Effect of atherothrombotic aorta on outcomes of total aortic arch replacement

Kenji Okada, MD, PhD, Atsushi Omura, MD, Hiroya Kano, CE, Takeshi Inoue, MD, Takanori Oka, MD, Hitoshi Minami, MD, PhD, and Yutaka Okita, MD, PhD

Objective: The effect of an atherothrombotic aorta on the short- and long-term outcomes of total aortic arch replacement, including postoperative neurologic deficits, remains unknown. We evaluated this relationship and also elucidated the synergistic effect of multiple other risk factors, in addition to an atherothrombotic aorta, on the neurologic outcome.

Methods: A group of 179 consecutive patients undergoing total aortic arch replacement were studied. An atherothrombotic aorta was present in 34 patients (19%), more than moderate leukoaraiosis in 71 (39.7%), and significant extracranial carotid artery stenosis in 27 (15.1%). In-hospital deaths occurred in 2 patients, 1 (2.9%) of 34 patients with and 1 (0.7%) of 145 patients without an atherothrombotic aorta ($P = .26$). Permanent neurologic deficits occurred in 4 (2.2%) and transient neurologic deficits in 17 (9.5%) patients. Multivariate analysis demonstrated that the risk factors for transient neurologic deficits were an atherothrombotic aorta (odds ratio, 4.4), extracranial carotid artery stenosis (odds ratio, 5.5), moderate/severe leukoaraiosis (odds ratio, 3.6), and cardiopulmonary bypass time (odds ratio, 1.02). To calculate the probability of transient neurologic deficits, the following equation was derived: probability of transient neurologic deficits $= \{1+\exp[7.276-1.489$ (atherothrombotic aorta) -1.285 (leukoaraiosis) -1.701 (extracranial carotid artery stenosis) -0.017 (cardiopulmonary bypass time)$]\}^{-1}$. An exponential increase occurred in the probability of transient neurologic deficits with presence of an atherothrombotic aorta and other risk factors in relation to the cardiopulmonary bypass time. Survival at 3 years after surgery was significantly reduced in patients with vs without an atherothrombotic aorta ($75.0\% \pm 8.8\%$ vs $89.2\% \pm 3.1\%$, $P = .01$).

Conclusions: Patients with an atherothrombotic aorta and associated preoperative comorbidities might be predisposed to adverse short- and long-term outcomes, including transient neurologic deficits. (J Thorac Cardiovasc Surg 2013;145:984-91)

ACD

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Although the short- and long-term outcomes of total aortic arch replacement (TAR) have been improving during the past decade,[1-3] the procedure is likely to be associated with life-threatening complications, such as neurologic deficits, pulmonary dysfunction, and bowel ischemia/necrosis. Because postoperative neurologic deficits have been reported to adversely affect the short- and long-term outcomes,[4,5] it is crucial to identify the risk factors and prevent complications to the extent possible. Atherosclerotic disease of the aortic arch itself has been historically reported by Amarenco and associates[6] to be a potential source of cerebral emboli. ''Shaggy aorta,'' a term advocated by Hollier and associates,[7] was defined as very extensive atheromatous disease with diffuse ulcers associated with soft, loosely held debris and a paucity of actual thrombus, now recognized as an atherothrombotic aorta, a pathologic entity. Recent advances in contrast-enhanced computed tomography (CT) have allowed accurate preoperative imaging of the atherothrombotic aorta. However, to date, no reports have specifically studied the effect of an atherothrombotic aorta on the short- and long-term outcomes of TAR, including postoperative neurologic deficits.

Neurologic deficits can be caused not only by embolic events such as those resulting from the presence of an atherothrombotic aorta, but also by inadequate perfusion during cardiopulmonary bypass (CPB). Cerebrovascular disease, including leukoaraiosis and carotid artery stenosis/occlusion, are also believed to augment ischemic events during CPB. Leukoaraiosis is defined as patchy punctuate or confluent hyperintensity in the white matter and deep gray nuclei on T_2-weighed brain magnetic resonance imaging (MRI), reflecting chronic ischemic changes in the myelin and axons.[8] In the current era of an aging population, the number of patients with the combination of an

From the Division of Cardiovascular Surgery, Department of Surgery, Kobe University Graduate School of Medicine, Kobe, Japan.

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Address for reprints: Yutaka Okita, MD, PhD, Division of Cardiovascular Surgery, Department of Surgery, Kobe University Graduate School of Medicine, 7-5-2, Kusunoki-Cho, Chuo-Ku, Kobe, Hyogo 650-0017, Japan (E-mail: yokita@med.kobe-u.ac.jp).

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Abbreviations and Acronyms

CPB	= cardiopulmonary bypass
CT	= computed tomography
euroSCORE	= European System for Cardiac Operative Risk Evaluation
MRA	= magnetic resonance angiography
MRI	= magnetic resonance imaging
OR	= odds ratio
PND	= permanent neurologic deficit
P_{TND}	= probability of TNDs
RCP	= retrograde cerebral perfusion
SCP	= selective cerebral perfusion
TAR	= total aortic arch replacement
TND	= transient neurologic deficit

atherothrombotic aorta, leukoaraiosis, and carotid artery disease is increasing. Accordingly, it has become important to determine whether there are synergistic adverse effects of these multiple risk factors on the neurologic outcome after TAR. Therefore, we performed the present retrospective study to investigate the effect of an atherothrombotic aorta and associated risk factors on the short- and long-term outcomes after TAR.

METHODS

Our institutional review board approved the present study, and the need for individual consent was waived. We retrospectively studied 179 consecutive patients with a mean age of 73.8 ± 7.7 years who had undergone TAR through a median sternotomy from January 2002 to December 2010. All patients at our institute routinely undergo MRI/magnetic resonance angiography (MRA), duplex ultrasonography, and CT before undergoing elective aortic surgery. According to the concepts formulated by Hollier and colleagues[7] and Amarenco and colleagues,[6] when fragile and spiculated atheroma that exceeded 5 mm in the thickness was confirmed by CT in the ascending aorta or aortic arch but excluding the aneurysm itself, an ''atherothrombotic aorta'' was diagnosed (Figure 1). In the present series, an atherothrombotic aorta was present in the ascending or aortic arch in 34 patients (19.0%). Patients with an atherothrombotic aorta were compared with 145 patients without an atherothrombotic aorta with regard to preoperative patient characteristics, intraoperative variables, and short- and long-term outcomes.

Neuromagnetic Imaging

Brain MRI was performed using a 1.5-T scanner. A standardized imaging protocol was used, consisting of axial T_1-weighted, T_2-weighted, and fast fluid attenuated inversion recovery images. The intracranial and extracranial vasculature was evaluated preoperatively using MRA. All patients underwent routine 2-dimesional time of flight MRA through the neck and 3-dimensional time of flight MRA through the circle of Willis. Postoperative cerebral infarction or ischemia was detected using diffusion-weighted-MRI or brain CT, when patients had any symptoms related to transient neurologic deficits (TNDs) or permanent neurologic deficits (PNDs).

Leukoaraiosis Rating

Leukoaraiosis was rated using the Scheltens scale.[9] Each cerebral region was initially scored for lesion size and then for lesion number. In accordance with this scale, the periventricular white matter hyperintensities were scored on 3 regions: the frontal and occipital caps and the periventricular bands. They were rated as none, score 0; 5 mm or less, score 1; and confluent lesions and those greater than 5 mm, score 2. The deep white matter hyperintensities were examined in 4 subcortical regions (frontal, parietal, temporal, and occipital lobes). These lesions were rated as none, score 0; 3 mm and smaller and 5 or fewer lesions, score 1; 3 mm or smaller and 6 or more lesions, score 2; 4 to 10 mm and 5 or fewer lesions, score 3; 4 to 10 mm and 6 or more lesions, score 4; 10 mm or larger and 1 or more lesions, score 5; and large confluent lesions, score 6. The total leukoaraiosis score is the sum of the periventricular white matter intensity and deep white matter hyperintensity subscores, with a maximum score of 30. A score greater than 10 was defined as more than moderate leukoaraiosis.

Evaluation of Intracranial Carotid Artery by MRA

The severity of the involvement of the intracranial vasculature and the circle of Willis was evaluated by MRA. Because precise evaluation of the degree of stenosis was difficult, the occlusion of 1 of the intracranial vessels (ie, intracranial carotid artery; anterior, middle, or posterior cerebral artery; basilar artery; or the circle of Willis) was considered indicative of the presence of significant intracranial vascular disease.

The evaluation of the extracranial carotid artery focused on the common carotid artery, which was evaluated by both MRA and duplex ultrasonography. Carotid stenosis was defined as the presence of stenosis of greater than 70%, combined with the demonstration of a peak systolic velocity greater than 250 cm/s on duplex ultrasound imaging using the North American Symptomatic Carotid Endarterectomy method.[10]

The patient characteristics are listed in Table 1. Of the 179 patients, 174 (97.2%) underwent TAR on an elective basis. No significant differences were found between patients with and without an atherothrombotic aorta in age, gender, diabetes mellitus, or chronic kidney disease (creatinine ≥2.0 mg/dL), although significant differences were found in coronary artery disease, left ventricular dysfunction (ejection fraction ≤40%), and chronic obstructive pulmonary disease. Regarding preoperative cerebrovascular disease, no significant difference was found between the 2 groups in the history of cerebral infarction, intracranial or extracranial carotid artery disease, or leukoaraiosis. Significant differences were present between patients with and without an atherothrombotic aorta in the additive European System for Cardiac Operative Risk Evaluation (euroSCORE) (8.6 ± 1.9 vs 7.6 ± 2.0, respectively; $P = .009$), logistic euroSCORE (16.1 ± 8.9 vs 12.2 ± 7.0, respectively; $P = 0.007$), and Japan score[11] (6.3 ± 4.2 vs 4.8 ± 2.5, respectively; $P = .01$), indicating that patients with an atherothrombotic aorta were at greater risk.

Surgical Protocol

The details of TAR at our institute have been previously reported.[3] The cannulation site and type of arterial cannulation for CPB is particularly important. Both transesophageal and periaortic echocardiography were applied to interrogate the ascending aorta and determine the proper cannulation site. A 24F dispersion arterial cannula (Duraflo II; Edwards Lifesciences, Irvine, Calif) was inserted near the aortic root with perfusion toward the aortic valve in 85.3% of patients with an atherothrombotic aorta ($P = .0002$ vs without an atherothrombotic aorta). After the tympanic temperature had decreased to 20° to 23°C and the rectal temperature to less than 30°C, the aortic arch aneurysm was opened, and retrograde cerebral perfusion (RCP; n = 2) or antegrade selective cerebral perfusion (SCP; n = 177) was instituted. RCP was applied for 2 patients with mobile plaques in their common carotid arteries. If the ostium of the arch vessels were severely atherosclerotic, arteriotomy of the arch vessels was extended from the diseased ostium to a relatively clear distal part and then cannulas were placed in position under direct vision. The distal aortic arch or descending aorta was divided from inside the aorta to avoid injury to the recurrent nerve during circulatory arrest to the lower body. A gelatin-impregnated quadfurcated Dacron graft (Gelweave, Vascutek, Terumo, Scotland, UK; J Graft Shield Neo, Japan Lifeline, Tokyo, Japan) or Triplex (Terumo, Tokyo, Japan)