

Radiofrequency Ablation in Interventional Pain Management Using RF Multitined Expandable Electrode

First Edition

By Robert E. Wright, MD, DABPM, FIPP, FFPMANZCA
Edited by Aaron Calodney, MD, DABA, FASA, FIPP, ABIPP

Radiofrequency Ablation in Interventional Pain Management Using RF Multitined Expandable Electrode

First Edition

ISBN 979-8-9920765-0-9

Springer Healthcare LLC, New York City

© Stratus Medical LLC

This work is subject to copyright. All rights are reserved by Stratus Medical LLC, whether a portion or the entirety of the material is concerned, including without limitation the rights of translation, reprinting, reuse of images or illustrations, recitation, broadcasting, reproduction on any physical medium, transmission of or storage and retrieval of information, electronic adaptation, computer software, or by similar or dissimilar methodology now known or hereafter developed. Exempted from this legal reservation are brief excerpts in connection with reviews or scholarly analysis or material supplied specifically for the purpose of being entered and executed on a computer system solely for use exclusively by the purchaser of the work. The use of generally descriptive names, registered names, trademarks, service marks, etc. in this publication does not imply that such names are exempt from the relevant protective laws and regulations and therefore are free for general use. While the advice and information in this book are believed to be true and accurate at the date of publication, none of the authors, editors, or publisher are responsible for any errors or omissions that may be present therein. The authors, editors, and publisher make no warranty, whether express or implied, with respect to the material contained herein.

Please refer to the Nimbus® Electrosurgical RF Multitined Expandable Electrode Instructions for Use (IFU) for indications, instructions for use, warning, precautions and contraindications.

Springer Healthcare LLC is part of Springer Nature (www.springernature.com)

Radiofrequency Ablation in Interventional Pain Management Using RF Multitined Expandable Electrode

First Edition

Author

Robert E. Wright, MD, DABPM, FIPP, FFPMANZCA
Resolve Pain, Sunshine Coast, Queensland, Australia

Editor

Aaron K. Calodney, MD, DABA, FASA, FIPP, ABIPP
Precision Spine Care, Tyler, TX, USA

Preface

Marc Russo, MBBS, DA (UK), FANZCA, FFPMANZCA
University of Newcastle/Hunter Pain Specialists,
New South Wales, Australia

Funding Statement

Financial support for this work was provided by
Stratus Medical (Magnolia, TX, USA).

AUTHOR BIO



Robert E. Wright

Robert E. Wright, MD, is internationally recognized in the field of pain medicine, with over 30 years of experience in the subspecialty of interventional pain management.

He completed his core training in anesthesiology and pain medicine at the University of Utah, where he trained in the interdisciplinary model of pain management.

Early in his career, he was fortunate to connect with the International Pain and Spine Intervention Society (IPSIS) in its earliest days, where he was exposed to and learned the discipline of interventional pain management from the esteemed founders of that organization, Drs Rick Derby, Charlie Aprill, and Nik Bogduk.

Over time, he became instructor of IPSIS and helped develop accepted guidelines for safe and effective interventional pain practice. He proudly continues to serve as a master instructor. Also known for innovation, Dr Wright has produced original research on new techniques and technologies and has created new devices, including the Dekompressor™ discectomy probe and NIMBUS® radiofrequency ablation device, holding multiple patents.

He has received recognition as a Diplomat of the American Board of Pain Medicine (DAPM) and Fellow of Interventional Pain Practice (FIPP) and was most recently elected as a Fellow of the Australian Faculty of Pain Medicine. Dr Wright continues to be active in patient care, physician education, and developing new pain management technologies.

**Robert E. Wright, MD, DABPM, FIPP, FFPMANZCA
Resolve Pain, Sunshine Coast, Queensland, Australia**



Aaron K. Calodney

Aaron K. Calodney, MD, is past president of the Texas Pain Society and the American Society of Interventional Pain Physicians (ASIPP). He served on the board of the International Pain and Spine Intervention Society (IPSIS) and was director of education and a master Instructor. Dr Calodney is board certified in anesthesiology and carries subspecialty certification in pain management through the American Board of Anesthesiology.

Dr Calodney earned his medical degree from the University of Missouri School of Medicine. His residency in anesthesiology and subsequent interventional pain management fellowship was completed at the University of Texas Health Science Center at Houston. He subsequently completed a fellowship in pediatric anesthesia at the Denver Children's Hospital.

With particular interest in spine and special interests including neuromodulation, intrathecal drug delivery, biological treatment of the disc, and radiofrequency ablation, Dr Calodney has presented and published many articles and textbook chapters. He is actively involved in clinical research and has delivered hundreds of invited lectures in the US and abroad.

Aaron K. Calodney, MD, DABA, FASA, FIPP, ABIPP
Precision Spine Care, Tyler, TX, USA

REVIEWERS

Cervical (C2 ventral plexus, TON-C7):

Helen Blake, MD, MBA

Pain & Rehabilitation Specialists, Chesterfield, MO, USA
President of The Society of Women Innovators in Pain Management

Thoracic:

Gurbir Kaur, MBBS, DNB Anesthesiology, FFPMANZCA

Pain Medicine Specialist., Sydney, Australia

Michael Veltman, MBBS, FANZCA, FASE, FFPMANZCA

Director PainScience, Joondalup, Australia

Deputy Director of Medical Services, Joondalup Health Campus,
Joondalup, Australia

Staff Specialist Pain Medicine, Sir Charles Gairdner Hospital,
Nedlands, Australia

Lumbar:

Dawood Sayed, MD

Professor of Anesthesiology and Pain Medicine

Division Chief, Pain Medicine

Program Director, Multidisciplinary Pain Fellowship

University of Kansas Medical Center, Kansas City, KS, USA

Vice Chairman of the Board, American Society of Pain and
Neuroscience

Dorsal sacroiliac joint:

Serge Nikolic, MD, FRCA, FFPMRCA

Consultant, NHS and St Bartholomew's Hospital, London, UK

Shoulder:

Dan T.D. Nguyen, MD

Neuroradiology & Pain Solutions of Oklahoma, Edmond, OK, USA

Past President of American Society of Spine Radiology

Genicular:

Zachary L. McCormick, MD, FAAPMR

Vice Chair, Department of Physical Medicine & Rehabilitation

Chief, Spine and Musculoskeletal Medicine

University of Utah, Salt Lake City, UT, USA

Hip:

Jaspal (Ricky) Singh, MD

Director of Interventional Spine

Co-Director, Center for Comprehensive Spine Care

Weill Cornell Medicine, New York, NY, USA

To all my mentors over the years who spared nothing, including my feelings, to instruct a no-nonsense and rigorous approach to the conduct of interventional pain medicine. Their dedication to simple, safe, and effective patient care provided the context for my career and is manifested in the NIMBUS device.

Rob Wright

PREFACE



Marc Russo

I "grew up" in an era of textbooks that had perfunctory descriptions and even more perfunctory grainy image intensifier pictures that purported to tell you all you needed to know to perform a procedure. They left a significant gap in desired knowledge and had to be extensively supplemented by prolonged exposure to a practitioner of their art who had transcended to mastery, and detailed observation of them had to be made, as sometimes they could not explain how they did what they did! Oh, how I wish I had such a textbook as you are now holding in your hands.

The only benefit to these inadequate early "how to" books came from when I lined them all up side by side on individual techniques and realized that they sometimes contradicted each other and sometimes were anatomically incorrect. This eureka moment for me freed me from my blind copying and reproducing function to nuanced analysis of the pathoanatomy in front of me and a consideration of the best way to achieve this particular procedure in this particular patient. It also allowed me to realize that these were not "tablets of Moses" and it might be possible to improve upon them, and this led to developing new techniques and approaches that I continue to teach today.

This is the textbook that I had wished to have when starting my journey in mastering radiofrequency neurotomy. Detailed, step-by-clear-step, clear pictures across multiple imaging modalities, pearls and pitfalls outlined and appropriately referenced. This textbook is not only very user friendly but a joy to read. I hope it is continued and updated for years to come.

I commend Dr Wright and his co-authors for producing this excellent monograph. It will have pride of place on my bookshelf and will be compulsory reading for my fellows and trainees. I commend it to you wholeheartedly with the universal caveat that there is no universal truth and our understanding of science and medicine is continually evolving. For my professional interventional pain work, I would want this fine book always by my side.

Marc Russo, MBBS, DA (UK), FANZCA, FFPMANZCA
Associate Professor
School of Biomedical Sciences
University of Newcastle
Australia

TABLE OF CONTENTS

Introduction.....	1	Lumbar Medial Branch Radiofrequency Neurotomy.....	41
Background and NIMBUS® Design Rationale	1	Positioning	42
NIMBUS Lesion Geometry	1	Technique	43
Scientific Validation	2	Technique Images	46
NIMBUS Device	3	Recommended Reading	50
Monopolar Thermographic Lesion Analysis	4		
NIMBUS Monopolar Lesion Geometry	4	Dorsal Sacroiliac Joint Radiofrequency Neurotomy.....	51
Monopolar Comparison	5	Background	51
NIMBUS Bipolar	6	Technical Overview	52
Bipolar Thermographic Lesion Analysis	7	Positioning	53
NIMBUS Bipolar Comparison	7	Technique	54
FAQs	8	Technique Images	57
Patient Selection	12	Recommended Reading	59
Radiofrequency Ablation for Lateral Atlantoaxial Joint Pain.....	13	Shoulder Radiofrequency Neurotomy.....	60
Background	13	Background	60
Considerations	13	Anatomic Overview	61
Positioning	14	Positioning	62
Technique	15	Technique	63
Technique Images	16	Technique Images	66
Recommended Reading	18	Recommended Reading	69
Radiofrequency Ablation for Cervical Facet Pain.....	19	Knee Radiofrequency Neurotomy....	70
Background	19	Background	70
Positioning	20	Anatomic Overview	71
Technique	21	Considerations	71
Technique Images	25	Positioning	71
Recommended Reading	30	Technique #1	72
		MRI Validation	75
Thoracic Facet Joint Radiofrequency Neurotomy.....	31	Technique #1 Images	76
Background	31	Technique #2	78
Positioning	32	Technique #2 Images	80
Technique	32	Recommended Reading	84
Technique Images	37		
Recommended Reading	40	Hip Radiofrequency Neurotomy.....	85
		Background	85
		Positioning	86
		Technique	87
		Technique Images	90
		Recommended Reading	92

INTRODUCTION

BACKGROUND AND NIMBUS® DESIGN RATIONALE

Optimal patient outcome following radiofrequency (RF) thermal ablation demands ideal patient selection, precise cannula placement, and a sufficient volume of RF-induced tissue coagulation of the pain-transmitting pathway to ensure significant and durable pain relief. Relevant neuroanatomy and appropriate targets for RF ablation (RFA) have been well described. However, to date, inherent limitations in conventional RF cannulas have compromised universally positive outcomes.

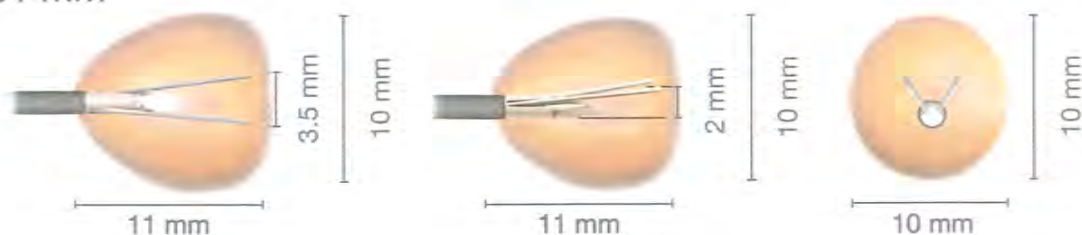
Over the past 20 years, significant time and effort has been devoted to developing strategies and teaching technically intensive techniques to compensate for the limitations of conventional RF cannulas, while little attention has been devoted to improving the technology. The mission of Stratus® Medical and the NIMBUS device is to advance RF technology for the treatment of pain to improve patient outcomes for chronic pain patients.

The NIMBUS Multitined Expandable Electrode (NIMBUS MEE) uses deployable tines as a simple and robust solution for creating optimal lesion geometry in terms of size and shape using simplified procedures. The size and shape of the NIMBUS MEE lesion was rationally derived from current anatomical knowledge and allows for consistent, safe, and thorough target tissue coagulation via technically simple and easily mastered techniques, as illustrated in this book.

NIMBUS LESION GEOMETRY

Volume:

601 mm³



SCIENTIFIC VALIDATION

The scientific basis for the safety and efficacy of the NIMBUS MEE was established in preclinical and early clinical testing. The following investigations were conducted:

1. **Quantitative lesion analysis:** the size and shape of the lesion were evaluated in various tissue types, including egg white, muscle tissue, and organ tissue. The geometry of the lesion was predictable and highly reproducible.¹
2. **Qualitative lesion analysis:** the evolution of the lesion was observed under thermography to monitor consistency and symmetry. The NIMBUS MEE lesion progressed smoothly and without asymmetry in all instances.¹
3. **In vivo temperature mapping:** temperature mapping with a discrete thermocouple was executed during medial branch neurotomy. Ex vivo lesion data were confirmed.¹
4. **Magnetic resonance imaging (MRI) scan:** an MRI protocol was developed to accurately evaluate the volume of tissue coagulation following an RF procedure with NIMBUS. The bipolar and monopolar lesions observed post in vivo techniques were as predicted from ex vivo validation.¹
5. **Paraspinal electromyography:** denervation of relevant lumbar multifidi was documented in the initial cohort of lumbar medial branch neurotomy patients, demonstrating a physiological correlate of the procedure's effectiveness.²

The NIMBUS MEE testing protocol is accepted as having established a new and unique benchmark for evaluating RF devices.

NIMBUS DEVICE

The device consists of five main components:

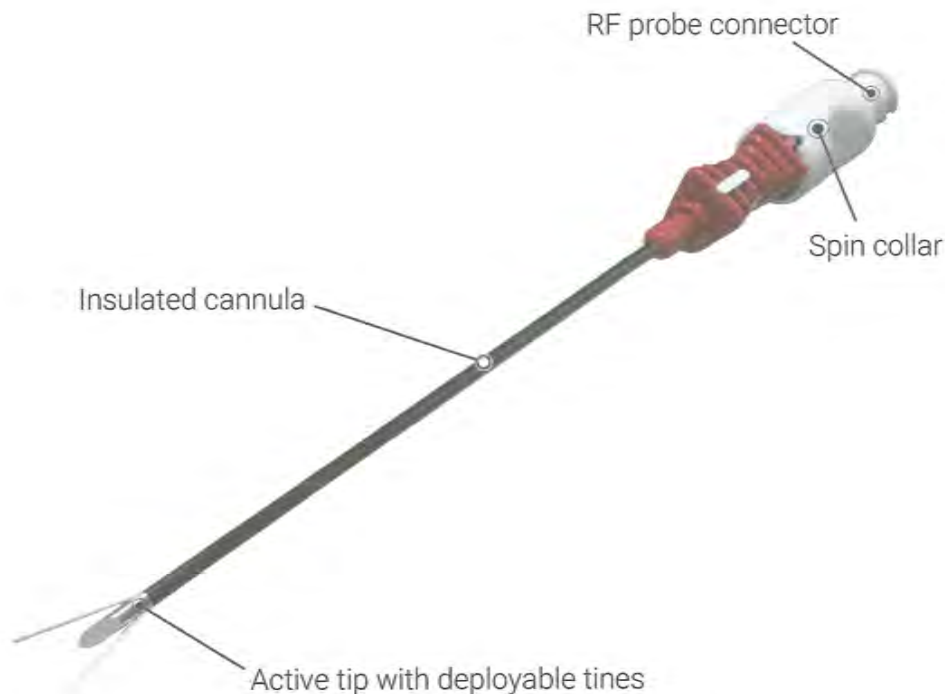
Spin collar: helical, clockwise rotation of the spin collar deploys tines and secures them in place with a locking mechanism when completely deployed. Hub is sealed after spin collar is clicked into place, allowing for fluid injection. Counter-clockwise rotation retracts tines into tip for repositioning or removal of device.

Main hub: ergonomic, triangular design provides a familiar pencil grip. Stripe indicator on color-coded hub indicates the direction of tine deflection.

Insulated cannula: main shaft containing continuous filament and lumen for injection purposes.

Tip: metal infusion-molding production process employed for consistent quality; bezel shaped for ease of navigation with occluded non-coring distal tip.

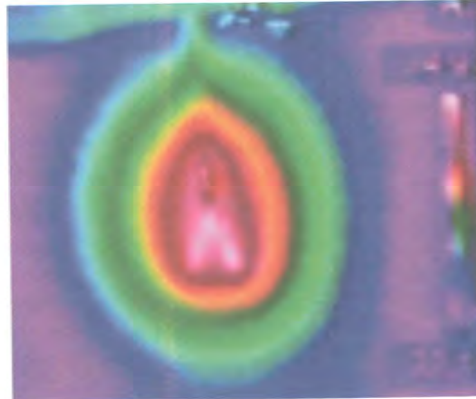
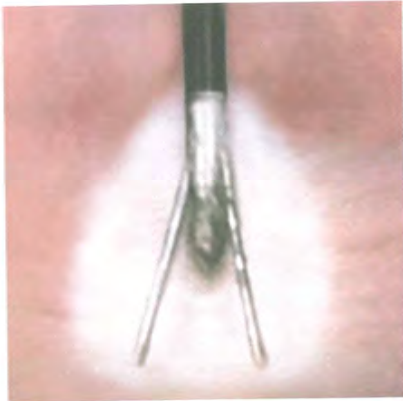
Dual deployable tines: stable and durable tines are the distal tips of continuous filament, minimizing the risk of dislodging or fracturing and providing excellent electrical interface with thermocouple probe.



Features

- Lesion produced is elongate spheroid with 10 mm axial diameter and 11 mm length.
- Perpendicular placement will treat 10 mm of target tissue.
- Lesion is offset from central axis of device to allow directed lesioning of target to better spare collateral tissue.
- Capable of meaningful motor and sensory stimulation.
- Contains lumen for injection with tines deployed.
- Robust and simple mechanical design.
- No additional equipment requirement.

MONOPOLAR THERMOGRAPHIC LESION ANALYSIS

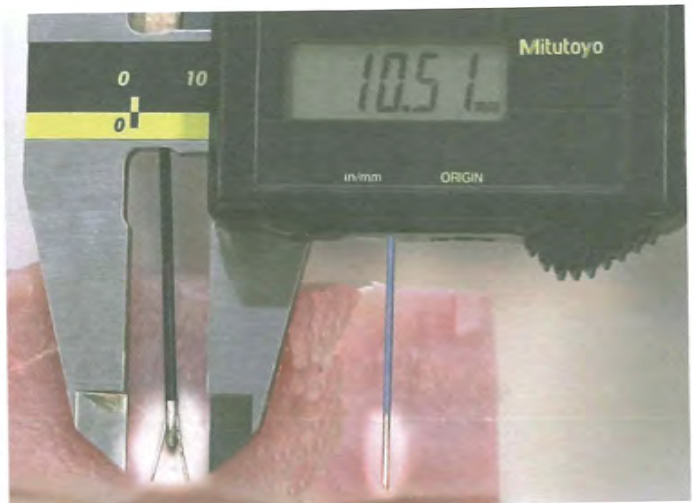


NIMBUS thermographic lesion analysis and visible tissue change

NIMBUS MONOPOLAR LESION GEOMETRY



NIMBUS lesion diameter axial slice



NIMBUS lesion width at distal tip compared to 20 g cannula



NIMBUS lesion height

NIMBUS MONOPOLAR LESION GEOMETRY (CONT'D)

1. Symmetric progression
2. No hot spots/cavitation
3. Smooth consolidation of tissue coagulation
4. Stable isotherms
5. Set to measured temperatures correlated

MONOPOLAR COMPARISON

	NIMBUS [®]	Cooled RF	18g PE	16g Mono	18g Mono
Lesion Volume ³	601 mm ²	595 mm ²	215 mm ²	360 mm ²	169 mm ²
Perpendicular placement					
Deployable/retractable tines					
Single lesion time (90 s or less)					
Procedure cost					

NIMBUS BIPOLAR



NIMBUS spacing at 20 mm



NIMBUS lesion sliced

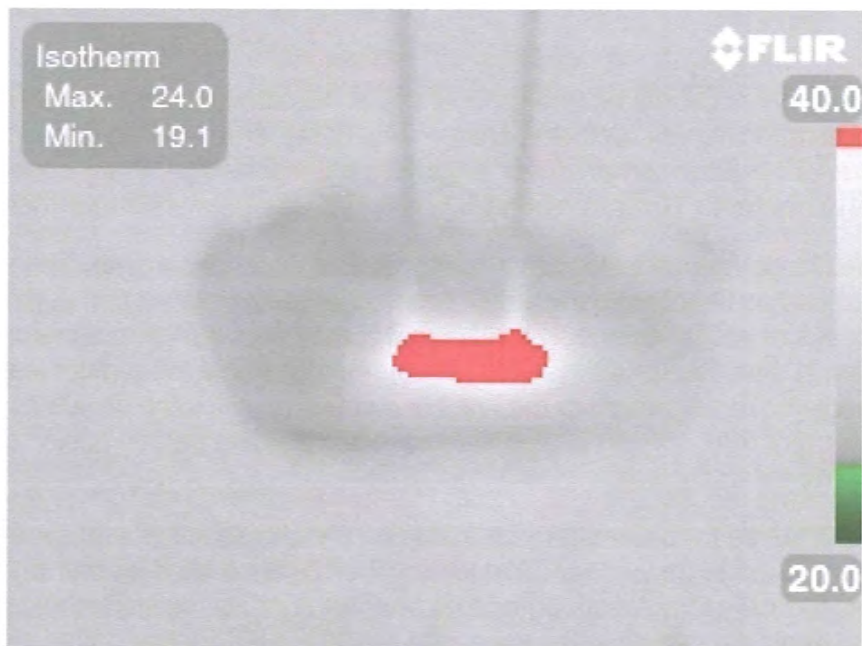


NIMBUS bipolar lesion width measured



NIMBUS bipolar lesion height measured

BIPOLAR THERMOGRAPHIC LESION ANALYSIS



NIMBUS BIPOLAR COMPARISON

	NIMBUS [®]	Protruding Electrode 18g	Monopolar 16g	Monopolar 18g
Capable of 15–20-mm spacing	●	●	●	●
Homogenous lesion	●	●	●	●
Single lesion time (120 s)	●	●	●	●

FAQs

WHAT IS A LARGE-VOLUME RF LESION, AND WHAT ARE THE SPECIFIC BENEFITS OF THE NIMBUS MEE?

RF lesion size and geometry are critical factors for successful outcomes. Effective pain relief requires coagulating all pain-generating nerves, including anatomic variants, and creating sufficient ablation volume to delay nerve regeneration. The benchmark for a "large-volume" lesion is generally considered a roughly spherical lesion with a diameter of 10 mm creating 500 mm³ volume per single-treatment cycle.⁴

NIMBUS MEE pioneered large-volume lesions through the use of expandable tines. The size and shape of the NIMBUS MEE lesion has been extensively characterized through ex vivo and in vivo work, including post-procedure MRI scans of actual lesions. The NIMBUS MEE creates a prolate spheroid lesion shape 11 mm long and 10 mm in diameter, creating 601 mm³ volume per single monopolar lesion cycle at 80°C for 80 seconds. The triangulated arrangement of the tines and active tip gives the device its unique "footprint," allowing effective placement from varying angles of incidence, including perpendicular, to the target to create a 10-mm diameter prolate-spherical lesion.

The footprint feature is required for several targets, including the shoulder, hip, and sacroiliac joints, and the simplified coaxial approach to the lumbar facet joints. The 10-mm wide diameter of the lesion makes it ideal for ablating longitudinally (craniocaudal)-oriented nerves such as the splanchnic nerves, the lumbar sympathetic chain, and genicular nerves at the knee. The NIMBUS MEE further optimizes lesion control by the directional offset of the tines; this asymmetric tine extension intelligently directs 60% of the thermal injury toward the intended tissue while avoiding collateral damage. Selecting the ideal direction of the tines gives the proceduralist more control over "fine tuning" the lesion on a patient-specific basis. The white stripe on the NIMBUS hub indicates the preferential direction of the lesion. Finally, the expanded tine surface area produces large, contiguous bipolar lesions between adjacent devices spaced up to 20 mm apart at 85°C for 150 seconds, resulting in 28-mm x 10-mm x 13-mm lesion volume.

IS NIMBUS COMPATIBLE WITH ALL RF GENERATORS AND THERMOCOUPLE PROBES?

The basic design of the NIMBUS MEE incorporates a central shaft with a lumen to accept a conventional thermocouple probe. The expandable tines create the unique lesion of the NIMBUS MEE but are incorporated into the design and require no specialized capability of the RF generator. One central design consideration behind the NIMBUS MEE was to create a compatible device for RF generators and probes less than 850V that would allow practitioners with a range of experience to efficiently create the optimal lesion for every target and achieve consistent and high-quality outcomes across the community.

WHAT IS THE PROPER PROCEDURE SPACE FOR A NIMBUS MEE PROCEDURE?

The techniques described are done in an operating theater or similarly equipped procedure room with adjustable arm X-rays able to obtain and archive necessary images. Ideally, the procedure table is configured as a specialty imaging table without obstacles to obtaining essential X-ray views. Patients typically require an IV cannula and supplemental oxygen, with standard blood pressure monitoring, cardiac rhythm, and oxygen saturation. The site (as with all procedure rooms) should be equipped to perform advanced life support.

FAQs (CONT'D)

IS SEDATION RECOMMENDED OR REQUIRED FOR A NIMBUS PROCEDURE?

Sedation is not required for any RF procedure. Still, in the author's opinion, sedation administered by a dedicated provider creates a safer, more efficient procedure and a more comfortable experience for the patient. The anesthesiologist or nurse anesthetist will administer sedation, typically using a hypnotic, such as propofol, combined with parenteral opioids and midazolam in anxious patients. Sedation for RF procedures is a collaborative effort between the anesthesia provider and proceduralist, and a plan for postoperative pain control is essential. In some cases, the proceduralist can combine a regional technique, such as a caudal anesthetic injection during sacroiliac joint neurotomy, to minimize the depth of sedation required and improve post-procedure pain relief.

CONSIDERATIONS FOR UTILIZING PROCEDURAL SEDATION

- **Necessity and communication:** sedation is not universally essential for most interventional pain procedures. However, in specific situations, such as movement disorders, high anxiety levels, or past vasovagal reactions, it might be beneficial. Notably, certain RFA procedures are more painful than others, and consideration should be given to use of procedural sedation. For example, genicular nerve RFA is typically more painful than lumbar medial branch RFA.
- **Individual assessment:** the choice to deploy procedural sedation should be individually tailored. Notably, several medical associations advise against routine sedation for interventional processes.
- **Supervision and administration:** if the treating physician chooses to oversee the sedation, they should be adequately qualified and trained. In such cases, an additional healthcare professional should be present to handle medication administration and patient monitoring.
- **Preparedness:** when opting for sedation, it is essential to have resuscitation medicines, monitoring tools, a suction apparatus, oxygen, and emergency airway equipment on hand.

HOW DO YOU CHECK THE NIMBUS MEE BEFORE THE PROCEDURE?

Inspect the device for any breaks in the insulation, deploy and retract the tines to confirm function, and ensure that the spin hub clicks into place when the tines are in the fully deployed position.

Read the IFU for complete warnings and contraindications.

HOW IS THE NIMBUS MEE INSERTED AND ADVANCED TO TARGET?

The skin and subcutis are infiltrated with a local anesthetic over insertion sites before inserting the NIMBUS MEE through the skin. Ensure that the tines are fully retracted. A gentle but firm push is required to insert the NIMBUS MEE through the skin. Orient the NIMBUS "down-the-beam" in the coaxial view with the hub over the bevel affording a straight pass to the target centered on the X-ray; alternatively, a slight "off-beam" approach may be required for certain targets such as C2 ventral plexus. The NIMBUS MEE is advanced by gripping the hub and making incremental advances with fluoroscopic confirmation. Once at the target, the white stripe on the hub is pointed toward the direction the proceduralist wants to direct the tines (based on patient-specific anatomy, NIMBUS tip placement, and proceduralist judgment). The helical spin collar is rotated to deploy the tines until the audible and tactile click is appreciated. Fluid (eg, local anesthetic) can be injected at this point. If fluid leakage occurs around the hub, first confirm that the hub is securely clicked into the final position, and if so, reposition the device tip to move it away from the occlusive tissue.

FAQs (CONT'D)

CAN YOU MANIPULATE THE NIMBUS MEE ONCE THE TINES ARE DEPLOYED?

The Nimbus MEE should not be manipulated once the tines are deployed, with the exception that the device can be withdrawn (pulled back) while the tines remain deployed. This is relevant in two specific circumstances:

First, withdrawal may be necessary when tine deployment at the desired target location results in the device being "pushed back" to a less optimal position. In such cases, the Nimbus should initially be positioned deeper than the intended final position. The tines should then be deployed at this deeper position, then the cannula withdrawn to the final desired location. This technique is frequently useful during procedures like cervical medial branch neurotomy and genicular neurotomy, where optimal placement often requires initial positioning deeper than the final desired 'pulled-back' position.

Second, withdrawal with deployed tines is commonly performed at the conclusion of the procedure to allow for continuous local anesthetic injection along the cannula track for post-procedure pain management.

ARE DIAGNOSTIC BLOCKS REQUIRED BEFORE A NIMBUS PROCEDURE?

The ability to temporarily abolish pain by an anesthetic block of the structure or sensory innervation is a prerequisite to defining a pain-generating source. Diagnostic block before RF informs the likely outcome from a well-performed RF and constitutes a central part of patient education and the risk-benefit discussion. For specific procedures such as cervical and lumbar facet neurotomy, we know that complete relief of pain for the duration of the local anesthetic effect on two successive medial branch blocks translates into a predictably excellent and durable outcome. However, legitimate debates continue around diagnostic injection pre-RF, particularly in shoulder, knee, and hip joint procedures. It is the author's practice to conduct at least one anesthetic injection on the nerve supply targeted for RF coagulation with 75% relief of the patient's typical pain before offering RF.

CAN YOU USE THE NIMBUS MEE WITHOUT DEPLOYING THE TINES?

Tines should be fully deployed before performing any RF thermal ablation procedure with the NIMBUS MEE. Some practitioners skilled in pulsed RF techniques advocate performing sensory mapping initially with tines retracted by delivering a 50-Hz stimulus to localize a target in the awake patient. In this fashion, the NIMBUS can be advanced during stimulation. Pulsed RF procedures on peripheral nerves such as occipital, suprascapular, intercostal, ilioinguinal, and posterior tibial nerves are examples. Once the device tip is sufficiently close to the target nerve to elicit paresthesia at 1 volt or lower, tines are deployed as the voltage is lowered to the standard 0.5-volt threshold. The tines can be retracted and redeployed until paresthesia capture occurs at an acceptable voltage threshold. This is a reasonable technique for sensory mapping with the NIMBUS MEE before a pulsed RF treatment.

CAN YOU PERFORM PULSED RF WITH THE NIMBUS MEE?

Formal clinical studies using the Nimbus MEE for pulsed radiofrequency procedures have not been published to date.

From a safety perspective, bench work conducted during device validation studies confirms that its distal tine temperatures accurately match radiofrequency generator settings, maintaining the typical 42°C upper limit during pulsed RF.

Regarding potential effectiveness, it is accepted that outcomes following pulsed radiofrequency relate to the treatment parameters of voltage, pulse width, frequency, and total treatment time. Additionally, recent literature offers support for the use of larger electrode surface areas for pulsed RF delivery, as demonstrated in bipolar pulsed radiofrequency clinical trials.⁵ The Nimbus MEE's deployable tine construct expands the electrode surface area in a predictable fashion and may offer similar benefits.

Currently, many practitioners report positive anecdotal results using the Nimbus MEE for various peripheral nerve pulsed RF procedures, and clinical investigations are being developed to validate these observations.

FAQs (CONT'D)

WHAT ARE TYPICAL TEMPERATURE AND TIME SETTINGS FOR NIMBUS PROCEDURES?

The proceduralist should select the ramp cycle's total time, target temperature, and duration for any RF procedure based on experience, judgment, and individual patient considerations. However, general guidance is as follows:

Monopolar settings:

- Target temperature: 80–90°C
- Ramp: 30 seconds
- Time at target temperature: 80–90 seconds
- Total time: 110–120 seconds

Bipolar settings (NIMBUS devices spaced 15–20 mm):

- Target temperature: 85°C delivered (65°C acceptable for return electrode)
- Ramp: 30 seconds
- Time at target temperature: 120 seconds
- Total time: 150 seconds

Pulsed RF settings:

- Temperature limit: 42°C
- Ramp: none
- Voltage: 45–65 volts
- Pulse width: 5–20 ms
- Frequency: 2–10 Hz
- Total time: 4 minutes or 480 pulses

INSTRUCTIONS FOR USE

Please see the NIMBUS RF Multitined Expandable Electrode IFU for a complete list of warnings, precautions, and contraindications.



Available at: or stratusmedical.com/ifu,

or contact Stratus Medical at quality@stratusmedical.com or +1 346 703 0642.

PATIENT SELECTION

Determining the source of a patient's pain is a complex process that involves multiple factors. Specialists use a combination of the patient's history, pain referral patterns, physical examination findings, and imaging results to guide their intuition about the likely pain generator. To confirm that a specific structure is the source of pain, a local anesthetic block of the relevant sensory innervation should be performed. The commonly accepted criterion for a successful block is that the patient experiences a minimum of 50% relief of their target pain during the local anesthetic window. Replicating this result with a confirmatory block reduces the likelihood of a false-positive response from a single block.

The author believes that the best outcomes for RF ablation are achieved when patients experience 80% relief after a single anesthetic block or 70% relief with dual blocks of the target innervation. However, practice patterns may vary depending on the provider, institution, region, and payer. Deviations from prevailing guidelines can be justified if they are patient-centric and involve shared decision-making with honest disclosure to the patient about the likelihood of a positive outcome based on the selection criteria used.

When using diagnostic injection for patient selection, technical factors and meticulous patient assessment are crucial. The anesthetic block should be performed skillfully, under image guidance, and with a small volume of anesthetic. Inaccurate or high-volume anesthetic injections contribute only cost and unreliable data to patient assessment. Practitioners must also interpret the patient's response correctly by educating them about the purpose of the diagnostic block and ensuring that they understand the concept of "index pain" or "the pain you want to have treated." Skilled assessment shortly after the procedure, taking the patient through previously painful provocative maneuvers, is essential for correct interpretation. Minimizing sedation, particularly opioids and benzodiazepines, is necessary to obtain accurate data regarding the analgesic response to the block and for the patient to remember the outcome of the injection. A poorly performed diagnostic procedure is worse than no procedure at all.

The decision between single and dual blocks involves a trade-off. Dual blocks minimize false-positive responses but increase false negatives. This means that while dual blocks lead to more predictably successful outcomes from RF ablation, they may also deny safe and valuable treatment to patients who would benefit from it.

Lastly, it is essential to acknowledge that interventional pain management tools are indicated to assist in functional recovery and overall wellness. Well-selected patients are those who are willing and able to participate in their recovery and take advantage of the window of relief provided by the procedure to adjust medications, reduce or eliminate opioids, and achieve functional gains. Consistently good outcomes from RF techniques require a blend of art and science to achieve the "right patient, right procedure, at the right time."

REFERENCES

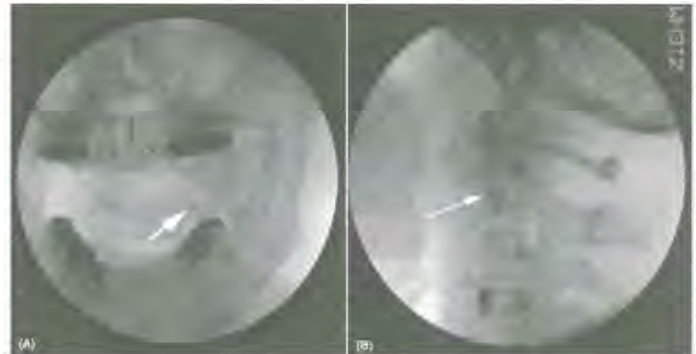
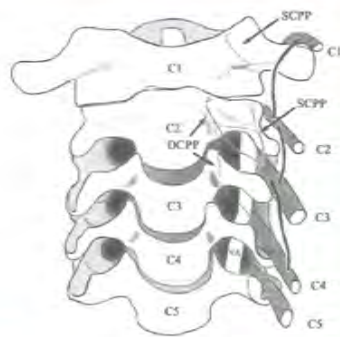
1. Wright RE, Allan KJ, Kraft M, Holley BR. Radiofrequency ablation using a novel multitined expandable electrode: device description and research study. *Minimally Invasive Surgery for Pain*. 2013;2(1):41-54.
2. Bainbridge JS, Wright RE, Pappas CD, Light S, McQueen RB. Technical efficacy of a direction-specific radiofrequency device in the performance of lumbar medial branch neurotomies – an MRI and EMG confirmation study (interim analysis). *Pain Medicine*. 2015;16(8):1650.
3. Cedeno DL, Vallejo A, Kelley CA, Tilley DM, Kumar N. Comparisons of Lesion Volumes and Shapes Produced by a Radiofrequency System with a Cooled, a Protruding, or a Monopolar Probe. *Pain Physician*. 2017 Sep;20(6):E915-E922.
4. Wright RE, Brandt SA. An ex vivo study on radiofrequency tissue ablation using a novel multitined expandable electrode. *Pain Medicine*. 2011;12(9):1446. Presented at: International Spine Intervention Society 19th Annual Meeting, Chicago, IL. Best Basic Science Abstract
5. Luo Q, Zhao Z, Yi D, Li S, Liu X. Dorsal root ganglion pulsed radiofrequency using bipolar technology in patients with lumbosacral radicular pain duration ≥ 2 years. *Front Neurosci*. 2022 Nov 3;16:1021374.

RADIOFREQUENCY ABLATION FOR LATERAL ATLANTOAXIAL JOINT PAIN

Reviewed by: **Helen Blake, MD, MBA**

Pain & Rehabilitation Specialists, Chesterfield, MO, USA

President of The Society of Women Innovators in Pain Management



BACKGROUND

The C1/2 articulation, also known as the *lateral atlantoaxial joint (LAAJ)*, is recognized as a source of upper neck discomfort and headaches. The incidence of these symptoms is observed to increase with age, previous history of cranial trauma, and particularly in individuals suffering from arthritis, including rheumatoid arthritis. The pain patterns associated with joint distension have been delineated and documented using healthy volunteers. Furthermore, if the LAAJ is the root cause of the symptoms, the pain can be temporarily abolished through an intra-articular injection of an anesthetic. Various interventional techniques have been proposed and documented. These strategies range from simple corticosteroid injections to surgical arthrodesis. More recently, a device designed specifically for C1/2 arthroplasty is under development for clinical use.

Radiofrequency ablation (RFA) for addressing pain associated with the LAAJ was not a considered therapeutic approach until 2008, when Dr Way Yin and his team distinguished C1/2 articular innervation originating in the ventral gutter of the C2 vertebral body distinct from the dorsal joint innervation arising from branches of the ventral rami of the top two cervical nerves. In his paper, Dr Yin further demonstrated that this large sensory afferent plexus could be effectively targeted with RFA, thereby introducing a treatment option for patients with persistent C1/2 pain. In a 2020 study by Bainbridge and colleagues, a retrospective analysis of 19 patients who underwent this procedure showed promising results. Out of the total patient pool, 17 experienced a positive impact, which lasted for an average duration of over 7 months.

Given the unique positioning and syncytial characteristics of the C2 ventral plexus, it is ideal to use a large directional lesion to deliver an adequately sized lesion in the right location with a single attempt. However, this method demands a high level of skill and extensive experience in conducting upper cervical spine injections and should, therefore, be entrusted to highly skilled practitioners.

CONSIDERATIONS

Consider magnetic resonance angiography (MRA) if vascular anatomy of internal carotid and vertebral not well visualized on magnetic resonance imaging (MRI).

POSITIONING



Patient is placed initially in lateral decubitus position on procedure table with treatment side up.



Horseshoe gel pad is placed under head to maintain neutral spine position.



Bolster is placed adjacent to spine; patient slowly leans back into bolster to achieve a semi-decubitus position.



Dependent arm is brought behind head, while opposite arm is brought to side to drop shoulder, providing access to lateral neck without interference of shoulder, which is paramount for ease of proceduralist.



Pillow is placed between knees, which are slightly flexed for comfort and stability.

Sheet is tucked under patient to create a "swaddle" effect and maintain position. Strap is secured across shoulder and lower torso.

TECHNIQUE

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Adjust the X-ray for a true lateral view of the upper cervical spine. Ensure that the shadows of the transverse processes (TP) occupy the posterior superior quadrant of the vertebral body. The disc spaces should be clear, with about half the width of the vertebral canal visible behind the articular pillar. Superimpose the articular pillars to achieve a clear C2/C3 disc space. The posterior ring of C1 should be seen edge-on and the image centered on the C2/C3 intervertebral disc.
3. Identify the mid-body of C3 under true lateral imaging. Anesthetize the entry point. Note the shadow running obliquely across C2 from ventral-superior to dorsal-inferior, indicating the C2 ventral gutter or "groove" critical to this procedure.
4. Advance the NIMBUS from the starting position to contact the base of the C2 ventral gutter, moving it caudally to cranially slightly "off-beam."
5. Upon contacting bone, slowly advance the NIMBUS medial and cranial to a position 1/2 to 2/3 cranial in the groove. Bony contact should be felt as you advance the NIMBUS device. If you lose bony contact, recheck the X-ray and adjust the trajectory.
6. Obtain an anterior-posterior (AP) view of C2 with the C2 bifid spinous process projected over the odontoid process and symmetric LAAJ lucency. If there is significant dental artifact, the mouth may need to be open.
7. Deploy the tines: hold the NIMBUS in place, and rotate the helical spin collar clockwise until the tines are fully deployed, with the white stripe pointing anteriorly to allow the tines to project away from bone. You will notice a distinct tactile click, indicating full engagement.
8. The ideal position for the first lesion is with the distal tip of the tines at approximately the halfway to two-thirds position across the joint lucency toward the midline when viewed from true AP. If the position is too medial, you may withdraw slightly with the tines deployed.
9. Stimulation: stimulation is not required. However, you may perform motor stimulation testing with 2-Hz frequency at 1.5 volts to document the absence of contractions.
10. Obtain/save AP and lateral images of this position.
11. With tines fully deployed, inject long-acting local anesthetic if desired (allow time for effect).
12. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 90°C for 90 seconds with a 30-second ramp time.
13. A second, more lateral lesion is recommended to fully capture afferents. Under AP imaging, withdraw the NIMBUS laterally (tines can remain deployed) to position the distal tines between the middle and lateral third of the joint lucency.
14. Repeat lesion cycle.
15. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and apply a self-adhesive dressing over the puncture site.
16. Appropriate post-procedure care is then provided.

TECHNIQUE IMAGES



True lateral radiographic view of the upper cervical spine at C2/3 level. Key landmarks: C3 vertebral body with transverse process in superior-dorsal quadrant; clearly visible C2/3 intervertebral disc space; superimposed C3 articular pillars and C2 dorsal arch; edge-on view of C1 ring. Note ventral groove of C2 appearing as diagonal shadow across vertebral body (anterior-superior to posterior-inferior). Skin entry point located at midpoint of C3 vertebral body, immediately anterior to transverse process shadow.

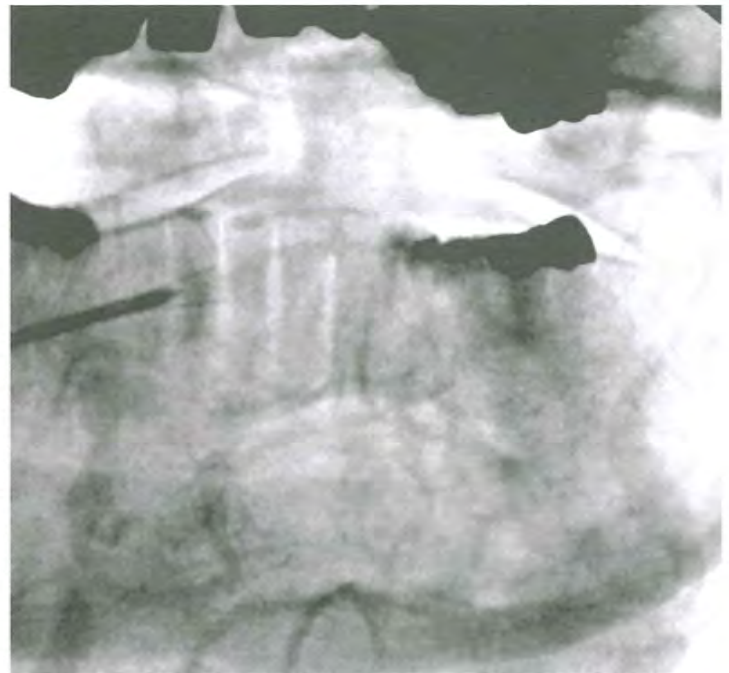
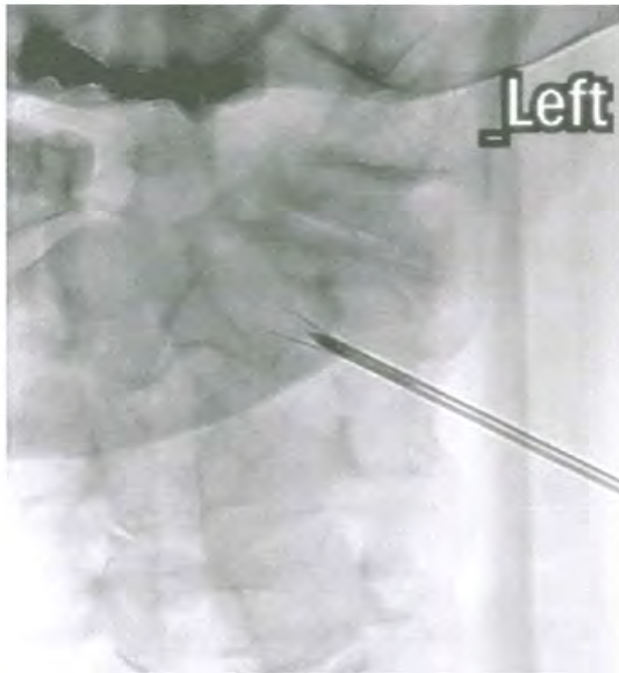


Under continuous or intermittent fluoroscopic guidance, advance cannula through skin entry point at C3 mid-body with initial 45-degree cephalad trajectory. Maintain true coronal plane alignment without anterior-posterior deviation until contacting bone at midpoint of C2 ventral groove.

Petitioner's Exhibit 1051

Avanos v. Stratus

TECHNIQUE IMAGES (CONT'D)



After bone contact from the lateral approach, obtain true AP view of upper cervical spine, confirming bifid C2 spinous process alignment with odontoid process and clear LAAJ visualization. Advance cannula tip while maintaining bone contact to approximately mid-width of LAAJ lucency. Deploy tines. Inject contrast under live fluoroscopy before local anesthetic administration; if vascular uptake noted, perform digital subtraction angiography to differentiate venous from arterial flow. Following the initial lesion, retract cannula 5 mm for second lateral lesion to ensure complete coverage of ventral plexus afferent nociceptive anatomy.



Under continuous or intermittent fluoroscopic guidance, advance cannula through skin entry point at C3 mid-body with initial 45-degree cephalad trajectory. Maintain true coronal plane alignment without anterior-posterior deviation until contacting bone at midpoint of C2 ventral groove.

Petitioner's Exhibit 1051

Avanos v. Stratus

RECOMMENDED READING

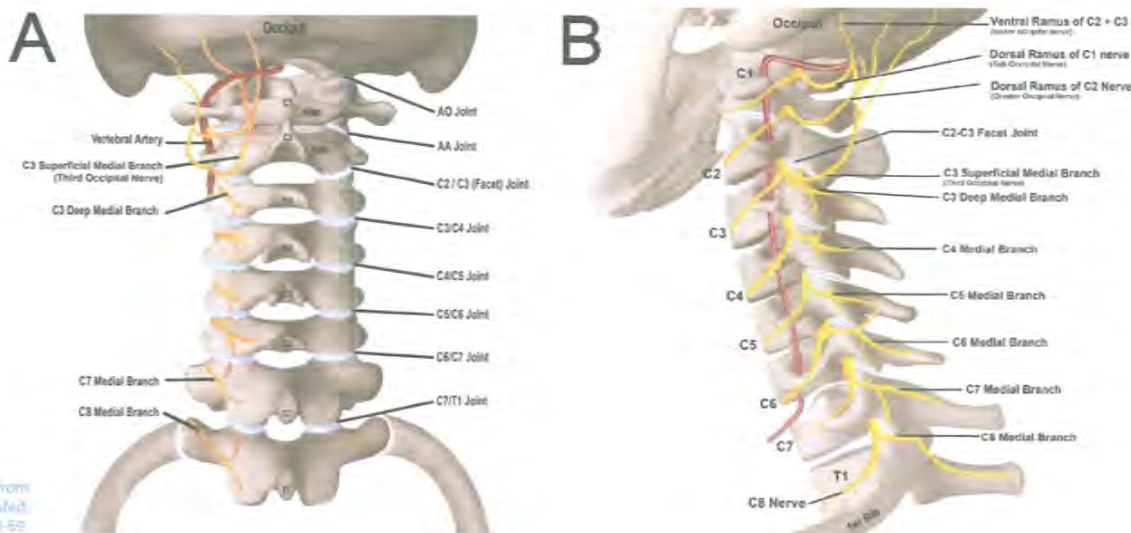
- Aprill C, Axinn MJ, Bogduk N. Occipital headaches stemming from the lateral atlanto-axial (C1-2) joint. *Cephalalgia*. 2002 Feb;22(1):15-22.
- Bainbridge JS, Vangeison CT, Trainor, DM DM, Light S. Effectiveness of C2 Anterior Plexus Radiofrequency Ablation to Treat C1-2 Lateral Joint Pain as Measured by the PEG-3, Global Perception of Change and Patient Report – A Retrospective Case Series *Pain Medicine*, Volume 21, Issue 9, September 2020, Pages 2018–2019.
- Betsch MW, Blizzard SR, Shinseki MS, Yoo JU. Prevalence of degenerative changes of the atlanto-axial joints. *Spine J*. 2015 Feb 1;15(2):275-80. doi: 10.1016/j.spinee.2014.09.011. Epub 2014 Sep 30. PMID: 25277533.
- Busch, Eric, and Peter R. Wilson. "Atlanto-occipital and atlanto-axial injections in the treatment of head and neck pain." (1989): 45-45.
- Dreyfuss P, Michaelsen M, Fletcher D. Atlanto-occipital and lateral atlanto-axial joint pain patterns. *Spine (Phila Pa 1976)*. 1994 May 15;19(10):1125-31. doi: 10.1097/00007632-199405001-00005. PMID: 8059267.
- Ehni G, Benner B. Occipital neuralgia and the C1-2 arthrosis syndrome. *J Neurosurg*. 1984 Nov;61(5):961-5.
- Lin X, Zhu HJ, Xu Y, Zheng T, Lin FY, Yin XM. Prevalence of Vertebral artery anomaly in upper cervical and its surgical implications: a systematic review. *Eur Spine J*. 2021 Dec;30(12):3607-3613. doi:10.1007/s00586-021-07015-8. Epub 2021 Oct 3. PMID: 34601625.
- Loeweneck H. Über die sensible Innervation der articulationes intervertebrales. Diss., Munchen 1966. Cited in Lang J, *Clinical anatomy of the cervical spine*, 1993, New York: Thieme. p 69.
- Narouze SN, Casanova J, Mekhail N. The longitudinal effectiveness of lateral atlantoaxial intra-articular steroid injection in the treatment of cervicogenic headache. *Pain Med*. 2007 Mar;8(2):184-8.
- Ogoke BA. The management of the atlanto-occipital and atlanto-axial joint pain. *Pain Physician*. 2000 Jul;3(3):289-93. PMID: 16906186.
- Way Yin, MD, Frank Willard, PhD, Tanya Dixon, DO, Nikolai Bogduk, MD, BsC, Ventral Innervation of the Lateral C1–C2 Joint: An Anatomical Study, *Pain Medicine*, Volume 9, Issue 8, November 2008, Pages 1022–1029.

RADIOFREQUENCY ABLATION FOR CERVICAL FACET PAIN

Reviewed by: **Helen Blake, MD, MBA**

Pain & Rehabilitation Specialists, Chesterfield, MO, USA

President of The Society of Women Innovators in Pain Management



Reprinted with permission from
Hodges RW, et al. *Reg Anesth Pain Med*
2012;47:3-59

BACKGROUND

Cervical medial branch radiofrequency ablation (CMBRFA) is an extremely effective, evidence-based technique for treating neck and head pain originating from the cervical facet joints. Cervical facet joint pain is a common spine pain condition, accounting for 15–45% of chronic neck pain and up to 60% of head and neck pain associated with whiplash mechanism injuries. Prevalence increases substantially with age as facet joint degeneration occurs. The patient's symptoms, examination, and imaging studies may suggest cervical zygapophyseal joint pain, but the diagnosis requires high-grade relief following meticulous medial branch blocks for confirmation.

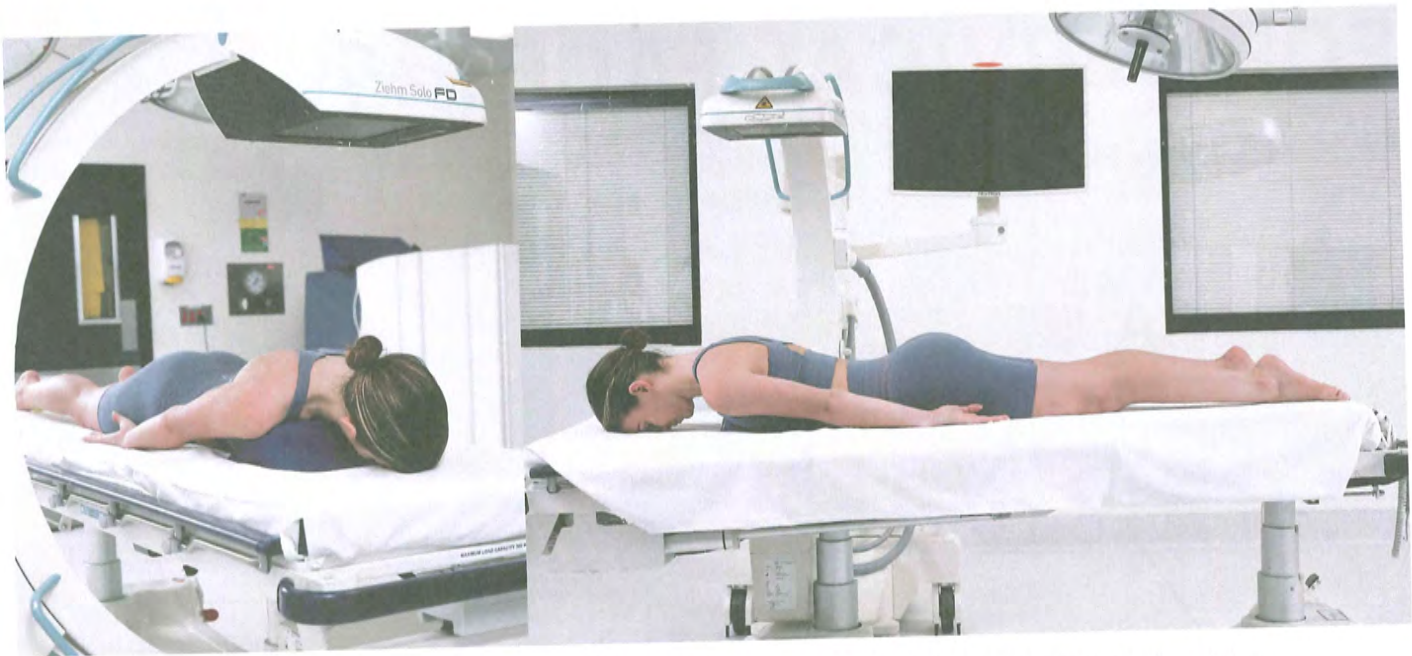
The seminal 1996 publication by Lord, Barnsley, Wallis, and Bogduk first established CMBRFA as an effective treatment for cervical facet pain. Since then, interventional pain specialists worldwide have successfully used CMBRFA for long-term relief of facet-mediated pain. High-quality clinical trials confirm that CMBRFA provides complete, durable pain relief and restoration of function in over 60% of properly selected patients; this is maintained long-term without the need for additional healthcare. Looking out as far as 2 years, studies consistently demonstrate durable relief and minimal need for additional procedures. Repeating CMBRFA once pain recurs can reliably reinstate relief. In well-selected patients, CMBRFA has also been shown to alleviate associated psychological distress, depression, and anxiety. While adverse effects can include dysesthesias, numbness, bruising, and motor nerve injury, absolute risks remain very low, at 2% or less with proper technique.

As with all radiofrequency ablation (RFA) procedures, the area treated must fully encompass the afferent nociceptive pathway, including anatomic variation, and create a sufficient zone of coagulation to support a durable response. The anatomic variation in the target is least for the C4 and C5 medial branches but significantly increased at C3, C6, and C7 to a maximum variability of the larger and highly variable third occipital nerve (TON). Predictably creating a sufficient zone of coverage efficiently with the lowest X-ray exposure is an ideal application for a large-volume directional RFA using the posterior parasagittal approach described here.

Petitioner's Exhibit 1051

Avanos v. Stratus

POSITIONING



The patient is positioned prone with support under the chest and shoulders and arms to the sides.



Head should be in a neutral position or rotated (slightly) away from target area.

TECHNIQUE

TON/C3

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Identify target levels with anterior-posterior (AP) imaging. Use craniocaudal adjustments to optimize the convexity of the lateral aspect of the C2/C3 joint.
3. Identify and anesthetize the skin entry point, slightly lateral and inferior to the bony target.
4. Target the lateral aspect of the C2/C3 joint and the lateral mass of C3.
5. Grip the central hub (colored), and advance NIMBUS® to a bony endpoint at the most dorsal and lateral aspect of the C2/C3 Z-joint complex joint lucency with the tines deployed.
6. Obtain a lateral image, and advance NIMBUS ventrally to slip across the lateral aspect of the joint.
7. With the tip of the central NIMBUS near the ventral margin of the C2/3 Z-joint, orient NIMBUS to project tines toward the midline. (The directional stripe on the main hub will point directly toward the spine.)
8. Deploy tines: rotate the helical spin collar clockwise until fully advanced. You will notice a distinct tactile click, indicating full engagement. *Note:* if resistance prevents full deployment of the tines, withdraw the central NIMBUS slightly, move the device tip ventrally, deploy the tines, and withdraw NIMBUS to the desired depth to place the tines in the desired position.
9. The optimal initial position shows tines "straddling" the joint lucency immediately posterior to the foramen. Utilize the AP, lateral, and contralateral oblique (CLO; foraminal) fluoroscopic views to confirm the final position.
10. The superior tine should align with the superior articular process (SAP) of C3, and the inferior tine should align with the inferior margin of the C3 intervertebral foramen. In most cases, three separate positions will be required: above joint lucency, across joint lucency, and below joint lucency.
11. Stimulation: stimulation is not required. However, you may perform motor stimulation testing with 2-Hz frequency at 1.5 volts to document the absence of contractions.
12. With tines fully deployed, inject long-acting local anesthetic if desired (allow time for effect).
13. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 80°C for 80 seconds with a 30-second ramp time.
14. Based on the craniocaudal height of the C3 foramen, additional TON lesions may be placed above and below the C2/3 joint line, with the ideal separation of one lesion width.
15. Fully retract the tines, and reposition NIMBUS caudally near the mid-position on the C3 articular pillar.
16. Repeat the lesion cycle.
17. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
18. Provide appropriate post-procedure care.

TECHNIQUE (CONT'D)

C4 & C5

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Identify target levels with AP imaging. Use craniocaudal adjustments to optimize the concavity (waist) of the articular pillar at C4 and C5.
3. Identify and anesthetize the skin entry point, slightly lateral and inferior to the bony target.
4. Target the concavity at the waist of the respective articular pillars.
5. Grip the central hub (colored), and advance NIMBUS to a bony endpoint at the most dorsal and lateral aspect at the waist of the articular pillar.
6. Obtain a lateral image, and advance NIMBUS to the ventral margin of the articular pillar.
7. Place the tip of NIMBUS near the ventral margin of the articular pillar to project the tines toward the midline. (The directional stripe on the main hub will point directly toward the spine.)
8. Deploy tines: rotate the helical spin collar clockwise until fully advanced. You will notice a distinct tactile click, indicating full engagement. *Note:* if resistance prevents full deployment of the tines, withdraw the central NIMBUS slightly, move the device tip ventrally, deploy the tines, and withdraw NIMBUS to the desired depth to place the tines in the desired position.
9. On the lateral image, position the tines at the center of the lateral mass with tines dorsal to the neural foramen (slightly cranial to mid-position for C4; true mid-position for C5 is optimal).
10. The optimal initial position shows tines "straddling" the joint lucency immediately posterior to the foramen. Utilize the AP, lateral (LAT), and CLO/foraminal fluoroscopic views to confirm final position.
11. Motor stimulation: use a 2-Hz frequency at 1.5 volts to rule out ventral ramus activation (absent radicular fasciculations).
12. With tines fully deployed, inject long-acting local anesthetic if desired (allow time for effect).
13. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 80°C for 80 seconds with a 30-second ramp time.
14. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
15. Provide appropriate post-procedure care.

TECHNIQUE (CONT'D)

C6 & C7

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Identify target levels with AP imaging. Use craniocaudal adjustments to optimize the concavity (waist) of the articular pillar lower levels. The target groove is cranial at C6 and C7, based on the bony anatomy (typically more variable).
3. Identify and anesthetize the skin entry point, slightly lateral and inferior to the bony target.
4. The C6 target coverage for tines is in the lateral concavity extending cranially along the SAP. The C7 target coverage for tines is on the C7 articular pillar, with tines straddling the C6/7 joint lucency on lateral view. Consider a second C7 lesion more laterally along the transverse process for patients where this structure is prominent.
5. Use the CLO view to confirm optimal tine positioning, particularly at C6 and C7, due to the difficulty in obtaining a lateral view at these levels.
6. Deploy tines: rotate the helical spin collar clockwise until fully advanced. You will notice a distinct tactile click, indicating full engagement.
7. Motor stimulation: use a 2-Hz frequency at 1.5 volts to rule out ventral ramus activation (absent radicular fasciculations).
8. With tines fully deployed, inject local anesthetic if desired.
9. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 80°C for 80 seconds with a 30-second ramp time.
10. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
11. Provide appropriate post-procedure care.

TECHNIQUE (CONT'D)

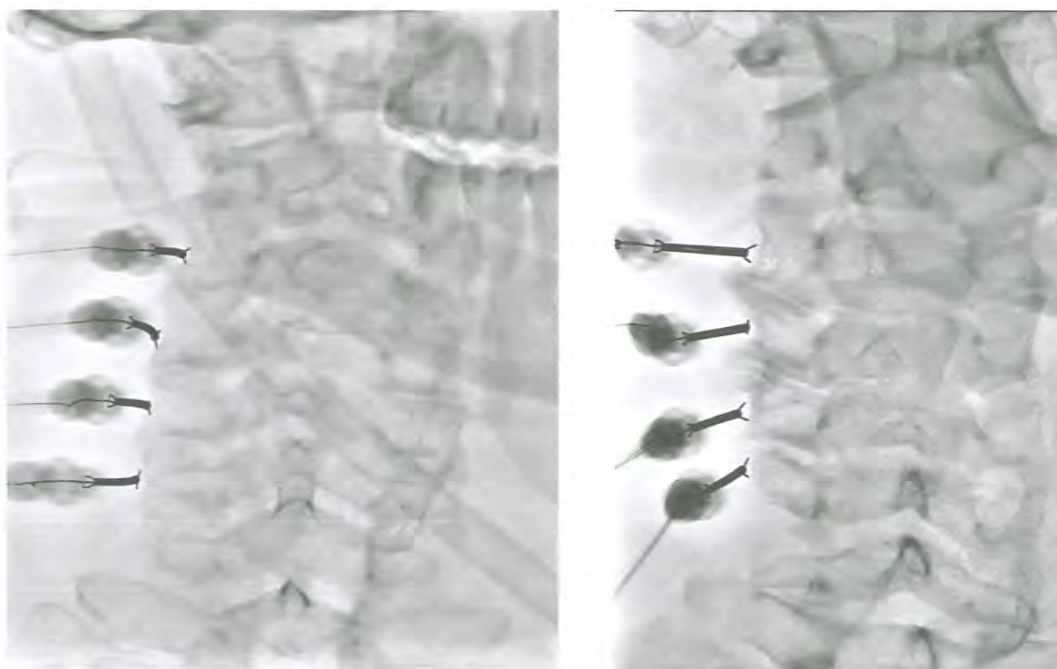
C8 MEDIAL BRANCH

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Identify the target level with AP imaging.
3. Target the superior lateral corner of the T1 transverse process (TP) for C8.
4. Identify and anesthetize the skin entry point, approximating the middle of the T1 transverse process.
5. Advance cannula to contact the most superior and lateral aspect of the T1 transverse process.
6. Deploy tines: straddle the corner of TP, and rotate the helical spin collar clockwise until fully advanced (ventral projection of the tines – the directional marker on the hub will be in a ventral position, facing the transverse process). A distinct tactile click confirms full engagement and deployment of the tines.
7. Motor stimulation: use a 2-Hz frequency at 1.5 volts to rule out ventral ramus activation (absent radicular fasciculations).
8. With tines fully deployed, inject local anesthetic if desired.
9. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 80°C for 80 seconds with a 30-second ramp time.
10. Consider a second lesion more laterally along the transverse process for patients where this structure is prominent.
11. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
12. Provide appropriate post-procedure care.

TECHNIQUE IMAGES

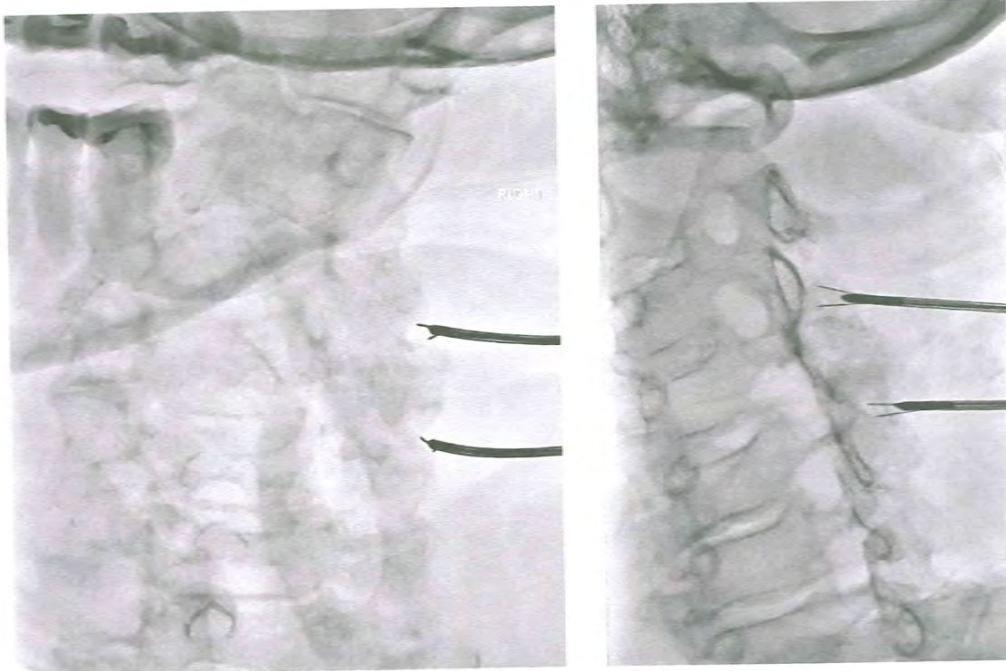


AP image of cannula targeting TON, C3, C4, and C5 medial branches in the setting of extreme arthropathic change.
Note: cannula targeting TON is directed to the lateral lucency of the C2/3 joint.

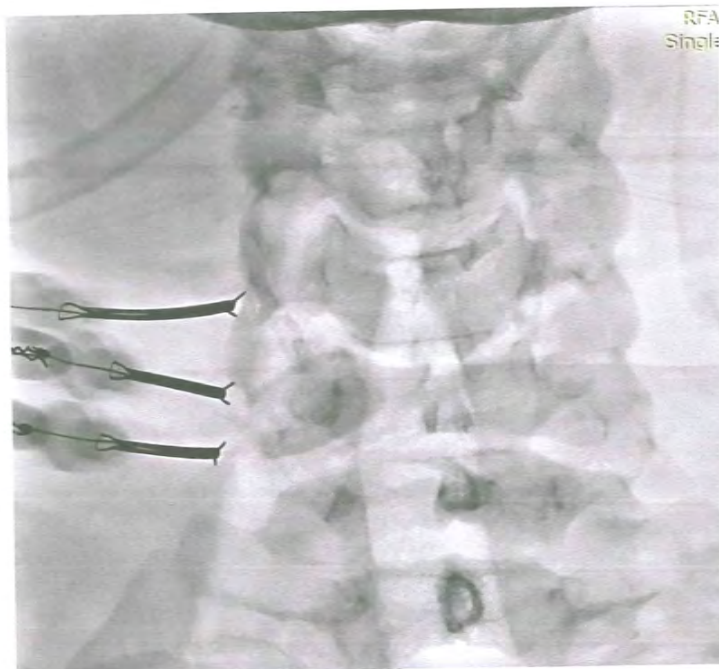


AP image demonstrating C3, C4, C5, and C6 medial branch targets.

TECHNIQUE IMAGES (CONT'D)

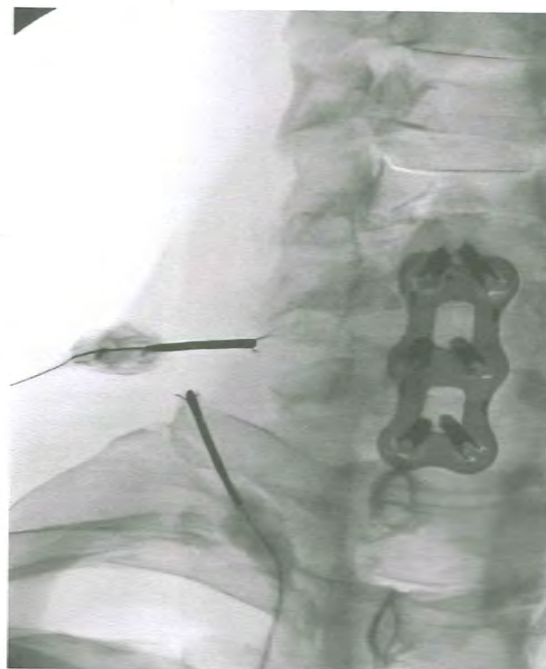


AP and CLO views of cannula placed for the C3 and C4 medial branches bracketing a prominent right C3/4 lateral osteophyte.

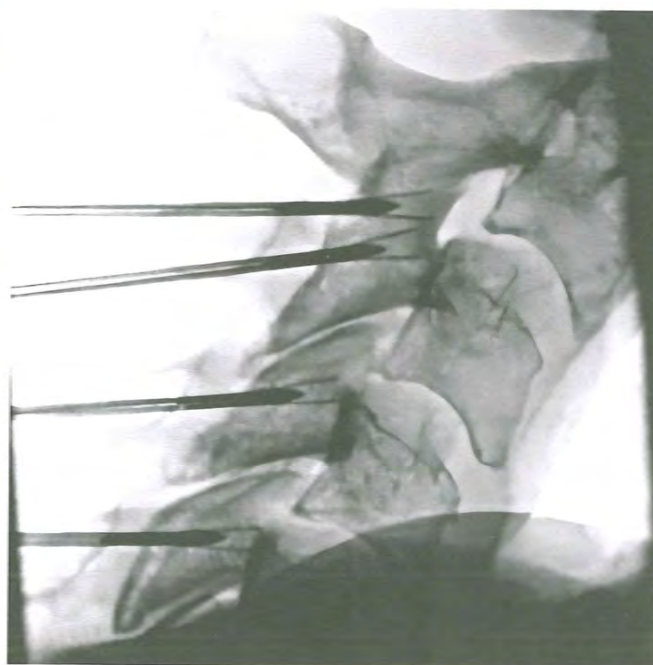
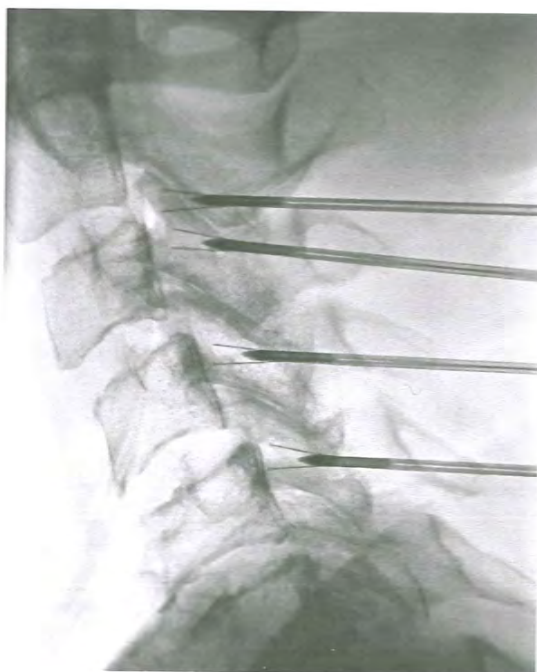


Anterior-posterior image demonstrating cannula positioned for C5, C6, and C7 medial branches. Note: tines are positioned to cover variant C7 medial branch anatomy along the superior articular process.

TECHNIQUE IMAGES (CONT'D)

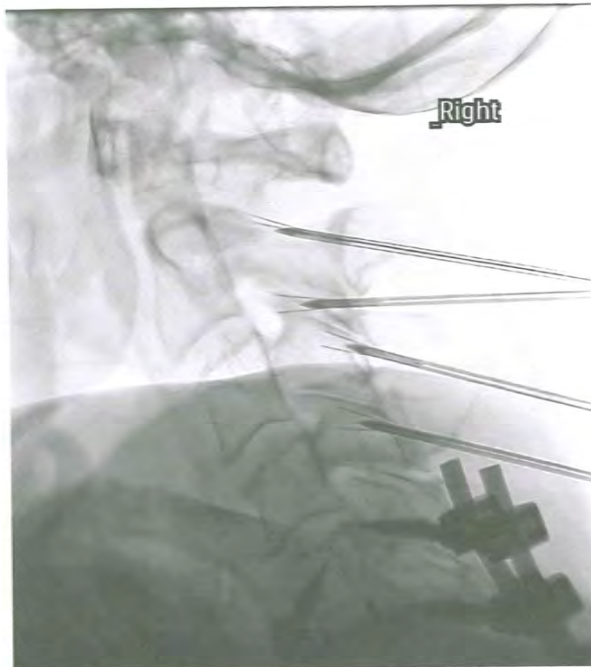


Cannula positioned for C7 and C8 medial branches targeting the C7-T1 facet joint.



Lateral views of cannula positioned at the TON, C3, C4, and C5 medial branch locations. Note: most superior tine of the TON cannula aligns with the SAP of C3 to fully incorporate anatomic variability of TON.

TECHNIQUE IMAGES (CONT'D)

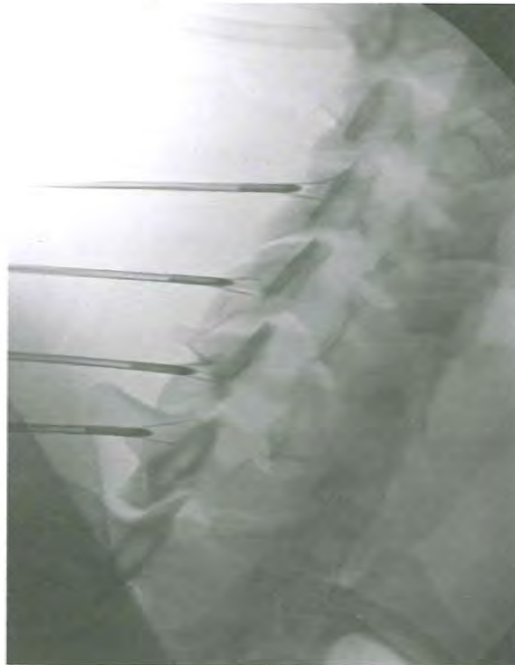


Lateral image showing perpendicular approach to the TON spanning the lateral C2/3 joint line; superior tine aligned with C3 superior articular pillar. Note: a cannula is positioned to target the C2 dorsal root ganglion with a pulsed nonthermal radiofrequency treatment. This technique is not covered in the text.

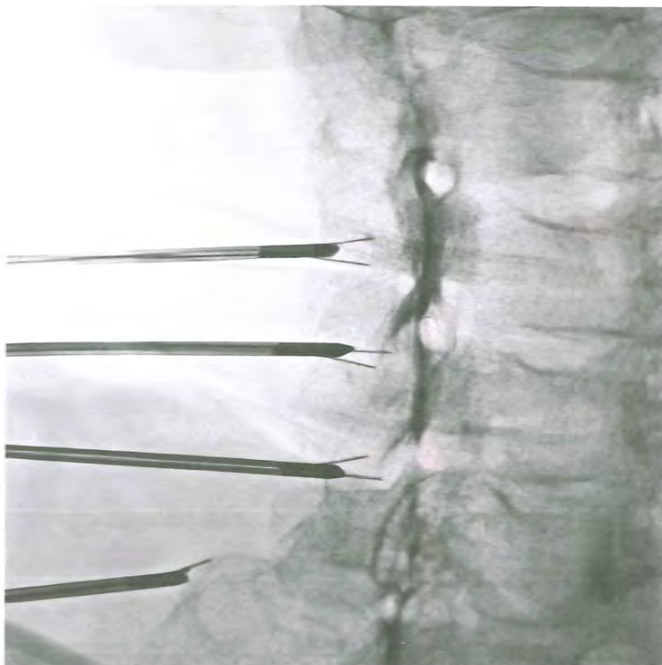


Lateral image showing cannula positioned for C3, C4, and C5 medial branch coagulation.

TECHNIQUE IMAGES (CONT'D)



Contralateral oblique imaging showing cannula positioned for C5, C6, and C7 medial branch targets – contralateral oblique views can be useful in the cervical spine when lateral imaging is frequently difficult below C5, but motor stimulation as described in text is required to rule out dangerous proximity to spinal nerves.



CLO imaging showing cannula positioned for the C5, C6, C7, and C8 medial branches. Note: cervical interlaminar epidural was performed for perioperative analgesia, and several spinal nerves are outlined in their foramina.



CLO imaging showing cannula positioned for the C3, C5, and C6 medial branches.

RECOMMENDED READING

- Barnsley L. Percutaneous radiofrequency neurotomy for chronic neck pain: outcomes in a series of consecutive patients. *Pain Med.* 2005;6:282-286.
- Engel A, King W, Schneider BJ, Duszynski B, Bogduk N. The effectiveness of cervical medial branch thermal radiofrequency neurotomy stratified by selection criteria: a systematic review of the literature. *Pain Med.* 2020;21:2726-2737.
- Husted DS, Orton D, Schofferman J, Kine G. Effectiveness of repeated radiofrequency neurotomy for cervical facet joint pain. *J Spinal Disord Tech.* 2008;21:406-408.
- Lord SM, Barnsley L, Wallis BJ, Bogduk N. Chronic cervical zygapophysial joint pain after whiplash: a placebo-controlled prevalence study. *Spine (Phila Pa 1976).* 1996;21:1737-1745.
- Lord SM, Barnsley L, Wallis BJ, McDonald GJ, Bogduk N. Percutaneous radiofrequency neurotomy for chronic cervical zygapophyseal-joint pain. *N Engl J Med.* 1996;335:1721-1726.
- MacVicar J, Borowczyk JM, MacVicar AM, Loughnan BM, Bogduk N. Cervical medial branch radiofrequency neurotomy in New Zealand. *Pain Med.* 2012;13:647-654.
- Matar HE, Navalkissoor S, Berovic M, et al. Is hybrid imaging (SPECT/CT) a useful adjunct in the management of suspected facet joints arthropathy? *Int Orthop.* 2013;37:865-870.
- McDonald GJ, Lord SM, Bogduk N. Long-term follow-up of patients treated with cervical radiofrequency neurotomy for chronic neck pain. *Neurosurgery.* 1999;45:61-68.
- Sapir DA, Gorup JM. Radiofrequency medial branch neurotomy in litigant and nonlitigant patients with cervical whiplash: a prospective study. *Spine (Phila Pa 1976).* 2001;26:E268-E273.
- Smuck M, Crisostomo RA, Trivedi K, Agrawal D. Success of initial and repeated medial branch neurotomy for zygapophysial joint pain: a systematic review. *PM R.* 2012;4:686-692.
- Wallis BJ, Lord SM, Bogduk N. Resolution of psychological distress of whiplash patients following treatment by radiofrequency neurotomy: a randomized, double-blind, placebo-controlled trial. *Pain.* 1997;73:15-22.

THORACIC FACET JOINT RADIOFREQUENCY NEUROTOMY

Reviewed by: **Gurbir Kaur, MBBS, DNB Anesthesiology, FFPMANZCA**
Pain Medicine Specialist, Sydney, Australia.

BACKGROUND



Reprinted with permission from
Abhi Elmsel & Radiofrequency Ablation
Techniques, Elsevier, 2022

The thoracic zygapophyseal joint is a common source of both local and referred pain, estimated to account for up to 48% of chronic thoracic spinal pain in some studies. Radiofrequency ablation (RFA) is generally held to be useful in well-selected patients, but the best technique for joint denervation is still debated. The original dissection of the thoracic medial branches was by Chua and Bogduk and published in 1995. This study did not specifically seek to describe joint innervation, but it was reasonably assumed that the medial branches carried nociception from the joint in a fashion similar to the cervical and lumbar anatomy. Thus, the locations of the thoracic medial branches defined in this study were embraced as true targets for diagnostic block and RFA. However, recently detailed cadaver dissections have raised questions about the precise anatomical locations and sensory origins of the articular innervation. In the 2012 study by Ishizuka et al and the 2019 study by Joshi et al, cadaveric dissections demonstrated articular branches arising very close to or inside the neural foramen anatomically distinct from the location of the thoracic medial branches published by Chua and Bogduk. The two recent studies do not reveal safe, effective, or reproducible sites for diagnostic block or thermocoagulation. Thus, putting forth a technique for RFA of the thoracic Z-joints in 2024 is an uncertain business. The following chapter represents two approaches that may have merit.

1. **A pragmatic approach using the Chua and Bogduk landmarks.** In the decades since 1995, proceduralists have relied on these landmarks to accomplish thoracic facet denervation. Supportive literature is limited, but Wright et al's study presented in 2009, followed by Gungor and Candan's retrospective study from 2020, provides guidance that when a large-volume lesion is used to thermocoagulate sensory targets previously identified by meticulous block, then radiofrequency can replicate and significantly extend the relief provided by the blocks. Said another way: pragmatically, if a patient's index pain is relieved by at least 75% following accurate anesthetic blockade of the medial branch nerve as described by Chua and Bogduk, it is reasonable to infer that creating a sufficient volume of radiofrequency coagulation around this target will provide durable pain relief.
2. **A novel approach extrapolating from the multifidus-sparing radiofrequency neurotomy technique for facet joint pain invented by Russo and Santarelli.** This strategy targets the embedded nociceptors in the facet joint capsule proper. The scientific basis for applying therapeutic heat to a joint capsule is established, and histopathology confirms the presence of capsular nociceptors. There is a scientific basis for the safety and efficacy of direct capsule radiofrequency. Russo's publication in 2021 demonstrated the noninferiority of capsule heating relative to medial branch neurotomy for lumbar facet pain. An intra-articular facet joint injection providing 75% relief is the appropriate selection criterion for the capsule heating technique.

POSITIONING



The patient is positioned prone with support under the chest and shoulders.
The arms can be positioned either at the sides or above the patient's head.

TECHNIQUE

PROCEDURE USING THE CHUA/BOGDUK LANDMARKS

The anatomy of the thoracic medial branches as described by Chua and Bogduk is characterized by anatomic variability between spinal levels and needs to be conceptualized in three distinct groupings when planning radiofrequency neurotomy:

- T1–3, T8, T9, and T10 medial branch nerves maintain a consistent course contacting the superolateral corner of the transverse process. This predictable location allows for relatively straightforward targeting.
- T4–7 medial branch nerves do not always assume direct contact with the transverse process. Instead, the nerves are often suspended in the intertransverse space, dorsal to the rib and cephalad to the target points for the medial branches at other thoracic levels. This increased variability in location presents challenges for complete ablation.
- T11 and T12 medial branch nerves are located analogous to lumbar medial branch anatomy, at the junction of the roots of the superior articular process and transverse process.
- Covering variant anatomy for neurotomy and creating sufficient lesion volume across all thoracic levels requires a large-volume lesion technique. Making multiple adjacent placements with a conventional cannula increases X-ray exposure, anesthesia time, and risk of collateral tissue damage. Publications from Vallejo and Cedenio have demonstrated that bipolar techniques can be unpredictable in the ablation created between electrodes and the largest protruding electrode cannula does not exceed the lesion volume of a standard 16-gauge monopolar cannula.

Desai's publication highlights concern about unpredictable lesion sizes created by internally cooled devices when near the bone, plus the internally cooled device carries significant expense and time requirements. The above considerations support using the multitined expandable electrode for thoracic targets. Furthermore, the multitined expandable electrode is required for the capsular heating approach.

TECHNIQUE (CONT'D)

T1-T3, T8, T9, & T10

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Obtain a "true" segmental anterior-posterior (AP) fluoroscopic image, and identify the target level by counting from T1 and T12.
3. Rotate the C-arm slowly to an ipsilateral oblique position until the costotransverse joint lucency and/or lateral edge of the transverse process is identified. This position usually corresponds to an oblique angle of 10 degrees to a maximum of 15 degrees. In the thorax, always direct NIMBUS® on a slight lateral-to-medial trajectory aiming toward the "safe zone" medial to the pleural cavity. In many cases, the target transverse process can be seen from true AP, and only minimal rotation is required to establish a safe lateral-to-medial trajectory for the NIMBUS device.
4. Identify and anesthetize the skin entry point over the superior-lateral corner of the transverse process.
5. Advance approximately "down the beam," always staying over the bone (lateral edge of the transverse process) until contact is made.
6. Rotate contralateral oblique (CLO; approximately 30 degrees) until the targeted transverse is elongated (the "Pinocchio" view).
7. Cautiously advance the active tip of NIMBUS to approximate the superolateral corner of the target transverse process.
8. Deploy tines: rotate the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and deployment of the tines.
9. Obtain and save AP and lateral images of this position. Ensure that the active NIMBUS Multitined Expandable Electrode (MEE) tip is radiographically well posterior to the intervertebral foramen. Stimulation is not necessary for this step.
10. Motor stimulation: for right T8/T9 placement, use a 2-Hz frequency at 1.5 volts to rule out ventral ramus activation (absent radicular fasciculations).
11. With tines fully deployed, inject long-acting local anesthetic if desired, and allow time for it to take effect.
12. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 80°C for 80 seconds with a 30-second ramp time.
13. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS.
14. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
15. Provide appropriate post-procedure care.

TECHNIQUE (CONT'D)

T4, T5, T6, & T7

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Obtain a "true" segmental AP fluoroscopic image, and identify the target level by counting from T1 and T12.
3. Rotate the C-arm slowly to an ipsilateral oblique position until you identify the costotransverse joint lucency and/or lateral edge of the transverse process. This position usually corresponds to an oblique angle of 10 degrees to a maximum of 15 degrees. In the thorax, always direct NIMBUS on a slight lateral-to-medial trajectory aiming toward the "safe zone" medial to the pleural cavity. In many cases, the target transverse process can be seen from a true AP, and only minimal rotation is required to establish a safe lateral-to-medial trajectory for the NIMBUS device.
4. Identify and anesthetize the skin entry point over the superior-lateral corner of the transverse process.
5. Advance approximately "down the beam," always staying over the bone (lateral edge of the transverse process) until contact is made.
6. Rotate to a CLO position (approximately 30 degrees) until the targeted transverse process is elongated (the Pinocchio view).
7. Cautiously advance the active tip of the NIMBUS device to approximate the superolateral corner of the target transverse process.
8. Further advance the NIMBUS tip 5 mm into the intertransverse space, maintaining the lateral-to-medial trajectory obtained at onset. This active tip position is required to cover the medial branches suspended in the intertransverse space at these levels. Use the Pinocchio view to monitor the advance over the superior edge of the transverse process.
9. Deploy tines: rotate the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and deployment of the tines.
10. Obtain and save AP and lateral images of this position. Ensure that the active NIMBUS MEE tip is radiographically well posterior to the intervertebral foramen. Stimulation is not necessary for this step.
11. Motor stimulation: for right T8/T9 placement, use a 2-Hz frequency at 1.5 volts to rule out ventral ramus activation (absent radicular fasciculations).
12. With tines fully deployed, inject long-acting local anesthetic if desired, and allow time for it to take effect.
13. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 80°C for 80 seconds with a 30-second ramp time.
14. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
15. Provide appropriate post-procedure care.

TECHNIQUE (CONT'D)

T11 & T12

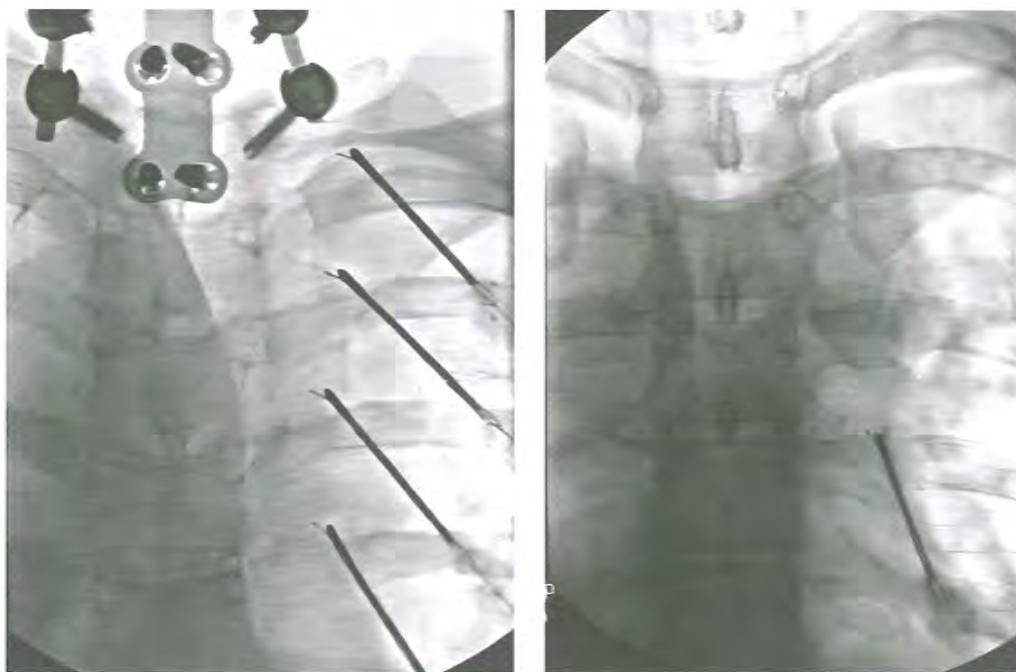
1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Obtain a "true" segmental AP fluoroscopic image, and identify the target level by counting from T1.
3. Identify and anesthetize the skin entry point.
4. The T12 transverse process is typically shortened, and the T11 medial branch runs across the lateral surface of the root of the articular process of T12. Minimal obliquity is required to identify the base of the superior articular process (SAP). Advance the NIMBUS active tip down the beam to the sulcus where the root of the transverse process joins the root of the SAP, staying over the bone. Confirm the position to be dorsal to the intervertebral foramen on lateral images. The Pinocchio view is not required for this level.
5. The T12 medial branch on the L1 vertebra assumes a course analogous to lumbar medial branches. Advance NIMBUS "down the beam," always staying over the bone at the sulcus, between the SAP and transverse process until contact is made. Rotate to a deeper obliquity (45 degrees), and advance the tip of NIMBUS to the cranial edge of the transverse process at the base of the SAP.
6. Obtain and save AP and lateral images of this position. The active tip of NIMBUS should be radiographically well posterior to the intervertebral foramen, and stimulation is not necessary.
7. Deploy tines: rotate the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and deployment of the tines.
8. Obtain and save AP and lateral images of this position. The active tip of NIMBUS should be radiographically well posterior to the intervertebral foramen.
9. Stimulation: stimulation is not required. However, you may perform motor stimulation testing with 2-Hz frequency at 1.5 volts to document the absence of contractions.
10. With tines fully deployed, inject long-acting local anesthetic if desired, and allow time for it to take effect.
11. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 80°C for 80 seconds with a 30-second ramp time.
12. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
13. Provide appropriate post-procedure care.

TECHNIQUE (CONT'D)

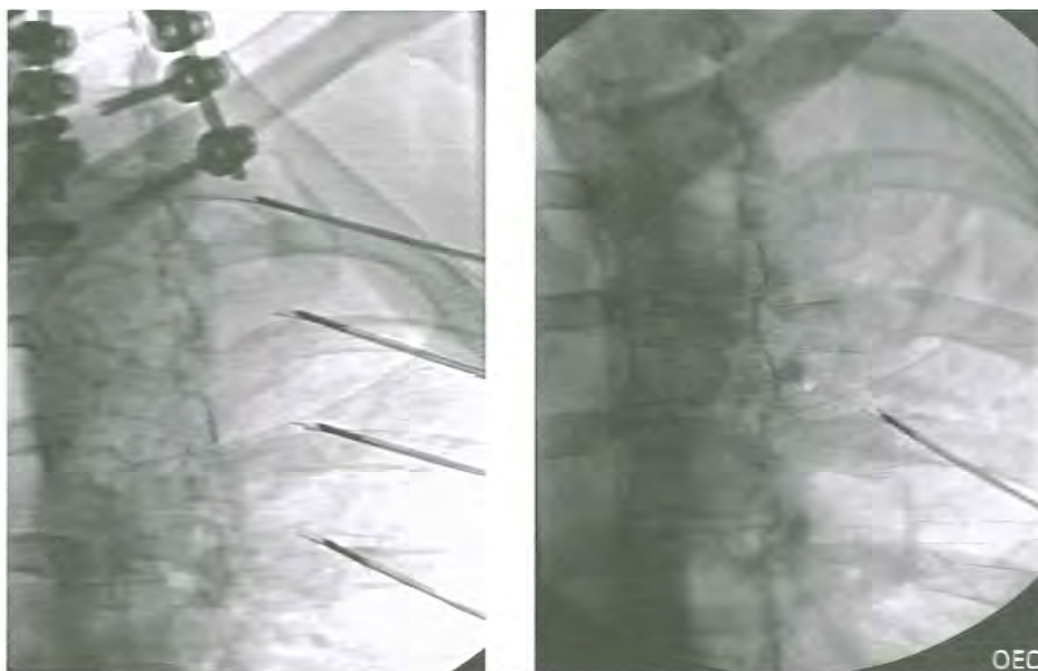
FACET JOINT THERMAL CAPSULORRHAPHY (ALTERNATIVE TECHNIQUE)

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Obtain a "true" segmental AP fluoroscopic image, and identify the target level by counting from T1 and T12.
3. Identify the pedicles that "bracket" the thoracic facet joint of interest. For example, if the T6/7 facet joint is the target, identify the T6 and T7 pedicles.
4. Skip one pedicle caudad, and start at the 12 o'clock position on that pedicle. For example, if the T6/7 joint is the target, start at the 12 o'clock position on the T8 pedicle.
5. Identify and anesthetize the skin entry point. Advance slightly "off-beam," and touch the center of the pedicle above, staying in a parasagittal plane without deviating medially or laterally.
6. Once touching bone, rotate the X-ray beam into a near-lateral position, and adjust it to obtain a good image of the facet lucency. Depending on the theater setup, a slight tilt of the bed may be required to obtain this view.
7. Deploy tines: gently reposition the tip to abut the inferior (caudal) recess of the facet joint lucency, and, while holding firmly, deploy the tines. The goal is to capture the capsule in the tines and not necessarily have the tines enter the joint space proper.
8. Obtain and save AP and lateral images of this position. The active tip of NIMBUS should be radiographically well posterior to the intervertebral foramen, and stimulation is not necessary.
9. With the tines fully deployed, inject long-acting local anesthetic if desired, allowing time for it to take effect.
10. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 90° C for 90 seconds with a 30-second ramp time.
11. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
12. Provide appropriate post-procedure care.

TECHNIQUE IMAGES

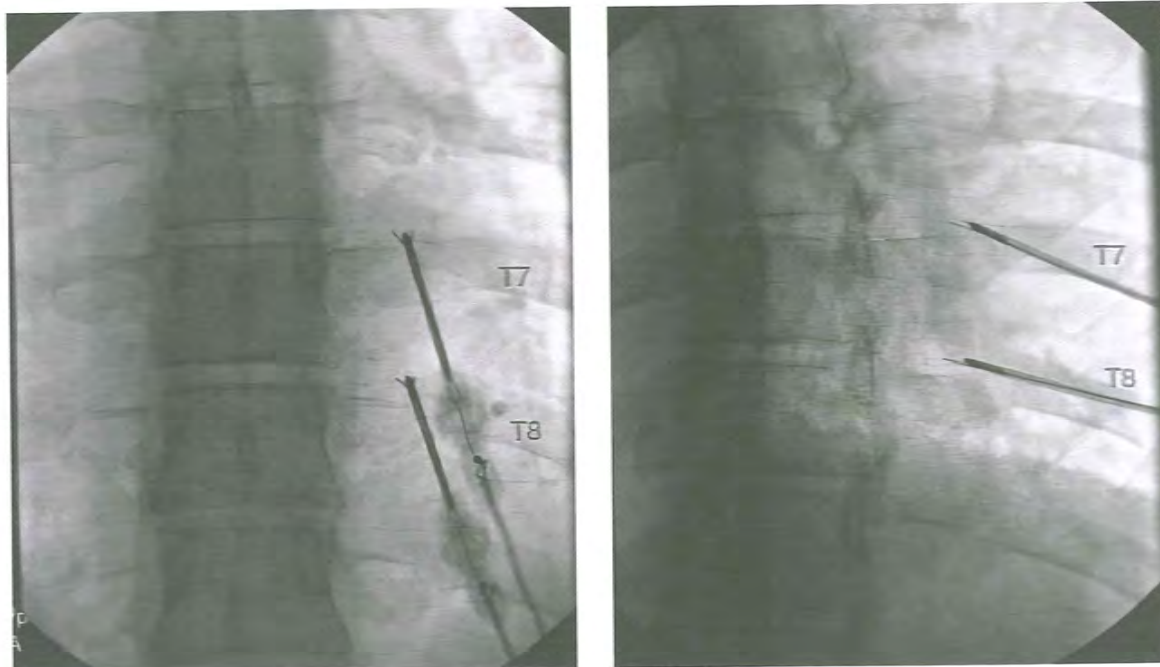


Anterior-posterior (AP) views demonstrate cannula placement at the most superior and lateral aspects of the transverse processes for RFA of the respective medial branches. The cannulas are advanced in a lateral-to-medial trajectory to minimize pleural puncture risk.

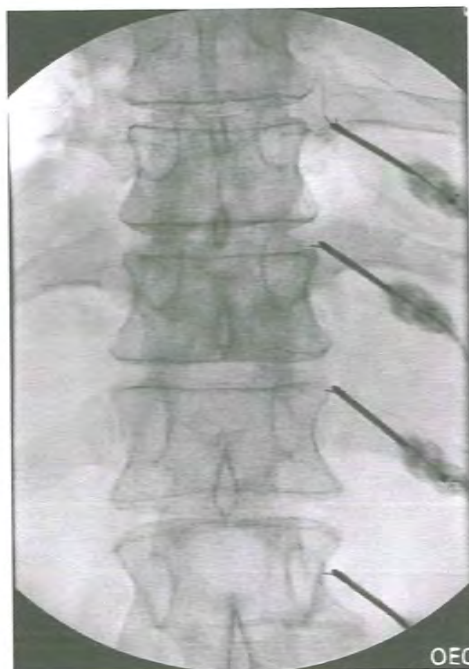


The X-ray is then rotated to a CLO angle sufficient to visualize an elongated view of the transverse processes – the Pinocchio view – allowing for precise adjustment of the active tip to approximate the most superior and lateral aspect of the target transverse process. For the T1–4 medial branches on the T2–5 transverse processes, the medial branch nerve maintains close proximity to the bone.

TECHNIQUE IMAGES (CONT'D)

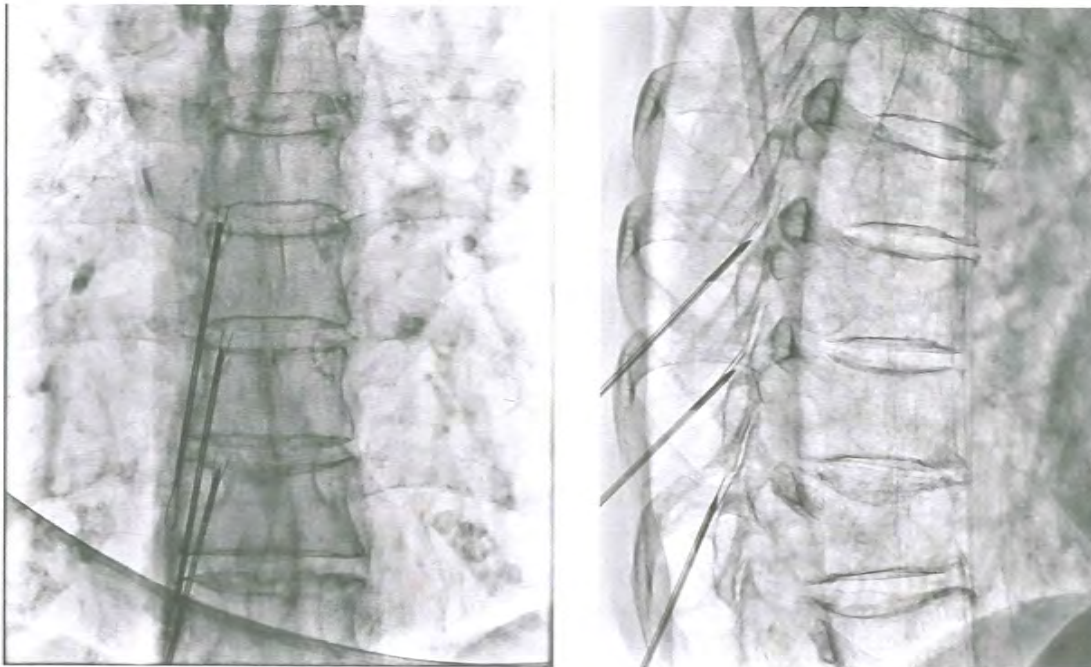


Representative AP and Pinocchio views demonstrate cannula placement on the T7 and T8 transverse processes, targeting the T6 and T7 medial branches. The CLO (Pinocchio) view illustrates advancement of the active tip just beyond the corner of the transverse process. The T5–8 medial branches are more variably located off the bone in the intertransverse space, necessitating this adjustment to the technique at these levels.



The T9–12 medial branches return to bony contact and adopt an increasingly medial location, with T12 assuming a course analogous to the lumbar medial branches.

TECHNIQUE IMAGES (CONT'D)



Given evolving knowledge of the innervation of the thoracic facet joints, an alternative approach to joint denervation can be reasonably based on Dr Marc Russo's technique for multifidus-sparing direct capsular heating, extending the lumbar approach to the thoracic spine. Using the parasagittal approach as described for intra-articular injection, the cannula can be positioned into the inferior joint capsule. This approach is currently the author's preference and is undergoing further study.

RECOMMENDED READING

- Chua WH, Bogduk N. The surgical anatomy of thoracic facet denervation. *Acta Neurochir (Wien)*. 1995;136:140-144.
- Dreyfuss P, Tibiletti C, Dreyer SJ. Thoracic zygapophyseal joint pain patterns: a study in normal volunteers. *Spine (Phila Pa 1976)*. 1994;19:807-811.
- Fukui S, Ohseto K, Shiotani M. Patterns of pain induced by distending the thoracic zygapophyseal joints. *Reg Anesth*. 1997;22:332-336.
- Gungor S, Candan B. The efficacy and safety of cooled radiofrequency neurotomy in the treatment of chronic thoracic facet (zygapophyseal) joint pain: a retrospective study. *Medicine (Baltimore)*. 2020;99: e19711.
- Hambraeus J, Hambraeus KS, Persson J. Radiofrequency denervation improves health-related quality of life in patients with thoracic zygapophyseal joint pain. *Pain Med*. 2017;19:914-919.
- Ishizuka K, Sakai H, Tsuzuki N, Nagashima M. Topographic anatomy of the posterior ramus of thoracic spinal nerve and surrounding structures. *Spine (Phila Pa 1976)*. 2012;37:E817-E822.
- Jacobson RE, Palea O, Granville M. Bipolar radiofrequency facet ablation of the lumbar facet capsule: an adjunct to conventional radiofrequency ablation for pain management. *Cureus*. 2017;9:e1635.
- Joshi A, Amrhein TJ, Holmes MA, Talsma J, Shonyo M, Taylor AB. The source and the course of the articular branches to the T4–T8 zygapophysial joints. *Pain Med*. 2019;20:2371-2376.
- Kim D. Bipolar intra-articular radiofrequency thermocoagulation of the thoracic facet joints: a case series of a new technique. *Korean J Pain*. 2014; 27:43-48.
- Manchikanti L, Kaye AD, Soin A, et al. Comprehensive evidence-based guidelines for facet joint interventions in the management of chronic spinal pain: American Society of Interventional Pain Physicians (ASIPP) Guidelines Facet Joint Interventions 2020 Guidelines. *Pain Physician*. 2020;23(3S):S1-S127.
- Neurolytic blockade for noncancer pain. In: Ballantyne JC, Fishman SM, Rathmell JP, Macvicar J, Bogduk N. *Bonica's Management of Pain*. 5th edn. Lippincott Williams & Wilkins; 2018.
- Russo MA, Santarelli DM. Development and description of a new multifidus-sparing radiofrequency neurotomy technique for facet joint pain. *Pain Pract*. 2021;21:747-758.
- Speldewinde GC. Thoracic zygapophysial joint thermal neurotomy: a cohort revealing additional outcomes by specific joint groupings. *Pain Med*. 2021;22:273-281.
- Stolker RJ, Vervest AC, Groen GJ. Percutaneous facet denervation in chronic thoracic spinal pain. *Acta Neurochir (Wien)*. 1993;122:82-90.
- Stolker RJ, Vervest AC, Groen GJ. The treatment of chronic thoracic segmental pain by radiofrequency percutaneous partial rhizotomy. *J Neurosurg*. 1994;80:986-992.
- Stolker RJ, Vervest AC, Ramos LM, Groen GJ. Electrode positioning in thoracic percutaneous partial rhizotomy: an anatomical study. *Pain*. 1994;57:241-251.
- Tzaan WC, Tasker RR. Percutaneous radiofrequency facet rhizotomy – experience with 118 procedures and reappraisal of its value. *Can J Neurol Sci*. 2000;27:125-130.
- van Kleef M, Stolker RJ, Lataster A, Geurts J, Benzon HT, Mekhail N. Thoracic pain. *Pain Pract*. 2010;10:327-38.
- Wright RE. Cooled radiofrequency system for the treatment of thoracic facet pain: the first prospective case series using a novel placement technique. *Reg Anesth Pain Med*. 2011;36(7):Sept-Oct Suppl.
- Wright RE, Brandt SA, Allan KJ, Wolfson J. Thoracic radiofrequency medial branch ablation: description of a novel device, novel technique, and in vivo temperature study. *Pain Medicine*. 2009;10:947-955(15).

LUMBAR MEDIAL BRANCH RADIOFREQUENCY NEUROTOMY

Reviewed by: Dawood Sayed, MD

Professor of Anesthesiology and Pain Medicine

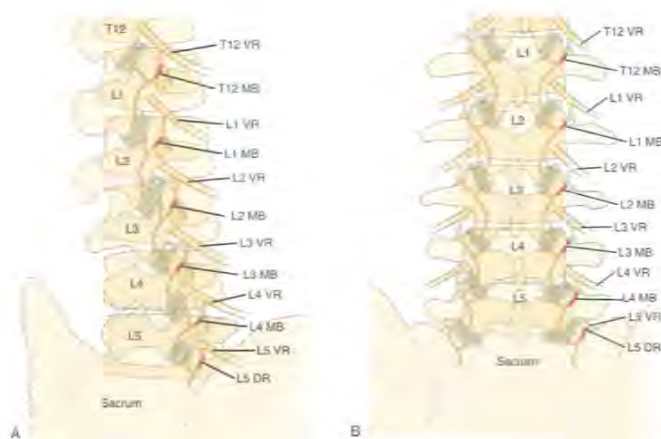
Division Chief, Pain Medicine

Program Director, Multidisciplinary Pain Fellowship

University of Kansas Medical Center, Kansas City, KS, USA

Vice Chairman of the Board, American Society of Pain and Neuroscience

BACKGROUND



(reprinted with permission from Firman MB, ed. *Atlas of Image-Guided Spinal Procedures*. Elsevier 2008)

Lumbar medial branch radiofrequency ablation (LMBRFA) is a common treatment for chronic low back pain from lumbar facet joints. This condition accounts for 15-45% of axial low back pain in the general population and up to 40% in older adults. The prevalence increases with age due to facet joint arthropathy. While symptoms, examination, and imaging may suggest facet syndrome, definitive diagnosis requires positive response to controlled diagnostic medial branch blocks.

Bogduk and Long's 1979 anatomical studies established the foundation for LMBRFA. Dreyfuss and colleagues later refined the technique in their observational study published in 2000. Van Kleef's 1999 randomized trial though small showed significant improvement over sham treatment at 12 months. Later studies from

MacVicar and colleagues in New Zealand (2012) demonstrated that strict adherence to technical requirements could yield complete pain relief in up to 70% of patients at 12 months when the proper patient selection criteria were met. Their rigorous case series highlighted that while some trials showed mixed results, optimal technique and patient selection remain crucial for successful outcomes.

In well-selected patients, LMBRFA typically provides 6-12 months of pain relief. Success rates vary across studies. Repeat procedures often achieve similar relief when pain returns. Some studies suggest improvements in function and quality of life, though more research is needed.

Complications are rare with a proper technique. These include temporary pain flare, numbness, and rarely motor nerve injury or infection. Large case series report adverse events in about 1% of cases, with success depending on creating an adequate denervation zone that accounts for anatomical variation. This variation is greatest at L5-S1 and least at L2-L4. The L5 dorsal ramus presents special challenges due to its size and variable course.

The conventional radiofrequency cannulas have significant technical limitations. They require deep oblique and caudad-declined fluoroscopic views for placement. Multiple parallel placements of the active tip adjacent to each target nerve are needed to ensure complete coagulation of the pain pathway. The Nimbus expandable multi-tined cannula offers important advances. It can be placed using a coaxial ("down the beam") technique similar to that of diagnostic blocks. Once in position, its expandable tines create a large lesion footprint. This design particularly helps in challenging cases like high BMI patients, advanced arthropathy, and spondylolisthetic segments where conventional placement may be impossible. While conventional methods need multiple repositioning steps and lesion cycles, the Nimbus creates one comprehensive lesion. This approach reduces procedure time and radiation exposure while increasing the likelihood of complete denervation. Additionally, it eliminates the variability inherent in serial conventional lesioning. These advantages make the Nimbus well-suited for reliable medial branch neurotomy while using familiar procedural techniques.

POSITIONING



Position the patient prone on the procedure table with sufficient support under the abdomen to reverse the lumbar lordosis and make the spine as flat as possible. Flattening the lumbar spine will reduce the cephalocaudal tilting required between levels and increase procedural efficiency while decreasing X-ray exposure.

Positioning images demonstrate optimal position (top left) and preserved or enhanced lordosis with insufficient or mispositioned support (top right, bottom left, bottom right, respectively).

TECHNIQUE

L5 DORSAL RAMUS

1. The targeted side is prepped with an alcohol-based disinfectant solution and draped in a sterile manner.
2. Obtain a true segmental anterior-posterior (AP) fluoroscopic view with the L5 spinous process centered between the pedicle shadows of L5. Tilt the X-ray beam cranially to clearly visualize the L5/S1 disc and a crisp superior endplate of S1.
3. Identify the base of the superior articular process (SAP) of S1 at its junction with the sacral ala on the target side, typically 8–10 degrees. Limited use of live X-rays may help identify the groove at its most prominent.
4. Identify and anesthetize the skin entry point.
5. Grip the central hub, and advance NIMBUS® using a down-the-beam approach to make contact with bone at the juncture of the base of the SAP and sacral ala (groove).
6. Advance the NIMBUS tip slightly ventral (1 mm) to confirm that it is traversing in the groove.
7. Deploy tines: direct the white stripe cephalad, and deploy tines in the groove by rotating the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and full deployment of tines. The tines are deployed at this point.
8. Check the lateral view to confirm active tip and tines are positioned midway across the L5/S1 facet complex and posterior to the L5/S1 neural foramen. In cases where the NIMBUS Multitined Expandable Electrode (MEE) stopped on the posterior aspect of the S1 SAP, the NIMBUS/tines will be seen as entirely behind the L5/S1 facet complex on lateral. This is a common positioning error and indicates that the NIMBUS failed to enter the groove between the S1 SAP and sacral ala; starting positioning should be redefined from the oblique projection until the NIMBUS can be navigated successfully into the groove containing the L5 dorsal ramus.

TECHNIQUE (CONT'D)

L1-L4 MEDIAL BRANCHES

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape in a sterile manner.
2. Obtain a true segmental AP view of the target segment by centering the spinous process of the vertebra between pedicles and flattening the superior endplate of the target level (eg, top of the L4 vertebral body for the L3 medial branch).
3. Rotate the X-ray beam obliquely toward the target to identify the junction of the SAP and transverse process. Typically seen with 20–30 degrees of obliquity, this view demonstrates the classic "Scotty dog" outline, reflecting the posterior oblique view of the lumbar spine.
4. Identify and anesthetize the skin entry point.
5. Grip the central hub, and advance NIMBUS using a down-the-beam approach to touch the bone at the juncture of the base of the SAP and root of the transverse process in the most cranial half of the pedicle shadow. Positions more caudal may overlap the mamillo-accessory ligament and diminish the effective area of coagulation.
6. Check depth on lateral imaging, ensuring a true lateral view of the lumbar spine with clear superimposition of the articular pillars and a single iliopectineal line.
7. An additional view that is useful in confirming NIMBUS MEE position and guiding the tine direction: re-establish the segmental AP view, and tilt the X-ray into a caudal decline (20–30 degrees) to elongate the SAP and visualize NIMBUS position and tine direction relative to the SAP and transverse process seen from an oblique decline view.
8. Deploy tines: rotate the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and deployment of the tines.
9. Obtain and save AP and lateral images of this position (at a minimum).
10. With the tines fully deployed, inject long-acting local anesthetic (if desired), allowing time for it to take effect.
11. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 80°C for 80 seconds with a 30-second ramp time.
12. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
13. Provide appropriate post-procedure care.

TECHNIQUE (CONT'D)

MULTIFIDUS SPARING FACET JOINT CAPSULE (ALTERNATIVE TECHNIQUE)

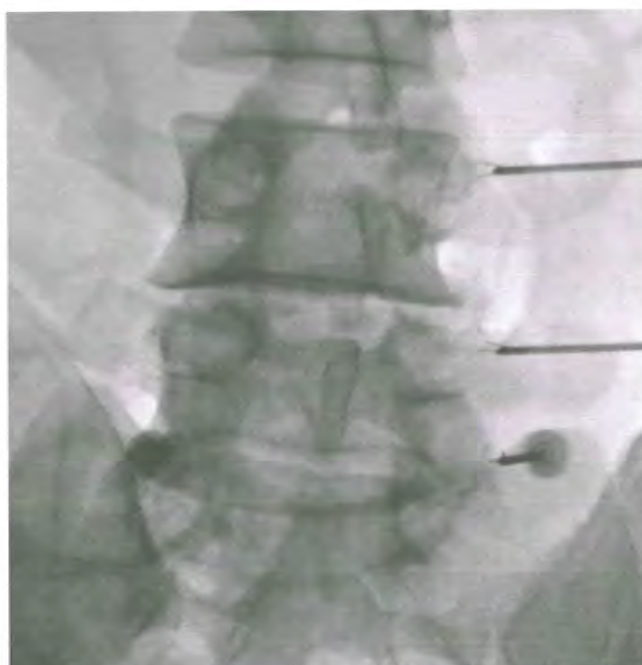
Radiofrequency (RF) ablation of the medial branches and dorsal ramus supplying facet joints has been used for decades to effectively treat persistent low back pain in carefully selected patients. An alternative target is the facet joint capsule itself. The capsule is rich with nociceptors and represents a distinct and rational target for RF treatments. Capsule targeting spares the multifidus muscle, which is believed to be important for recovery from low back pain yet can be affected by traditional RF approaches. The significance of multifidus denervation resulting from the traditional technique is debated, but most agree that avoiding denervation may offer an advantage. A capsule-targeting technique is the multifidus-sparing radiofrequency technique, first described by Dr Marc Russo. In this technique, a NIMBUS MEE is positioned under fluoroscopic guidance to contact the facet capsule, and tines are deployed to embed in the capsule tissue prior to lesioning. Dr Russo published his experience over a 2-year period comparing 401 initial multifidus-sparing radiofrequency technique procedures and 94 traditional medial branch radiofrequency technique procedures performed for facet joint low back pain. The proportion needing repeat procedures was similar between groups at 28.4% for multifidus-sparing and 23.4% for the conventional radiofrequency technique. The median repeat interval was 12 months for both groups. Effectiveness and safety appear similar. In summary, multifidus-sparing RF allows facet joint denervation while potentially maintaining normal multifidus function.

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape it in a sterile manner.
2. Obtain a true segmental AP view of the target segment by centering the spinous process of the vertebra between pedicles and flattening the superior endplate of the target level.
3. Rotate the X-ray beam obliquely toward the target to identify the junction of the SAP and transverse process. Identify the target facet joint in the 30-degree oblique fluoroscopic plane.
4. Identify and anesthetize the skin entry point.
5. Place the NIMBUS MEE in the "gun barrel" view to touch the facet joint capsule exactly midway vertically and horizontally within the joint itself.
6. Deploy tines: rotate the helical spin collar clockwise while exerting downward pressure on the device to ensure that the tines embed into the tissue of the facet joint capsule. A distinct tactile click confirms full engagement and deployment of the tines.
7. Orient the tines to be in the vertical plane of the facet joint line. Confirm this on the fluoroscopic image, taking particular care to ensure that the tines are not on either side of the joint line in the oblique view.
8. Lesion: perform a single-cycle monopolar lesion at this site. Recommendation: 90°C for 90 seconds with a 30-second ramp time.
9. Following the lesion cycle, the tines may remain deployed to inject additional local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS.
10. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
11. Provide appropriate post-procedure care.

TECHNIQUE IMAGES



Slight left posterior oblique imaging demonstrates starting position for the left L5 dorsal ramus, visualizing the groove at the base of the S1 SAP and sacral ala. Typically, 5–10 degrees of obliquity is sufficient to identify a trajectory to the L5 dorsal ramus and avoid the dorsal aspect of the SAP, preventing cannula placement dorsal to the effective treatment site. Cannulas are positioned for right L3, L4 medial branch, and L5 dorsal ramus treatment.



Coaxial view of the left L5 dorsal ramus cannula advanced to the cranial edge of the sacral ala into the groove at the base of the S1 SAP.

TECHNIQUE IMAGES (CONT'D)



Lateral view demonstrating cannulas contacting transverse processes, with tines approximating coronal facet joint lucency. At the L5 dorsal ramus, the cannula is deep to the dorsal facet complex, with tines at the coronal lucency. All cannulas are in safe positions dorsal to respective foramina. Iliopectineal lines are superimposed, confirming true lateral view.



Right posterior oblique view demonstrates coaxial placement of the cannula at the base of the L3, L4, and L5 SAPs and roots of the transverse processes. Minimal but sufficient obliquity is required to visualize the 12 o'clock position on the pedicle shadow while avoiding the lateral edge of the SAP. Initially, 20 degrees of rotation is typical, with potential increases needed for arthritic joints. However, minimizing oblique rotation decreases skin-to-target distance and facilitates cannula navigation. Lumbar lordosis should be reduced using abdominal support cushions. With neutralized lordosis, X-ray should not require excessive cranial-caudal adjustment. Targeting the cranial edge of the transverse process at the SAP base minimizes parallax effects when the superior endplate is not perfectly crisp.

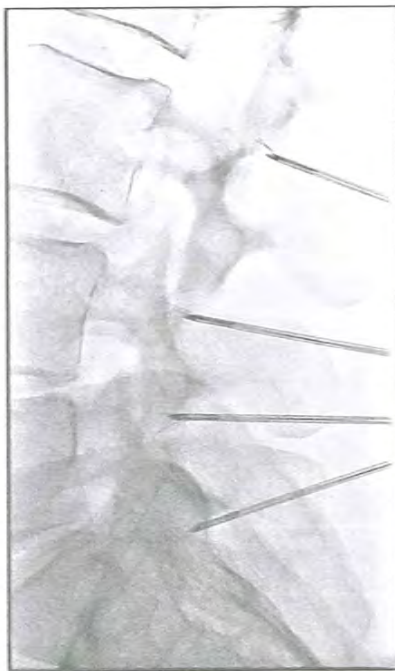
Petitioner's Exhibit 1051

Avanos v. Stratus

TECHNIQUE IMAGES (CONT'D)



Sufficient caudal decline to elongate the SAPs from either AP or slight oblique (10 degrees) view documents the tines at the base of the SAP. This further confirms optimal cannula positioning for treatment. In this view, the proceduralist can leverage the directionality of the tines to guide the lesion placement.

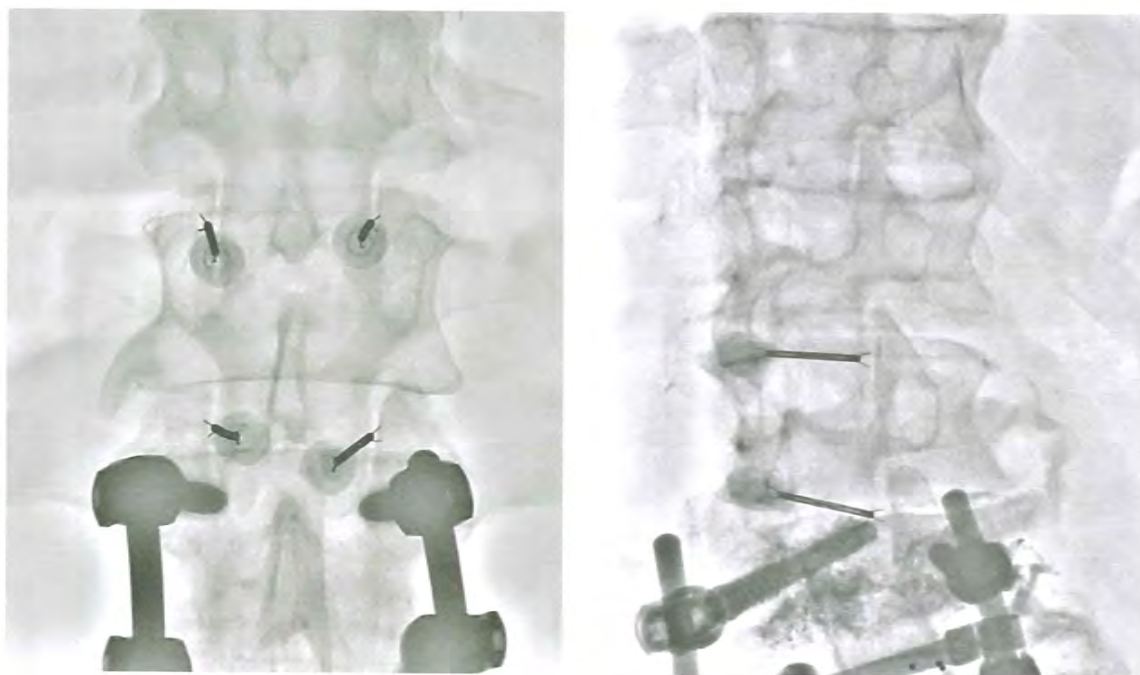


Lateral views demonstrate cannulas contacting transverse processes, with tines approximating coronal facet joint lucency. At the L5 dorsal ramus, the cannula is positioned deep to the dorsal facet complex, with tines at the coronal joint lucency. All cannulas are safely positioned dorsal to their respective foramina. Superimposed ilipectineal lines confirm true lateral views in both images. The left image shows ineffectively neutralized lumbar lordosis, resulting in varying cranial-caudal angle cannula trajectories. In contrast, the right image demonstrates parallel cannula trajectories, reflecting better lordosis correction.

Petitioner's Exhibit 1051

Avanos v. Stratus

TECHNIQUE IMAGES (CONT'D)



The thermal capsulorrhaphy (multifidus sparing) technique, originally described by Dr Marc Russo, is particularly effective for treating segments adjacent to fusions, offering a solution to the challenging anatomy in these regions.

RECOMMENDED READING

Bogduk N, Dreyfuss P, Govind J. A narrative review of lumbar medial branch neurotomy for the treatment of back pain. *Pain Med.* 2009;10:1035-1045.

Du R, Xu G, Bai X, Li Z. Facet joint syndrome: pathophysiology, diagnosis, and treatment. *J Pain Res.* 2022;15:3689-3710.

MacVicar J, Borowczyk JM, MacVicar AM, Loughnan BM, Bogduk N. Lumbar medial branch radiofrequency neurotomy in New Zealand. *Pain Med.* 2013;14:639-645.

Russo MA, Santarelli DM. Development and description of a new multifidus-sparing radiofrequency neurotomy technique for facet joint pain. *Pain Pract.* 2021;21:747-758.

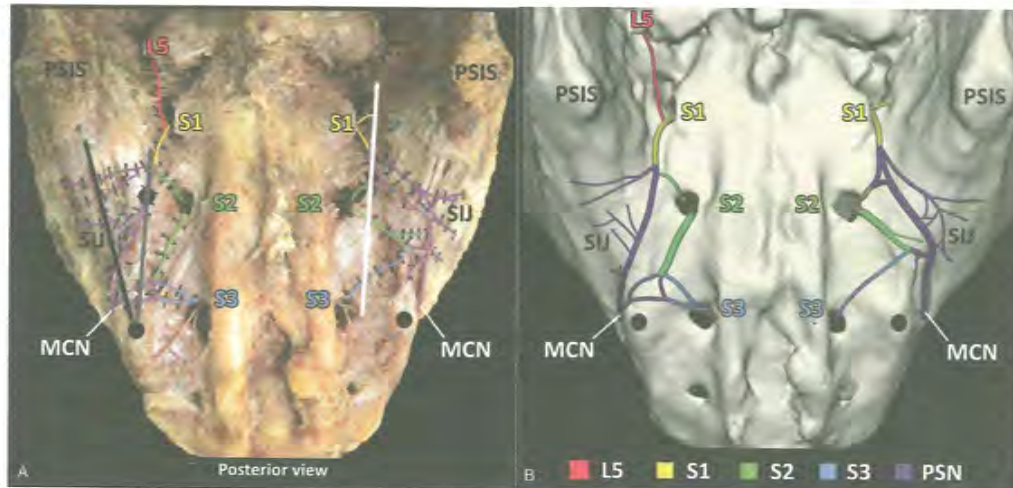
Tran J, Peng P, Loh E. Anatomical study of the medial branches of the lumbar dorsal rami: implications for image-guided intervention. *Reg Anesth Pain Med.* 2022;47:464-474.

Waring PH, Landers MH, Bogduk N. Correcting the nomenclature of medial branch neurotomy to medial branch coagulation. *Pain Med.* 2022;23:603-604.

DORSAL SACROILIAC JOINT RADIOFREQUENCY NEUROTOMY

Reviewed by: **Serge Nikolic, MD, FRCA, FFPMRCA**

Consultant, NHS and St Bartholomew's Hospital, London, UK



Reprinted with permission from Roberts S, et al. *Reg Anesth Pain Med*. 2014;39:456-464.
© 2014, BMJ Publishing Group Ltd and American Society of Regional Anesthesia and Pain Medicine

BACKGROUND

The growing recognition that the sacroiliac joint (SIJ) is a common source of disabling spine pain has created the need for a straightforward, cost-effective, and dependable method for radiofrequency (RF) denervation of the dorsal SIJ. Although various surgical techniques for SIJ arthrodesis have been described, including percutaneous approaches, RF denervation remains an essential and valuable technique in the conservative treatment of painful SIJ dysfunction.

Patient selection for dorsal SIJ neurotomy can be based on a thorough physical examination combined with significant pain relief following at least one imaging-confirmed intra-articular injection. The author's practice also requires over 70% pain relief during the anesthetic phase after multi-site, multi-depth lateral branch blocks, as described by Dreyfuss et al.

The highly variable dorsal innervation of the SIJ necessitates a robust technique to effectively lesion the lateral branches of S1, S2, and S3. The target lateral branch nerves exhibit significant variation in their exit path from their respective posterior foramen, both in the cranio-caudal direction and from dorsal to ventral, with lateral branches potentially floating up to 10 mm off the bone.

An anatomical study published by Robert et al instructs that effective neurotomy of the S1, S2, and S3 lateral branches requires a lesion following a parasagittal line 5–10 mm lateral to the S1–S3 posterior sacral foraminal aperture (PSFA) to create a 10-mm wide and 10-mm deep zone of coagulation. This volume and shape of the coagulated area is required to encompass variable anatomy and create a wide enough interruption in the lateral branch to provide a durable clinical response.

A recent retrospective review published by Drs Wright and Block showed a trend toward improved outcomes when the medial branch of L4 and dorsal ramus of L5 were included in the treatment, which now informs the recommended protocol. In the event that the L4 medial branch and L5 dorsal ramus are inaccessible (fusion) or recently treated, those targets can be omitted.

Petitioner's Exhibit 1051

Avanos v. Stratus

TECHNICAL OVERVIEW

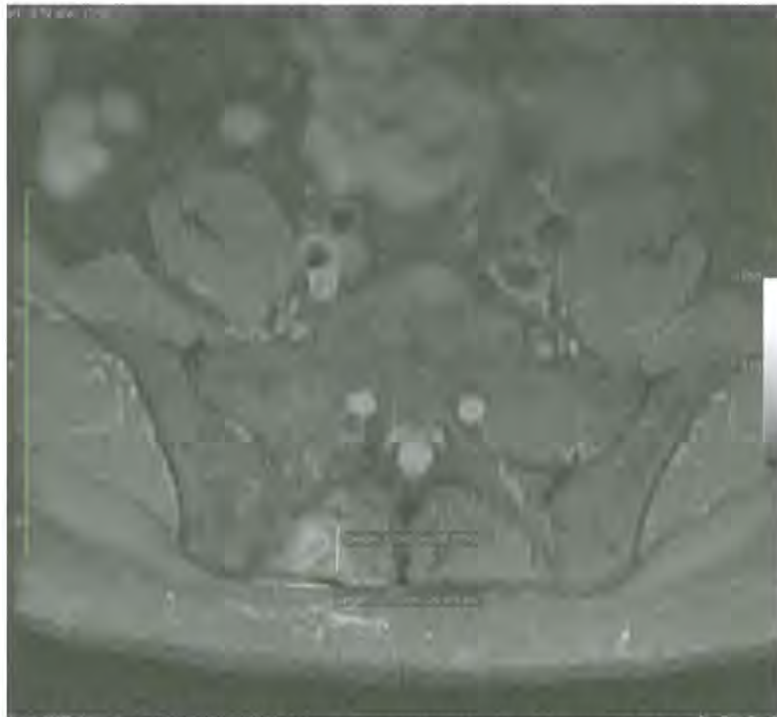
It is important to note that conventional RF cannulas are used by some to create a strip lesion, but this approach suffers from key technical limitations:

- The conventional cannula creates only a "point lesion" on the sacrum and cannot coagulate lateral branch nerves running on the dorsum of the sacrum.
- The width of the lesion correlates with the durability of relief, and the conventional 16-gauge cannula is limited to creating a strip of coagulated tissue less than 6 mm wide, versus the 10 mm required for extended pain relief.
- Achieving contiguous bipolar coagulation with the conventional cannula requires precise spacing and alignment in three dimensions, which is virtually impossible to accomplish given the dorsal sacral anatomy.

The NIMBUS® Multitined Expandable Electrode (MEE) was tested in a bipolar configuration and consistently produced a contiguous lesion of the desired dimensions in ex vivo and in vivo studies, as validated with post-procedure magnetic resonance imaging (MRI).

To summarize the technique:

- Place the L4 medial branch and L5 dorsal ramus NIMBUS MEE devices as they would be for standard L5/S1 facet joint RF ablation. Two additional devices are placed above and below the S2 arcuate line, 5–10 mm lateral to the S2 PSFA, separated by approximately 15 mm. A monopolar heat cycle is accomplished at these targets.
- Next, the NIMBUS MEE devices from L4 medial branch and L5 dorsal ramus are removed and placed at the S1 and S3 positions. The dual bipolar mode lesion is made to coagulate lateral branches via a strip lesion extending along a parasagittal line 5–10 mm lateral to the posterior foramen of S1, S2, and S3 using the four NIMBUS devices.
- During NIMBUS validation, it was noted empirically that if all NIMBUS devices register $>63^{\circ}\text{C}$, then an adequate size and shape of lesion for SIJ neurotomy is accomplished with a single heat cycle. However, changing the pairing between the four devices and using a second heat cycle will ensure thorough coagulation.



Representative sacral axial section demonstrating tissue change 2 weeks after continuum.
Lesion in vivo conforms to ex vivo prediction.

POSITIONING



Position the patient prone on the procedure table with sufficient support under the abdomen to reverse the lumbar lordosis and make the spine as flat as possible. Flattening the lumbar spine will reduce the cephalocaudal tilting required between levels and increase procedural efficiency while decreasing X-ray exposure.

Positioning images demonstrate optimal position (top left) and preserved or enhanced lordosis with insufficient or mispositioned support (top right, bottom left, bottom right, respectively).

TECHNIQUE

IDENTIFICATION OF SACRAL ANATOMY

1. Prep the targeted side with an alcohol-based disinfectant solution, and drape it in a sterile manner.
2. Obtain a true segmental anterior-posterior (AP) view of the sacrum by adjusting the cephalocaudal tilt of the X-ray to flatten the superior endplate of S1 and positioning the spinous processes of the sacrum in the midline, equidistant from the pedicle shadow of S1.
3. Identify the S1 superior articular process (SAP), and note its juncture with the sacral ala.
4. The correct position of the strip lesion extends caudally from the base of the S1 SAP along a parasagittal line lateral to the PSFAs of S1, S2, and S3.
5. Identify the arcuate lines of S1, S2, and S3, which represent the lateral wall of the sacral neural foramen radiographically.

IDENTIFY L5 DORSAL RAMUS (DESCRIBED IN LUMBAR CHAPTER)

Tilt the X-ray beam caudally to visualize a crisp endplate of L5, and rotate further obliquely (typically 20 degrees) to identify the juncture of the base of the L5 SAP and the root of the L5 transverse process. The X-ray should be rotated until the circular pedicle shadow is clearly visible and not obscured ("Scotty dog" view).

IDENTIFY L4 MEDIAL BRANCH (DESCRIBED IN LUMBAR CHAPTER)

Advance the NIMBUS MEE in a coaxial fashion to target the L4 medial branch at the base of the L5 SAP between the center and cranial edge of the pedicle shadow.

IDENTIFY S2 LATERAL BRANCH

1. Identify the lateral foraminal walls (arcuate lines) of the S1, S2, and S3 spinal foramen. The PSFA for the relevant lateral branch nerve is typically at the "inflection" point of these lines.
2. Place two NIMBUS devices "above and below" the S2 arcuate line 5–10 mm lateral to the PSFA.
3. Check a lateral or deep contralateral oblique (CLO) "safety view" to ensure that the tines are on the dorsum of the sacrum.
4. Motor stimulation at 2 Hz up to 1.5 volts can be used for additional safety checks if desired.
5. With tines fully deployed, inject the local anesthetic of choice before lesioning.

TECHNIQUE (CONT'D)

S1, S2, & S3 STRIP LESION

1. For the S1 lateral branch, identify a target 5–10 mm lateral to the PSFA and 5–10 mm cephalad. Typically, the S1 PSFA can be identified medial to the arcuate line of S1 at the midpoint of the line. At the S1 level, a lucent area corresponding to the superposition of the larger ventral and smaller posterior foramen can usually be seen.
2. Identify and anesthetize the skin entry point. Then insert a NIMBUS MEE device through the skin and direct it in a coaxial manner to touch the sacrum.
3. Deploy tines: rotate the helical spin collar clockwise with the white stripe directed toward the feet. A distinct tactile click confirms full engagement and deployment of the tines.
4. Identify the arcuate line of S2 and the "inflection" point where it transitions from a caudal slope to an inferolateral slope.
5. The S2 PSFA is located at this transition, at the level of the posterior superior iliac spine for additional orientation.
6. Identify a target position 5–10 mm superior to the S2 arcuate line, directly caudal to the NIMBUS MEE placed for the S1 lateral branch. These two devices will typically be separated by 15–20 mm. The distance between the arcuate lines in the average human is 18–22 mm.
7. Identify and anesthetize the next skin entry point. Then insert a NIMBUS device through the skin and direct it in a coaxial manner to touch the sacrum.
8. Deploy tines: rotate the helical spin collar clockwise with the white stripe directed toward the head. A distinct tactile click confirms full engagement and deployment of the tines.
9. Obtain and save AP and lateral images of this position (at a minimum).
10. With the tines fully deployed, inject long-acting local anesthetic (if desired), allowing time for it to take effect.
11. Stimulation: stimulation is not required. However, you may perform motor stimulation testing with a 2-Hz frequency at 2 volts as an additional safety check.
12. Lesion: perform a single-cycle bipolar lesion at this site. Recommendation: 85°C for 150 seconds. A 2-minute bipolar pulsed RF treatment (42°C/20 ms/2 Hz/45 volts) can be delivered prior to the thermal

TECHNIQUE (CONT'D)

S1, S2, & S3 BIPOLAR (CONT'D)

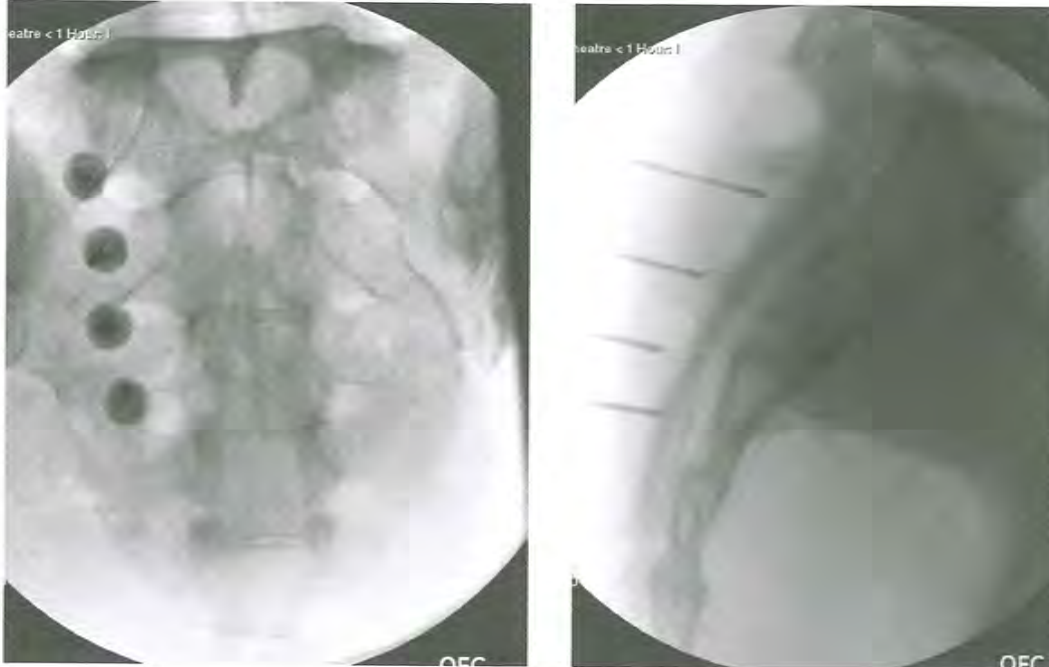
ablation treatment to potentially minimize post-procedure discomfort.

13. When using two NIMBUS devices, they can create a bipolar lesion between the S1 and superior S2 NIMBUS devices after confirming a lateral or deep CLO safety view.
14. Identify the second target for the S2 level 5–10 mm inferior to the previously identified S2 arcuate line.
15. For a two-device technique, remove the superior (S1) NIMBUS, retract the tines, and after skin anesthesia, insert the NIMBUS in a coaxial fashion to touch approximately 15 mm inferior to the cranially situated device.
16. Deploy the tines with the white stripe pointed toward the head, directing the tines toward each other. Use safety views, inject local anesthetic, and perform RF delivery as described above.
17. Identify the S3 arcuate line approximately 20 mm caudal to the S2 arcuate, presenting radiographically as a near-horizontal line.
18. Identify the S3 target inferior, and align with the previous NIMBUS placements.
19. Remove the most cranial NIMBUS MEE from its position above the S2 arcuate line, anesthetize the skin, and with a coaxial technique, advance the NIMBUS to the bone 15–20 mm inferior to the NIMBUS device still positioned below the S2 arcuate line.
20. Deploy the tines with the white stripe pointed cranially. Retract the tines on the device below the S2 arcuate, rotate 180 degrees, and redeploy with the white stripe directed inferior, pointing the tines toward the tines from the S3 NIMBUS.
 - Use safety views, inject local anesthetic, and perform RF delivery as described above.
 - Following the lesion cycle, the tines may remain deployed to inject additional local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS.
 - Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
 - Provide appropriate post-procedure care.

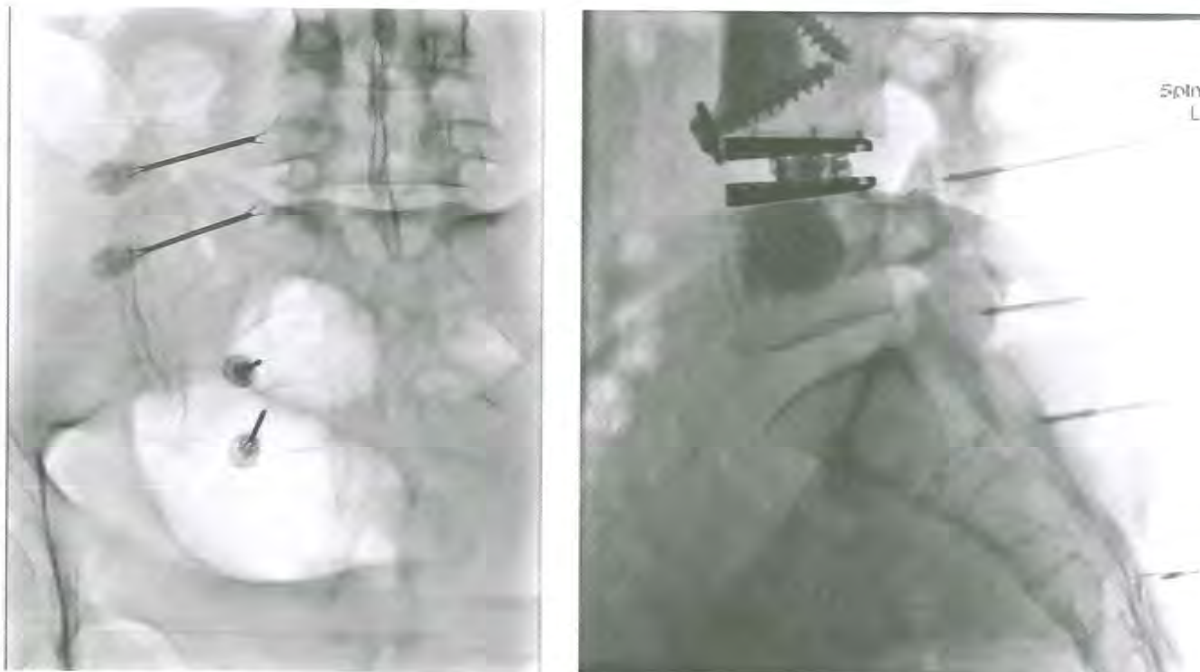
TECHNICAL CONSIDERATIONS FOR BIPOLAR

In situations where four NIMBUS devices can be used, the targets remain the same. Two bipolar pairs are used for the lesion. If the anode (return NIMBUS) temperatures exceed 63°C, a confluent lesion has been created. If all temperatures do not exceed 63°C, a second lesion is made with alternate bipolar pairing. Anatomical evidence suggests that the lesion between the NIMBUS above and below the S2 arcuate line is very important to complete the ablation of afferent nociception from the SIJ. Using four devices simultaneously, when possible, reduces procedure time, X-ray exposure, and length of anesthesia.

TECHNIQUE IMAGES



AP view of the sacrum with the S1 endplate "crisp" and X-ray positioned to create a true perpendicular (en face) view of the sacrum. Lateral foraminal walls/arcuate lines of S1, S2, and S3 (also known as *Charlie's lines*) are easily visualized. Cannulas are placed at targets immediately superolateral to the S1 arcuate line, above and below the S2 arcuate line, and lateral to the S3 line. Lateral view demonstrates placement on the dorsum of the sacrum. Cannulas are activated as bipolar pairs; if all anode (return) cannulas register above 63°C, then a single heat cycle will suffice. However, most practitioners will change bipolar pairing to ensure inclusion of the cannulas bracketing S2.

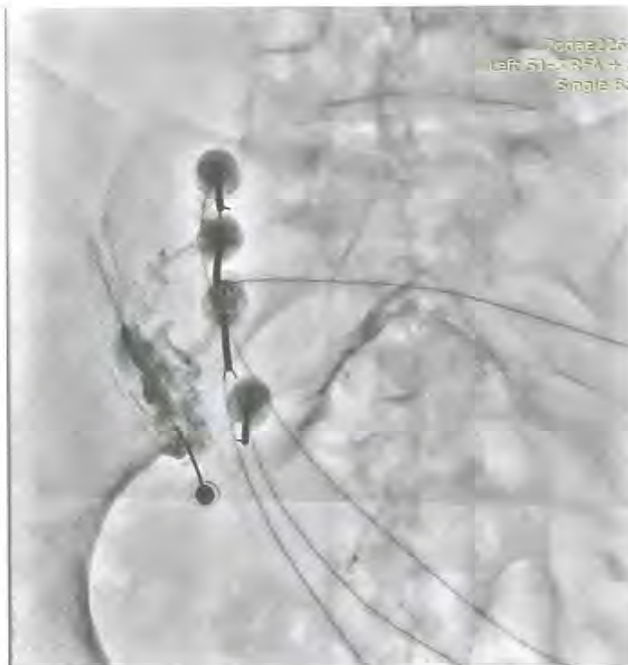


When the treatment plan includes targeting the L4 medial branch and L5 dorsal ramus, technique efficiency is achieved by first placing the cannulas at the L4 medial branch and L5 dorsal ramus targets (as in standard lumbar RF of the L5/S1 facet joint), along with two cannulas bracketing the S2 arcuate line. At this position, perform a monopolar treatment cycle. Then remove the cannulas from the L4 medial branch and L5 dorsal ramus targets, and reposition them at the S1 and S3 targets for a bipolar RF cycle; this sequence optimizes procedure efficiency.

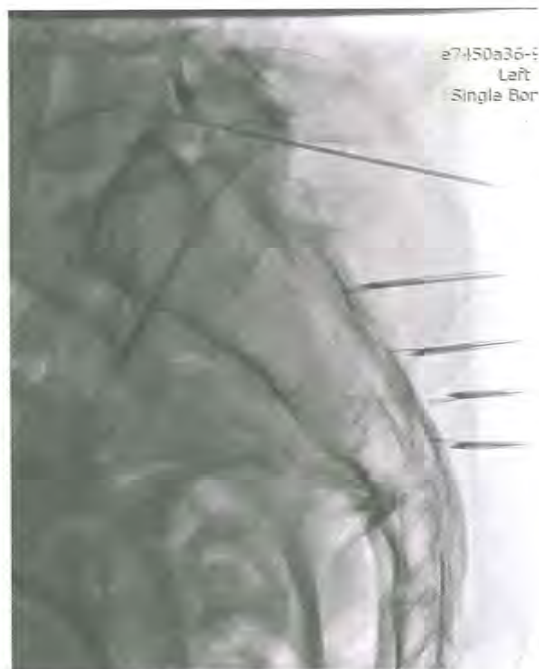
Petitioner's Exhibit 1051

Avanos v. Stratus

TECHNIQUE IMAGES (CONT'D)



Cannulas are positioned for bipolar treatment cycle imaging. The author frequently administers an intra-articular SIJ injection in conjunction with denervation – in this instance, contrast is seen in the joint for confirmatory arthrogram, but dorsal extravasation is noted tracking along lateral branches. Also note the washout view of contrast from caudal anesthetic injection, which is routinely administered prior to cannula placement for perioperative analgesia.



In cases with a steep angle of the dorsal sacrum or relatively lateral placement of cannulas, true lateral imaging may incorrectly suggest cannula tip placement deep to the dorsum of the sacrum in the caudal canal. More accurate imaging can be achieved with deep CLO views, visualizing the dorsal sacrum end-on and correctly showing cannula placement on bone without egress into the caudal canal. In this image, a cannula is seen in the inferior caudal canal demonstrating true caudal epidural space. *Note:* the cannula at L5 is positioned for nonthermal treatment of the L5 dorsal root ganglion, a technique not covered in this text.

Petitioner's Exhibit 1051

Avanos v. Stratus

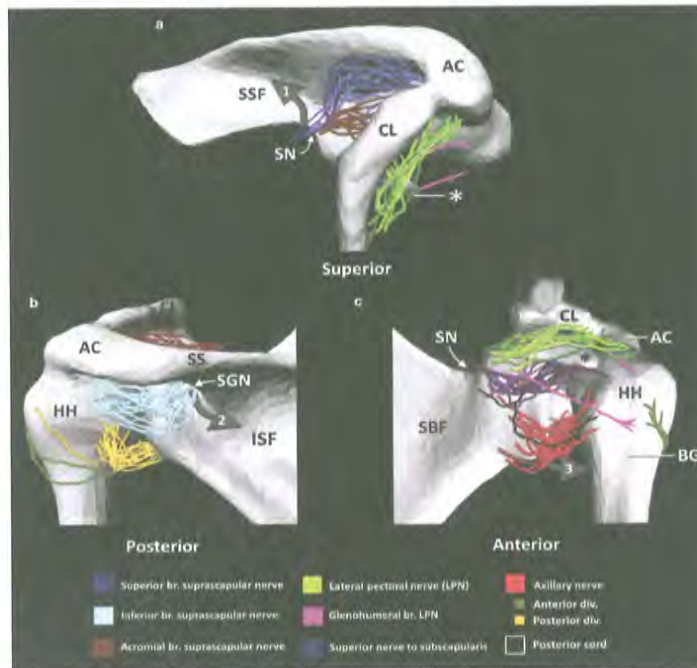
RECOMMENDED READING

- Aranke M, McCrudy G, Rooney K, et al. Minimally invasive and conservative interventions for the treatment of sacroiliac joint pain: a review of recent literature. *Orthop Rev (Pavia)*. 2022;14:31915.
- Buchanan P, Vodapally S, Lee DW, et al. Successful diagnosis of sacroiliac joint dysfunction. *J Pain Res*. 2021;14:3135-3143.
- Chen CH, Weng PW, Wu LC, Chiang YF, Chiang CJ. Radiofrequency neurotomy in chronic lumbar and sacroiliac joint pain: a meta-analysis. *Medicine (Baltimore)*. 2019;98:e16230.
- Cher D, Polly D, Berven S. Sacroiliac joint pain: burden of disease. *Med Devices (Auckl)*. 2014;7:73-81.
- Cohen SP, Abdi S. Lateral branch blocks as a treatment for sacroiliac joint pain: a pilot study. *Reg Anesth Pain Med*. 2003;28:113-119.
- Cohen SP, Hurley RW, Buckenmaier CC 3rd, Kurihara C, Morlando B, Dragovich A. Randomized placebo-controlled study evaluating lateral branch radiofrequency denervation for sacroiliac joint pain. *Anesthesiology*. 2008;109:279-288.
- Cox M, Ng G, Mashriqi F, et al. Innervation of the anterior sacroiliac joint. *World Neurosurg*. 2017;107:750-752.
- Cox RC, Fortin JD. The anatomy of the lateral branches of the sacral dorsal rami: implications for radiofrequency ablation. *Pain Physician*. 2014;17:459-464.
- Dreyfuss P, Henning T, Malladi N, Goldstein B, Bogduk N. The ability of multi-site, multi-depth sacral lateral branch blocks to anesthetize the sacroiliac joint complex. *Pain Med*. 2009;10:679-688.
- Ikeda R. [Innervation of the sacroiliac joint: macroscopical and histological studies]. *Nihon Ika Daigaku Zasshi*. 1991;58:587-596.
- Loh E, Agur AM, Burnham RS. Ultrasound-guided radiofrequency ablation for SI joint pain: an observational study. *Intervent Pain Med*. 2022;1:100118.
- Lowe M, Okunlola O, Raza S, et al. Radiofrequency ablation as an effective long-term treatment for chronic sacroiliac joint pain: a systematic review of randomized controlled trials. *Cureus*. 2022;14:e26327.
- Mitchell B, MacPhail T, Vivian D, Verrills P, Barnard A. Diagnostic sacroiliac joint injections: is a control block necessary? *Surg Sci*. 2015;6:273-281.
- Roberts SL, Burnham RS, Ravichandiran K, Agur AM, Loh EY. Cadaveric study of sacroiliac joint innervation: implications for diagnostic blocks and radiofrequency ablation. *Reg Anesth Pain Med*. 2014;39:456-464.
- Shih CL, Shen PC, Lu CC, et al. A comparison of efficacy among different radiofrequency ablation techniques for the treatment of lumbar facet joint and sacroiliac joint pain: a systematic review and meta-analysis. *Clin Neurol Neurosurg*. 2020;195:105854.
- Tinnirello A. Reduction of opioid intake after cooled radiofrequency denervation for sacroiliac joint pain: a retrospective evaluation up to 1 year. *Korean J Pain*. 2020;33:183-191.
- Wright RE, Block JE. Radiofrequency neurotomy for sacroiliac joint pain: twelve month outcomes and comparison between two techniques. *Med Res Arch*. 2023;11.
- Yang AJ, Wagner G, Burnham T, McCormick ZL, Schneider BJ. Radiofrequency ablation for chronic posterior sacroiliac joint complex pain: a comprehensive review. *Pain Med*. 2021;22(Suppl 1):S9-S13.

SHOULDER RADIOFREQUENCY NEUROTOMY

Reviewed by: **Dan T.D. Nguyen, MD**

Neuroradiology & Pain Solutions of Oklahoma, Edmond, OK, USA
Past President of American Society of Spine Radiology



Reprinted with permission from Peng Educational Series

BACKGROUND

German anatomist Nikolaus Rüdinger's pioneering publication in 1857 on the sensory innervation of the shoulder laid the groundwork for selective joint denervation. Since then, our knowledge of shoulder innervation has expanded through various dissections and studies, including the innovative work of John Tran and colleagues in Toronto and the clinically focused work spearheaded by Maxim Eckmann of San Antonio.

Shoulder pain is the third most common musculoskeletal complaint, following spine and knee pain. It can be a source of disability that is not always suitable for surgical treatment. Therefore, it is appropriate to consider using procedural pain medicine tools to address this clinical problem. While there is no complete consensus on the neuroanatomy of shoulder pain, we have sufficient information to formulate conservative, safe, and likely effective treatments using radiofrequency (RF) energy.

When developing new techniques, it is important to extend existing approaches and ensure that they are as simple as possible to understand and execute. Additionally, clarity regarding the desired outcome of a new technique is vital. The goal of RF ablation (RFA) for shoulder pain is not to render the joint insensate, but rather to reduce the patient's nociceptive burden. By diminishing pain, patients can engage in rehabilitation, decrease medication use, and pursue meaningful recovery with improved quality of life. With these principles in mind, a pragmatic approach to the shoulder can be followed. Understanding the suprascapular, axillary, and lateral pectoral nerves, along with their sensory articular branches, is crucial for successful shoulder RF procedures. The subscapular nerve, which does not innervate any target zone uniquely, is only variably identified in studies and will not be incorporated into this technique.

Petitioner's Exhibit 1051

Avanos v. Stratus

ANATOMIC OVERVIEW

The **suprascapular nerve** provides innervation to the glenohumeral joint (GHJ), the acromioclavicular joint (ACJ), the subacromial bursa (SAB), and the coracoid ligaments. The suprascapular nerve can be found at the suprascapular notch.

A small retrospective study (Simopolous, 2012) describes continuous RF thermal ablation of the suprascapular nerve at the suprascapular notch, where it is a mixed nerve (motor/sensory). However, RFA of distal sensory articular branches is more widely adopted for certain conditions.

Suprascapular nerve sensory articular branch targets:

1. Superior (subacromial branch/acromial branch): target the mid-position on the dorsum of the coracoid lateral to the suprascapular notch, considering a bipolar construct. This branch innervates the coracoclavicular ligaments, ACJ, and SAB.
2. Inferior (posterior glenohumeral branch): this branch travels from the suprascapular notch to the spinoglenoid notch and extensively innervates the posterior capsule of the GHJ. Target the posterior glenoid rim, aiming for a contiguous lesion to provide optimal coverage.

Note: For patients with nociplastic shoulder pain, nonablative RF treatment (pulsed RF) of the suprascapular nerve at the notch may offer benefits if performed in conjunction with thermal ablation of sensory afferents.

The **axillary nerve** provides innervation to the GHJ and the subacromial/deltoid bursae.

The axillary nerve emerges from the quadrangular space (formed by teres minor, teres major, the long head of triceps, and the surgical neck of the humerus).

The posterior division supplies articular branches to the posterior inferior GHJ capsule after passing through the quadrangular space. These branches extend into the posterior inferior capsule and can be coagulated with the inferior aspect of the posterior glenoid rim strip lesion. The superior division of the ascending axillary nerve supplies articular branches to the lateral joint capsule and SAB. Target the posterolateral aspect of the greater tuberosity, superior to the surgical neck. Motor stimulation (2 Hz x 1 volt recommended) should be performed to avoid lesioning the inferior motor division.

The **lateral pectoral nerve** innervates the ACJ, coracoid ligaments, SAB, and anterior GHJ capsule. The articular branch lies along the superficial and dorsal aspect of the coracoid process, proximal and posterior to the thoracoacromial artery. Target the dorsum of the "neck" of the coracoid, dorsal to the tip of the process.

POSITIONING

SUPRASCAPULAR & AXILLARY



The patient is placed prone on the procedure table with a support pad at the clavicle level to allow slight neck flexion and an unobstructed airway.

The preferred position is with the arm above the head (abducted shoulder and flexed elbow with the hand near the head). This position provides X-ray visualization of the target anatomy with less rotation and tilt of the C-arm. However, many patients with shoulder pain cannot tolerate this position. In such cases, the arm can be positioned at the side.

LATERAL PECTORAL



For lateral pectoral nerve ablation, the patient is placed in the supine position with a small pad positioned between the scapula to provide scapular retraction and facilitate the visualization of the coracoid process.

TECHNIQUE

SUPRASCAPULAR NOTCH

1. Prep the targeted area with an alcohol-based disinfectant solution, and drape it in a sterile manner.
2. Rotate the X-ray to identify the coracoid process in the most elongated projection.
3. Tilt the X-ray to maximize the space between the coracoid process and the superior margin of the glenoid.
4. If needed, rotate the X-ray to visualize the GHJ space and tilt it so that the scapular spine bisects the glenoid.
5. In optimal imaging, the suprascapular notch is commonly seen as a "U" shape, although it may occasionally appear as a "V" shape.
6. Identify and anesthetize the skin entry point.
Note: A NIMBUS device can be advanced coaxially to touch the bone at the inferior aspect of the notch and then slightly advanced (1–3 mm) over the bone to enter the notch.
7. Deploy tines: rotate the helical spin collar clockwise with the white stripe directed toward the head. A distinct tactile click confirms full engagement and deployment of the tines.
8. Motor stimulation: use a 2-Hz frequency at <0.6 volts to confirm accurate location by eliciting fasciculations of the supraspinatus and infraspinatus.

SUPRASCAPULAR – ACROMIAL BRANCHES

1. With the tines fully deployed, inject long-acting local anesthetic if desired (allow time for it to take effect). *Note:* the suprascapular procedure can be performed with pulsed or at traditional recommended lesion settings. Alternatively, a 3.5-inch spinal needle can be placed in a similar fashion for an anesthetic block for perioperative analgesia.
2. From this view, target the acromial branch of the suprascapular nerve on the mid-posterior surface of the coracoid process.
3. Motor stimulation: use a 2-Hz frequency at 1 volt to guide placement to minimize fasciculation of the supraspinatus and infraspinatus muscles.
4. Lesion: perform two single-cycle monopolar lesions separated by 10–15 mm, or a bipolar construct on the posterior coronoid process will produce an adequate zone of coagulation. Recommendation: 80°C for 80 seconds for monopolar with 30-second ramp time and 85°C for 150 seconds for bipolar with 30-second ramp time.
5. Following the lesion cycle, the tines may remain deployed to inject local anesthetic if desired. Once finished, fully retract the tines and remove NIMBUS. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
6. Provide appropriate post-procedure care.

TECHNIQUE (CONT'D)

GLENOID RIM & GLENOHUMERAL JOINT

1. Identify and anesthetize the skin entry point.
2. Place two NIMBUS devices along the glenoid rim, from slightly below the spinoglenoid notch to the inferior aspect of the joint.
3. Deploy tines: prior to motor stimulation, rotate the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and full deployment of tines. Tines are deployed at this point.
4. With tines fully deployed, inject long-acting local anesthetic if desired (allow time for effect).
5. Lesion: perform a bipolar lesion at this site. Recommendation: 85°C for 150 seconds for bipolar with 30-second ramp time. If the return (passive) cannula temperature does not reach 63°C, swap the thermocouple probes between cannulas to reverse the active and passive roles, then perform a second lesion cycle to ensure complete coagulation.
6. Following the final lesion, withdraw the NIMBUS devices. If desired, the tines can remain deployed to inject local anesthetic before removal. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
7. Provide appropriate post-procedure care.

GREATER TUBEROSITY OF THE HUMERUS

1. Translate the X-ray to center the humeral head.
2. The greater tuberosity of the humerus is a posterolateral protuberance extending from the anatomic neck of the humerus to the surgical neck.
3. The presentation of the greater tuberosity will depend on the arm position. It may appear as a prominent peak or a curved line without rotating the X-ray. Either presentation allows targeting of sensory branches of the axillary nerve.
4. Position NIMBUS devices for a bipolar treatment on the superior and inferior aspects of the greater tuberosity, using either a coaxial or off-beam approach.
5. Deploy tines: prior to motor stimulation, rotate the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and full deployment of tines. Tines are deployed at this point.
6. Motor stimulation: 2-Hz frequency at 1 volt via the NIMBUS closest to the surgical neck should be performed to ensure that motor branches of the axillary nerve are not ablated.
7. By targeting the sensory branches of the suprascapular and axillary nerves as described in this technique, a substantial interruption of afferent nociception from the shoulder joint can be achieved. The ablation of the lateral pectoral nerve can be reasonably delayed to assess improvement or performed on the same day, based on clinical judgment and primary location of pain.

TECHNIQUE (CONT'D)

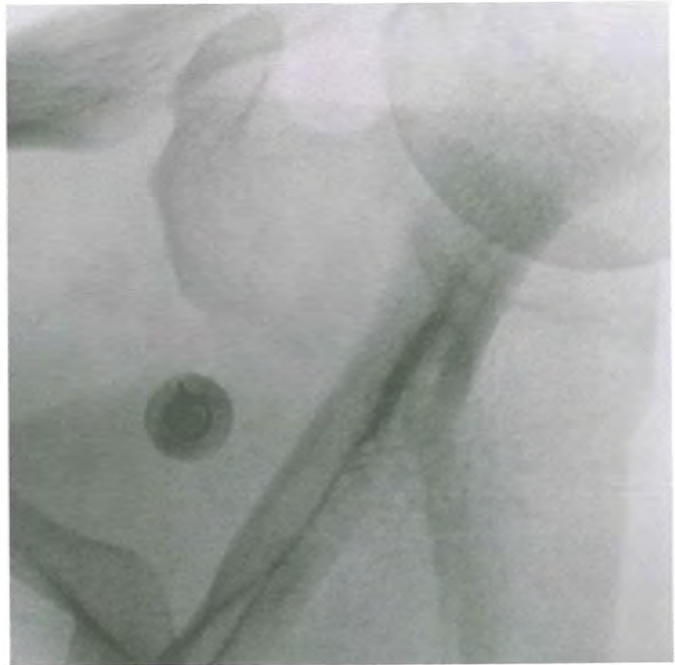
LATERAL PECTORAL NERVE AT CORACOID PROCESS (VENTRAL APPROACH)



Reposition patient as shown from positioning page. For lateral pectoral nerve ablation, the patient is placed in the supine position with a small pad positioned between the scapula to provide scapular retraction and facilitate the visualization of the coracoid process.

1. Prep the targeted area with an alcohol-based disinfectant solution, and drape it in a sterile manner.
2. Center the shoulder and distal clavicle with a standard anterior-posterior (AP) view. Identify and anesthetize the skin entry point.
3. Identify the coracoid process, and advance a NIMBUS device in a coaxial fashion to the superior lateral aspect of the circular target seen on the AP image.
4. Tilt the X-ray cranially and rotate it to the side of the procedure (10–20 degrees tilt and rotation) to confirm placement on the neck of the coracoid process.
5. Deploy tines: prior to motor stimulation, rotate the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and full deployment of tines. Tines are deployed at this point.
6. Motor stimulation: use a 2-Hz frequency at 1 volt to guide placement to minimize fasciculation of the supraspinatus and infraspinatus muscles.
7. Lesion: perform one single-cycle monopolar lesion. Recommendation: 80°C for 80 seconds for monopolar with 30-second ramp time.
8. Following the final lesion, withdraw the NIMBUS devices. If desired, the tines can remain deployed to inject local anesthetic before removal. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
9. Provide appropriate post-procedure care.

TECHNIQUE IMAGES

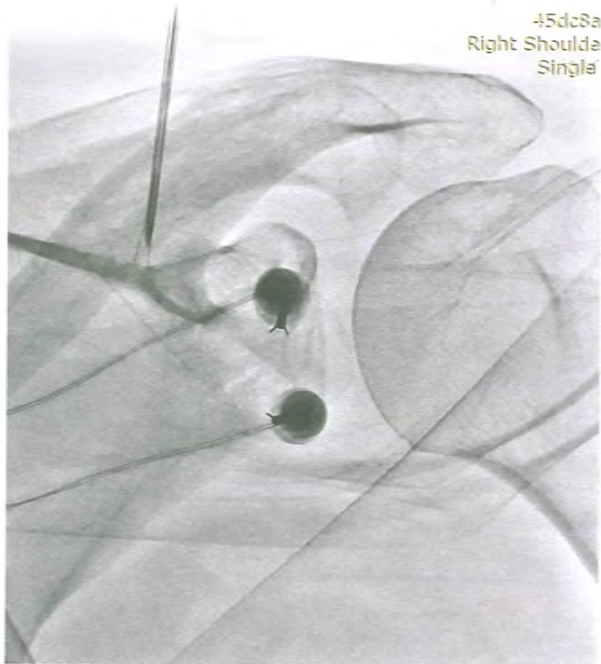


Proper visualization of the suprascapular notch is demonstrated. The cannula is inserted coaxially until bony contact is demonstrated and then advanced slightly off bone into the suprascapular notch to approximate the suprascapular nerve. Both thermal and nonthermal techniques are described for this anatomical target.

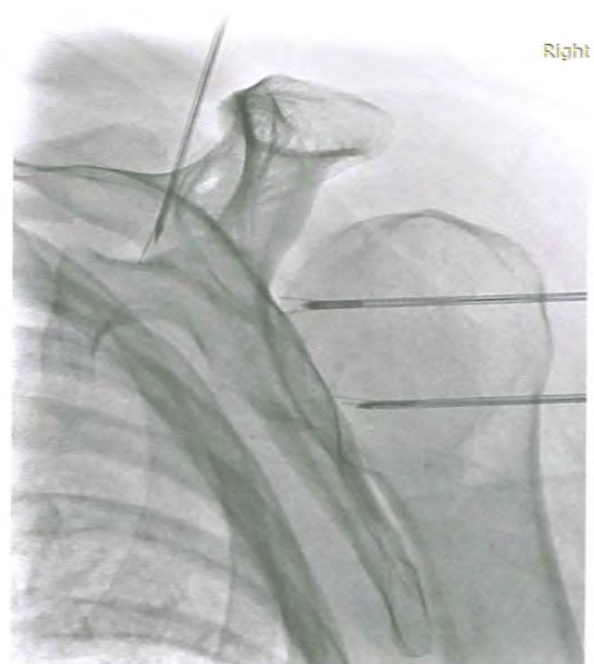


Bipolar pair positioned on the dorsum of the coracoid process, targeting branches of the suprascapular nerve, may be useful as a supplemental target if the acromioclavicular joint is a significant pain generator.

TECHNIQUE IMAGES (CONT'D)



Caudal decline view demonstrates bipolar pair alignment along the glenoid rim, with the superior cannula positioned immediately below the spinoglenoid notch to capture articular sensory branches of the suprascapular nerve. Typically, two cannulas (one bipolar pair) will adequately coagulate these branches. If the anodal (return) cannula temperature is below 63°C, spacing between cannulas can be decreased and additional lesions created along the length of the glenoid rim. Note: the cannula is positioned at the suprascapular notch for monopolar treatment.

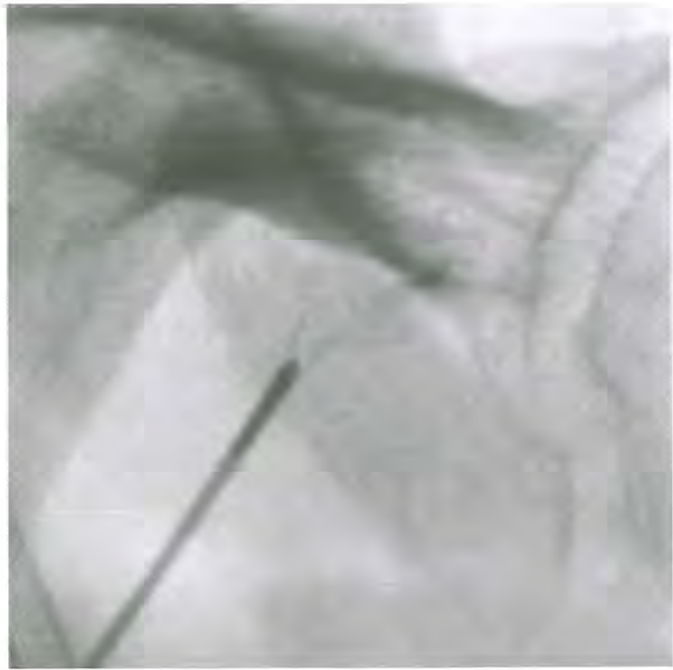
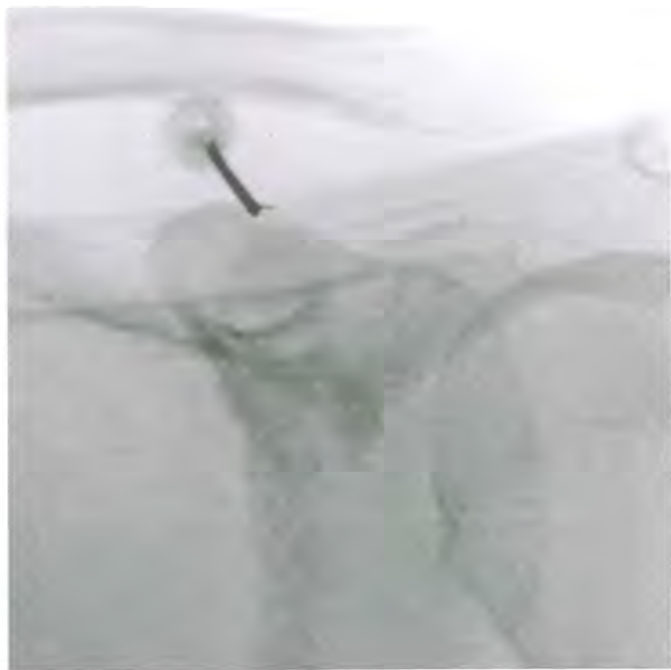


Deep contralateral oblique view demonstrates the scapula from its lateral projection, illustrating cannula positions for monopolar treatment at the suprascapular notch and bipolar treatment inferior to the scapular spine.

TECHNIQUE IMAGES (CONT'D)



Bipolar pair is positioned on the greater tubercle of the humerus superior to the surgical neck targeting axillary sensory branches. A second bipolar pair is seen along the glenoid rim inferior to the spinoglenoid notch. Intra-articular corticosteroid and local anesthetic administration is easily performed, as demonstrated by arthrogram.



Single cannula is advanced to contact the coracoid process from the ventral approach, placement is further confirmed with cranial tilt demonstrating tines at the lateral pectoral nerve target. This target is indicated for anterior shoulder pain syndromes and is not universally required in the more common posterior and lateral shoulder pain presentations.

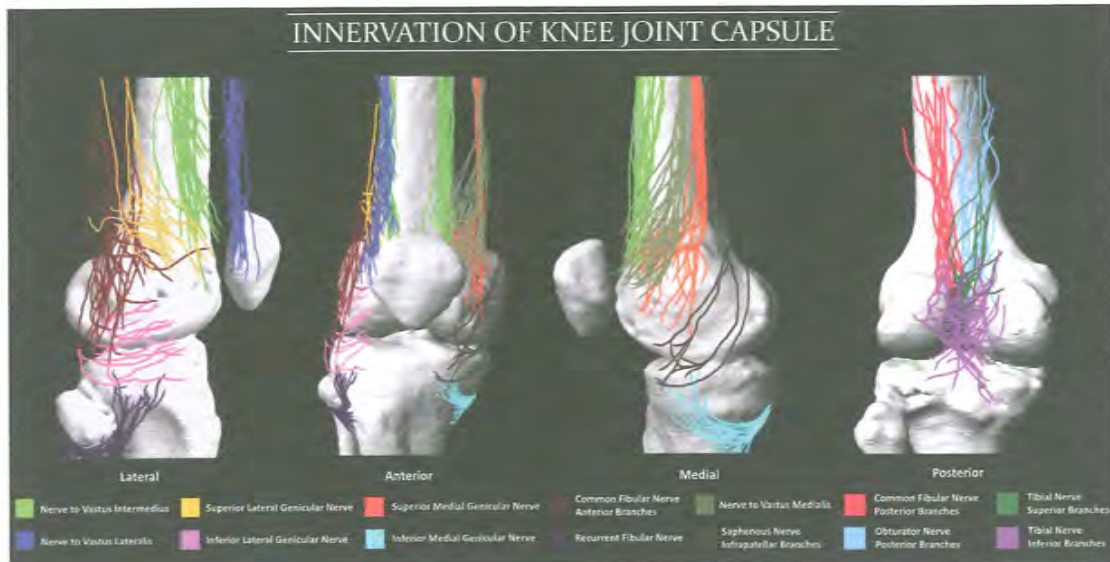
RECOMMENDED READING

- Aszmann OC. Innervation of the human shoulder joint and its implications for surgery. *Clin Orthop Relat Res*. 1996;(330):202-207.
- Bennett DL, Cronin AM, Palmer WE, Kattapuram SV, Huang AJ. Optimization and standardization of technique for fluoroscopically guided suprascapular nerve blocks. *AJR Am J Roentgenol*. 2014;202:576-584.
- Bickelhaupt B, Eckmann MS, Brennick C, Rahimi OB. Quantitative analysis of the distal, lateral, and posterior articular branches of the axillary nerve to the shoulder: implications for intervention. *Reg Anesth Pain Med*. 2019;rapm-2019-100560.
- Borbás P, Eid K, Ek ET, Feigl G. Innervation of the acromioclavicular joint by the suprascapular nerve. *Shoulder Elbow*. 2020;12:178-183.
- Burnham TR, Miller S, Cooper AN, et al. Shoulder terminal sensory articular nerve radiofrequency ablation for non-surgical refractory shoulder pain due to rotator cuff pathology and osteoarthritis: a technical note. *Pain Med*. 2024;pnae035.
- Ebraheim NA, Whitehead JL, Alla SR, et al. The suprascapular nerve and its articular branch to the acromioclavicular joint: an anatomic study. *J Shoulder Elbow Surg*. 2011;20:e13-e17.
- Eckmann MS, Bickelhaupt B, Fehl J, et al. Cadaveric study of the articular branches of the shoulder joint. *Reg Anesth Pain Med*. 2017;42:564-570.
- Eckmann MS, Johal J, Bickelhaupt B, et al. Terminal sensory articular nerve radiofrequency ablation for the treatment of chronic intractable shoulder pain: a novel technique and case series. *Pain Med*. 2020;21:868-871.
- Eckmann MS, McCormick ZL, Beal C, Julia J, Cheney CW, Nagpal AS. Putting our shoulder to the wheel: current understanding and gaps in nerve ablation for chronic shoulder pain. *Pain Med*. 2021;22(Suppl 1):S2-S8.
- Eckmann MS, Lai BK, Uribe MA 3rd, Patel S, Benfield JA. Thermal radiofrequency ablation of the articular branch of the lateral pectoral nerve: a case report and novel technique. *A A Pract*. 2019;13:415-419.
- Gardner E. The innervation of the shoulder joint. *Anat Rec*. 1948;102:1-18.
- Kennedy DJ, Mattie R, Nguyen Q, Hamilton S, Conrad B. Glenohumeral joint pain referral patterns: a descriptive study. *Pain Med*. 2015;16:1603-1609.
- Kumar P, Hoydonckx Y, Bhatia A. A review of current denervation techniques for chronic hip pain: anatomical and technical considerations. *Curr Pain Headache Rep*. 2019;23:38.
- Laumonerie P, Tibbo ME, Robert S, et al. Sensory innervation of the human shoulder joint: the three bridges to break. *J Shoulder Elbow Surg*. 2020;29:e499-e507.
- Plancher KD, Evely TB, Brite JE, Briggs KK, Petterson SC. Endoscopicarthroscopic decompression of the suprascapular nerve at the spinoglenoid notch: indications and surgical technique. *JSES Rev Rep Tech*. 2021;1:198-206.
- Pushparaj H, Hoydonckx Y, Mittal N, et al. A systematic review and meta-analysis of radiofrequency procedures on innervation to the shoulder joint for relieving chronic pain. *Eur J Pain*. 2021;25:986-1011.
- Simopoulos TT, Nagda J, Aner MM. Percutaneous radiofrequency lesioning of the suprascapular nerve for the management of chronic shoulder pain: a case series. *J Pain Res*. 2012;5:91-97.
- Tran J, Peng PW, Agur AM. Anatomical study of the innervation of glenohumeral and acromioclavicular joint capsules: implications for image-guided intervention. *Reg Anesth Pain Med*. 2019;rapm-2018-100152.
- Tran J, Peng P, Agur A, Mittal N. Diagnostic block and radiofrequency ablation of the acromial branches of the lateral pectoral and suprascapular nerves for shoulder pain: a 3D cadaveric study. *Reg Anesth Pain Med*. 2021;46:305-312.
- Tran J, Switzer-McIntyre S, Agur AM. Overview of innervation of shoulder and acromioclavicular joints. *Phys Med Rehabil Clin N Am*. 2021;32:667-674.

KNEE RADIOFREQUENCY NEUROTOMY

Reviewed by: **Zachary L. McCormick, MD, FAAPMR**

Vice Chair, Department of Physical Medicine & Rehabilitation
Chief, Spine and Musculoskeletal Medicine
University of Utah, Salt Lake City, UT, USA



Reprinted with permission from Peng Educational Series.

BACKGROUND

The prevalence of symptomatic knee pain, particularly in the aging population, is significant. Approximately 25% of adults over age 55 experience persistent knee pain. While corticosteroids and viscosupplements may be injected into the joint for short-term pain relief, there is limited evidence for their value as a long-term strategy to mitigate disability or reduce analgesic consumption, particularly in patients with more advanced stages of knee osteoarthritis. Total knee arthroplasty (TKA) is a validated surgical intervention, but patients may experience knee pain impacting their lives long before they are ready to undergo TKA or before the surgeon offers it. Others have medical comorbidities that create a contraindication for this surgery. Even after technically successful TKA, estimates of the prevalence of ongoing chronic knee pain may be as high as 30%, with associated limitations in activity, requirement for analgesics, and further treatments.

The first reported surgical denervation of the knee joint was in 1914 by White and Sweet. They described an operative technique involving the excision of infrapatellar branches of the saphenous nerve to treat pain associated with an anterior knee pain syndrome. However, it was not until the publication of the study by Choi et al titled "Radiofrequency treatment relieves chronic knee osteoarthritis pain: a double-blind, randomized controlled trial," published in *Pain* in 2011, that interest in knee denervation returned to the interventional literature. Since the Choi publication, a robust body of medical evidence supporting radiofrequency ablation (RFA) for knee pain has emerged; however, the ideal selection of location and number of targets for RFA remains a subject of active research and debate. Since the Choi publication, additional targets have been proposed in order to more completely denervate the sensory afferents responsible for transmitting knee pain.

Petitioner's Exhibit 1051

Avanos v. Stratus

ANATOMIC OVERVIEW

The nerve supply to the knee joint capsule is derived from the obturator, sciatic, and femoral nerve branches. The genicular nerves are the articular sensory branches of these larger nerves responsible for providing sensation from the anterior knee. The superior lateral genicular nerve (SLGN), superior medial genicular nerve (SMGN), inferior medial genicular nerve (IMGN), and inferior lateral genicular nerve (ILGN) were the three RFA targets in the original Choi study; further cadaveric and clinical research supports targeting the recurrent fibular nerve (RFN), the infrapatellar branch of the saphenous nerve (IPBSN), and sensory innervation derived from the terminal articular branches of the common fibular nerve (TABCFN) and the terminal articular branches of the nerves supplying the vastus medialis (VM), vastus intermedius (VI), and vastus lateralis (VL).

Drawing upon our current knowledge of neuroanatomy and informed by the author's experience and practice, a technique is presented for placement of the NIMBUS® Multitined Expandable Electrode (MEE) to target the most relevant nociceptive anatomy while ensuring safety, effectiveness, and efficiency. This technique is designed to optimize outcomes by incorporating a synthesis of contemporary neuroanatomical understanding with the practical expertise of the authors.

CONSIDERATIONS

Consider the depth of tissue between skin and periosteum at the various intended sites of radiofrequency (RF) lesioning. Skin burn has been described, and risk mitigation strategies should be implemented (or a specific site avoided) depending on local soft tissue depth.

In post-TKA patients, rule out structural or other addressable etiologies of chronic knee pain, such as prosthetic infection, loosening, or periprosthetic fracture, among others.

POSITIONING



The patient is positioned supine with a roll under the target knee to achieve 20 degrees of flexion, with the contralateral knee extended in a neutral position. This minimizes the requirement for the cephalocaudal tilt of the C-arm while allowing for unobstructed lateral imaging.



TECHNIQUE #1

ESTABLISHING TRUE ANTEROPOSTERIOR (AP) VIEW

ROTATIONAL ADJUSTMENT

- Femoral condyles symmetrically bracket the intercondylar fossa, which should be seen as a "U" when viewed with correct rotation (i.e., "straight down the tunnel").
- Intercondylar eminence centered in the intercondylar fossa.
- Patella approximately centered over intercondylar fossa (some patient variation is expected).
- Space between the tibia and fibula is optimized, and the base of the tibiofibular joint is visible.

CEPHALOCAUDAL TILT

Medial and lateral tibial plateau flattened (crisp appearance) with slight caudal tilt.

ESTABLISHING TRUE LATERAL VIEW

ROTATIONAL ADJUSTMENT

- Femoral condyles are superimposed.
- Dorsal aspect of the patella is crisp.

YAW ADJUSTMENT (WIGWAG)

Tibial plateaus should be superimposed.

GENERAL NOTES

The tines on the NIMBUS MEE can be safely left in the deployed position as the device is being removed (but never when being advanced). In this fashion, anesthetic can be deposited along the track when removing the device.

RFA of the knee is frequently associated with more immediate post-procedure pain (in this author's experience).

All AP placements are performed using the initial AP setup described above.

TECHNIQUE #1 (CONT'D)

FIRST HALF PROCEDURE STEPS: SMGN, SLGN, IMGN, RFN

1. Identify the transition from femoral diaphysis to metaphysis on lateral and medial aspects of the femur:
 - This is the AP target for the SMGN and SLGN.
 - Anesthetize the skin and deep subcutaneous tissue slightly (5 mm) lateral to the lateral target and medial to the medial target.
2. Using a slightly off-beam approach, advance NIMBUS MEE from start positions to touch the ventral surface of femur:
 - Redirect the NIMBUS MEE away from the femur and advance until it begins to "slide" along bone on the medial and lateral aspect of femur.
 - Once NIMBUS devices are noted to be in contact with bone along the "sides" of the femur, stop advancing, as depth of insertion will be guided by lateral imaging.
3. Identify the transition from tibial diaphysis to metaphysis on the medial aspect of the tibia:
 - This is the target for the IMGN.
 - Anesthetize the skin and subcutaneous tissue 5 mm medial to the target.
 - Advance NIMBUS MEE to contact the tibia on its ventral surface.
 - Redirect device away from the tibia, and advance until it begins to "slide" along bone; then stop advancing, as depth of insertion will be guided by lateral imaging.
4. Identify the inferior aspect of the tibiofemoral joint:
 - This is a location for lesioning the RFN.
 - Adjust beam rotation as necessary until a sharp inverted "V" is identified.
 - Anesthetize skin slightly below the tibiofemoral articulation, and advance NIMBUS MEE in a coaxial fashion until contact with bone (typically lateral tibia) is noted.
5. Go to lateral view:
 - Advance femoral NIMBUS MEE to approximately 70% of the way toward dorsal margin of femur.
 - Deploy tines with white stripe directed toward bone.
 - Tip of tines should be documented approximately 75% of the way toward dorsal aspect of femur.
 - If the NIMBUS MEE devices are pushed back when tines deploy, then retract tines and advance device tip deep to the initial placement and pull back if required after tines are deployed.
6. Position tibial device:
 - Advance tibial NIMBUS device approximately 50% of the way toward dorsal aspect of tibia.
 - Deploy tines targeting the IMGN toward bone and tines targeting the recurrent fibular nerve facing cephalad.
7. Treatment Cycle 1:
 - Inject anesthetic, and perform lesion 80°C for 90 seconds still under lateral view.

TECHNIQUE #1 (CONT'D)

SECOND HALF PROCEDURE STEPS: DISTAL SENSORY AFFERENT BRANCHES OF THE VM/VI/VL, IPBSN, AND ADDITIONAL LESION OF RFN

1. Continue with lateral view:
 - Remove the NIMBUS MEE targeting the IMGN.
2. Perform additional lesion of the RFN below the medial tibial plateau:
 - Retract tines of the device positioned at tibiofibular joint, and withdraw to the ventral surface of tibia.
 - Advance cephalad using a very flat angle until active tip slides on bone to base of tibial plateau.
 - Evaluate tissue depth before performing a thermal lesion at this location.
 - If tissue depth insufficient, consider nonthermal RF (pulsed) or abandon site. (*Critical note: in many patients', skin and subcutaneous tissue at this site are minimal, and performing a thermal lesion will risk skin damage.*)
3. Address distal sensory afferent branches of VM/VI/VL:
 - Retract tines and withdraw the femoral device to ventral aspect of femur.
 - Drop angle of NIMBUS MEE device to nearly coronal, and slide along the ventral surface of femur.
 - Stop once device begins to slide on ventral femur for further adjustments under AP.
 - Return to AP view.
 - Advance the femoral device to approximately 1 cm medial to outer margin of femur (will be 4-6 cm cephalad to superior pole of patella).
4. Target IPBSN posterior to the medial femoral condyle:
 - Anesthetize skin at a point 5 mm lateral to medial joint line.
 - Advance NIMBUS MEE in a slightly medial and cephalic fashion to contact femur near the medial condyle.
 - Return to lateral view.
 - For suprapatellar device: deploy tines either away or toward femur, depending on whether active tip is contacting bone (deploy away from bone) or slightly off bone (deploy toward bone).
 - Adjust device posterior to the medial femoral condyle; adjust position to target the nerve posterior to the condyle as illustrated.
5. Treatment cycle 2:
 - Inject anesthetic, and perform lesion 80°C for 90 seconds still under lateral view (consider nonthermal only for the second RFN position if indicated by skin thickness).
 - Withdraw NIMBUS MEE with tines deployed to inject anesthetic on tissue track.

ADDITIONAL INFORMATION

Basis for targeting the IPBSN at the described location to the posterior femoral condyle illustrated in magnetic resonance imaging (MRI) series.

MRI VALIDATION

3T MRI of IPBSN at knee
Siemens MAGNETOM Vida Fit 3T MRI system
18-channel transmit/receive knee coil



7 cm above the medial femoral condyle (MFC) joint line, showing the SMGN, saphenous nerve main trunk, and IPBSN.

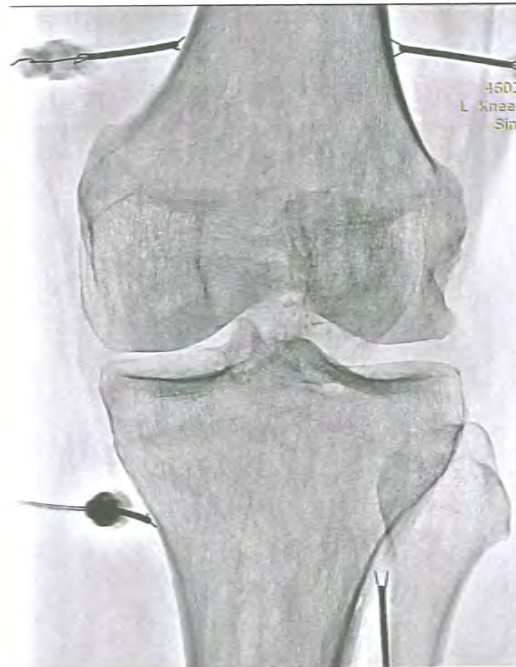


At the MFC joint line, showing the SMGN, saphenous nerve main trunk, and IPBSN.



On axial and coronal images, the IPBSN is reliably seen superficial to the medial collateral ligament at or just below the medial femoral epicondyle.

TECHNIQUE #1 IMAGES



AP view of cannula positioned to treat SMGN, SLGN, IMGN, and RFN at the proximal tibiofibular joint.



Lateral view demonstrating depth of placement to approximate SMGN, SLGN, IMGN, and RFN at the proximal tibiofibular joint.

TECHNIQUE #1 IMAGES (CONT'D)



AP view showing cannula originally at SMGN and SLGN targets, withdrawn to ventral femoral surface and repositioned to capture distal sensory branches of the femoral nerve divisions. A second cannula is placed medial and posterior to femoral condyle, targeting IPBSN. The cannula initially targeting RFN at proximal tibiofibular joint is repositioned to a second position near tibial plateau.



Lateral view showing cannula on ventral femoral surface (repositioned from SLGN and SMGN targets from first treatment cycle). Another cannula is positioned in groove posterior to MFC, targeting IPBSN. Third cannula is moved from proximal tibiofibular joint (initial RFN treatment site) to lateral tibial plateau. Ensure adequate subcutaneous tissue at lateral tibial plateau, or consider pulsed RF nonthermal treatment.

TECHNIQUE #2

ESTABLISHING TRUE AP VIEW

Patella centered over intercondylar eminence; Intercondylar eminence centered in the intercondylar fossa.

Medial and lateral femoral epicondyles are symmetrically represented.

There is space between the tibia and fibula, and the fibular head is viewed as distinct from the lateral tibial condyle and not substantially superimposed.

Tibial plateau is aligned/"crisp" when an AP view of the tibial epicondyles/shaft is desired. Notably, a true AP view of the femoral epicondyles/shaft involves relative cephalad tilt when the knee is in flexion.

SMGN, SLGN, NERVE TO VM (NVM), AND TABCFN

Anesthetize the skin 1 cm medial and 1 cm lateral to the femur at or slightly above the junction of the respective medial and lateral diaphyses (shaft) and metaphyses (epicondyles).

Advance NIMBUS MEE to touch bone on the respective anterior medial and lateral aspects of the junction of the femoral shaft and epicondyle.

Note: Use of track needles and a field block along the intended path of the NIMBUS devices or intra-articular injection into the joint may be considered an adjunctive technique for relative procedural analgesia. In this example, contrast is dispersed into a medial retrocondylar bursa, as seen on the lateral.

IMGN AND RFN

Anesthetize the skin 1 cm medial and 1 cm lateral to the tibial diaphysis (shaft) and metaphysis (epicondyle) junction of the respective medial and lateral diaphyses and metaphyses.

Advance NIMBUS to touch bone on the respective anterior medial and lateral aspects of the junction of the tibial shaft and epicondyles.

Note: Use of track needles and a field block along the intended path of the NIMBUS devices or intra-articular injection into the joint may be considered an adjunctive technique for relative procedural analgesia.

ESTABLISHING AN ACCURATE LATERAL VIEW

When establishing an accurate lateral view, ensure the following:

- Femoral condyles superimposed.
- Tibial plateau is close to "flat" and aligned.

Once you have an accurate lateral view, advance the SMGN/NVM and SLGN/TABCFN NIMBUS devices across the femur from anterior to posterior, and deploy tines with stripes toward the femur at the margin of the posterior cortex of the femur.

Advance the IMGN and RFN NIMBUS devices to approximately 80% of the tibial diameter, closest to the posterior cortex in the lateral view.

Once RF lesions are created at the above locations, withdraw the SMGN/NVM and SLGN/TABCFN NIMBUS devices to create a second lesion, consecutive but anterior to the first set in order to capture additional tissue territory given the variable locations of these nerves across individuals.

TECHNIQUE #2 (CONT'D)

OPTIONAL: NERVE TO VI (NVI), NERVE TO VL (NVL), AND IPBSN

Targeting of the NVI and NVL may be considered when there is a dominant component of pain localizable to the patellofemoral compartment.

Targeting of the IPBSN may be considered when there is pain in the inferomedial region of the knee that is not completely addressed by the IMGN or in the case of persistent post-arthroplasty pain in which neuralgia of the IPBSN is possible.

In the AP view, withdraw the NIMBUS devices from the femoral diaphysis/epicondyle positions, and reorient them to positions that approximately flank the quadriceps tendon, 4-6 cm superior to the superior pole of the patella. These device positions target the NVI and NVL, respectively.

In an AP view, place a NIMBUS MEE relatively parallel to the periosteum of the medial tibial epicondyle, at least 1 cm inferior to the joint line (to avoid violating the joint capsule) and along a cephalocaudal line approximately 4 cm medial to the inferior pole of the patella. This NIMBUS MEE will ultimately be sequentially repositioned to create a strip lesion capturing the IPBSN.

In the lateral view, the NVI NIMBUS tip should appear approximately 1 cm deep to the anterior cortex of the femoral shaft, while the NVL NIMBUS tip should appear at approximately 0.5 cm superficial to the anterior cortex of the femoral shaft. The IPBSN NIMBUS tip should appear deep to the anterior cortex of the tibia and at least 1 cm inferior to the joint line.

In a true AP of the tibia with the tibial plateau aligned, sequential lesions are created with the IPBSN NIMBUS MEE in order to create a "strip lesion" that captures the tissue territory of known variability of the IPBSN.

BIPOLAR TECHNIQUE FOR CAPTURING SMGN, SLGN, NVM, AND TABCFN

This bipolar technique may be considered for more comprehensive capture of the SMGN, SLGN, NVM, and TABCFN given the known variability of these nerves between individuals.

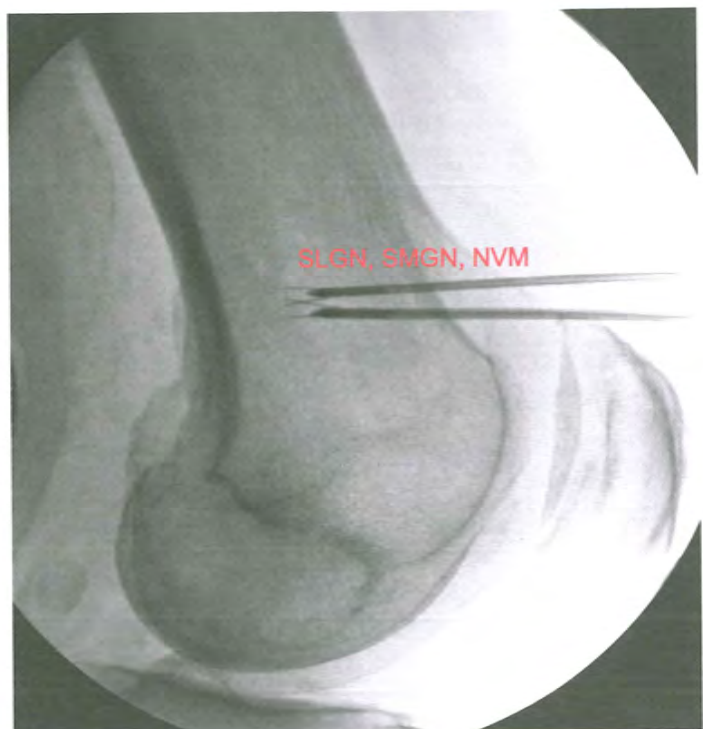
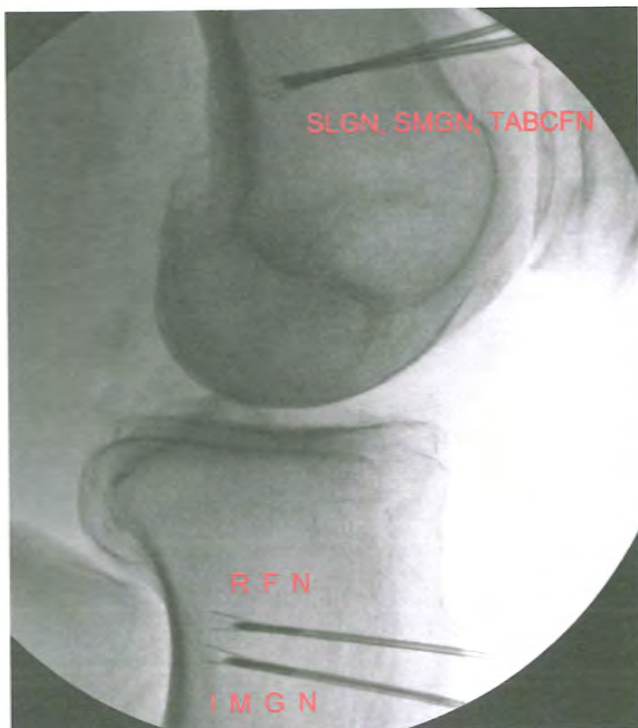
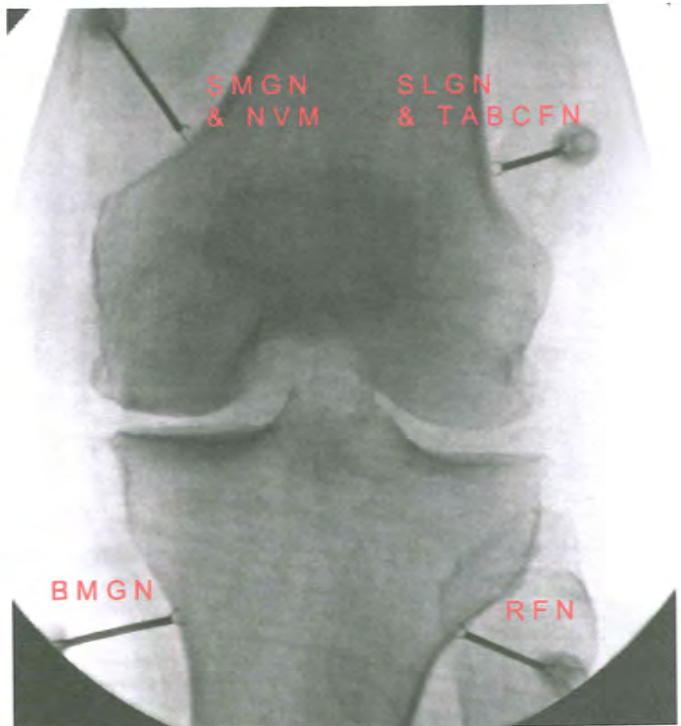
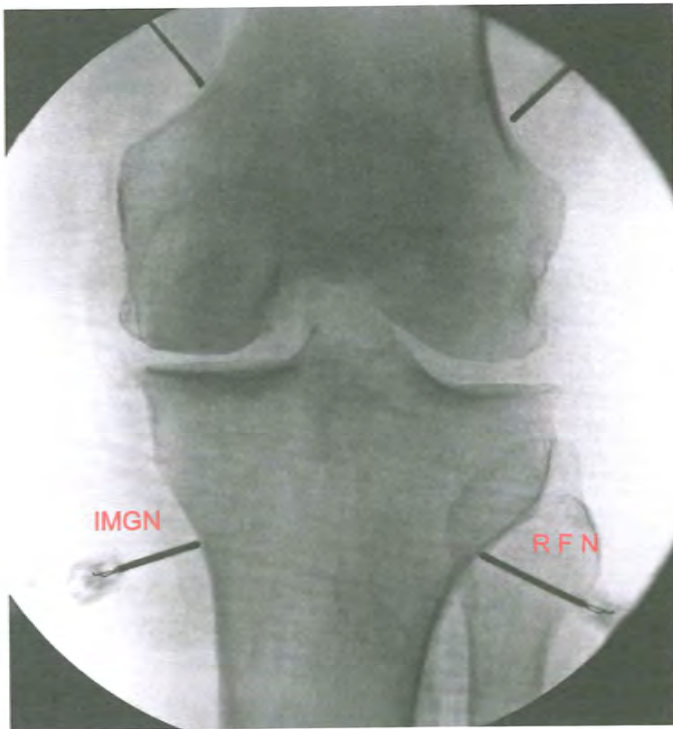
Use the same technique described above for monopolar lesioning of the SMGN, SLGN, NVM, and TABCFN, except introduce two NIMBUS MEE devices in parallel that straddle the junction of the respective medial and lateral diaphyses (shaft) and metaphyses (epicondyles).

Advance devices to touch bone on the respective anterior medial and lateral aspects of the junction of the femoral shaft and epicondyle.

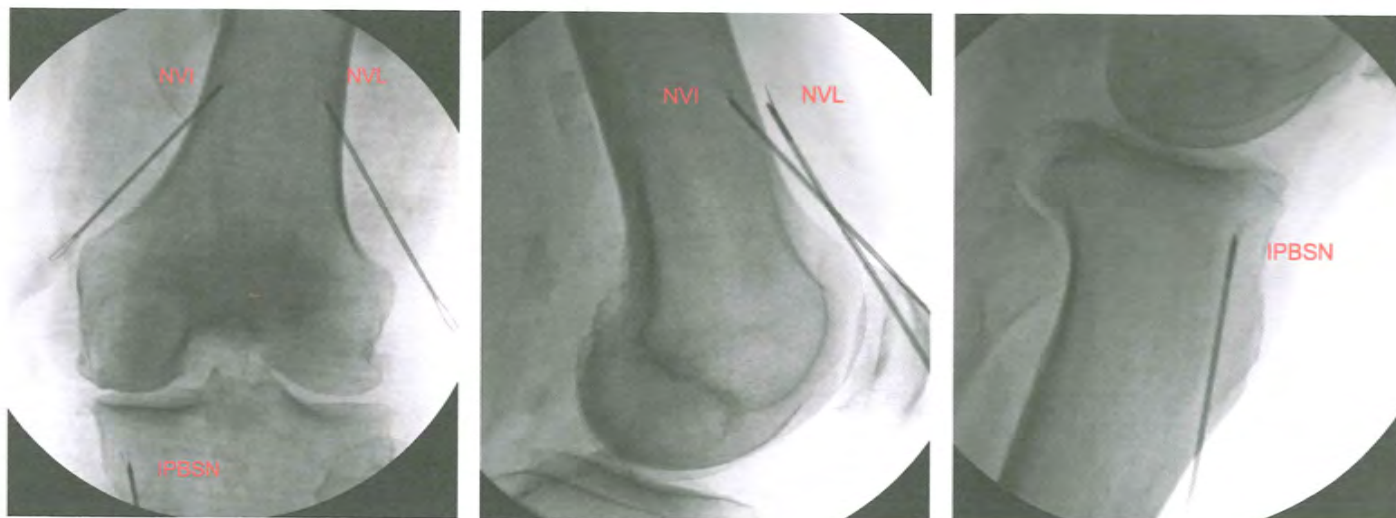
Similar to the monopolar technique, advance the SMGN/NVM and SLGN/TABCFN NIMBUS MEE devices across the femur from anterior to posterior, and deploy tines with stripes toward the femur at the margin of the posterior cortex of the femur.

Once RF lesions are created at the above locations, withdraw the SMGN/NVM and SLGN/TABCFN devices to create a second lesion, consecutive but anterior to the first set in order to capture additional tissue territory given the variable locations of these nerves across individuals.

TECHNIQUE #2 IMAGES



TECHNIQUE #2 IMAGES (CONT'D)



In the AP view, withdraw the NIMBUS devices from the femoral diaphysis/epicondyle positions, and reorient them to positions that approximately flank the quadriceps tendon, 4–6 cm superior to the superior pole of the patella. These device positions target the NVI and NVL, respectively.

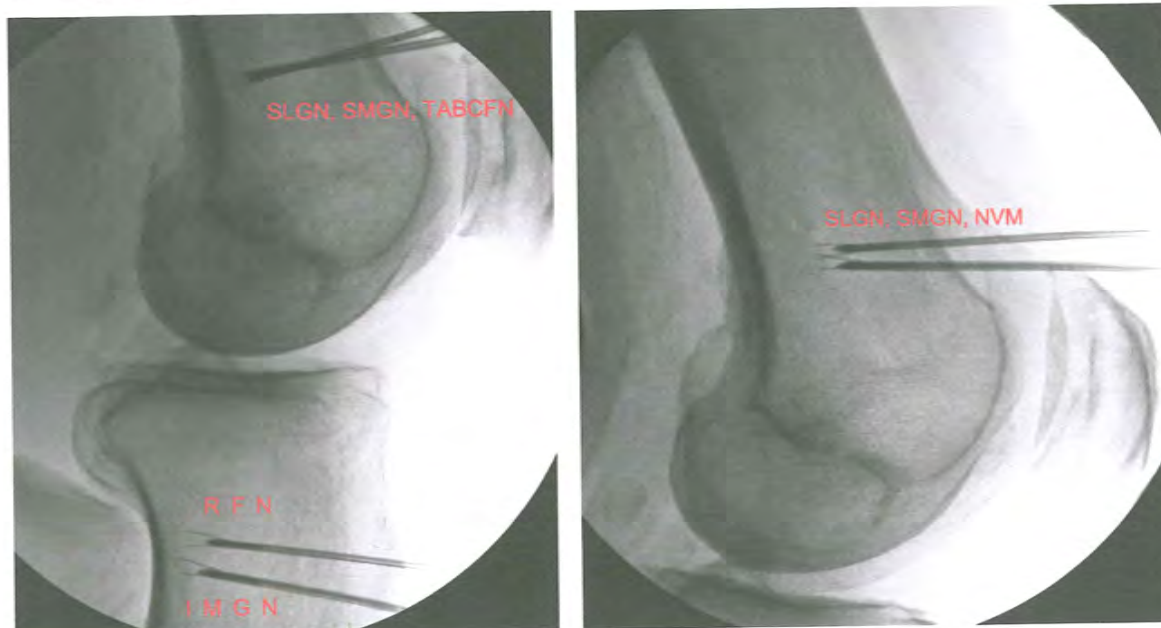
In an AP view, place a NIMBUS MEE relatively parallel to the periosteum of the medial tibial epicondyle, at least 1 cm inferior to the joint line (to avoid violating the joint capsule) and along a cephalocaudal line approximately 4 cm medial to the inferior pole of the patella. This NIMBUS MEE will ultimately be sequentially repositioned to create a strip lesion capturing the IPBSN.

In the lateral view, the NVI NIMBUS tip should appear approximately 1 cm deep to the anterior cortex of the femoral shaft, while the NVL NIMBUS tip should appear at approximately 0.5 cm superficial to the anterior cortex of the femoral shaft. The IPBSN NIMBUS tip should appear deep to the anterior cortex of the tibia and at least 1 cm inferior to the joint line.

TECHNIQUE #2 IMAGES (CONT'D)

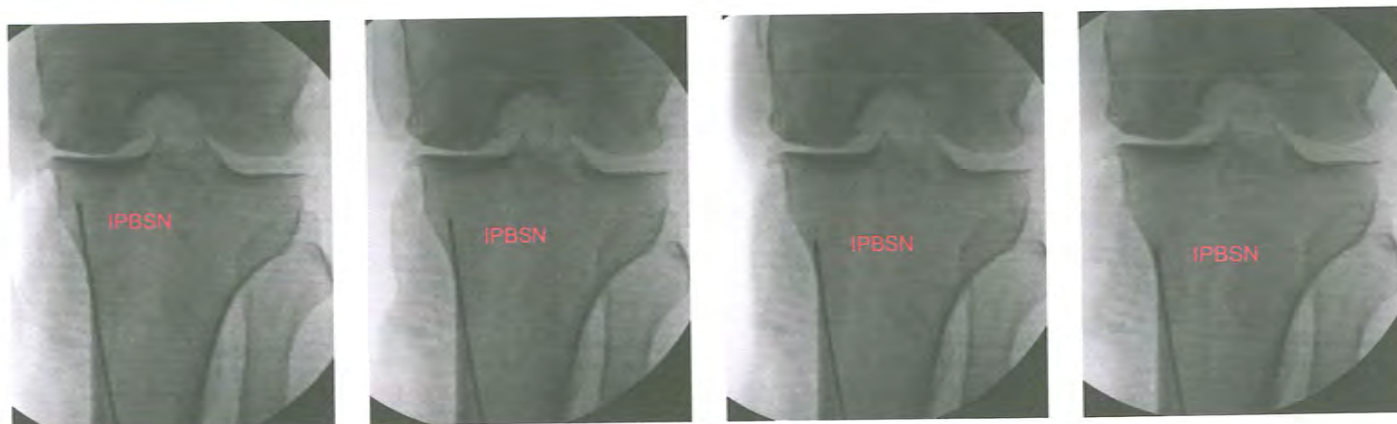
IMGN AND RFN

Advance NIMBUS to touch bone on the respective anterior medial and lateral aspects of the junction of the tibial shaft and epicondyles.



In this example, contrast is dispersed into a medial retrocondylar bursa, as seen on the lateral.

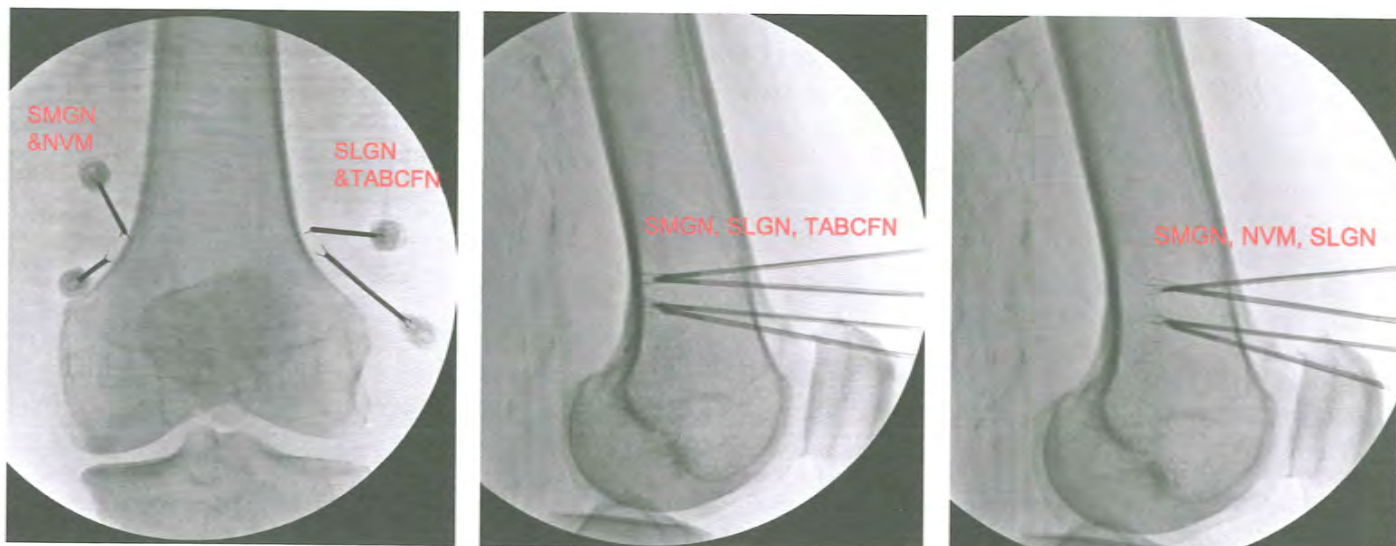
NVI, NVL, AND IPBSN



In a true AP of the tibia with the tibial plateau aligned, sequential lesions are created with the IPBSN NIMBUS MEE device in order to create a "strip lesion" that captures the tissue territory of known variability of the IPBSN.

TECHNIQUE #2 IMAGES (CONT'D)

BIPOLAR TECHNIQUE FOR CAPTURING THE SMGN, SLGN, NVM, AND TABCFN



Use the same technique described above for monopolar lesioning of the SMGN, SLGN, NVM, and TABCFN, except introduce two NIMBUS devices in parallel that straddle the junction of the respective medial and lateral diaphyses (shaft) and metaphyses (epicondyles).

Advance NIMBUS to touch bone on the respective anterior medial and lateral aspects of the junction of the femoral shaft and epicondyle.

Similar to the monopolar technique, advance the SMGN/NVM and SLGN/TABCFN NIMBUS devices across the femur from anterior to posterior, and deploy tines with stripes toward the femur at the margin of the posterior cortex of the femur.

RECOMMENDED READING

- Choi WJ, Hwang SJ, Song JG, et al. Radiofrequency treatment relieves chronic knee osteoarthritis pain: a double-blind, randomized controlled trial. *Pain*. 2011;152:481-487.
- Conger A, Gililland J, Anderson L, Pelt CE, Peters C, McCormick ZL. Genicular nerve radiofrequency ablation for painful knee osteoarthritis: current evidence and future directions. *Pain Med*. 2021;22(Suppl 1):S20-S23.
- Cheppalli N, Bhandarkar AW, Sambandham S, Oloyede SF. Safety and efficacy of genicular nerve radiofrequency ablation for management of painful total knee replacement: a systematic review. *Cureus*. 2021;13:e19489.
- Forero M, Olejnik LJ, Stager SC. Six-target radiofrequency ablation of the genicular nerve for the treatment of chronic knee pain. *Reg Anesth Pain Med*. 2023:rapm-2023-104643.
- Kapural L, Minerali A, Sanders M, Matea M, Dua S. Cooled radiofrequency ablation provides prolonged pain relief compared to traditional radiofrequency ablation: a real-world, large retrospective clinical comparison from a single practice. *J Pain Res*. 2022;15:2577-2586.
- Liu J, Wang T, Zhu ZH. Efficacy and safety of radiofrequency treatment for improving knee pain and function in knee osteoarthritis: a meta-analysis of randomized controlled trials. *J Orthop Surg Res*. 2022;17:21.
- Lyman J, Khalouf F, Zora K, et al. Cooled radiofrequency ablation of genicular nerves provides 24-month durability in the management of osteoarthritic knee pain: outcomes from a prospective, multicenter, randomized trial. *Pain Pract*. 2022;22:571-581.
- Ng TK, Lam KH, Allam AE. Motor-sparing neural ablation with modified techniques for knee pain: case series on knee osteoarthritis and updated review of the underlying anatomy and available techniques. *Biomed Res Int*. 2022;2022:2685898.
- Tran J, Peng P, Agur A. Evaluation of nerve capture using classical landmarks for genicular nerve radiofrequency ablation: 3D cadaveric study. *Reg Anesth Pain Med*. 2020;45:898-906.
- Tran J, Peng PW, Chan VW, Agur AM. Overview of innervation of knee joint. *Phys Med Rehabil Clin N Am*. 2021;32:767-778.

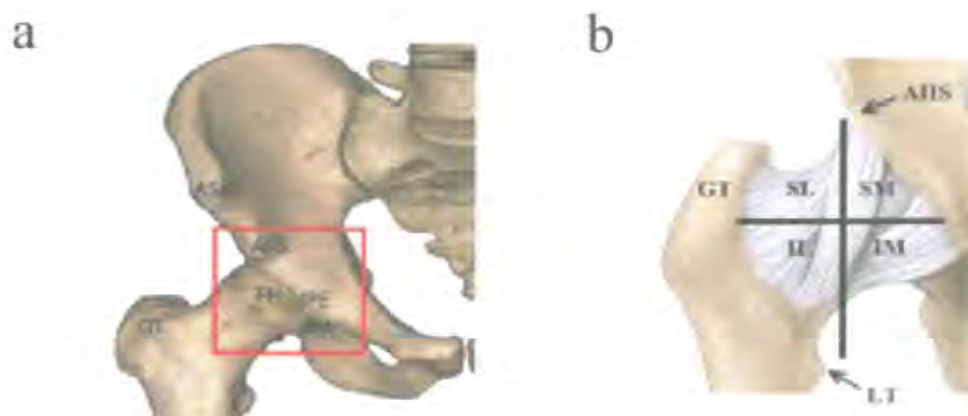
HIP RADIOFREQUENCY NEUROTOMY

Reviewed by: Jaspal (Ricky) Singh, MD

Director of Interventional Spine

Co-Director, Center for Comprehensive Spine Care

Weill Cornell Medicine, New York, NY, USA



Reprinted with permission from McCarthy J, et al. *Reg Anesth Pain Med*. 2022;48:220-230.
© 2022, BMJ Publishing Group Ltd and American Society of Regional Anesthesia and Pain Medicine

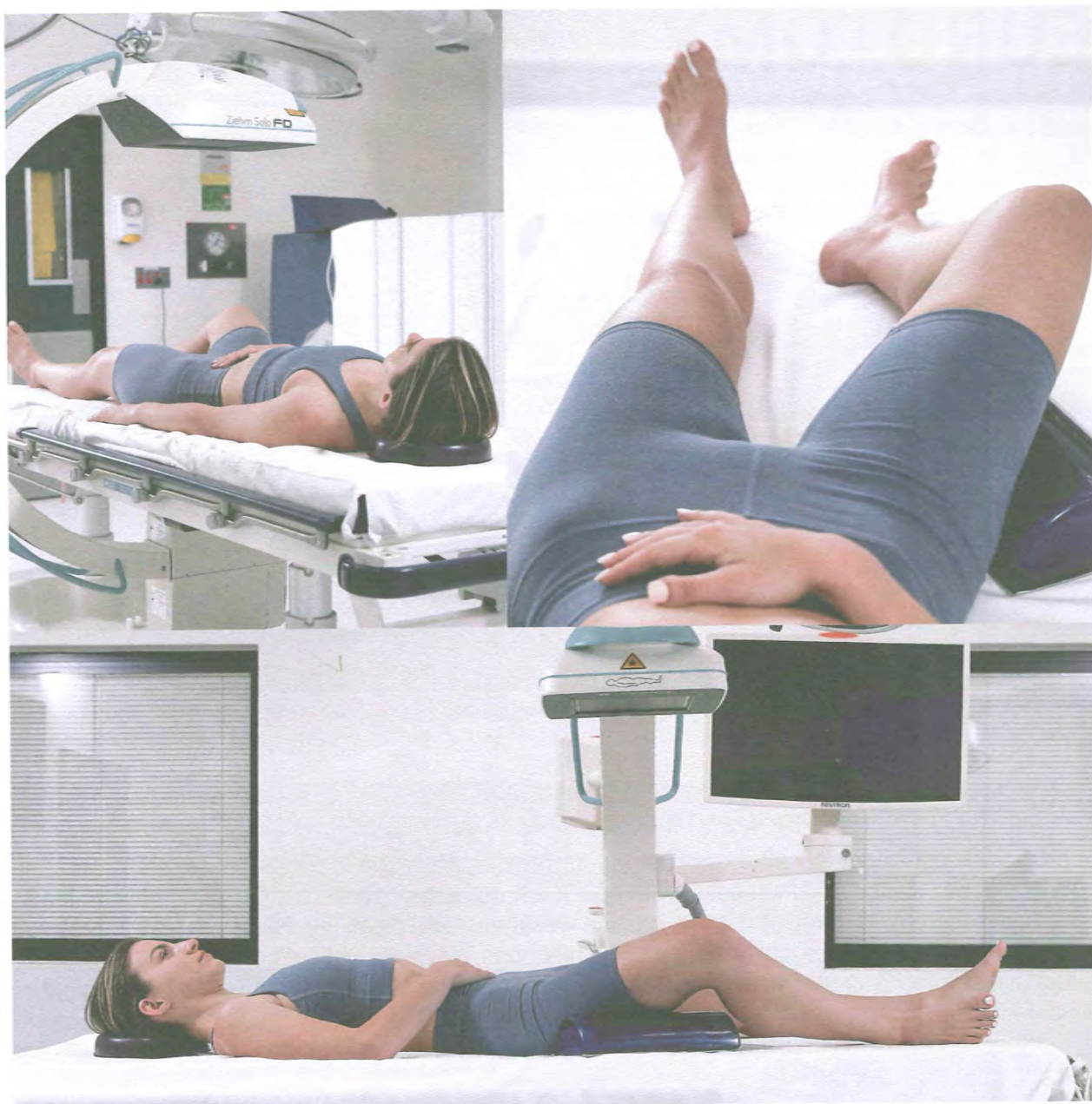
BACKGROUND

Chronic hip pain, most frequently attributed to osteoarthritis, is common in adults over age 45, affecting up to 10% of this population and increasing with age. If left untreated, persistent hip joint pain can lead to reduced activity, decreased range of motion, muscle weakness, and disability. First-line treatments include physical therapy, oral analgesics, and intra-articular injections. However, patients often choose between long-term opioid use or joint replacement surgery. While joint replacement can be curative for selected patients, the risks of failed surgery requiring revision and persistent post-arthroplasty pain are not trivial. Given this context, interest has emerged in using radiofrequency ablation (RFA) to provide a minimally invasive option for sustained relief from painful hip conditions.

The primary sensory innervation of the anterior hip joint is well defined by cadaveric study and accessible to straightforward RFA techniques. The lateral articular branches of the femoral nerve and obturator nerve subserve pain perceived in the anterior, medial, and lateral aspects of the hip and are the best presumptive targets for RFA. Fluoroscopy identifies two key landmarks for RFA: the incisura acetabuli, or "teardrop" at the inferior-medial base of the acetabulum, and the region inferior to the anterior inferior iliac spine (AIIIS). In proximity to both fluoroscopic landmarks, nerve bundles enter the hip joint capsule. Complete coverage of the target anatomy, including anatomic variation, requires a large-volume lesion RFA approach; it is the author's preference to employ a bipolar construct using the NIMBUS® Multitined Expandable Electrode (MEE) to effect complete afferent nociceptive interruption while minimizing or avoiding the requirement for cannula repositioning.

Two principal caveats apply to this technique; motor stimulation is required to prevent injury to motor nerves, and the femoral neurovascular bundle must be circumvented to avoid hematoma or femoral nerve injury. The approach presented is modified from a technique originally published by [Patterson et al. 2018](#)

POSITIONING

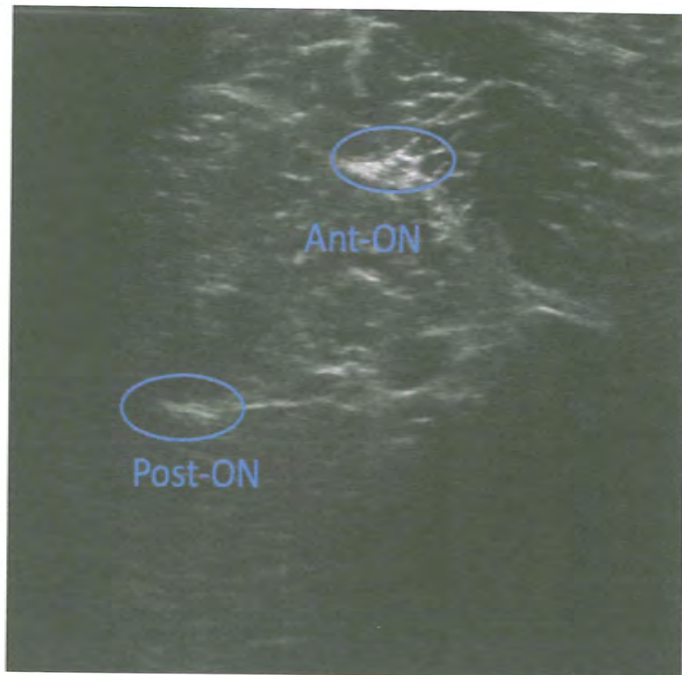


The patient is positioned supine with the ipsilateral extremity in a relaxed "frog leg" position with support placed underneath the ipsilateral knee for stability and comfort.

Obtain true anterior-posterior (AP) of the pelvis by rotating the X-ray beam to align the mid-sacrum with the lucency of the pubic symphysis, and then adjust the tilt to maximize the obturator foramen.

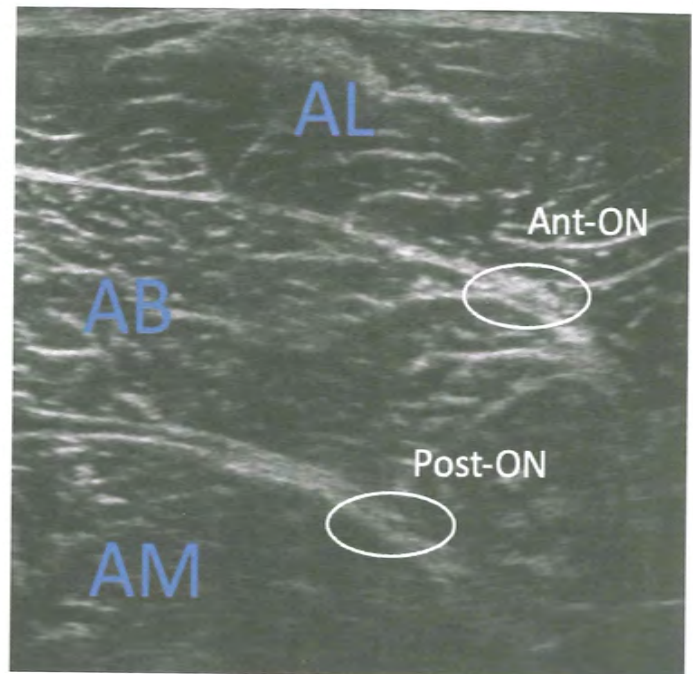
TECHNIQUE

USING ULTRASOUND



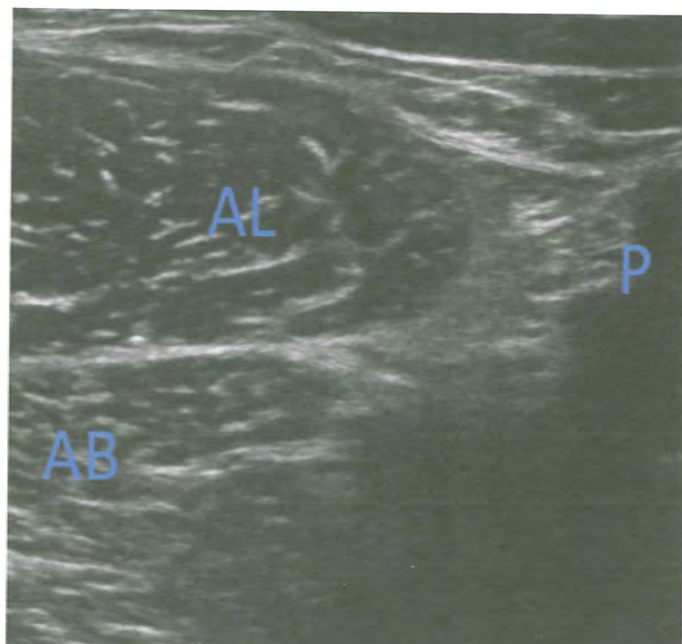
Courtesy of Jaspal (Ricky) Singh, MD.

Ant-ON=anterior branch of obturator nerve;
Post-ON=posterior branch of obturator nerve.



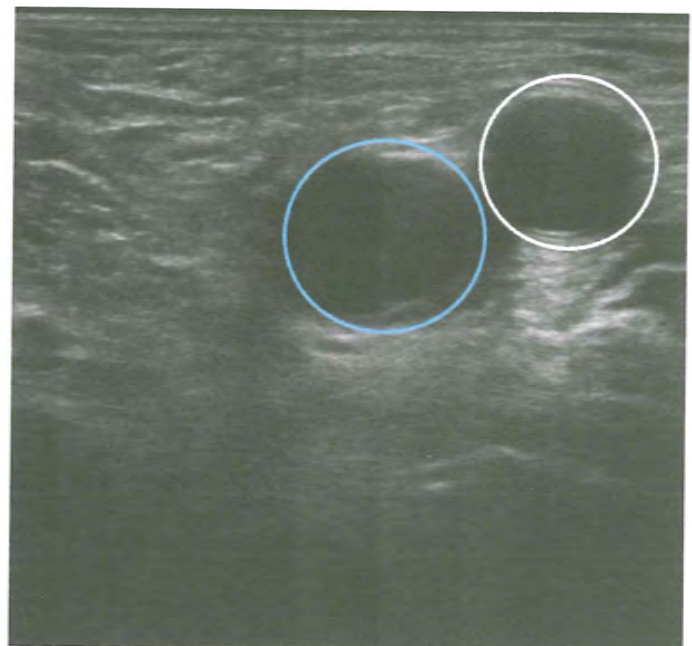
Courtesy of Jaspal (Ricky) Singh, MD.

AB=adductor brevis; AL=adductor longus; AM=adductor magnus; Ant-ON=anterior branch of obturator nerve;
Post-ON=posterior branch of obturator nerve.



Courtesy of Jaspal (Ricky) Singh, MD.

AB=adductor brevis; AL=adductor longus; P=pectineus.



Courtesy of Jaspal (Ricky) Singh, MD.

Blue=femoral vein; white=femoral artery.

Petitioner's Exhibit 1051

Avanos v. Stratus

TECHNIQUE (CONT'D)

OBTURATOR ARTICULAR SENSORY BRANCHES

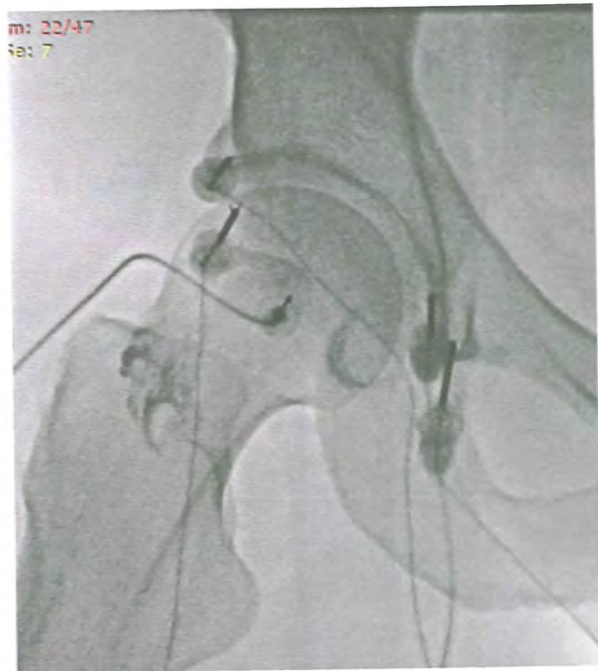
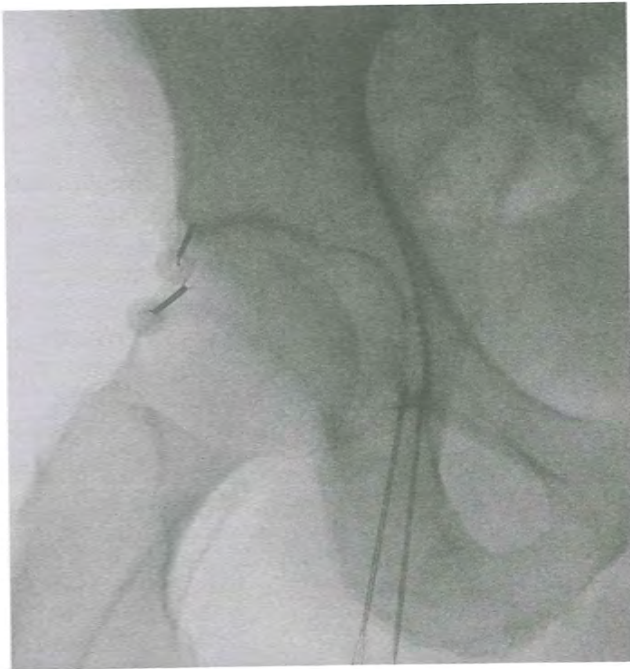
1. Prep the targeted area with an alcohol-based disinfectant solution, and drape it in a sterile manner. Once initial AP is obtained, adjust rotation and tilt ± 10 degrees to sharply visualize the incisura acetabuli teardrop structure (inferior-medial acetabular rim).
2. Identify the femoral artery by palpable pulsation if easily appreciated or confirm location with ultrasound. Mark skin longitudinally along the course of the femoral artery.
3. Identify and anesthetize the skin entry point with starting position 2 cm medial to the femoral artery and 4 cm inferior to incisura acetabuli. The combination of external hip rotation and NIMBUS MEE trajectory navigates the device in a plane inferior and lateral to the femoral neurovascular structures.
4. Advance the first NIMBUS MEE in an off-beam approach to target the teardrop structure on the most inferior medial edge. The angle of entry at the skin is dependent on habitus but typically less than 45 degrees. If the distal tip of the NIMBUS is projected by fluoroscopy to be over the teardrop and the bone has not been touched, then steepen the angle to touch the bone. In difficult anatomy, a 25-gauge needle can be placed directly onto the teardrop using a down-the-beam approach to serve as a guide for the NIMBUS device using 45-degree contra-oblique fluoroscopic imaging.
5. Once the initial NIMBUS has been placed, pass a second NIMBUS adjacent and parallel to the first and contact the most inferior lateral edge of the teardrop.
6. These NIMBUS devices represent the bipolar pair positioned to denervate the bulk of lateral obturator articular branches.
7. Deploy tines: deploy tines by rotating the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and full deployment of tines. Tines are deployed at this point.
8. Motor stimulation: use a 2-Hz frequency at <1.5 volts and reposition the NIMBUS laterally if fasciculation of medial thigh musculature present.
9. With tines fully deployed, inject long-acting local anesthetic if desired (allow time for effect).
10. Perform bipolar coagulation cycle. Lesion: perform one single-cycle bipolar lesion. Recommendation: 85°C for 150 seconds for bipolar with 30-second ramp time.
11. Following the final lesion, withdraw the NIMBUS devices. If desired, the tines can remain deployed to inject local anesthetic before removal. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
12. Provide appropriate post-procedure care.

TECHNIQUE (CONT'D)

FEMORAL ARTICULAR SENSORY BRANCHES

1. Under AP imaging, as above, identify the AIIS and confirm with 30-degree contralateral oblique fluoroscopic image if required.
2. Place the first NIMBUS down-the-beam to a position on bone inferior to the AIIS above the apparent joint lucency.
3. Place the second NIMBUS onto superolateral femur lateral to acetabular ridge 10–15 mm inferior to the first NIMBUS.
4. Confirm placement with 30 degrees contra-oblique fluoroscopic projection demonstrating placement inferior to AIIS.
5. These NIMBUS devices represent the bipolar pair positioned to denervate the bulk of lateral obturator articular branches.
6. Deploy tines: deploy tines with white stripes facing, by rotating the helical spin collar clockwise until fully advanced. A distinct tactile click confirms full engagement and full deployment of tines. Tines are deployed at this point.
7. Motor stimulation: use a 2-Hz frequency at <1.5 volts and reposition the NIMBUS laterally if fasciculation of medial thigh musculature present.
8. With tines fully deployed, inject long-acting local anesthetic if desired (allow time for effect).
9. Lesion: perform one single-cycle bipolar lesion. Recommendation: 85°C for 150 seconds for bipolar with 30-second ramp time.
10. Following the final lesion, withdraw the NIMBUS devices. If desired, the tines can remain deployed to inject local anesthetic before removal. Apply pressure to achieve adequate hemostasis, and then apply a self-adhesive dressing over the puncture site.
11. Provide appropriate post-procedure care.

TECHNIQUE IMAGES



Following ultrasound localization of the femoral neurovascular complex, cannulas are directed from a medial to lateral trajectory to pass medial and inferior to the femoral neurovascular structures onto the incisura to create a bipolar lesion of the obturator articular branches. This placement is sufficient to account for anatomic variability and produce an adequate area of coagulation for durable results. Cannulas are also placed over the superolateral aspect of the femoral head, inferior to the anterior inferior iliac spine, to coagulate the sensory articular branches of the femoral nerve subserving capsular innervation. Intra-articular injection of anesthetic and corticosteroid can be easily accomplished for periprocedural analgesia, as demonstrated in the image showing contrast washout.

TECHNIQUE IMAGES (CONT'D)

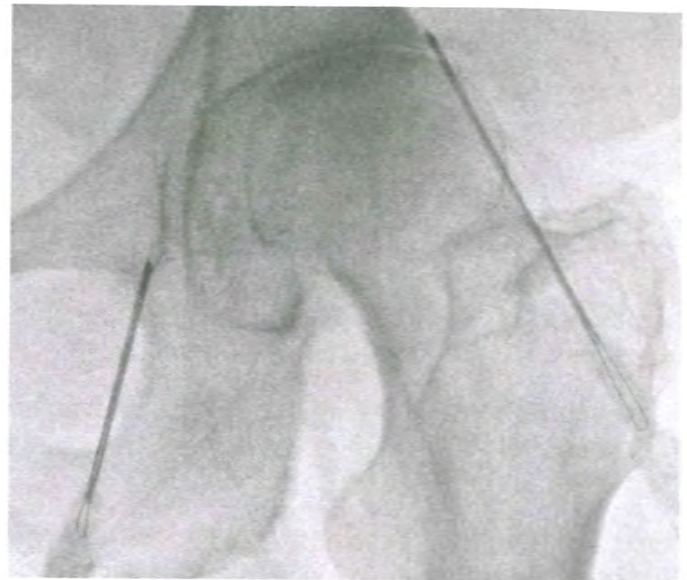
ADDITIONAL VIEWS



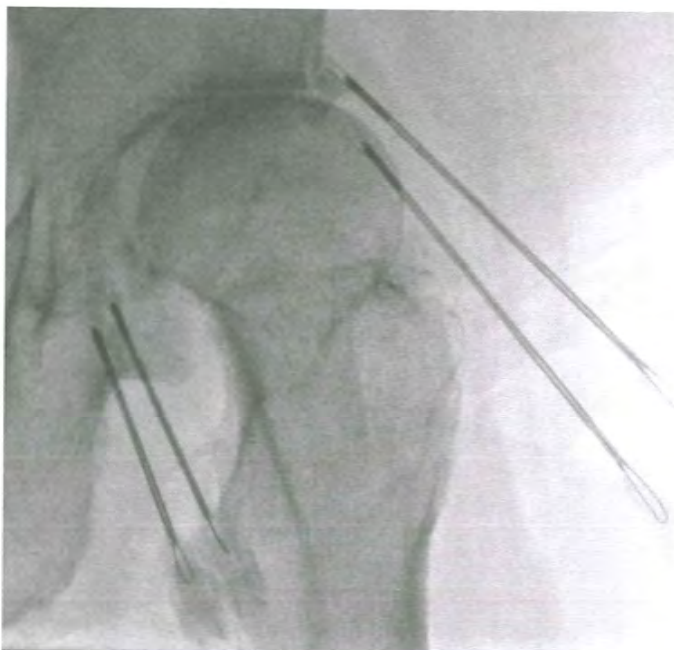
AP view with pubic symphysis approximately over mid-sacrum.

Obturator foramen open "circle" navigation from inferior and medial to femoral neurovascular structures.

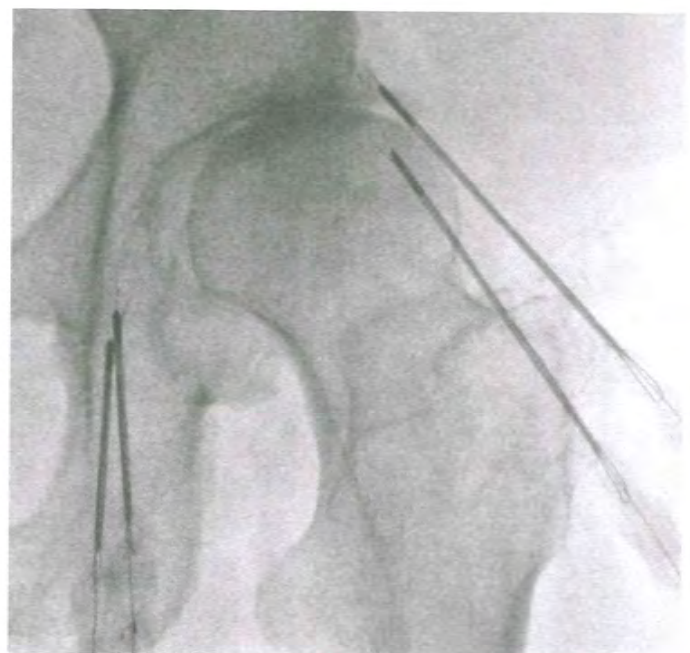
NIMBUS touching inferior margin of incisura acetabuli "teardrop."



Second NIMBUS passed to superior-lateral edge of acetabulum inferior to AIIS.



Place second of each bipolar pair spaced 10–15 mm apart covering the incisura acetabuli and superior-medial aspect of apparent femoral head inferior to AIIS.



Slight rotation confirming NIMBUS position with tines deployed.

RECOMMENDED READING

Beswick AD, Wylde V, Gooberman-Hill R, Blom A, Dieppe P. What proportion of patients report long-term pain after total hip or knee replacement for osteoarthritis? A systematic review of prospective studies in unselected patients. *BMJ Open*. 2012;2:e000435.

Bhatia A, Hoydonckx Y, Peng P, Cohen SP. Radiofrequency procedures to relieve chronic hip pain: an evidence-based narrative review. *Reg Anesth Pain Med*. 2018;43:72-83.

Cheney CW, Ahmadian A, Brennick C, et al. Radiofrequency ablation for chronic hip pain: a comprehensive, narrative review. *Pain Med*. 2021;22(Suppl 1):S14-S19.

Kapural L, Jolly S, Mantoan J, Badhey H, Ptacek T. Cooled radiofrequency neurotomy of the articular sensory branches of the obturator and femoral nerves – combined approach using fluoroscopy and ultrasound guidance: technical report, and observational study on safety and efficacy. *Pain Physician*. 2018;21:279-284.

Kapural L, Naber J, Neal K, Burchell M. Cooled radiofrequency ablation of the articular sensory branches of the obturator and femoral nerves using fluoroscopy and ultrasound guidance: a large retrospective study. *Pain Physician*. 2021;24:E611-E617.

Short AJ, Barnett JJ, Gofeld M, et al. Anatomic study of innervation of the anterior hip capsule: implication for image-guided intervention. *Reg Anesth Pain Med*. 2018;43:186-192.

Tavernier, L. Surgical treatment of degenerative arthritis of the hip; articular denervation. *Rheumatism*. 1948;4:176-179.

van Dijk GM, Veenhof C, Spreeuwenberg P, et al. Prognosis of limitations in activities in osteoarthritis of the hip or knee: a 3-year cohort study. *Arch Phys Med Rehabil*. 2010;91:58-66.



Radiofrequency Ablation in Interventional Pain Management Using RF Multitined Expandable Electrode

Robert E. Wright, MD, DABPM, FIPP, FFPMANZCA, and Aaron K. Calodney, MD, DABA, FASA, FIPP, ABIPP, bring over 30 years in the interventional pain field to this book. This is a step-by-step manual with background and diagnostic, patient positioning, and procedure steps for all of the most common RFA procedures: cervical, thoracic, lumbar, sacroiliac joint, shoulder, genicular, and hip. Each chapter has been reviewed by experts in the field and includes an in-depth list of reading materials on diagnosis and treatment of the particular modality.

"This is the textbook that I had wished to have when starting my journey in mastering radiofrequency neurotomy. Detailed, step-by-clear-step, clear pictures across multiple imaging modalities, pearls and pitfalls outlined and appropriately referenced. This textbook is not only very user-friendly but a joy to read. I hope it is continued with and updated for years to come."

— Marc Russo, MBBS, DA (UK), FANZCA, FFPMANZCA