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Original article

Accuracy and usefulness of aortic annular measurement using real-time three-dimensional transesophageal echocardiography: Comparison with direct surgical sizing

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ABSTRACT

Background: There is a paucity of data that demonstrates a clinical impact of anatomical measurements of the aortic annulus by three-dimensional (3D) transesophageal echocardiography (TEE) on surgical aortic valve replacement (AVR). The aim of this study is to validate the accuracy of 3D TEE measurements compared with the direct intraoperative annular diameter and to investigate an impact of 3D TEE on a prediction of AVR with aortic annular enlargement (AAE).
Methods and results: We retrospectively enrolled 61 patients who underwent both two-dimension (2D) and 3D TEE and transthoracic echocardiography (TTE) before AVR. The annular diameters were measured noninvasively with 2D TEE (D_{2D}) and TTE (D_{TTE}) in a classical manner and the area- and perimeter-derived annular diameters (D_{area}, D_{perim}) were measured from using 3D TEE analysis. Intraoperative annular diameter was measured with the manufacture's sizer ($D_{intraope}$). D_{area} showed the best agreement with $D_{intraope}$ in the Bland–Altman analysis. D_{area}, D_{perim}, D_{2D}, and D_{TTE} correlated well with $D_{intraope}$ ($r = 0.821$, 0.820, 0.532, and 0.610, respectively; all $p < 0.001$). Three patients underwent AVR with AAE and the specificity of D_{perim} for prediction of AAE was significantly higher than D_{2D} ($p = 0.008$).
Conclusions: 3D TEE measurement of aortic annular diameter showed better agreement with the direct intraoperative measurement than 2D TEE and TTE measurements. 3D TEE measurement could predict AVR with AAE more accurately than 2D TEE and TTE measurements.

Introduction

Accurate preoperative measurement of aortic annular diameter is useful for surgical aortic valve replacement (AVR). That enables surgeons to know which size of prosthesis is required to avoid patient-prosthesis mismatch and whether aortic annular enlargement (AAE) is necessary [1–7]. Recently, preoperative imaging assessment has been becoming more important with the advent of transcatheter aortic valve implantation (TAVI) because the size and shape cannot be directly assessed [8–10]. Several studies have shown that three-dimensional (3D) measurements by multidetector computed tomography (MDCT) or 3D transesophageal echocardiography (TEE) are more accurate in assessing the aortic annulus than two-dimensional (2D) TEE, which improved paravalvular leakage after TAVI [9,11–16]. On the other hand, there is a paucity of investigation which demonstrates a clinical impact of anatomical measurements of the aortic annulus by 3D TEE on AVR. The aim of this study is to validate the accuracy of 3D TEE measurements of aortic annulus using direct intraoperative measurement as a reference and to investigate an impact of 3D TEE on a prediction of AVR with AAE.

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Methods

Study population

Eighty-six patients underwent both 2D and 3D TEE (Vivid E9, GE Healthcare, Horten, Norway) within 70 days before elective surgical AVR at Tokyo Bay Urayasu/Ichikawa Medical Center from October 2013 through October 2015. We excluded 2 patients undergoing aortic root reconstruction for infectious endocarditis, 2 patients undergoing redo AVR, and 4 patients with inadequate imaging quality of 3D TEE datasets. In addition, we excluded 17 patients with 25 mm prosthesis, in whom we cannot validate TTE and TEE using a direct intraoperative aortic annulus diameter as a reference because we use 25 mm prosthesis for all patients with an aortic annulus greater than 25 mm. Therefore, we reviewed 61 AVR patients for the analysis. This study was approved by the institutional review board.

Echocardiography

TTE was performed at baseline and after surgical AVR. All TTE images were acquired using a Vivid E9 ultrasound system with an M5S transducer (GE Healthcare) and an iE33 ultrasound system (Philips Medical Systems, Andover, MA, USA) with an S5-1 phased-array transducer (Philips Medical Systems). Our echo laboratory is maintained under the guidelines of the Japanese Society of Echocardiography [17]. The aortic annulus diameter (D_{TTE}) was measured in the long-axis view on the mid-systole frame. Conventional TTE parameters including cardiac dimensions and left ventricular ejection fraction by a biplane Simpson's method were calculated according to a recommendation [18]. In aortic valve stenosis (AS) patients, a peak transaortic velocity and mean transaortic pressure gradient (MPG) were derived from transaortic flow recorded with continuous-wave Doppler using a multi-window approach. Aortic valve area (AVA) was calculated according to the continuity equation [19]. Patient-prosthesis mismatch (PPM) was defined as none if effective orifice area (EOA) index was >0.85 cm^2/m^2, as moderate if EOA index was $>$ 0.65 and ≤ 0.85 cm^2/m^2, as severe if EOA index was ≤ 0.65 cm^2/m^2 [20]. EOA was calculated according to the continuity equation. AVA and EOA index (EOAI) were calculated by dividing AVA and EOA by body surface area, respectively.

All TEE images were acquired using the Vivid E9 ultrasound imaging system with a transesophageal transducer (6VT D), which has 3D TEE capabilities. 3D TEE data were acquired to ensure that the entire aortic root from the aortic annulus to the sino-tubular junction for later off-line analysis. The 2D diameter of the aortic annulus (D_{2D}) was determined with a long-axis view of the aortic valve (around 135°) by measuring the distance between the hinge points of the aortic valve leaflets including all calcifications on the mid-systole frame.

3D-TEE measurement of aortic annulus

All volumetric images were analyzed offline using commercially available software (EchoPAC, version 113, GE Healthcare). Two orthogonal long-axis planes of the aortic valve were extracted from 3D datasets using multiplanar reconstruction mode. The third plane perpendicular to both of the long-axis plane was manipulated to obtain the orthogonal 2D short-axis cutting plane of the aortic annulus (Fig. 1). After choosing the mid-systole frame, we obtained the 2D transverse plane at the level of the aortic annulus which is defined as the plane including all lowest cusp hinge point. Then we traced the aortic annulus and consequently measured the

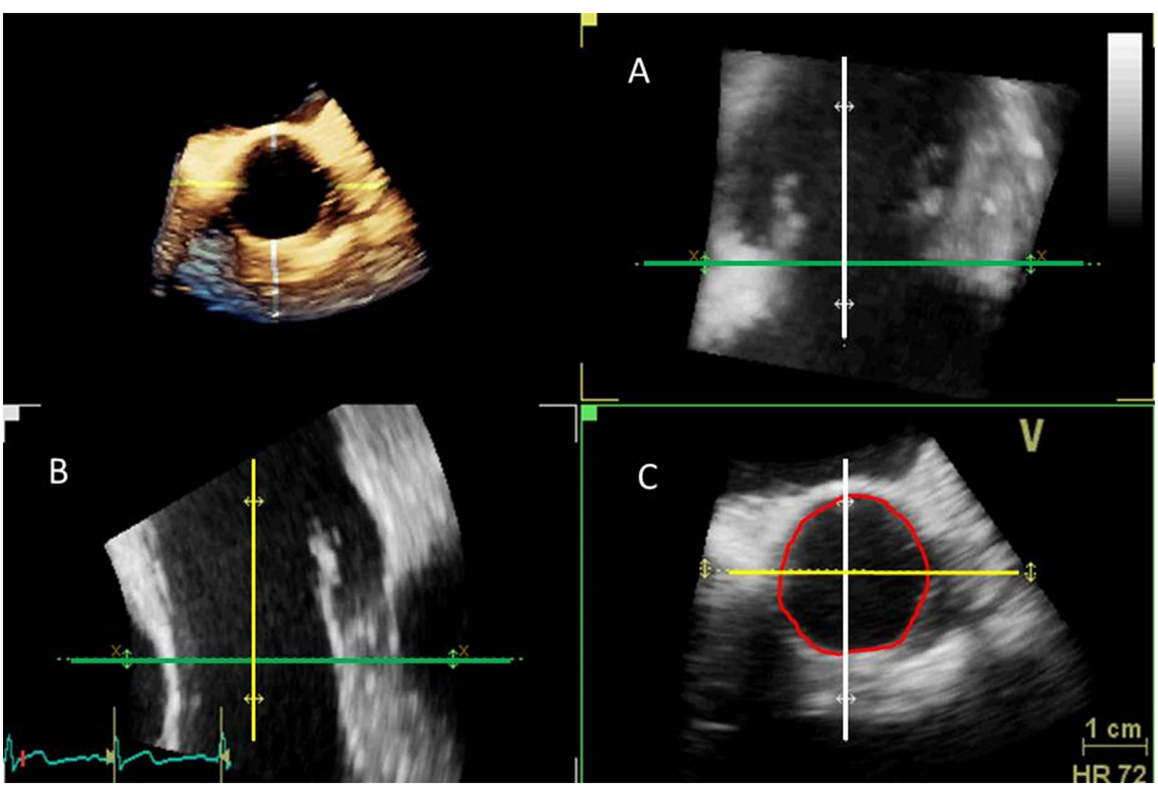

Fig. 1. Three-dimensional transesophageal echocardiography (3D TEE) analysis of the aortic annulus. From the 3D zoom datasets, 2 long-axis views of the aortic valve (A, B) and the short-axis view orthogonal to these long-axis views are extracted (C). The short-axis view of the aortic annulus is depicted, the aortic annulus is traced and the annulus measurements are calculated from perimeter and area.

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