Radiofrequency and Neurolysis for the Treatment of Chronic Visceral Abdominal Pain

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Introduction

When considering neurolytic techniques for visceral pain control, the practitioner has many options. Therapeutic options may rely on diagnostic blocks with local anesthetic, usually with image guidance of the target site. Once a target has been chosen for neurolysis, a neurolytic technique can be used for potential prolonged pain relief. This chapter describes the various neurolytic techniques available for pain control in patients with chronic visceral pain.

Neurolytic Techniques

Chemical Neurolysis

Chemical neurolysis provides long-term analgesia by administering chemical agents capable of destroying neural structures. These techniques originated in the 1930s when chemical agents were first used to treat severe malignant pain and other non-malignant chronic conditions [1]. Two common chemical agents used are phenol and alcohol.

Phenol was first used by Putnam and Hampton as a neurolytic agent in 1936 with the goal to destroy the nerves responsible for the patient's pain [1]. Today, phenol is prepared to a maximum concentration of 6–9 % solution in water and can be prepared with alcohol, glycerol, saline, and radiocontrast dye. When mixed with glycerol, the solution is localized to the targeted area as opposed to mixtures with water which are more permeable and cause larger areas of destruction [1].

Phenol causes nerve destruction by inducing protein precipitation, causing a loss of cellular fatty elements, separation of the myelin sheath from the axon, and axonal edema. Nerve arborization and neuroma formation can result at the site of nerve disruption, perhaps leading to deafferentation pain. The true effects of the block cannot be fully evaluated until 24–48 h after the treatment due to the use of local anesthetics during the procedure. As long as the nerve cell body is intact, nerve regeneration occurs at a rate of 1–3 mm/day. In addition to peripheral targets, phenol can be injected intrathecally or epidurally [1].

Ethyl alcohol was first reported to produce satisfactory analgesia by Labat and Greene in 1933 with an injection of 33.3 % alcohol. Ethyl alcohol is usually distilled to a 95 % solution and a 50–95 % alcohol can be used as a neurolytic agent. The exact minimum concentration for neurolysis has not been established. While its mechanism of nerve destruction may be similar to phenol, it can also lead to wallerian degeneration. The potential for the myelin sheath being intact may lead to less neuroma formation. Similar to phenol, the effects of neurolysis are usually seen after 12–24 h [1, 2]

Cryoablation

Throughout history, physicians have used "cold" techniques to treat pain with the earliest methods dating back to Hippocrates [3]. The advantage of cryoablation compared to other methods is that it may reduce the incidence of neuritis or neuralgia following treatment [3]. However, efficacy of cryoablation of peripheral nerve targets is limited in the current literature.

Cryoablation "freezes" specific nerve targets via contact with a cryoprobe, which extracts heat from surrounding tissue

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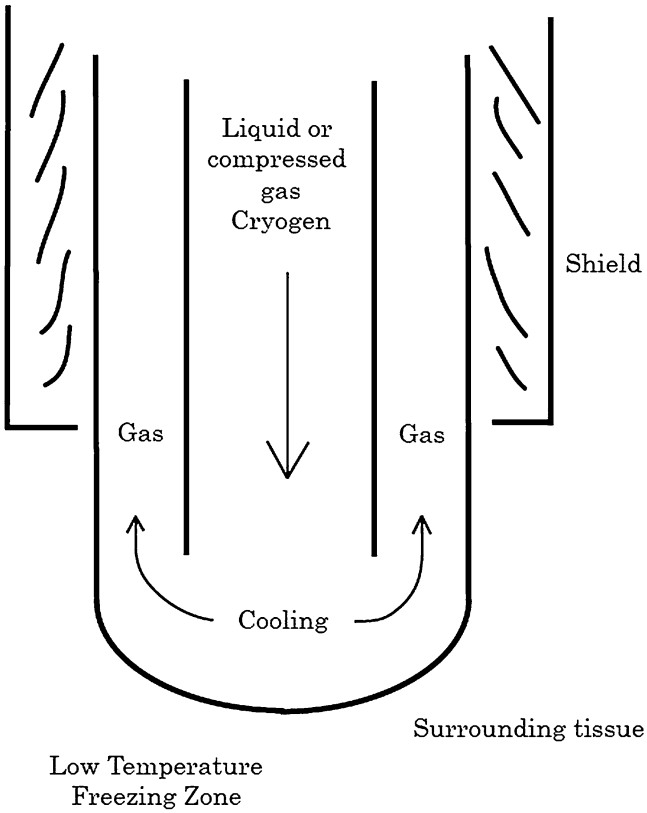

Fig. 16.1 The flow of cryogen in a cryoprobe. The majority of the cryoprobe is protected by a shield, allowing the tip to extract heat from the surrounding tissue. The choice of cryogen determines the lowest temperature of the cryoprobe

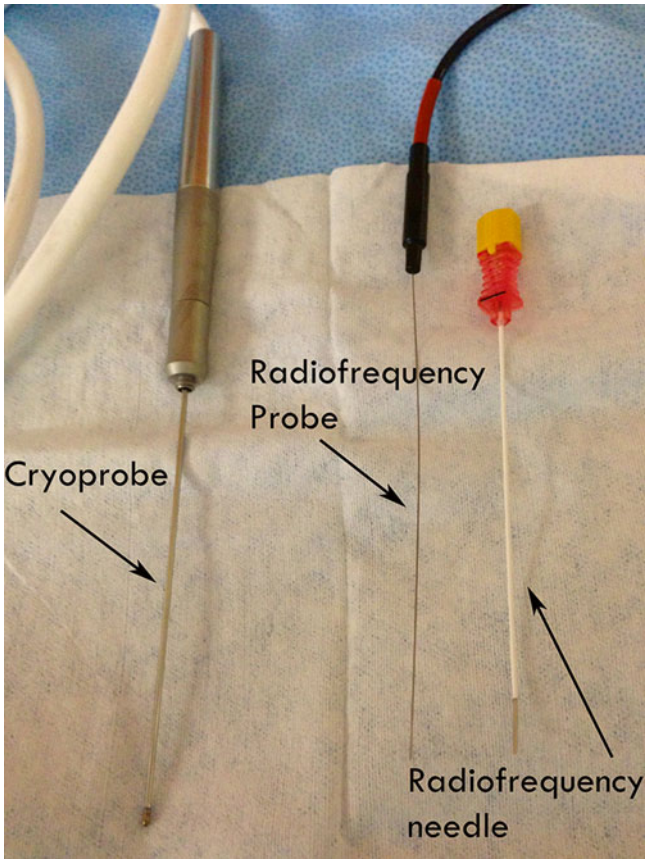

Fig. 16.2 Shown is a cryoprobe with a diameter of 1.7 mm, a RF probe with a much smaller relative diameter, and a 20-gauge RF needle that allows the probe to be introduced to the target

using supercooled liquid or compressed gas. Commonly, pressurized gas is forced through a small (0.002 mm) opening at the tip of the probe (Fig. 16.1). Heat is extracted from the tip of the cryoprobe, forming an ice ball with temperatures reaching −40 to −100 °C. Most probes are between 1.4 and 2.0 mm in size and have a thermistor to regulate temperature at the tip [3].

Using continuous freeze/defrost cycles and a larger probe can maximize disruptions within the nerve, causing both osmotic and mechanical damage. The repeat cycles decrease the temperature at sites away from the target nerve and maximize the size of the ice ball on the nerve target. At −20 °C, all nerve fibers stop conducting impulses through the nerve, and lower temperatures may lead to Wallerian degeneration, leaving the myelin sheath, endoneurium, and Schwann cell basal lamina intact allowing for regeneration. The extent of the block depends on the duration of exposure and temperature of the probe. However, long-term effects are thought to be caused by autoimmune responses via the release of sequestered proteins at the site of the treated nerve [3].

Radiofrequency Ablation

Radiofrequency (RF) ablation is a minimally invasive percutaneous procedure that is thought to reduce pain by altering the transmission of pain impulses [4, 5]. Conventional RF ablation (CRFA) causes controlled tissue destruction by irreversible coagulative necrosis [6]. However, recent evidence demonstrates that CRFA provides only a transient sensory loss in contrast to a much longer duration of pain relief. Electric fields produced by RF current may induce changes in the nerve cells and alter pain processing mechanisms at various sites, particularly at the molecular level [4].

All RF ablation techniques involve the transfer of alternating RF current (450–1,200 kHz) through insulated needle electrodes. The electrode is insulated, except for 2–10 mm at the tip. RF needles tend to be smaller than cryoprobes (Fig. 16.2). The electrode is positioned close to the target using nerve stimulators and image guidance. In conventional RF neurotomy, the electrode is positioned parallel to the target as the electrode coagulates transversely. A generator produces an electric field concentrated at the uninsulated tip of

the electrode. The transfer of energy generates molecular oscillations that produce ionic friction and heat within the tissues. Once the cells are heated above a certain temperature, controlled tissue destruction occurs causing a lesion surrounding the uninsulated tip [6]. Early studies claimed that RF coagulation destroyed Aδ and C fibers preventing nociception. However, subsequent studies have shown that RF coagulation is non-selective and disrupts all nerves [4–7].

Pulsed Radiofrequency Ablation

Pulsed RF ablation (PRFA) was described by Slappendel et al. that compared the outcomes of cervical RF at the dorsal root ganglion (CRFA) in patients treated with lesions made at 40 °C to those at 67 °C [8]. While changing the temperature did not impact efficacy, it was believed that the RF current itself was therapeutic because of the overall electrical effects on the target nerve. The therapeutic effect of PRFA current is provided by applying brief bursts of RF energy and allowing the heat to dissipate at the target tissues, avoiding further damage to the nerve [9].

In PRFA, a current of 50,000 Hz is usually delivered in 20-msec pulses at a frequency of 2 per second (other protocols have been described). The electrode temperature is limited to 42 °C preventing any thermal lesion [8, 10]. The current is densest distal to the tip of the electrode and in contrast to CRFA, the electrode is applied perpendicular to the target nerve. Laboratory studies show that heating a nerve to a lower temperature (40–45 °C) causes reversible conduction blocks, but no pathologic lesion is produced [9, 11]. The distance of the electrode from the nerve target influences tissue damage in both CRFA and PRFA. Within 500 μm from the electrode, both CRFA and PRFA protocols produced tissue damage. Between 500 and 1,000 μm, tissue damage occurred with CRFA protocols, but not in PRFA protocols. Electron microscopy shows that ganglia treated with CRFA causes significant neuronal damage, whereas the ganglia treated with PRFA leaves nuclear membranes intact. However, studies demonstrating the efficacy of PRFA is limited as truly randomized clinical trials are lacking [8, 11].

Cooled RF Ablation

Cooled RF ablation (cooled RFA) is a newer RF technique used to treat various pain syndromes. The mechanism of pain relief is similar to CRFA. An electrode is placed close to the target nerve and conduction is disrupted relieving the pain. Cooled RFA utilizes a specialized electrode which is actively cooled by a continuous flow of water at ambient temperatures. This prevents the electrode from acquiring high surrounding tissue temperatures and increases the overall exposure to the RF current, heating larger tissue volumes with a higher thermal lesion. Similar to conventional RF, the lesion size depends on the size of the probe, the electrode temperature, and the duration of RF current that is applied [12]. Perhaps by delivering larger amounts of RF current to the target nerve, cooled RFA can be used in treating pain syndromes where conventional RF is unsuccessful [13, 14].

The Neuroanatomy of the Viscera

Most painful stimuli from abdominal viscera are transmitted by unmyelinated C fibers found in muscle, periosteum, mesentery, peritoneum, and viscera. The pain is characterized as dull, cramping, burning, gnawing, and gradual in onset. Secondary autonomic effects such as sweating, restlessness, nausea, vomiting, perspiration, and pallor can accompany the visceral pain. Abdominal visceral nociceptors respond to both mechanical and chemical stimuli. Visceral pain tends to be midline as sensory afferents are sent to both sides of the spinal cord. It is also poorly localized since the innervation is multi-segmental and the number of nerve endings is minimal [15]. The afferent fibers that mediate abdominal visceral pain usually follow the distribution of the autonomic nervous system, and consequently, the autonomic ganglia are the main targets for pain relief.

Sympathetic Nervous System

The sympathetic nervous system originates from the spinal cord in the thoracolumbar region, arising from the T1 to L3 levels. The preganglionic sympathetic fibers have cell bodies in the intermediolateral columns. From these cell bodies, nerve fibers continue to paired sympathetic chains, unpaired distal plexuses, or collateral ganglia near target organs. The paired sympathetic chains form 22 paired ganglia that lie on either side of the vertebral column. The preganglionic fibers leave the cord in the anterior nerve roots, join the spinal nerve trunks that connect the ganglia to each other, and enter the ganglion through the white ramus at their respective level. Additionally, the gray rami communicans connect the ganglia to the spinal nerves [15].

In the upper abdominal cavity, preganglionic fibers from T5 through T9 join together to form the greater splanchnic nerves serving the *celiac ganglia*. In the middle abdomen, nerve fibers from T10 and T11 form the lesser splanchnic nerves serving the *aorticorenal ganglia*. In the lower abdomen, nerve fibers from T12 form the least splanchnic nerves serving the *superior mesenteric ganglia* and nerve fibers from L1 through L3 form the lumbar splanchnic nerves serving the *inferior mesenteric ganglia*. The postganglionic fibers from the celiac, superior, and inferior mesenteric

plexuses innervate the viscera of the abdomen and pelvis. Postganglionic fibers arising from synaptic links of the thoracic, lumbar, and pelvic sympathetic fibers form numerous plexuses, such as the cardiac, celiac, hypogastric, and plevic plexuses. Lastly, ganglia of the third type, the terminal or collateral ganglia, form near their target organs (e.g., adrenal medulla) [16, 17].

Parasympathetic Nervous System

The parasympathetic nervous system arises from cranial nerves III, VII, IX, and X and from the sacral spinal cord. The vagus nerve supplies the heart, tracheobronchial tree, liver, spleen, kidney, and entire gastrointestinal tract except for the distal part of the colon. Most vagal fibers do not synapse until they arrive at *small ganglia* on and about the thoracic and abdominal viscera. The preganglionic fibers are long, but the postganglionic fibers are short. The second through fourth sacral nerves form the pelvic splanchnic nerves. They synapse in terminal ganglia associated with the rectum and genitourinary organs also known as the *ganglion impar* [15].

Enteric Nervous System

The enteric nervous system (ENS) consists of a network of neurons within the walls of the gastrointestinal tract, the pancreas, and the gallbladder. The ENS functions independently from the sympathetic and parasympathetic systems as seen when digestion and peristalsis occur after spinal cord transection [18]. While not directly involved in pain sensation, secretory and neuronal mediators can cause signaling along the autonomic nervous system, which may be perceived as discomfort.

Referred Pain

Stimulation of the autonomic nervous system in the viscera may lead to referred pain, defined as a sensation perceived at a remote area from the site of the stimulus. Referred pain results from visceral and somatic afferent neurons converging on second-order neurons in the spinal cord. The best-known example is the pain experienced during a myocardial infarction. The damaged myocardium transmits pain signals via visceral afferent neurons to the T1–T4 levels of the spinal cord on the left side. These signals "converge" with somatic afferent neurons of the left chest and left arm at the same level. Thus, damaged myocardium is perceived as left chest and arm pain [19]. Similar pain is seen with pancreatic cancer (mid-back pain) and renal disease (groin and testicular pain) (Table 16.1).

Table 16.1 Common somatic referral patterns for chronic visceral pain [19]

Visceral pain location	Somatic referral pattern
Esophagus	Upper back and left chest
Pancreas and duodenum	Epigastric and mid-thoracic back
Liver disease and capsular pain	Right shoulder and right upper abdomen
Splenic disease and capsular pain	Left shoulder and left upper abdomen
Kidney and bladder	Flank pain, groin pain, testicular pain
Ovary	Groin and flank pain
Distal colon	Left lower abdominal quadrant
Testicular, prostate	Flank and groin pain

Autonomic Targets for Visceral Pain

Thoracic Sympathetic Block [20]

Indications: Pain related to lung and esophageal cancer, post-herpetic neuralgia, thoracic vertebral pain

Anatomy: Since the thoracic somatic nerves are close to the thoracic sympathetic chain, both neural pathways may be neurolyzed when approaching the thoracic sympathetic ganglion. The lower cervical ganglion and first thoracic ganglion are fused to make up the stellate ganglion at the level of the 7th cervical vertebrae. In moving caudad, each upper thoracic ganglia lie just beneath each rib. The lower thoracic ganglia are more anterior to the upper thoracic ganglia and lie along the posterolateral surface of each vertebral body. The pleural space is in close proximity and lies lateral and anterior to the thoracic sympathetic chain.

Technique: Usually the sympathetic chain is targeted using fluoroscopic or CT guidance. The needle is usually directed to the tip of the transverse process and redirected inferiorly to the inferior margin of the transverse process. After verifying the correct position, the needle is aspirated to ensure no blood or CSF and neurolysis is performed.

Complications: Pneumothorax, hemothorax, intrathecal neurolysis

Celiac Plexus Block [21, 22]

Indications: The celiac plexus block is used to treat pain related to pancreatic cancer, bile duct cancer, gastric cancer, or primary liver neoplasm; as well as chronic pancreatitis and chronic abdominal pain.

Anatomy: The plexus is located at the level of the upper part of the 1st lumbar vertebra and surrounds the celiac artery.

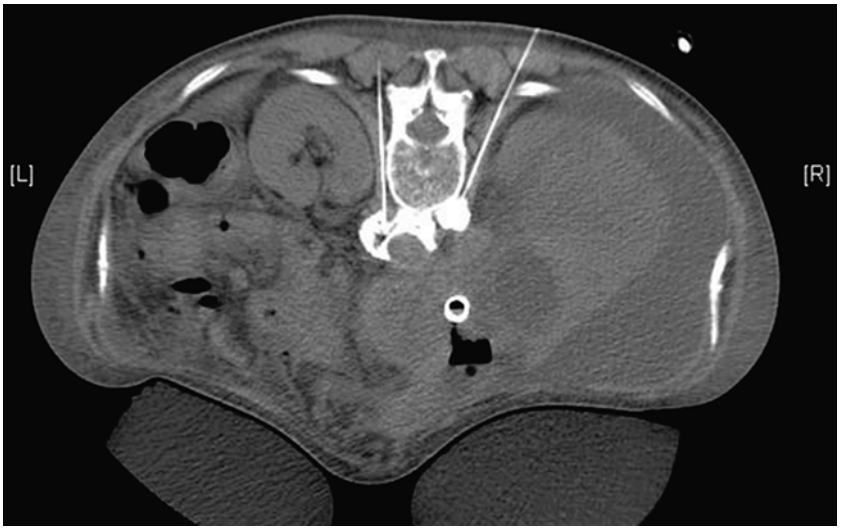

Fig. 16.3 Celiac plexus block performed under CT guidance. Alcohol neurolysis is performed after using contrast dye to determine the spread of the neurolytic. The right side approach is retrocrural and targets the lumbar splanchnics, while the left side approach is transcrural, targeting the left portion of the celiac plexus

It lies in between the suprarenal glands, in front of the crura of the diaphragm and abdominal aorta, and behind the stomach and omental bursa.

Technique: The approach has been described using CT, fluoroscopic, and ultrasound guidance. Given the various techniques, the celiac plexus and associated splanchnic nerves can be targeted independently for specific pain syndromes (Fig. 16.3).

Complications: Hypotension, diarrhea, intravascular/spinal/epidural injections of neurolytic substance, back/shoulder pain, leg weakness, sensory deficits, paresthesias, and paraplegia

Lumbar Sympathetic and Splanchnic Nerve Block [23]

Indications: The lumbar sympathetic block is used to treat claudication of the lower extremities, CRPS, herpetic neuralgia, or phantom limb syndrome; while the splanchnic nerves can be targeted for abdominal and pelvic visceral pain.

Anatomy: The lumbar sympathetic ganglion is located along the anterolateral surface of the lumbar vertebral bodies and anteromedial to the psoas muscle. The vena cava lies just anterior to the right sympathetic chain and the aorta lies anterior to the left sympathetic chain on the left. The splanchnic nerves and lumbar splanchnic chain are usually medial to the lumbar sympathetic chain and may travel around the large blood vessels of the abdomen (Fig. 16.4).

Technique: Either CT or fluoroscopic guidance is used to target the sympathetic and splanchnic chains. For specific targets, stimulation with a RF probe may allow the practitioner to locate either chain. RF may lead to more discreet lesions compared to chemical neurolysis.

Complications: Hypotension, Back/shoulder pain, Intravascular/spinal/epidural injections of neurolytic substance, genitofemoral neuralgia, psoas, and lumbar plexus damage.

Superior Hypogastric Plexus Block [24]

Indications: The superior hypogastric plexus block is used to treat lower abdominal and pelvic pain associated with cancer, bladder spasm/pain, or testicular pain

Anatomy: The plexus is located in the retroperitoneal space, starts at the lower part of the 5th lumbar vertebral body, and reaches the upper part of the 1st sacral vertebral body, close to the aortic bifurcation. It transfers visceral impulses from the upper vagina, cervix, uterus, fallopian tubes, bladder, and right colon to the dorsal horns of the spinal cord through sympathetic thoracic lumbar fibers

Technique: Approaching the hypogastric plexus has been described in many techniques using image guidance. Approaches include transdiscal, anterolateral vertebral, and trans-abdominal, under CT and fluoroscopic guidance. Because the plexus is diffuse, having imaging of the patient's abdomen and pelvis may help determine which

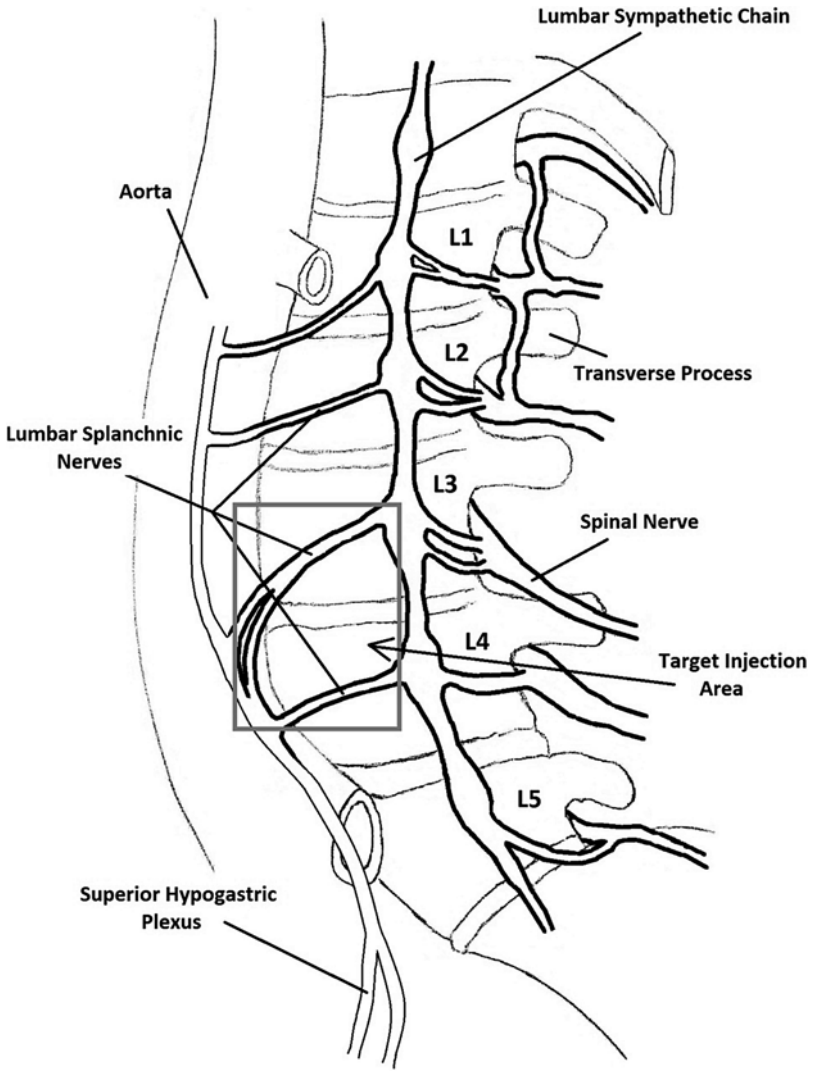

Fig. 16.4 The lumbar splanchnic nerves as they join the thoracic splanchnics and traverse around the abdominal vessels and merge to form the superior hypogastric plexus

approach may yield optimal results and reduce vascular trauma (Fig. 16.5).

Complications: Infection, damage to the aorta/iliac vein/lumbar nerves, retroperitoneal bleeding.

Ganglion of Impar Block [25, 26]

Indications: The Ganglion of Impar block is used to treat rectal pain, perineal pain, rectal spasm, or coccydynia

Anatomy: The ganglion of Impar is located anterior to the sacrococcygeal junction where the two pelvic sympathetic trunks converge at the cranial base and travel retroperitoneal to form the solitary median ganglion.

Technique: The ganglion is usually targeted anterior to the sacrococcygeal or coccygeal ligament. Trans-ligament, lateral, or infracoccygeal technique has been described in the literature as effective approaches for neurolysis of the ganglion (Fig. 16.6).

Complications: Infection, accidental perforation of the rectum, impaired bladder/bowel/sexual/motor/sensory function, post-interventional neuralgia

Nociceptive Irritation and Somatic Pain

Nociceptive irritation results from mechanical, thermal, or chemical excitation of nociceptors. Nociceptors are located throughout the body, including the skin, subcutaneous tissue,

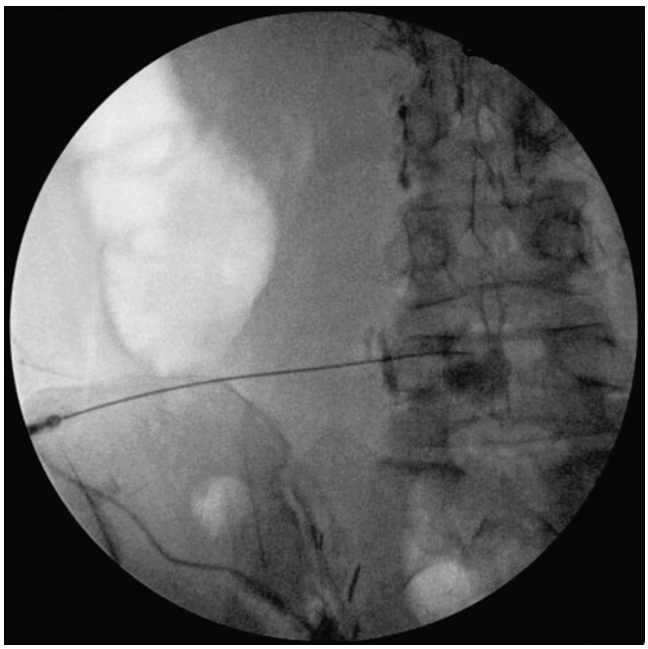

Fig. 16.5 Shown is an AP view of a fluoroscopic-guided L5 superior hypogastric block. The block can also target the sacral promontory below the L5–S1 discal junction

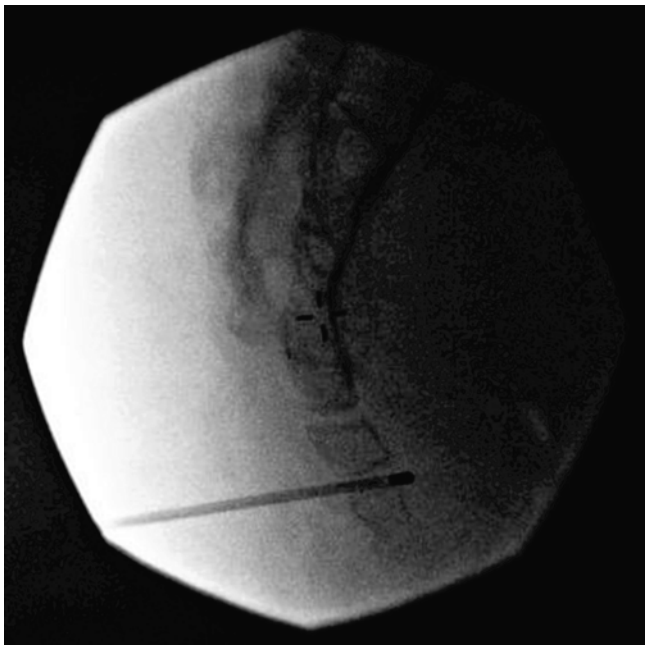

Fig. 16.6 An AP view under fluoroscopy showing a cryoprobe placed for neurolysis of the ganglion of impar. The probe is directed through the coccygeal ligament

bone, muscle, connective tissue, viscera, and blood vessels [27]. Somatic pain of the abdomen and pelvis may occur with visceral pain (such as in cancer pain syndromes) or may be difficult to distinguish from visceral pain (i.e., ilioinguinal neuralgia from surgery). As a result, diagnostic blocks and subsequent neurolysis may be performed for patients with concurrent somatic and visceral pain.

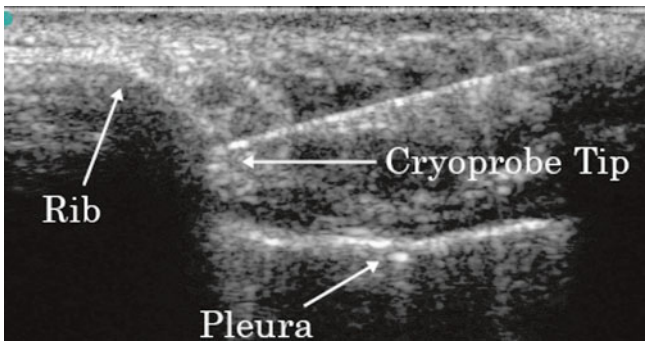

Fig. 16.7 A cryoprobe is placed to the inferior border of the rib under ultrasound guidance, targeting the ICN. Note the close proximity of the pleura to the location of the cyroprobe

Intercostal Nerves

The skin and muscles of the chest and abdominal are mostly innervated by the intercostal nerves (ICN). Acute use of local anesthetic around ICN can reduce pulmonary complications and narcotic requirements after upper abdominal surgery. As these procedures have advanced, ICN blocks are now used in a great variety of acute and chronic pain conditions involving the chest and upper abdomen (Fig. 16.7). The advantages of these blocks include superior analgesia, opioid-sparing, improved pulmonary mechanics, reduced CNS depression, and avoidance of urinary retention. The disadvantages include risks of pneumothorax and local anesthetic toxicity when blocking multiple levels [28, 29].

Iliohypogastric and Ilioinguinal Nerves

The iliohypogastric nerve courses the transverse abdominal muscles and the external oblique aponeurosis, while the ilioinguinal nerve travels between the second and third layers of abdominal muscles before coursing the inguinal canal. Both of these nerves are primarily derived from L1 spinal nerve with occasional contributions from T12, L2, or L3 nerves. These nerves are typically injured during hernia repair, trocar placement, Pfannenstiel incisions, needle suspensions of the bladder neck, and TVT procedures for correction of urinary complications [30]. Patients with low anterior pelvic and groin pain may benefit from neurolysis of these nerves.

Pudendal Nerves

Pudendal neuralgia is a neuropathic condition involving the dermatome of the pudendal nerve and is localized to the vulva, vagina, clitoris, perineum, and rectum in women and to the glans penis, scrotum (excluding testicles), perineum, and rectum in men. The incidence in the general population is around 1 % and affects women more than men. The nerve is derived from the sacral roots S2–S4 and forms the dorsal nerve of the penis/clitoris, the perineal nerve, and the inferior anal nerve. Since the pudendal nerve caries motor, sensory, and autonomic fibers, both afferent and efferent pathways are affected by nerve entrapment.

Patients often have associated symptoms of urinary frequency, urgency, dyspareunia, persistent sexual arousal, hyperalgesia, allodynia, and paresthesias. The three most common causes of pudendal nerve entrapment are surgical injury, pelvic trauma, and child birth. In terms of diagnosis, the "Nantes Criteria" are widely used and accepted to help diagnosis and treat pudendal neuralgia [31]. Because of motor and sensory function, neurolysis of the pudendal nerves is often seen as a "last resort", with possible consideration for PRFA techniques (Fig. 16.8).

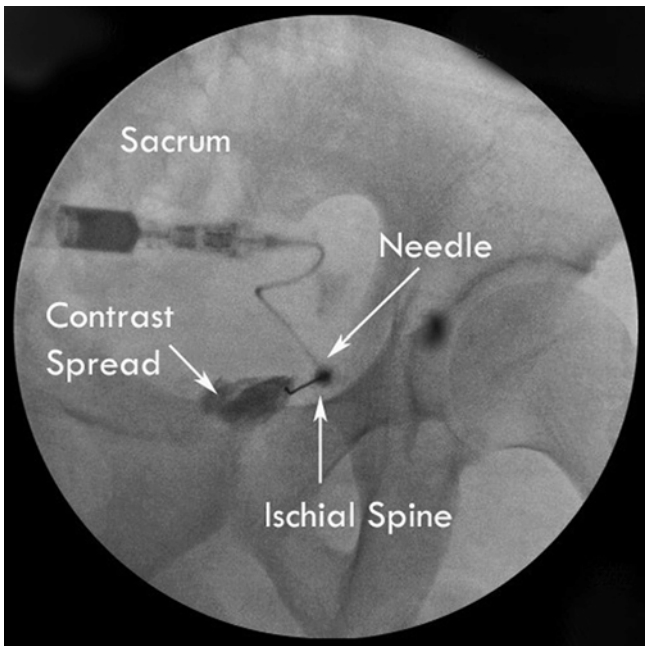

Fig. 16.8 Shown is a fluoroscopically guided technique in performing a pudendal nerve block. A needle is guided to the border of the ischial spine (*shown*), and contrast spread medial and above the ischial spine indicates the spread of the injectate and likely location of the pudendal nerve

Anterior Cutaneous Nerve Entrapment Syndrome

Anterior cutaneous nerve entrapment syndrome (ACNES) is a commonly misdiagnosed cause of abdominal pain. It generally occurs when a peripheral nerve is entrapped at specific anatomic sites, such as a fibrous or osseofibrous tunnel or when it passes over a fibrous or muscular band [32]. The pain at these sites is believed to be caused by mechanically induced irritation. The most common cause of abdominal wall pain is nerve entrapment at the lateral border of the rectus muscle [33]. It is believed that localized compression of the nerve at the ring of the rectus muscle bundle causes nerve ischemia, and subsequently pain. The acute pain is described as localized, dull, or burning. Often there is a sharp component radiating horizontally in the upper half of the abdomen and obliquely downward in the lower abdomen. The pain may exacerbate when the patient twists, bends, or sits up and is usually unilateral [32].

In terms of treatment, administration of local anesthetic can completely relieve the pain of ACNES [34]. The needle should be correctly positioned beneath the aponeurotic opening (using ultrasound guidance may improve the targeting of this area). The injection can relieve pain and reduce herniation of the neurovascular bundle through the fibrous ring. The patient usually will have immediate relief of pain if the treatment is effective [32]. When local anesthetic does not relieve the pain, phenol or alcohol can be used to treat ACNES.

Conclusion

Various neurolytic techniques have been described for treating chronic visceral pain. Diagnostic blockade of either the sympathetic or somatic innervation of the abdomen and pelvis will help determine which targets are amenable for neurolysis for prolonged pain control. Choosing which neurolytic technique involves careful understanding of the advantages and disadvantages when performing the neurolysis. Patient selection is also valuable in the decision whether to proceed to neurolysis for pain control. As our understanding of visceral neurophysiology improves, improved techniques and targets will allow for better pain control in our chronic visceral pain patient.

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