Surgical technique for preservation of extrathoracic collateral networks in thoracoabdominal aortic surgery

Masayuki Otani, MD, Shintaro Katahira, MD, PhD, Koki Ito, MD, PhD, and Yoshikatsu Saiki, MD, PhD, Sendai, Japan

From the Division of Cardiovascular Surgery, Tohoku University Graduate School of Medicine, Sendai, Japan.

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Address for reprints: Yoshikatsu Saiki, MD, PhD, Division of Cardiovascular Surgery, Tohoku University Graduate School of Medicine, 1-1 Seiryomachi, Aoba-ku, Sendai, Japan 980-8574 (E-mail: yoshisaiki@med.tohoku.ac.jp).

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Extrathoracic collateral to Adamkiewicz artery was explored to modify surgical approach.

CENTRAL MESSAGE

Identifying and preserving potential extrathoracic collateral vessels is advisable when stenosis or occlusion of the origin of a critical segmental artery connected to the Adamkiewicz artery is seen.

▶ Video clip is available online.

Spinal cord ischemic injury (SCII) is a tragic complication of thoracoabdominal aortic repair (TAAR). The importance of collateral networks for spinal cord perfusion is recognized.[1] The modes of collateral networks are classified into intraspinal, paraspinal, and extrathoracic collateral[2-4]; however, few reports have addressed collateral system functions. We reviewed patients who underwent TAAR or descending thoracic aortic replacement (DTAR) employing selective hypothermic intercostal artery perfusion (HIAP).[5] We emphasized the importance of identifying and preserving of potential extrathoracic collateral vessels when stenosis or occlusion of the origin of a critical segmental artery (cSA) connected to the Adamkiewicz artery (AKA) was noted preoperatively.

CLINICAL SUMMARY

We retrospectively analyzed the preoperative computed tomography and magnetic resonance imaging of the patients who underwent TAAR or DTAR using HIAP at Tohoku University Hospital between January 2011 and December 2020. The images were evaluated by multiple cardiovascular radiology specialists.[6,7] Informed consent was obtained from the patients. This study received ethical approval (institutional review board: 11000628; date: April 4, 2022; approval number: 25142.)

The overall incidence of SCII including transient neurologic symptom was 8.2%. Of the 134 patients, AKA was identified in 124 (92.5%) through preoperative imaging. Among them, 20 (16.1%) had stenosis or occlusion of the cSA at its origin. Intraspinous or paraspinous network was present in 19 of the 20 cases. Notably, 5 of those 19 patients exhibited significant extrathoracic collaterals. The extrathoracic networks comprised the left subclavian artery downstream in 2 cases, the external iliac artery downstream in 2, and both downstream in 1. Of these 5 cases (Table 1), SCII was avoided in all but case 4 by performing specifically modified surgical procedures that considered the presence of these extrathoracic networks (Figure E1).

In cases 1 and 2, the chest was opened anteriorly using a modified Stoney incision to preserve the collateral pathways from the lateral thoracic and subscapular arteries, as previously described.[3] In case 3, instead of a conventional retroperitoneal approach, a midline laparotomy incision was performed to avoid an injury to the left inferior epigastric artery, which had developed as a collateral pathway.[4] In case 4, the left deep iliac circumflex and iliolumbar arteries

TABLE 1. Summary of variable extrathoracic collateral vessels to the AKA and corresponding surgical technical modifications

Case	Age, y	Sex	Aortic pathology	Previous surgery	Crawford extent	Range of replacement	Origin of AKA	Collateral	Inflow	Meticulous surgical technique	SCII	Long-term outcomes
1	35	M	Chronic dissection	ARR (MS) TAR (MS)	II	Th4-terminal aorta	Left eighth ICA (Occluded)	Lateral thoracic artery Subscapular artery	LSA	Anterolateral thoracotomy	None	8 y out Without aortic events
2	72	M	Chronic dissection	TAR (MS)	II	Th6-L4	Left ninth ICA (Occluded)	Subscapular artery	LSA	Anterolateral thoracotomy	None	3 y out Without aortic events
3	55	M	Chronic dissection	ARR (MS) TAR (MS) DAR (LT)	III	Th8-terminal aorta	Left ninth ICA (Already ligated)	Inferior epigastric artery	EIA	Midline laparotomy	None	7 y out Without aortic events
4	74	M	Degenerative	Y-grafting (MAI) CABG (MS)	II	Th6 - L2	Left 11th ICA (Almost occluded)	Deep iliac circumflex artery Iliolumbar artery	EIA IIA	(Arterial perfusion route) (Clamping site)	Paraparesis	4 y out Without aortic events
5	75	M	Degenerative	Y-grafting (MAI)	III	Th8-Y graft	Left 10th ICA (Occluded)	Deep iliac circumflex artery	EIA	Dissection line Development of the surgical field Arterial perfusion route	None	Died of Cerebral hemorrhage After 6 mo

AKA, Adamkiewicz artery; *SCII*, spinal cord ischemic injury; *M*, male; *ARR*, aortic root replacement; *MS*, median sternotomy; *Th*, thoracic vertebrae; *ICA*, intercostal artery; *LSA*, left subclavian artery; *TAR*, total arch replacement; *L*, lumbar vertebrae; *EIA*, external iliac artery; *DAR*, descending aorta replacement; *LT*, left thoracotomy; *MAI*, midline abdominal incision; *CABG*, coronary artery bypass grafting; *IIA*, internal iliac artery.

were prominent and demonstrated as meaningful collaterals (Figure 1, *A* and *B*). Cardiopulmonary bypass was established with right femoral venous drainage and ipsilateral arterial return via the right common femoral artery. Postoperative paraparesis was observed. Magnetic resonance imaging revealed focal ischemic changes in the watershed area of the spinal cord between fourth and sixth thoracic vertebrae level.

In case 5, the AKA branched off the left 10th intercostal artery (ICA) occluded at its origin. Collateral blood flow

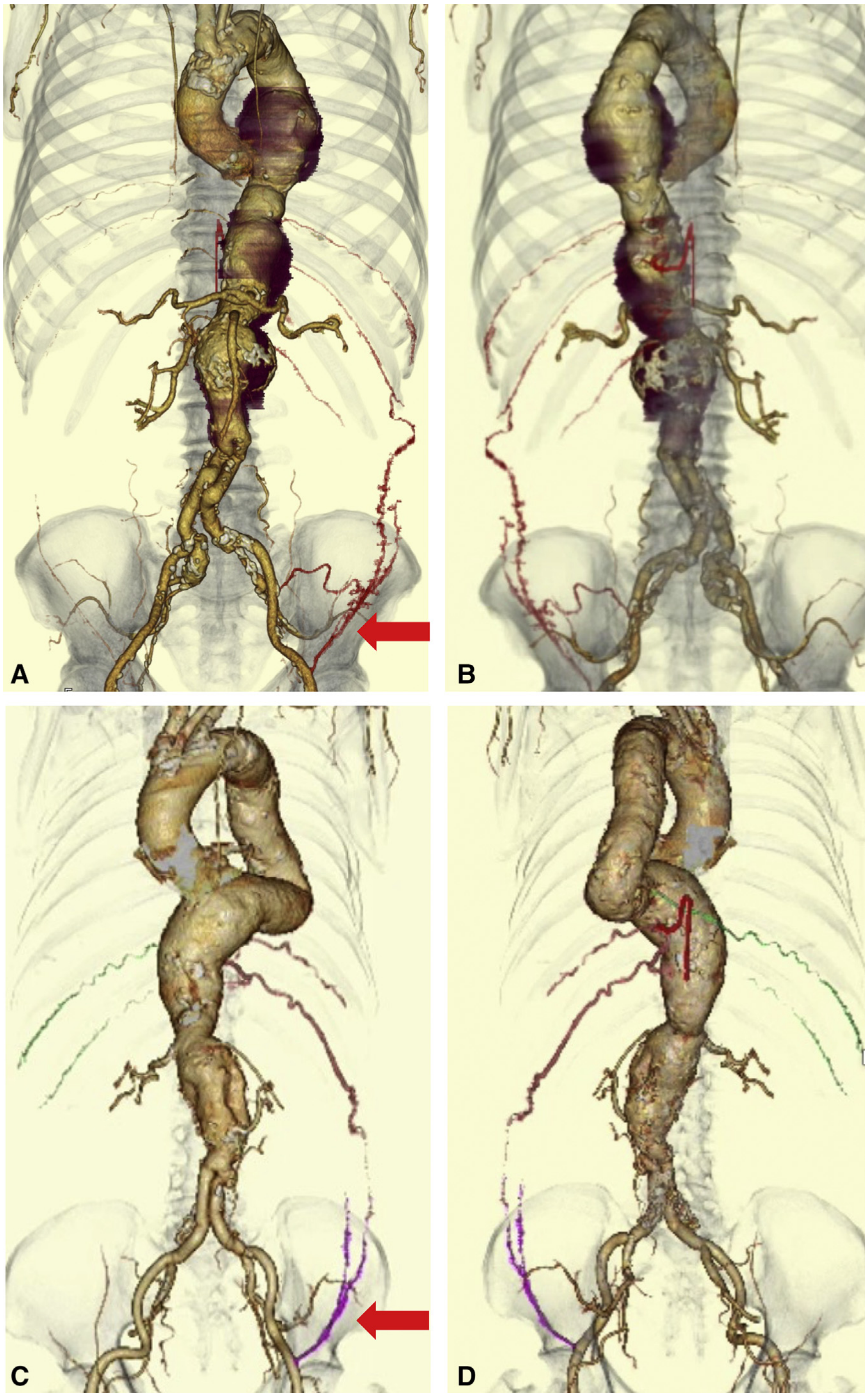

FIGURE 1. A, Ventral view of the aorta in case 4; B, Dorsal view of the aorta in case 4; C, Ventral view of the aorta in case 5; D, Dorsal view of the aorta in case 5. Representative extrathoracic collateral vessels revealed by preoperative computed tomography in case 4 (*upper panels*) and case 5 (*lower panels*). Well-developed collateral blood vessels via the left deep iliac circumflex artery to the Adamkiewicz artery are illustrated in both cases. Another collateral vessel through the iliolumbar artery derived from the left internal iliac artery is depicted in case 4.

VIDEO 1. In response to the preoperative diagnostic evaluation that the collateral vessel from the left deep iliac circumflex artery was visualized as running intramuscularly towards the critical segmental artery, care was taken to meticulously stay on the peritoneum when dissection of the retroperitoneal tissue through a pararectal incision was performed. Video available at: https://www.jtcvs.org/article/S2666-2507(22)00383-2/fulltext.

was supplied via the left deep iliac circumflex artery. A connection from the left 11th to 10th ICA was also noted (Figure 1, *C* and *D*). Dissection of the retroperitoneal tissue through a pararectal incision was performed, meticulously staying on the peritoneum to avoid damaging the collateral vessel (Video 1). A Doppler flowmeter (HT353; NIHON KOHDEN) was repeatedly applied to the distal left 11th ICA to ensure that the collateral pathway was not disturbed during the development of surgical field in the retroperitoneal space (Figure E2). Arterial return to the left common femoral artery was established for cardiopulmonary bypass to maintain collateral perfusion via the left deep iliac artery.

DISCUSSION

The significance of the vessels running along the chest or abdominal wall can be recognized in the cases in which the cSA has already occluded (Table 1). In those patients, the proximal or distal aortic replacement had been performed previously. The presence of occluded cSA associated with a history of proximal or distal aortic surgery implicates unexplored extrathoracic vessels. More specifically, in cases after total arch replacement or DTAR, the left subclavian artery can be a source for downstream collaterals, whereas in cases after open abdominal aortic aneurysm repair, the iliac artery can be the one.

The contribution of extrathoracic collaterals to spinal cord perfusion was assured by examining the relationship in temperature changes between body and spinal fluid. In case 5, the spinal fluid temperature decreased faster than body temperature after the initiation of hypothermic perfusion (1.3 °C/5 minutes vs 0.6 °C/5 minutes), suggesting that the collateral plays a predominant role in spinal cord perfusion.

In summary, when an origin of the cSA is occluded or stenosed on preoperative imaging, identifying potential collateral sources requires vigorous pursuit. Accordingly, surgical approach modification to preserve important collaterals should be considered for spinal cord protection. Furthermore, HIAP may be useful in confirming the presence of extrathoracic collaterals by observing temperature changes in the body and spinal fluid.

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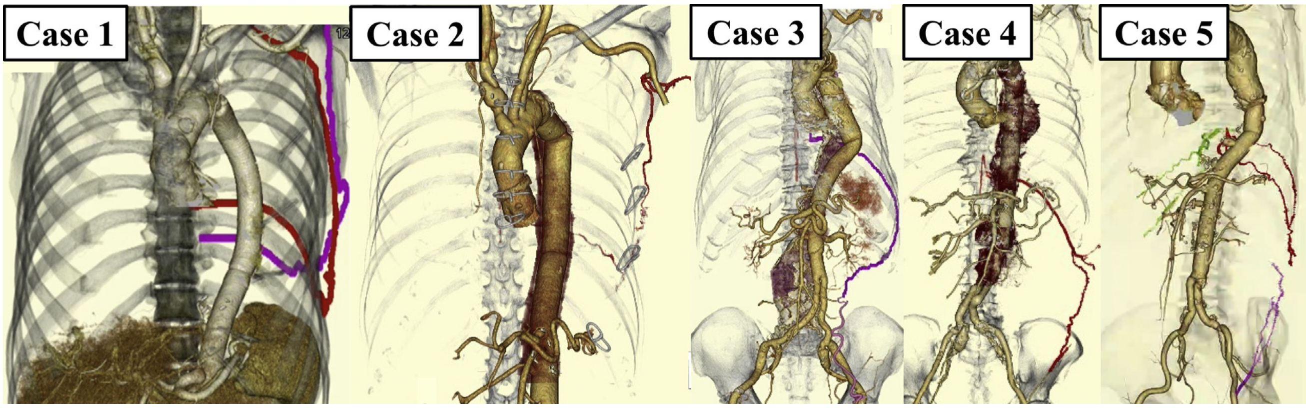

FIGURE E1. Postoperative computed tomography images of all 5 cases are shown with 3-dimensional construction. All the extrathoracic collaterals were found to be preserved.

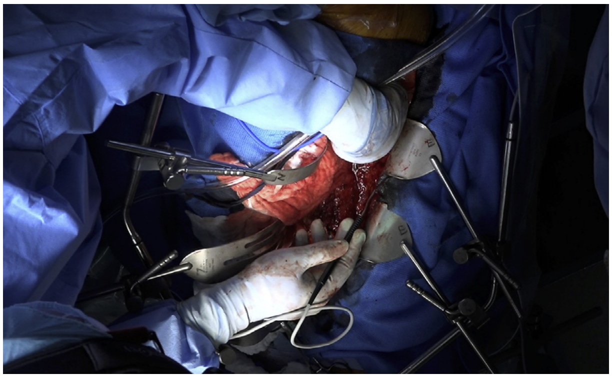

FIGURE E2. A Doppler flowmeter was repeatedly applied to the distal left 11th intercostal artery to ensure that the collateral pathway was not disturbed during the development of surgical field in the retroperitoneal space.