Autonomic Nerves of Abdominopelvic Organs

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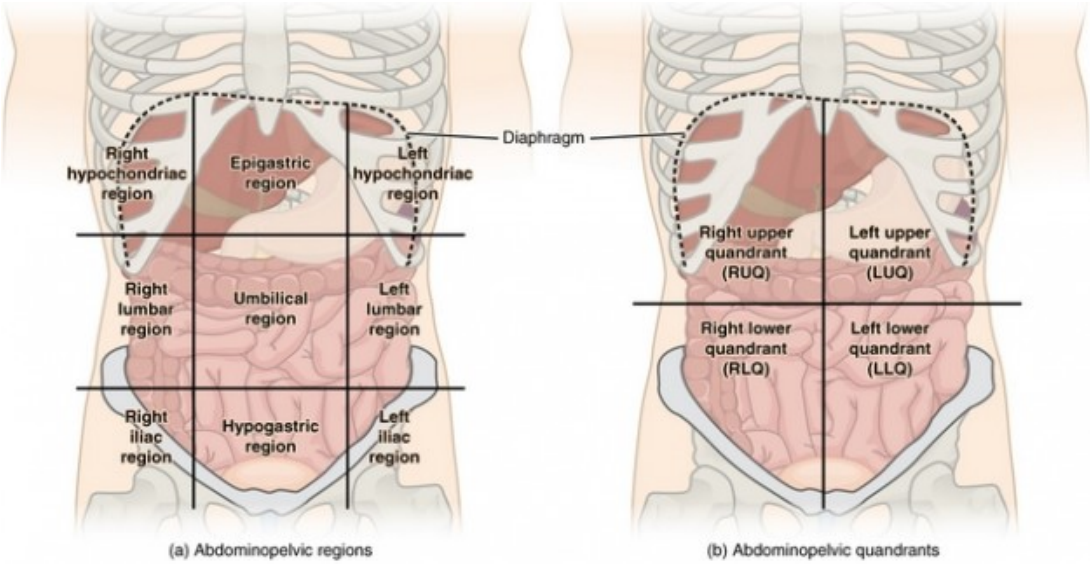
Together, the primitive embryonic foregut, midgut, and hindgut form the gastrointestinal tract. The foregut extends from the mouth to the proximal two-thirds of the duodenum. The midgut extends from the distal one-third of the duodenum to the proximal two-thirds of the transverse colon, while the hindgut extends from the distal one-third of the transverse colon to the anus. The autonomic nervous system, with its sympathetic and parasympathetic fibers and their opposing actions, controls all these organs.



Autonomic Nervous System

The autonomic nervous system consists of parasympathetic and sympathetic fibers. The vagus, along with the pelvic splanchnic plexus, forms the main parasympathetic supply to the foregut, midgut, and hindgut. It stimulates peristalsis and secretion of the glands in the gut, thereby assisting in the digestion of ingested food. In the pelvis, it takes part in the regulation of micturition, defecation, and, in the male, erection and ejaculation.

The greater and lesser thoracic splanchnic nerves and a few fibers from the upper lumbar splanchnic nerves form the sympathetic innervation, which inhibits digestion by diverting blood flow to the limbs and trunk during the “flight or fight” response.

Stimulation of the parasympathetic nerve results in increased intestinal peristalsis with the opening of the valves, while sympathetic stimulation causes closure of the valves with inhibition of motility. The sight, smell, and taste of food stimulate the vagus. This effect can last for up to 30 minutes and leads to the direct stimulation of the chief cells in the stomach to secrete pepsinogen in anticipation of digesting proteins, and indirectly

stimulates the gastric parietal cells to secrete hydrochloric acid.

Parasympathetic Fibers

The 10th cranial nerve, the vagus, forms the anterior and posterior trunks and carries the parasympathetic fibers to the esophagus and the abdomen. The vagal trunks carry visceral afferent fibers to the periarterial and aortic plexuses, as well as the presynaptic parasympathetic fibers.

The anterior rami of the 2nd, 3rd, and 4th sacral nerves help to form the pelvic splanchnic nerves, which carry presynaptic parasympathetic fibers to the pelvic plexus. The walls of the abdominal organs also have parasympathetic ganglia.

Sympathetic Fibers

The sympathetic fibers arise from the cells of the lateral horn of the 7th thoracic to the 2nd lumbar vertebrae. The presynaptic fibers travel through the anterior nerve roots, the anterior rami, and the communicating branches of the spinal nerves toward the sympathetic trunks.

The presynaptic fibers pass through the paravertebral ganglia without synapsing and then form the splanchnic nerves; however, as they pass through the prevertebral ganglia and autonomic plexuses located along the abdominal aorta and its branches, they synapse with the postsynaptic neurons. Sympathetic fibers are sensory as well as motor. The sensory fibers respond to the distension of the viscera.

The pelvic portion of each sympathetic trunk is situated in front of the sacrum, medial to the anterior sacral foramina. It consists of 4 or 5 small sacral ganglia, connected together by interganglionic cords, and continuous above with the abdominal portion. Below this area, the 2 pelvic sympathetic trunks converge and end at the front of the coccyx in a small ganglion, the ganglion impar (or ganglion of Walther).

There are 2 main splanchnic nerves:

1. **Thoracic splanchnic nerves** carry the majority of the presynaptic sympathetic fibers through the greater, lesser, and lowest or least splanchnic nerves. They accompany the aorta as it passes through its diaphragmatic hiatus into the abdomen. Their fibers contribute to the celiac, aorticorenal, and superior mesenteric ganglia and plexuses.
2. **Lumbar splanchnic nerves** originate within the abdominal sympathetic trunk and form approximately 3–4 lumbar splanchnic nerves, which enter the intermesenteric, inferior mesenteric, and hypogastric plexuses.

Autonomic Plexuses in the Abdomen

- The **autonomic plexuses** in the abdominopelvic cavity carry both sympathetic and parasympathetic fibers. They are located in the abdominal aorta and its various branches. They include the celiac, aortic, hepatic, superior mesenteric, inferior mesenteric, intermesenteric, renal, superior hypogastric, and right and left inferior hypogastric plexuses. (See figure: https://commons.wikimedia.org/wiki/File:Gray848.png#/media/File:Gray848.png.)
- The **celiac plexus** is situated at the origin of the celiac trunk at the level of

the 12th thoracic and 1st lumbar vertebra. It contains the paired celiac ganglia and receives parasympathetic fibers from the vagus nerve and sympathetic fibers from the lesser and greater splanchnic nerves.
- The **left gastric plexus** innervates the lesser curvature of the stomach.
- The **hepatic plexus** derives fibers from the celiac plexus through the right and left vagus nerves, as well as the phrenic nerves. It is situated around the hepatic artery, portal vein, and their branches. It provides fibers to the cystic plexus.
- The **splenic plexus** receives fibers from the right vagus nerve, the celiac plexus, and the left celiac ganglion. It innervates the blood vessels, the splenic capsular smooth muscle, and trabeculae.
- The **suprarenal plexus** is connected to the celiac plexus and sends fibers to the suprarenal medulla.
- The **superior mesenteric plexus** is located on the superior mesenteric artery. It is formed by fibers from the celiac plexus and the lesser and least splanchnic nerves. It sends fibers to the pancreas, duodenum, jejunum, ileum, and the proximal two-thirds of the transverse colon (midgut derivatives).
- The **inferior mesenteric plexus** is located on the inferior mesenteric artery and is formed by fibers from the intermesenteric plexus and the 2nd and 3rd lumbar splanchnic nerves. It innervates the distal one-third of the colon and the rectum.
- The **aortic plexus** is situated around the abdominal aorta and its branches. It supplies the inferior vena cava and connects the superior and inferior mesenteric plexuses.
- The **intermesenteric plexus** is located between the superior and inferior mesenteric plexus and provides fibers to the renal, testicular, and uterine plexuses.
- The **renal plexus** is formed by fibers from the celiac ganglion and plexus, the aortic plexus, the 1st lumbar splanchnic, and the least splanchnic nerve. It is situated on the renal arteries. It gives off fibers to the ureteric and gonadal plexuses.
- The **superior hypogastric plexus** is a continuation of the intermesenteric plexus and lies anterior to the abdominal aortic bifurcation, the 5th lumbar vertebra, and the sacral promontory. It receives fibers from the 3rd and 4th lumbar splanchnic nerves and the aortic plexus. It bifurcates into the right and left hypogastric nerves, which join the inferior hypogastric plexus inferiorly.
- The **inferior hypogastric plexus** receives fibers from the superior hypogastric plexus and from the pelvic splanchnic nerves (S2–4), which provide the parasympathetic fibers. It is located lateral to the base of the urinary bladder, vagina, and the rectum, against the posterolateral pelvic wall. It supplies nerve fibers to the hindgut derivates, namely the descending colon, the sigmoid colon, and the rectum, as well as the pelvic organs up to the anorectal junction. It gives rise to several plexuses: the middle rectal plexus, the vesical plexus, the prostatic plexus, the uterovaginal plexus, and the deferential plexus (plexus of the ductus deferens).

Note: The portion of the anal canal and external anal sphincter below the pectinate line are not derived from the hindgut and are innervated by the somatic pudendal nerve; hence, the anal canal below the pectinate line is very sensitive to pain.

Enteric Nervous System

The enteric nervous system is formed with parasympathetic fibers from the vagus and sympathetic fibers from the prevertebral ganglia and is located within the lining of the gastrointestinal tract. The enteric motor neurons act on the intestinal smooth muscles to control peristalsis, while the other neurons control enzymatic secretion. The enteric neurons are aggregated in 2 types of ganglia/plexuses:

- The **myenteric (Auerbach's) plexus** is located between the layers of the muscularis externa.
- **Meissner's submucosal plexus** is located within the submucosa of the small intestine.

The parietal peritoneum from the 6th thoracic vertebra to the 12th thoracic vertebra is innervated by cerebrospinal nerves with the same segmental supply as the lower thoracic dermatomes. The visceral peritoneum has no innervation.

Referred Pain

Abdominal pain is transmitted via splanchnic and cerebrospinal afferent nerve fibers. The splanchnic afferent nerve receptors, free nerve endings, and Pacinian corpuscles are located within the walls of the viscera and are stimulated only by spasm or distension (stretching). On the other hand, the cutaneous receptors of the cerebrospinal nerves are stimulated by temperature, pressure, friction, or injury. The ganglia of the splanchnic nerves and the cerebrospinal nerves lie next to each other within the dorsal root ganglia.

This close proximity may account for the spilling over of visceral pain arising from rapid distension into the cerebrospinal nerve ganglia, resulting in "referred pain" to the skin overlying the affected viscus.

Because the gastrointestinal organs are derived from the primitive embryonic gut as midline structures, their innervation from the splanchnic nerves is bilateral, and pain originating from the viscera is first noted in the midline; hence, pain arising from the foregut viscera is referred to the region below the costal intersection and epigastrium. Pain from the midgut viscera is referred to the umbilical region, and pain from the hindgut viscera is referred to the suprapubic region.

Clinical Relevance

Understanding the innervation of the gastrointestinal tract is essential to accurate diagnosis of the cause of abdominal pain. This is best exemplified in acute appendicitis, when pain starts initially in the midline, periumbilical region, as splanchnic nerves are only stimulated by stretch and distension within the hollow, inflamed appendix. As the condition progresses and the parietal peritoneum overlying the appendix becomes inflamed, pain localizes to the right iliac fossa overlying the appendix.

Similarly, knowledge of the embryonic origin of the gastrointestinal tract and its innervations can help one understand why internal hemorrhoids are painless, and external are not. As the internal hemorrhoids originate in the region of the hindgut supplied by the splanchnic plexuses, there is no sensation of pain. However, external hemorrhoids arise in the region inferior to the pectinate line supplied by the pudendal (somatic nerve), which is sensitive to pain.

References

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Notes