Spinal Cord Stimulation in Visceral Pathologies

Yasin N. Khan, MD, Shariq S. Raza, MD, and Elizabeth A. Khan, MD
Comprehensive Pain Centers, Allentown, Pennsylvania, USA

ABSTRACT

Spinal cord stimulation (SCS) has widely been applied for the treatment of neuropathic pain with excellent outcomes. However, there seems to be a general lack of consensus on the modalities and treatment approaches for the visceral component of nociceptive pain syndromes. There have recently been some interesting developments in the domain of visceral pain treatment by utilizing SCS. We have published case studies to exemplify the viscerotomal distribution of abdominal visceral pain pathways and the application of traditional SCS techniques for its treatment in another recent article. Spinal stimulation was successfully applied in patients experiencing abdominal visceral pain due to various conditions, including chronic nonalcoholic pancreatitis, post-traumatic splenectomy, and generalized abdominal pain secondary to laparotomies performed to relieve gastrointestinal adhesions. There was a significant reduction in the visual analog scale scores along with a substantial decrease in narcotic use. This article is meant to provide the anatomical basis and rationale for the clinical application of SCS in various abdominal visceral pain syndromes. SCS holds great promise as a highly effective, nondestructive, and reversible treatment modality for abdominal visceral pain disorders.

Key Words. Visceral Pain; Abdominal Pain; Viscerotomes; Nociceptive Pain; Spinal Cord Stimulation

Visceral pain of any origin can be extremely disabling. It influences all aspects of the patient's life, including bodily functions and family relations, and can be a major cause of disruption of employment and family structure. Moreover, these conditions are highly prevalent; data from the 1986 National Health Interview Survey suggest that nearly 15 million Americans suffered from acute disorders of gastrointestinal (GI) tract [1]. More than 30 million people were listed as having “selected chronic digestive conditions,” including 4.5 million with ulcers, 3 million with gastritis or duodenitis, 2.5 million with enteritis or colitis, 5.3 million with frequent recurrent periods of pain caused by indigestion, and more than 1.6 million patients with spastic colon associated with abdominal pain.

In 1987, American Cancer Society estimated 224,000 new cases of cancer of digestive organs, and 22,000 new cases of cancer of the kidneys and ureters, while the total deaths from each group of cancers were 125,000 and 9,400, respectively—higher compared with any other cancer [2]. Furthermore, 1986 data suggest approximately 20% of Americans had abdominal pain that required medical attention [3].

Treatment for visceral pain has always been a dilemma. For most patients, medical therapy is not successful and surgical intervention becomes necessary [4]. Neuroablation, celiac plexus blocks, and destruction of celiac ganglia cannot be definitively advocated due to a lack of reproducible results from previous studies [4,5]. Customary pharmacological and surgical approaches for some common painful abdominal conditions are listed in Table 1.
Causes of Abdominal Pain

Causes of abdominal pain include:

- Disorders of abdominal viscera
- Neuropathic pain due to disorders of spinal cord
- Lower six thoracic nerves
- Diseases of muscle and fascia and other somatic structures
- Referred pain to the abdomen due to diseases of chest as somatic and visceral nerve supply to both regions has common segmental distribution in the spinal cord

Some other causes of abdominal pain include:

- Pain of porphyria or lead colic causes hyperperistalsis and mimics intestinal obstruction
- Pain due to uremia and diabetes is diffuse and shifts location and intensity
- Black widow spider bites produce rigidity of abdominal and back muscles
- Vascular diseases, e.g., embolism, aneurysm
- Psychological origin

Spinal cord stimulation (SCS) is one of the most innovative techniques in the arsenal of a pain management practitioner, and it is traditionally utilized in pain syndromes that are only neuropathic in nature. There is a lack of evidence of its application in visceral and somatic pain syndromes owing to the long-held belief that nociceptive pain cannot be modulated by stimulation of the spinal cord [6–8].

Types of Pain

Pain can be characterized into two broad divisions: neuropathic pain (arising from actual damage to peripheral nerves or central nervous system) and nociceptive pain (arising from nerve irritation or tissue damage). Nociceptive pain is further subdivided into somatic and visceral pain based upon the organ where the nociceptive stimuli originate.

Abdominal pain can be subdivided into visceral and parietal (somatic) pain. Four types of pain are associated with visceral disease: unreferred (true) visceral pain, referred visceral pain, unreferred parietal pain, and referred parietal pain. For the purposes of this report, we will limit ourselves to the discussion of unreferred (true) visceral pain.

Visceral Pain

Visceral pain up till now has been thought of as a vague generalized pain syndrome that does not seem to have any correlation between the visceral innervations (or the levels of their afferents in the spinal cord) and the location of the pain experienced. In reality, however, visceral innervation, in a manner analogous to cutaneous dermatomes, follows the embryologic origin and location of the viscera and is arranged in viscerotomes [9]. Painful visceral afferents can be traced back into the spinal cord at the corresponding viscerotome and also project their painful sensations in the concordant dermatome.

True visceral pain arises very early in the disease. Because the viscera have fewer nerve endings compared with the skin, and there is usually a multisegmental involvement, visceral pain is a vague, diffuse, dull, and poorly localized pain. As its intensity and duration increase, it radiates and seems to originate from a wider area. It is frequently accompanied with a feeling of malaise and autonomic phenomenon like sweating, vasomotor responses, bradycardia, nausea, and vomiting.

Visceral diseases are frequently manifested by secondary hyperalgesia in the dermatomes supplied by the same spinal segments that supply the viscera. This hyperalgesia may involve the entire dermatome(s) or only part of a specific dermatome. Visceral pain is also referred to the skin

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Customary management approaches for common painful abdominal conditions</th>
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<tr>
<td>Peptic ulcer disease</td>
<td>Parietal cell vagotomy, vagotomy with pyloroplasty</td>
</tr>
<tr>
<td>Gastric cancer</td>
<td>Narcotic analgesics, intraspinal narcotics, splanchnic nerve block, celiac plexus block, neuroablation, intercostal neurolytic blocks</td>
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<tr>
<td>Crohn's disease</td>
<td>Oral narcotics with atropine, anticholinergics</td>
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<td>Ulcerative colitis</td>
<td>Sulfasalazine, corticosteroids, colectomy</td>
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<tr>
<td>Intestinal neoplasms</td>
<td>Narcotic analgesics, celiac plexus block, subarachnoid alcohol injection, epidural morphine injection</td>
</tr>
<tr>
<td>Hepatocellular carcinoma</td>
<td>NSAIDs, narcotics, cryoablation, segmental epidural analgesia, intraspinal narcotics</td>
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<td>Postcholecystectomy pain</td>
<td>Chemical splanchnicectomy, intrathecal opioids</td>
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<td>Chronic pancreatitis</td>
<td>Dietary manipulations, splanchnic nerves block, left celiac ganglion block, celiac plexus block, celiac ganglia resection, spinal opioids</td>
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<tr>
<td>Pancreatic cancer</td>
<td>Oral opioids, celiac plexus block, surgical splanchnicectomy, epidural opioid analgesia</td>
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NSAIDs = nonsteroidal anti-inflammatory drugs.
and other somatic structures at a considerable distance from the diseased viscus and follows a segmental dermatomal pattern. It has been well documented that anesthetizing the source of the visceral pain can relieve this referred pain [10–12].

Because of the nature of visceral nociceptors, cutting, tearing, or crushing of viscera does not cause any pain; stretch, distension, traction, inflammation (bacteria and/or chemical), and ischemia do stimulate the nociceptors and cause visceral pain.

Visceral Innervation
The viscera get their innervation through the sympathetic and parasympathetic pathways. The parasympathetic afferents travel into the anterior and posterior vagal trunks and are not a good candidate for pain control through neuromodulation because of the nature of vagal nerve fibers and the sensory information being transmitted through them. The sympathetic afferents, however, carry nociceptive information in small-diameter C and A-delta fibers and follow a different course; they travel back from the viscera to enter the lower six thoracic and the upper three lumbar spinal segments. It is these spinal nerve root levels that we targeted in our application. We applied SCS with the expectation that this would provide pain relief by blocking the transmission of visceral pain signals in the sympathetic fibers traveling back in the splanchnic nerve.

Peritoneal Nerve Supply
The upper 85% of the abdominal wall is supplied by the lower six or seven thoracic somatic spinal nerves. Parietal peritoneum embryologically derives its nerve supply from the spinal nerves, which also supply the skin and the muscle. Visceral peritoneum derives its nerve supply from the autonomic nerve supply of the viscera. Diaphragmatic parietal peritoneum is innervated peripherally by the lower thoracic nerves and centrally by the phrenic nerve, thereby referring the pain in C3–C5 distribution.

Abdominal Visceral Nerve Supply
The abdominal viscera receive both sympathetic and parasympathetic innervations, and their afferents are widely distributed in the GI system. All abdominal organs have bilateral innervation except the kidneys, ureters, cecum, and the ascending, descending, and sigmoid colon, which are all unilaterally innervated.

Painful stimuli from the periphery are transmitted to the substantia gelatinosa of the medullary dorsal horn of the spinal cord via the small-diameter, unmyelinated C-fibers and lightly myelinated A-delta fibers. Other sensory information, such as touch and vibration, is transmitted to the same spinal region via large myelinated A-beta fibers.

Parasympathetic Visceral Innervation
The parasympathetic afferent (sensory) and efferent (motor) fibers to the abdominal viscera are contributed by branches of the vagus nerve and the sacral splanchnic nerves. A total of 90% of the vagus fibers are afferent, out of which 80–90% are unmyelinated; the rest are A-delta and A-beta fibers. The parasympathetic afferents pass through the superior mesenteric plexus into the celiac plexus and continue to travel on through the smaller and the larger celiac branches into the anterior and posterior vagal trunks, respectively. Owing to the nature of the vagal fibers, we leaned toward the sympathetic afferents for neuromodulation.

Sympathetic Visceral Innervation
Sympathetic innervation is derived from the thoracic, lumbar, and sacral splanchnic nerves. Before reaching the viscera, the fibers from the upper and middle thoracic splanchnic nerves traverse the celiac and mesenteric plexus and synapse in the corresponding ganglia. The cell bodies of the efferent nerves to the viscera are in the celiac ganglion while those of afferent sympathetic nerves are located in the dorsal root ganglia. The sympathetic afferents travel back from the viscera in a reverse route to the celiac and the superior and inferior mesenteric plexuses. From there on, they pass through the greater and the lesser splanchnic nerves and the sympathetic trunk ganglia to enter the spinal cord.

Less than 20% of the splanchnic nerve fibers are afferent fibers, while the rest are preganglionic fibers; a vast majority (70%) of these sensory afferents are small-diameter, unmyelinated nociceptive fibers, 15% are A-delta, and 8–10% are A-beta. The sympathetic afferents in the lower six thoracic and the upper three lumbar spinal segments have been shown to transmit painful impulses from the viscera [13–18] and convey information about mechanical, chemical, thermal, and osmotic changes. They are also subjected to modulating
influences in neuroaxis and here were our target for stimulation in the spinal cord.

Mechanism of Action of Spinal Cord Stimulation

As already noted, the substantia gelatinosa of the medullary dorsal horn of the spinal cord receives nociceptive stimuli via small-diameter, unmyelinated C-fibers and lightly myelinated A-delta fibers, and also receives other sensory information via large myelinated A-beta fibers. Melzack and Wall’s gate control theory of pain [19], which suggested that stimulation of these large A-beta fibers would inhibit reception of painful small-diameter fiber information, led to the development of SCS.

Since then, SCS has been used for numerous neuropathic pain conditions. The use of SCS for the treatment of complex regional pain syndrome (CRPS), which is mediated through sympathetic afferents in the spinal cord in a manner similar to visceral afferents, has also been widely documented [20–22]. By taking this association between SCS and a sympathetically mediated pain syndrome to its theoretical extension, we have applied it to the treatment of visceral pain that is mediated in much the same way. Abdominal visceral pain so far has been thought of as only having nociceptive pain component.

Viscerotomes and Its Dermatomal Pattern of Distribution

Just as cutaneous dermatomes are arranged according to the embryologic anatomy of the tissues, viscerotomes are arranged according to the embryologic location of the viscera and involve both mesodermal and endodermal tissues. Viscerotomes, and the anatomy and physiology behind it, have been extensively studied [9]. Although the viscera follow the viscerotomal pattern of innervation, their somatotopic progress is not always obvious because of their migration and rotation during the embryologic development. The proximal ends of the afferent nerves mediating nociceptive and other sensory impulses from the abdominal viscera synapse in the same spinal cord segments as the somatic spinal nerves, thereby following the viscerotomal distribution of innervation. However, as only about 20% of the splanchnic nerve fibers are responsible for the nociceptive afferents from the abdominal viscera, it is fitting that the visceral pain is felt as a vague and poorly localized pain. This is also why the general notion of differentiating between neuropathic and nociceptive pain based upon the localization and character of pain itself is not particularly appropriate for visceral pain characterization.

We have used this theory and achieved successful results and excellent outcomes [23]. SCS was applied to control visceral pain in patients with chronic nonalcoholic pancreatitis, generalized abdominal pain (and pain secondary to repeated surgeries performed to relieve gastrointestinal adhesions and resulting in abdominal wall neuromas), and pain after post-traumatic splenectomy.

Spinal Stimulation Levels Based on Viscerotomal Innervation

The spinal levels for stimulation in each case were based upon the presentation of pain and the viscerotomal innervation pattern, e.g., a lead was placed at the T5–T6 level to cover pancreatic pain and at the T6–T7 level for postsplenectomy pain. This generally translates to a spinal stimulation level that is two vertebral levels higher than the viscerotomal innervation of the painful viscera.

Our case reports have shown the efficacy and safety of spinal column stimulation therapy in controlling visceral pain, and this methodology can be applied for the treatment of other painful abdominal conditions, including complications from pathologies such as ulcerative colitis and Crohn’s disease. SCS seems to be a very effective tool in managing abdominal visceral pain. It is especially appealing as it is a nondestructive and reversible procedure. The full potential of this approach still largely remains untapped, and it offers great hope to those who suffer from visceral pain and its debilitating effects.

References

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