Radiofrequency for the Treatment of Chronic Pain

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Radiofrequency-Induced Lesions in Chronic Pain Therapy

Following the initial attempts of Harvey Cushing, around 1920, who used radiofrequency (RF) in electro-surgery, research advanced toward 1950, and in the next 3 decades the technique was perfected, with the aim of improving control of the damaged area. Similarly, the development of multifunction electrodes has become essential for monitoring the procedure and improving safety.

Although numerous neurodestructive techniques with selective applications have been used in the central or peripheral nervous system in recent decades, RF techniques are the most efficacious and most widely used. The advantages of RF techniques over other neurodestructive techniques can be used as follows:

- The lesion can be controlled.
- Electrode temperature can be controlled.
- Electrode position is verified by stimulation test and impedance registry.
- Most RF techniques require only sedation or local anesthesia.
- There is a short recovery time after the procedure.
- Morbidity and mortality rates are low.
- The lesion can be reinduced in cases of neural regeneration.

PRINCIPLES OF RADIOFREQUENCY-INDUCED LESIONS

The basic principle of the RF technique consists of an electricity-generating source applied to an insulated electrode, whose distal end is not insulated, situated in or near the vicinity of nervous tissue. The electrical impedance of the surrounding tissue permits the flow of current from the generating source to the same tissue.\(^1\) The voltage of the generator is established between the electrode (active) and the ground plate (dispersive) placed on the patient's arm or leg. Body tissues complete the circuit, and the RF current flows through the tissue, producing an electric field. This electric field creates an electric force in the ions of tissue electrolytes that produces rapid motion and friction. The frictional dispersion of the ionic current within the fluid causes tissue warming. The heat produced by RF energy is generated in the tissues, which thus heats the tip of the electrode and not vice versa.\(^2\) At this moment, the temperature of the electrode tip is the same as the most hyperthermic zone of the tissue. As the current flows from the tip of the electrode to the tissue, the warmest zone of the lesion is found where the current is densest, that is, in the tissue closest to the electrode tip.\(^1\)

In this way, the size of the lesion produced can be controlled by thermal coagulation, because lesion size depends on the temperature of the damaged zone, the length and diameter of the active tip of the electrode, and the vascularity of the tissue. Modern cannulas are equipped with electrodes that accurately measure the temperature.

In 1972, Alberts et al\(^3\) found that frequencies higher than 250 kilocycles per second (kHz), approximately 500 kHz, should be used to avoid undesirable responses because more uniform and better circumscribed lesions are obtained. Although direct current and low-frequency alternating current are easy to generate, they do not facilitate good control of lesion size, the effects of the stimulation are painful at the lesion site, and therefore they are not used. Given that high frequencies, between 300 and 500 kHz, were also used in radiotransmitters, the current was called radio-frequency. The first RF generator commercialized by Aranow and Cosman carne onto the market at the end of the 1950s.

Thermal balance is achieved at an exposure time of approximately 60 seconds but varies in richly vascularized tissue zones. In highly vascularized tissue, more time is required to obtain thermal balance because blood vessels tend to destabilize this balance, allowing heat to flow away. The most appropriate method of controlling lesion size is to maintain a con-
stant temperature of the electrode tip for 1 to 2 minutes. Occasionally, shorter lasting lesions can be induced with higher temperatures, as in the case of percutaneous cordotomy by RF.

The size of the lesion also depends on the diameter of the electrode and the length of the noninsulated (active) tip of the electrode. In 1984, Cosman and co-workers' first established that, with the active tip at 75°C, the size of the lesion increases by approximately 20% after a lesion induction time of 30 seconds. After 60 seconds, the size of the lesion does not increase further.

According to the experimental work of Bogduk et al.,4 RF lesions do not spread distally from the electrode but radially around the active tip, in the form of an oblong spheroid with an actual maximum radius of 2 mm, using a 21-gauge (G) electrode with a 3-mm active tip. Other authors5-6 have concluded that the size of the lesion does not increase significantly after 20 seconds when different lesion times are used with the same temperature.

The effects of RF current on nerve fibers is still controversial. Some studies suggest that heat may modify nerve function so that the harmful transmission is interrupted in nonfunctional fibers while other neural functions will remain intact. RF heat damages only nonmyelinated or thinly myelinated fibers (C and A delta fibers), which are involved mainly in pain transmission, whereas the myelinated A and AB fibers remain intact.7 Other studies8-11 were unable to reproduce this "specificity phenomenon," and presently it is assumed that all nerve fiber types are being damaged when a conventional RF lesion is produced.

It is still required that experimental studies reproduce the conditions under which RF-induced lesions are applied in current clinical practice.

ELECTROMAGNETIC FIELDS

Doubts have arisen recently as to whether heat alone is the decisive factor causing RF lesions because heat is not the only factor during production of the lesion. Surrounding tissue is also exposed to an electromagnetic field (EMF), and these fields exert notable physiologic effects, particularly on the cellular membrane. This has led to an investigation of the so-called isothermal RF procedures.10n Theoretically, an EMF can be applied in three ways without generating heat:

- By breaking the circuit by disconnection from the ground (creates an EMF without producing heat because there is no current)
- By producing an RF lesion with a temperature of 42°C (applying very low voltage)
- By applying pulsed RF (pRF), which consists of an active cycle during which an EMF is applied with heat generation and a silent phase to permit elimination of the heat. Studies using computerized models indicate that the active cycle should not exceed 20 msec/sec to maintain the active tip at a temperature of 42°C. Comparison of results shows pRF to be a most effective method, and a special pRF option is available on a lesion generator (RFG-3C Plus, Radionics).

The RF-EMF procedure has the following characteristics:

- Unlike the heat-induced lesion, which increases with the application time, EMF extension is constant.
- The heat lesion is neurodestructive, whereas the EMF lesion is not; furthermore, no transient sensory deficit has been observed.
- Vascularization around the electrode decreases the extension of the heat effect. In the EMF procedure, the vascularization enhances the efficacy because a greater output of the generator can be used without raising the temperature beyond 42°C.

This method offers some advantages:

- Because it is not neurodestructive, the EMF technique can be used in cases of neuropathic pain or in target structures where conventional RF cannot be applied, such as the C8 dorsal root ganglion.
- Postlesion discomfort is less than with conventional RF.
- RF-EMF presents no permanent sensory deficit as a complication, whereas sensory deficits do sometimes occur with conventional RF.

RF-EMF also has its disadvantages:

- RF-EMF is not useful as a technique for producing sensory deficit, as in the case of trigeminal neuralgia.
- RF-EMF is not a useful technique for seeking effects at a distance from the electrode because the heat diffuses, whereas RF-EMF does not, for example, in the intervertebral disc.

The method still requires validation through double-blind studies.

Sluijter (personal communication, Sept. 2001) stated that, at Durham University, basic research has shown that by treating C6 dorsal root ganglia in rats with pRF, the wide dynamic range (WDR) cells of the dorsal horn showed an increased c-fos gene expression in acute and middle terms. This finding could provide a neurophysiologic basis for the effect of pulsed RF on neural tissue.
CONCEPTS OF SPINAL MORPHOLOGY AND IMPLICATIONS FOR THERAPY

The difficulty in treating chronic spinal pain necessitates the study of the anatomy and pathoanatomy of the components of the vertebral column commonly involved in the genesis and perpetuation of chronic spinal pain. The backbone possesses numerous potential pain generators. In fact, every structure in the spine that is innervated can be a potential source of pain. Some areas identified by neuroanatomic dissection include the annulus fibrosus (AF) of the disc, posterior and anterior longitudinal ligaments, some portions of the discal sheath, zygapophyseal articulations and their capsules, spinal nerve roots and dorsal root ganglia, sacroiliac articulation and its capsule, and associated musculature. Several specific RF techniques have been developed for zygapophyseal articulations, nerve roots, and sacroiliac articulation. To date, no specific RF techniques have been described for the treatment of pain of dural or articulation. To date, no specific RF techniques have been developed for zygapophyseal articulations, nerve roots, and sacroiliac articulation. Several specific RF techniques have been developed for zygapophyseal articulations, nerve roots, and sacroiliac articulation. To date, no specific RF techniques have been described for the treatment of pain of dural or ligamentous origin, or at trigger points.

Descogenic Pain

The intervertebral disc may be a source of pain. In 1947, Inman and Saunders\textsuperscript{14} showed how the discs receive innervation and are therefore potential sources of pain; however, until the last decade,\textsuperscript{15} this concept was side-stepped, leading to confusion and diagnostic errors in the question of discogenic pain. From an anatomic viewpoint, the fact that the disc may be a source of pain is not currently under debate.

Data on disc pathology are incomplete and circumstantial, although the experimental reproduction of pain does not correlate with degeneration of the disc but with the degree of fissures found in it.\textsuperscript{16-17} Three grades of intensity with which the fissures penetrate the annulus have been defined.\textsuperscript{18} The term internal disc disruption (IDD) signifies that the internal architecture of the disc is broken, while the external surface remains normal, with no protrusion or herniation. Pathologically, IDD is characterized by nucleus pulposus (NP) matrix degradation and the presence of radial fissures that reach the external third of the AF.\textsuperscript{15-19} This condition cannot be diagnosed clinically, although it is demonstrable by disc stimulation and postdiscography computed tomography (CT). A strong correlation exists between pain reproduction and the presence of grade 3 fissures,\textsuperscript{16} and can be defined as paradigmatic in the field of lumbar pain.

Internal disc disruption may be painful because of enzymatic nociception, the metabolic products implicated in the degenerative process of the disc, and mechanical activation of AF nociceptors.

Some studies of patients with chronic lumbar pain have shown the prevalence of internal disc disruption to be at least 39%. This prevalence points to internal disc disruption as the most frequent cause of objectively demonstrable chronic lumbar pain.\textsuperscript{20}

Finally, it should be mentioned that pain conditions that have prompted greater clinical dedication to spinal pain, such as muscle pain and trigger points, are associated with less scientific evidence; a great void exists of scientific data on the pain mechanisms in these conditions, and no reproducible diagnostic tests have been established. In contrast, the greatest amount of scientific information is available\textsuperscript{21} for the less frequently diagnosed conditions, such as sacroiliac joint pain, zygapophyseal articulation pain, and internal disc disruption. Prevalence data indicate that these conditions are common, comprising over 60% of patients with chronic lumbar pain.

Zygapophyseal Articulations

Zygapophyseal articulations (ZA) are innervated by the medial branch of the dorsal ramus.\textsuperscript{22-23} In 1933, Ghormley coined the term facet syndrome, and over the past 2 decades the entity has acquired great clinical importance. Standard criteria for diagnosing facet syndrome include anesthesia of one or more ZAs, although the high rate of false-positive results has invalidated the test.

In two studies,\textsuperscript{24-25} the prevalence of ZA pain ranged between 15% in a sample of North American workers who underwent RF-induced lesions, and 40% in a population of elderly patients in Australia reeled in a rheumatology unit, with confidence limits of 10% to 20% and 27% to 53%, respectively.

ZA pain thus occurs among patients with chronic lumbar pain and is very common; it constitutes an independent disorder because it is rarely associated with discogenic pain or sacroiliac articulation pain.\textsuperscript{26} Postmortem studies\textsuperscript{27} and radiologic surveys\textsuperscript{28} have shown that lumbar ZA very often involves osteoarthritis. Although it has been claimed that zygapophyseal arthritis is secondary to disc degeneration and spondylolisthesis, it may be an independent entity in approximately 20% of cases.\textsuperscript{27} Data on the diagnostic value of CT are controversial, which suggests that the diagnosis of painful zygapophyseal arthropathy should be considered using plain radiology.

Sacroiliac Articulation

The sacroiliac articulation (SA) is innervated by branches of the dorsal rami L4-5, S1, and S2, which run to the posterior sacroiliac and interosseous sacroiliac ligaments.\textsuperscript{29} In fact, the sacroiliac articulation receives branches from the obturator nerve, lumbo sacral trunk, and superior gluteal nerve,\textsuperscript{30} although controversy exists as to whether the innervation stems from the dorsal and ventral zones or is exclusively posterior.
The articulation may be a source of lumbar pain, with a variable reference pattern toward the lower limb. Rigorous studies have demonstrated that SA pain can be diagnosed by using intra-articular injections of local anesthetic. In patients with chronic lumbar pain, the prevalence of SA pain is approximately 15%. The pathology of the pain is unknown, although occasionally ventral capsula disease may be observed. Although SA pain is common in patients with chronic lumbar pain, it can be diagnosed only with the use of articulation blockade with local anesthetics.

CHARACTERISTICS OF DIVERSE RADIOFREQUENCY LESIONS

**Facet Denervation**

Facet denervation consists of producing an RF lesion of the medial branch of the posterior primary branch that innervates the zygapophyseal articulation. Although incorrectly called "rhizolysis," because the root is not damaged, the term survives. The aim of the procedure is to interrupt completely the medial branch because the danger of causing sequelae by deafferentiation does not exist when a small area is innervated.

The lesion is produced at 80°C for 60 seconds, when a temperature monitoring system (SMK-system) is used. The procedure must be performed at various vertebral levels because an intersegmental crossing exists in the innervation. The procedure is generally safe and free of complications in expert hands.

**Sympatholysis**

Sympatholysis by RF can be used in two pathologic circumstances: in the treatment of sympathetically maintained pain such as complex regional pain syndrome, and in pain caused by deafferentiation of the anterior zone of the discal annulus fibrosus, interrupting the fibers that travel with the sympathetic system toward the neuronal body in the dorsal root gan-glon (DRG).

Complications seldom arise from the sympatholysis itself. In rare instances, the lower extremity can become red, edematous, and hyperthermic; however, recovery is generally spontaneous.

In Sympatholysis of the superior cervical ganglion, Horner's syndrome is produced in approximately 2% of cases and remits spontaneously, although it may persist for several months. Complications do not tend to arise in Sympatholysis by RF of the damaged ganglion when performed by experienced practitioners.

**Radiofrequency Lesion Adjacent to the Dorsal Root Ganglion**

Producing this type of lesion usually is performed in refractory cases of monosegmental pain. The lesion should not be produced inside the DRG because it causes total fiber destruction and, consequently, deafferentiation sequelae. If the sensory stimulation threshold is too low (below 0.3-V), the electrode should be repositioned at a safer distance. Although not the cause of microscopic changes, the lesion does induce degenerative changes in the ganglion, which are demonstrable by histochemical techniques. Since 1998, the application of pRF on the DRG seems to be as effective as the conventional RF heat lesion.

There are several advantages of pRF over conventional RF. First, as far as we know, the pRF technique is not damaging to the nerve; second, it can be used for treating neuropathic pain conditions; and third, with little postprocedure discomfort, pRF allows the treatment of several levels in the same operative session.

**Radiofrequency Lesion of the Intervertebral Disc**

This procedure is used in treating discogenic pain. The particular properties of the intervertebral disc should be borne in mind:

- The disc is avascular.
- The center of the disc has very low electrical impedance, indicating very high conductivity to heat.
- The vertebral end plates of adjacent vertebrae act as insulators.

These properties contribute to establishing an ample lesion, with the heat expanding as far as the annulus fibrosus, heating this structure enough to reduce the activity of fine fibers and nerve endings. The effect is probably increased by generation of heat within the annulus, originated by the high current required to heat the active tip of the electrode because of its low impedance and high conductivity.

It has not been possible to reproduce experimentally the discal damage caused by this procedure. Magnetic resonance imaging studies of the disc show no variation or modification in the height of the disc several years after the procedure. Similarly, producing a lesion in extradiscal structures is not acceptable because the annulus fibrosus is surrounded by vascular tissue that would eliminate the heat emitted by the annulus.

**Diagnostic Blockades before Production of Radiofrequency Lesion**

To establish a correct diagnosis and rule out pathologic causes for which treatment is available, the following are required: a detailed anamnesis, an appropriate physical examination, neurophysiologic studies, and other tests, if indicated, together with psychological...
assessments if suffering or psychoaffective alterations are concomitant with the chronic pain condition.  

Although occasionally an anatomic substrate, which may justify the patient's pain, is not found, particularly in spinal disorders, the selective use of diagnostic blockades can aid in the diagnosis of the origin of the pain. Spinal innervation is profuse and complex. According to current knowledge, only the yellow ligament and venous plexuses are not innervated; thus, all remaining spinal structures should be considered potential sources of pain.

It has been demonstrated that pain referred by a particular spinal segment may originate in different structures at different levels. The only exception to multisegmental innervation of spinal structures could be the ventral dura, which is innervated at a specific level in its lateral zone and devoid of innervation at its middle part, receiving more or less a monosegmental innervation.

It is important to consider that the multisegmental and bilateral innervation patterns may occasionally cal for bilateral blockades at several levels. Moreover, the finding that spinal innervation, particularly in the ventral compartment, shares common pathways with autonomic nerves (e.g., sympathetic trunk and rami communicantes) may suggest that the autonomous nervous system plays a role in the maintenance of spinal pain, with corresponding therapeutic repercussions.

Furthermore, it is necessary to stress the importance of physical examination of the patient during the latency and pharmacologic action periods of the local anesthetic, with the aim of establishing a correlation between the response to pain and the presence of accompanying physical signs and symptoms.

Once the temporary response to a diagnostic blockade has been verified, the RF or thermal lesion should be considered because this type of lesion offers as its main advantage exact control or limitation of the lesioned area. Such control does not occur in chemical neurolysis because the neurolytic fluids that are injected may spread unpredictably, causing unexpected complications.

Similarly, the RF lesion is preferable to the cryolesion because the latter remains for shorter periods of time, usually not exceeding several months.

The sole aim of a diagnostic blockade is to verify the cause of the pain. Although not totally specific, it is useful in some pain conditions. The false-positive result usually is caused by the spread of local anesthetic into tissues or different structures off the target; thus, a radiologic contrast medium should always be used to ensure correct location of the cannula and to judge the spread on injection of the contrast. A small volume of local anesthetic should be administered to avoid false-positive block. The false-negative result is usually caused by the injection of local anesthetic into a highly vascularized area or an intramuscular region.

Poor communication between the physician and the patient may cause false-positive results, a negative block, or both.

The following diagnostic blockades are currently considered useful in clinical practice:

- Sphenopalatine ganglion blockade
- Sympathetic chain blockade at different levels
- Segmental neural blockade
- Ramus communicans blockade
- Intervertebral disc blockade

The diagnostic blockade of zygapophyseal articulations, widely used in the past, has proved to be of insufficient specificity owing to the frequent extra-articular diffusion of the local anesthetic solution; therefore, its efficacy is now in doubt. The medial branch block with local anesthesia of the posterior ramus is probably more reliable.

In some cases, it is not easy to distinguish between pain originating from the dorsal and ventral spine compartments because they may share common symptoms. Both compartments are closely related in the lumbar spine because they originate in the same "triartricular complex" (three-joint complex). In these cases, selective blockades are of value because the diagnosis of the ventral compartment syndrome is established by the positive response to blockades of the sinuvertebral nerves, rami communicantes, and sympathetic chain. Blockades of the rami communicantes and sympathetic chain are of prognostic value owing to the possibility of producing RF lesions in these structures. At present, the sinuvertebral nerves, which are responsible for the posterior innervation of the ventral compartment, cannot be selectively blocked. This represents a disadvantage because the discal disease of the posterior zone, particularly at the L4-5 and L5-S1 levels in adults, is clinically more significant. In these cases, Sluijter reported positive results in a series of patients following lesions of the rami communicantes.

Another indication for producing RF-induced lesions in the rami communicantes is in treating pain originating from a so-called burned-out disc, in which the disc is so degenerated that there is too little substrate for an RF disc lesion.

Radiofrequency Lesion Methodology

To produce an RF lesion, follow the following steps:

1. Access the target structure using the RF electrode cannula, using radiographic visualization and a C-arm in different views. The tunnel vision technique is often used, with the x-ray beam parallel to the electrode.
2. Obtain neurophysiologic confirmation of the correct positioning of the cannula by electrostimulation.
A. Administer sensory stimulation at 50 Hz to confirm the proximity of the target structure.

B. Administer motor stimulation at 2 Hz to confirm absence of motor fibers in the vicinity.

3. Administer local anesthesia to the target structure.

4. Induce the lesion by RF:
   A. Apply conventional RF (thermocoagulation), typically at 80°C to 82°C for 60 to 90 seconds. B. Apply pulsed RF (electromagnetic fields), typically at 40°C to 42°C for 120 seconds.

Techniques for RF-produced lesions are described in the appendix of this chapter. It is important to remember that an adequate facility, equipment, and needles are required, along with a trained staff, to ensure good outcome with the procedures (Fig. 31-1A-C).

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Radiofrequency Techniques

1. GASSERIAN GANGLION

Tic douloureux was the standard type of neuralgia for which neurolytic block treatment was tried. In 1902, Pitre treated trigeminal neuralgia for the first time by injecting alcohol into the nerve.47 He was followed by other authors who gave this technique a great deal of publicity. By 1905, Schlosser48 had reported 68 cases of severe trigeminal neuralgia treated successfully by alcohol nerve block. According to Cushing,413 Hartel was the first to block the gasserian ganglion (GG) itself with alcohol. In the early 1930s, Kirschner50 began to use radiofrequency neurolysis, using diathermy to produce high-current lesions of the gasserian ganglion, for relief of trigeminal neuralgia, the first report in medical literature to use radiofrequency for the treatment of chronic intractable pain.

Putnam and Hampton,51 who reported 18 cases of trigeminal neuralgia and four cases of oral carcinoma, recommended radiographically guided control during the procedure. Their procedure used 0.5 mL of 5% phenol, and they were the first to publish the use of phenol as a neurolytic agent for the treatment of this condition.

In 1983, Håkansson52 advocated injecting the GG with glycerol; however, although good results have been reported, interest in glycerol has recently decreased. From 1969 through 1986, Sweet and Wepsic developed percutaneous thermal retrogasserian rhizotomy for the treatment of trigeminal neuralgia.53

A. Indications

- Idiopathic cranial nerve V neuralgia
- Some secondary cranial nerve V par neuralgias (e.g., multiple sclerosis)
- Alleviation of cancer pain in the head and neck
- Alleviation of pain resulting from acute trigeminal herpes zoster (using pRF)

B. Contraindications

- Neuropathic pain in the trigeminal area
- Local infection, sepsis
- Coagulopathies
- Increased intracranial pressure
- Major psychopathology

C. Material

SMK* needle: 10 cm, 22-gauge (G); 0.2-cm active tip

D. Patient position

Patient is in a decubitus supine position. Frontal mentonian plane parallel to the table. Head secured to the table with lateral bands. E. Anesthesia

- Superficial intravenous sedation (e.g., propofol or methohexital [Brevital]); the patient must be able to collaborate when the stimulation test is performed.
- Local anesthesia of the zone to be incised is not needed. F. Anatomic references

1. The GG contains sensory and motor fibers of the face, nasal and oral mucosae, teeth, and anterior two thirds of the tongue, and motor fibers for the masticatory muscles.
2. The GG links with the autonomic nervous system through the ciliary, sphenopalatine, otic, and submaxillary ganglia, and communicates with the oculomotor, facial and glossopharyngeal nerves.
3. Entry point: 2 to 3 cm lateral to the corner of the mouth, homolateral to the lesion.
4. Homolateral pupil
5. Cannula should be inserted following the bi-sector (45 degrees) of the sagittal plane, which passes through the pupil and the frontal-menton plane at the level of external auditory meatus. G. Radiographic technique

1. Oblique projection: Lateral inclination of approximately 30 degrees toward the side of the lesion, with a caudal inclination of approximately 30 degrees. The mentonian arch must be seen and, in the upper internal quadrant to it, the foramen ovale submentovertex projection (Fig. 31-2A).
2. Lateral projection: Performed when the cannula has been inserted into the foramen ovale. This lateral view is useful to calculate the insertion of the cannula into the bony tunnel of the foramen ovale. The tip of the cannula must not exceed 2 mm from the plane of the clivus (see Fig. 31-26).

*Refers throughout to SMK disposable carnudas, COTOP International, Amsterdam, the Netherlands.
H. Risks and complications
   Hemorrhage at the insertion site; perform compression.
   Perforation of the oral cavity; to avoid this, the cannula should be guided with the index finger placed intraorally.
   If leakage is abundant, dural puncture occurs. In such cases, continuation of the technique must be assessed. If cerebrospinal fluid is not abundant, the procedure may be continued. I. Stimulation parameters
   Voltage: 0 to 1 V
   Sensory: 50 Hz; paresthesia induced between 0.05 and 0.3 V must be noted in the painful zone.
   Motor: 2 Hz; at 0.6 to 1 V there must be no or only minimal motor contraction of the masseter muscle. If no motor contraction occurs, the tip of the needle is positioned in branches I or II of cranial nerve V. J. Lesion parameters
   First lesion: 60 seconds at 65°C. When the lesion has been induced, check the bilateral corneal reflex and pain sensitivity in the neuralgic and contralateral zones.
   Second lesion: 60 seconds at 70°C. Proceed in a similar manner as above.
   Third lesion: 60 seconds at 72°C to 75°C. Proceed in a similar manner as above.
   Fourth lesion: This may be assessed at 75°C if pain involves two branches of cranial nerve V. K. Comments
   Because RF thermocoagulation is painful, the patient is given a short anesthetic sleep using a suitable dose of intravenous anesthetic. Intravenous anesthetic may sometimes be supplemented by intermittent nasal insufflation of a nitrous oxide-oxygen mixture during each coagulation to accelerate anesthesia and recovery. The patient must be conscious between each coagulation so that sensory testing of the face can take place. The end point is reached when the desired division of the trigeminal nerve has become slightly analgesic but not anesthetic. Usually, at approximately 70°C, analgesia occurs, and further coagulations are performed at the same temperature until some analgesia is produced in the required division. At this stage, the time for each coagulation can be increased or decreased; however, if the temperature is increased without first trying extra time, anesthesia will suddenly develop. Analgesia produced by this method tends to increase over the first 2 hours. If slight leakage occurs during the procedure, it should be considered a consequence of the ganglion puncture, with the risk of a cerebrospinal fluid fistula being minimal.
   Weakness of the homolateral masseter muscle may occur during the postoperative period. During the lesion induction periods, correct ventilation of the patient must be ensured; therefore, oxygen must be administered with a mask.
   Sequential throbbing of the cannula may occasionally be observed during the early seconds of lesion induction. This movement is due to the fact that in conventional RF, current is emitted every 0.66 seconds but in pulsed RF current is emitted every 20 milliseconds.
   Pulsed RF is not useful in the treatment of cranial nerve V neuralgia. It is indicated in treating postherpetic cranial nerve V par neuralgia, together with other pharmacologic therapies, and in managing the painful sequel of "anesthesia dolorosa" in the cranial nerve V territory by conventional RF, with variable results.
2. SPHENOPALATINE GANGLION

A. Indications
- Sphenopalatine (SP) neuralgia
- Migraine headache
- Cluster headache
- Pain in T and N distributions of cranial nerve V

B. Material
- SMK needle: 10-cm, 5-mm active tip and KF curved blunt 10-cm, 10-mm active tip

C. Patient position
- Patient in supine decubitus position
- Head secured to the table with lateral bands
- Superficial intravenous sedation

D. Anesthesia
- Mild intravenous sedation (e.g., propofol) if needed
- Local anesthesia of the zone to be incised
- Patient should be monitored by electrocardiography and pulse oximetry

E. Anatomic references
1. The sphenopalatine ganglion (SPG) is located in the pterygopalatine fossa just posterior to the middle turbinate, lying 1 to 9 mm deep to the lateral turbinates; it is the largest nerve center outside the cranial cavity.
2. The sphenopalatine fossa is located at the end of the petrous bone, below the sphenoidal sinus (Fig. 31-3).
3. The puncture site is located below the zygomatic arch and between the mandibular arch, in the posterior zone.

F. Radiographic technique
1. Lateral projection: Define the sphenopalatine (SP) fossa, sella turcica, clivus, and petrous bone. The SP fossa is situated below the anterior portion of the petrous bone, which underlies approximately the clinoid apophysis, anterior to the sella turcica. Insert the needle perpendicular to the skin, as far as the SP fossa (see Fig. 31-3A).

G. Stimulation parameters
- Voltage: 0 to 1 V
- Sensory: 50 Hz; 0, 3 to 0, 4 V. Sensory stimulation is considered positive when paresthesias are achieved in the palate, and particularly in the nasal region. If the stimulation occurs only in the palate, insert the cannula slightly medial and cephalad.
- Motor: 2 Hz; verify absence of maxillary contraction

H. Lesion parameters
- Prior to performing the lesion, inject 1 mL of 2% lidocaine (some authors use lidocaine injection as a prognostic blockade).
- First lesion: 60 seconds, 80°C, administered in the sphenopalatine fossa

2. Using a lateral projection, place a metallic marker above the SP fossa. Perform the puncture in the upper zone of the mandibular arch and progress perpendicularly until the patient notices paresthesia in the jawbone.

3. Anteroposterior (AP) projection: Vary the radioscope at an AP projection and advance the cannula medially until it is adjacent to the lateral wall of the nasal cavity. Insert the cannula 1 to 2 mm until it slides within the recess (see Fig. 31-3B).

4. The tip of the needle should pass over the vomer bone by approximately 1 to 2 mm; care should be taken not to pierce the partition between the nostrils.

G. Risks and complications
- Lesion of the second branch of cranial nerve V may occur in the initial section of the puncture.
- Nasal hemorrhage: Five percent of patients present with epistaxis. Do not discharge the patient until hemorrhage resolves. In rare cases, placement of a nasal tamponade is needed and should be performed by an otolaryngologist.
- Infection
- Numbness of upper teeth or hard palate

FIGURE 31-3 A, Lateral view of the base of the skull showing the sphenopalatine fossa. B, Posteroanterior view of the nasal and maxillary regions. The sphenopalatine ganglion is within the lateral wall of the nasal cavity.
Second lesion: 60 seconds, 80°C, administered somewhat more medially (1 to 2 mm)
Third lesion: 60 seconds, 80°C, administered somewhat more medially (3 mm)
Pulsed RF may be used. To induce a single lesion, administer for 4 minutes; or, to induce three lesions, administer for 1 minute each, in diverse locations, in the same way as with conventional RF. However, the 10-cm, 10-mm active tip needle can be used.

J. Comments
Correct placement of the electrode is always controlled by impedance (normally, approximately 250 milliohms [mil]). If an air space (e.g., nostril) is reached, impedance increases significantly (to between 800 and 1000 mil).
Postoperative discomfort of 2 weeks' duration may ensue. Some patients present with decreased sensitivity in the soft palate side of nose and upper lip.

3. STELLATE GANGLION

The stellate, or cervicothoracic, ganglion (SG) is formed by the two inferior cervical ganglia and the first segmental thoracic ganglion. It is situated on the lateral edge of the transverse process muscle between the base of the seventh cervical transverse process and the neck of the first rib. The SG contributes to the sensorimotor process of the sympathetic function of the upper limbs, neck, and face.

SG blockade has been used for a range of pathologic conditions, including glaucoma, neuritis of the optic nerve, heart failure, arrhythmia, and pulmonary embolism. It is currently used in the treatment of painful conditions of the facial and cervicobrachial region, and in the treatment of hyperhidrosis and intractable angina pectoris.

Generally, the anterior paratracheal route is used for the SG approach, with the administration of local anesthetic solutions such as bupivacaine, ropivacaine, or lidocaine. If the painful syndrome responds to the SG blockade, the procedure is usually repeated once or several times.

Since 1992, the RF-induced lesion of the SG has been used with selected patients, at least 50% of whom reported pain relief following previous local anesthesia blockade. The main advantage of the RF-induced lesion is the ability to limit or control the lesion, with fewer adverse effects than other neurolytic procedures, particularly chemical neurolysis. A. Indications
Complex regional pain syndrome (CRPS) types I and II
Raynaud's phenomenon
Upper limb hyperhidrosis
Chronic, painful facial conditions
Chronic, painful cervical conditions
Intractable angina pectoris
If the pain is located in the hand, assess T2-3 sympathectomy because a significant number of sympathetic fibers stem from T2-3. The SG is a combination of the inferior cervical sympathetic and first thoracic ganglia and forms a diffuse structure lying on the longus colli muscle, on the lateral anterior edge of the C7 vertebral body. Inducing partial SG lesions may produce high-quality, long-term pain relief.

B. Material
POLE-RC COTOP needle: 60-mm, 24-G, for anesthetic blockade
SMK CIO needle; 22-G needle for RF lesion

C. Patient position
Patient is in a decubitus supinus position, with cervical hyperextension.

D. Anesthesia
Mild intravenous sedation, if needed
Local anesthesia of the zone to be punctured.

E. Anatomic references
1. Sternocleidomastoid muscle, medial edge
2. Palpate the carotid artery; the carotid artery is kept aside with the tips of the fingers of the contralateral operating hand.

F. Radiographic technique
1. AP projection: With caudal-cranial rotation
2. Target: C7 pedicle (internal part). The thoracic sympathetic chain runs through the bony canal formed by the pedicle and the vertebral bodies.
   The needle is inserted to make contact with the C7 transverse process just lateral to its origin from the lamina. The tip of the needle must be in contact with bone.
3. Oblique projection, 30 degrees. In an oblique projection, the needle tip should lie anterior to the anterior border of the intervertebral foramen. The correct position of the needle tip is at the union of the C7 vertebral body with the transverse apophysis.
4. Inject 0.3 to 0.5 mL iohexol and observe diffusion in the sympathetic chain. Inject 2% lidocaine, which acts as a prognostic test (relieves pain in local anesthetic latency time) (Fig. 31-4). Neither the contrast nor the needle enters the foramen.
5. A total of 0.2 mL of contrast is injected to confirm - the characteristic spread and to rule out intravascular positioning of the needle tip.

G. Risks-and complications
Radicular and vertebral artery puncture
Phrenic nerve and recurrent laryngeal lesion

H. Stimulation parameters
Stimulation is important to avoid producing lesions
Perform three lesions in a triangular pattern to interrupt the fibers of the cervical sympathetic chain.

Conventional RF: Administer 30 to 60 seconds at 80°C.

If the patient suffers intense cervical pain during the lesion induction, interrupt the procedure because the recurrent laryngeal nerve may be damaged. J. Conunents

The lesion produced does not interrupt the entire ganglion. This technique may be repeated if the clinical situation persists. This SG lesion does not usually produce Horner's syndrome. If this syndrome occurs, it is transient and resolves spontaneously.

4. DENERVATION OF CERVICAL FACETS C2-6

Although chronic spinal pain often has a complex mechanical or radicular etiology, sympathetic involvement may dominate the pain condition, producing individual clinical profiles in which more than one structure is involved in the pain syndrome.

The treatment of cervical pain syndromes poses challenges for the clinician. Effective alleviation of pain, although a difficult task, is achieved in over 80% of cases, in experienced hands.

During the last decade, much work has led to new approaches for treating amenable cervical structures with RF-induced lesions and to identifying new syndromes based on advances in anatomy and neurophysiology. Pain emanating from facet joints usually leads to local cervicalgia and may be amenable to treatment with RF denervation, or medial branch neurotomy.

When selecting patients for RF denervation of cervical facets, a clear distinction must be established between radicular, segmental, referred, and related pain prior to the therapeutic indication. The most frequent cause of radicular pain is degenerative changes in discs and facet joints, which irritate the exiting segmental nerve in the intervertebral foramen. These patients require assessment for surgical treatment to be sure that no surgical pathology exists. Referred pain to the shoul-der, or brachialgia, without dermatomal distribution is a common cause of cervical facet pain in the midcervical area. In this area, referred pain to the maxillary area may be of facet origin in the upper cervical area, owing to ongoing noxious input in the upper cervical area and participation of the caudal nucleus of cranial nerve V, which descends the cervical spinal cord to level C3.

Attention must be paid to related pain conditions such as atypical facial pain, cervicogenic headaches, and cluster headaches. In these chronic pain syndromes, correct physical examination, imaging studies (including functional radiography), and differential di-
agnosis are essential because "cervicogenic headache" and "cervical migraine" respond to radiofrequency treatment, whereas tension headache and "classic migraine" do not. A. Indications

Pain originales in cervical facet articulations, which produces cervical pain, and in the scapular girdle (belt). Referred pain (ear, facial pain, headache) is frequent.

Cervical facet blockade with local anesthetic may be performed prior to performing the RF lesion. Roots of C2, C3, and C4 have connections with the superior cervical ganglion. Roots of C4 are interrelated with the deep petrous nerve, reaching the vidian nerve and the sphenopalatine ganglion. For this reason, some alterations in the cervical column may produce referred pain in the maxillary region.

B. Material

COTOP 23-G, 6-cm needle (0.5-cm active tip) C.

Patient position

Patient is in a supine decubitus position Head secured with side bands D. Anesthesia

Superficial intravenous sedation E.

Anatomic references

The facet joints are innervated by the posterior primary ramus of the segmental nerve, which leaves the segmental nerve immediately after it exits from the foramen, and runs posteriorly adjacent to the spine in the transversal plane from the caudal part of the intervertebral foramen. Determine the cervical horizontal plane from the mastoid insertion of the sternocleidomastoid muscle. Entry points are marked at the posterior border of the sternocleidomastoid muscle at the level of the caudal part of each relevant foramen.

F. Radiographic technique

1. During a facet denervation, it is very important to ensure that the insertion plane of the needles is situated posterior to the plane that joins the posterior margins of the intervertebral foramina. Radiographic projections used are oblique projection to insert the needle, lateral projection to progress to the lamina, and AP projection to ensure that the needle is in the cavity adjacent to the spine.

2. Oblique: 20 to 30 degrees to correctly view intervertebral foramina. Mark 1 to 2 cm below the line of the spinal apophyses.

3. Puncture below the external jugular vein.

4. Target: Upper edge of the pedicle, except in C2 (midportion of the pedicle or articular process). Insert needles starting with C6 and in an upward direction (approximately 10 degrees) (Fig. 31-54).

5. The puncture is perpendicular to the skin. If paresthesia occurs due to radicular puncture, the needle is too far forward.

6. The position for performing the lesion in C2 is somewhat different. The primary posterior C2 ramus is larger than the anterior ramus. To perform a facet denervation, only some branches of the primary posterior C2 ramus, which innervate the C2-3 facet, are damaged. The electrode should be placed on the vertebral arch of C2 at the level of the upper edge of the intervertebral foramen of C3.

7. Lateral projection: Advance the needle as far as the middle portion of the laminae (see Fig. 31-5B).

8. AP projection: Check the tips of the needles in the articular process cavity. The tip of the needle should always be in contact with bone. The frontal projection is performed after the sensitivity test at all levels to be treated. When repositioning the needles, the tips must be carefully situated anteriorly, maintaining contact with bone and leaving the tip just a few millimeters posterior to the intervertebral foramen (see Fig. 31-5C).

9. Examine for rotation of vertebrae. Rotated vertebrae could distort the theoretical position of the needle with standard radiographic views. G. Risk

Puncture of the vertebral artery, nerve root (if the puncture is very anterior), and the medulla (if the puncture is very posterior). Use of curved blunt needle reduces these risks. H.

Stimulation parameters

Scale: 0 to 1 V

Pulse duration: 1.00 second

Sensory: 50 Hz. A tingling or pressure sensation, of different quality from that felt previously by the patient, is achieved with a desirable level below 0.5 V (e.g., in the neck and shoulder).

Motor: 2 Hz; should be negative. A certain degree of fasciculation in paracervical musculature may exist. Motor stimulation may not be required if anatomic references are correct on radiography. I. Lesion parameters

Inject 2% lidocaine, 0.3 mL through each cannula. Reposition needles if necessary.

60 to 90 seconds, 20 V (75°C to 80°C). Temperature is not used as a control because the mandrel is not inserted, but is achieved by creating a direct circuit with this type of needle.

2.0 to 2.4 W; 97 to 120 mA; 19 to 20 V

If the patient feels pain during the lesion induction, decrease the voltage from 20 to 15 V in order to avoid temperature above 80°C. J. Comments

Reinject lidocaine whenever necessary. If a large quantity of local anesthetic is injected, the provo-
cation test is modified before inducing the lesion, but this is not important for the lesion.

Begin with the fifth needle and work upward (C6-2).

Mark the target 1 to 2 cm below the apophysis plane, below the jugular vein.

Guide the needle slightly anteriorly and upward, always in contact with bone.

At the C7-8 level, perform the procedure with the patient in a prone decubitus position (as in thoracic and lumbar facet denervation).

The usual practice is to treat four to five facets in one session.

The electrical connection for needle stimulation must be made with the diathermia cable because it ensures better contact.

A C2 lesion can be performed with pulsed RF to avoid paresthesia and postlesional occipital pain owing to its proximity to common sensitive fibers of the great occipital nerve (Sluijter, personal communication, Sept. 2001).

In short necks, it is often difficult to reach C6 by a lateral approach. In these cases, a posterior route must be used, with the patient in the prone decubitus position; also, in such cases, the C5 level appears to be situated in the cervicothoracic skin fold.

When local anesthetic is injected prior to performing the lesion, the needle should be repositioned. The needle should be reinserted until the tip touches the periosteum, because it may be discretely rejected owing to pressure of the liquid injected.

A crossing of sensitive fibers exists between the two sides of the vertebral column. The nerve plexus that is formed from the sinuvertebral nerves is situated over the posterior longitudinal vertebral ligament and runs through the anterior part of the vertebral canal. Occasionally, the development of pain, or cervicobrachialgia, contralateral to the side previously subjected to facet denervation, warrants a new operation on this side if signs of facet involvement are found.

5. CERVICAL DORSAL ROOT GANGLION

The accepted mechanism for producing analgesia by means of an RF-induced lesion is the destruction of nervous tissue and, consequently, the reduction of the
nociceptive input. The RF lesion induced adjacent to the dorsal root ganglion (DRG), however, causes only transitory sensory loss, whereas the relief of pain may be of much longer duration.

The pain relief could be explained by the selective action of heat on unmyelinated C fibers, but such a selective effect has not been confirmed by pathologic studies. At present, some evidence has been published to support the hypothesis that the effect of an electromagnetic field (EMF) may be instrumental in causing the clinical effect of the RF lesion adjacent to the DRG. The clinical effect of EMF, however, should be attributed to the electrical field, because the magnetic field is of insignificant intensity.

Caution is mandatory, because this lesion may potentially produce pain by deafferentation. Thus, strict patient inclusion criteria must be accomplished before performing a DRG lesion; include the following:

- Chronic pain with radicular distribution lasting more than 6 months
- Condition refractory to conservative therapies
- No indication of surgical intervention
- Absence of sensory abnormalities in the dermatome
- Positive response to prognostic segmental nerve block

A. Indications

- Treatment of discogenic or segmental pain secondary to spinal nerve disease
- Cervicobrachialgia of monosegmental origin
- RF of the C2-3 DRG may be useful for treating refractory C2-3 facet pain

B. Material

- SMK 10-cm needle (active tip, 0.4-0.5 cm) with thick necks
- SMK 54-mm, 22-G needle (active tip, 0.4 cm) with thin necks

C. Patient position

- Patient is in a supine decubitus position
- Head secured to table with side bands

D. Anesthesia

- Light intravenous sedation
- Local anesthesia before RF lesioning

E. Anatomic references

1. RF of the DRG is performed with the same technique, from levels C3 to C8. Access is situated at C3, at the anterior edge of the sternocleidomas-toid muscle, and common carotid artery pulsation is observed. At lower levels, access is through the aforementioned muscle. F. Radiographic technique

2. Oblique projection, 30 degrees: Locate C3 to C5 foramina (except in C2). The first round foramen in the oblique view is the C3 foramen in the cervical column. The DRG is located between the middle and lower thirds of the foramen. Insert the needle using the tunnel vision technique

(see earlier) as far as the foramen (the needle tip will be at 6 o'clock in the posterior foraminal canal) (Fig. 31-6A)

2. AP projection: The tip of the needle should reach halfway through the articular process. The cannula must stay on the "floor" of the canal to remain at a distance from the vertebral artery. Perform a stimulation test.

3. When the intervertebral foramen is reached, bone must be touched at the dorsal caudal part of the canal; the needle is then withdrawn and discretely inserted 2 mm, until the ganglion or its surroundings are reached.

4. Inject contrast: The contrast is seen in the ganglion and also extraspinally (extraforaminal). It does not enter the medullary canal (see Fig. 31-6B).

5. The target is not in the nerve, but adjacent to the nerve.

6. Using this technique, damage to motor fibers is avoided, and the chance of puncturing the vertebral artery is minimized (the vertebral artery is positioned in the ventral part of the foramen). G. Risks

- Puncture of the nerve root, the vertebral artery, and the spinal cord, injection into segmental artery and the spinal cord infarction.

H. Stimulation parameters

- Scale: O to 1 V
- Sensory: 50 Hz. A tingling sensation in the corresponding dermatome must be obtained between 0.3 and 0.7 V.
- Motor: 2 Hz. Motor fasciculations should not occur below at least 1.5 V, which is the threshold value required to achieve sensory stimulation at 50 Hz. Do not perform a lesion if radiating pain and muscle contraction occurs during stimulation, because it indicates proximity to a motor nerve. In this case, the needle must be repositioned more dorsally.

If muscle contraction without radiating pain is obtained with motor stimulation, the lesion may be performed, provided the motor stimulation parameter is 1.5 times higher than that required to elicit sensory stimulation. I. Lesion parameters

- Inject 1 mL of 2% lidocaine and wait 10 minutes for it to take effect.
- First lesion: 120 seconds, 42°C, or 45 V, pulsed RF; temperature not higher than 42°C.
- A further option is to perform a thermal lesion (90 seconds, 62°C to 67°C, depending on the results of stimulation parameters). J. Comments

- Consider injecting steroids after inducing the lesion (<40 mg of triamcinolone) to prevent neuritis.
The aim of an RF-induced lesion in the DRG is to provoke a mild lesion while preserving touch, motor function, and proprioception. Wait 4 to 6 weeks to observe the results of the procedure. The patient may notice sensory changes in the first few weeks. Foraminal stenosis may occur: caution must be observed with conventional RF, because the lesion may expand due to tissue changes that affect electrical and heat conductivity. The method requires meticulous attention to detail because cases of irreversible neurologic damage have been reported.

6. THORACIC SYMPATHECTOMY (T2-3)

A. Indications
   - Segmental radiation pain, with sympathetic burning component at upper dorsal levels Complex regional pain syndrome (CRPS) type I (upper limb)
   - Hyperhidrosis of upper limbs
   - Intractable coronary pain and tachyarrhythmias

B. Material
   - SMK 10-cm needle, 23-G; active tip, 0.5 cm; 10-cm curved blunt Racz-Finch needle with 10-mm active tip and introducer needle C.

C. Patient position
   - Patient is in a prone decubitus position, with pillow under the chest

D. Anesthesia
   - Superficial intravenous sedation
   - Local anesthesia of the zone to be incised

Finger plethysmography and skin temperature measurements can be used to document sympathetic denervation.

E. Anatomic references
   - Vertebral bodies C7, T1-3

The sympathetic chain is situated at this level, posterior and lateral to the vertebral body. F. Radiographic technique

1. First view: Oblique projection, 15 to 30 degrees, toward the side of the lesion, with approximately 10 to 30 degrees cephalad-caudal rotation of C-arm to allow visualization of vertebral body of T2 and T3. Two skin wheals are raised 5 or 6 cm lateral to the midline on the side to be sympathectomized. The needle must lie 2 to 5 mm lateral and rostral to the rostrocaudal midpoint of the second and third thoracic vertebral body, beneath the head of the third rib (Fig. 31-7A).
2. Second view: Lateral projection X-ray. At this level, the sympathetic chair is more posterior than at lower levels. The needle tip is inserted to the junction of the medial and posterior thirds of the vertebral body (see Fig. 31-7B).

3. Repeat the procedure at level T3. G.

Risks
Pneumothorax H.

Stimulation parameters
Sampling: 0 to 10 V
Sensory: 50 Hz; no response up to 1.5 to 2 V
Motor: 2 Hz; no response up to 2 to 2.5 V I.

Lesion parameters
Pulse RF: 42°C, 120 seconds.
Conventional RF: 60 seconds, 80°C, if Stimulation parameters do not indicate closeness to intercostal nerves. A second conventional RF lesion, ad-ministered for 60 seconds, can be repeated. J. Comments

For T2 and T3 sympathectomy, a total of six RF lesions are made, two at each of three sites adjacent to and ventrolateral to the second and third thoracic vertebrae.

If local anesthesia at one of the rostral sites produces Horner's syndrome, this would obscure assessing the risk of producing Horner's syndrome from subsequent, more caudally placed lesions. Because creating Horner's syndrome must be avoided, the most caudal site is anesthetized and treated first, saving the most rostral site for last.70.

At the conclusion of the procedure, the patient's chest must be examined by auscultation, and a chest radiograph must be obtained to exclude the possibility of pneumothorax. The patient must be informed of the possibility of delayed onset pneumothorax. Advise against air travel for a couple of days, and repeat chest radiographs should be ordered prior to such activity. The use of the curved blunt needles has reduced the incidence of pneumothorax. At discharge from the day surgery unit, patients must be instructed to avoid vigorous activities for several days.

SPLANCHNIC NERVES

Splanchnic nerves transmit the major part of nociceptive input from the viscera. A subset of patients who fail to obtain relief from celiac plexus block can obtain pain relief with splanchnic nerve block.

Kappis introduced splanchnic anesthesia in 1914, reporting a series of 200 cases; however, the technique was criticized by contemporary colleagues and rapidly abandoned, owing to the high complication rate and unexpected side effects of the chemical neurolytic agents that were used.

Interest in this technique has been regenerated by the introduction of the CT-guided approach and, recently, by the use of RF-produced lesions.75-76 Raj and associates reported good outcome with RF lesioning using the Racz-Finch curved blunt needles. A. Indications
Palliation of acute pancreatitis
Diagnosis of sympathetically mediated abdominal pain
Pain secondary to malignancies of the retroperitoneum and upper abdomen B.

Material
Curved blunt Racz-Finch 15-cm needle; active tip, 15 mm
16-G introduces cannula for skin entry prior to RF blunt needle insertion
Two 10-mL plastic syringes, one each with local
Radiofrequency for the Treatment of Chronic Pain

anesthetic and steroid (for injection after stimulation and before lesioning)

One 10-mL syringe with contrast (iohexol) C.

Patient position

Patient is in the prone decúbitos position, with a cushion under the abdomen D.

Anesthesia

Light intravenous sedation

Local anesthesia of the points to be injected E.

Anatomic references

The splanchnic nerves are contained in a narrow compartment formed by the vertebral body medially and the pleura laterally, the posterior mediastinum ventrally, and the pleural attachment to the vertebra dorsally. The compartment is limited caudally by the crura of the diaphragm. The volume of this compartment has been determined to be approximately 10 mL on each side (Fig. 31-SA). F.

Radiographic technique

1. First view, AP projection: The T12 vertebral body is identified, and a mark is made on the T11 or T12 vertebra.

2. Second view, oblique projection, approximately 25 to 30 degrees: The edge of the diaphragm lateral to the vertebral body is viewed. If the diaphragm shadows the T12 vertebra and its rib, then the T11 is identified. The point of entry for both levels is at the junction of the rib and vertebra. The tip of the needle is advanced anteriorly, bearing in mind that the needle hugs the lateral aspect of the T11 or T12 vertebral body, close to the costovertebral angle.

3. Third view, lateral: The needle needs to lie on the midthird portion of the lateral side of the T11 or T12 vertebral body. The needle should remain retrocrural and posterior to the descending aorta. The needle is aspirated for fluid, which may be blood, air, or chyle.

4. If the aspiration is negative, oblique views are then taken to confirm the final position of the curved needle on the vertebral body. Target sites on T12 vertebral body on the lateral view: the superior and anterior one third. On T11: the inferior and middle one third. In the oblique view, inject 5 mL iohexol to flow medially to the interpleural space, above the crus of the diaphragm and anterior to the foramen (see Fig. 31-8B).

G. Stimulation parameters

Scale: 0 to 1 V. Impedance should be below 250 mil

Sensory: 50 Hz; up to 1-V stimulation may be felt by the patient in the epigastric region. If stimulation is sensed around intercostal spaces, in a girdle-like fashion, the needle needs to be pushed anteriorly.

Motor: 2 Hz; up to 3 V may be used. If intercostal muscle contraction is negative, test stimulation is satisfactory.

H. Lesion parameters

Inject 2 to 5 mL of local anesthetic with 40 mg triamcinolone through the RF needle.

Lesion: 80°C, 90 seconds

A second lesion is performed at the same setting by turning the RF needle 180 degrees.

When bilateral neurolysis is required, the same procedure is performed on the opposite side. I.

Risks and complications

Pneumothorax

Kidney injury

Damage to blood vessels (aorta, inferior vena cava, and the artery of Adamkiewicz), particularly when using chemical neurolytic agents

These complications can be observed when using a lateral entry 6 to 8 cm lateral to the spinous process of T12 or T11 over the rib. Complications can be reduced by staying close to the paravertebral border, approximately 3 to 4 cm lateral to the TU to T12 spinous processes.

FIGURE 31-8 * Splanchnic nerve, lateral view: trunk.
8. LUMBAR SYMPATHETIC CHAIN

Radiofrequency percutaneous lumbar sympathectomy is a procedure for permanent interruption of the lumbar sympathetic chain that involves less morbidity than open surgical techniques or chemical sympatholysis. A. Indications

Peripheral vascular disease, such as arteriosclerotic and vasospastic Raynaud's phenomena, frostbite

Complex regional pain syndrome, types I and II B. Material

SMK 15-cm needle (active tip, 0.5 cm), Racz-Finch curved blunt 10-mm active tip needle with introducer C. Patient position

Patient is in the prone decubitus position, with a pillow under the abdomen. It is important to eliminate as much lumbar lordosis as possible by this maneuver. D. Anesthesia

Light intravenous sedation

Local anesthesia of zones to be incised E. Anatomic references

The lumbar sympathetic chain carries preganglionic fibers that descend from the lower thoracic chain, sending rami communicantes to the first and second lumbar segmental nerves. It passes forward on the psoas fascia lying along the anterolateral aspect of the vertebral bodies and medial border of the psoas muscle. Beginning posteriorly, the diaphragm is pierced; the chain passes anteriorly and then falls posteriorly as it approaches the promontory of the sacrum. The point at which the sympathetic chain no longer lies on the psoas muscle (i.e., where the psoas muscle diverges laterally from the vertebral column) is where it varies from the upper third of L3 to the upper third of L5.\textsuperscript{79}

In the sagittal plane, the lumbar ganglia are most often present opposite the middle of the body of the third vertebra, L3, and at the discs above and below. In the horizontal plane, the ganglia lie from 0 to 0.5 cm posterior to the anterior border of the third lumbar vertebra and 1.8 to 3.0 cm laterally from the center of the third lumbar vertebra.\textsuperscript{80,81} The aorta lies anteromedially to the left chain, whereas the vena cava lies anterior to the right chain. The segmental spinal vessels lie posterior to both chains.

The rami communicantes to and from the lumbar ganglia pass in tunnels formed by the ligamentous attachments of the psoas muscle to the sides of each vertebral body (Figs. 31-9 and 31-IQ4, B).

Great variability exists with regard to the branches given off by the sympathetic chain. Grey rami leave the ganglia to join spinal nerve roots and may number as many as three nerves to one root, or one ganglion may give rise to three nerves that pass to three separate spinal nerves. F. Radiographic technique

1. First view, oblique projection, 15 to 20 degrees (until the vertebral body "covers" the transverse process): Mark the point of entry of the needle below the transverse process and in line with the lateral edge of the vertebral body. Rotate C-arm to allow visualization of vertebral body. Puncture 6 to 7 cm from the midline.

2. Second view, lateral projection: The needle tip is 2 cm behind the anterior edge of the vertebral body (see Fig. 31-9B)

3. Third view, AP projection: The needle tip progresses 1 cm within the vertebral body, inferior to the pedicle (see Fig. 31-9A). The needle is correctly positioned when the tip is behind the facetal line while in bone contact with the vertebral body.

4. Verify the needle's position with 1 mL of contrast. If the contrast spreads into the psoas or into the sheath, the tip is too lateral and should be repositioned more medially. If the contrast is behind the facetal line, the tip is in the appropriate place. There should be no resistance when injecting contrast. G. Risks

Puncture of roots and paravertebral vessels

Lesion of genitofemoral nerve

H. Stimulation parameters

Scale: 0 to 10 V

Sensory: 50 Hz; the patient will feel vague discomfort in the back with 0.2 to 0.5 V. If paresthesia exists in the groin at the L2-3 level, reposition the cannula (due to proximity of the genitofemoral nerve).

Motor: 2 Hz; there are no fasciculations up to 3 V. I. Lesion parameters

Inject 1 mL 2% lidocaine before producing the lesion.

RF: 80°C, 60 to 90 seconds

The lesion should extend to 10 mm in L2 and 15 mm in L3-4. This is achieved by inserting the L3 to L4 cannulas 5 mm. A 15-mm lesion is required in L5. It is advisable to use 15-cm curved blunt Racz-Finch needles with 10-mm active tip. J. Complications

Intravascular or subarachnoid injection, neuralgia, and muscular spasm.

Retrograde ejaculation is rare in sexually active men. Bilateral sympathectomy is rarely indicated.

Postoperative discomfort lasts for approximately 5 days.

Neuralgia may occur owing to the spread of the neurolytic material into a somatic nerve root. The nerve most susceptible to this complication is the genitofemoral nerve.\textsuperscript{81}

K. Comments
Produce a lesion of L2 if there is lumbar pain, L3 if pain is in spine or knee, L4 if pain is in lower limb, and L4 and L5 if pain is in ankle or foot. Several lesions may be performed at different levels.
Before the RF procedure, it is advisable to perform a diagnostic blockade using 1% lidocaine (or 0.25% bupivacaine) to avoid false-positives (e.g., injection of somatic nerves). For lower extremity sympathetic block, the level needs to be at L2-4, and if the foot is involved, block L3-5. No sensory or motor blockade should be produced.

9. L2 COMMUNICATING RAMUS
Percutaneous facet denervation and percutaneous partial rhizotomy have traditionally been the minimally invasive RF techniques used in the treatment of back pain. Recent advances in knowledge of the innervation of the anterior vertebral compartment have led to the development of performing RF lesions close to the exiting segmental nerves, with the aim of interrupting part of the afferent impulses from the anterior mechanical compartment. Based on anatomic considerations, the following technique describes the approach of the communicating ramus of the segmental nerve with the lumbar sympathetic chain, suitable for interruption by means of an RF lesion (see Fig. 31-10A, B). A. Indications
Discal pain, occurring at either single or multiple lumbar levels
Complex pain of vertebral structures
B. Material
SMK 145-mm Radionics Pole needle; active tip, 0.5 cm or 10- to 15-cm curved blunt needle used with an introducer C.
Patient position
Patient is in the prone decubitus position, with a pillow under the abdomen.
D. Anesthesia

Superficial intravenous sedation

Local anesthesia of the zone to be injected E.

Anatomic references

The communicating ramus branches off the segmental nerve immediately after it exits from the foramen. While the segmental nerve continues its path in a caudal, lateral, and anterior direction, the communicating ramus runs anteriorly, in close contact with the vertebral body en route to the sympathetic chain.

Although there are anatomic variations, the typical communicating ramus runs deep to the psoas muscle; however, it also may run between the psoas fibers or may be embedded in the connective tissue of the intervertebral disc. Two communicating rami may even branch off from one segmental nerve. Therefore, the relationship with the vertebral body is variable, but the proximal part of the communicating rami usually runs adjacent to the middle or caudal part of the vertebral body.⁴⁶

F. Radiographic technique

1. First view, oblique projection, approximately 30 degrees toward the side of the lesion: Caudal oblique 25 to 30 degrees. Observe the following references:
   a. Transverse process
   b. Neural foramen

The vertebral body must be approached in the space formed in this view by the transverse process, vertebral body, and superior edge of the segmental nerve. Beware of the rotated spine, in which the reference points will change. Be cautious with the variability of the L2 communicating ramus; in patients with degenerative disease, it is even more distorted.

2. Mark the point of entry of the needle below the transverse process and in line with the lateral edge of the vertebral body. Rotate C-arm until vertebral body is visualized. Puncture 6 to 7 cm from the midline.

3. The initial target lies under the inferior edge of the transverse process and 1 to 2 cm from the anterior edge of the vertebral body. The needle advances, touching the periosteum of the vertebral body in its middle portion, and finally reaches the central point of an imaginary cross traced on the vertebral body on a lateral view. If accidental contact is made with the segmental
nerve, withdraw the needle slightly and correct the position in a more cranial direction.
4. A prominent iliac crest may be a problem for the L5 communicating ramus. In most patients, the area is accessible, but rotating movements have to be made with the C-arm to determine the most advantageous projection.
5. Second view, lateral projection: The tip of the needle in the lateral view should be situated in the middle portion of the L2 vertebral body, touching the periosteum, and in a position behind (exactly at the lateral edge of the vertebral body) the lumbar sympathetic chain, because the L2 communicating ramus is in contact with bone. Check the needle's position with 1 mL of contrast (see Fig. 31-10).
6. Third view, AP projection: Correct needle position is behind the facet joint line while in bone contact with the vertebral body. Check the position with 1 mL of contrast. If contrast spreads into the psoas or sheath, the tip is too lateral and must be repositioned (more medially). If the contrast is behind the facet line, the tip is in the right place. There should be no resistance on contrast injection. The contrast dot must be located closely lateral to the vertebral body and just caudal to the transverse process. G. Risks
Puncture of root and paravertebral vessels Lesion of genitofemoral nerve H. Stimulation parameters Scale: 0 to 1 V Sensory: 50 Hz; patient feels discomfort from 0.2 to 0.5 V. Observe in L2 whether radiating pain to the groin occurs. If so, reposition the needle because proximity to the genitofemoral nerve is indicated. Motor: 2 Hz; no response should be elicited. I. Lesion parameters RF; 80°C, 60 to 90 seconds
J. Comments
The L2 communicating ramus lesion should be considered whenever sympathetic pain of discal origin is determined. In these cases, diagnostic °block followed by RF lesioning of the L2 ganglion can be carried out.

The L2 communicating ramus lesion is particularly useful when discal pain is present at several levels. Coldness of feet can indicate sympathetic involvement.
Performing the communicating ramus lesion should be preceded by a prognostic local anesthetic (0.3 mL 1% lidocaine) in the L2 communicating ramus. After 1 to 2 minutes, if the pain disappears, the RF lesion procedure can proceed at a setting of 80°C for 60 seconds. In the case of spinal fibrosis postdiscectomy, the combination of pulse RF of DRG L5 (discectomy level L5-S1) and later an L5 communicating ramus lesion, after a test with local anesthetic, can be used.

10. LUMBAR DORSAL ROOT GANGLIA
If prognostic blockades of the posterior (facets) and anterior (discs) compartments have been negative and the pain is located in the lower limb, then selective radicular blocks can be considered. It is common for a patient also to report lumbar pain, and the determination must be made whether to treat mechanical lumbar pain with referred pain to the limbs, or pain caused by spinal nerve pathology. Once a referred mechanical origin of the pain has been ruled out, diagnostic blockades of spinal nerves and sympathetic chains should be performed to ensure against a sympathetically maintained pain (SMP), because the treatment is different.

Pain by deafferentation, postherpetic neuralgia, thalamic syndrome, multiple sclerosis, and SMP should not be treated with this procedure. The aim of this technique is to produce a well-defined lesion in the DRG while maintaining the unaltered afferent input. It is not desirable to produce dysesthesia-paresthesia in the injured zone. If dysesthesia-paresthesia is produced for a prolonged period of time, pain by deafferentation will be produced.

Cells of the DRG are more sensitive to heat than other structures, and for this reason the clinician uses a differential heat-induced lesion to affect nerve pathways while leaving motor innervation, proprioception, and afferent pathways relatively intact. High temperatures are more likely to produce afferent decrease (input) and provoke pain by deafferentation. If several ganglia are to be treated, it is better to space the procedures at intervals over 1 month. A. Indications
Chronic pain of spinal radicular origin, with segmental distribution, that does not respond to conservative therapies where surgery is not indicated B. Material
SMK 10- to 15-cm needle; active tip, 0.5 cm
C. Patient position
Patient is in the prone decubitus position, with a pillow under the abdomen
D. Anesthesia
Mild intravenous sedation
Local anesthetic of the points to the injection sites E. Radiographic technique
1. First view, AP projection: Locate the level below the pedicle, parallel to the inferior vertebral hiatus
2. Second view, oblique projection at 15 to 20 degrees: Locate foramen to be treated. Paramedial
puncture 7 to 8 cm from midline. Trace a line between the iliac crest and foramen, parallel to the inferior vertebral hiat. Follow the direction of the previously traced line with the needle, particularly if performing an L5 injection.

3. Third view, lateral projection: Advance the needle as far as the upper third of the foramen where the dorsal root ganglion is located.

4. Fourth view, AP projection: Inject 1 mL of contrast and visualize the nerve root.

5. With an oblique, 30- to 40-degree view, clearly visualize the neural foramen to be injected. Direct the needle to the upper dorsal square. Check the position of the needle tip with an AP view. It should be on the facet line. Verify the tip of the needle in the AP and lateral positions prior to initiating the stimulation (Fig. 31-11).

F. Risks

Neuritis is rarely observed in practice because pulse RF does not produce a lesion, but reorganization of the electromagnetic fields and the temperature should not exceed 40°C to 42°C. G. Stimulation parameters

Scale: 0 to 1 V
Sensory: 50 Hz; reproduce the pain or paresthesia in the territory between 0.2 and 0.5 V.
Motor: 2 Hz; evoke motor fasciculations with the voltage necessary to achieve sensory stimulation, although occasionally twice the voltage is required.
Impedance: Approximately 200 to 300 mil

With sensory stimulation (50 Hz), the patient should note paresthesia in the affected dermatome with less than 0.5 V. Paresthesia felt with less than 0.3 V verifies proximity to the ganglion. Ideal stimulation is between 0.2 and 0.5 V, with 50 Hz.

An evident dissociation must exist between the sensory and motor stimuli such that the voltage required to produce paresthesia with 2 Hz must be at least double the voltage necessary to produce paresthesia with 50 Hz. If this dissociation is not observed, the needle is not aligned with the ganglion, and producing this lesion is not recommended. For example, paresthesia is evoked at 50 Hz with 0.3 V, and fasciculations are evoked at 2 Hz with 0.6 V. Before performing the lesion, inject 2 mL of 2% lidocaine and wait 10 minutes. H. Lesion parameters

First-pulse RF lesion: 120 seconds, 40°C to 42°C Second-pulse RF lesion: 120 seconds, 40°C to 42°C Third-pulse RF lesion: 120 seconds, 42°C RF lesion: 60 seconds, 67°C (at a lower stimulation threshold, decrease the lesion temperature). The lesion can be performed only by conventional RF when sensory stimulation is achieved with high voltages (>1 V), indicating that the zone may be affected by scar tissue. I. Comments

Inject 40 mg triamcinolone and 2 mL 2% lidocaine after performing the lesion. Contrast may be injected, although in a small quantity (0.2 to 0.3 mL), to check the position of the needle. For the correct approach of an RF-produced lesion of the DRG L5, bear in mind that the iliac crest will cover the direction used in upper levels for the DRG lesion. Thus, a more medial direction must be taken. The tip of the needle will reach the DRG directly instead of being positioned in parallel, as in upper levels.

11. DENERVATION OF LUMBAR FACÉS

The dorsal spine compartment is innervated by the medial and lateral branches of the dorsal ramus. The articular facets are innervated by the medial branch of the dorsal ramus of the superior segment and one or more segmental levels.

The multisegmental organization of spinal innervation has an effect on spinal pain therapy because, in the absence of a technique for selectively producing a lesion of the sinuvertebral nerve in the treatment of dorsal compartment or articular facet syndromes, the target structures are the medial branch of the dorsal rami of spinal roots or nerves and, in ventral compartment syndromes, the target structures are the sympathetic chain and the communicating ramus.

The dorsal compartment syndrome, or articular facet syndrome, usually presents nonspecific symptoms; its diagnosis is therefore based on some common clinical criteria: (1) medial and/or paravertebral hemi-or bilateral lumbar pain, either continuous or during most of the day; (2) absence of neurologic deficits; (3)
pain on pressure on paravertebral masses; and (4) pain on lumbar hyperextension.

The pain is usually deep, and nonsegmental radiating pain together with limited lumbar mobility are common. Occasionally, the pain occurs when the patient maintains a posture or in continued exercise such as walking.

Radiologic signs are not specific, and in many cases radiographic study is normal or is accompanied by inflammatory or degenerative signs (e.g., arthritis, dislocation, discopathy, spondyloarthritis). A. Indications

Lumbar facet pain syndrome

B. Material

SMK 10- to 15-cm needle (active tip, or curved blunt or sharp RFK, 0.5 to 1 cm) C.

Patient position

Patient is the prone decubitus position, with a large pillow under the abdominal region

D. Anesthesia

Superficial intravenous sedation

Local anesthesia in the points to be injected E.

Radiographic technique

1. First view, oblique projection, 5 to 15 degrees: Visualize the facet articulation and Luschka's canal between the superior articular and transversa process. Tilt the craniocaudal x-ray head (toward caudal) (Fig. 31-12A, B).

2. Second view, AP projection: Check the position of the needle in Luschka's canal.

3. Third view, lateral projection: The needle is in the articular mass, without reaching the foramen (see Fig. 31-12C). Five points should be lesioned in a patient with facet disease, at L4-5 and L5-S1 (see Fig. 31-12).

First target: Superolateral margin of foramen S1

Second target: Upper medial zone of the sacral groove

Third target: Upper and medial zones of L5 transverse process

Fourth target: Upper and medial zones of L4 transverse process

Fifth target: Upper and medial zones of L3 transverse process

In the third, fourth, and fifth targets, there is union of the transverse process with upper articular face. Vary the craniocaudal orientation of the radiogram for appropriate visualization of the target.

4. Puncture point is 5 to 6 cm from midline, with an infernal tilt of approximately 10 to 15 degrees.

5. Insert needle in chosen points.

a. First needle (S1): The tip of the needle reaches the external superolateral margin of the foramen, but does not enter the foramen, b. Second needle (L5 in the sacral groove): The cannula slides along the edge of the perios-teum and enters 2 mm to align the cannula with the nerve.

b. With the third, fourth, and fifth cannulas, an oblique view (5 to 15 degrees) is used to visualize the most medial aspect of the transverse apophysis. The cannula must be parallel to the nerve because the degree of the lesion is determined by the length of the injured nerve. Once the five cannulas are in place, it is advisable to measure the impedance, which is usually above 300 mfi (range, 300 to 700 mu). Verify (with lateral radiograph) that the tips of the L3, L4, and L5 cannulas are posterior to the foramina.

Minor congenital anomalies of the lumbar and sacral structures may often be seen and render determination of the target sites more difficult. Oblique positioning, stimulation, and structural imagination on the part of the surgeon also play important roles. Additional lesions may be required to cover the probable variant pathways of zygapophyseal joint nerve filaments. Decide on prepuncture examination which facets are to be treated by applying pressure 2 to 3 cm from the midline. The level above and below the painful facet should be treated. Occasionally, it is necessary to perform a treatment at the sacral level. Blockade of S1 to S3 requires a craniocaudal oblique radiographic view.

F. Risks

Segmental root puncture G. Stimulation parameters Scale: O to 10 V Sensory: 50 Hz, between 0.2 and 0.5 V: evoke paravertebral and hip paresthesia Motor: 2 Hz; must be negative at 2 V H. Side effects

Lower limb weakness, probably due to lidocaine extravazation; resolves in 1 to 2 hours

Paravertebral and gluteal discomfort for 1 to 2 weeks

Hip pain usually begins on the third day and may last 10 days. Treat with nonsteroidal anti-inflammatory drugs (NSAIDs). The pain may be due to a spasm of the quadratum lumborum muscle. I. Comments

Ghormley was the first to use the term facet syndrome, in 1933, to indicate the relationship between facet joint disease and low back and leg pain. In 1971, Skyrme Rees was the first to use partial denervation of the facet joints, using a stiletto-like knife in the structures adjacent to the lumbar facet joints. Shealy modified the technique by using a percutaneous RF thermocoagulation probe similar to that used for percutaneous cordotomy.
FIGURE 31-12 * Target sites for lumbar facet denervation.
Very few controlled studies have been published on the efficacy of this technique in articular facet syndrome. Following the initial modification of the technique by Shealy, which was carried out by Bogduk and Long in 1980,87 based on anatomic data, several prospective controlled studies with placebo have reported good results.88-90

12. SACROILIAC JOINTS

A. Indications

Sacroiliac pain: The pain is usually located in the gluteus and referred to the groin, hip, and the thigh through its anterior plane and calf. The pain is more intense in the morning and remits during the day. Pressure on the articulation is painful. Diagnostic blockades with local anesthetic are useful for diagnostic and predictive purposes. B. Material

SMK, 100-mm needle; active tip, 0.5 cm SMK, 145-mm needle; active tip, 0.5 to 1.0 cm C. Patient position

Patient is in the prone decubitus position, with a large pillow under the abdominal region D. Anesthesia

Superficial intravenous sedation Local anesthesia in the points to be punctured E. Radiographic technique

1. First view, oblique projection: Cephalic 15 to 25 degrees; enough to open disc space at L5-S1. 2. Second view, AP projection: Start with an oblique view, then rotate toward the AP view to visualize the widest space at the most inferior aspect of the sacroiliac joint.

This "scout" image must show the entire sacroiliac joint visualized for needle entry at the most inferior aspect of the joint. The C-arm is angled in such a way that the lines of the posterior and the anterior aspects of the joint are seen to overlap. An injection of contrast spreads throughout the sacroiliac joint in an inferior-to-superior fashion, with opacification of the ventral and dorsal joint lines. F. Risks

Segmental root puncture G. Stimulation parameters Scale: 0 to 1 V Sensory: 50 Hz; paresthesia of the zone must be noted above 0.5 V Motor: 2 Hz. Must be negative at 2 V. H. Lesion parameters

Inject 1 mL 2% lidocaine before producing the RF lesion at 80°C for 90 seconds. Multiple lesions must be completed along the entire posterior joint line. The cannula entry point must be located more medially as the lesions are more cranial, to facilitate positioning beneath the posterior iliac crest.

I. Side effects

Following sacroiliac joint RF denervation, some patients will experience gluteal discomfort, hip pain, or referred posterior thigh pain. Usually, pain resolves in 10 to 15 days. Adjunct analgesic oral therapy can be prescribed. Patchy hypoesthesia in the buttocks can be seen, but it resolves spontaneously within 2 to 4 weeks.

J. Comments

The facets and root ganglia should both be lesioned for the complete treatment. It is advisable to perform pulsed RF lesions in DRG S1, S2, and S3, and to perform conventional RF in L4-5 and L5-S1 medial branches. The S2 segmental root contributes greatly to the innervation of the sacroiliac joint, and lesions produced in the S2 DRG by pulsed RF can alleviate residual symptoms after sacroiliac denervation.

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