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Development of Collaterals to the Spinal Cord after Endovascular Stent Graft Repair of Thoracic Aneurysms

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WHAT THIS PAPER ADDS

The supply to the Adamkiewicz artery after the segmental artery feeding into it is occluded by a stent graft has been investigated. Computed tomography angiography was performed in patients who underwent thoracic endovascular aortic repair (TEVAR) for thoracic aortic and thoraco-abdominal aortic aneurysms. The distribution of feeding arteries (collaterals) into the Adamkiewicz artery after TEVAR was determined as three different patterns. Almost all of the post-operative collaterals consisted of a segmental artery below the occluded segmental artery and branches of the left subclavian artery.

Objectives: In thoracic and thoraco-abdominal aortic aneurysm repair, spinal cord injury (SCI) is devastating. Detection of the Adamkiewicz artery might be important for preventing SCI. Although thoracic endovascular stent grafts often occlude the segmental artery, the incidence of SCI in thoracic endovascular aortic repair is thought to be low compared with open repair. This study aimed to evaluate how the Adamkiewicz artery is supplied after segmental arteries are occluded by stent grafts.

Methods: From March 2007 to August 2015, 32 patients were enrolled whose segmental arteries that were connected to the Adamkiewicz arteries were occluded by stent grafts. Segmental arteries, Adamkiewicz arteries, collateral circulation into the Adamkiewicz arteries, and anterior spinal arteries were pre- and post-operatively evaluated by computed tomography angiography.

Results: Post-operatively, Adamkiewicz arteries were detected in 24 (75%) patients, except for two patients with paraplegia and six without paraplegia. Post-operative Adamkiewicz arteries were the same as pre-operative Adamkiewicz arteries, except for one Adamkiewicz artery that was located at two vertebral levels below the pre-operative level. SCI occurred in two (6.3%) patients. The distribution of feeding arteries into the Adamkiewicz artery post-operatively was divided into three patterns as follows: a segmental artery below the distal landing zone of the stent graft (53%), branches of the left subclavian artery (33%), and a branch of the left external iliac artery (13%).

Conclusions: The length of the stent graft should be as short as possible. Blood supply to the left subclavian artery should be maintained because segmental arteries below the segmental artery occluded by the stent graft and branches of the left subclavian artery can become collaterals post-operatively.

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INTRODUCTION

In thoracic aortic aneurysm (TAA) and thoraco-abdominal aortic aneurysm (TAAA) repair, spinal cord injury (SCI) is a devastating complication. Methods of preventing SCI after aneurysm repair have been the focus of many studies.[1—10] Reconstruction of segmental arteries, deep hypothermia, monitoring somatosensory evoked potentials, motor evoked potentials, or cerebrospinal fluid drainage, and segmental clamping of the aorta are effective for preventing SCI during TAA and TAAA repair.[6—10] Recently, detection of segmental arteries supplying anterior spinal arteries (ASAs) via Adamkiewicz arteries has become feasible. Maintaining blood supply to Adamkiewicz arteries is thought to be an important factor in reducing the risk of SCI.[2,7,11—14]

Although a thoracic endovascular stent graft often occludes the segmental artery connecting to the Adamkiewicz artery, the incidence of paraplegia in thoracic endovascular aortic repair (TEVAR) is low compared with open repair of

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TAAs and TAAAs.[15–18] Higher blood pressure (BP) and lower blood loss are associated with a low incidence of SCI in TEVAR.[15–18] Prevention of SCI by maintenance of a higher BP in TEVAR indicates that spinal cord blood supply is unlikely to depend on a single segmental artery, and occlusion of the segmental artery may not be the only causative factor affecting SCI.[9,10,19] However, how the spinal cord circulation is maintained in these patients with segmental arteries occluded by a stent graft has not been investigated in detail. Therefore, this study aimed to evaluate how Adamkiewicz arteries are supplied after segmental arteries that feed into the Adamkiewicz arteries are occluded by a stent graft.

METHODS

From March 2007 to August 2015, 186 patients were treated by TEVAR for TAAs and TAAAs. They routinely underwent identical 128 slice computed tomography angiography (CTA) pre-operatively to detect segmental arteries, Adamkiewicz arteries, and ASAs. The rate of detection of those arteries was 90% (168/186), except in 18 patients (emergent case, $n = 10$; poor image, $n = 8$). Overall post-operative SCI was observed in five (5/186, 2.7%) patients. In 41 of 186 patients, segmental arteries feeding into the Adamkiewicz artery were occluded by a stent graft. Among them, 32 patients whose segmental arteries, Adamkiewicz arteries, and ASAs were evaluated pre- and post-operatively by CTA were enrolled in this study. Nine patients who did not have post-operative paraplegia were excluded, and could not undergo post-operative CTA because of various factors (hospital death, $n = 2$; old age, $n = 3$; rising creatinine levels after TEVAR, $n = 4$). Patient characteristics are shown in Table 1. Thirty-two TEVARs (20 men, 12 women; aged 29–89 years; mean age ± standard deviation, 73.5 ± 11.5 years) were performed for degenerative TAA ($n = 24$) and aneurysms in chronic aortic dissection ($n = 8$). Emergency operations were performed in six patients. Prophylactic cerebrospinal fluid drainage was performed routinely. New collateral circulation to the spinal cord was evaluated after the segmental artery feeding into the Adamkiewicz artery was occluded by a stent graft. All pre- and post-TEVAR CTA examinations were evaluated by an experienced radiologist. The first follow-up CTA examination was typically performed within approximately 2 weeks of TEVAR. This study was approved by the Ethics Committee of the Hyogo College of Medicine, and informed consent was obtained from all of the patients.

A 128 slice CT scanner (Somatom Definition AS+; Siemens, Tokyo, Japan) was used to detect segmental arteries, Adamkiewicz arteries, and ASAs. A contrast medium (Iopamiron, Bayer, Osaka, Japan) with a high iodine concentration was used to achieve high contrast density. A standard volume of 100 mL was administered to each patient by automated injection. The reconstruction field of view was set to the area around the aorta and spine. The image datasets were transferred to a workstation (Zio; Ziosoft, Tokyo, Japan). Volume rendered images of the entire aorta were routinely generated. Multiplanar reconstruction images, including oblique coronal images with craniocaudal angulations and curved planar reconstruction images, were reconstructed to investigate ASAs, and the side and level of segmental arteries and Adamkiewicz arteries.

Values are expressed as mean ± standard deviation for continuous variables and as frequency and percentage for categorical variables.

Table 1. Baseline characteristics of the patients and operative results ($n = 32$).

Age (years)	73.5 ± 11.5
Female (%)	37.5
Pathology	
Atherosclerosis	24
Dissection	8
Emergency operation	6
Comorbidity	
HT	21
DM	6
HL	5
COPD	2
Previous CI	1
Previous aortic surgery	
TAR	4
GR of AAA	6
TEVAR	3
EVAR	1
GR of descending aorta	1
Operative results	
Hospital death	0
Cerebral infarction	0
Operation time (minutes)	132 ± 57
Mean device number	1.7 ± 0.6
Aortic coverage (mm)	212 ± 77
Blood loss (mL)	196 ± 203
SCI	2 (6.3%)

Note. Values are mean ± SD, number, or %. AAA = abdominal aortic aneurysm; CI = cerebral infarction; COPD = chronic obstructive pulmonary disease; DM = diabetes mellitus; EVAR = endovascular aortic aneurysm repair; GR = graft replacement; HL = hyperlipidemia; HT = hypertension; SCI = spinal cord injury; TAR = total arch replacement; TEVAR = thoracic endovascular aortic repair.

RESULTS

Pre-operative continuity of the vasculature from the segmental artery to the ASA via the Adamkiewicz arteries was detected in all patients. All patients had only one segmental artery connecting to the Adamkiewicz artery. The Adamkiewicz arteries were detected between vertebral levels T8 and L1, and were derived from the left side in 26 (81%) patients. The Adamkiewicz arteries were located at T10 (11/32, 34%) most frequently, followed by T8 (7/32, 22%) and T9 (7/32, 22%). Segmental arteries that connected to the Adamkiewicz arteries were located at T10 (11/32, 34%) most frequently, followed by T9 (9/32, 28%) (Appendix I). When comparing the branching level of the Adamkiewicz