Anatomical Pattern of Feeding Artery and Mechanism of Intraoperative Spinal Cord Ischemia

Norihiko Shiiya, MD, PhD, Satoru Wakasa, MD, PhD, Kinya Matsui, MD, Takashi Sugiki, MD, Yasushige Shingu, MD, Tomoshi Yamakawa, MD, and Yoshiro Matsui, MD, PhD

Department of Cardiovascular Surgery, Hokkaido University Hospital, Sapporo, Japan

Background. We evaluated correlation between anatomical pattern of the spinal cord feeding artery, detected by preoperative multidetector row computed tomography, and the mechanism of spinal cord ischemia during aortic surgery.

Methods. One hundred sixteen patients underwent multidetector row computed tomography before descending or thoracoabdominal replacement. Segmental arteries feeding the spinal cord were detected in 92 patients (79%), and were classified into "critical" (isolated hairpin shaped) or "supplemental" (confluence-shaped or multiple). Spinal cord ischemia was monitored together with distal aortic perfusion in 53 of them by motor-evoked potentials, evoked spinal cord potentials, or both. The relationship between monitoring results and operative management to the detected feeding arteries was analyzed.

Results. When no feeding segmental artery was involved in the extent of replacement (n = 18), spinal cord ischemia was detected in 1 (6%), which was due to cross-clamping the subclavian artery. When a supplemental feeding artery was involved (n = 15), ischemia was detected in 7 patients (47%), and was reversed by stopping back-bleeding. When a critical feeding artery was involved (n = 20), ischemia was detected in 6 (30%). In 3 of them, ischemia was reversed by stopping back-bleeding, whereas it was reversed only after reconstruction of the critical feeder in the remaining 3. Paraparesis occurred in 1 of the latter 3, and the incidence of spinal cord injury was 2% (1 of 53).

Conclusions. When the involved feeding artery is a supplemental one, the steal phenomenon is the predominant mechanism of ischemia. Conversely, blood flow interruption to the critical feeding artery may cause spinal cord ischemia without steal phenomenon.

(Ann Thorac Surg 2009;88:768–72)

Ischemic spinal cord injury is a devastating complication of aortic surgery. Although it is a multifactorial event, there is no doubt that anatomical characteristics of the spinal cord blood supply play a pivotal role. Spinal cord blood supply has multiple feeders and rich collateral networks both inside and outside the spinal canal, and is not dependent upon any single artery [1]. However, several anatomical studies have pointed out that the anterior spinal artery is sometimes hemodynamically discontinuous at its junction with the radicular artery [2, 3], which may be a cause of insufficient collateral blood flow to this area.

With the recent advance in the imaging technologies, noninvasive visualization of the spinal cord feeding arteries has become reliable, either by magnetic resonance imaging (MRI) [4–6] or multidetector row computed tomography (MD-CT) scan [7, 8]. We have been using MD-CT scan for this purpose [8]. Based on this experience, we hypothesized that anatomical pattern of the spinal cord feeding arteries, visualized by MD-CT scan, reflects hemodynamic continuity of the anterior spinal artery and is related to the prevalence and mechanism of intraoperative spinal cord ischemia. The study aim was to test this hypothesis in our clinical experiences.

Material and Methods

We retrospectively analyzed a total of 116 patients who underwent MD-CT scan to detect spinal cord feeding arteries, as a part of preoperative evaluation, from September 2001 through January 2009. There were 39 descending and 77 thoracoabdominal lesions, and 36 of the latter had Crawford I or II extent. Forty-eight had aortic dissection. The imaging system used had 64 detector rows. This study was approved by the Institutional Review Board. All the patients gave informed consent.

Segmental arteries that fed the spinal cord were detected in 92 patients (79%), and were multiple in 34 patients (29%). Their anatomical pattern was classified into the "hairpin" shaped and the "confluence" shaped (Fig 1). The latter were frequently accompanied by a more proximally located hairpin-shaped feeding artery. Distribution of these feeding arteries is shown in Figure 2, with respect to each anatomical pattern. The hairpin-

Accepted for publication May 8, 2009.

Presented at the Forty-fifth Annual Meeting of The Society of Thoracic Surgeons, San Francisco, CA, Jan 26–28, 2009.

Address correspondence to Dr Shiiya, Department of Cardiovascular Surgery, Hokkaido University Hospital, N14W5, Kita-ku, Sapporo, 060-8648, Japan; e-mail: shiyanor@med.hokudai.ac.jp.

Published by Elsevier Inc

0003-4975/09/$36.00
doi:10.1016/j.athoracsur.2009.05.026

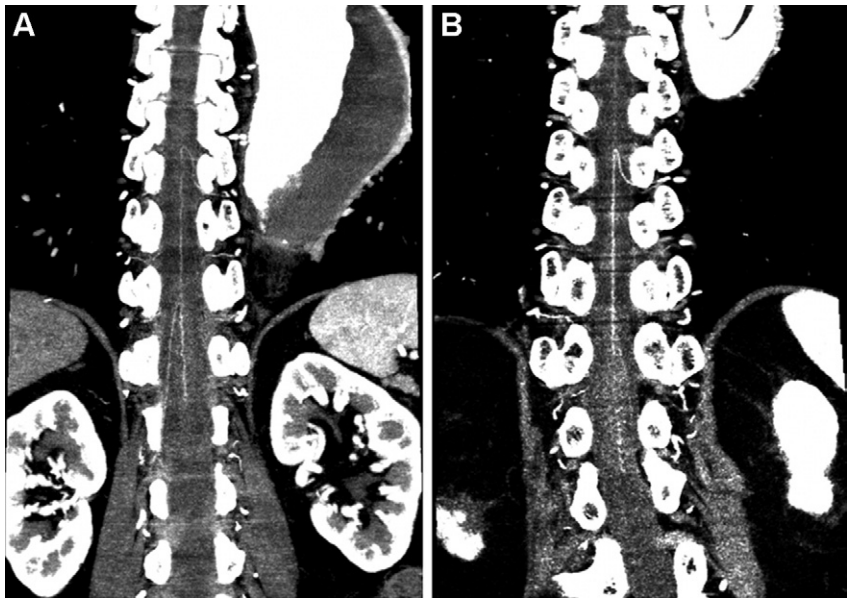

Fig 1. Anatomical patterns of the spinal cord feeding artery detected by multidetector row computed tomography (MD-CT) scan: (A) confluence-shaped, (B) hairpin-shaped. The confluence-shaped arteries were frequently accompanied by a more proximally located hairpin-shaped artery, as in this Figure.

shaped ones were arising from T7 to L1, predominantly in the left. This finding is consistent with our current knowledge of the great radicular artery. On the other hand, confluence shaped ones were distributed more distally, in accordance with a previous anatomical study [9].

For the following study on the prevalence and mechanism of intraoperative spinal cord ischemia, isolated hairpin-shaped feeders were classified as "critical" and confluence-shaped ones or hairpin-shaped ones that were accompanied by distal confluence shaped ones (multiple feeders in continuity) were classified as "supplemental," based on the assumption that multiple feeders were not clamped simultaneously.

Study on Prevalence and Mechanism of Intraoperative Spinal Cord Ischemia

Among the 92 patients in whom spinal cord feeding arteries were detected, 28 without electrophysiologic monitoring, 10 undergoing deep hypothermic operation, and 1 without distal aortic perfusion were excluded from the study. Therefore, the study subjects consisted of the remaining 53 patients who underwent surgery with monitoring and distal aortic perfusion. There were 17 descending and 36 thoracoabdominal lesions, and 18 of the latter had Crawford I or II extent. Sixteen had aortic dissection, and none had acute presentation.

Our surgical technique, which we call the multisegmental sequential repair, has been reported previously [10]. Briefly, the distal one third of the descending thoracic aorta, where spinal cord feeding arteries were usually present, was opened in two or more sequences, and segmental arteries, usually one pair from each segment, were reattached sequentially by separate tube grafts. Presence of mural thrombus did not preclude the use of this technique as long as the aorta could be clamped and blood flow through distal aortic perfusion could effectively be blocked. The rationale of this technique was to expect collateral blood flow through the neighboring segmental arteries during reattachment of a segmental artery, and to minimize the steal phenomenon in opening the aorta. In this technique, we always noticed

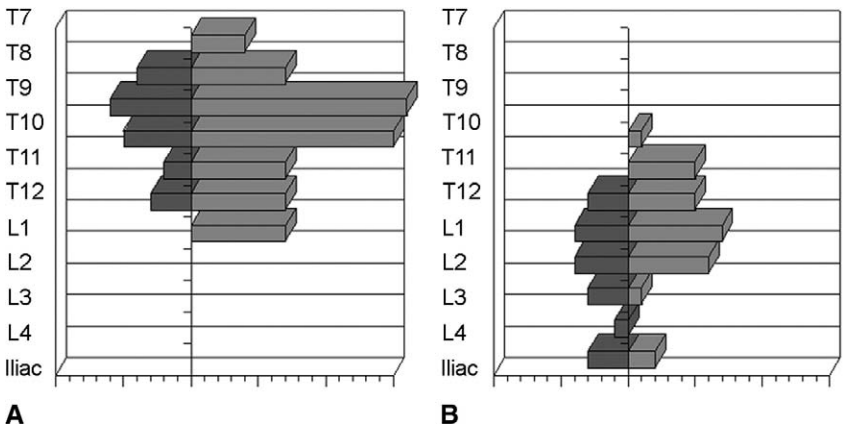

Fig 2. Distribution of the spinal cord feeding arteries with respect to each anatomical pattern: (A) hairpin shaped, and (B) confluence shaped.