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FactFinders

FactFinders for patient safety: Motor stimulation testing in lumbar radiofrequency neurotomy and radiofrequency neurotomy in patients with posterior hardware

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A B S T R A C T

This series of FactFinders presents a brief summary of the evidence and outlines recommendations regarding the use of motor stimulation testing in lumbar radiofrequency neurotomy and performance of radiofrequency neurotomy in patients with posterior spinal hardware.

The evidence in support of the following facts is presented: (1) Motor stimulation does not inherently protect against unwanted damage to the spinal nerve, exiting spinal nerve root or its ventral ramus due to a lack of sensitivity of this test for identification of electrode contact or close proximity to sensorimotor nerves. Even when motor stimulation is performed, verification of correct electrode placement with multiplanar imaging including a minimum of true anterior-posterior and lateral fluoroscopic views is a recommended safeguard. (2) The existence of posterior spinal hardware is not an absolute contraindication to radiofrequency neurotomy, but direct contact with hardware should be avoided.

Motor Stimulation Testing in Lumbar Radiofrequency Neurotomy

Mathew Saffarian, DO, Vivek Babaria, DO, and Zachary L. McCormick, MD, on behalf of the Spine Intervention Society's Patient Safety Committee

Myth: Motor stimulation testing prior to lumbar radiofrequency neurotomy guarantees prevention of inadvertent damage to the exiting spinal nerve or its ventral ramus.

Fact: Motor stimulation does not inherently protect against unwanted damage to the spinal nerve, exiting spinal nerve root or its ventral ramus due to a lack of sensitivity of this test for identification of electrode contact or close proximity to sensorimotor nerves. Even when motor stimulation is performed, verification of correct electrode placement with multiplanar imaging including a minimum of true anterior-posterior and lateral fluoroscopic views is a recommended safeguard.

Radiofrequency neurotomy (RFN) is an effective treatment for chronic lumbar zygapophysial joint pain when performed according to clinical practice guidelines [1–3]. When performed according to these standards, the rate of adverse events is very low [1,4–6]. If improper technique is used, the procedure is likely to be ineffective [7] and complications may occur [5,6,8]. In particular, if an electrode is advanced into the posterior aspect of the neuroforamen, damage to the exiting spinal nerve or its ventral ramus is possible [7,8].

Recent multispecialty working group recommendations promote the performance of motor stimulation testing to help ensure safety when performing lumbar RFN [9]. This guidance was based on a single case of dropped head syndrome following a cervical RFN [9,10]. Some clinicians may also use motor stimulation testing with the rationale that it aids in identifying proximity of the RFN electrode to the medial branch nerve, though the evidence for this practice is based on low quality evidence [11]. Alternatively, Spine Intervention Society guidelines recommend

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that with proper procedural anatomical location and accurate technique, motor stimulation testing of the medial branch nerve is not necessary for optimizing treatment outcomes or aiding in prevention of damage to the exiting spinal nerve or its ventral ramus [3]. Given this discrepancy, the following FactFinder describes the available published evidence relevant to motor stimulation testing as a risk mitigation strategy to prevent lumbar spinal nerve and/or ventral ramus injury during lumbar RFN. The use of motor stimulation testing to optimize treatment outcomes is beyond the scope of this article; an evidence-based discussion of optimizing outcomes of lumbar RFN has been described previously [12].

The fact is that no study to date has specifically investigated the ability of motor stimulation to prevent inadvertent damage to the spinal nerves during a lumbar RFN procedure. However, indirect information can be gleaned from studies performed on other nerves, which may be the best available evidence to determine whether motor stimulation, prior to thermocoagulation, can reliably prevent subsequent injury to the spinal nerve and/or its ventral ramus during lumbar RFN.

Electrical stimulation as a safeguard against neural injury has been studied extensively in relation to peripheral nerve blocks. In the 1950s, nerve stimulator use became popular to locate nerves [13] and to decrease the incidence of injury during peripheral nerve blocks [14]. Prior to the use of nerve stimulators, it was assumed that eliciting a paresthesia may predict proximity to a specific nerve. However, reports in the early 2000s questioned the correlation of needle-tip-to-nerve distance, paresthesia provocation, and the ability to produce a motor response [13,15].

The introduction of ultrasound allowed for objective measurement of needle proximity to a target nerve. Perlas et al. studied the use of motor stimulation during ultrasound-guided axillary nerve blocks [16]. These investigators found that application of 0.5 mA of current during epineural contact failed to produce a motor response in 25% of subjects. Bigeleisen et al. investigated the ability to evoke a motor response by stimulation of the supraclavicular nerve with needle tip contact of epineurium versus intraneural position [17]. Provocation of a motor response required greater than 1.0 mA of current in 18% (CI 95% 6%–30%) of subjects in the epineural contact group. Alternatively, intraneural stimulation was associated with a motor response upon application of 1.0 mA of current or less in all cases, though greater than 0.5 mA was required 10% of the time. Robards et al. investigated motor stimulation thresholds during ultrasound-guided intraneural sciatic nerve blocks and found that a current of 1.5 mA failed to elicit a motor response in 17% (95% CI 2–32%) of subjects [18]. This body of evidence indicates that a proportion of patients exhibit no motor response with both intraneurally and epineural needle tip position when a magnitude of current that maintains specificity is applied to peripheral nerves.

Animal studies provide additional evidence that motor stimulation lacks a reliable relationship with needle-tip-to-nerve proximity. Chan et al. placed 22-gauge needles into nerves of the brachial plexus of pigs via open surgery for direct visualization [19]. They found no relationship between the magnitude of electrical current applied during and a motor response, which occurred anywhere from 0.2 mA to greater than 1.0 mA. Tsai et al. found that a motor response was absent upon sciatic nerve stimulation in pigs 30% (95% CI 56%–84%) of the time with a needle-tip-to-nerve distance of 1 mm [20]. At a needle-tip-to-nerve distance of 2 mm, these investigators reported failure to evoke a motor response upon all attempts, despite application of a current up to 1.7 mA. These findings reinforce that motor stimulation lacks sensitivity for needle tip proximity to a nerve that may result in thermal injury during lumbar RFN.

There are additional reasons that motor stimulation prior to lumbar RFN may not be a reliable indicator of needle proximity to the exiting spinal nerve or its ventral ramus. Sensorimotor fascicular organization in the nerve root is likely to vary across patients [17], which may influence the ability to evoke a motor response upon stimulation. Furthermore, patients with diabetes, and other medical co-morbidities that predispose to polyradiculoneuropathy, may require higher stimulation thresholds to elicit motor responses [17]. Genetics, age, psychology, medications, use of sedation, and underlying pathology may further complicate a patient's response to motor stimulation [21]. Finally, use of conducting solutions, such as normal saline or lidocaine, decrease tissue impedance adjacent to the electrode. This will lead to an increase in lesion size during RFN [22]. Therefore, even if motor stimulation fails to provoke a motor response in the distribution of the exiting spinal nerve, once conducting fluid such as local anesthetic is applied prior to RFN, the tested area can expand and cause spinal nerve injury during RFN despite negative motor stimulation response. All of these factors may contribute to the insensitivity of motor testing to provide accurate information regarding electrode location, creating a false sense of security that an electrode is positioned at a safe distance from the exiting spinal nerve or its ventral ramus.

In summary, the available evidence indicates that motor simulation testing alone (at current magnitudes that maintain target specificity) lacks adequate sensitivity for both intraneural and close perineural RFN electrode position. If used, it should be combined with multiplanar fluoroscopic imaging to verify correct electrode position. However, more evidence is needed to show if this combination of precautionary measures works better than verifying electrode position by multiplanar fluoroscopic imaging alone.

Conclusions/recommendations

- Motor stimulation testing without verifying electrode position by multiplanar fluoroscopic imaging prior to RFN does not inherently protect against unwanted damage to neural structures. Absence of a response to motor testing may give a false security that the RFN electrode is located in a safe position.
- Prevention of spinal nerve and/or ventral ramus injury during lumbar RFN is best ensured by multiplanar fluoroscopic imaging (*true* AP and lateral views at minimum) in order to verify that electrode position is dorsal to the associated lumbar intervertebral foramen.
- If despite these measures abnormal sensations are reported during thermocoagulation, the physician should halt the radiofrequency lesion, re-check multiplanar fluoroscopic views, and correct the electrode position, if appropriate. Ensuring that the patient is awake and able to report abnormal sensations is an important safety measure in preventing neural injury.

Radiofrequency Neurotomy in Patients with Posterior Spinal Hardware

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Myth: Radiofrequency neurotomy (RFN) cannot be performed in the setting of posterior spinal hardware due to the risks of heating undesired neurologic structures and unintended nerve injury.

Fact: The existence of posterior spinal hardware is not an absolute contraindication to RFN, but direct contact with hardware should be avoided.

Facetogenic pain is a common cause of chronic low back pain that is commonly treated with RFN of the spinal medial branch nerves [23,24]. RFN involves conversion of radiofrequency waves transmitted via an electrode, introduced into a cannula, and conducted through a metal tip. Radiofrequency waves are then converted into thermal energy in the tissues adjacent to the metal tip of the cannula. Thermal energy is also conducted after conversion through the adjacent tissue. The resultant thermal coagulation of the medial branch nerves disrupts the pain signaling pathways from the facet joint(s) to the central nervous system, allowing for durable analgesia. RFN is a low-risk procedure [25]. While conventional RFN is commonly performed at 80–90 °C, neural injury can occur at temperatures as low as 42 °C [26].

Facetogenic pain may develop in the setting of a prior spinal arthrodesis. The spine is predisposed to accelerated degeneration adjacent to fused segmental levels [27]. If hardware is utilized to establish spinal stability, there will be hardware present at the medial branch level that innervates the mobile facet joint immediately adjacent to the fused segments. Additionally, incomplete fusion resulting in the presence of pseudarthrosis may also result in persistent pain [28,29]. There is controversy as to whether the medial branch nerve is destroyed by the surgical exposure or by the pedicle screw itself at most lumbar levels. However, because the medial branch nerve may remain intact in a proportion of these patients, as well as at levels of posterior cervical and thoracic fusions, many physicians elect to place an RFN electrode in close proximity to spinal hardware. RFN may be effective at controlling pain in these scenarios. Sensitive neurologic structures that are not the intended target of RFN may be in proximity to posterior spinal hardware (*e.g.,* the spinal nerve exits beneath the pedicle through which a pedicle screw might pass). Concern has been raised about the safety of RFN in the setting of posterior spinal hardware.

A 2015 cadaveric study evaluated temperature changes resulting from lumbar spinal medial branch RFN in the presence of both titanium and steel pedicle screws [30]. Direct contact of the radiofrequency cannula metal tip with the pedicle screws produced temperature changes of the pedicle screw and surrounding soft tissue compared to controls. The effect was more pronounced with titanium than with stainless steel. The temperature of the titanium screw heads increased by 6.66 °C and the screw tips increased by 16.72 °C when the cannula was placed on top of the pedicle screw and heated to 80 °C for 90 s. In contrast, the temperature of stainless-steel screw heads increased by 4.4 °C at the head and 2.46 °C at the tip when there was contact of the RFN cannula with the pedicle screw at the same location. Titanium, therefore, appears to heat to a greater extent and conduct heat through the length of the screw more effectively than stainless steel, presenting a greater potential risk for unintended neural or vascular injury at and distal to the RFN site if there is contact with the pedicle screw. The risk of neural injury may be greater in the setting of malpositioned/migrated hardware (*e.g.,* pedicle screws in close proximity to spinal nerve roots due to extra-osseous passage in any direction). When the cannula was placed at or near the conventional RFN target, but not in direct contact with the pedicle hardware, there was heating of the hardware, but that difference (up to 1.84 °C for titanium and 0.86 °C for stainless steel) was small in comparison to direct contact, and likely of no clinical significance. The study did not make note of the exact distance between the cannula and the hardware. The study had several limitations, including the use of a cooled cadaver torso with a non-standardized baseline temperature. The heat generated from RFN increased the baseline temperature of the local cadaveric tissue to closer to room temperature. Even after allowing cooling time between repeated ablation cycles, the cadaver temperature did not return to baseline. Finally, the cadaver model was dissected such that the spine was open.

In 2016, a prospective study evaluated six patients during a total of 10 RFN procedures, in which a temperature probe was placed via a cannula adjacent to posterior hardware in order to monitor temperature during RFN [31]. Pedicle screw head temperature increased during six of the 10 RFN procedures. In two cases, the temperature rapidly rose to 42 °C requiring abrupt termination of the procedure. The authors concluded that monitoring of hardware temperature should be performed during RFN using a secondary probe. Limitations of this study included the small sample size and the fact that cannulae appeared to be placed under oblique fluoroscopy without a corroborating AP or lateral view. In particular, the supplied image appears to demonstrate a cannula position more lateral on the transverse process rather than at its junction with the superior articular process, in closer proximity to the hardware. It also appears that the temperature monitoring cannula was of different gauge than the therapeutic cannula, which is of uncertain but potential significance.

Additional studies have not demonstrated evidence of increased risk of neural injury when RFN is applied in patients with posterior spinal hardware. A 2018 retrospective review of 56 RFN procedures (11 cervical, one thoracic, 44 lumbar, with levels ranging from the third occipital nerve to the L5 dorsal ramus) also reported no complications [32]. The paper includes fluoroscopic procedural images demonstrating suboptimal needle placement and multiple cases of mislabeling of the intended procedures. This generates concerns regarding the authors' understanding of the RFN procedures, the ability to have appropriately analyzed the data from a retrospective chart review; and therefore, the validity of the conclusions drawn. A 2020 retrospective case-control study that evaluated 52 patients who had received RFN at the level of hardware, of which 36 were spinal, reported no complications [33]. The retrospective nature of the study, limited population, and the lack of clarity regarding procedural standards were all limitations of this paper.

Conclusion

RFN causes heating of soft tissue surrounding posterior spinal hardware. Further, heat may be transmitted through the length of the hardware. One study reported a marked difference between heating at the distal ends of titanium screws compared to steel, especially when there was direct contact of the RFN cannula with hardware [30]. Although there is evidence of temperature elevation in the tissue surrounding the hardware when the cannula tip is placed at conventional RFN target sites but not in direct contact with the pedicle hardware, the effect appears to be of negligible clinical significance. Monitoring of hardware temperature has been performed concurrently during RFN procedures. The necessity of temperature monitoring has not yet been clearly demonstrated, though it may present a safeguard to unintentional hardware heating. There has yet to be a report of unintended neural injury associated with a spinal RFN procedure in the setting of posterior spinal hardware. While larger cohort studies would provide additional reassurance, it appears that RFN may be performed safely in patients with posterior spinal hardware when the cannula tip is not in direct contact with the hardware.

Recommendations

- The medial branch nerves may be destroyed in the process of placing pedicle screws for securing posterior spinal hardware. However, in cases where there is concern that the medial branch nerve has not been destroyed, RFN may be considered if there has been an appropriate response to initial and confirmatory medial branch blocks targeting the post-surgical level(s).
- The greatest risk of undesired heat conduction through posterior spinal hardware likely occurs when the RFN cannula tip is in direct contact with the hardware. Care should be taken to ensure there is no direct contact of the cannula with posterior spinal hardware.
- Heat may conduct through the entire length of the pedicle screw. Axial imaging should be reviewed prior to RFN to identify malpositioned/migrated hardware particularly if extra-osseous migration/placement has occurred with deviation of metal adjacent to neural or vascular elements.
- As with all medial branch RFN procedures, physicians should communicate with and monitor patients to assess for pain that may signal heating of undesired neurologic structures.
- Physicians may consider temperature monitoring of adjacent hardware with the use of an additional probe while performing RFN at a level that incorporates posterior spinal hardware, particularly if titanium pedicle screws are present. Consideration should be given to abort the RFN procedure if temperature reaches or exceeds 42 °C.
- The safety of cooled RFN in this setting has not been established.

Declaration of competing interest

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

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