Technical Report

Radiofrequency Cannula with Active Tip Radio-opaque Marker: Image Analysis for Facet, Gray Ramus, and Dorsal Root Ganglion Techniques

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Disclaimer: There was no external funding in the preparation of this manuscript. Materials used were supplied in an unrestricted fashion from Baylis Medical, Montreal, Canada.
Conflict of interest: None.

Manuscript received: 06/16/2008
Revised manuscript received: 07/30/2008
Accepted for publication: 08/13/2008

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Background: Radiofrequency neurolysis is a common technique used in the treatment of chronic pain, particularly facet (zygapophyseal joint) arthralgia. A needle-like cannula is insulated except for the exposed active tip, which is positioned as parallel and adjacent as possible to the targeted nerve branch. Via an inserted probe connected to a radiofrequency generator, energy flowing from the tip of the cannula creates a heat lesion in the 80 – 85 degree Celsius range mostly about the length of the exposed active tip and in proportion to the diameter of the probe. The common active tip lengths used for neurolysis are 5mm or 10mm. The cannulae are FDA approved. The manufacturer advises physicians not to bend or otherwise modify a cannula prior to use. The cannulae are available straight or bent, sharp and blunt.

The technique is guided under C-arm fluoroscopy. X-rays passing through the patient demonstrate in 2 dimensions the projected relative radio-opaque bony landmarks and the metallic cannula. Most currently available cannulae are uniform in their radio-opacity from tip to hub. The physician must make an educated guess as to the portion of the cannula that will be making the lesion in relationship to the bony landmark.

Objective: A new radiofrequency cannula with a radio-opaque marker (ROC) delineates the proximal end of the active tip. The cannula was used in a phantom model. Images were reproduced with explanation of the potential advantage of the new device.

Result: The marker on the new cannula was visible and did help delineate the active tip as well as its orientation. It was also helpful in making sequential lesions at the same nerve using a “tip to tail” repositioning technique.

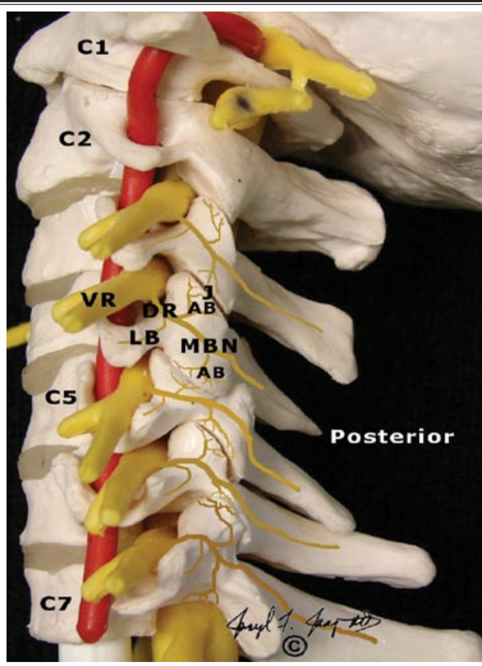
Conclusion: The ROC did represent an improvement over standard cannulae to optimize visualization of cannula and thus lesion placement using a phantom model. The applications described were only for conventional or “hot” RF.

Key words: Anesthesiology, neurology, neurosurgery, physical medicine and rehabilitation, radiology, radiofrequency, neurolysis, rhizotomy.

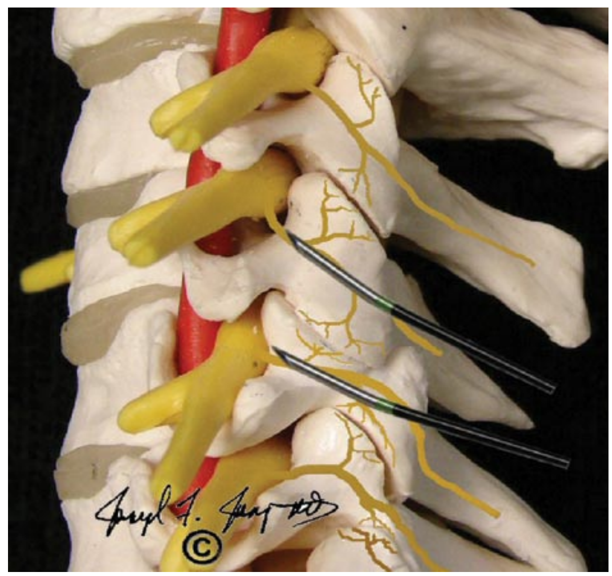
Pain Physician 2008; 11:6:863-875

The primary application of conventional radiofrequency (RF) today is to treat patients with chronic moderate to severe arthritis pain of the spine. It has been established that zygapophyseal joints, commonly referred to as facet joints, are a common etiology of lumbar pain (1,2). The objective is to induce neurolysis via thermal coagulation of the dorsal medial branch nerves innervating articulations of the facets (3). The diagnosis is usually made in patients with axial pain by subjecting the patient to at least 2 specific joint blocks due to a relatively high false-positive rate of 45% with single blocks. Medial branch blocks may be preferred over unpredictable leaking or difficult intraarticular joint blocks. At least one of the block sessions should use a highly specific block of the medial branch nerves (4-9). The age related prevalence of significant facet joint pain in one interventional pain practice was recently studied (10). Overall, it demonstrated a lumbar prevalence of 27% and cervical 39%.

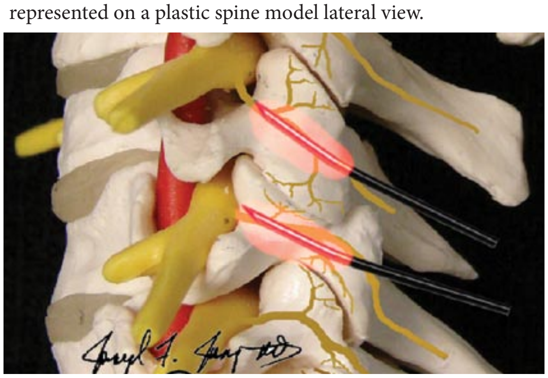
The medial branches of the dorsal rami innervating the facet joints originate from the segmental nerves as they exit intervertebral foramina, then course along dorso-lateral bones of the spine. In the neck the nerve branches course along the waist regions of the facet pillar or lateral mass (Figs. 1 & 2). In the lumbar region



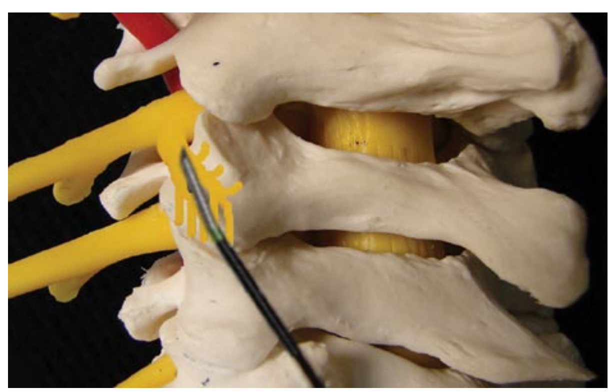
A. Cervical medial branch nerves of the dorsal rami represented on a plastic spine model lateral view.



B. Placement of cannulae for hot RF of medical branch nerves.

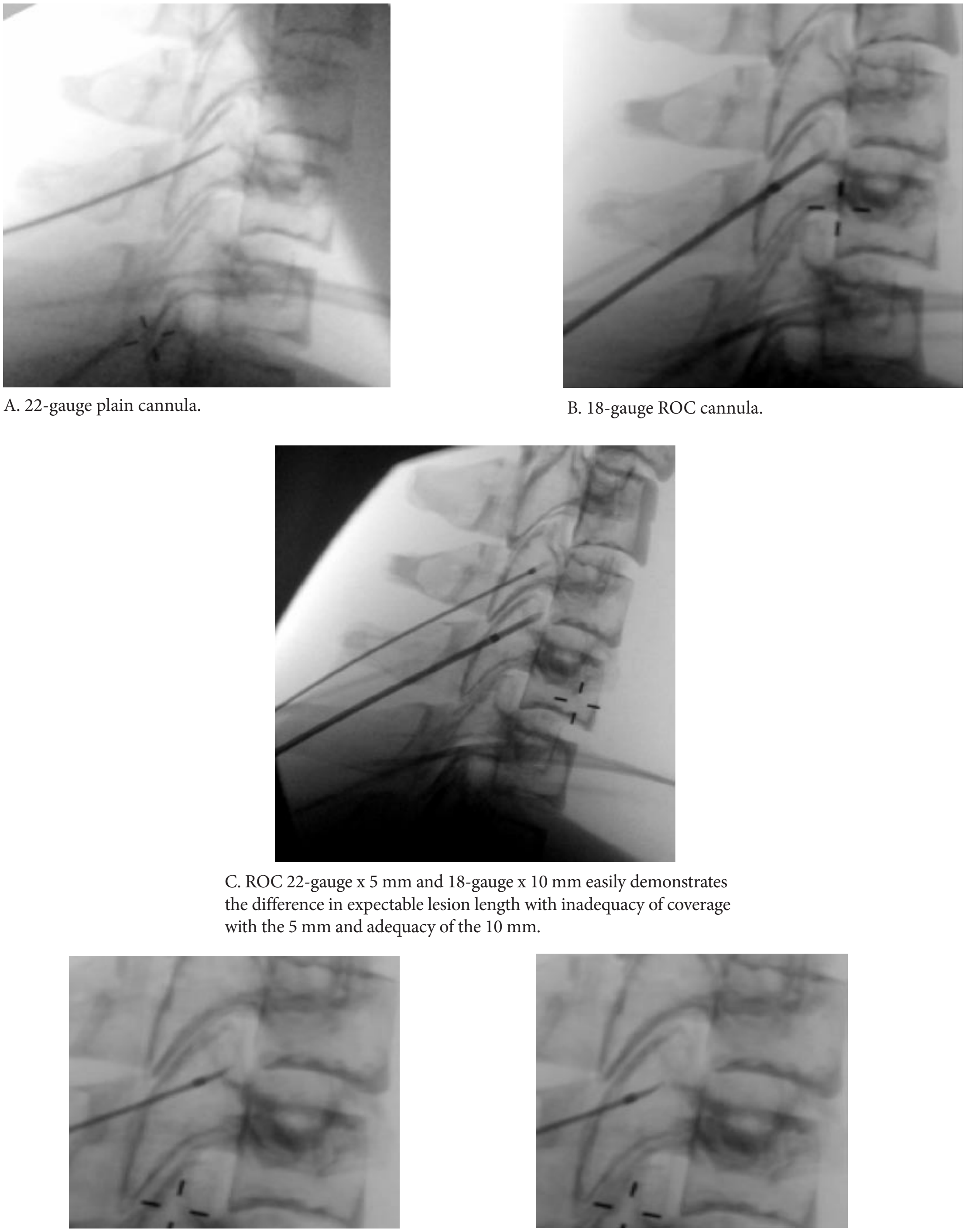


C. Expected heat lesion.



D. Oblique view of spine model with cannula within the waist.

Fig. 1. *Cervical medial branch nerves.*



A. 22-gauge plain cannula.

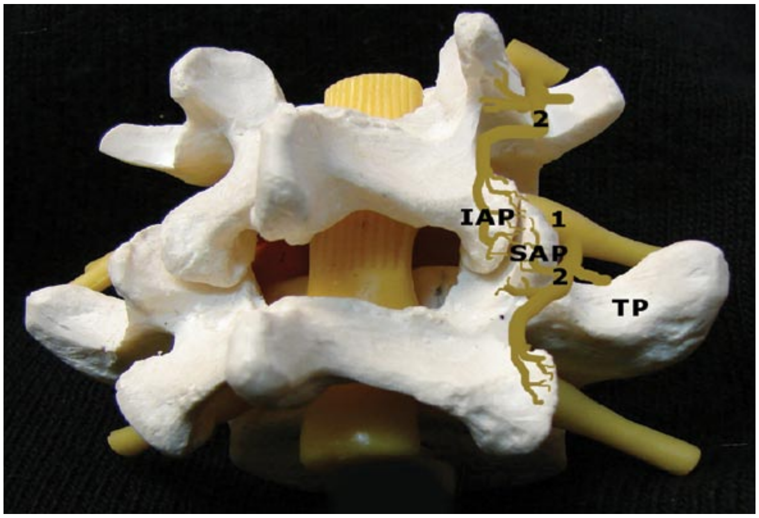
B. 18-gauge ROC cannula.

C. ROC 22-gauge x 5 mm and 18-gauge x 10 mm easily demonstrates the difference in expectable lesion length with inadequacy of coverage with the 5 mm and adequacy of the 10 mm.

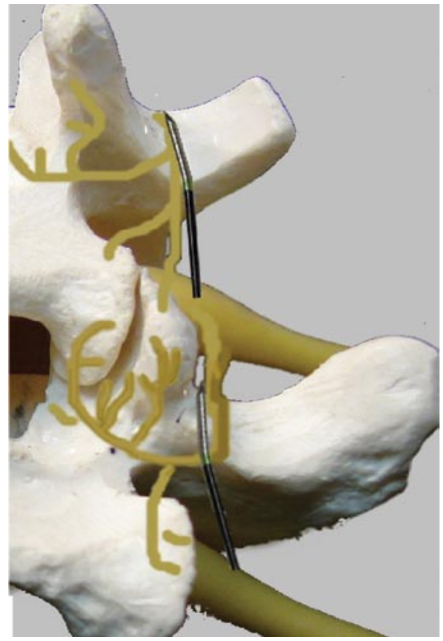
D, E. Tip to tail pull back. D. The first lesion is made deep toward the root of the medial branch nerve. The ROC marker position is noted and the tip of the cannula pulled back to that point (E.) to create a longer lesion without gaps.

Fig. 2. *X-ray of cervical medial branch neurolysis.*

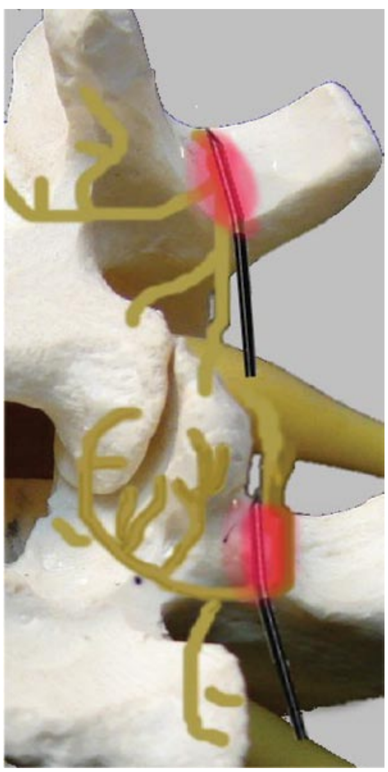
the nerves course through the valley-like junction between the superior articular process and transverse process (Fig. 3–5). The thoracic facet nerve course is a bit less predictable relative to bone and pierces the



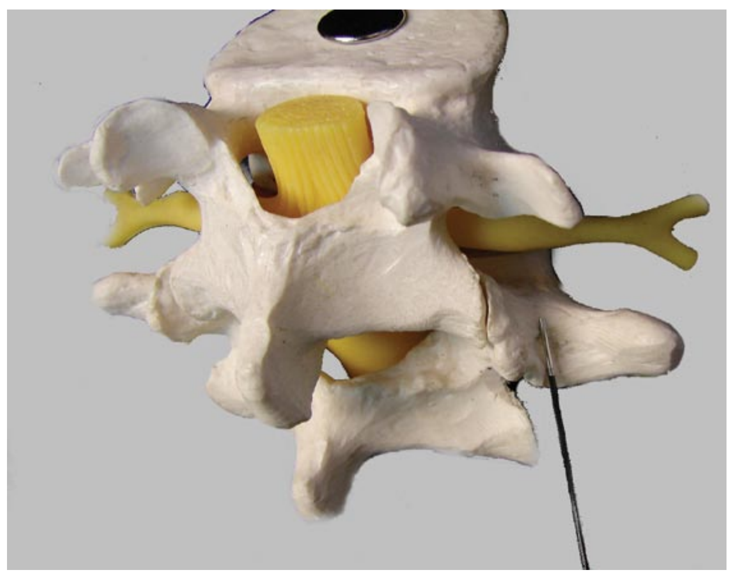
A. Lumbar medial branch nerve representation on a plastic spine model with some rotation and caudal to craniad obliquities. SAP = superior articular process; IAP-inferior articular process; TP = transverse process; 1 = emerging segmental nerve; 2 = medial branch B with RF cannula.



B. With RF cannula.

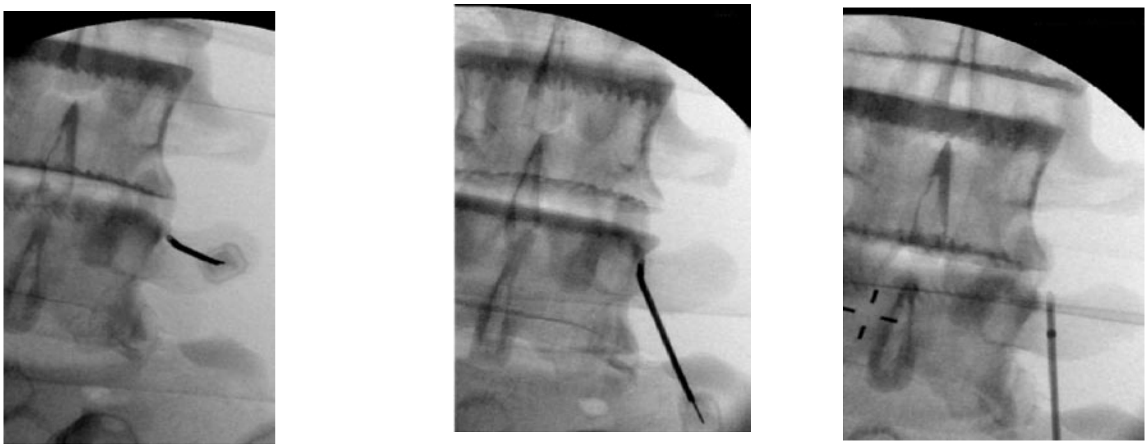


C. Expected lesion.



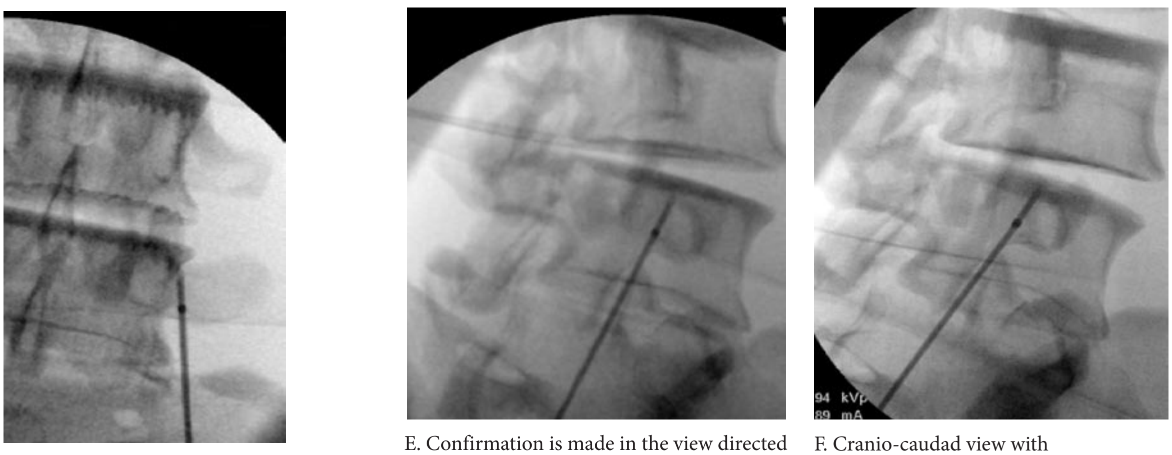
D. Cannula placement on plastic spine with cranial to caudad and 45 degrees of oblique. The cannula lies in the sulcus where the root of the SAP meets the root of the TP.

Fig. 3. ***Lumbar medial branch***.



A. Steep approach is okay for injection or PRF but almost perpendicular to nerve..Therefore conventional RF lesion would not induce an adequate lesion of the MBNB.

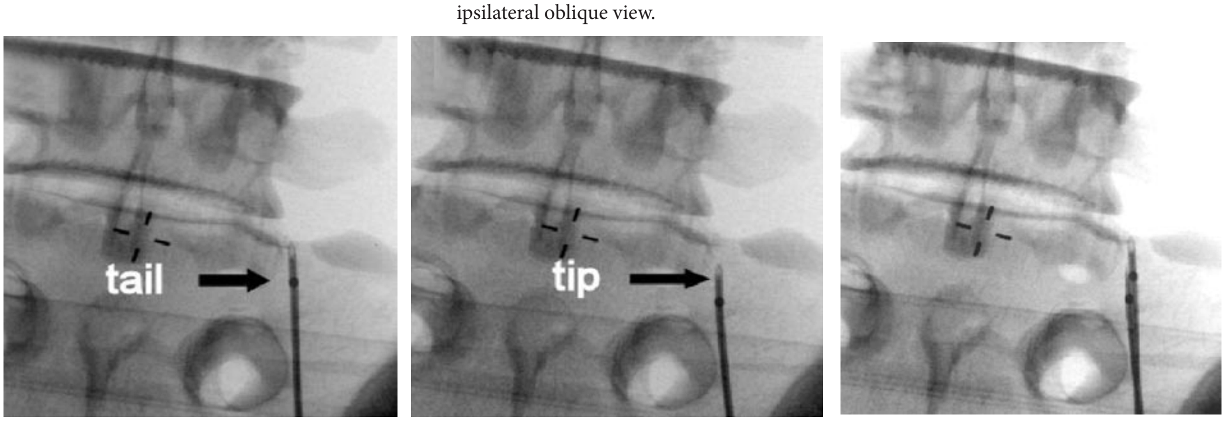
B, C. As the cannula is progressively passed at shallower angles, the ROC marker to tip length becomes longer, therefore more perpendicular to the x-ray beam and more in line with the course of the MBN, but C. is wide of the nerve at the marker end.



D is properly placed for an effective lesion.

E. Confirmation is made in the view directed perpendicular to the groove formed by the SAP-TP junction requiring 45 degrees ipsilateral oblique view.

F. Cranio-caudad view with maximization of apparent active tip length demonstrated.



G, H, I. The right L5 dorsal ramus is long and often better treated with two lesions using the tip to tail method. The initial lesion is made deeper at the postion demonstrated in G. The cannula's proximal ROC marked position, or "tail," is noted, either relative to a landmark or using an external radio-opaque placeholder. The cannula is then repositioned and lesion made with the tip relocated where the tail was previously, thus providing an extended lesion as seen in I, the summation picture of G, H.

Fig. 4. *AP X-rays of lumbar RF cannula in place for lesion of right L4 medial branch nerve.*

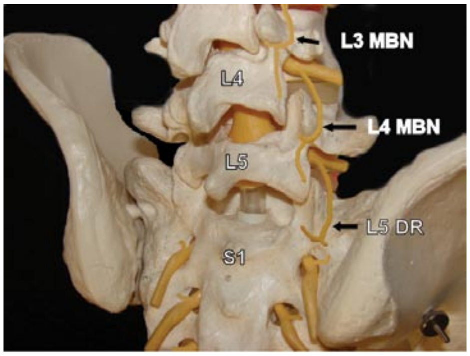


Fig. 5. *Plastic spine model demonstrating the long course of the L5 dorsal ramus (L5 DR) as it courses in the groove between the sacral ala and the superior articular process of the sacrum until it passes the mammillary process and hooks around toward the articular surface of the L5-S1 facet joint. Compare this to the relatively shorter courses of the L3 and L4 medial branch nerves (MBN).*

inter-transverse fascia branching further toward the articular capsule (Figs. 6, 7). These tracts are rarely straight lines, having a curving if not compound curving course. The dorsal branches split into medial and lateral branches. The articular branches of the dorsal medial branch nerves are the specific conductive path of facet joint pain.

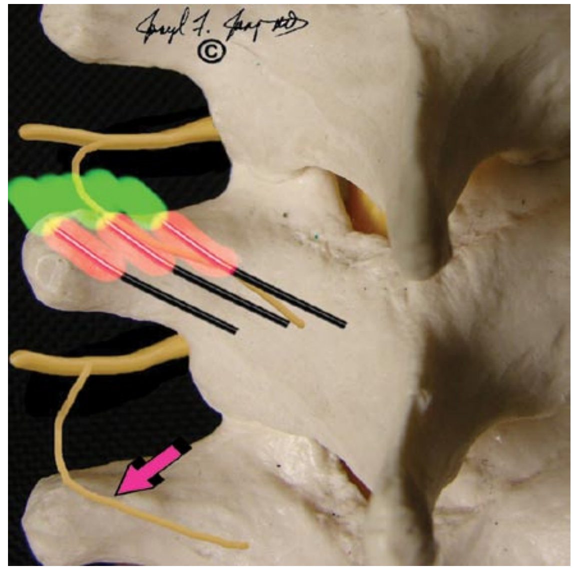
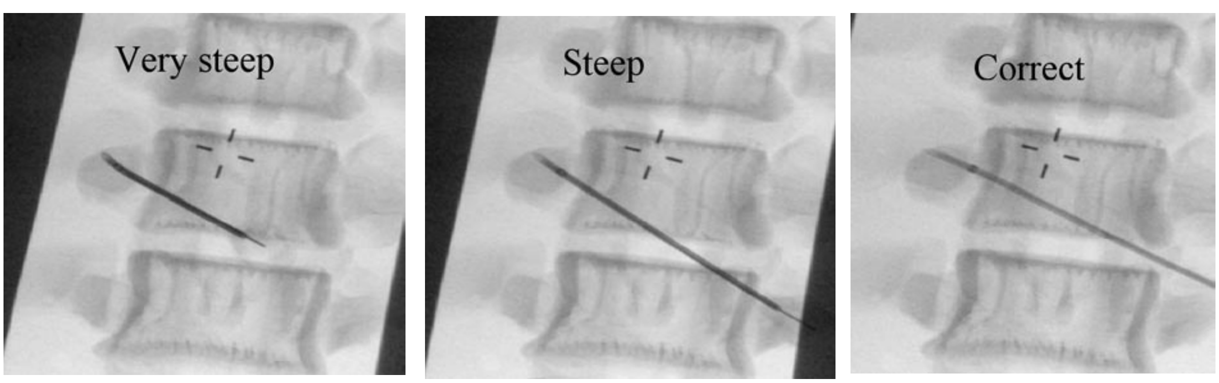


Fig. 6. *Thoracic MBNB represented on plastic spine model without ribs. Black and white arrows point to intervertebral facets. Pink arrow points to approximate location where dorsal branch nerve crosses the superior border of the transverse process after it pierces the intertransverse space. Location is variable (after Chua), therefore multiple hot lesions are made and often supplemented with 6–10% phenol in glycerol (green).*



A, B. demonstrate too steep angles with shortening of the active tip clearly delineated by the ROC marker to tip distance; risk of pneumothorax is greater and lesion not parallel to articular fibers.

C. The correct trajectory

Fig. 7. *Thoracic MBN RF cannula X-ray. The needle is inserted over bone and down to the tranverse process.*

Older texts remind us of neurolysis being achieved with infiltration of phenol to chemically coagulate the proteins in the articular nerves to effect pain relief (11). Chemo-neurolysis has fallen out of favor for the lumbar and cervical facets due to the possibility of spread of the lytic solution to non-targeted nerve roots or unintentional intravascular spread resulting in disastrous cord lesions. It is the author's opinion and practice that phenol still has value in some atypical situations such as post fusion or highly distorted anatomy. Others continue to use phenol to supplement RF thoracic medial branch neurolysis extending the lesion into the inter-tranverse space (12).

Radiofrequency neurolysis has gained the majority of favor as the technique to treat facet joint pain (13-16). Recently, a systematic review was performed confirming at least moderate strength of evidence in support of facet diagnostics and neurolysis (17). Two forms are being utilized: conventional continuous or "hot" RF, and pulsed or "cold" RF. This article only addresses standard RF.

The specific protocol for making these lesions are discussed elsewhere (9,12,18-20). A needle-like cannula is insulated except for the exposed active tip, which is positioned as parallel and adjacent to the targeted nerve branch as possible (Fig. 8). A probe inside the conductive cannula is inserted and connected to a radiofrequency generator. Energy flowing from the tip of the needle creates a heat lesion mostly about the length of the exposed tip and in proportion to the diameter of the probe. A thermocouple permits temperature control adjacent to the tip typically in the 80 – 85 degree Celsius range. This results in a predictably sized lesion that induces neurolysis via coagulation and axonal death. Common active tip lengths used for neurolysis are 5 mm or 10 mm. Common cannula gauges are 22, 21, 20, and 18. A wider cannula such as 18-gauge results in a larger diameter lesion.

The technique is guided under C-arm fluoroscopy. X-rays passing through the patient demonstrate in 2 dimensions the projected relative radio-opaque bony landmarks and the metallic cannula. Most currently available cannulae are uniform in their radio-opacity from tip to hub. The physician must make an educated guess as to the portion of the cannula that will be making the lesion in relationship to the bony landmark. Optimally the lesion created will be along the entire available course of the targeted nerve. Further, it is desirable to reduce unnecessary exposure of the energy to non-targeted tissue, maximizing safety and minimizing collateral damage. The radio-opaque cannula delineates the proximal end of the active tip. Thus, the location and size of the lesion is theoretically predicted with greater reliability under fluoroscopic imaging using radio-opaque markers (Fig. 9).

Additional applications exist. More common are lumbar and thoracic sympatholysis, gray ramus communicans ablation, and dorsal root ganglion ablation, although this last application may be best applied with a different cannula angle and pulsed RF not described in this article.

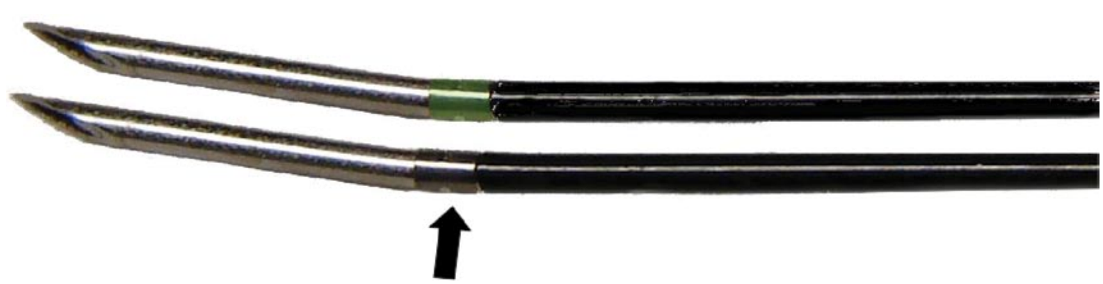


Fig. 8. *The active tip exists from the end of the insulating coating to the point of the cannula. The radio-opaque marker is seen at the proximal tip indicated by green highlighting or arrow.*

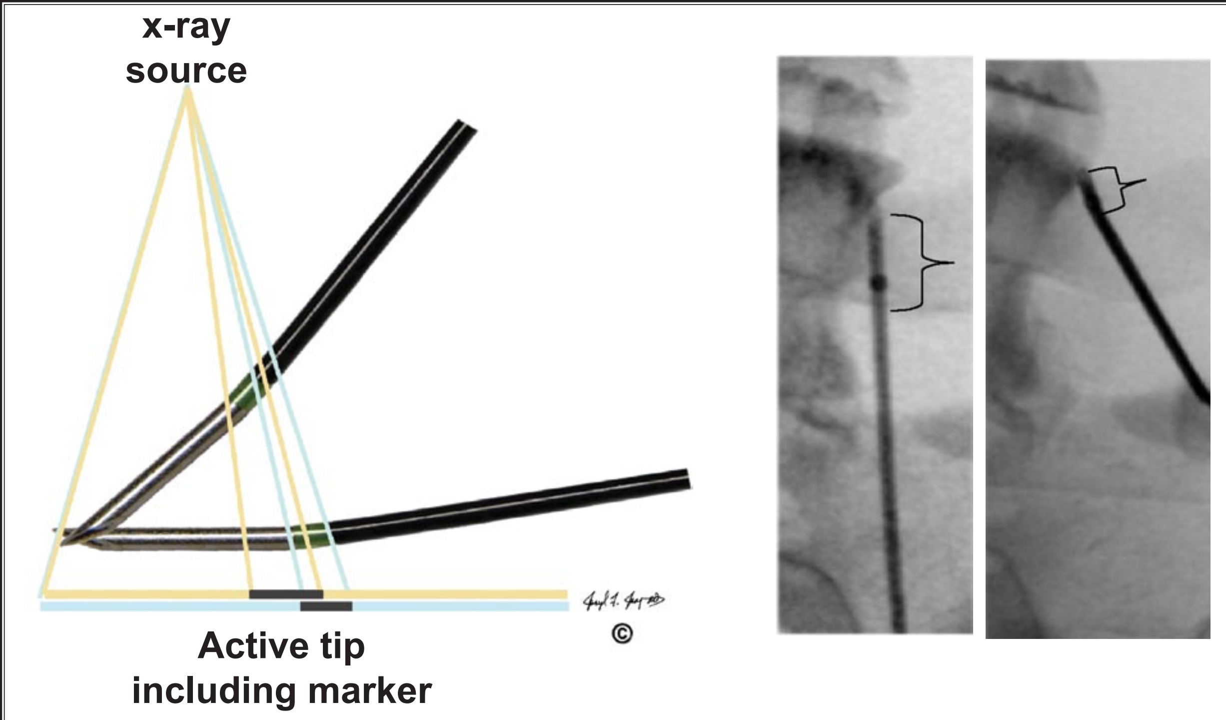


Fig. 9. *Fluoroscopic projection of RF cannula when the beam is perpendicular casts the longest appearance of the active tip (blue). When not perpendicular the relative length of the active tip appears shortened (orange). This effect is exemplified in the X-rays to the right with the bracket indicating active tip apparent length.*

Methods

Samples of new sterile radio-opaque marked cannulae (ROC) were provided as a grant without restriction. Also provided was a "Phantom" spinal injection mannequin. Both non-marked standard and ROC cannulae were placed in the phantom model. Situations were simulated in the Phantom to help demonstrate the utility and potential advantage of the marker. Multiple images were retained for review. Other than labeling and cropping, digital manipulation of the X-ray was limited to Fig. 4I only for summation.

Results

Cervical Medial Branch Nerves

The anatomic target for cervical medial branch nerve (MBN) (Figs. 1, 2) is the waist region of the lateral facet pillar at each vertebral level above and below the targeted joint line. The MBN courses along this groove from the foramen in a posterior and inferior direction. The bony surface and thus nerve course may be rounded, hence a recommendation to make lesions in the 90 degree and 20 degree ipsilateral oblique approach (9). Some physicians advocate using 5 mm active tip length for cervical RF facet neurolysis. This study demonstrates the inadequacy of the 5 mm length in our model if one is relying on a single lesion. However, the ROC 5 mm cannula could take advantage of the marker in sequential positioning tip to tail lesioning as when following the recommendation for 2 angles of sequential lesions. The marker reassures one of the adequacy of coverage in most patients with a single 10 mm active tip cannula position on a relatively flat lateral mass. The lateral mass may be highly curved at some levels. The marker does not add much to planar alignment beyond what classic down the beam oblique views permit, particularly with a curved cannula. The converse is also true: in a patient with a short lateral mass, an excessively long active tip can be discerned. One might opt then for a 5 mm tip to avoid excessive heating of tissues dorsal to the target.

One can observe these concepts in Figs 1, 2. Plain

10 mm, 5 mm ROC, and 10 mm ROC cannulae were observed. It was unclear where the dorsal extent of a 10 mm lesion would occur with a plain cannula. It was clear that sequential depth lesions would be necessary with a 5 mm ROC cannula, an observation that would not be known with a standard cannula. The 10 mm ROC cannula marking made clear the adequate length of the active tip relative to the lateral mass.

Lumbar Medial Branch Nerves and L5 Dorsal Branch

The target for lumbar medial branch nerves (Figs. 3–5) lesioning is the junction of the root of the SAP with the root of the transverse process (TP). The MBN courses through this notch then dividing into branches superiorly to the joint above and another rounding the mammilary process and base of the SAP to the joint of the same level (18,19). Thus, the L3-4 facet receives innervation from the L2 branch crossing the L3 transverse process and from the L3 branch crossing the L4 transverse process.

The ROC marking and the apparent length from the tip to the marking provide an appreciation of the active tip and its orientation that is not available in standard cannulae (Figs. 8 & 9). One can determine if the entire available course of the medial branch nerve from its cranial transverse process point to the point where it wraps around the caudal root of the SAP has been included in a single lesion or not. If a portion of the active tip is too lateral or if the approach too steep, either the cannula may be repositioned or a second lesion may be made. When appropriate posterior caudal cranial tilt and obliquity are applied to bring the X-ray beam, a tunnel view to the target is obtained. When posterior cranio-caudal tilt with similar obliquity perpendicular to the dorsal surface of the TP-SAP groove, the orientation of the needle should be relatively perpendicular to the X-ray beam and the active tip visualized as flat and long as possible. The L5 dorsal branch is long wrapping around the most caudal extent of the L5-S1 facet. Due to its long course, 2 lesions are typically required ,placed in line “tip to tail,” that is 2 lengths of the active tip, a procedure aided by the ROC marking.

Thoracic Medial Branch Nerves

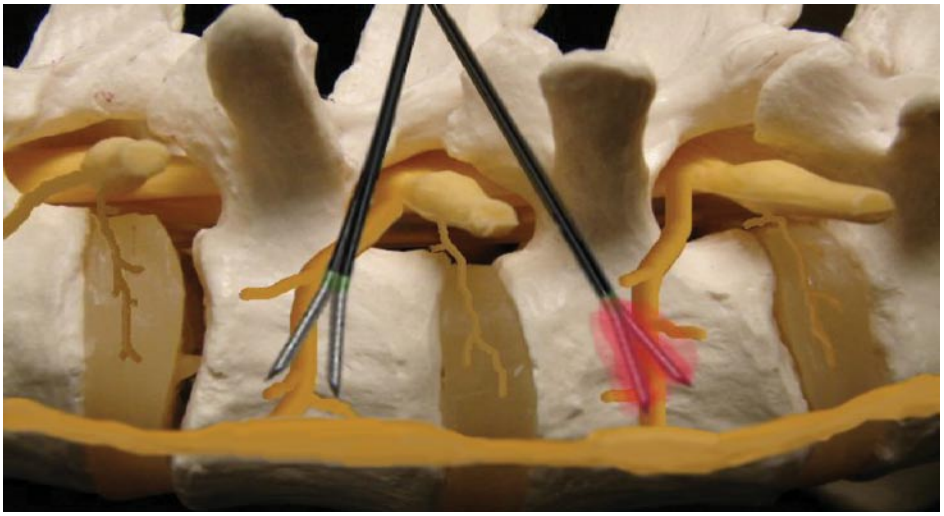
The anatomic target for thoracic facet neurolysis is different from lumbar. At most thoracic levels the dorsal medial branch nerve crosses close to the supero-lateral margin of the transverse process then continue medially and inferiorly along the dorsal surface of the transverse process or within the fascial plane between the multifidi and semispinalis muscles to terminate in articular branches and branches to the multifidi (20) and beyond. Due to variability of location of the MBN, several parallel lesions are made to assure coverage and may be supplemented, particularly T5-8, with neurolytic injection of phenol in glycerol 6–10% (12). The needle is inserted over bone medially and skipped across the TP to the target. The largest advantage of the ROC marking in the thoracic region is assuring orientation of the insertion angle of the active tip as flat to the plane of the TP and thus parallel to the nerve. This advantage is not present with standard cannulae. Refer to the 3 X-rays in Figs. 6 and 7 and note the difference in the apparent tip to marker length. The longer this apparent length the more perpendicular to the AP X-ray beam the cannula tip lies, and thus more of the cannula should lay along the transverse process surface and thus contact more of the MBN.

Lumbar Gray Ramus and Sympathetic

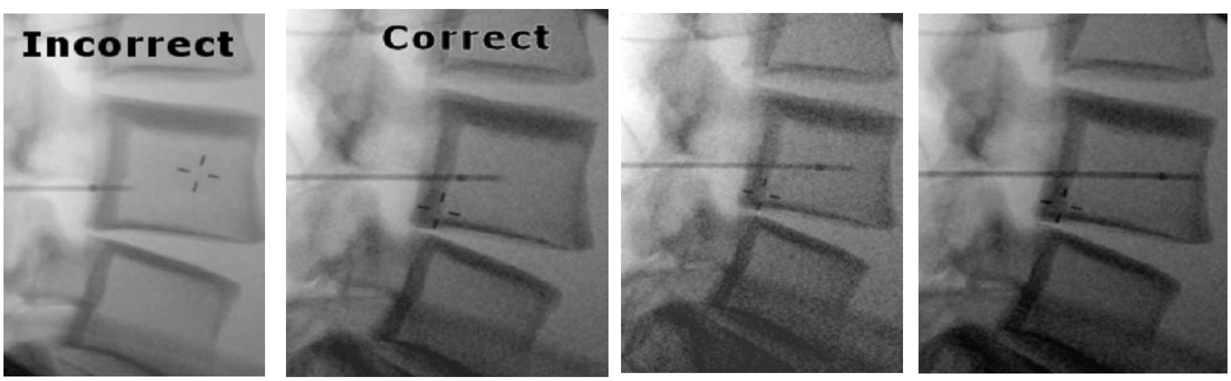
Gray rami are targets for RF lesions in the treatment of anterior element pain from vertebral bodies such as vertebral compression fracture. The anatomic site of RF treatment is the lateral waist of the vertebral body beyond the neural foramen (21,22). Test stimulation should confirm a lack of ventral ramus stimulation. The ROC marking clearly assists the operator in avoiding active tip placement too close to the foramen and thus ventral root (Fig. 10). Thus, the use of a ROC cannula should add an element of safety to gray ramus lesions versus the standard cannulae.

Lumbar Dorsal Root Ganglion

Dorsal root ganglion lesions have been performed for relief of radicular symptoms, intercostal neuralgia, inguinal neuralgias, discogenic pain, and failed back surgery syndrome (23-47). Both conventional continuous RF and pulsed RF have been used, but pulsed RF has largely become favored due to decreased potential for serious complications (31,41). The target is the dorsal aspect of the dorsal sensory ganglion, which in the lumbar region is typically the foramen. For a conventional continuous RF lesion, a shallow angle of approach is used. However, the marker to tip ap-



A. Gray rami communicantes and sympathetics depicted on the plastic spine model.



B. Too shallow and at risk of ventral root stimulation and damage

C. Relatively safer point to begin lesioning

D. By advancing the active tip positioning the ROC marker where the tip had been, the lesion is contiguously extended

E. Placement for sympathetic trunk lesion.

Fig. 10. *Gray rami communicantes and sympathetics. The gray rami do communicate with the ventral rami. The ROC marker provides additional assurance that one is lesioning deeper than the foraminally exiting ventral ramus. By turning the needle 180 degrees one can considerably enlarge the lesion created. The approach can be either skipping past the inferior versus the superior margin of the transverse process, whichever provides optimal placement in the waist and midpoint of the vertebral body lateral margin without causing dysesthesia in the segmental nerve. The sympathetic chain itself is lesioned a bit deeper with the tip at the anterior border of the vertebral body in the lateral view. The radiographs demonstrate cannula placement with the curve facing inward.*

parent length visualization is helpful to assure relatively parallel course to the segmental nerve (Fig. 11). The tip should be dorsal to the ganglion and produce stimulation with 0.2 volts or less and > 200ma indicative of proximity to the sensory ganglion for improved efficacy (43,44).

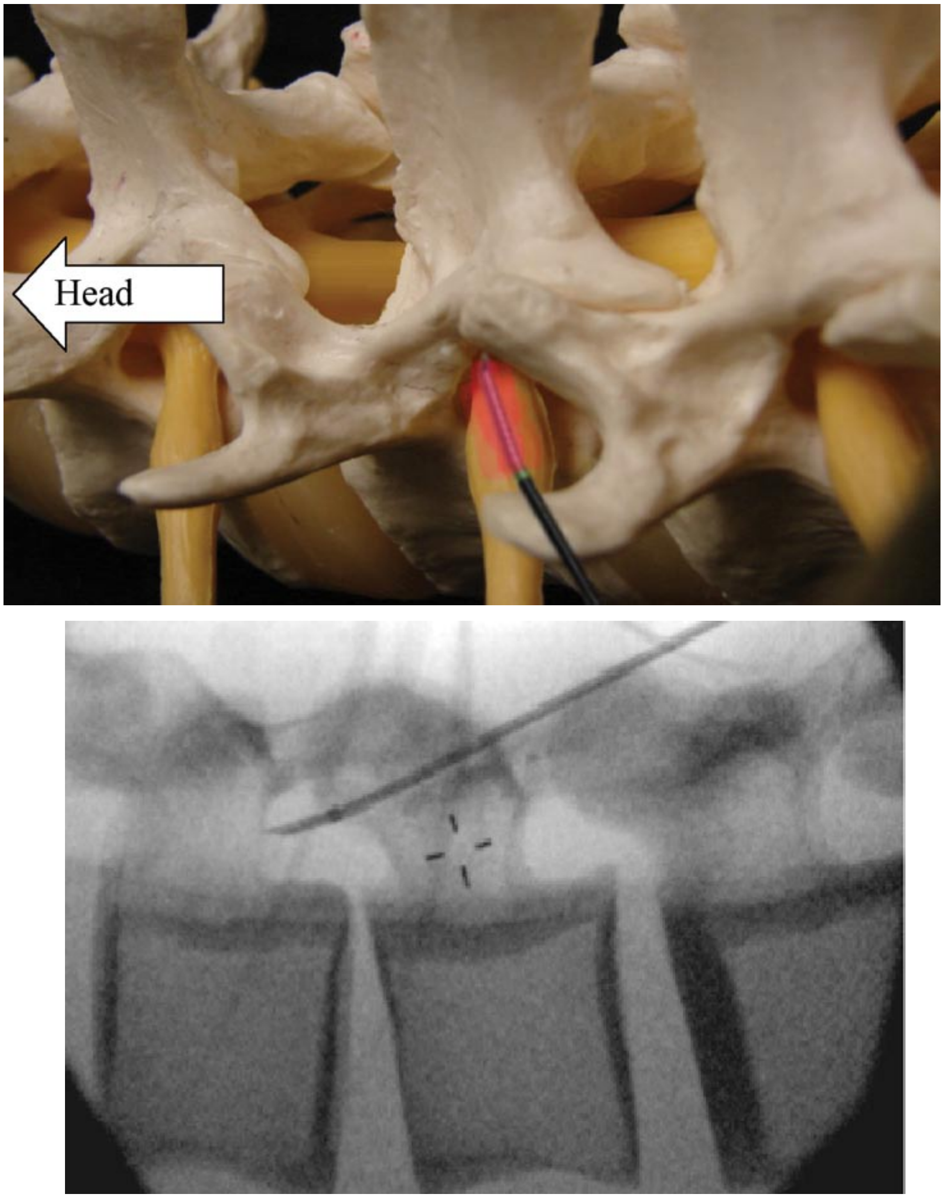


Fig. 11. *Lumbar dorsal root ganglion caudo-cranial and lateral oblique view. A shallow and laterally oblique approach over the tip of the TP a level below into the dorsal aspect of the foramen is used. Confirmation of placement is made in the lateral view (bottom). A blunt tip is preferred to decrease the risk of dural or neural puncture. Due to the risk of permanent segmental nerve damage and deafferentiation pain, conventional RF of the DRG may be replaced by pulsed RF.*

Conclusion

The efficacy of RF lesions is dependent on adequate coverage of the specific targeted nerve in relationship to the visualized anatomy. Although the use of radio-opaque markers have been utilized for guidance in cardiac catheters and other minimally invasive devices, the procedural value of radio-opaque makers had not been reported for radiofrequency neurolysis. The study presented does not provide clinical data to prove an outcome advantage. In the application of RF lesions studied, the ROC cannulae do represent an improvement over standard cannulae to enhance visualization of active tip length and orientation and thus likely optimize effected lesion placement using a phantom model. Advantages are visualization of lesion length, adequacy of target coverage, and "tip-to-tail" cannula placement in sequential lesioning along the length of a nerve, particularly for the L5 dorsal branch nerve.

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