Technique

Technique Considerations to Improve Efficacy in Sacroiliac Radiofrequency Ablation

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Background: Chronic low back pain is a global health burden with significant health care costs. Accurate diagnosis and treatment are often complicated due to its multifactorial nature. The sacroiliac joint has been identified as a major source of lower back pain, especially among the elderly and individuals with a history of lumbar fusion surgery. Conservative treatments frequently fall short in providing relief, leading to the exploration of alternative interventions such as sacroiliac joint radiofrequency ablation (RFA).

Objectives: We aimed to demonstrate a novel approach for sacroiliac joint RFA based on new ex vivo evidence.

Study Design: Development of a novel methodology integrating ex vivo evidence and clinical approach.

Setting: Academic health care institution.

Methods: Current radiofrequency methods, such as conventional RFA, water-cooled RFA, and cryoneurolysis, involve 2 main needle placement strategies: the palisading and the strip lesioning techniques. Additionally, the periforaminal/intraforaminal lesion technique, performed with fluoroscopy, visualizes the dorsal sacral foramina by adjusting the beam according to sacral tilt while the patient is prone. Targeting the lateral borders of the S1–S3 foramina, the technique aims to reach described lateral branch neural locations. Needle placement focuses on the lateral borders of the posterior sacral foramina, spaced one mm to 10 mm from the foraminal border, often following a clock face analogy. Protruding electrode RFA needles are recommended because of their demonstrated larger lesion width. After directing the needles to the lateral border of the S1–S3 posterior sacral foramina and then medially into the foramen, a lateral projection confirms proper needle placement beyond the posterior sacral ridge. Sensory-motor testing follows, with 0.5 mL of iohexol 180 administered to assess vascular flow and minimize contrast medium migration. Subsequently, 0.5 mL of lidocaine 2% is given for ablation anesthesia.

Results: This technique achieves an estimated 95% needle approximation of the lateral branches, enhancing neural ablation efficacy by optimizing needle tip positioning.

Limitation: Our technique faces challenges as lesion success rates decrease with distance from the foramen.

Conclusion: Adipose interference is minimized when a protruding electrode RFA needle is used within a posterior sacral foramen; neural approximation may be enhanced by giving 2% lidocaine prior to ablation. Considerable gaps in knowledge still exist despite advances in our understanding of the effect of tissue on RFA. Thorough research aimed at refining RFA procedures is essential to ensuring the best feasible patient care and sustainable pain relief. For sacroiliac joint RFA, perineural lateral branch ablation is a viable option that needs further clinical research.

Key words: Sacroiliac joint, radiofrequency ablation, fluoroscopy, lateral branch, chronic low back pain

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Chronic low back pain has been demonstrated to be the leading cause of years lived with disability worldwide, with approximately 80% of adults experiencing back pain at some point during their life (1). This high prevalence has led to increased health care utilization with costs estimated as high as $90 billion in the United States alone (2). One factor that may be driving these costs is that chronic low back pain can be secondary to a number of etiologies which demonstrate overlapping constellations of symptoms, making it difficult for even adept clinicians to determine the primary pain generator.

One source of low back pain that has gained increased attention is the sacroiliac joint (SIJ). Currently it is estimated that SIJ pain comprises 10% to 30% of lower back pain (3,4), with increased prevalence demonstrated in elderly, and postsurgical lumbar fusion populations (5,6). Unfortunately for many patients, conservative treatments with physical therapy and medications often fail to provide significant relief.

One technique to treat refractory SIJ pain is SIJ radiofrequency ablation (SIJ RFA). SIJ RFA is a minimally invasive technique that uses an alternating electrical current to generate thermal energy to burn or ablate a targeted nerve. This procedure's efficacy is debated in the literature and many insurance carriers have recently removed it from their coverage plans (3,7,8). Despite conflicting evidence, its popularity has drastically increased with some reports estimating a 130% increase in the number of RFA procedures performed in recent years (9). The increase in volume suggests that practitioners believe that the procedure fills a need in pain care and that real-world outcomes challenge some published reports. Patient selection, pre-RFA diagnostic block procedure type (intraarticular vs extraarticular vs lateral branch blocks), research design, anatomical variations, and ablation characteristics may explain these conflicting findings.

At present, there is no consensus as to a standard or optimized technique. In this regard, in order to adequately determine the efficacy of SIJ RFA, a more nuanced discussion of technique considerations is warranted. The palisade and strip lesion techniques have been described, but superiority data is lacking. New evidence may elucidate the reason for clinical variability and suggest that a modification of existing techniques may improve patient outcomes (10-12). In the present investigation, therefore, we describe a novel method of SIJ RFA.

Anatomical Considerations

The anterior and posterior SIJ have different sources of innervation. The anterior SIJ is innervated by the lumbosacral trunks, obturator nerve, and gluteal nerves. The posterior SIJ is innervated by the posterior sacral network, which consists of a plexus of nerves emanating from a fibrofatty, vascular milieu contained within the S1-S3 dorsal rami (10,13,14).

Most SIJ ablation techniques have attempted to disrupt the posterior innervation. Several investigators have shown that the S1 lateral branches exit the foramen at the inferolateral quadrant of the posterior sacral foramen (PSF [10,13]). At S2, it has been reported that up to 2 lateral branches exit from the superolateral and/or inferolateral quadrants of the PSF (13). Finally, at S3 the lateral branches exit from the superolateral aspect. These trunks then combine to form the posterior sacral network. The L5 dorsal ramus may also contribute to the innervation of the posterior SIJ but a number of anatomical studies have demonstrated some degree of innervation (10,13,15) with anastomosis to the posterior sacral network likely occurring just lateral to the S1PSF. Therefore, successful S1 dorsal nerve ablation generates a lesion sufficient to ablate L5 contributions (16).

1. Anatomical Considerations

It is accepted that precise needle location and lesion size expansion is necessary for successful neural ablation, since adipose tissue can mitigate lesion size (11). Radiology, cardiology, and oncology physicians commonly perform RFA and have developed technology to overcome this barrier (17-20). However, until recently this critical information was not universally known or appreciated by pain practitioners. Shahgholi, et al (11) demonstrated that overcoming the negative effect of adipose tissue is an important consideration when performing RFA for interventional pain procedures. Ortiz, et al (12) further demonstrated that lesion length can be increased with iohexol 240, and width can be expanded using lidocaine 2%.

Conversely, while adipose tissue has been demonstrated to attenuate lesion size, bone has been demonstrated to have an amplifying effect. Eckmann, et al (21) investigated lesion properties at the bone-muscle interface and found that lesions located at this junction were essentially doubled perpendicular to the needle axis. The authors, therefore, have used these relevant findings to develop a novel technique for S1–S3 lateral branch ablation (21).From a mechanistic perspective, this effect may be the result of bone acting as an insulator or passive heat sink and directing current toward soft tissue. This is critical for clinicians to consider, as choice of needle placement may leverage this principle to improve clinical outcomes.

Lastly, although bone may act as a passive heat sink, it should be noted that other active heat sinks exist and include factors including blood flow, cerebrospinal fluid, and potentially localized edema. Within the field of pain medicine, there are limited studies that have examined the role of these circulating fluids, however in the field of oncology, numerous studies have demonstrated that increasing blood flow near the RFA lesion decreases lesion size while decreasing blood flow increases lesion size (22-26).

2. Technique Considerations

a) Lesioning Technique

Current radiofrequency methods include conventional RFA, water-cooled RFA and cryoneurolysis. There are 2 primary needle placement strategies described in practice: the palisading technique and the strip lesioning technique.

The linear strip lesion technique is reported to create an uninterrupted lesion either using ultrasound along the lateral crest (27), or using fluoroscopy located just lateral to the PSF (28,29), and over the posterior SIJ (30). Described protocols vary in describing the lesion's size, with some suggesting needle placement from the S1 articular process extending to the fourth PSF (31).

The palisading technique is performed with alternating needles in a configuration perpendicular to the sacral surface. In a typical scenario, 5–7 multipolar probes are placed perpendicular to the dorsal lateral sacral surface, with spacing between the individual probes in order to provide coverage for the intended lesion length based on predetermined lesion characteristics of the selected RFA tool. However, regardless of described protocols, the primary objective should include placing the RF cannulae over the dorsal sacral surface between the S1-S3 foramina and the SIJ line (Fig. 1) (30,32).

Cadaveric studies have estimated that these techniques may affect 93.4% to 99.7% of lateral branches with complete capture of lateral branches being estimated at 62.5% to 97.5% (13,27). However, clinical reports demonstrate efficacy in 38% to 69% of patients (27-29). The authors of this study have concluded that this discrepancy may partially be explained by sacrum topography, which is not a linear flat surface, and as a result may have uneven lesion distribution patterns.

Recent studies have revealed a host of variables shedding light on the mismatch between outcomes proposed by past cadaveric studies vs actual clinical results, when employing techniques lateral to the dorsal sacral foramina (10,11,33,34). These factors include: 1) the obstructive influence of adipose tissue (11); 2) the wide variability of lateral branch exit points from the dorsal sacral foramina (10); 3) the lateral branches are part of the dorsolateral sacral plexus, an internet-like network with multiple, redundant connections to the dorsal rami neural backbone; consequently, one "wire/nerve" or "node" can be lesioned while the network may continue (as a whole) to function (33); 4) the obstructionist potential of layered and discontiguous dorsal SI ligamentous bands (34). Additional limitations may be incomplete lesioning of the nerves related to adipose tissue density that is located in the presacral area (Figs. 2, 3) (35). Yet, despite the differences in estimated capture rates between various techniques, clinical outcomes seem to be consistent (31,36).

b) Periforaminal/Intraforaminal Lesion

The periforaminal/intraforaminal lesion technique is conducted with fluoroscopy.

First, the dorsal sacral foramina are visualized by positioning the beam commensurate with sacral tilt while the patient is prone. We recommend that patients remain fasting for at least 8 hours prior to the procedure in order to minimize gas and bowel distortion of the osseous anatomy. The lateral borders of the S1–S3 foramina are targeted commensurate with described lateral branch neural location. In this method, the lateral borders of the PSF are the intended needle placement targets with needles spaced one mm to 10 mm from the foraminal border (22).

Protocols often describe needle placements using the analogy of a clock face (37-41). Using cadaveric models, optimal needle placements for the S1 foramina have been proposed at the 4:30 and 6:00 o'clock position; for the S2 foramina the 2:30, 4:00, and 5:30 position; and for the S3 foramina the 1:00 and 2:30 position. We recommend using a protruding electrode RFA needle. Protruding electrode RFA needles have demonstrated larger lesion widths than single point needles (42).

The needles should be directed to the lateral border of the S1–S3 PSF using a target approach, landing the needles on the lateral border of the sacral PSF. The

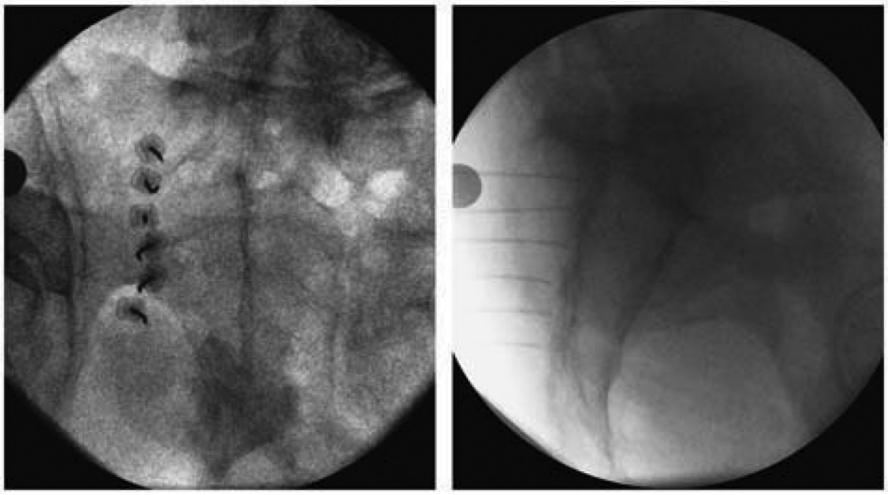

Fig. 1. *Anteroposterior and lateral fluoroscopic views of the radiofrequency ablation needles placed lateral to the sacral foramina of S1-S3.*
Adapted from doi:10.1097/AAP.0000000000000385, with permission.

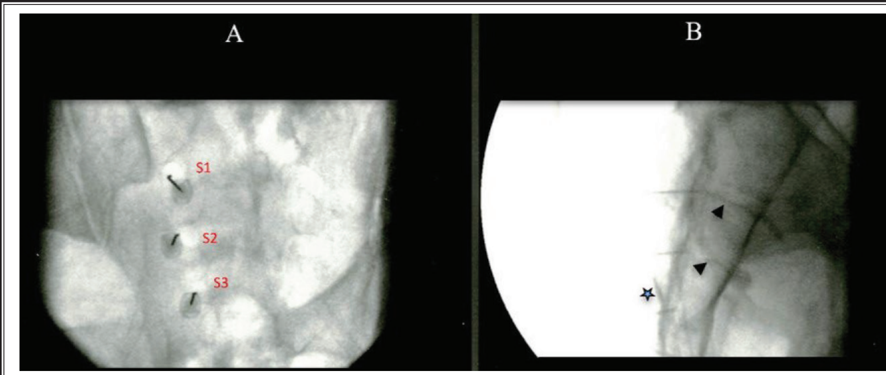

Fig. 2. *A) S1-S3 anteroposterior view of the sacrum with tilt commensurate with the sacrum angle. Overnight bowel prep can be recommended to improve visualization by limiting intestinal contents. Note that the needles are placed in the lateral ridge of each foramina, where the lateral branches have been described in multiple anatomical studies. B) Lateral view after positioning of the needles on anteroposterior view. Confirmation of needle position within the foramina after one mL of iohexol contrast medium administration in sacrum lateral view (arrowheads). Iohexol migrating posterior to the sacrum, indicating that the S3 needle is not positioned within the foramina (star). The needles are placed slightly anterior to the posterior sacral line to prevent ablation of the ventral sacral nerves. Caution should be taken to deliver no more than one mL of local anesthetic in the S1 foramina and no more than 0.5 mL into S2 and S3 for radiofrequency ablation local anesthesia, as it may increase the chance of postprocedure paresthesia due to ventral spinal nerve block.*

needles should then be directed medially to enter the lateral border of the foramen. A lateral projection is taken to ensure that the needles have moved beyond the posterior sacral ridge; this is confirmed if the needle can be advanced without resistance. The needles are then pulled back to the posterior rim of the sacrum using lateral fluoroscopic imaging. Sensory-motor testing is then initiated.

It is uncommon to interrogate motor activation at this location because lateral branches are primarily sensory fibers. However, sensory examination may be muted if the patient has received local anesthesia or is sedated. We suggest 0.5 mL of iohexol 180 be delivered to assess for vascular flow and to ensure minimal migration of contrast medium to the ventral foramen. After the protruding electrode probes have been placed, 0.5 mL of lidocaine 2% should be administered for ablation anesthesia. Using this model, needle approximation of the lateral branches is estimated to be 95% (43).

The juxtaposed active tip of the needle to the latter border of the bone and administration of 2% lidocaine increases the lesion width, maximizing the likelihood of neural ablation. Iohexol 240 is not recommended as it may enhance ventral migration of the lesion and increase the possibility of unintended spinal nerve ablation (14).

Discussion

Sacral dysfunction is a common cause of low back pain. In this regard, a common treatment is SIJ RFA. However, mixed published results have led to questioning the clinical value of SIJ RFA. Patient selection is a known major limitation (4,44,45). However, there are also inherent challenges with current strip lesioning and palisade techniques which affect proper RFA neural targeting (46). Based on recent ex vivo data (12) our technique provides a novel method of SIJ RFA that improves needle approximation to the lateral branches, while maximizing lesion size.

Based on the current literature, we highlight some factors that may not have been previously considered which may ultimately improve SIJ efficacy. As there has been, and continues to be, much debate regarding radiofrequency methods, optimal needle size, current duration, needle type, etc., we have refrained from these important considerations and have highlighted important factors that have only recently been discussed in the literature. First, given the unique shape of the sacrum, clinicians may utilize the positive effects of active and passive heat sinks. The effects of bone should be considered as it has been demonstrated to increase lesion size. This factor likely favors the periforaminal approach since cannula placement near the foraminal border is likely to amplify the predicted lesion size. Conventional strip and palisade lesioning does not take advantage of this effect, since the proximity of the cannula to bone is limited by the curvature of the sacrum. Further, perisacral adipose tissue around, and within, the lateral branches limits RFA lesion size. Myriad potential lateral branch dorsal sacral foraminal exit points, redundancy of lateral branches to the dorsal rami, and branch-to-branch internuncial connectivity all reduce lesion capture probability. The use of a protruding electrode RFA needle within a PSF minimizes adipose tissue interference. Utilizing 2% lidocaine immediately prior to initiating ablation may further improve lateral branch neural approximation with the ablation.

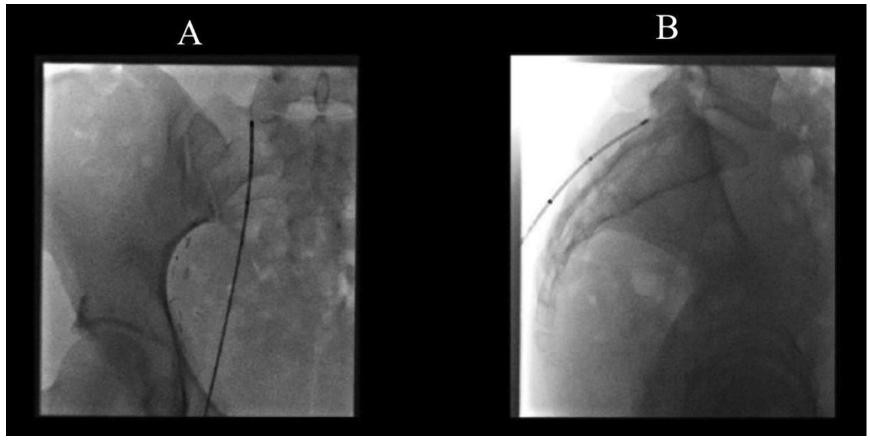

Fig. 3. *A) Simplicity probe anteroposterior view, B) Simplicity probe lateral view.* Adapted from doi:10.1177/2049463715627287, with permission.

While we are beginning to better appreciate how solutions and tissue affect RFA characteristics, there are clearly gaps in knowledge that require a more rigorous evaluation. Research dedicated to optimizing RFA procedures is necessary in order to ensure that patients receive the best quality care and lasting pain relief. While we submit that the technique here may be beneficial for SIJ RFA, clinical evidence is needed to validate the efficacy of this procedure.

While we have applied the proposed technique without incident for nearly 30 years, we recognize that it is an advanced technique because the probe positions are closer to the ventral rami than conventional techniques. Accordingly, a keen awareness of neuromodulatory safety measures as well as in-depth knowledge of the 3-dimensional imaging anatomy of the sacrum and its foramina are required to ensure against a negative outcome, including deafferentation syndrome, dysautonomia, detrusor dysfunction, or lower extremity neuromuscular deficit.

Limitations

The basis of our technique becomes more challenging when we consider that the likelihood of a lesion being successful lessens with distance from the foramen.

Conclusion

Perineural lateral branch ablation should be considered as an approach to perform SIJ RFA. Future studies, including clinical outcomes focused on this technique, are warranted.

Ethical Statement

The present manuscript is an original work by the authors, not previously published, and is not undergoing consideration for publication elsewhere currently. All sources utilized are duly acknowledged through accurate citation. It is imperative to properly cite and enclose any literal copies of text with quotation marks to indicate their source. Every author has contributed significantly to the paper through personal and active involvement, and they shall accept public liability for its content.

Data Availability Statement

All data supporting the findings of this study are available within the paper.

Contributorship Statement

Dr. Sayed Emal Wahezi, MD is responsible for the overall content as guarantor. He accepts full responsibility for the finished work and/or the conduct of the study, had access to the data, and controlled the decision to publish.

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