Introduction

Excellent long-term clinical results of aortic valve replacement (AVR) with a Carpentier-Edwards PERIMOUNT (CEP) bioprosthetic valve (Edwards Lifesciences, Irvine, California, USA) have been reported in the literature.1,2) In particular, the actuarial rate for freedom from structural valve deterioration (SVD) was described as 68%–77% 20 years postoperatively.1) The surgical indication for SVD is wide according to functional valvular deterioration by Doppler study of transthoracic echocardiography (TTE).3,4) The surgical procedure is almost always replacement. Thus, surgeons do not pay attention to the degree of valvular deformity. Therefore, morphologic diagnosis of SVD in bioprosthetic valves, even by transesophageal echocardiography (TEE), is still difficult because of poor echocardiographic images by artifacts due to metallic stents or acoustic shadowing due to severe calcification of the valve cusps.5–11)

On the other hand, recent electrocardiographically gated multidetector row computed tomography (ECG-gated MDCT) enables visualization of the morphology and motion of native or diseased stenotic aortic valves with mild artifacts.7–9,12–14) However, reported reoperation cases of SVD evaluated by ECG-gated MDCT are extremely rare. This is the first reported reoperation case of aortic SVD clearly visualized by ECG-gated MDCT.

Keywords: multidetector row computed tomography, structural valve deterioration, bioprosthetic valve

Diagnosis of Structural Deterioration in an Aortic Bioprosthesis Valve by Multidetector Row Computed Tomography: Report of a Case

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A 32-year-old female patient presented with shortness of breath. The patient had received aortic valve replacement with a 25-mm bioprosthetic valve at the age of 22, and had had two babies, postoperatively. Ten years later, echocardiography showed the calcified bioprosthetic valve with a high peak pressure gradient (70 mmHg) and a reduced valve orifice area (0.46 cm²). Electrocardiographically gated multidetector row computed tomography (ECG-gated MDCT) clearly demonstrated calcified bioprosthetic cusps with reduced mobility, and the valve orifice area was measured to be 0.64 cm² by direct planimetry. These findings observed by ECG-gated MDCT were confirmed at reoperation. This is the first reported reoperation case of aortic structural valve deterioration clearly visualized by ECG-gated MDCT.

Keywords: multidetector row computed tomography, structural valve deterioration, bioprosthetic valve
A 32-year-old female patient presented with shortness of breath. The patient had a history of AVR with a 25-mm CEP valve (model 2900), closure of a ventricular septal defect, and repair of right ventricular outflow tract obstruction at the age of 22, and she had had babies without any complications at the ages of 25 and 27, postoperatively. She had almost no risk factors resulting in SVD. She had no type II diabetes mellitus, metabolic syndrome, high cholesterol, cigarette smoking or patient-prosthesis mismatch, except for younger age.

TTE performed 10 years after AVR showed severe prosthetic valve stenosis with marked cusp calcification, and Doppler study revealed 70 mmHg peak pressure gradient (PPG) across the CEP valve and an aortic valve orifice area (AVA) of 0.46 cm² (Fig. 1-A and 1-B). By TTE it was difficult to visualize the CEP valve in the long-axis view because of an acoustic shadow from the CEP (Fig. 1-A). TTE barely confirmed the three leaflets of the CEP valve in the short-axis view (Fig. 1-B). Pre-operative TEE was not performed as three-dimensional echo was not available.

ECG-gated MDCT using a 256-slice CT system (Brilliance iCT; Philips Healthcare, Cleveland, Ohio, USA) revealed clear detection of the CEP valve cusps in the open position at midsystole (30% RR interval), as shown in Fig. 1-C to 1-F. Although mild artifacts due to calcified cusps and metal struts of the CEP valve were found, the restricted cusp opening was clearly observed during the systolic phase. In particular, mobility of the right- and left-coronary cusps was severely restricted (Fig. 1-E and 1-F). These cusps showed the same attenuation as those of the valve strut (Fig. 2-A and 2-D). The non-coronary cusp had mild calcification; therefore, the image was unclear because of motion artifacts (Fig. 1-E and 1-F). The non-coronary cusp disappeared while processing the extraction of calcification because the CT window level (400) and window width (1000) were used. TTE: trans-thoracic echocardiography; MDCT: multidetector row computed tomography; AVA: aortic valve area; R: right-coronary cusp; L: left-coronary cusp; N: non-coronary cusp; AO: ascending aorta; LA: left atrium; LV: left ventricle.
Attenuation value of the non-coronary cusp was lower than that of the others (Fig. 2-A and 2-D). The AVA was measured with direct planimetry of the maximal opening of the cusp tip in systole on short-axis views, and it was calculated to be 0.64 cm² (Fig. 1-C). To assess cusp mobility, the opening angle between each cusp tip and the bioprosthetic annulus plane was measured at maximum systolic opening of valve cusps on long-axis views, and was calculated to be approximately 30° at the right- and left-coronary cusp (Fig. 1-D), although the opening angle in the non-coronary cusp was difficult to measure. Based on these findings, the diagnosis of SVD of the aortic CEP valve was made.

At reoperation, the patient underwent re-replacement of the CEP valve with a mechanical bileaflet valve. Intra-operative TEE was performed. Unfortunately, TEE was not recorded; however, with TEE it was difficult to visualize the CEP valve. Macroscopic examination (Fig. 2-B and 2-E) and soft X-ray radiography (Fig. 2-C and 2-F) of the excised CEP valve showed strong calcification of the right- and left-coronary cusps with rigidity and poor mobility. These macroscopic and radiographic findings corresponded well with the findings obtained from ECG-gated MDCT (Fig. 2-A and 2-D).

**Discussion**

Surgical AVR is the gold standard for symptomatic patients with an aortic valve disease, and AVR with a bioprosthetic valve is generally accepted for female patients aiming to have children; however, the principal problem with bioprosthetic valves remains the development of SVD over time, despite the development of new generations of bioprosthetic valves. This SVD of pericardial bioprosthetic valves is characterized by calcification. Alvarez, et al. have reported that stenosis due to valve calcification was the most common cause at reoperation, and it was found in 98% of patients requiring reoperation.

TTE including Doppler study is the most commonly used diagnostic technique to detect prosthetic valve dysfunction such as SVD or valve thrombosis. Transvalvular pressure gradients and AVA derived from echocardiography have been established parameters evaluating prosthetic valve function in the aortic position. Of these two parameters, AVA is accepted as a more reliable index of prosthetic valve stenosis. AVA can be calculated indirectly and non-invasively using the continuity equation by TTE. Recently, the usefulness of the accurate
assessment of AVA using three-dimensional echocardiography was reported, however, in patients with severe valve calcification, it is often difficult to measure accurate left ventricular outflow tract geometry because of poor echocardiographic windows, echographic artifacts, and acoustic shadowing, particularly in patients with a prosthetic valve or severe calcification. This difficulty may increase the possibility of over- or under-estimation of the AVA. In addition, although transvalvular pressure gradients are useful for the diagnosis of aortic stenosis, they might be overestimated when a pressure recovery phenomenon has occurred; therefore, TTE including Doppler study is essential for the diagnosis of aortic stenosis, but it also has limitations.

On the other hand, ECG-gated MDCT gives high resolution images and large amounts of information. Arrhythmia has been considered to be one adverse factor for which good quality images can be obtained. The latest dual-source CT scanner had no effect on atrial fibrillation. Direct planimetric measurement of an AVA has been successfully performed using ECG-gated MDCT, and good correlation of planimetric AVA with Doppler-derived AVA using TTE and TEE has been indicated. Although blooming artifacts due to cusp calcification are well documented as a serious factor causing difficulty in direct planimetry of an AVA, restricted cusp opening was clearly observed during the systolic phase and planimetric measurement of the AVA was easily performed using 256-slice CT in the present patient. Furthermore, Klass, et al. have reported that TEE measurement of AVA was not applicable due to severe aortic valve calcification and a small valve area in 4 of 26 patients with high-grade aortic valve stenosis, but planimetric AVA measurement using 256-slice CT was feasible for these 4 patients with moderate and good image quality.

To assess cusp mobility in bioprosthetic valves, Chenot, et al. measured the opening angle between each cusp tip and the bioprosthetic annulus plane on long-axis views of CT images. They demonstrated that the opening angle was greater than 70° (average opening angle; 79 ± 3°) in all 11 patients with normally functioning bioprosthetic valves, and an opening angle less than 70° was defined as restricted cusp motion in their study. Moreover, they also showed that the opening angle was directly correlated to the effective valve orifice area at TTE and was inversely correlated with the mean transvalvular gradient.

In addition, less-invasive assessment of left ventricular function and coronary artery disease, and morphological evaluation of surrounding structures, including the severity and distribution of perivalvular calcification are simultaneously feasible with MDCT. ECG-gated MDCT-based evaluation of the aortic annulus is essential for the prevention of perivalvular leakage and residual aortic regurgitation in transcatheter aortic valve implantation (TAVI). In the future, ECG-gated MDCT examination will be important in deciding the surgical strategy for cases using the valve-in-valve technique of TAVI.

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Disclosure Statement

The author declares that he has no conflicts of interest.

References


