Ligation of Major Thoraco-Lumbar Spinal Cord Arteries in Monkeys*

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It has often been stated that occlusion of the artery radiculo-medullaris magna (ARMM), also called the "arteria radiculare anterior magna," "great anterior medullary artery," and "artery of Adamkiewicz" (Fig. 1), will cause severe ischemia of the lower spinal cord.1,3,7,8,10-15,17 Most of the evidence stems indirectly from clinical observations, mainly reports of paraplegia following aortic surgery and thoraco-lumbar sympathectomies.1,3,7,10-12 The pathological findings in these reports are inconclusive. In addition, there are very few experimental findings to support this statement.17

If the ARMM could be sacrificed without danger to the patient, it might have practical value in the neurosurgical management of spinal cord tumors and arteriovenous malformations.5,14,15 During our experiments with spinal cord angiography in the monkey, we have developed a technique which enables us consistently to demonstrate the ARMM.4,6 We therefore decided to study the neurological consequences of ARMM ligation. As part of this study we also ligated the anterior spinal artery above and below its junction with the ARMM. In a single monkey both the ARMM and proximal anterior spinal artery were ligated.

Materials and Methods

We used 31 Rhesus monkeys ranging in weight from 3 to 4.5 kg. We chose Macaca mulatta for the experiments because the vascular anatomy of the Macaque spinal cord, including the levels at which the ARMM enters the spinal cord, has been shown to be strikingly similar to that in man.10 The animals were first tranquilized with Sernylan,† received for publication April 28, 1969.

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† Parke Davis and Company, Detroit, Michigan.

3 mg/kg injected intramuscularly, and then anesthetized with intravenous sodium pentobarbital, 30 mg/kg, for angiography. Similar dosages of both drugs were also used for surgical anesthesia. Animals that developed neurological deficits after angiography or did not survive the immediate post-surgical period were excluded from this study.

Angiographic Technique. The ARMM and anterior spinal artery were identified (Fig. 2) by introducing a polyethylene catheter (PE 160) through an arteriotomy in the femoral artery, threading it into the lower thoracic aorta,6 and then injecting 200 mg of Levarterenol,‡ immediately followed by 10 cc of methylglucamine iothalamate.§ The vaso-

‡ Levophed, Winthrop Laboratories, New York, N.Y.
§ Conray 60, Mallinkrodt Pharmaceuticals, St. Louis, Missouri.

FIG. 1. Schematic representation of the arterial supply of the human thoraco-lumbar cord. Arrow points to the ARMM.
pressor agent was contained in 10 cc of 5% dextrose solution and was manually injected at the same rate as the opaque medium. Serial filming was performed with a Sanchez-Perex cassette changer.

**Surgical Technique.** The approach to the spinal cord was made with the monkey in the lateral decubitus position. After sterile preparation, an incision was made parallel to the rib or transverse process appropriate to the level of the vessel to be ligated. Electrocautery was used to incise the paravertebral muscles. The laminae, articular facets, transverse processes, and pedicles were removed from two to three vertebrae on one side. The dura was incised longitudinally midway between the anterior and posterior aspects of the cord. The denticulate ligaments were sectioned and fine sutures were placed in the ligaments at the cord surface for purposes of retraction. This maneuver exposed the vessels on the anterior aspect of the spinal cord (Fig. 3). There was no need to section roots to gain adequate exposure. We used 7–0 silk sutures on round needles to ligate the ARMM and anterior spinal artery. Cautery was never used in the vicinity of these blood vessels. No attempt was made to close the dura.

**Neurological Evaluation.** The monkeys were observed daily in their cages for their ability to stand, jump, and climb. Detailed neurological examinations were performed following angiography but prior to surgery, and prior to sacrifice. The macaques were placed in special restraining chairs* without any sedation, and we examined muscle tone and power in the extremities, grasping power of toes, deep tendon reflexes, cremasteric and plantar reflexes. Sensory examinations were abandoned because they were extremely difficult to interpret. Animals were graded according to the following functional classifications:

0 = Normal motor examination
1 = Minimal motor disability, abnormal reflexes; legs could still be used in climbing
2 = Moderate paraparesis, standing accomplished with support of arms

* Foringer and Company, Rockville, Maryland.

3 = Marked paraparesis; legs could move against gravity but could not be used for support
4 = Paraplegia; minimal or no voluntary movement in legs.

All monkeys were sacrificed between 4 and 10 days after surgery. Those that were completely intact or paraplegic were sacrificed earlier than those with partial deficits. The latter were given slightly more time for neurological recovery.

**Postmortem Studies.** The animals were heavily anesthetized with intraperitoneal Pentobarbital; then both femoral arteries were tied off and a polyethylene catheter (PE 160) was passed into the iliac artery. The chest was opened and the thoracic aorta clamped at the T-8 level. A 20% suspension of micropaque†

† Damancy Ltd., Ware, Herts., England.