Experimental Study of Ischemic Damage to the Cervical Spinal Cord*

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The pathogenesis of myelopathies associated with human cervical spondylosis has been the subject of controversy, and no single explanation suffices for all clinical and anatomical findings. Etiological considerations have included such factors in spinal cord damage as direct compression, "anchoring,"18,19,26,44,86,82 recurrent minor trauma,3,8,88 and circulatory disturbances.

The fact that in man the neurological level of dysfunction does not always correspond to the level of the main spondylotic lesions shown by x-ray and that at surgery the cord is seldom found to be compressed has recently interested a number of authors in the importance of vascular factors. Bolton7 and Tureen69 have pointed out the importance of the vertebral artery as a source of blood supply to the cervical segments of the cord. Bauer, et al.,3 Maslowski,33 and Hutchinson and Yates87 have assumed without actual proof that spondylosis may cause cervical ischemic myelopathy through compression of the vertebral artery.

Tureen,59 Suh and Alexander,58 and Herren and Alexander24 have described the segmental character of the spinal circulation and suggested that the cervical cord is largely dependent for its blood supply on three to five anterior radicular arteries. Woollam and Millen64 called attention to the importance of the anterior radicular arteries by emphasizing that the anterior spinal artery is in reality nothing but an anastomotic chain formed by ascending and descending branches of each anterior radicular artery. Störebecker61 suggested that the clinical signs of amyotrophic lateral sclerosis in two cervical spondylotic patients may have been due to local chronic hypoxemia of the spinal cord and brain stem induced by very slowly progressive partial compression of radicular and/or vertebral arteries. Taylor96 noted the similarity between the spinal cord syndromes produced by ligation of the abdominal aorta in cats and the clinical syndromes of cervical myelopathy. He also found compressed radicular arteries in the narrowed foramina, and fibrous perineural root sleeves at surgery, and considered obstruction of the radicular arteries to be the cause of spondylotic myelopathy.

Mair and Druckman,31 on the basis of four autopsy cases of spondylotic myelopathy, proposed a relationship between the degenerated region of the spinal cord and that supplied by the anterior spinal artery. Logue49 believed that repeated friction injured the anterior spinal artery and caused the myelopathy. Others, however, question these theories by pointing out that the degenerated area of the cord does not correspond to the territory supplied by the anterior spinal artery. Girard, et al.,19 noted hyaline degeneration of small arterioles in the interior of the cord at autopsy. Breig, et al.,10 made microangiographic studies of the shape of the cervical spinal cord during neck motion and emphasized the luminal narrowing of the regional intraspinal arteries.

Most of these theories are hypothetical. Wilson and Landry68 tried an experimental production of ischemic cervical myelopathy in dogs, but results were disappointing. Thus, an experimental study of cervical ischemic myelopathy seemed justified. Our study deals with an experimental ischemic myelopathy successfully obtained in mongrel dogs in which the vascular factors were clearly related to the localization and extent of the lesion. However, the relationship of the experimental findings obtained in dogs to those

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of cervical spondylosis in man is still undetermined.

The Arterial Anatomy of the Canine Cervical Spinal Cord

As in man, the canine cervical spine consists of seven cervical vertebrae; its vertebral artery also arises from the subclavian artery and enters the bony canal at the transverse process of the sixth cervical vertebra. The two vertebral arteries give origin to symmetrical radicular arteries at each segmental level. These enter the spinal canal through the corresponding intervertebral foramina and divide into ventral and dorsal radicular arteries. The ventral radicular arteries, larger than the dorsal, run with the ventral spinal nerve rootlets and join the anterior spinal artery near the midline on the ventral surface of the cord. The dorsal radicular arteries reach the surface of the spinal cord with the dorsal spinal rootlets, where they divide into cranial and caudal branches which form the dorsolateral spinal artery (Fig. 1). On the surface of the cord there is the so-called pial plexus, which, though incomplete, encircles the cord and makes an anastomosis between the ventral and dorsolateral spinal arteries. From these arteries on the surface of the cord many arterioles arise which penetrate the interior of the cord; some supply the white substance while others reach the gray substance where they divide into fine capillaries. The largest penetrating branch is the ventral median fissure artery.

In the dog, the largest anterior radicular artery enters the spinal canal through the intervertebral foramen between C-2 and C-3 on each side. The anterior spinal artery enlarges abruptly at the point of junction with the C-3 radicular arteries and ascends to form an arterial diamond (the cerebrospinal junction) with the basilar artery and the occipitovertebral arteries. The vertebral artery tapers after sending off the C-3 radicular artery and is distributed to the occipital muscles.

Material and Methods

Experimental Animals. Forty-six adult mongrel dogs were used for experiments; four of them were used as the control group to provide the normal histological sections. Among 42 operated dogs, 11 died during or after surgery and were excluded from further histological examination.

Operative Technique. Through a median longitudinal incision on the ventral surface of the neck, a paratracheal approach to the vertebral artery was carried out under Nembutal. (The right vertebral artery is situated more superficially and is more easily accessible; that on the left is crossed by the thoracic duct, which causes a little difficulty in dissection.) In some cases, muscle attached to the ventrolateral aspect of the C-3 and C-4 vertebral bodies was partially removed and the ventral wall of the foramen transversarium opened with rongeurs or the electric reamer.

Technique of Sacrifice. Under Nembutal anesthesia, a glass catheter was introduced into the abdominal aorta toward the heart, and after exsanguination, 500 ml of 3% Berlin blue solution were injected. Immedi-

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FIG. 1. Diagram of the arterial system of the canine caudal medulla and cervical spinal cord (redrawn from the article of Wilson and Landry69).