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A description and outcome evaluation of sacrococcygeal joint radiofrequency neurotomy for treatment of chronic coccydynia – A dorsal approach

Scott WJ. Moorman [a,*], Josh Kutcher [a,b], Robert Burnham [a,b,c]

[a] Division of Physical Medicine and Rehabilitation, University of Alberta, Edmonton, Alberta, Canada
[b] Vivo Cura Health, Calgary, Alberta, Canada
[c] Central Alberta Pain and Rehabilitation Institute (CAPRI), Lacombe, Alberta, Canada

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ABSTRACT

Background: Coccydynia is a condition characterized by pain and tenderness in the coccyx region of the spine. Chronic coccydynia (≥3-months) management remains a clinical challenge. Radiofrequency neurotomy (RFN) targeting the sacrococcygeal joint (SCJ) and/or 1st intercoccygeal joint (ICJ) margins has emerged as an alternative, minimally invasive intervention for refractory coccydynia.

Objective: The objective of this study was to evaluate the safety and effectiveness of an RFN technique targeting the dorsal aspect of SCJ and/or 1st ICJ for treatment of patients with chronic coccydynia.

Methods: Retrospective analysis of prospective outcomes for patients with chronic coccydynia (≥3-months) who underwent RFN to dorsal SCJ and/or 1st ICJ between 2009 - 2023. RFN technique was a dorsal approach targeting the distal sacrum and proximal coccyx, which form the SCJ or 1st ICJ margins. Numerical rating scale (NRS) and Pain Disability Quality-of-Life Questionnaire-Spine (PDQQ-S) scores were completed pre- and 3-months post-RFN. Successful RFN was defined as ≥50% reduction or minimal clinical important difference (MCID) in PDQQ-S and NRS pain scores. The primary outcome measures were the proportion of patients achieving ≥50% reduction in NRS pain and PDDQ-S scores following primary and repeat RFN to SCJ and/or 1st ICJ. Secondary outcomes included the proportion of patients achieving MCID on NRS pain and PDQQ-S scores following RFN, as well as mean NRS and PDQQ-S scores pre- and 3-months post-RFN, and magnitude of improvement for patients following successful RFN procedures.

Results: A total of 52 RFN procedures (n = 30 primary, and n = 22 repeat procedures) were performed on 30 patients (female = 25, male = 5, mean age 55.1 ± 13.0yrs). Ten patients (33.3%; 95% CI = 17.3–52.8) reported ≥50% pain reduction as measured by NRS pain and PDQQ-S scores following primary SCJ and/or 1st ICJ RFN at 3-months follow-up. Fifteen patients (50%; 95% CI = 31.3–68.7) reported MCID NRS pain reduction and 12 patients (40.0%; 95% CI = 22.7–59.4) reported MCID PDQQ-S scores at 3-months following primary RFN. The mean magnitude of improvement for patients with primary successful RFN, as defined as ≥50% reduction in either NRS pain or PDQQ-S scores, was 77.4% (±SD 21.4%) and 74.9% (±SD = 19.9%), respectively. Similarly, the mean magnitude of improvement for patients with successful RFN, as defined by MCID reduction in NRS pain or PDQQ-S scores, was 62.6% (±SD = 28.2%) and 69.3% (±SD = 22.3%), respectively. At 3-months follow-up, 14 patients (63.6%; 95% CI = 40.7–82.8) reported ≥50% pain reduction as measured by either NRS pain and PDQQ-S scores following repeat RFN. Nineteen patients (86.4%; 95% CI = 65.1–97.1) reported MCID NRS pain reduction and 16 patients (72.7%; 95% CI = 49.8–89.3) reported MCID PDQQ-S scores at 3-months following repeat RFN. Statistically significant differences were observed between pre- and post-RFN NRS pain and PDQQ-S scores ($p < 0.005$) in both primary and repeat procedures.

Discussion/conclusion: This study represents an introductory step in evaluating the efficacy of a dorsal approach RFN technique targeting the SCJ and/or 1st ICJ as a treatment option for chronic coccydynia. Primary RFN demonstrated pain reduction and improvement in function at 3-months in 33.3% of patients. Several limitations remain, including heterogeneity in patient population, small sample size, and no control groups. Future detailed investigations include cadaveric studies to clarify sensory innervation and enhance reliability of our targets

* Corresponding author. 10964 129th Street NW, Edmonton, Alberta, T6G 0Y1, Canada.
E-mail address: moorman@ualberta.ca (S.WJ. Moorman).

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during RFN. Larger prospective studies of long-term outcomes, including comparison with control groups, are required to further evaluate the efficacy of our dorsal RFN approach.

Abbreviations

SCJ	Sacrococcygeal joint
ICJ	Intercoccygeal joint
ESWT	Extracorporeal shockwave therapy
RFT	Radiofrequency therapy
RFN	Radiofrequency neurotomy
PSCP	Posterior sacrococcygeal plexus
CP	Coccygeal plexus
CoN	Coccygeal nerve
S4	Sacral 4th ventral rami
S5	Sacral 5th ventral rami
NRS	Numerical rating scale
PDQQ-S	Pain Disability Quality-of-Life Questionnaire-Spine
MCID	Minimal clinical important difference
CI	Confidence Interval

1. Introduction

Coccydynia, also known as coccygodynia, is a condition characterized by pain in the coccyx region of the spine [1]. Clinically, the diagnosis of coccydynia is often made based on history of pain in the sacrococcygeal joint area worsened by sitting, transitioning from sit-to-stand, defecating, or sexual intercourse, and physical examination findings of palpable tenderness to coccygeal region. The exact incidence of coccydynia is not known, however, limited studies have suggested that 1–2.7% of back pain complaints in the emergency department are related to coccydynia [2] and women tend to have a five-times higher incidence compared to men [3]. Coccydynia is most frequently associated with single-axis traumatic injury to the coccyx, either through direct acute external trauma secondary to a fall, repetitive microtrauma, or internal trauma from difficult childbirth often necessitating instrumentation (50–65%) [2,4–7]. These mechanisms can ultimately result in fracture, subluxation or dislocation, instability, or pelvic floor dysfunction. Non-traumatic [7–9] and idiopathic [3,8–12] causes make up the remaining proportion of coccydynia.

There are multiple potential pain generators within the coccygeal region, including but not limited to bony, soft-tissue and/or neurological structures that can lead to clinical and functional impairment. Anatomically, the coccyx is the terminal segment of the spine and is a triangular bone consisting of 3–5 vertebral segmental divisions [6–8,10,11]. The first coccygeal vertebrae is the largest and articulates with the sacrum via a symphysial joint containing a thin intervertebral disc of fibrocartilage, forming the SCJ [8]. Subsequent joint segments between coccygeal vertebral bodies form the intercoccygeal joints (ICJ) [12]. Our current understanding of the neural innervation along the terminal sacrum and coccyx includes a network known as the posterior sacrococcygeal plexus (PSCP), with the more distal neural network dorsally across the coccyx called the coccygeal plexus (CP). The CP is composed of the sacral 4th and 5th ventral rami (S4, S5), which emerge from the sacral dorsal foramen, and the coccygeal nerve (CoN), which exits through the sacral and coccygeal cornu (Fig. 1A) [8,13–16]. Ultimately, the S4, S5 and CoN ventral rami combine to give rise to the anococcygeal nerve [14], which provides sensation to the perianal region. There are anatomical variations in the PSCP and CP, but, collectively, this dorsal sacrococcygeal network is presumed to supply the skin and soft-tissue overlying the ventral and dorsal aspects of the coccyx, SCJ margin, coccygeal periosteum, and pelvic floor musculature. Recent literature has improved our understanding of dorsal sacrococcygeal innervation, including terminal sensory afferent innervation across SCJ and surrounding region [13], however, our understanding still remain grossly limited.

As the majority of coccydynia clinically presents in the acute phase with mild symptoms, primary treatment is typically conservative therapy, often requiring no specific treatment regimen, or a combination of rest, physical therapy, ergonomic modifications, and/or non-steroidal anti-inflammatory drugs [8,17–19]. Most coccydynia cases (90%) respond positively to conservative treatment within a few weeks-to-months. However, there remains a subset of patients who continue to have chronic coccydynia, often defined as persistent symptoms ≥3-months despite conservative efforts, and who remain a clinical management challenge. For these remaining cases where pain, functional impairment affecting activities-of-daily living, and/or reduced

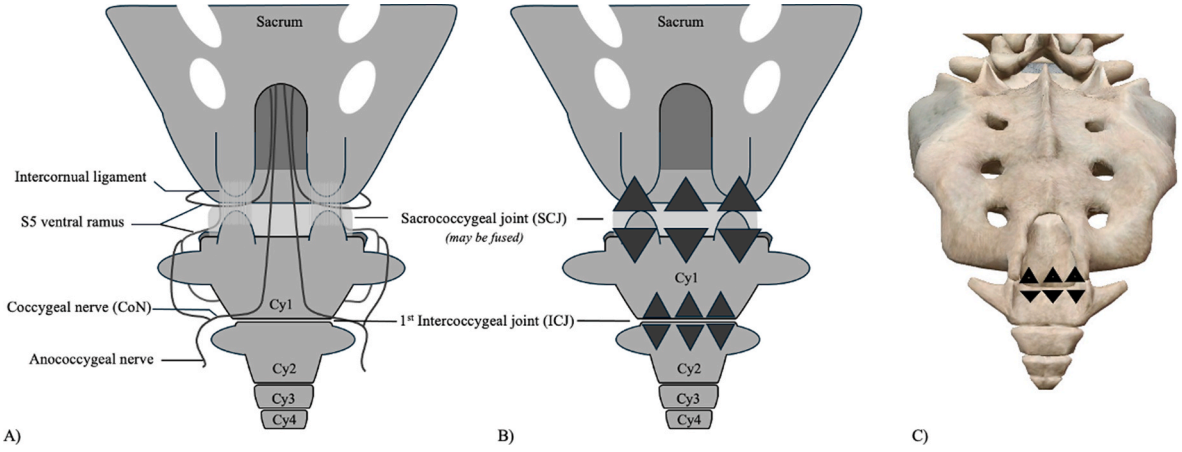

Fig. 1. Schematic representation of the A) dorsal innervation of the sacrococcygeal (SCJ) and 1st intercoccygeal joint (ICJ), B) the location of radiofrequency neurotomy (RFN) lesions in this study along the superior and inferior dorsal joint line of the SCJ and 1st ICJ – denoted by the black triangles, and C) a 3D-bony illustration of location of RFN lesion location across SCJ (ICJ not shown). Schematic is not to scale and exact location of the innervation is a gross illustration. S4 ventral ramus is not depicted in diagram – which has been described in the literature to be involved in the coccygeal plexus. Cy1 represents first coccygeal vertebral segment, followed by 2nd coccygeal vertebra (Cy2), 3rd (Cy3), and 4th (Cy3).

overall quality of life persist, varying degrees of invasive treatment options can be offered. Minimally invasive interventions include coccygeal manipulation, local anesthetic or corticosteroid injections, caudal epidural block, extracorporeal shockwave therapy (ESWT), radiofrequency neurotomy (RFN) [20,21], and ganglion impar sympathetic neurolysis [22–25]. For select patients who fail minimally invasive treatment, surgical interventional options include partial or total coccygectomy [2,9,15,17,18,26–28].

RFN is a thermal ablative procedure that utilizes radiofrequency current delivered through an electrode placed nearby nociceptive pathways to cause focal tisse destruction and interruption of nerve impulses responsible for pain transmission and/or modulation. The majority of RFN treatment of refractory coccydynia has targeted the ganglion impar (GI) along the anterior surface of the SCJ and ICJ. The GI is the most caudal paravertebral sympathetic chain and provides nociceptive and sympathetic innervation to pelvic, visceral, and perineal regions including the SCJ [20,22,23,29,30]. Plancarte et al. (1990) first proposed an approach to target the GI along the anterior sacrococcygeal junction to treat malignant pelvic pain [22], followed by Reig et al. (2005) who demonstrated 50% pain reduction by thermocoagulation radiofrequency in individuals with non-cancerous pelvis pain [23]. Subsequent modifications have included alternate approaches to target the GI, including transsacrococcygeal joint [24,31], and use of pulsed RF [21,24,30,32]. The major limitation remains the technical challenge of accessing its small sometimes poorly fluoroscopically visualized targets, variable localization of nearby visceral organs along the anterior aspect of the sacrum and coccyx, as well as its mixed sensory, motor, and autonomic innervation to both somatic and visceral organs.

As our understanding of anatomy becomes more refined, including improved localization of pure sensory afferent fibers innervating painful joints, alternate RFN targets and approaches can be applied clinically. For instance, RFN targeting terminal dorsal sensory afferent fibers has successfully been demonstrated as an effective treatment modality for axial skeleton pathologies, such as chronic neck pain, facetogenic arthropathy, and sacroiliac dysfunction [33–35]. Despite its success, there are few well described specific RFN methods with a dorsal approach targeting SCJ or distal coccygeal segments for target treatment of coccydynia [36–40]. At this time, there are no current evidence-based guidelines outlined for patient selection with regards to RFN targeting the dorsal SCJ and 1st ICJ as a treatment for chronic coccydynia. We hypothesize that RFN targeting the dorsal SCJ ± 1st ICJ margins would: a) lesion the terminal sensory branches to the SCJ ± 1st ICJ, thus minimizing the risk of perianal sensory, motor or automatic dysfunction, b) avoid the risk of thermal injury to the rectum, and c) have a good safety profile because the dorsal SCJ and 1st ICJ lines are readily visible using a combination of ultrasound and fluoroscopic imaging. The objective of this study was to evaluate the safety and effectiveness of an RFN technique targeting the dorsal aspect of SCJ and/or 1st ICJ for treatment of patients with chronic coccydynia.

2. Materials and methods

This study was a retrospective analysis of prospectively gathered outcomes for patients who underwent RFN to dorsal SCJ and/or 1st ICJ between 2009 - 2023. Patient demographic information and outcome measure data were obtained from the electronic medical records of a single physiatrists practice (Vivo Cura Health, Calgary, AB, Canada; Central Alberta Pain and Rehabilitation Institution, Lacombe, AB, Canada). All patients included in our study were diagnosed with chronic coccydynia based on pain ≥3-months, local tenderness SCJ and/or 1st ICJ to palpation including under fluoroscopy, focal pain worse with sitting, and absence of other physical exam findings. The registry data protocol was approved by the Conjoint Health Research Ethics Board at the University of Calgary (Ethics ID#: REB20-0355). The study was conducted according to the Declaration of Helsinki. Patients who underwent RFN were those who underwent at least one diagnostic dorsal sensory block of the SCJ, 1st inter-coccygeal (ICJ), or both SCJ/ICJ with ≥50% pain reduction. A diagnostic block was completed with an anesthetic agent (1.5 – 2 mL of 2% lidocaine). A primary RFN was defined as the first RFN procedure performed on an individual to either the SCJ, 1st ICJ, or both SCJ/ICJ, whereas a repeat RFN was a second or sequential RFN procedure to the same region. Patients completed pre- and 3-month post-RFN Pain Disability Quality-of-Life Questionnaire-Spine (PDQQ-S) for primary and repeat procedures. The PDQQ-S is a patient reported outcome measure that assesses the domains of pain, disability and life satisfaction/quality (average for the prior week) using 2 questions per domain [41]. The 1st question of the PDQQ-S is the numerical rating scale (NRS) of pain intensity. Our practice routinely offered clinical reassessment to patients who did not achieve significant relief at 3-months post-RFN. If patients did well post-RFN, they were not seen until their pain recurred. For those patients wishing to undergo a repeat RFN, no repeat diagnostic block was required for patients who were satisfied with the magnitude and duration of pain relief from previous RFN, and pain recurred in the same location and with similar pain quality and characteristics. If there were any changes in pain that recurred, patients were clinically reassessed and repeat diagnostic blocks (if indicated) were completed to define pain generator. Parameters of repeat RFN were maintained as per primary or previous procedure and pre- and 3-month post-RFN procedure PDQQ-S scores were similarly recorded. (Fig. 2).

2.1. Outcome measures

The primary outcome measures in this study were the proportion of patients achieving ≥50% reduction in NRS pain and PDQQ-S scores at 3-months following primary and repeat RFN to SCJ and/or 1st ICJ. Secondary outcomes included the proportion of patients achieving minimal clinical different (MCID) on NRS pain and PDQQ-S scores at 3-months following primary and repeat RFN. Additional outcome measures included mean NRS pain and PDQQ-S scores 3-months post-RFN for both primary and repeat procedures, as well as the magnitude of improvement for patients following successful RFN procedures at 3-months. A successful patient outcome following RFN was defined as ≥50% reduction in pain measured on NRS and/or PDQQ-S, or a MCID on NRS or PDQQ-S of ≥2 and ≥17, respectively [42]. MCID is generally accepted as the smallest difference in score reported by patients that correlates with a clinically relevant improvement compared to a prior time or pre-treatment. Patients who underwent RFN procedure but did not achieve the above criteria for successful RFN, either by failing to return for follow-up assessment and/or completing the post-RFN NRS and PDQQ-S scores, were considered treatment failures. For any missing post-RFN procedure NRS or PDQQ-S scores, patient pre-RFN scores (n = 8/52) were carried forward and assumed to be unchanged.

2.2. Diagnostic block and radiofrequency neurotomy technique

The primary target for diagnostic block and RFN was the dorsal periosteum of distal sacrum and proximal coccyx, or the distal 1st coccygeal and proximal 2nd coccygeal segment which form the SCJ or 1st ICJ margins, respectively (Fig. 1B and C). The determination of the exact location for diagnostic block and RFN was dependent on focal area of tenderness on palpation while laying prone under both ultrasound and fluoroscopy (Fig. 2). Ultimately, the location for RFN lesions were dictated based on the result of previous blocks. As part of our protocol, all diagnostic blocks and RFN lesions were performed using a combination of ultrasound and fluoroscopic guidance. Under ultrasound, a curvilinear or linear transducer was placed over the dorsal sacrococcygeal and/or 1st intercoccygeal joint to visualize the joint line deep to area of maximal tenderness. Superficial landmarks on the skin were made with a marking pen, outlining the trajectory of the joint line. Confirmation of the SCJ and/or 1st ICJ margins were confirmed with fluoroscopy. Diagnostic blocks and RFN lesions were completed under

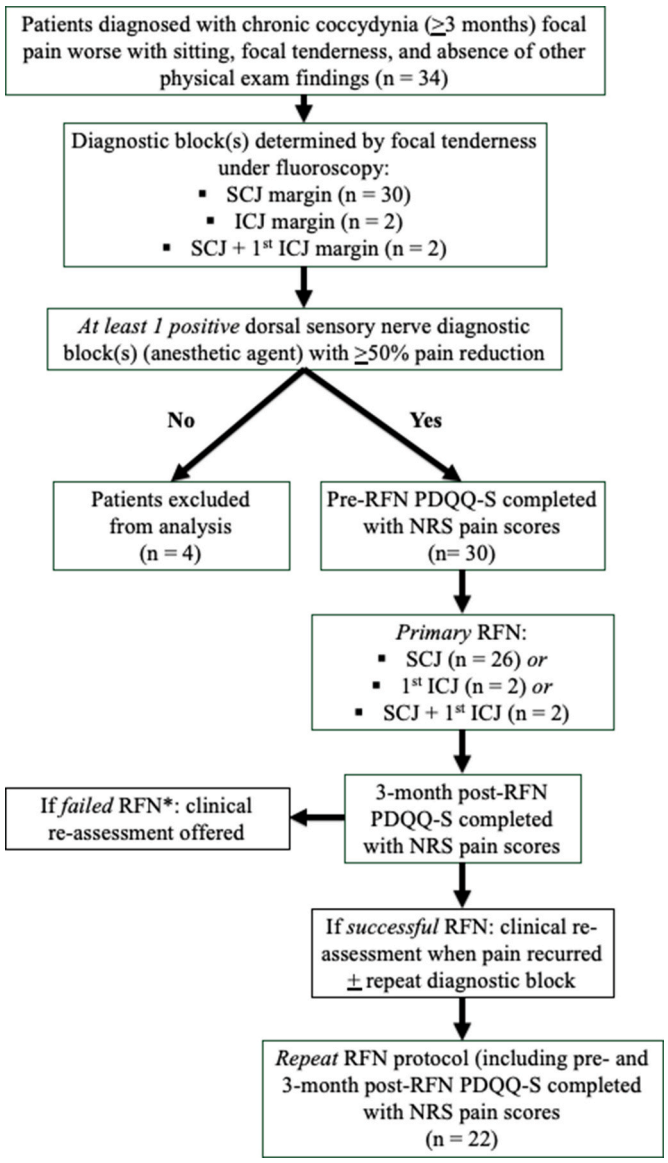

Fig. 2. Schematic representation of study design. Abbreviations: Radiofrequency Neurotomy (RFN), Numerical Rating Scale (NRS), Pain Disability Quality-of-Life Questionnaire-Spine (PDQQ-S), Sacrococcygeal Joint (SCJ), Intercoccygeal joint (ICJ), * = insignificant relief/poor response experienced by patient post-RFN.

fluoroscopy and needle placement confirmed along the dorsal periosteum of the SCJ and/or 1st ICJ with 2 orthogonal views (AP and lateral views). With regards to diagnostic blocks, the needle was placed over the superolateral and mid aspect of the joint margin on each side seen on AP view, followed by both inferolateral and mid aspects of the joint margin. Local anesthetic (1.5–2% lidocaine) was injected in 0.2 mL aliquots at 3 or 4 locations along each of the upper and lower dorsal joint margins. As we were primarily interested in anesthetizing the dorsal surface of the distal sacrum and proximal coccyx and, presumably, targeting the terminal branches of the sensory nerves overlying the dorsal joint margins, we assumed small volumes of anesthetic used across the upper and lower dorsal joint margins would minimize intra-articular spread. Patients were given a pain diary to record an NRS pain score at 30-min intervals for 6h following the blocks. A positive diagnostic block was defined as ≥50% pain reduction following injection within 6h post-injection using a 0–10 NRS of pain intensity.

The same dorsal periosteal target sites were used for SCJ and/or 1st ICJ RFN. Given that the protocol spanned from 2009 to 2023, the type and orientation of the cannula varied over time and was influenced by patient body habitus. Prior to 2015, all RFNs were performed using a 22-gauge 5 mm exposed tip bipolar cannula configuration (Fig. 3A). In 2015, the option to use a multi-tined cannula (Trident™ Diros Technology Inc, Markham, ON, Canada) monopolar lesion became available to patients, however, only for patients with ≥10 mm soft-tissue coverage over the SCJ and/or 1st ICJ due to inherent risk of thermal injury (Fig. 3B). The configuration of the multi-tined cannula thermal lesion is a 7 x 7 x 8 mm globular triangle at the distal end with an 8 mm deep tail. Therefore, patients with overlying subcutaneous tissue ≤8 mm would be at risk for thermal injury to the skin. Ultimately, ultrasound was used to objectively measure the subcutaneous tissue overlying the SCJ and/or 1st ICJ and determine the cannulae type. For patients with a subcutaneous tissue layer <10 mm, a 22-gauge 5 mm exposed tip (conventional) monopolar cannula was used, while those with ≥10 mm, a multi-tined cannula was used to complete RFN lesions. Each cannulae was advanced under fluoroscopic guidance until the tip contacted the dorsal periosteum. When using a 22-gauge 5 mm expose tip conventional monopolar cannulae, the cannulae were typically placed perpendicular to the bone and dorsal joint lines. Once a lesion was completed, one cannula was leapfrogged to the next position along the joint line, and the next lesion was performed. If a multi-tined cannula was used, either a perpendicular to the bone approach or slightly oblique was used to perform multiple individual lesions across the superior and inferior sacrum and coccyx joint line. The inter-electrode distance was 6 – 8 mm regardless of cannulae type. Thermal lesions were performed at 80°C for 2 min after a 15 s ramp-up time. All procedures were performed with the patient in a prone position and using sterile technique.

2.3. Statistical analysis

Descriptive statistics were used to summarize patient demographics, number, location of diagnostic block and RFN procedures, and type of RFN cannula used. Logistic regression analysis was used to calculate the odd ratios (OR) and their corresponding 95% confidence intervals (CIs). Wilcoxon Signed-Rank test was used to determine if pre- and post-RFN procedure mean NRS and PDQQ-S scores were statistically significant for all procedures completed (i.e. those deemed successful and failed), as well as for only those deemed successful based on MCID.

3. Results

A total of 59 RFN procedures were performed on 34 patients. However, 7 RFN procedures were not included in the retrospective analysis due to: 1) patient outcomes following diagnostic block were <50% pain reduction (n = 5), 2) patients undergoing diagnostic block and/or RFN to locations other than SCJ and/or 1st ICJ margins (n = 1), or 3) incomplete patient pre-RFN NRS and/or PDQQ-S scores (n = 1). These 7 RFN procedures were performed on a total of 4 patients, who were excluded from analysis. Therefore, 52 RFN procedures (n = 30 *primary*, and n = 22 *repeat* procedures) were performed on 30 patients (mean age 55.1 ± 13.0 years) (Table 1). A total of 20 patients underwent a single diagnostic block and experienced ≥50% pain reduction, whereas 10 patients underwent two separate (double) diagnostic blocks with ≥50% pain reduction prior to RFN. Nineteen patients underwent primary SCJ and/or 1st ICJ RFN using the conventional monopolar cannula, while the multi-tined (Trident™) cannula was used for 11 patients.

At 3-months follow-up, 10 patients (33.3%; 95% CI = 17.3–52.8) reported ≥50% pain reduction as measured by NRS pain and PDQQ-S scores following primary SCJ and/or 1st ICJ RFN (Table 2). Fifteen patients (50%; 95% CI = 31.3–68.7) reported MCID NRS pain reduction and 12 patients (40.0%; 95% CI = 22.7–59.4) reported MCID PDQQ-S scores at 3-months following primary RFN. The mean magnitude of improvement for patients with primary successful RFN, as defined as ≥50% reduction in either NRS pain or PDQQ-S scores, was 77.4% (±SD 21.4%) and 74.9% (±SD = 19.9%), respectively (Table 2). Similarly, the

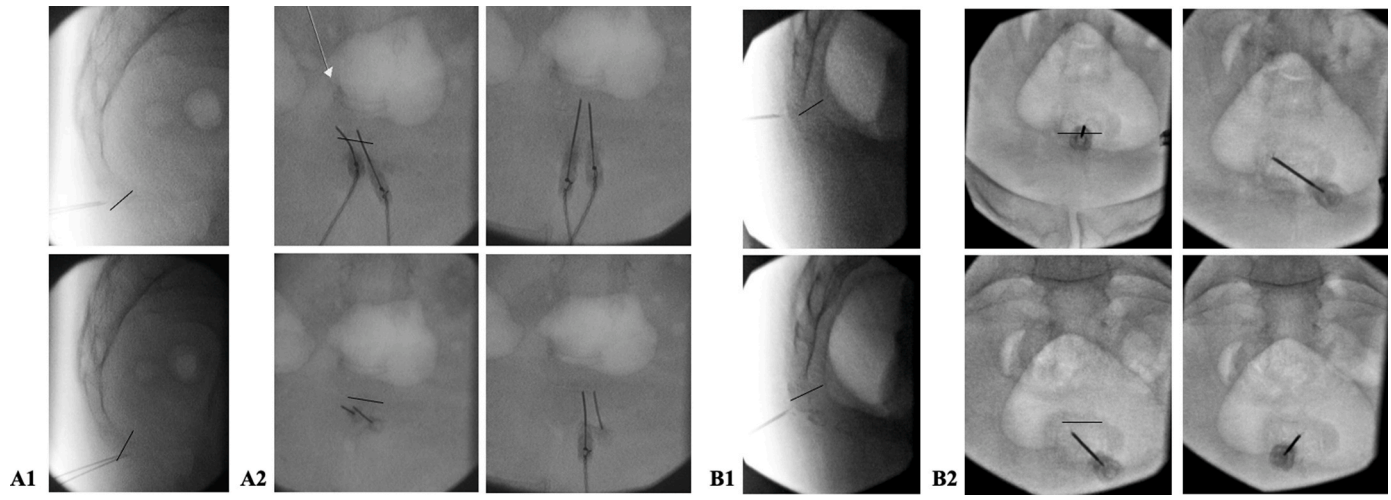

Fig. 3. Schematic representation of radiofrequency neurotomy lesion placement using A) conventional monopolar cannula (22-gauge 5 mm exposed tip) in a bipolar configuration and, B) multi-tined cannula captured on fluoroscopy. Black line marker represents location of sacrococcygeal joint and dorsal target. Fluoroscopy radiographic images captured in lateral view (A1, B1) and anterior-posterior (AP) view (A2, B2) for conventional monopolar and multi-tined techniques, respectively. (Left lateral and mid RFN lesions shown. Right lateral lesion not shown).

Table 1
Patient demographic information.

Total patients, *n*	30
Gender, *n* (%)	
Female	25 (83)
Male	5 (17)
Mean age, *yrs.* (±SD)	55.1 (±13.0)
Minimum	31.0
Max	80.0
Median	52.5
RFN procedures, *n*	
Primary	30
Repeat	22
RFN procedures by region, *n*	
SCJ margin	26
1st ICJ margin	2
SCJ + 1st ICJ margin	2
Primary RFN BMI, kg/m^2, (±SD)	
Female	26.7 (±5.91)
Male	29.3 (±4.01)
Mean	27.1 (±5.63)
Mean time with pain prior to primary RFN, *yrs.* (±SD)	8.5 (±10.2)
Minimum	1
Maximum	41
Median	5
# of diagnostic blocks prior to primary RFN, *n*	
Single	20
Double	10
Primary RFN lesion type, *n*	
Conventional monopolar cannula	19
Multi-tined cannula	11

Abbreviations: Radiofrequency neurotomy (RFN), Sacrococcygeal joint (SCJ), Intercoccygeal joint (ICJ), Body mass index (BMI).

mean magnitude of improvement for patients with successful RFN, as defined by MCID reduction in NRS pain or PDQQ-S scores, was 62.6% (±SD = 28.2 %) and 69.3% (±SD = 22.3%), respectively. Six out of 30 patients reported a mean duration of ≥50% pain relief following primary RFN of 7.2 ± 2.1 months, with a mean magnitude of pain relief equal to 71.7 ± 19.4%. The remaining patients did not provide this information.

Nine patients returned for repeat RFN procedures, including 4 patients who underwent multiple (≥3) repeat RFNs. At 3-months follow-up, 14 patients (63.6%; 95% CI = 40.7–82.8) reported ≥50% pain reduction as measured by either NRS pain and PDQQ-S scores following repeat SCJ and/or 1st ICJ RFN (Table 3). The mean magnitude of improvement for patients with successful repeat RFN, as defined as ≥50% reduction in either NRS pain or PDQQ-S scores, was 78.7% (±SD = 12.2%) and 75.4% (±SD = 12.9%), respectively (Table 3). Nineteen patients (86.4%; 95% CI = 65.1–97.1) reported MCID NRS pain reduction and 16 patients (72.7%; 95% CI = 49.8–89.3) reported MCID PDQQ-S scores at 3-months following repeat RFN. The mean magnitude of improvement for patients with successful repeat RFN, as defined by MCID reduction in NRS pain or PDQQ-S scores, was 66.6% (±SD = 23.4%) and 71.7% (±SD = 16.9%), respectively.

The mean NRS pain scores pre- and 3-months post-RFN following primary procedures were 7.07 (±SD 1.86) and 5.12 (±SD 3.16), respectively, with a mean percent difference of 27.6% (Table 4). The mean PDQQ-S scores for pre-RFN and 3-months post-primary RFN procedures were 46.8 (±SD 7.87) and 32.5 (±SD 17.6), respectively, with a 31.3% mean difference. There was a significant difference ($p < 0.005$) between NRS pain and PDQQ-S scores pre- and 3-month post-RFN for all primary procedures (Table 4).

The mean NRS pain scores pre- and 3-months post-RFN following repeat procedures were 6.89 (±SD 1.69) and 2.95 (±SD 2.40), respectively, with a mean percent difference of 57.1% (Table 5). The mean PDQQ-S scores for pre-RFN and 3-months post-repeat RFN procedures were 43.9 (±SD 7.27) and 19.1 (±SD 13.4), respectively, with a 56.4% mean difference. There was a significant difference ($p < 0.005$) between

Table 2
Primary RFN responder rate based on outcome measure, and magnitude of improvement of positive responders.

Outcome Measure	Patients with successful RFN	Responder Rate (95% CI)	Mean magnitude of improvement in positive responders (±SD)
≥50% drop in NRS pain score	10	33.3% (17.3–52.8)	77.4% (21.4)
≥50% drop in PDQQ-S score	10	33.3% (17.3–52.8)	75.0% (19.9)
MCID[a] NRS pain score	15	50.0% (31.3–68.7)	62.6% (28.2)
MCID[a] PDQQ-S score	12	40.0% (22.7–59.4)	69.4% (22.3)

[a] MCID NRS (≥2) and PDQQ-S (≥17).

Table 3
Repeat RFN responder rate based on outcome measure, and magnitude of improvement of positive responders.

Outcome Measure	Patients with successful RFN	Responder Rate (95% CI)	Mean magnitude of improvement in positive responders (±SD)
≥50 % drop in NRS pain score	14	63.6% (40.7–82.8)	78.7% (12.2)
≥50 % drop in PDQQ-S score	14	63.6% (40.7–82.8)	75.4% (12.9)
MCID[a] NRS pain score	19	86.4% (65.1–97.1)	66.7% (23.4)
MCID[a] PDQQ-S score	16	72.7% (49.8–89.3)	71.1% (16.9)

[a] MCID NRS (≥2) and PDQQ-S (≥17).

Table 4
Mean NRS pain and PDQQ-S scores at 3-months for all patients after primary RFN procedures.

Outcome Measure (n = 30)	Mean pre-RFN (±SD)	Mean post-RFN (±SD)	Δ	Mean percent difference (%)	*p*-value
NRS pain scores	7.07 (1.86)	5.12 (3.16)	1.95	27.6	<0.005
PDQQ-S scores	46.8 (7.87)	32.5 (17.6)	14.3	31.1	<0.005

Table 5
Mean NRS pain and PDQQ-S scores at 3-months for all patients after repeat RFN procedures.

Outcome Measure (n = 22)	Mean pre-RFN (±SD)	Mean post-RFN (±SD)	Δ	Mean percent difference (%)	*p*-value
NRS pain score	6.89 (1.69)	2.95 (2.40)	3.93	57.1	<0.005
PDQQ-S score	43.9 (7.27)	19.1 (13.4)	24.7	56.4	<0.005

NRS pain and PDQQ-S scores pre- and 3-month post-RFN for all repeat procedures (Table 5).

There was 1 post-RFN procedure (1/37) complication in this study. The patient reported worsening pain and swelling across the sacrococcygeal region. The patient had an elevated white blood cell count and erythrocyte sedimentation rate, with positive sonographic and magnetic resonance imaging findings suggestive of osteomyelitis and abscess along the distal posterior aspect of the coccyx. Ultimately, they required parenteral antibiotic treatment, resulting in clinical and radiographic resolution of the infection. Otherwise, there were no other neurological or bleeding complications following RFN procedures.

4. Discussion

Most patients with acute or subacute coccydynia will recover without specific treatment or with conservative measures such as rest, activity modifications, physical therapy, and/or non-steroidal anti-inflammatories. However, for the small subset of patients who continue to have pain and disability despite conservative treatment, clinicians are tasked with relying on interventions with varying degrees of invasiveness to relieve pain and improve function and quality of life. Radiofrequency neurotomy (RFN) is a minimally invasive, steroid-sparring, modality that blocks nociceptive signals from being transmitted along the afferent sensory nerve fibers. This study describes a RFN technique targeting the terminal sensory afferent nerves along the dorsal aspect of the SCJ and/or 1st ICJ. Our study found 33.3% (95% CI = 17.3–52.8) of patients reported ≥50 % pain reduction as measured by NRS pain and PDQQ-S scores at 3-months follow-up. To the best of our understanding, this was the largest retrospective analysis of prospectively gathered data obtained from primary and repeat RFN targeting the dorsal SCJ and/or 1st ICJ in patients with chronic refractory coccydynia.

In a recent systematic review by Andersen et al. (2022) [18], the effectiveness of RFN, as a whole, for treatment of chronic coccydynia was determined to be roughly 82%. While overall quite successful compared to other treatments, including conservative treatment/usual care (31%), injections (53%), and ganglion impar (GI) block (75%) [18], many discrepancies were present between the RFN studies. These discrepancies include criteria to define a successful procedure, study design, specific RFN techniques (i.e., pulsed versus continuous), and specific targets for treatment, such as caudal epidural space [39], intercoccygeal disk [32,37], and the GI from an anterior or transcoccygeal approach [20,21,29]. RFN for chronic coccydynia (≥3-months) primarily focused on targeting the GI, the most caudal paravertebral sympathetic ganglion, which innervates the pelvic, visceral, and perineal regions, including SCJ and ICJ. Despite achieving positive outcomes for patients ranging from 50 to 75% pain relief [18,30], the primary limitation with GI blocks remains the technical challenges accessing and accurately localizing the GI. A limited number of robust studies have evaluated the efficacy of a dorsal approach RFN technique targeting the terminal sensory branches, which make up the PSCP and CP, along the SCJ and/or 1st ICJ. There remains heterogeneity in studies that have targeted the dorsal aspect of the sacrum and coccyx. Scemama et al. (2012) [37] first described a case report of one patient who experienced 70% pain relief for 6-months following RFN to the 1st ICJ. Chien et al. (2022) [38] targeted the anococcygeal nerve along the lateral edge of the coccyx in one patient resulting in qualitative improvement in pain, with no quantitative or primary measures reported. Both studies completed by Scemama et al. and Chien et al. demonstrate potential, however, they were limited in sample size. The largest case series outlining response of a dorsal approach RFN for coccydynia was by Chen et al. (2017) [36], who reported a success rate of 67%, with 8 of 12 patients experiencing ≥50% pain relief for 6-months and mean reduction in pain scores of 55 %. However, this study contained heterogeneity in their technique, including variable number of lesions (2–9), lesion sites (SCJ joint line and/or dorsal coccyx lesions), use of post-lesion corticosteroid, RF cannula types (conventional versus cooled), and RF current (continuous versus pulsed). In comparison, our interventional technique only varied with lesion configuration, such as a bipolar strip compared to a multi-tined cannula. These both can be categorized as "expanded lesion" techniques, resulting in a more uniform study design and outcome evaluation, rather than a series of techniques. We observed an overall patient success rate that was lower compared to other primary RFN techniques studied for treatment of coccydynia. The challenge in evaluating efficacy of our protocol against others, including other RFN techniques and targets for coccydynia, as well as those used to treat other axial skeleton pathology [33–35], is the significant heterogeneity and lack of standard criteria or guidelines. There are no current evidence-based guidelines outlined for patient selection with regards to RFN targeting the dorsal SCJ and 1st ICJ as a treatment for chronic coccydynia. Ultimately, our goal was to

see whether our protocol of targeting the dorsal sensory innervation of the distal sacrum and coccyx was feasible in providing pain relief and improvement in function. With further detailed understanding of terminal branch sensory innervation and modifications to radiofrequency lesioning protocol target sites, more stringent definition for success and positive responder rates may be applied to help define patient selection.

A secondary outcome obtained in this study was that half of patients (95% CI = 31.3–68.7) treated with primary RFN had a clinically significant reduction in NRS pain scores, while 40.0% of patients (95% CI = 22.7–59.4) had improvement in function (reduction in PDQQ-S scores), both based on MCID at 3-months. While MCID is not a standard criterion for reporting successful outcomes for patients, especially compared to typical measure of ≥80% pain relief by 6-months in other RFN protocols for axial skeletal pathology [33–35], some advocate that MCID of NRS and PDQQ-S scores [42] is a validated outcome measure and has been accepted as a method to evaluate efficacy of treatment protocols. We recognize that, by reporting MCID, the threshold to consider a procedure successful is more sensitive and inherently captures a much larger cohort of individuals. While some contend for more rigorous outcome measures of success, primarily percentage difference in NRS pain scores (i.e. ≥80% reduction), others reason that less stringent outcome measures, such as reporting significant clinical difference or ≥50% reduction, provides beneficial treatment to individuals with refractory pain [43]. Overall, we uphold that there remains a possibility for improvement in our protocol and to offer a larger percentage of patients with pain relief and improved function for longer periods of time.

The RFN protocol outlined in this study targeted the dorsal supero- and infero-lateral edges of the SCJ and ICJ margins based on our current understanding of the anatomical location of the ventral rami of S4, S5, and CoN – which provides primary afferent fibers to the PSCP and CP. Consensus from a number of studies [7,9,26,36,44] agree that the SCJ and ICJ, along with adjacent soft-tissue structures, including the sacrospinous and coccygeal ligaments, perineum, and anterior pelvic floor musculature, are innervated by the PSCP and CP along the dorsal aspect of the distal sacrum and coccyx. Fibers from the CP, distal sensory branch, and anococcygeal nerve also contribute to the unpaired sympathetic ganglion chain, known as the GI which is located variably along the ventral aspect of the sacrum/coccyx [16,36] and may contribute to the ventral sensory innervation of the coccyx. Radiofrequency approaches targeting that GI rely on penetrating through the cornua, sacrococcygeal ligament, SCJ, ICJ, or lateral to the edge of the sacrum/coccyx. One primary reason why GI blocks/RFN fail remains their uncertain location along the anterior aspect of the sacrum/coccyx [29]. Furthermore, the GI has close proximity to visceral organs, and has mixed sensory, motor, and autonomic innervation to both visceral and somatic structures – both of which can result in significant complications. Chen et al. (2017) [36] described an RFN technique targeting the PSCP with multiple lesions (2–9) from the SCJ margin distal to the lower third of the coccyx in both clock-wise and counter-clockwise adjustments. Like Chen et al., we utilized both ultrasound and fluoroscopy to confirm placement of our cannula at our desired target to optimize repeatability between diagnostic blocks and RFN lesions. Given the superficial nature of the SCJ and ICJ to the cutaneous tissue, our RFN technique attempted to optimize the neuro-blockade of afferent fibers of the PSCP and CP with the least number of radiofrequency lesions, and minimize the risk of complications, such as cutaneous burn. Furthermore, the selection of targeting the SCJ and/or 1st ICJ allowed for a more reliable target under fluoroscopy that can be seen both in anterior-posterior, and lateral fluoroscopic views.

For those patients who underwent repeat RFN procedures, we identified a higher responder rate and success (63.6%; 95% CI = 40.7–82.8) at 3-months for those with ≥50% reduction in NRS pain and PDQQ-S scores, respectively, compared to their primary procedure. These findings are not necessarily surprising given the inherent disposition for patients who have a positive response. For example, those who have a positive primary RFN treatment, are more likely to return for repeat RFN treatment for consistent underlying pain compared to those who have an initial negative response and are less likely to undergo repeat procedure. Interestingly, the mean magnitude of improvement per patient with either ≥50% reduction in both NRS pain and PDQQ-S scores were similar for both primary (77.4% and 62.6%, respectively), and repeat RFN procedures (78.7% and 75.4%, respectively). These outcomes were similar when comparing MCID as well. These results would suggest that, if an individual has a positive response with reduction in pain and disability, they will likely have similar outcomes on repeated procedures for a minimum of 3-months, as well as a higher likelihood that their pain is the primary pain generator rather than being multi-factorial or multi-segmental. Furthermore, this suggests that repeatedly targeting the supero- and infero-lateral aspects of the SCJ and/or 1st ICJ can disrupt the re-innervated afferent nociceptive signals transmitted through dorsal PSCP and/or CP. To the best of our understanding, this is the first study that introduces the possibility for repeat RFN procedures targeting the dorsal aspect of the SCJ and/or ICJ for long-term treatment.

From a safety perspective, there was only one documented complication associated with our study and protocol. This patient required antibiotics for source control to treat an underlying infection. We feel that this complication was likely more so related to the baseline inherent risks associated with introducing a needle into the soft-tissue space rather than any specific technical aspect of our RFN approach. There did not appear to be any autonomic or motor dysfunction reported by patients, or any significant clinical sensory disturbances affecting function.

While our study provides valuable contribution towards understanding the efficacy of dorsal approach RFN for treatment of chronic coccydynia and addresses the paucity of evidence in the literature, there remain several limitations. Firstly, there is significant heterogeneity in patient selection and small sample size. Furthermore, we did not have a control group to compare efficacy of our protocol versus conservative management, and/or other interventional procedures. The benefits documented following RFN cannot be definitively attributed to the treatment itself, as other potentially confounding factors were not controlled for. Next, our definition of a successful diagnostic block(s) of ≥50% reduction in NRS pain score is more liberal than the criteria used in other areas of research and clinical practice, such as for facet lumbar arthropathy or sacroiliac joint which recommends dual blocks with ≥80% pain relief prior to RFN [34,35]. Although the improvements in pain, disability, and quality-of-life seen in our study are clinically and statistically significant, they are not of equal magnitude typically seen compared to other targets or approaches for RFN in treatment for coccydynia, or other axial skeleton joints, which have a more robust understanding and experience in the underlying sensory innervation. As an introductory step in evaluating the efficacy of targeting the dorsal sensory innervation of the distal sacrum and coccyx, our goal was to initially see if this was a feasible technique and would be best evaluated with a lower threshold for a positive response (i.e., ≥50%). Another large procedural limitation includes the high variability of nerve contributions, innervation patterns, and predominant anatomical location of the PSCP and CP. Despite our protocol utilizing a consistent target that can be visualized under ultrasound and fluoroscopy – i.e. SCJ and 1st ICJ - this results in a limitation in procedural consistency. The efficacy of our RFN protocol may be significantly influenced by the high variability amongst the surrounding PSCP and CP, and further detailed investigations, including cadaveric studies, would enhance the consistency and reliability of our targets during RFN for optimal pain relief. Other factors that may have impacted the outcome measures include eventual introduction of multi-tined cannula, which were not available for implementation at the beginning of the study. Unfortunately, we were unable to complete cannula comparison analysis due to small sample size, although presumed to have a minimal effect given appropriate adjustments to ultimately produce a strip lesion across the superior and inferior aspects of the SCJ and ICJ. Similarly, the follow-up

duration was short (3-months) and did not provide information about the durability of the treatment. Ideally, introducing a 6-month and 12-month post-RFN follow-up would provide more information.

Future prospective studies including larger sample size, long-term follow-up, a control group, and possible refinements in RFN technique based on an updated anatomical study would help strengthen our evidence supporting the effectiveness of a dorsal approach RFN for coccydynia. With further detailed understanding of terminal branch sensory innervation and modifications to radiofrequency lesioning protocol target sites, more stringent definition for success and positive responder rates may be applied to help define patient selection. Finally, more detailed studies including improved strategies to target anterior innervation of the SCJ and/or 1st ICJ could be considered.

5. Conclusion

Overall, this study represents an introductory step in evaluating the efficacy of a dorsal approach RFN technique targeting the SCJ and/or 1st ICJ as a treatment option for chronic coccydynia. Primary RFN demonstrated pain reduction and improvement in function at 3-months in 33.3% of patients. Several limitations remain in our protocol, including heterogeneity in patient population, small sample size, no control groups, and broader definition of success (i.e. $\geq$50% reduction in pain and disability) for diagnostic blocks and RFN outcome measures. Future detailed investigations are required to optimize our approach and enhance the accuracy and reliability of targets during RFN, including cadaveric dissections to clarify SCJ and 1st ICJ sensory innervation. Larger prospective studies of long-term outcomes, including comparison with control groups, are required to further evaluate the efficacy of our dorsal RFN approach.

Disclosure

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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