THE SACRAL PARASYMPATHETIC INNERVATION OF THE COLON

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TWO FIGURES

Autonomic nerves distribute by a variety of methods. They are recognized as components of all spinal and some cranial nerves, but they also have a strong tendency to exhibit a hitch-hiker relationship to arteries and to other nerves. The perivascular plexuses of the head and neck, and of the thorax and abdomen, are especially typical of peripheral sympathetic distribution. In the parasympathetic division, preganglionics arising in the third, seventh, and ninth cranial nerves utilize the branches of the trigeminal nerve for passage to the structure innervated. The vagus nerve is a main parasympathetic route to structures of the neck and chest and its terminal fibers end in the abdomen by mingling in the celiac plexus with sympathetic postganglionic fibers. Intestinal autonomics are perivascular for both sympathetic and parasympathetic divisions. At the brim of the pelvis the perivascular plexus of the aorta forms the hypogastric nerves which descend across the sacral promontory and distribute to the pelvic viscera without following their blood vessels. With these predominantly sympathetic nerves, parasympathetic fibers pass to the viscera of the pelvis and perineum.

Anatomical description has recognized that the parasympathetic innervation of the descending and sigmoid portions of the large intestine is provided by components of the sacral parasympathetic roots from sacral nerves two, three, and four, which ascend from the pelvis to reach the colon. Implicit

in most descriptions is an assumption that fibers of this character ascend through the pelvic plexuses, mingle with the nerves of the abdominal portion of the hypogastric plexus, and distribute by means of the perivascular nerve plexuses along the inferior mesenteric artery and its branches. A suggestion of a different route for the parasympathetic fibers to the descending colon is to be found in stimulation experiments of Langley and Anderson reported in 1895. These observers noted in the rabbit that stimulation of strands of the pelvic plexus gave rise to contractions in the descending colon but that stronger contractions followed stimulation of a "strand of nerve fibers which ascends in the mesentery ventrally of the hypogastric nerves." Anatomic verification of such nerves was given by Telford and Stopford ('34) in their description of two small nerve bundles which arose from the ventral aspect of the hypogastric nerves just distal to the division of the hypogastric plexus and fused into a small but definite nerve trunk to the left side of the hypogastric plexus. These authors traced the nerve trunk upward and to the left over the left common iliac artery to a junction with the inferior mesenteric artery at a point one to one and one-half inches from its origin from the abdominal aorta. Joining the perivascular plexus of the inferior mesenteric artery, the fibers of the parasympathetic nerve trunk mixed with the sympathetic fibers of the plexus and continued with them along the branches of the artery, mainly the left colic artery and its ascending and descending branches. As the nerve trunk crossed the left common iliac artery, branches were reported as passing to the sigmoid and superior hemorrhoidal arteries and distributing with the perivascular plexuses of these arteries. These authors believed they could trace the components of the nerve trunk inferiorly through the hypogastric nerves into continuity with the pelvic splanchnic nerves (sacral parasympathetic roots). They believed, further, that this path constituted the main path of parasympathetic innervation to the descending and sigmoid colon, although they could not deny the possibility of some few fibers ascending all the way

through the hypogastric plexus to the inferior mesenteric plexus. Trumble ('34) confirmed the origin of nerves from the upper parts of the hypogastric nerves as described by Telford and Stopford but pointed out that these were only the uppermost of a series of parasympathetic contributions. He described and illustrated a number of ascending "pelvic colonic nerves," some arising close to the pelvic plexus at the side of the rectum, others at the position of origin of the nerve trunk of Telford and Stopford, and still others passing from the hypogastric nerves midway between these two. He pointed out that these nerves do not enter the sympathetic perivascular plexuses but merely communicate with them, passing across the arteries and entering the mesenteric border of the gut directly. Trumble also described the normal separation of the right and left sides and stated that the uppermost nerves (those of Telford and Stopford) often do not unite but pass one on either side of the inferior mesenteric artery and its nerve plexus. The findings of Trumble received general confirmation from Mitchell ('35) in a study of 15 dissections. This investigator found three to 10 nerves on each side which passed directly to the descending and sigmoid colon, did not follow the blood vessels and communicated with, but did not join, the inferior mesenteric plexus. The prominent nerves seen by Telford and Stopford in the region of the sacral promontory were noted by Mitchell and were usually bilateral. Lannon and Weller ('47) reported dissections of the parasympathetic supply of the distal colon in 9 infant and 9 adult bodies. They concluded that fibers from the sacral parasympathetic roots arising from the second and third sacral nerves distributed directly to the distal part of the colon. Such nerve bundles exhibited connections with the pelvic plexuses but had direct origin from the sacral nerves. The parasympathetic supply consisted of three to 6 nerves on each side which did not follow the arterial distribution. The highest branches of the system reached usually the middle of the descending colon where the smaller terminals were associated with the ascending branch of the

left colic artery. The system of innervation was found to be bilateral with no demonstrable connection between the nerves of the two sides.

It has seemed worthwhile to investigate a system of nerves which appeared not to conform in course and relationships to the general pattern of the autonomic supply of the gastrointestinal tract and to attempt to reconcile the conflicting accounts of previous reporters. After preliminary studies it became apparent that significantly greater certainty of observation pertained in dissections of fresh tissue and that there were also advantages in studying the nerve pattern in young subjects in which relatively little fat was to be expected. Fifteen cadavers have been examined, only 4 of which were over 14 years of age. These dissections provide confirmation of certain of the contributions made by each of the authors cited and give the basis for a more complete description of the origin, course, and relations of this parasympathetic supply. No significant variations have been encountered such as to require the study of large numbers of specimens and statistical treatment of the resulting data.

The parasympathetic nerves of the descending and sigmoid portions of the colon do ascend directly to the bowel and are quite unrelated to the blood vessels supplying it. In a fresh specimen in which there is little fat in the sigmoid mesocolon these nerves can be seen under the mesentery without dissection as silvery strands ascending parallel to the lower sigmoid colon or coursing obliquely toward the upper sigmoid or lower descending segments of the colon (figs. 1, 2). They are distinctly diagonal to the vessels of the inferior mesenteric system and do not join the perivascular plexuses of these vessels although communications are made with such plexuses as they cross them. In general the parasympathetic nerves run with only the terminal branches of the blood vessels, the vasa recta.

The sacral portion of the parasympathetic division of the autonomic nervous system is represented by the sacral parasympathetic roots (pelvic splanchnic nerves) which arise from

sacral spinal nerves two, three, and four. In the photographed specimen (fig. 1) these roots are shown artificially tied together around a pin. Such parasympathetic roots course anteriorly to join the pelvic plexuses or hypogastric nerves

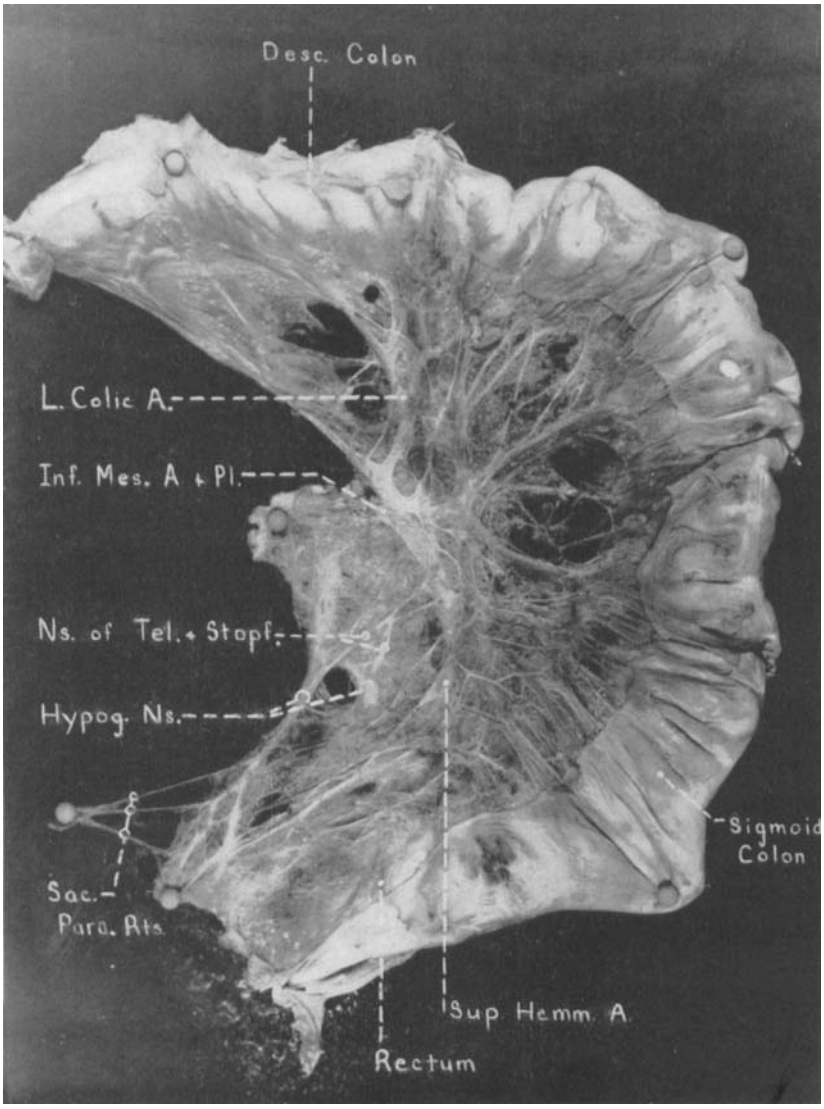

Figure 1

on either side of the rectum. From the resulting expansion of the pelvic plexuses nerve fibers distribute rather profusely to the rectum and anteriorly to the bladder and to both pelvic and perineal portions of the genital system (fig. 2): in the manner well described in all anatomical accounts. From

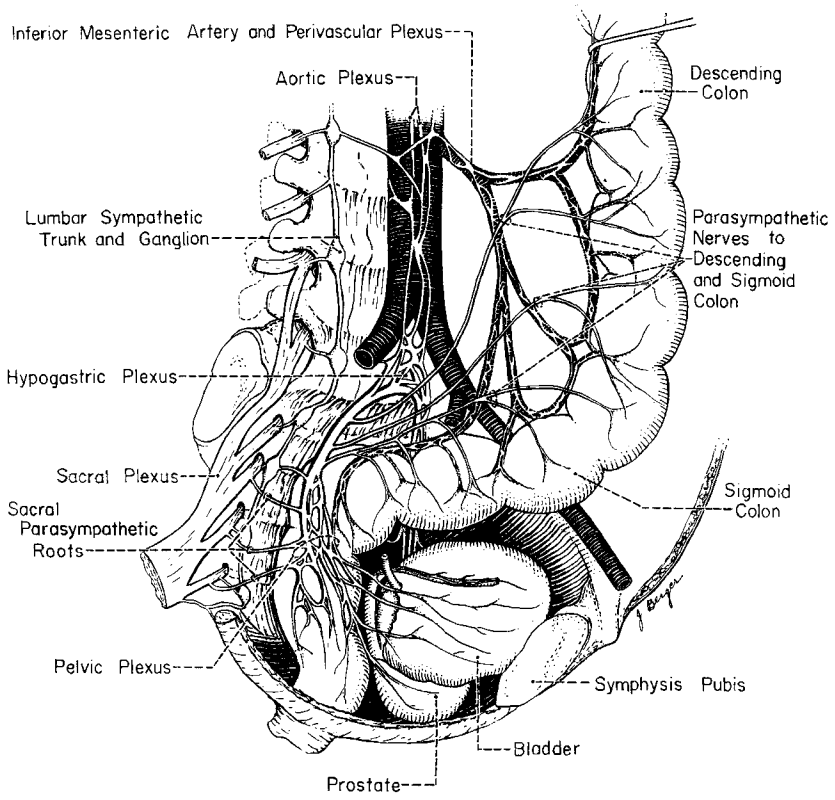

Figure 2

the pelvic plexuses at the sides of the rectum, and sometimes clearly in continuity with the fibers of the parasympathetic roots, one or more strands of nerve pass on either side into the sigmoid mesocolon and along the mesenteric aspect of the colon. Such nerves parallel the lower sigmoid colon and are not far removed from the superior hemorrhoidal vessels but reach the lower sigmoid directly or adjacent to the vasa

recta of the sigmoidal arteries. These nerves are clearly separable from the perivascular nerve networks but may communicate with them as they cross the vessels. Two or three other nerves, usually more slender, arise from the hypogastric nerves somewhat proximal to the rectal plexuses and ascend diagonally through the sigmoid mesocolon to the upper part of the sigmoid colon. These nerves pass obliquely to the sigmoid blood vessels, communicate with but do not join the perivascular plexuses, and reach the colon in company with the vasa recta or frequently quite isolated from even these terminal vessels. These nerves are likewise present bilaterally.

In the region of the sacral promontory, a short distance distal to the division of the hypogastric plexus into its two trunks, the hypogastric nerves each give rise to a somewhat more robust nerve strand which ascends diagonally in the sigmoid mesocolon and reaches the level of the left colic artery and the descending colon. It is this nerve that doubtless forms the basis for the report of Telford and Stopford. The nerves of the right and the left sides communicate with each other and with the perivascular plexus on the inferior mesenteric branches across which they pass but in no dissection were they considered to join the perivascular plexus and distribute with it. Rather did they continue independently and bilaterally under the mesocolon as far as the middle of the descending colon or higher levels. These nerves gave rise to branches to the descending colon some of which accompanied the vasa recta and some of which ran separately to the wall of the bowel. They were traceable to at least the mid-levels of the descending colon.

It seems likely that the uppermost offshoots of the hypogastric nerves are the nerves describd by Telford and Stopford ('34) (fig. 1). All studies following theirs confirm the origin and general destination of these nerves but deny that they unite to form one nerve or that they join and distribute by the perivascular plexuses. All studies have called attention to other nerves which leave the hypogastric trunks

between the sacral promontory and the rectum. These nerves, frequently 2 to 4 on each side, distribute to the lower descending and upper sigmoid parts of the colon by direct courses beneath the mesocolon quite independent of the blood vessels and the perivascular nerves. The later studies have also shown that there are one or two nerves which arise at the level of the rectal plexuses and distribute to the lower sigmoid by following a course adjacent to the wall of this segment of the colon. I am unable to be as certain as were Lannon and Weller that the latter nerves arise directly from the sacral nerves through the parasympathetic roots; certainly the nerves frequently appear to simply pass through or to bipass the rectal plexus. The nerves of the colon, at all levels of distribution, are bilateral and no significant differences between the sides appear.

These gross observations do not yield positive information as to the point along the colon at which the vagal supply ends and the sacral portion of the parasympathetic innervation begins. The uppermost nerves were traceable as high as the middle of the descending colon in all cases and, in a few, closer to the splenic flexure. It is certainly likely that they continued under the peritoneal layer and intramuscularly for some distance beyond their grossly observable termination. The problem was attacked by Schmidt ('33) in experiments in which, in different groups of dogs and cats, the vagus nerves were cut just below the diaphragm or the sacral parasympathetic roots were sectioned. After three weeks the animals were killed and parts of the ascending, transverse, and descending colon were studied both macroscopically and microscopically. After vagal section, degenerated nerve fibers were seen in pyridine silver sections in considerable numbers in the ascending colon, were less numerous in the transverse colon, and were absent in the descending colon. After section of the sacral parasympathetic roots, degenerated nerve fibers were identified in all parts of the large intestine but were progressively fewer in number from the splenic flexure to the proximal end of the ascending colon. It would appear

from this evidence that a considerable region of overlap exists in the distribution of these parts of the parasympathetic innervation. In a study of the motor innervation of the colon using physiologic techniques, Wells, Mercer, Gray and Ivy ('42) observed that stimulation of the pelvic nerves resulted in contraction of both longitudinal and circular musculature and a progressive shortening and drawing down of the colon toward the pelvis in dogs, monkeys and pigs. This response occurred only in the descending and sigmoid colon and rectum. With reference to the path of the pelvic innervation to the colon, Wells and his colleagues observed that stimulation of the central cut end of the hypogastric nerves produced no motor effect on the colon. This is additional evidence that the sacral portion of the parasympathetic supply does not reach the descending and sigmoid colon by ascending through the hypogastric plexus to the perivascular plexus of the inferior mesenteric system of arteries. The independent path of such autonomic nerves has been discussed.

The exclusion of parasympathetic fibers clarifies the composition of the hypogastric plexus, reserving to it sympathetic and afferent constituents only. As pointed out by Telford and Stopford, section of the hypogastric plexus or "presacral nerves" is a pure sympathetic section and does not interfere with the parasympathetic innervation of either the distal part of the colon and rectum or the pelvic and perineal organs.

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