

RADIOFREQUENCY

Carl Noe, M.D. and Gabor B. Racz, M.D.

Electrical current has been used to produce neural lesions in patients for a hundred years. Modern radiofrequency thermocoagulation has been used to ablate pain pathways in the trigeminal ganglion, spinal cord, dorsal root entry zone, dorsal root ganglion, sympathetic chain and peripheral nerve. Unfortunately, the long term effects of ablative techniques on clinical pain syndromes is incompletely known.

The radiofrequency lesion is formed when neural temperature exceeds 45 degrees C. as a result of frictional heat generated by molecular movement in a field of alternating current which alternates at a radio wave frequency. Frequencies above 250 kHz are used to produce an electromagnetic field about an active electrode. The active electrode is placed to the desired anatomical location, and an indifferent electrode is placed, such as to minimize current passage across the myocardium. Current disperses via the second electrode, usually a high area contact plate. Wattage is gradually increased and heat develops in the tissue, which conducts to the active probe. Heat is generated as current flows through the probe which has the thermocouple built into it. Thus, the thermocouple needle combination allows lesioning, monitoring and injecting without movement of the appropriately-positioned device. The probe itself assumes equilibrium with the tissue heat that surrounds it. This is important to understand that the heat is not emitted from the probe itself. It is the current movement that generates the heat as it passes through the tissues. This temperature is monitored and wattage is adjusted to a target temperature, which is a primary determinate of lesion size. 10-20 watts are used for low power procedures, such as facet denervation, and as much as 10-20 watts for hypophyseal destruction. Other factors are active electrode diameter and length. Tissue blood flow is important since significant heat convection can

occur with significant blood flow in the area of the lesion. Homogenous tissue is necessary for a lesion shape that is symmetrical. (1)

Lesion size has a near linear relationship with temperature. The advantage of the radiofrequency technique for neurolytic procedures is the ability to monitor temperature during lesion formation. Lesion size plateaus with time such that after 60 seconds at a given temperature, lesion growth is minimal so the time of lesion creation can be limited once the target temperature is reached. Lesions may extend a few mm beyond the active electrode tip, but the majority of the lesion volume surrounds the axis of the active electrode. The commercially available electrodes are insulated to expose a relatively short tip which acts as the active electrode. Stimulation can be performed at frequencies from 5-100 Hz and 0.1-10 v to assist placement and insure safety. Higher frequencies and lower voltages are used to reproduce pain while localizing the target structure while low frequency and higher voltages are used to assess neuromuscular activity prior to lesion generation.

45 degrees C. produces irreversible neuronal injury but temperatures as high as 90 degrees C. have been used clinically to produce lesions of adequate size. In homogeneous tissue, lesions have smooth borders along the 45 degree C. isotherm. Blood flow will convect heat away from the lesion area and reduce predicted lesion size. Earlier direct current radiofrequency lesions were associated with irregular borders and less control. Lesion temperatures above 90 degrees C. should be avoided to prevent boiling and tissue tearing with electrode removal.

Lesion shape is spheroid around the active electrode and tapers at the tip such that minimal lesion formation occurs beyond the tip of the active electrode. The clinical implication is

that the placement of the active electrode should be oriented in an axis that will produce a spheroid lesion along the desired location for neurolysis. (2)

Wilkinson introduced sympatholysis using radiofrequency energy at the upper thoracic chain. (3,4) Rocco, Haynsworth and Noe have described results from use at the lumbar sympathetic chain. (5,6,7) Horner's syndrome and pneumothorax are the primary complications from the upper thoracic technique and post-sympatholysis neuralgia and incomplete sympatholysis are remaining problems with lumbar radiofrequency sympatholysis. While the active radiofrequency electrode may be placed radiographically, the location of the sympathetic chain has proven itself to be most variable. This variability, as well as the consequences of sympathetic destruction, have limited widespread use of these techniques.

AN EXAMPLE: LUMBAR LESIONING

The lumbar technique is performed in the prone position with the dispersal plate on the thigh. Radionics 15 cm., 5mm bare tip, Sluyter-Mehta cannulae are placed 6-8 cm. lateral to the midline at the second, third and fourth lumbar vertebrae. Skin entry is made just inferior to the transverse process so that the probe can be passed under the transverse process but over the exiting nerve root. This approach is simplified by oblique fluoroscopy along the axis from the skin entry site and the anterolateral surface of the vertebral body. Once the probe has reached the psoas muscle, a lateral fluoroscopic image should be used to avoid advancement anterior to the vertebral body. Since the sympathetic chain lies just anterior to the psoas muscle, lesions should be placed when the probe tip penetrates the psoas. This can be determined with contrast injection, after aspiration to exclude intravascular placement, and fluoroscopy in the lateral and anterior-posterior placement, and fluoroscopy in the lateral and anterior-posterior views. The lateral view will frequently reveal contrast spread in a thin ribbon both superiorly and interiorly. The anterior-posterior

view will show contrast spreading laterally into the psoas muscle if the tip has failed to penetrate the anterior psoas fascia. Once placement is radiographically satisfactory, aspiration is repeated and stimulation at 5 Hz and 4 V is performed. No neuromuscular activity should be experienced by the patient nor observed. 1 ml of 0.5% lidocaine is administered for analgesia and lesion formation is initiated. 80 degrees C. for 60 s is desirable. The probe can be advanced in 0.5 cm increments until lesions have been placed to the anterior aspect of the vertebral body as viewed by lateral fluoroscopy. Aspiration, contrast injection and stimulation should be repeated prior to each lesion placement. This process can be repeated from the anterior psoas muscle to the anterior aspect of the vertebral body. 20 mg of methylprednisolone in 3 ml 0.5% bupivacaine injected following lesion production may reduce the severity of post sympatholytic neuralgia.

DISCUSSION

Radiofrequency lesioning is a neurodestructive procedure. Therefore, it has to be considered as an end-of-the-line procedure where conservative therapeutic modalities have failed. The physician getting involved in radiofrequency procedures must have appropriate training and experience prior to carrying out such neurodestructive procedures. All of these procedures are done under fluoroscopic guidance after appropriate test stimulation and verification of the tissues about to be destroyed. The different temperatures have various levels of neurodestructive capabilities. It is very rarely necessary to have numbness or motor paralysis as a consequence of the lesioning. The tissues can be injured anywhere along the passing of the needle probe if there is a break in the insulation; therefore, supermaximal motor stimulation is always part of the procedure before lesioning is carried out in the event the insulated portion of the needle passes near a motor nerve such as in lumbar sympathetic lesioning, and if there was a break in insulation, one may end up not only with neurodestruction of the lumbar sympathetic ganglion but also the neurodestruction of a lumbar nerve root which definitely is not the desired outcome. It is

certainly recommended that one reads and gets familiar with information regarding such topics as radiofrequency lesioning as well as observes or trains through a fellowship program prior to carrying out procedures. A handy little reference book by M.T. Kline (9) is a good starting point. When one considers neurodestructive procedures, radiofrequency lesioning can have definite advantages over alternative neurodestructive procedures, primarily because the lesion is precise, it does not spread, and it cannot go to distant sites. The proximal and distal spread of the lesion beyond the uninsulated tip of the probe is only one millimeter, and the cross sectional diameter of the lesion is five to six millimeters of the type of lesions that one is using in clinical practice. The listed advantages include

- 1) well-controlled lesion size;
- 2) temperature monitoring in the core of the lesion by the built-in thermal couple;
- 3) electro placement is verified under fluoroscopic guidance by electrical stimulation and impedance monitoring;
- 4) procedure can be carried out with patient cooperation under local regional anesthesia;
- 5) recovery period following lesioning is swift, and the final recognition of the effectiveness of the lesion is within approximately four weeks;
- 6) low morbidity and mortality from the lesioning itself; however, the probe is in dangerous areas, and extreme care must be exercised in carrying out the injection of local anesthetic and steroids;
- 7) procedure can be repeated;
- 8) appropriate patient monitoring must be carried out as radiofrequency equipment can interact with pacemakers and spinal cord stimulators.

The equipment utilized in carrying out procedures must be safe, precise, reproducible, producing reproducible results and should include the following parameters:

The equipment must have the ability to

- 1) measure impedance;
- 2) have the ability to stimulate wide range of frequencies;
- 3) accurately time the duration of the lesion for accurately measuring the temperature in the core of the lesion tissue;
- 5) accurately measure and indicate amperage and voltage;
- 6) have the ability to gradually increase temperature with time.

Patient selection criteria should include the following:

- 1) Non-evasive conservative measures have failed.
- 2) Drug seeking behavior has been identified and dealt with, such as narcotics, sedative, alcohol, and patient has been entered into such program to resolve the issues in addition to symptom control. This does not apply to cancer pain.
- 3) Appropriate psychological assessment and therapy has been carried out for issues like depression, anxiety, anger and secondary gain. And patient has been entered into appropriate behavioral management program.
- 4) The patient accepts the role that has been assigned by involvement in lifestyle changes addressing psychological issues and interact with physicians and therapists and psychologists in an appropriate manner.
- 5) Fully-informed consent, including recognition of realistic expectations and procedural risks are fully understood.

Procedural considerations must be preceded by full awareness of the anatomy, pain pathways, anticipated outcomes, and the need to have a multi-disciplinary team around the individual carrying out such procedures.

The most commonly used procedures include neurodestructive procedures around about facet joints in the neck (Fig.1) thoracic, lumbar and lumbar cervical areas. Anterior

compartment pain from lumbar disease can be solved by lesioning the anterior communicating branch. (10) Radiofrequency lumbar ganglionotomy, partial rhizotomy, sacral ganglionotomy, thoracic ganglionotomy, cervical ganglionotomy (Fig. 2), cervical facets, discs, nerve roots, myofascial tissues, sphenopalatine ganglion and radiofrequency lesioning of the stellate ganglion via the interior approach have been quite useful at C6, 7, and T1 areas.

The widest experience that has been gained, especially in neurosurgical circles, following the description by Sweet, et al, has been the radio frequency lesioning of the trigeminal ganglion. (11) The most studied and very well indicated procedure, especially in the treatment of cancer pain, is the technique of percutaneous cordotomy that has resulted in excellent unilateral pain relief especially affecting the torso on the contralateral side of the lesioning. The hazards of the procedure include worse pain in conditions where the patient outlives the duration of the lesioning, as well as the hazard of Ondine's Curse, if bilateral lesioning is carried out. The incidence of radiofrequency cordotomies, even in cancer pain, seem to have decreased since the introduction of spinal narcotics, and the other neuroaugmentation procedures, such as spinal cord stimulation in patients who have responded especially favorably to more modern forms of cancer therapies. It is especially tragic when complications of therapy such as permanent numbness or, in rare instances, development of neuropathic pain persist and the cancer is no longer a problem. As a general rule, deafferentation type pains do not respond to radiofrequency lesioning.

Special caution should be exercised in patients who have sensing pacemakers as the consequence of radiofrequency lesioning may very well be a period of asystole unless their pacemaker has an override. This of course can be prevented by appropriate monitoring of the patient. An additional problem that has not been fully documented but where a word of caution is in order concerns close distance radiofrequency lesioning, such as in stellate

ganglion radiofrequency thermolcoagulation, with patients who have cervical spinal cord stimulators. The current may actually pass in the direction of the spinal cord stimulator, and the possibility of spinal cord involvement appears to be a concern. We have no information in terms of long term effect, but data needs to be gathered.

At this time there are double blind studies going on in terms of appropriate location for facet lesioning in the cervical area that very likely will influence the practice of radiofrequency lesioning for cervical facet joint disease in the positive direction. The clinical impression is that radiofrequency lesioning is indeed a very useful technique that needs to be substantiated by studies. The equipment that has been used by most centers is the Radionics RFG-B and the newer RFG-F3C in attaining the appropriate lesioning in the appropriate sites.

Because all of these procedures are carried out under fluoroscopic control, the physician should exercise all caution in minimizing radiation exposure and injury to the patient as well as to the physician.

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