88%) reported ≥60% improvement, and 8/9 patients (89%, CI: 68–100%) reported ≥50% improvement.

Vanaclocha et al. (2018) compared the various SIJ treatment options to assess short- and long-term effectiveness [31]. Of 152 patients who showed a positive response (≥50% relief) to a single intra-articular SIJ block, 74 were treated with conservative medical management, 51 with monopolar RFN, and 27 with lateral-approach SIJ fusion. RFN lesions were placed at L4, L5, and at "various locations circumferentially near the S1, S2, and S3 branches," with temperatures of 90 °C for 90 s. In the RFN group, opioid use decreased initially before increasing at the final follow-up. At 6 months and beyond, the authors reported a mean difference between the RFN and fusion groups of approximately 4.5 points ($P < 0.001$), favoring fusion. ODI scores improved substantially after fusion but returned to baseline in the conservative management and RFN groups.

Yin et al. (2003) conducted a retrospective chart review studying the efficacy of sensory stimulation-guided SLBRFN [32]. The patients selected for neurotomy reported ≥70% improvement with fluoroscopically-guided, dual, SIJ deep interosseous ligament injection with corticosteroid and long-acting anesthetic. Fourteen patients were enrolled. After RFN, patients were observed for at least 6 months. Outcome measures included visual integer pain scores (VIPS) and percentage relief at 2 weeks, 1, 2, 3, and 6 months following RFN. Success was defined as ≥60% pain relief and ≥50% decrease in VIPS for at least 6 months. Before neurotomy, sensory stimulation was conducted from the L5 dorsal ramus and S1-S3 lateral branches. The S1-S3 lateral branches were stimulated directly adjacent to their respective foramen. A single RF lesion was created at each "symptomatic" level at 80 °C for 60 s. As a result, not all patients underwent neurotomy at the same levels. Additionally, the location of the symptomatic sacral lateral branch nerves varied markedly with regard to position relative to identifiable bony landmarks. However, all symptomatic branches were identified lateral to the rostral-caudal meridian of the related dorsal sacral foramina. All patients experienced symptomatic branches at the L5 dorsal ramus and S1 lateral branch. Additionally, 11 of 14 (78%) patients had a symptomatic lateral branch at S2, and six of 14 (42%) had a symptomatic branch at S3. At 6-month follow-up, nine patients (64%, 95% CI: 39–89%) experienced a successful outcome based on the criteria above, with five patients (36%, 95% CI: 11–61%) reporting complete pain relief. Details on the 14 neurotomy procedures were not included, particularly which and how many levels were ablated in each patient.

3.4.2. Cooled RFN

Most of the retrospective observational studies assessed cooled RFN targeting the sacral lateral branches. One of the earliest by Kapural et al. (2008) was a retrospective review of 27 patients with chronic low back pain who underwent cooled RFN of the S1, S2, and S3 lateral branches and the L5 dorsal ramus [33]. Patients were selected for inclusion if they experienced >50% pain relief after two diagnostic intra-articular SIJ injections. Ten patients underwent bilateral and 16 underwent unilateral RFN (one was lost to follow-up). Calculating response rates accounting for patients lost to follow-up as treatment failures, at 3 months, 13/27 patients (48%, 95% CI: 29–67%) reported at least 50% pain relief, and 4/27 patients (15%, 95% CI: 2–28%) reported at least 75% pain relief. The Pain Disability Index (PDI) was reduced in 23 patients, with three remaining unchanged at 3–4 month follow-up. The mean reduction in PDI in the 23 patients was 18.2 points (SD = 7.1). Eighteen patients (67%, 95% CI: 49–84%) rated their improvement in pain scores using GPE as improved or much improved, while eight patients (30%, 95% CI: 12–47%) claimed minimal or no improvement. Following RFN treatment, there was an observed decrease in opioid analgesic intake.

Ho et al. (2013) reported findings from a single-arm retrospective cohort study of 20 patients [34]. The patients were eligible for RFN if they had at least 50% relief from a fluoroscopically-guided single intra-articular SIJ block with steroid. Radiofrequency lesioning was performed at 60 °C for 150 seconds targeting the L5 dorsal ramus and the S1, S2, and S3 foramen. At 1 month, 10 of 20 patients (50%, 95% CI: 28–72%) reported at least 50% improvement in VAS. Seventy-five percent (95% CI: 56–94%), 70% (95% CI: 50–90%), 75% (95% CI: 56–94%), and 70% (95% CI: 50–90%) reported at least 50% improvement in VAS at 3, 6, 12, and 24 months, respectively.

In a retrospective cohort review, Kleinmann et al. (2020) reviewed outcomes from 28 patients who underwent SLBRFN selected by at least 50% pain reduction with dual intra-articular blocks [35]. Radiofrequency was applied at a temperature of 60°C for 180 s. An introducer was first positioned at the L5 dorsal ramus root, where the first lesion was made. Sacral lesions were created adjacent to the dorsal foramina. Twenty out of the original 28 patients completed the questionnaires. The mean follow-up period was 15.4 ± 6.8 months. There were no statistically significant differences in anxiety and depression scores from baseline to post-intervention. Accounting for patients lost to follow-up as failures, 11 out of 28 (39%, 95% CI: 21–57%) achieved a 30% reduction in NRS.

In a retrospective cohort study, Tinnirello et al. (2020) studied the effect of cooled RFN of the sacral lateral branches [36]. Patients who experienced at least 50% pain relief from single intra-articular blocks and were taking opioids were included in the analysis. RFN was performed for 150 seconds at 60 °C utilizing a periforaminal technique. Twenty-five

of the 27 included patients, 93% (95% CI: 83–100%) reported at least 50% reduction in NRS at 1-month follow-up, 17 patients (63%, 95% CI: 45–81%) reported at least 50% relief at 6-month follow-up, and 12 patients (44%, 95% CI: 25–63%) reported at least 50% relief at 12-month follow-up. Mean improvement in ODI was 61% (30.7 ± 12.6), 49% (24.6 ± 12.1), and 40% (20.2 ± 11.6) at 1-, 6-, and 12-month follow-up, respectively, over baseline of 50.1 ± 9.0. Four patients reported a reduction in opioid use ranging from 25 to 50%. Two patients (7.4%) who used opioids at 1 month were no longer using them at 6 and 12 months.

Stelzer et al. (2013) retrospectively studied cooled RFN targeting the S1-S3 lateral branches and L5 dorsal ramus utilizing a periforaminal technique in patients who experienced ≥50% pain relief from a single intra-articular SIJ block [37]. Of the 126 charts reviewed, 21 had incomplete data, leaving 105 patients. During chart review, the patients were stratified according to the time to final follow-up: 4–6 months (mean 4.9 ± 0.7 months; n = 26), 6–12 months (mean 7.9 ± 1.6 months; n = 45), and more than 12 months (mean 17.5 ± 2.8 months; n = 34). There were no raw data presented. A significant decrease in the mean VAS scores was observed in all groups. There was an 86% (95% CI: 73–99%) responder rate, defined as ≥50% decrease in VAS, at 4–6 months, 71% (95% CI: 58–84%) at 6–12 months, and 48% (95% CI: 31–65%) beyond 12 months. Quality of life (QOL) was also tracked, with reports of "much improved" QOL reported as 79% (95% CI: 63–95%), 70% (95% CI: 53–84%), and 69% (95% CI: 53–85%) in the 4–6 months, 6–12 months, and over 12 months follow-up groups, respectively. Ninety-seven charts had data from 3 to 4 weeks follow-up. These data were used to assess the diagnostic utility of intra-articular SIJ injections and short-term relief after RFN. A Pearson's product correlation coefficient of 0.58 suggests a moderate-to-strong correlation between a positive block and short-term relief. The caveat to the data reported was that it represents a "snapshot" of different patients at various follow-up points following SLBRFN. Follow-up intervals were not standardized. As a result, it was not possible to incorporate any of the categorical or continuous data into this review's data tables.

3.4.3. Multipolar strip lesion RFN

In a retrospective cohort study by Schmidt et al. (2014), 77 patients who reported >50% pain improvement with single intra-articular blocks were selected for multipolar strip lesion RFN [38]. At 6-week, 6-month, and 12-month follow-up, patients reporting at least 50% improvement were 71% (95% CI: 61–81%), 55% (95% CI: 43–66%), and 16% (95% CI: 8–24%), respectively.

Anjana Reddy et al. (2016) retrospectively studied the effectiveness of multipolar strip lesion RFN in patients who had experienced SIJ pain for at least 6 months, whose pain was refractory to "medical therapy" and who reported greater than 50% relief after intra-articular SIJ injection lasting at least 6 months with pain returning to baseline after 6 months [39]. Of the original 26 patients, ten were lost to follow-up and, when calculating success rates in this review, are categorized as treatment failures. At 6 and 12 months, 8/26 (31%, 95% CI: 13–49%) and 7/26 (27%, 10–44%) of patients achieved ≥50% improvement in NRS, respectively.

3.4.4. Mixed studies

In a retrospective cohort review, Cheng et al. (2013) collected data on 88 patients: 30 received monopolar RFN, and 58 received cooled RFN [40]. The patients were included if they experienced ≥50% pain relief with dual intra-articular SIJ blocks. At 1, 3, 6, and 12 months, ≥50% pain relief was reported in the cooled RFN group for 29/58 (50%, 95% CI: 37–62%), 23/58 (40%, 95% CI: 27–52%), 16/58 (28%, 95% CI: 16–39%), and 10/58 (17%, 95% CI: 7–27%) patients, respectively. In the conventional RFN group, ≥50% pain relief was reported in 18/30 (60%, 95% CI: 42–78%), 10/30 (40%, 95% CI: 22–57%), 9/30 (30%, 95% CI: 14–46%), and 5/30 (17%, 95% CI: 3–30%) patients at 1-, 3-, 6-, and 12-month follow-up, respectively. Based on these results, the authors concluded that clinical outcomes were not superior for cooled RFN compared with monopolar RFN of the sacral lateral branches.

Tinnirello et al. (2017) compared multipolar strip lesion RFN to cooled RFN in a retrospective observational study [41]. There were 21 patients in the multipolar strip lesion group and 22 in the cooled RFN group. Cooled RFN was performed utilizing a periforaminal technique at 60◦C for 150 s. In the multipolar strip lesion group, at 1-, 3-, 6-, and 12-month follow-up, 20/21 patients (95%, 95% CI: 86–100%), 19/21 patients (90%, 95% CI: 81–100%), 8/21 patients (38%, 95% CI: 32–44%), and 5/21 patients (24%, 95% CI: 19–29%) reported at least 50% pain reduction. In the cooled RFN group, at 1-, 3-, 6-, and 12-month follow-up, 22/22 patients (100%, 95% CI: 91–100%), 20/22 patients (91%, 95% CI: 82–100%), 18/22 patients (82%, 95% CI: 74–90%), and 16/22 patients (73%, 95% CI: 65–81%) reported at least 50% pain reduction.

In a retrospective review, Speldewinde et al. (2020) compared the success rates of two SLBRFN techniques: multipolar strip lesion RFN and small-lesion monopolar periforaminal RFN [42]. Seventy-three patients met the inclusion criteria, which included a 50% reduction in pain with a single intra-articular block. Forty-one patients underwent a total of 47 monopolar periforaminal neurotomies, and 32 patients underwent a total of 49 large continuous-lesion multi-electrode RFNs. Seventy-one percent of the large continuous-lesion multi-electrode RFN group and 65% of the periforaminal group reported "good to excellent pain relief."

Bayerl et al. (2020) retrospectively studied multipolar strip lesion RFN and conventional RFN [43]. Patients with at least a 50% reduction in NRS following single intra-articular blocks were selected. Forty-six of the 64 (72%, 95% CI: 61–83%) patients in the multipolar strip lesion RFN group and 22 of 57 (39%, 95% CI: 26–51%) patients in the conventional RFN group reported ≥50% pain relief at 12 months. At 12 months, 7/57 (12%, 95% CI: 4–21%) patients reported that their response to monopolar RFN was "excellent," "good" for 9/57 (16%, 95% CI: 6–25%), "fair" for 28/57 (49%, 95% CI: 36–62%), and "poor" for 13/57 (23%, 95% CI: 12–34%). In the multipolar strip lesion RFN group, 16/64 (25%, 95% CI: 14–36%) patients reported that their response was "excellent," "good" for 19/64 (30%, 95% CI: 18–41%), "fair" for 22/64 (34%, 95% CI: 23–46%), and "poor" for 7/64 (11%, 95% CI: 3–19%).

3.5. GRADE assessment of the evidence of effectiveness of PSIJC RFN

When applying GRADE to assess the overall quality of the evidence regarding the effectiveness of SLBRFN across all RF techniques and RF types, there were four explanatory RCTs and four pragmatic RCTs. With evidence available from multiple RCTs, the resulting body of evidence was initially assigned a "high" quality rating. However, this body of evidence was downgraded due to 1) risk of bias (5/8 studies with "some concern" or "moderate risk" of bias according to the Cochrane Risk of Bias tool) (*see* Table 5) and 2) indirectness (substantial differences in the technique and significant population differences). Only Patel (2016, 2018) received industry funding for the procedure, administration time, and personnel [12,28]. Downgrading for indirectness was based on study population heterogeneity given various inclusion and exclusion criteria (*e.g.*, variability in the diagnostic blocks used, different requirements for failed conservative management), as well as variability in follow-up intervals. As a result, the original "high" quality of evidence rating was downgraded to "moderate" quality of evidence that SLBRFN provides clinically significant reductions in pain and disability for up to 1 year.

Given the variability in SLBRFN techniques, the decision was made to assess the quality of evidence for techniques that have been anatomically validated. Two cadaveric studies have been performed exploring the optimal placement of the RFN cannulae during SLBRFN [44,45]. Roberts et al. conducted a cadaveric study of the sacral lateral branches as applied to various neurotomy types (monopolar, cooled, bipolar) and techniques (periforaminal, Palisade, Nimbus Continuum, posterior sacral network lateral crest) [46]. The authors concluded that periforaminal cooled and bipolar strip lesioning techniques with electrode placements perpendicular to the sacrum most effectively captured the sacral lateral branches.

Table 5
Cochrane risk of bias assessment for RCTs.

Reference	RF Type	COCHRANE RISK OF BIAS ASSESSMENT					
		Domain 1: Bias Arising from Randomization Process	Domain 2: Bias Due to Deviations from Intended Intervention	Domain 3: Bias from Missing Outcome Data	Domain 4: Bias in Measurement of the Outcome	Domain 5: Bias in Selection of Reported Results	Overall Risk of Bias
Explanatory RCTs							
Mehta 2018 [14]	Monopolar, Multipolar Strip Lesion	Low	Some Concerns	Low	Low	Low	Some Concerns
vanTilburg 2016 [13]	Bipolar	Low	Low	Some Concerns	Low	Low	Low
Patel 2012 [12]	Cooled	Low	Some Concerns	Low	Low	Some Concerns	Some Concerns
Cohen 2008 [11]	Monopolar at L4MB, L5DR; Cooled at S1-S3	Low	Low	Low	Low	Low	Low
Pragmatic RCTs							
Eissa 2022 [18]	Monopolar	Some Concerns	Low	Low	Low	Low	Low
Martinez 2016 [17]	Bipolar	Some Concerns	Some Concerns	Low	High	Low	Moderate
Salman 2016 [16]	Monopolar	Low	Low	Low	Low	Low	Low
Zheng 2014 [15]	Monopolar	Low	Some Concerns	Low	Low	Low	Some Concerns

Furthermore, they found that monopolar RFN was inferior to cooled and bipolar RFN, with the limiting factor of monopolar RFN being the relatively small size of the lesion created. This likely contributes to inconsistent clinical outcomes and less optimal improvements reported in those SLBRFN studies. While the multipolar probe used in a number of studies [13,14,26,38,41–43] is designed to produce a similar strip lesion lateral to the sacral foramen, this technique was excluded from these anatomical studies due to concerns that the probe is unlikely to capture all of the deep sacral lateral branches given variations in sacral anatomy. Therefore, the use of the multipolar probe has yet to be anatomically validated.

Including only anatomically validated RFN techniques, the GRADE assessment is more favorable. With three sham-controlled RCTs [11–13], the quality rating is downgraded one level due to "some concerns" for bias and some heterogeneous selection criteria but upgraded by one level for large attributable effect sizes. There is high-quality evidence that SLBRFN effectively reduces pain and disability for up to 1 year when utilizing periforaminal cooled and bipolar strip lesioning techniques, with electrode placements perpendicular to the sacrum, known to denervate the PSIJC effectively.

3.6. Adverse events

The incidence of adverse events was low in the reviewed studies, including data from 1367 patients. There were 29 total adverse events and three SAEs reported. Case reports discussed patients who developed various conditions, including radiculitis, hematoma, and transient procedural pain [46–49]. There was a single case of skin burn with SLBRFN [48]. There were two recorded cases of post-procedural infection [15, 47]. No permanent sequelae were reported (*See* Table 4).

3.6.1. GRADE assessment of the evidence of risks with SLBRFN

When applying GRADE to assess the quality of the evidence regarding the risks of SLBRFN, it is noted that the published evidence consists of reports from prospective studies and observational data from a small number of case reports. Given the paucity of data, according to GRADE, overall "very-low" quality evidence describes adverse events associated with SLBRFN. Notably, most of the studies included in this review reported no adverse events, which suggests that adverse event rates are so low that they cannot be captured in moderately-sized studies. A large cohort or registry study on SLBRFN SAE rates would aid in defining an accurate incidence rate.

4. Discussion

Two systematic reviews and one narrative review have been published since 2010 describing pain outcomes and other significant measures of treatment effectiveness of SLBRFN [1,5,6]. In this review of the published data, despite the variability in types of RF technology used, technique, nerve targets, and study methodology, most studies found SLBRFN to be an effective treatment for pain. Substantial proportions of patients achieved ≥50% relief at 1, 3, 6, and 12 months following SLBRFN, with a reduction in the proportion of responders reporting ≥50% relief at 12 months (Fig. 2). Functional outcomes were heterogeneously reported; these scores generally demonstrated improvement. Three of four sham-controlled RCTs included in this review demonstrated efficacy of SLBRFN when compared to sham (Tables 2 and 3) [11–13]. The three RCTs that employed an anatomically validated approach showed that SLBRFN outperformed sham, placebo, or intra-articular corticosteroid and anesthetic injection [11–13].

Overall synthesis of this published literature demonstrated that there is moderate-quality evidence that SLBRFN is an effective treatment for PSIJC pain, with outcomes indicating strong efficacy of SLBRFN. When only studies using anatomically validated SLBRFN techniques were evaluated, the evidence supporting SLBRFN as an effective treatment for PSIJC pain is high-quality, according to GRADE.

Assessment of the literature indicates that multiple selection paradigms to identify appropriate patients for SLBRFN lead to treatment success; however, an optimal selection paradigm has yet to be defined. All studies in this review included a diagnostic block of some type before performing RFN. Earlier studies used intra-articular SIJ injections with or without corticosteroids to select SLBRFN candidates. It is, however, now discouraged to use intra-articular SIJ injections, which lack face-validity, for SLBRFN selection as the SIJ and PSIJC have been clearly distinguished as unique pain generators. More recent studies have more appropriately utilized diagnostic sacral lateral branch blocks for patient selection. The lateral branch block studies used single-site, single depth

or multi-site, multi-depth lateral branch approaches. Despite this variability, there is no clear distinction in responders reporting ≥50% relief from SLBRFN when selected based on different thresholds for pain relief – 50%, 75%, or 80%.

Although there are no clinical studies that directly compared different diagnostic block paradigms and their effect on SLBRFN outcomes, Dreyfuss et al. showed that 1) single-site, single-depth block techniques do not adequately anesthetize the PSIJC, and 2) multi-site, multi-depth block techniques anesthetize the dorsal ligaments/SIJ, but not the entire SIJ capsule [2]. A recent study reported that successful blocks and ablation of the sacral lateral branches are associated with buttock hypoesthesia [50]. Furthermore, while the percentage of relief from diagnostic blocks has not been directly studied, this has been studied extensively for cervical and the lumbar medial branches with consensus cutoffs for both [51,52]. Based on previous studies for cervical and lumbar medial branch blocks, the use of a cutoff of ≥80% improvement is a logical diagnostic threshold for patient selection until high-quality studies addressing comparative outcomes with various block paradigms indicate otherwise.

All studies that reported categorical outcomes included lesioning of the S1-3 sacral lateral branches. The majority of these studies also included the L5 dorsal ramus. In the retrospective study by Yin et al. (2003), the authors conducted sensory stimulation-guided SLBRFN to identify which nerve branches were most involved in transmitting nociception from the PSIJC [32]. All patients had reported a concordant response during stimulation of the L5 dorsal ramus and S1 lateral branch nerve, with most patients also reporting a concordant response during stimulation of the S2 lateral branch nerve. Additionally, multiple cadaveric studies indicate that the L5 dorsal ramus innervates the posterior SIJ for at least a portion of the population. Of the anatomically validated techniques, a bipolar strip lesion is most likely to capture the branch from the L5 dorsal ramus, but the periforaminal cooled RFN technique was anatomically evaluated assuming a separate lesion to capture that branch (44,45). These data indicate that the inclusion of the L5 dorsal ramus is warranted also with the sacral lateral branches for outcome optimization.

Assessment of the published literature on complications of SLBRFN indicates the relative safety of this procedure. The two most commonly reported adverse events were transient post-procedural pain and transient neuritis. The procedure requires multiple large-gauge cannulae, passing through the skin, subcutaneous tissue, adipose, and musculature, and eventually contacting the sacral periosteum. Thus, it is expected that some level of post-procedure discomfort may occur. The overall lack of SAEs reported in all the reviewed studies suggests that SLBRFN is a safe procedure in the context of other treatments for refractory SIJ pain, namely SIJ fusion. Measurable rates of SAEs have been documented in moderately-sized studies of lateral SIJ fusion. In the iMIA study, two procedure-related reported SAEs (N = 52) were reported – postoperative nerve impingement and postoperative hematoma [53]. The INSITE study reported 17 procedure-related SAEs (N = 102), including wound hematoma, iliac bone fracture, postoperative nerve impingement, and postoperative atrial fibrillation/respiratory failure [54]. Larger studies evaluating SLBRFN SAE rates would increase the accuracy of the apparent negligible incidence reported in the present literature.

4.1. Limitations

There are limitations to this review. Although several databases were included in the literature search and a medical librarian assisted in formulating the search strategy, it is possible that all relevant studies were not identified. Valuable data may have been rejected if unavailable in English. With the potential for inadvertent confirmation bias, reviewers' assessments may be influenced by their experience and knowledge of SLBRFN and its effects.

5. Conclusion

Despite the variability in types of radiofrequency technology, technique, nerve targets, and study methodology, most studies found that substantial proportions of patients achieved ≥50% relief at 1, 3, 6, and 12 months following SLBRFN. According to GRADE, there is moderate-quality evidence that SLBRFN effectively reduces pain by at least 50% in patients with PSIJC pain and high-quality evidence that it effectively reduces pain by at least 50% in patients treated with anatomically validated techniques. Future studies of SLBRFN should use both validated block techniques and anatomically valid RFN techniques. Likened to cervical medial branch blocks and RFN, we recommend that studies use dual comparative multi-site, multi-depth lateral branch blocks with 80% or more relief. Use of intra-articular SIJ injections for patient selection is discouraged, as the SIJ and the PSIJC have been clearly distinguished as unique pain generators. This should then be followed utilizing one of the anatomically validated RFN techniques, including coverage of the L5 dorsal ramus. Such study designs would provide a baseline for the optimal effectiveness of SLBRFN for well-selected patients with PSIJC pain, after which comparative studies utilizing alternative block and RFN paradigms might be further explored.

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Appendix A. Supplementary data

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