Sympathetic Outflows from Cervical Spinal Cord in the Dog

Abstract. *In some dogs there are preganglionic fibers leaving the cervical spinal cord through the ventral roots of the lower cervical nerves. When these fibers are stimulated electrically in the anesthetized dog with skeletal muscle paralysis (induced by decamethonium), the effects are vasoconstriction in the front footpad, cardiac acceleration and augmentation, and a rise in arterial blood pressure.*

The sympathetic portion of the autonomic nervous system is often called "thoraco-lumbar" because preganglionic neurons have their cell bodies in the spinal cord from the first thoracic to the second or third lumbar levels. Axons of these preganglionic neurons leave the spinal cord through ventral roots of the thoracic and upper lumbar nerves and traverse the white communicating rami from spinal nerves to sympathetic trunks. If this anatomical description is correct, a person with a complete transection of the cervical spinal cord should have no sympathetic response to hypothalamic or other central nervous system activity. However, patients with cervical transections sometimes do have sweating responses which can be explained only by central nervous system influence over sympathetic outflow (*1*). Also, surgeons report that the sympathetic trunk can be severed above the first thoracic white communicating ramus and the inferior portion of the stellate ganglion removed without producing a Horner's syndrome, a condition in which there is a constricted pupil, dry and red face, and narrowed palpebral fissure due to loss of sympathetic innervation (*2*). This indicates that preganglionic axons reach the cervical sympathetic trunk superior to the first thoracic nerve.

The following experiments were performed on dogs to learn whether a sympathetic outflow from the cervical spinal cord could be demonstrated. Under α-chloralose anesthesia, the cervical spinal cord and the cervical dorsal and ventral roots were exposed. Muscular blockade was induced by decamethonium. Intact ventral roots, as well as the distal end of severed ventral roots, were stimulated before and after section of dorsal roots. Sympathetic responses were interpreted from records made on a model 5 Grass polygraph from a Statham pressure transducer connected to the femoral artery to measure blood pressure, and a photoelectric plethysmograph (*3*) on the large central pad of the front foot to measure cutaneous volume pulses.

Results of stimulating the ventral roots of cervical nerves are shown in Fig. 1. The upper tracing of each pair is a record of femoral arterial pressure that shows relatively large oscillations synchronous with the positive pressure respirator. Note the rise in blood pressure (20 to 60 mm-Hg, systolic) and the marked increase in heart rate (60 to 100 beats per minute) during each stimulation period. There was a gradation in response, the least being elicited by stimulation at C5 (fifth cervical nerve) and the greatest at C7 and C8. Onset of the response was prompt (within 3 to 5 seconds) and recovery was complete approximately 30 to 45 seconds after cessation of stimulation. These data are interpreted to mean that preganglionic sympathetic fibers are present in the ventral roots of the lower cervical nerves. Sectioning of the spinal cord between C8 and T1 (first thoracic nerve) did not prevent the response.

The lower tracing of each pair of records shows the changes in pulse amplitude in the footpad. Decrease in amplitude is due to vasoconstriction and decreased volume of blood flow through the footpad during each pulse. These data are also interpreted to in-

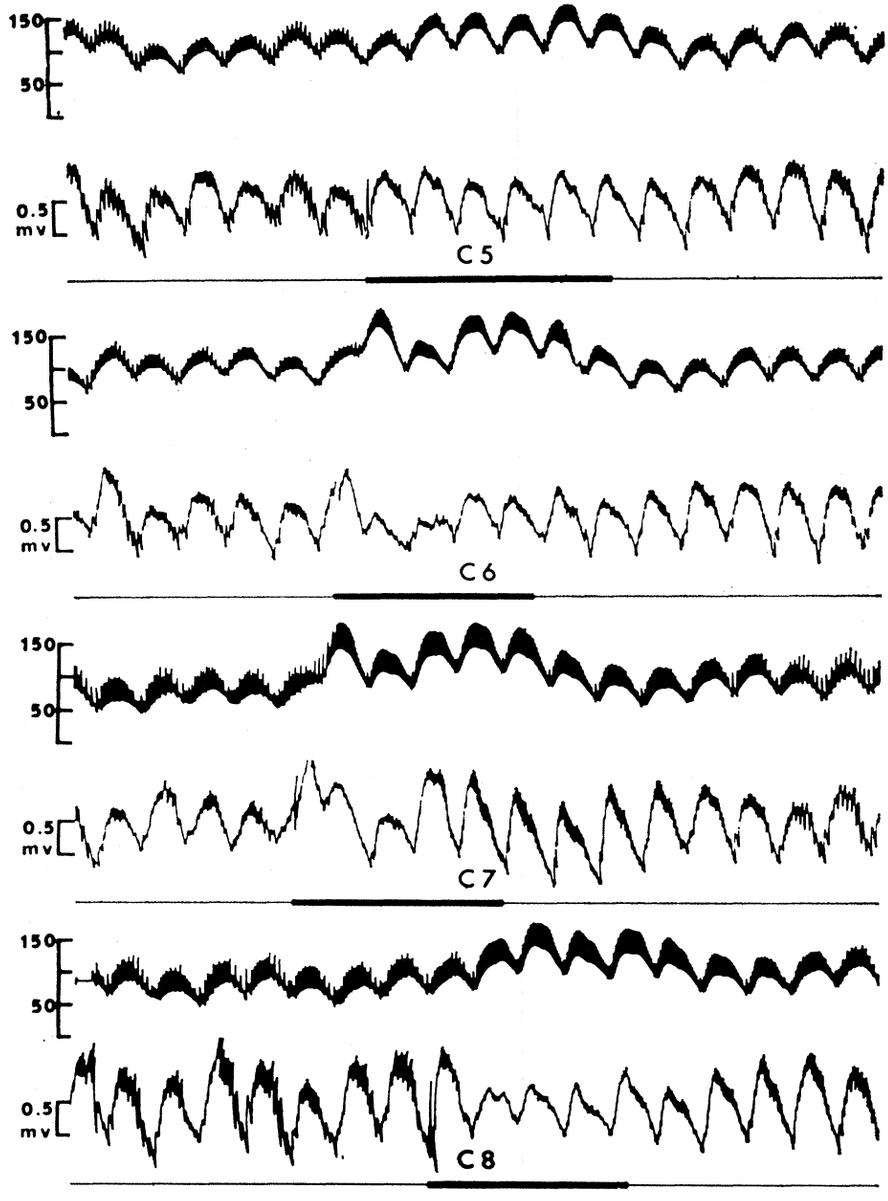

Fig. 1. Results of the stimulation of ventral roots of cervical nerves C5, C6, C7, and C8. Upper tracing, blood pressure; middle tracing, cutaneous volume pulse; and bottom line, time of stimulation. Paper speed, 2½ mm/sec.

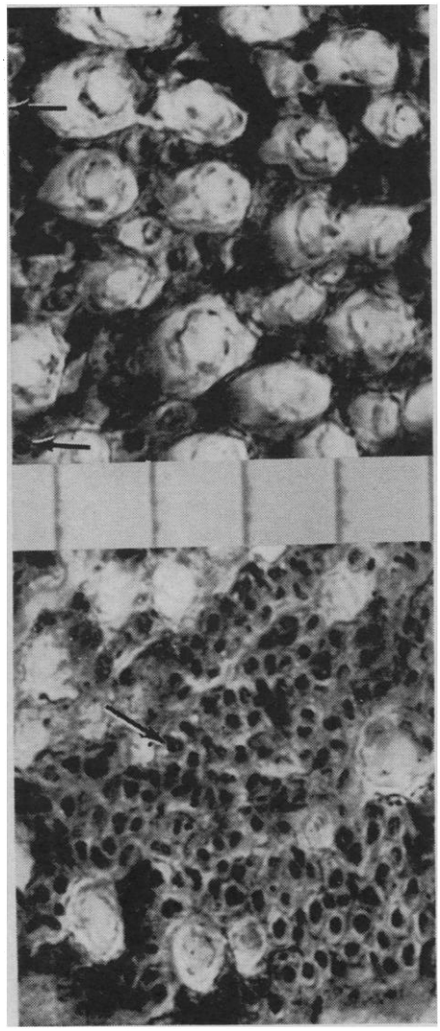

Fig. 2 (top). Cross section of ventral root C7. Fig. 3 (bottom). Cross section of ventral root T1. Arrows indicate small myelinated fibers. De Castro technique was used. Scale, 10 μ between lines.

dicate the presence of preganglionic sympathetic fibers in the ventral roots of these cervical nerves, stimulation of which resulted in vasoconstriction in the footpad.

Preganglionic sympathetic axons are small myelinated fibers from 1 to 3 μ in diameter. If such fibers are present in the ventral roots of cervical nerves, appropriately stained sections of these roots must reveal them. Figure 2 is a cross section of the seventh cervical ventral root of the dog which was stimulated to produce the functional responses shown in Fig. 1 (C7 stimulation). The photomicrograph reveals numerous small myelinated fibers scattered among much larger and heavily myelinated motor axons. When measured on the 10-μ scale included in the photograph, it is apparent that these small fibers are 1 to 2 μ in diameter and are, therefore, of the appropriate size to be classified as sympathetic preganglionic B fibers. Although at first glance the large motor fibers seem more numerous, an actual count reveals that small myelinated fibers outnumber large ones about three to one. Similar small fibers were found scattered throughout the sections made from the ventral roots of the C5, C6, and C8 nerves.

Figure 3 is a cross section of the first thoracic ventral root taken from the same animal and reveals the expected large population of small, thinly myelinated fibers. This photomicrograph was made at the same magnification as that in Fig. 2, and comparison of the small fibers reveals identical size and staining characteristics.

We conclude that in some dogs there are preganglionic fibers leaving the cervical spinal cord through the ventral roots of the lower cervical nerves. A comparable anatomical arrangement in humans would explain both the sweating patterns in patients with cervical cord lesions and the continued sympathetic innervation to the head after surgical removal of the inferior portion of the stellate ganglion.

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References and Notes

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Optomotor Response in Human Infants to Apparent Motion: Evidence of Innateness

Abstract. *Human infants were placed inside a stationary cylinder containing a columnar pattern like that used to elicit the optokinetic reflex. By sequential illumination of the columns, the pattern was made to appear to rotate. Optokinetic nystagmus was clearly evoked in 64.7 percent of the subjects, with a weak-positive response in an additional 11.8 percent.*

The newborn infant reacts innately to a truly moving striped field with optokinetic nystagmus (OKN) (*1*). Recent study of newborn guppies and newly hatched praying mantids provided evidence of an innate optomotor response to a truly moving striped pattern and to a stroboscopically flashed columnar pattern simulating true rotation (*2*). It was predicted that optomotor response to stimulation by apparent motion would also prove to be innate in newborn humans; our study was designed to test this prediction.

Since infants cannot report a perceptual experience, a device capable of eliciting motor response to stroboscopic stimulation had to be constructed. The design called for a columnar device flashing stroboscopically to simulate true movement. In stroboscopic stimulation there is no movement of the image across the retina. If it could be demonstrated that a columnar pattern in apparent movement elicited the OKN response in the infant, one could conclude that the response is innate.

A stroboscopic device was constructed comprising an optical presentation unit and an electronic control unit (*3*). The former consisted of a series of Sylvania electroluminescent light panels 61 cm long and 4.6 cm wide, mounted on a sheet of plastic, 61 cm wide and 2.4 m long, bent to form a cylinder 76 cm in diameter; the latter controlled the sequence and duration of light presentation. Additional controls allowed adjustment of the on-off times of the lamp from 0.01 to 1.1 seconds. The intensity of the illumination also could be regulated. The electroluminescent panels were free of glare, and maximum brightness intensity of the unit (24.7 lumen/m^2) was optimal for the experiment. Durations of lamp-on and dark intervals could be adjusted over a fairly broad range, although systematic analysis of the various combinations was not attempted. A lamp on-off ratio of 200 to 300 msec was selected for the experiment. Stripes of black adhesive tape, 2.5 cm wide and 61 cm long, were laid down the