BRIEF COMMUNICATIONS

THE ANTERIOR SPINAL ARTERY: THE MAIN ARTERIAL SUPPLY OF THE HUMAN SPINAL CORD—A PRELIMINARY ANATOMIC STUDY

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Paraplegia is the most feared complication of surgery of the thoracic aorta. Controversy continues regarding the continuity of the anterior spinal artery (ASA). We studied the arterial

vascularization of human spinal cord to indagate ASA continuity and possible anatomic variations of the arteria radicularis magna (ARM).

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Methods. From July 1998 to January 1999, 31 spinal cords from adult cadavers of both sexes were studied (mean age 72 ± 12 years). The cause of death was well established in each case and no one had spinal, cerebral, or significant aortic disease. The abdomen, thoracic viscera, and vessels were removed after 24 to 36 hours from death; only the upper trunks of the aorta were left in situ. The anterior vertebral spinal column was exposed and the attached muscles were divided. The vertebral bodies were removed with an electrical oscillating saw. The spinal cord in situ was exposed after a longitudinal paramedian incision of the dura mater. In all cases the course of the ASA was visualized and the distribu-

Fig 1. The dye injected through the left vertebral artery progressively colors the human spinal arteries.

Fig 2A. Level and localization of the arteria radicularis magna (ARM). R, Right; L, left.

tion of the radiculomedullary arteries was checked. Thereafter, a vertebral artery was cannulated with a 14F to 16F catheter, the contralateral vertebral artery was ligated, and after a craniotomy the basilar artery was clamped with a bulldog clamp. The spinal cord circulation was flushed with 300 to 500 mL of normal saline solution. Then 500 mL of polygelatin colored with 10 mL of 1% methylene blue was gently injected over a 3- to 5-minute period into the left (10 cases) or right (13 cases) vertebral artery (Fig 1). Finally, the spinal cord was removed from the brain stem to L2 to L3 and was fixed in a 15% formaldehyde solution for 15 to 20 days. The dissection was performed under optical magnification, and ASA diameters above and below the ARM were measured with a Palmer-type micrometer and were compared by the Student *t* test.

Results. In all cases the ASA coursed ventromedially on the spinal cord up to the cauda equina without interruption. In all cases, the dye progressively colored the ASA from the thoracic to the lumbosacral level, and all of the radiculomedullary arteries (ARM included) were colored in a retrograde manner.

The origin of the ARM varied greatly from T9 to L5, and it was more frequent between T12 and L3, accounting for 83.9% of the cases (Fig 2A). The ARM origin was from the left side in 21 cases (67.7%) and from the right side in 10 cases (32.3%). In all cases the ARM constituted the lower radiculomedullary blood supply, recognizable for its larger diameter and characteristic course as a *hairpin bend* just before joining the ASA (Fig 2, B and C). The diameter of the ARM varied from 730 to 1330 μm ; no relation could be detected between ARM diameter and ARM origin level. The diameter of the ASA was $468 \pm 85 \mu\text{m}$ and $1120 \pm 140 \mu\text{m}$ above and below the junction with the ARM, respectively ($P < .001$).

Discussion. Paraplegia is a devastating complication of repairs of the descending thoracic and thoracoabdominal aneurysm. Investigators still disagree about the anatomy and physiology of human spinal cord blood supply. Svensson, Klepp, and Hinder¹ in 1986 studied cord anatomy of 38 baboons and 8 human beings, documenting that in primates

the ASA was a continuous vessel arising from the vertebral arteries that reached to the filum terminalis. On the other hand, a recent review on spinal cord protection by Gharagozloo and colleagues² stated that the ASA was discontinuous and that blood supply of the spinal cord was segmental, via vertebral, intercostal, and lumbar arteries, with additional components from the cervical and iliac arteries.²

The features of human spinal cord blood supply can markedly affect the strategies that should be adopted to prevent paraplegia. If ASA is not continuous, the use of distal perfusion techniques and the reimplantation of intercostal arteries thought to be at major risk can be justified; on the other hand, if ASA continuity can be demonstrated, it could be hypothesized that the ASA could provide some blood supply to thoracolumbar spinal cord from distant sources like the vertebral and cervical arteries, even if all intercostal arteries are occluded or oversewn.³⁻⁵

The limits of this study are clear: the absence of aneurysmal disease of the aorta did not allow us to document possible differences in the spinal cord blood supply. In addition, the only way we could assess the blood flow in the ASA was static and not dynamic. On the other hand, this method allowed us to verify and visualize, in real time, the flow progression and direction of the colored solution through the spinal cord arterial supply and simulate the preferential direction of the blood flow in the ASA from the foramen magnum to the conus. We believe this is probably similar to what happens during aortic crossclamping.

The results of our study yield two main points: First, in cadavers of patients free of aortic disease, there is anatomic continuity among the vertebral arteries, ASA, and ARM. On the basis of that finding, the sacrifice of the segmental arteries emerging from the aneurysm, as suggested by Acher,³ Griep,⁴ and their coworkers, and more recently by Biglioli and associates,⁵ can be justified, especially with short aortic crossclamp times. In that case, it is possible to prevent the blood flow steal from the ASA via the radiculomedullary arteries to the aorta distal to the clamp (which can determine an ischemic injury of the anterior two thirds of the spinal cord,

Fig 2. B, Photograph of specimen 29: The *black arrow* indicates the ARM at the level of the 12th spinal anterior thoracic root, on the right side of the spinal cord. The *white arrow* shows the ASA below the junction with the ARM. On the left side of the specimen it is possible to see the tract of the ASA situated above the entry of the ARM. The ARM is recognizable for its characteristic course as a hairpin bend just before joining to the ASA. We injected the arteries with a 3.5% solution of colloidal polygelatin colored with 1% methylene blue diluted in water. **C,** Photograph of specimen 30: Differing from the previous specimen, the ARM is on the left side of the spinal cord (the most frequent finding) indicated by the *white arrow*, whereas the ASA is shown by the *black arrow*. In this case the ASA below the junction with the ARM is characterized by a twisted course.

including the critical motor area, and which is not completely avoided by the interruption of the intercostal arteries).³

Second, there is a remarkable variability of the ARM origin, but in more than two thirds of cases it comes off the lumbar arteries. This may imply that intercostal artery reimplantation during thoracic aortic surgery cannot reduce the incidence of paraplegia, but rather increase the risk of neurologic complications because of longer aortic crossclamping times.

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