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ORIGINAL ARTICLE

Comparison of left atrial appendage measurements between conventional transesophageal echocardiography and "Virtual TEE" reconstructed from computed tomography for pre-procedural planning of device closure

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Abstract

For pre-procedural planning of left atrial appendage (LAA) closure, sizing is crucial. Although transesophageal echocardiography (TEE) is a standard modality, cardiac computed tomography (CT) is also widely used. The virtual TEE (V-TEE) that our group developed enables us to reconstruct images similar to TEE images from CT images. The software should be helpful to understand and plan the procedure strategy. Accordingly, we investigated the utility of V-TEE. Sixty-six patients at 4 participating sites who completed both CT and TEE prior to LAA closure were included. The LAA diameter at the landing zone (LZ) for WATCHMAN™ device implantation was statistically compared at 0°, 45°, 90°, and 135° between V-TEE and TEE. Among 66 cases, only 3 cases were excluded due to poor imaging quality, and 63 cases were analyzed. The device LZ diameters based on V-TEE were strongly correlated with those based on TEE, despite the significantly greater diameter based on V-TEE with mean differences of 2.4 to 3.0 mm (all of them: $P < 0.001$). The discordances (V-TEE/TEE ratio) at most angles were significantly larger in the elliptical LAAs. V-TEE provides a valuable method for the evaluation of the LAA diameters. V-TEE-based measurements were larger than conventional TEE-based measurements, especially in cases of elliptical LAAs. The assessment by V-TEE has the potential benefit of ensuring proper device sizing regardless of the LAA morphology.

Keywords Atrial fibrillation · Stroke prevention · Left atrial appendage closure · Pre-procedural imaging

Introduction

To prevent cardioembolic stroke for non-valvular atrial fibrillation (AF) patients, although anticoagulation is a standard therapy [1], percutaneous left atrial appendage closure (LAAC) has emerged as a feasible alternative to address the unmet clinical need for prevention of cardiogenic embolism in selected patients with high bleeding risk [2–5]. For the procedure, the selection of the proper device size is integral to achieving optimal closure of the left atrial appendage (LAA). Normally, device size is determined by measurements of the maximum LAA diameter where the device is placed with transesophageal echocardiography (TEE) imaging at 4 angles (0°, 45°, 90°, 135°). Although 2D-TEE is a standard modality for pre-procedural evaluation, this invasive examination has inherent problems, including its intolerability by an unignorable number of patients as well as difficulty in visualization of global images or detailed anatomy

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of the LAA due to several artifacts. Recently, cardiac computed tomography (CT) has been widely used for LAAC pre-procedural assessment to provide accurate sizing of the LAA dimensions and to exclude thrombus [6]. CT is potentially superior to TEE in terms of minimal invasiveness as well as its capability of multiplanar reconstruction (MPR) to assess any complex shapes of the LAA, which is information that can be used for treatment planning [7].

Volume Extractor version 3.0 (i-Plants System Corporation, Morioka, Japan) is a dedicated software that implements functions such as 3D-image processing from CT images, image editing, quantitative analyses, and 3D-model printing. It has been used for treatment planning in several medical fields such as cardiology, dentistry, and orthopedics [8, 9]. Our group developed the virtual TEE (V-TEE) process by adding to existing Volume Extractor software, thus enabling the reconstruction of images similar to TEE images from CT images. Basically, V-TEE is less painful and burdensome to the patient than TEE. The tool would allow to identification of similar images between CT and TEE and this should be helpful in measuring the LZ, understanding the LAA anatomy, and planning the procedural strategy.

Accordingly, this study was designed to evaluate the correlation and differences of the LAA measurements between V-TEE and conventional TEE and to investigate the impact of the ellipticity of the LAA ostium causing the discordance.

Methods

Study design

From September 2019 to April 2021, patients who underwent LAAC with the WATCHMAN™ device (Boston Scientific, Marlborough, MA, USA) at 4 participating sites and had pre-procedural imaging by both cardiac CT and TEE within 1 year prior to LAAC were included. Subjects with inadequate LAA imaging based on CT or lack of LAA images at any of the 4 angles (0°, 45°, 90°, 135°) based on TEE were excluded. We investigated the correlations and differences in measurements of the LAA diameters between V-TEE and TEE, as well as the impact of the LAA ellipticity causing the discordance.

Imaging evaluation

All cardiac CT and TEE images were digitally stored and submitted after the LAAC procedure from the sites for offline analysis. Thereafter, the images were analyzed at the Iwate LAA imaging core laboratory (Iwate Medical University, Iwate, Japan) by trained analysts who were blinded to the clinical and procedural characteristics of the patients. V-TEE image analysis was performed using the measurement function provided by Volume Extractor. CT image (to calculate ellipticity) and TEE image analysis were provided by the commercially available OsiriX (Pixmeo, Switzerland) software package.

Definition of device landing zone

In this study, the device landing zone (LZ) diameters were measured with the assumed placement of the WATCHMAN device. The optimal device LZ is located slightly inside the ostium of the LAA. The device LZ was delineated by a line connecting the circumflex artery and a point 1–2 cm inside from the tip of the left superior pulmonary vein (LSPV) ridge, similar to a previous report [7]. In TEE or V-TEE, the device LZ diameters were measured at each angle (0°, 45°, 90°, 135°) (Fig. 1).

Computed tomography image acquisition

CT imaging was performed with prospective systolic triggered electrocardiogram synchronized cardiac-gating using the following CT scanners: a 320-detector row CT scanner (Aquilion ONE, Canon Medical Systems, Otawara, Japan), a 160-detector row CT scanner (Aquilion Precision, Canon Medical Systems, Otawara, Japan), an 80-detector row CT scanner (Aquilion PRIME, Canon Medical Systems, Otawara, Japan), or a 64-detector row CT scanner (Revolution EVO, LightSpeed VCT or Revolution HD, GE Healthcare, Milwaukee, WI, USA, or Aquilion CX, Canon Medical Systems, Otawara, Japan). Many variations exist about the scanning condition since this is a multi-center retrospective study, and a representative example of a pre-procedural CT protocol for LAAC was the followings. Contrast-enhanced images with 0.5–1.0 mm slice thickness were reconstructed. A volume of 40–100 ml of the contrast medium iohexol (350 mg I/ml, Daiichi Sankyo Company, Japan) or iopamidol (370 mg I/ml, Bayer Yakuhin, Japan) was injected at a rate of 3.0–6.0 ml/s. The dose was modulated and adjusted to weight. CT images were used to reconstruct V-TEE images and calculate the ellipticity of LAA, which were taken at the left ventricular end-systolic phase, corresponding to 30–40% of the RR interval, when applicable.

Reconstruction and measurements based on V-TEE

V-TEE images were reconstructed from the cardiac CT images by the following sequences. First, we marked several points at intervals where the esophagus was detected on the axial CT images (Fig. 2A), and then used the software to automatically determine the "esophagus line" as points of origin for further reconstruction of virtual TEE images (Fig. 2B). We were able to select preferable cross-sections in any direction as if we were manipulating the TEE probe to visualize cross-sections in the patient. The

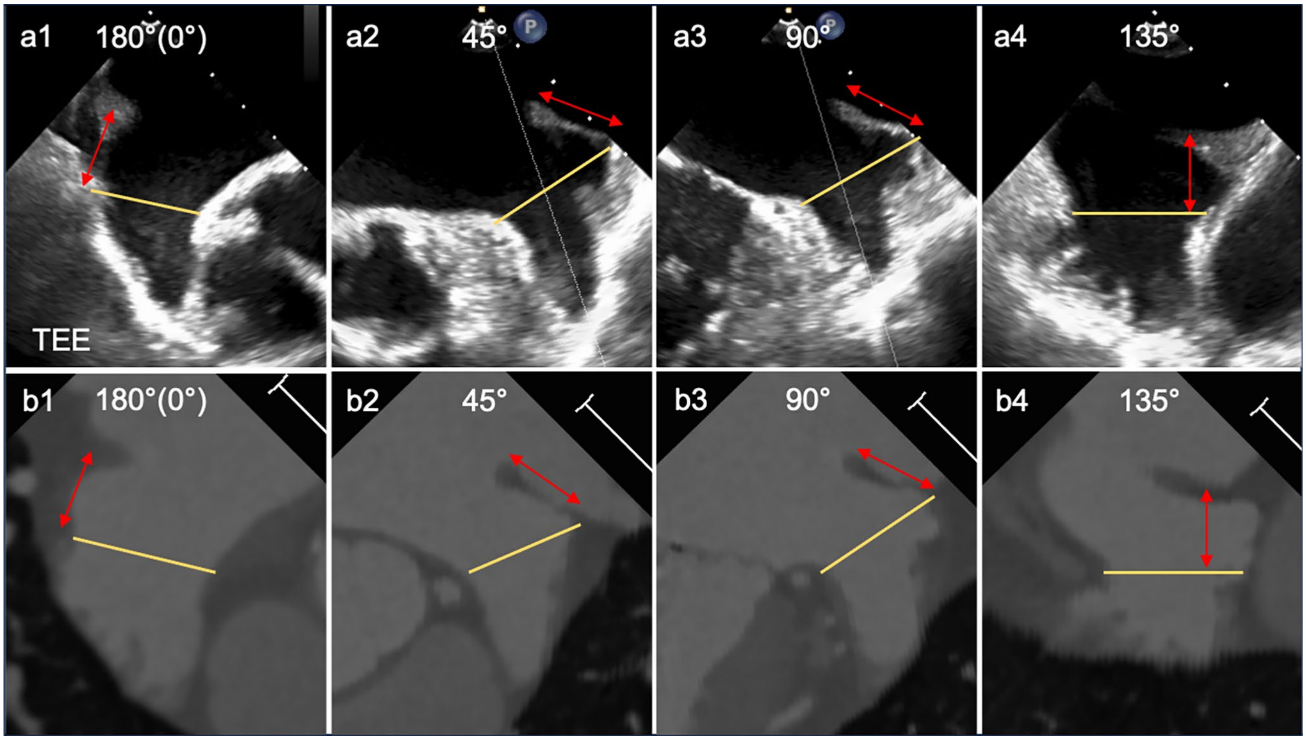

Fig. 1 Representative LAA images of TEE and V-TEE demonstrating the device landing zone a1–a4: TEE images at 4 angles, b1–b4: V-TEE images at 4 angles. Red arrows indicate distance of 1–2 cm from the tip of the left superior pulmonary vein limbus. Yellow lines indicate the plane of the device landing zone for the WATCHMANTM. *LAA* left atrial appendage; *TEE* transesophageal echocardiography; *V-TEE* virtual transesophageal echocardiography

detailed manipulation method is explained in Fig. 2C. Sectional views depicting the LAA selected at 4 angles were created and the device LZ diameters were measured.

TEE image acquisition and analysis

Patients were required to fast for at least 4 h prior to the TEE examination. All of them were monitored by a synchronized electrocardiogram. TEE was performed by experienced site physicians with a commercially available echocardiography machine (IE33 or EPIQ) and a transducer (X7-2t or X8-2t) (Philips, Andover, MA, USA). Then, well-visualized images in 4 angles were selected at the core laboratory from the collected images at each site. The device LZ diameters were measured at the left ventricular end-systolic phase, when applicable.

LAA ellipticity assessment

It is considered better to evaluate the ellipticity of the LAA using a 3D-imaging modality due to its complex morphology. Accordingly, in this study, ellipticity was calculated as the minimum LZ diameter divided by the maximum LZ diameter, as measured by 3D-MPR CT. For further analyses, enrolled patients were divided into two groups (circular and elliptical) using the median cutoff value by ellipticity.

Statistical analyses

Continuous variables are expressed as mean ± standard deviation. Categorical variables are presented as frequencies or percentages. Student's *t*-test or Mann–Whitney's *U* test was used for continuous variables, as appropriate. Fisher's exact test was used for comparison between categorical variables. Each measurement of the LAA diameter at the LZ based on TEE and V-TEE was analyzed to assess the normality of the distribution using Kolmogorov–Smirnov tests. The correlation between TEE and V-TEE was determined using Pearson correlation and regression analysis. The equivalence of the diameters at the LZ measured by TEE and V-TEE was investigated using Bland–Altman plots and the differences were compared by paired t-tests. The discrepancies of the device LZ diameters between TEE and V-TEE due to ellipticity were compared with the Mann–Whitney *U* test. Inter-observer and intra-observer agreements on measurements based on each modality were analyzed by the intra-class correlation coefficient. P value < 0.05 was considered to denote a

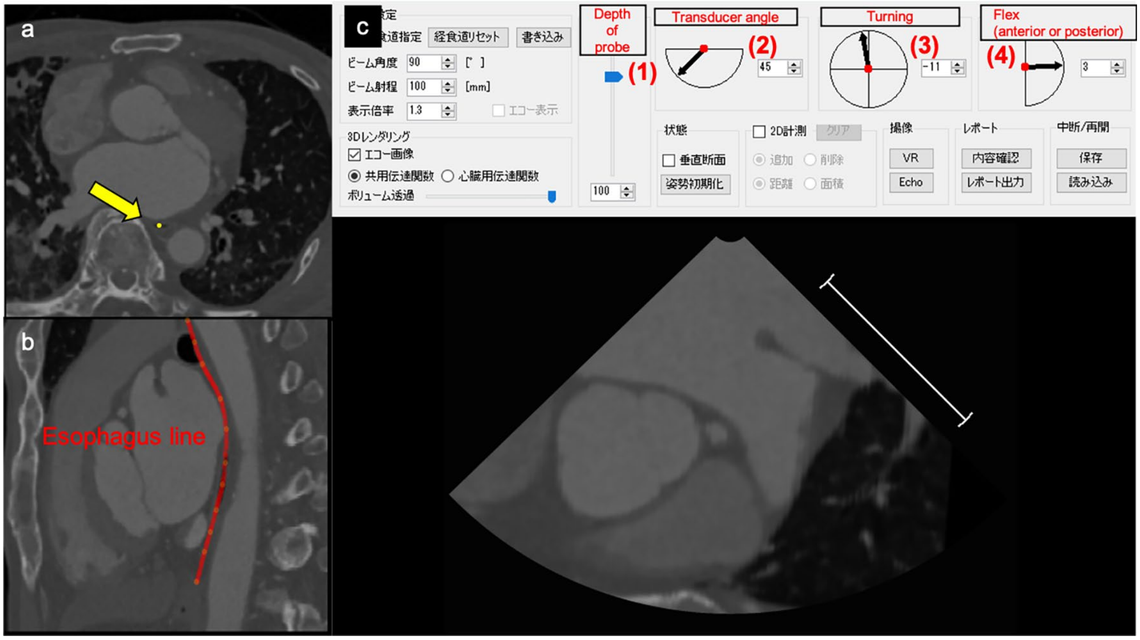

Fig. 2 Method of the reconstruction and manipulation of V-TEE. **a**: Several points (yellow arrow) were marked where the esophagus was detected on the axial CT images. **b**: The dots were connected automatically and defined as the "esophagus line" (red line). **c**: Reconstructed images similar to TEE images. The position of the virtual transducer can be advanced and withdrawn along the defined esophagus line (1), and the angle of image windows can be rotated forward or backward [0 to 180°] (2), as if we were turning the dial knob of the TEE probe. Furthermore, the virtual transducer can be turned to the right or left [any angle] (3), and flexed to the anterior or posterior position [− 90 to 90°] (4) similar to the TEE probe. *CT* computed tomography; *TEE* transesophageal echocardiography; *V-TEE* virtual transesophageal echocardiography

statistically significant difference. Statistical analyses were performed with SPSS software (IBM SPSS version 27, Armonk, NY, USA).

Ethical considerations

The study was conducted in accordance with the Declaration of Helsinki and the Ethical Guidelines for Medical and Health Research Involving Human Subjects. The study protocol was approved by the Ethics Committee at Iwate Medical University on 17 May 2021 (MH2021-021), and the trial was registered in the University hospital Medical Information Network (UMIN) Clinical Trial Registry (UMIN000045244).

Results

Study subjects

Between September 2019 and April 2021, 66 patients were recruited from 4 participating sites. Among them, 3 patients (4.5%) were excluded due to severe motion artifacts or inappropriate scan range of the CT images (2 patients) and the incompleteness of the angle series of the TEE images (1 patient). Therefore, 63 patients were analyzed in this study. No patient was excluded because of spontaneous echo contrast or filling defect due to inadequate contrast mixing in CT.

Baseline characteristics

The mean age was 72.7 ± 10.2 years, and 20 patients were female (31.7%). Paroxysmal AF was observed in 38.1% of patients. CHADS2 score, CHA2DS2-VASc score, and HAS-BLED score were 3.2 ± 1.2, 4.6 ± 1.5, and 3.3 ± 0.8, respectively. Though there was no significant difference in the duration of atrial fibrillation between the circular LAA group and the elliptical LAA group, chronic atrial fibrillation was significantly more frequent in the circular LAA group than in the elliptical LAA group (Table 1).

Comparison of the LAA measurements at the LZ between V-TEE and TEE

LAA diameters at the LZ measured by each modality are described in Table 2. There were strong correlations between diameters measured by V-TEE and TEE at each angle. Although diameters measured by V-TEE and TEE had good agreement in the Bland–Altman plots, mean differences were

Table 1 Baseline characteristics of study population

	All $N=63$	Circular LAA group $N=31$	Elliptical LAA group $N=32$	*P* value
Age (years), mean ± SD	72.7 ± 10.2	73.1 ± 7.4	72.4 ± 12.4	0.791
Female, *n* (%)	20 (31.7)	11 (35.5)	9 (28.1)	0.530
BMI (kg/m^2), mean ± SD	23.9 ± 3.6	24.5 ± 4.2	23.3 ± 2.8	0.192
Comorbidity, *n* (%) or value ± SD				
Atrial fibrillation				0.048*
Paroxysmal	24 (38.1)	8 (25.8)	16 (50.0)	
Chronic	39 (61.9)	23 (74.2)	15 (46.9)	
Atrial fibrillation terms				0.395
< 1 year	34 (54.0)	2 (6.5)	3 (9.4)	
1–10 year	22 (34.9)	17 (54.8)	18 (56.3)	
> 10 year	5 (7.9)	12 (38.7)	11 (34.4)	
$CHADS_2$ score	3.2 ± 1.2	3.2 ± 1.3	3.2 ± 1.1	0.823
CHA2DS$_2$VASc score	4.6 ± 1.5	4.7 ± 1.5	4.6 ± 1.5	0.894
HAS-BLED score	3.3 ± 0.8	3.3 ± 0.7	3.3 ± 0.8	0.834
Past history, *n* (%)				
Congestive heart failure	29 (46.0)	17 (54.8)	12 (37.5)	0.167
Hypertension	53 (84.1)	26 (83.9)	27 (84.4)	0.613
Diabetes mellitus	22 (34.9)	12 (38.7)	10 (31.3)	0.535
Ischemic stroke	25 (39.7)	12 (38.7)	13 (40.6)	0.399
Cardiogenic	19 (30.2)	11 (35.5)	8 (25.0)	
Non-cardiogenic	3 (4.8)	0 (0)	3 (9.4)	
Unknown	3 (4.8)	1 (3.2)	2 (6.3)	
Hemorrhagic stroke	18 (28.6)	9 (22.6)	9 (28.1)	0.936
CKD (serum cre > 2.26 mg/dl)	5 (7.9)	2 (6.5)	3 (9.4)	0.515
HD	3 (4.8)	1 (3.2)	2 (6.3)	0.512
Medication, *n* (%)				
Antiplatelet	18 (28.5)	7 (22.6)	11 (34.4)	0.300
Anticoagulant	60 (95.2)	29 (93.5)	31 (96.9)	0.444
Warfarin	16 (25.4)	6 (19.4)	10 (31.3)	
DOAC	44 (69.8)	23 (74.2)	21 (65.6)	
Laboratories, *n* (%)				
BNP≧100 or NTproBNP≧400 (pg/mL)	34 (54.0)	19 (61.3)	15 (46.9)	0.251

*< 0.05

BMI body mass index, *BNP* brain natriuretic peptide, *CKD* chronic kidney disease, *DOAC* direct oral anticoagulant, *HD* hemodialysis, *LAA* left atrial appendage, *NTproBNP* n-terminal pro-brain natriuretic peptide, *SD* standard deviation

Table 2 LAA diameter at LZ at each angle by V-TEE and TEE

	V-TEE	TEE	*r*	*P* value
0° (mm)	23.3 ± 4.3	20.3 ± 3.9	0.912	< 0.001*
45° (mm)	21.1 ± 3.7	18.3 ± 3.5	0.904	< 0.001*
90° (mm)	21.2 ± 3.9	18.8 ± 4.2	0.936	< 0.001*
135° (mm)	22.2 ± 4.5	19.6 ± 4.4	0.950	< 0.001*

Pearson correlation coefficient: $-1 < r < 1$

*< 0.05

CT computed tomography, *LAA* left atrial appendage, *LZ* landing zone, *MPR* multiplanar reconstruction, *TEE* transesophageal echocardiography, *V-TEE* virtual transesophageal echocardiography

significantly smaller in TEE (subtract TEE from V-TEE: 0°: 3.0 mm, 45°: 2.8 mm, 90°: 2.4 mm, 135°: 2.6 mm, respectively, all of them: $P < 0.001$) (Fig. 3). The majority of plots were scattered within the limits of agreement (0°: 93.7%, 45°: 98.4%, 90°: 98.4%, 135°: 100%, respectively).

Impact of ellipticity on LZ size discrepancy between the two modalities

The ellipticity was 0.47 to 0.98, and the median was 0.74. We divided patients into the circular group ($n = 31$) and elliptical group ($n = 32$). In order to analyze the impact of

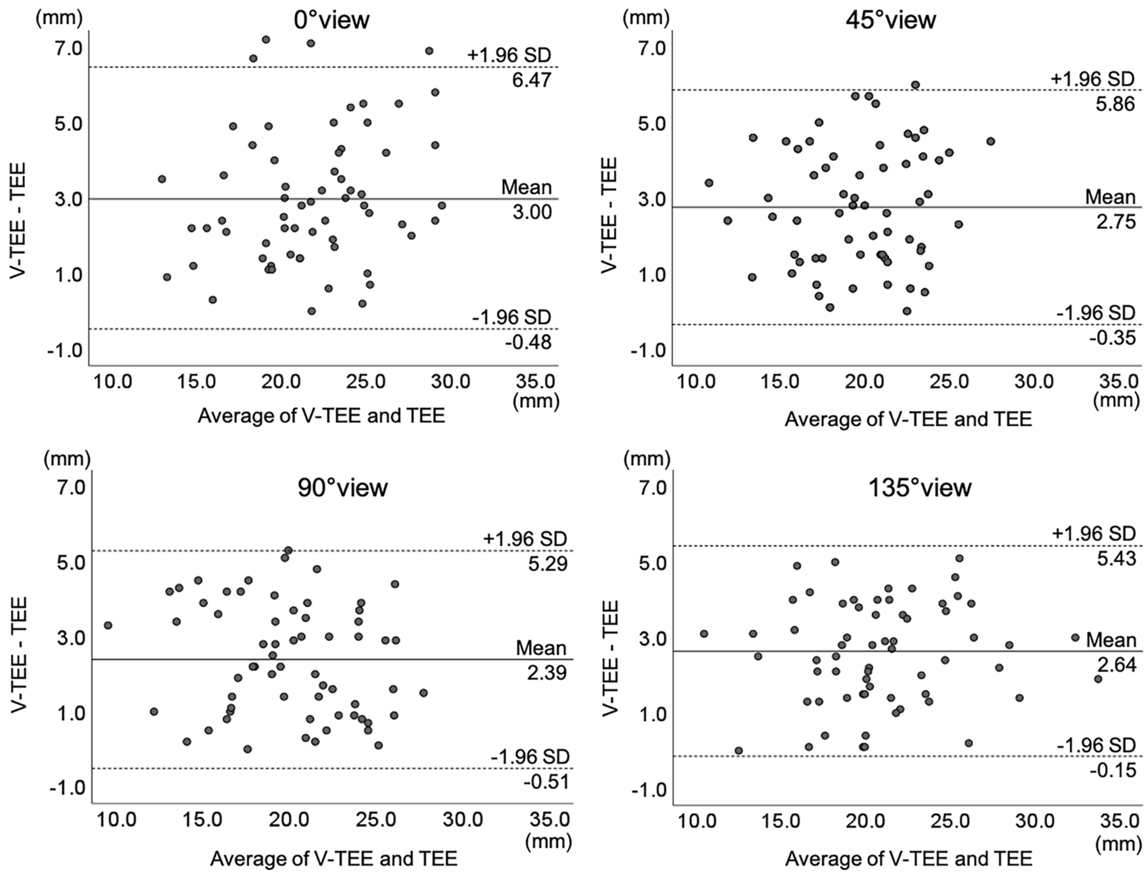

Fig. 3 Bland–Altman plot of discrepancy between the diameters at the LZs examined by V-TEE and TEE at 4 angles Bias is demarcated by the dotted line. Bland–Altman analyses clearly demonstrate that most plots are located on the positive side of scales. Most of the measurements by V-TEE are greater than those by TEE at any angle. The errors between the measurements of two modalities appear biased and fixed. *LZ* landing zone, *SD* standard deviation, *TEE* transesophageal echocardiography, *V-TEE* virtual transesophageal echocardiography

the ellipse on the size discrepancy between V-TEE and TEE, the ratio of the LZ diameter measured by V-TEE to that measured by TEE (V-TEE/TEE ratio) was calculated. The ratio was compared between the two groups at 4 angles. The V-TEE/TEE ratio was significantly greater in the elliptical group than in the circular group, except at 90° (Fig. 4).

Intra- and inter-observer variability

The diameters in 10 randomly selected patients were measured repeatedly by a trained analyst (NC) or by two independent trained analysts (NC and YN). The measurements were performed at least 2 days apart by the same observers who were blinded to their first measurement. Table 3 indicates that the LZ measurements with each modality provide reproducible results with little intra-observer and inter-observer variability.

Discussion

This study demonstrated the utility of V-TEE. The major specific findings of this study were: first, although strong positive correlations were observed in the measurements at each angle between the two modalities, absolute values measured by V-TEE were significantly larger than those measured by TEE. Second, the ellipticity of the LAA caused a greater size discrepancy between the two modalities.

Before analysis, a total of 3 cases were excluded, including 2 cases with poor rendering of the CT images and one case with incompleteness of the angle series for the TEE images. The LAA images based on CT allow for detailed observations in any arbitrary plane offline, when they are taken without motion artifacts, with adequate scan range, and properly contrasted. On the other hand, the LAA images based on TEE provide specified views and may not be captured appropriately due to artifacts such as acoustic shadows caused by surrounding structures or operator errors. In

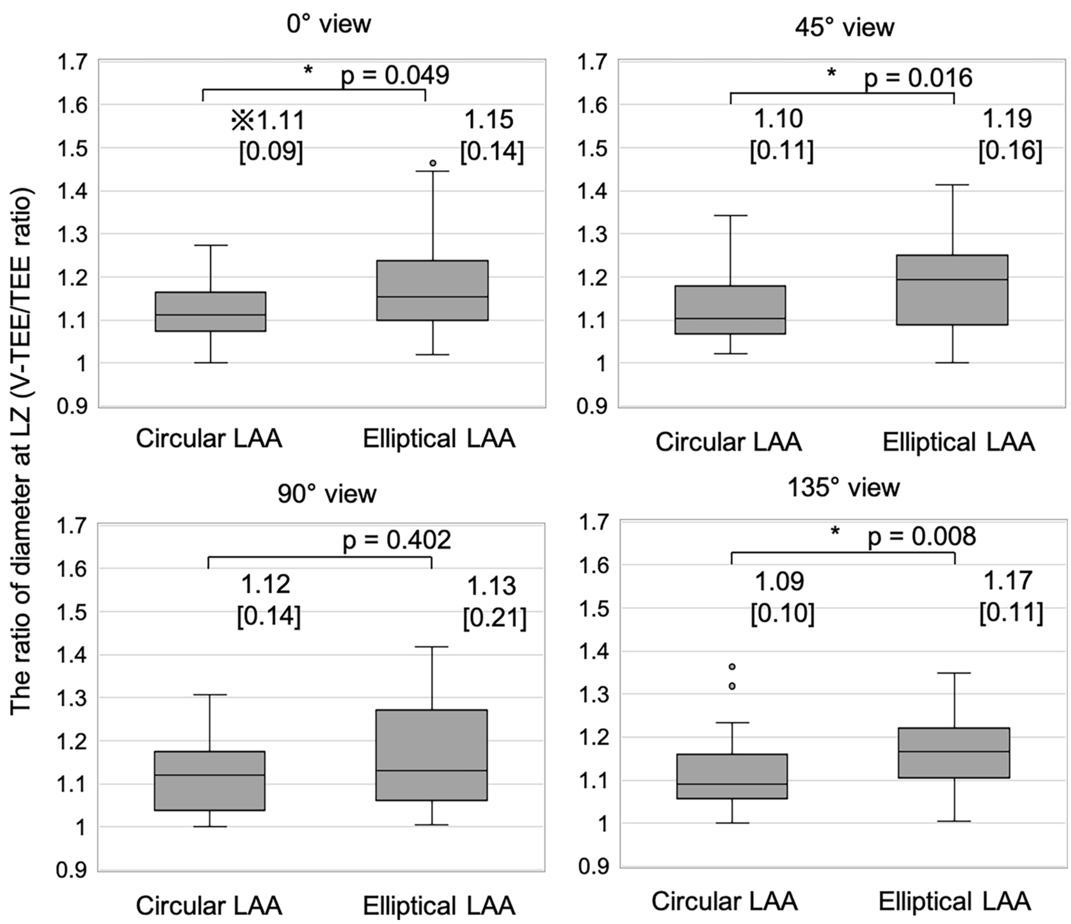

Fig. 4 Comparison of V-TEE/TEE ratios between circular and elliptical LAAs. The ratio of the diameter at the LZ measured by V-TEE to that measured by TEE (V-TEE/TEE ratio) was calculated using the corresponding diameters. This ratio indirectly indicates discordance of measurements between V-TEE and TEE. This parameter was significantly greater in the elliptical LAA at 0°, 45°, and 135°. ※Median *IQR* Interquartile range, *$P < 0.05$, *CT* computed tomography, *LAA* left atrial appendage, *LZ* landing zone, *MPR* multiplanar reconstruction, *TEE* transesophageal echocardiography, *V-TEE* virtual transesophageal echocardiography

addition to its advantages based on CT, V-TEE reconstructed from CT can depict multiple angles of the LAA similar to those viewed with TEE. This is one clear advantage of V-TEE compared with TEE. Additional potential limitations of CT are risks of exposure to radiation and possible reaction to the contrast agent.

Baseline characteristics were similar to the reported registry [5], and chronicity may affect the shape of the appendage orifice. Despite strong correlations in the corresponding measurements between the two modalities, TEE-based measurements tended to be smaller compared with V-TEE-based ones, and the absolute differences between them were 2.4 and 3.0 mm. In fact, Bland–Altman analyses suggested that these differences were fixed errors in most cases. During this study, we found that measurements of the LAA based on TEE tended to be underestimated compared with those based on CT, as previously reported in other studies [10, 11]. Underestimation of the LAA diameter can easily occur because the plane is not exactly aligned with the maximum diameter of the LAA orifice due to difficulty in visualization by TEE. Under-sizing of the LAA diameter may increase risks of peri-device leak and device embolization. Accordingly, the "maximum" diameter at the LZ is always used for device size selection. If we use TEE for the pre-procedural evaluation of LAAC, this feature should be taken into consideration. Currently, 2D-TEE is considered the standard pre-procedural assessment tool, in the future, V-TEE could be beneficial as the first-line modality after further validation.

In this study, we raised an issue associated with size discordance between the two modalities due to the ellipticity of the LAA orifice (determined by CT). In cases of elliptical orifice morphology, size discordance becomes greater. Meanwhile, approximately 70% of the LAA ostium are elliptical in shape [12, 13]. Selecting the most appropriate observational echo plane for assessment of the LAA is more difficult with TEE than CT because of barriers to TEE examinations such as patient pain and time restrictions

Table 3 Intra-observer and inter-observer variability in each LZ measurement

	Inter-observer difference		Intra-observer difference	
	r	*P* value	*r*	*P* value
CT (3D-MPR) diameter (mm)				
Maximum	0.748	0.004*	0.766	0.002*
Minimum	0.82	0.001*	0.862	< 0.001*
V-TEE maximum diameter (mm)				
0°	0.448	0.011*	0.851	< 0.001*
45°	0.772	0.003*	0.893	< 0.001*
90°	0.697	0.011*	0.858	< 0.001*
135°	0.779	< 0.001*	0.905	< 0.001*
TEE maximum diameter (mm)				
0°	0.753	0.002*	0.799	0.001*
45°	0.837	0.001*	0.861	< 0.001*
90°	0.806	< 0.001*	0.911	< 0.001*
135°	0.788	< 0.001*	0.909	< 0.001*

Pearson correlation coefficient: $-1 < r < 1$

*< 0.05

LZ landing zone, *CT* computed tomography, *MPR* multiplanar reconstruction, *V-TEE* virtual transesophageal echocardiography, *TEE* transesophageal echocardiography

for the examination. In the case of an elliptical LAA, the echo beam tends to cross the oblique plane as previously suggested [10,14], which leads to the undersizing of the maximum diameter at the LZ by mechanisms explained in Fig. 5. In fact, one previous report indicated that 2D-TEE-based size prediction might result in the undersizing of the diameter by 62% [15]. In contrast, since V-TEE enables us to analyze a patient repeatedly without pain and time constraints, we can better locate the observational plane. Using this software, we can move the "virtual transducer" (forward or backward, up or down, and clockwise or counter-clockwise) as necessary and set the optimally centered position of any imaging planes where each diameter is maximized. Most of the time, V-TEE provides the largest diameter at the LZ, which is considered critical for the treatment planning of LAAC. If V-TEE-based measurements were preoperatively used for actual LAAC cases, this could lead to a higher success rate and highlight the practicality of V-TEE as an ideal planning tool.

Although intra- and inter-observer correlations for the LZ measurements of LAA were high, those of V-TEE-based measurements were slightly lower than those of TEE-based measurements. This may be explained by how to decide the images before the measurement. In this study, the V-TEE images are reconstructed from original CT data requiring several steps to determine images. On the other hand, the TEE images had already been determined and recorded at each facility, and each analyst could measure the LZ just by matching the time phases.

Clinical implications

This study has several clinical implications for the planning of LAAC. Although pre-procedure measurements of the LAA using 3D-imaging techniques (CT or TEE) have recently become popular, still 2D-TEE remains the standard modality for pre-procedural measurement and the necessary guidance and a real-time monitoring tool during the LAAC procedure. Operators should be aware of the biases in measurements for each imaging modality. V-TEE can easily reconstruct data

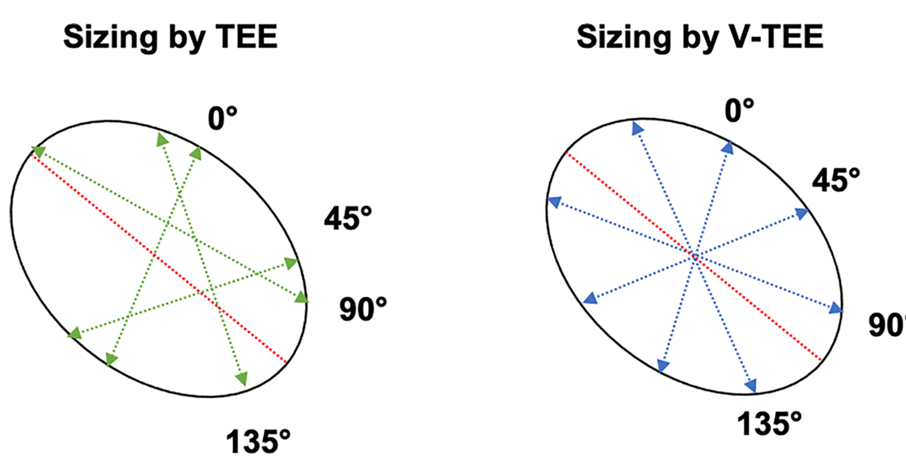

Fig. 5 Schematic presentation of relative positions of measured diameters by each modality Left: LAA sizing by TEE, right: LAA sizing by V-TEE. Potential mechanisms for the differences in LAA diameter between the modalities are well explained in this scheme. Red lines are maximum and minimum diameter lines. Green lines are typical error lines of diameter in each angle measured by TEE. Blue lines are typical error lines of diameter in each angle measured by V-TEE. *LAA* left atrial appendage, *TEE* transesophageal echocardiography, *V-TEE* virtual transesophageal echocardiography

from CT to provide images that are almost identical to TEE images without subjecting patients to additional physical distress. Such pre-procedural anatomical information could be very useful during the procedure. The other clear advantage may be avoidance of sizing errors by TEE especially when the LAA is elliptical. Such efforts to minimize sizing errors may be associated with reduced risk of intra- and post-procedural complications. V-TEE also has a potential benefit in assessing complex structures which are difficult to visualize by TEE, such as the morphological details of the LAA, a pre-existing LAA thrombus, and the intracardiac positional relationship. Future V-TEE applications may extend to the planning of other structural heart interventions.

Limitations

Several limitations need to be acknowledged. First, the sample size was relatively small. Second, each image was not taken under the exact same conditions because CT and TEE were mostly conducted on different days (the average time period was 38 days between CT imaging and TEE examination). If both images were taken on the same day, the measurement difference might have changed slightly. Third, we used several types of CT and TEE instruments, and other potential factors, such as fasting state, sedation, and saline loading, might be different since this was a multicenter retrospective study. The volume status factors might influence left atrial pressure and LAA diameter. However, to minimize these influences, basic imaging protocols were uniformly used across the facilities. Fourth, specific artifacts in CT images, such as blooming artifacts and motion artifacts, can potentially lead to an overestimation of LAA dimensions.

Conclusions

V-TEE provides a valuable method to enable the reconstruction of images similar to conventional TEE images for evaluation of the device LZ diameters. Although strong correlations were observed in measurements between V-TEE and TEE, V-TEE-based measurements were larger than TEE-based measurements, especially in elliptical LAAs. The assessment by V-TEE has the potential to ensure proper device sizing regardless of the LAA morphology.

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Data availability The deidentified participant data will not be shared.

Declarations

Conflict of interest YN, SK, and HH received lecture fees and consultancy fees from Boston Scientific, MN received lecture fees from Boston Scientific, and YM received a research grant and lecture fees from Boston Scientific. The other authors have nothing to disclose.

IRB information The study protocol was approved by the Ethics Committee at Iwate Medical University on 17 May 2021 (MH2021-021).

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