STUDIES ON THE FUNCTION OF THE LUMBAR
SYMPATHETIC OUTFLOW
I. THE RELATION OF THE LUMBAR SYMPATHETIC OUTFLOW TO THE
SPHINCTER ANI INTERNUS

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Within recent years the rapid development of surgery of the sympa-
thetic nervous system has emphasized the need of precise knowledge of
its anatomy and physiology. We were led to undertake this series of
studies by the suggestion that idiopathic dilatation of the colon (Hirsch-
prung's disease) be treated by removal of the lumbar sympathetic trunks
with their ganglions and communicating branches. The physiologic
principles on which this operation is based are sound, if Gaskell's concep-
tion of the innervation of the large bowel and its internal sphincter can be
proved to be correct. According to Gaskell, through the lumbar outflow
of the sympathetic system pass impulses which are inhibitory to the muscu-
lature of the large bowel and motor to the internal sphincter of the anus.
The operation reported by Judd and Adson would thus leave motor nerves
in less disputed control of the colon: according to Gaskell, these reach the
large bowel by way of the sacral sympathetic outflow. At the same time,
it would diminish the opposition to the expulsion of the contents of the
bowel offered by the internal sphincter of the anus.

In the present paper we shall record a series of experiments performed
on dogs which have convinced us that so far as the internal sphincter of
the anus is concerned, the lumbar sympathetic outflow has the influence
attributed to it by Gaskell. At this time we do not propose to review
previous work on this subject; when we have reported our observations on
other functions of the outflow, we shall be in a position to present a more
fruitful discussion of the whole matter.

ANATOMY. The connections of the inferior mesenteric ganglion of the
dog with the lumbar sympathetic trunks have been studied by von Frankl-
Hochwart and Frölich. Our dissections of material hardened in formalin
bear out the description in their paper. Connector fibers pass to the gan-
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glion from the second, third, and fourth lumbar ganglions of both sides, and
a nerve bundle, often of considerable size, reaches it from the network of
nerve fibers on the ventral aspect of the aorta. We have proved that the
majority of those fibers in the roots of the ganglion which are concerned
with the innervation of the internal sphincter of the anus have cell sta-
tions in the ganglion. From it, impulses controlling the sphincter pass,
usually in postganglionic fibers, by three routes: along the lumbar colonic
nerves, which form a thick strand accompanying the inferior mesenteric
artery, and along the right and left hypogastric nerves.

A long median abdominal incision allows good exposure of the whole of
the nervous apparatus from the lumbar trunks to the postganglionic fibers.
We have found it easiest technically to approach both lumbar trunks from
the left side, after incising the peritoneum along the outer side of the aorta
and displacing the vessel to the right side.

METHODS OF EXPERIMENTS. In all our experiments we used adult dogs
under ether anesthesia. The colon was washed out by an enema immedi-
ately before the experiment. To help to prevent contractions of the ex-
ternal sphincter of the anus from complicating our tracings, we gave the
anesthetized animals divided doses of curare intravenously, in an amount
sufficient to abolish respiratory movements. Thereafter anesthesia was
continued by artificial respiration through an intratracheal tube. It has
been maintained that the external sphincter is very resistant to the
action of curare, but in the course of these experiments we observed uniformly
that it was influenced by curare far more than we had expected. Tracings
of the blood pressure were taken from the left carotid artery, whereas the
right external jugular vein was exposed for the introduction of drugs.

For recording the tonus of the internal sphincter, we used a bulb of fine
rubber secured to a glass tube of 5 mm. bore in such a way that when the
bulb was introduced the glass tube lay in the grasp of the external sphin-
ter, while the rubber bulb lay in the grasp of the internal sphincter. A
strong rubber tube, with a side piece controlled by a clamp, passed from the
glass tube to the proximal limb of a manometer. After experimenting
with several fluids, we found that the manometer followed the changes of
the sphincter in tension most accurately when it was filled with kerosene.
After the bulb had been placed in position, it was inflated through the
side piece to a pressure of 12 to 14 cm. of kerosene. The distal limb of the
manometer was then connected to an air tambour, which recorded changes
in tension on a slowly moving drum.

Our results could be obtained only when the tambour was placed as has
been described; if it was introduced farther, so as to lie in the rectum,
responses could not be demonstrated. Therefore, we feel that these must
be attributed to the internal sphincter, and that our method excludes any
complicating contractions of the musculature of the rectum.
Fig. 1. Contraction of the sphincter after epinephrin intravenously. Toward the end of the contraction a tendency to rhythmic variations in tonicity is apparent. Time marker, four seconds.

Fig. 2. Summation of two contractions of the sphincter, both induced by epinephrin intravenously. The second dose was administered when the contraction resulting from the first was at its height. Time marker, four seconds.

Fig. 3. Contraction of sphincter on stimulation of either lumbar sympathetic trunk.

**Response of Sphincter to Epinephrin.** The intravenous injection of epinephrin is well known as a convenient test for sympathetic innervation. The dose we used was 0.02 cc. of a 1:1000 solution of epinephrin
for each kilogram of body weight, diluted with 5.0 cc. of water. Such a dose caused well marked contraction of the sphincter (fig. 1) after a latent period varying from fifteen to thirty-five seconds. The contraction attained its full height in from thirty to sixty seconds, and the high level was maintained for a considerable time, in one case for as long as two

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**Fig. 4.** Absence of contractions on stimulation of either lumbar sympathetic trunk, after nicotine solution 0.5 per cent had been painted on the inferior mesenteric ganglion. Time marker, four seconds.

**Fig. 5.** Contraction of sphincter on stimulation of hypogastric and lumbar colonic nerves. Contraction on stimulating peripheral segment of cut lumbar colonic nerve; no contraction on stimulating central segment. Time marker, four seconds.

**Fig. 6.** Record after ergotoxin intravenously. No contraction of sphincter on stimulating hypogastric or lumbar colonic nerves. Only a very slight contraction after epinephrin intravenously. Time marker, four seconds.

**Fig. 7.** Record after ergotoxin intravenously. Relaxation of sphincter on stimulation of hypogastric nerve, after sphincter was allowed to recover more of its normal tone. Time marker, four seconds.
hundred fifteen seconds. Often we found that after the injection of epinephrin, the tonus of the contracted sphincter varied in a rhythmic manner; these waves of contraction and relaxation had an almost constant periodicity of from twelve to fourteen seconds, irrespective of the size of the animal. It was possible to superimpose a second contraction on the first, by giving a second dose of epinephrin while the first contraction was at its height. The second contraction began after a shorter latent period than the first, and the total duration of the two contractions was increased (fig. 2.)

The response of the sphincter to an intravenous dose of epinephrin was so invariable that in all our work we produced it at the beginning and end of each experiment, as a test of the working of our recording apparatus.

Response of Sphincter to Stimulation of Lumbar Sympathetic Trunks. Stimulation of either lumbar sympathetic trunk with a faradic current was found to give rise to contraction of the sphincter (figs. 3 and 4). As was to be expected, we found that the more cranial the point stimulated, the more powerful was the resulting contraction, owing to the greater number of roots of the inferior mesenteric ganglion affected by the current. The results of stimulation of the lumbar trunks after the application of 0.5 per cent solution of nicotine to the inferior mesenteric ganglion varied; in most experiments there was no contraction of the sphincter, and in others only a slight one (figs. 3 and 4). This observation would appear to confirm Gaskell's contention that "the internal sphincter ani muscle is composed of two parts, of which one is supplied by motor and inhibitory neurones, which have traveled out together in the thoracico-lumbar outflow and are situated near the muscle, and the other is supplied by motor neurones belonging to the thoracico-lumbar outflow and situated in the inferior mesenteric ganglion." The majority of the fibers supplying the sphincter would appear from our results to belong to the latter group.

Response of Sphincter to Stimulation of Lumbar Colonic Nerves. We found that faradic stimulation of the lumbar colonic nerve, as it coursed in the mesocolon, gave rise to a well marked contraction of the sphincter. If the nerve bundle was completely divided, then stimulation of its peripheral segment led to a characteristic contraction, whereas stimulation of its central segment did not cause a contraction (fig. 5).

Response of Sphincter to Stimulation of Hypogastric Nerves. Faradic stimulation of either hypogastric nerve gave rise to a well marked contraction of the sphincter (fig. 5). This was always greater than the contraction obtained by stimulating the lumbar colonic nerve under the same experimental conditions.

Response of Sphincter after Administration of Ergotoxin. In our search in the lumbar outflow for inhibitory nerves to the sphincter, we took advantage of an observation by Dale, that ergotoxin paralyzes the
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FUNCTION OF LUMBAR SYMPATHETIC motor nerves of the sympathetic system but does not affect the inhibitory nerves. When investigating this point we did not give curare, as in our other experiments. By inducing very deep ether anesthesia, we placed the internal sphincter at rest, as was indicated by a level base line on the recording drum. The sphincter was found to react normally to epinephrine intravenously and to stimulation of the lumbar colonic and hypogastric nerves.

We then gave an intravenous dose of 0.0005 mgm. of ergotoxin in watery solution for each kilogram of body weight. We found that after such a dose of ergotoxin, the sphincter did not contract after the intravenous administration of epinephrin or after faradic stimulation of the lumbar colonic or hypogastric nerves (fig. 6). The motor component of its nerve supply was therefore paralyzed. We were unable to cause relaxation of the sphincter on stimulation of these nerves, until we allowed it to recover some of its tone by lessening the depth of the anesthesia. It was then found that stimulation of the hypogastric nerves caused definite relaxation of the sphincter, whereas stimulation of the lumbar colonic nerves did not produce this relaxation (fig. 7). It would appear that those inhibitory nerves which reach the sphincter from the lumbar sympathetic outflow pass by way of the hypogastric nerves.

SUMMARY AND CONCLUSIONS

1. A series of experiments on the relation of the lumbar sympathetic outflow to the sphincter ani internus is described.
2. The sphincter derives a certain amount of motor innervation through the lumbar sympathetic outflow.
3. The majority of the fibers concerned are postganglionic fibers arising in the inferior mesenteric ganglion.
4. A few motor fibers are not interrupted in the inferior mesenteric ganglion.
5. Inhibitory fibers from the lumbar sympathetic outflow pass to the sphincter by way of the hypogastric nerves.

BIBLIOGRAPHY