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● *Original Contribution*

# RAPID AND ACCURATE ASSESSMENT OF AORTIC ARCH ATHEROSCLEROSIS USING SIMULTANEOUS MULTI-PLANE IMAGING BY TRANSESOPHAGEAL ECHOCARDIOGRAPHY

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**Abstract—Transesophageal echocardiography (TEE) is widely used for the evaluation of aortic arch atherosclerosis which carries an increased risk of ischemic stroke. We investigated the feasibility of simultaneous multi-plane imaging by real-time 3-D TEE for the assessment of aortic arch plaques. In 152 patients, we assessed aortic arch plaques and measured their maximum thickness by both conventional TEE imaging and multi-plane TEE imaging. There was excellent correlation and good agreement between the two methods in the measurement of the maximum thickness of arch plaques ($r = 0.95$, mean difference, $-0.1 \pm 0.5$ mm). The mean image acquisition time required for aortic arch assessment by multi-plane imaging was significantly shorter than that required for conventional imaging in all patients ($p < 0.001$), especially those with complex plaques. These findings suggest that simultaneous multi-plane TEE imaging enables rapid and accurate evaluation of arch plaques and is therefore a useful tool for the assessment of aortic arch plaques in the clinical setting. (E-mail: k-sugioka@med.osaka-cu.ac.jp)** 

*Key Words:* **Aortic arch plaques, Transesophageal echocardiography, Simultaneous multi-plane imaging.**

## INTRODUCTION

Transesophageal echocardiography (TEE) provides precise information regarding atherosclerosis of the thoracic aorta. TEE can evaluate the morphologies and mobility of aortic plaques in real time (Evangelista et al. 2010; Kronzon and Tunick 2006). Therefore, this method has been used to assess the size and characteristics of aortic plaques for risk stratification of ischemic stroke (Amarenco et al. 1994; Di Tullio et al. 1996, 2000; The French Study of Aortic Plaques in Stroke Group 1996; Fujimoto et al. 2004; Jones et al. 1995; Sugioka et al. 2011; Tunick et al. 1991). In particular, aortic arch plaques ≥4 mm in thickness as measured by TEE, as well as complex arch plaques like ulcerated plaques and mobile plaques, are widely accepted as risk factors for stroke (Di Tullio et al. 1996, 2000; The French Study of Aortic Plaques in Stroke Group 1996; Fujimoto et al. 2004; Sugioka et al. 2011). However, the probe should be positioned high in the oropharynx when evaluating the aortic arch by TEE, and this positioning may cause the patient excess discomfort and gagging, even while under sedation (Nash et al. 2009). Recently, real-time 3-D TEE has been introduced; it is a novel technique that permits simultaneous visualization of multiple imaging by simultaneous multi-plane mode (Lang et al. 2012). This method allows comprehensive assessment by providing an approach from multiple views and quick acquisition of images, and may facilitate assessment of aortic arch atherosclerosis and reduction of patient discomfort.

In this study, we assessed the presence, thickness and morphologies of aortic arch plaques by real-time 3-D TEE with a simultaneous multi-plane mode. Furthermore, the image acquisition time required for the assessment of aortic arch plaques by multi-plane TEE imaging was measured and compared with that of conventional TEE imaging.

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## METHODS

*Study population*

The study included 154 consecutive patients who were referred for TEE from December 2010 to August 2011 in Osaka City University Hospital. We excluded 2 patients in whom the aortic arch could not be visualized fully by TEE. Thus, 152 patients (93 men; mean age, 66 ± 11 y) were enrolled in the present study. The clinical indications for TEE were evaluation of valvular pathology (77 patients, 51%), detection of vegetation with suspected infective endocarditis (21 patients, 14%), detection of a source of thromboembolism (44 patients, 29%), congenital heart disease (6 patients, 4%) and other reasons (4 patients, 3%). The hospital ethics committee approved the study protocol, and all patients provided written informed consent.

*Transesophageal echocardiographic examination*

Transesophageal echocardiography was performed using a commercially available ultrasound imaging system (iE33, Philips Medical Systems, Andover, MA, USA) with a 3-D matrix-array transesophageal transducer (X7–2 t). The same ultrasound imaging system was used for acquisitions by both conventional TEE imaging and simultaneous multi-plane TEE imaging.

After routine examinations of cardiac structures by conventional TEE imaging, the transducer was gradually withdrawn from the descending aorta to the level of the distal arch. The aortic arch was defined as the portion of aorta between the curve at the end of the ascending aorta and the origin of the left subclavian artery (Di Tullio et al. 1996, 2000, 2009; Sugioka et al. 2002, 2011). In conventional TEE imaging, images of the aortic arch were obtained in short and long axes with imaging at 0° and 90° of rotation, respectively. Conventional TEE imaging assessment of the aortic arch, performed by one of the two experienced echocardiographers (K.S., Y.M.), was followed by multi-plane TEE imaging assessment by the other experienced echocardiographer, who was blind to the conventional TEE imaging results.

The multi-plane TEE imaging was performed by real-time 3-D TEE with a simultaneous multi-plane (X-plane) mode. This method permits the use of a dual screen to display two real-time images simultaneously, thereby generating simultaneous images (Lang et al. 2012). In multi-plane TEE imaging, the first image is typically a reference view of a particular structure, whereas the second image represents a plane rotated 30° to 150° from the reference plane. We set a long-axis view of the aortic arch as the reference view, and we displayed serial short-axis images across the reference line on the long-axis image for the assessment of arch plaques (Fig. 1).

*Echocardiographic analysis of aortic arch plaques*

In both conventional TEE imaging and multi-plane TEE imaging, plaques were defined as discrete protrusions of the intimal surface of the vessel ≥2 mm in thickness that were different in appearance and echogenicity from the adjacent intact intimal surface (Evangelista et al. 2010). In cases of multiple plaques, the most advanced lesion was considered. An ulceration was defined as a discrete indentation of the luminal surface of the plaque with a base width and maximum depth of at least 2 mm each (Di Tullio et al. 2000, 2009; Sugioka et al. 2011). Plaques with ulceration or mobile components were defined as complex plaques (Di Tullio et al. 2000, 2009) (Fig. 2). The images of arch plaques were digitally stored and were analyzed separately later by two independent experts, who were blind to the multi-plane TEE imaging or conventional TEE imaging information. Before this study began, intra- and inter-observer variabilities of TEE imaging were obtained in 30 consecutive patients with arch plaques. Intra- and inter-observer variabilities for the measurement of arch plaque thickness were 4.5% and 8.9%, respectively. Furthermore, we measured the image acquisition time required for aortic arch assessment both by conventional TEE imaging and by multi-plane TEE imaging in 112 randomly selected patients. The timer was started when we obtained an image of the aortic arch in long-axis view by both conventional TEE imaging and multi-plane TEE imaging, and it was stopped at the end of the assessment of the aortic arch plaques by each imaging technique.

*Statistical analysis*

Linear regression analysis was used to compare the assessment of aortic arch plaque thickness by conventional TEE imaging and multi-plane TEE imaging. The differences between the measurements obtained the two methods are expressed as means ± standard deviations (SD). Differences in measurements were analyzed using the technique reported by Bland and Altman (1986). We used the paired *t*-test to compare the time required for assessment of the aortic arch using multi-plane TEE imaging with that required for conventional TEE imaging. The Mann-Whitney *U*-test was performed to compare two groups of continuous variables. Findings were considered significant at $p < 0.05$.

## RESULTS

*Comparison of conventional and multi-plane TEE imaging in the detection of aortic arch plaques*

Aortic arch plaques were detected in 78 of 152 patients (51%) by conventional TEE imaging. By multi-plane TEE imaging, arch plaques were detected