Comparison of Two and Three Dimensional Transthoracic Versus Transesophageal Echocardiography in Evaluation of Anatomy and Pathology of Left Atrial Apendage

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Objective: Our objective was the comparison of combined utility of two-dimensional (2D) transthoracic echocardiography (TTE) and three-dimensional (3D) TTE versus 2D and 3D transesophageal echocardiography (TEE) in evaluation of anatomy of the left atrium appendage (LAA) and for clot formation in LAA.

Background: 2DTEE as semi-invasive method has been for a long time used to visualize the LAA. Improved echocardiography technology has increasingly improved visualization of LAA by 2DTTE and 3DTTE in many patients and decreased the need for TEE performance.

Methods: We compared combined 2DTTE and 3DTTE with 2DTEE and 3DTEE in evaluating the LAA for anatomical features and thrombus. Eighty-six patients underwent 2DTTE, 3DTTE, 2DTEE and 3DTEE.

Results: LAA could be visualized in all patients. 31% of patients had one lobe, 43% had 2 lobes and 26% had > 2 lobes. Of 86 patients studied, 79 had no thrombus and 7 had thrombus in the LAA by all modalities. Six patients, 3 with atrial fibrillation (AF), and 4 in sinus rhythm (SR) had a suspected thrombus by 2DTEE. Only in one patient 3DTEE cropping has been needed to clearly show thrombus which was suspected in short axis view on 2DTEE as rounded echo dense mass.

Conclusions: Our preliminary study suggests that combined 2DTTE and 3DTTE has comparable accuracy to TEE in evaluating the LAA anatomy and pathology in terms of thrombus. Only in inappropriate (obese) patients 2TTE, but not 3DTTE, may misdiagnose pectinate musculature as thrombus.

Key words: left atrial appendage, transthoracic echocardiography, transesophageal echocardiography, three dimensional echocardiography, thrombus

1. INTRODUCTION

The Left Atrium Appendage (LAA) is a remnant of the original embryonic left atrium formed during the third week of gestation. The LAA lies within the pericardium in the close contact with the free wall of the left ventricle. Therefore, it is likely that blood flow, in and out of the LAA, depends to a significant degree on the properly functioning left ventricle. LAA empties into the left atrium through an orifice located between the left upper pulmonary vein and the left ventricle. The diameter of the opening varies between 10 and 40 mm, the overall volume of the LAA varies between 0.77 and 19.27 mL, and its length can vary between 16 and 51 mm (1-3). The left atrial appendage (LAA) is a long, hook-like true diverticulum of the left atrium (LA) (Figure 1). It is internally lined by pectinate muscles which are arranged in a parallel fashion, giving it a web-like appearance. Most pectinate muscles are greater than 1mm in size (4).

While parallel-running pectinate muscles are contained within the tubular LAA (Figure 2), the body of the LA is a smooth-walled structure (3-6). It’s multi lobulated structure has been described by Veinot et al. at the Mayo clinic based on autopsy studies.

The LAA may have anywhere between 1 and 4 lobes in 80% of the general population, with about 54% having 2 lobes (4). Left atrium (LA) is the most important location for the formation of thrombi in many cardiovascular conditions. Most of these clots occur in the left atrial appendage (LAA), which is a small finger-like out-pouching of the left atrium (7).

The LAA has several important physiological functions (1-3). It is more distensible than left atrium itself and acts as a decompression chamber when left atrial pressure is high. The LAA mediates in thirst and people without LAA might have greater tendency to become dehydrated.
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The LAA is a major endocrine organ and is the main producer of ANP (atrial natriuretic peptide) in the human heart. The ANP concentration is 40 times higher in the LAA walls than in the rest of the atrial free wall and in the ventricles. The LAA removal found a significantly lower ANP secretion and a commensurate increase in salt and water retention.

2. LAA ECHOCARDIOGRAPHIC EXPLORATION

Transesophageal echocardiography (TEE) is the diagnostic modality of choice for visualizing the LAA (4) and has been used extensively to characterize LAA structure and function as well as looking for clots, spontaneous echo contrast (SEC), and abnormalities in emptying flow velocities. 2DTEE is an integral part of any comprehensive ultrasonographic examination of the heart and great vessels because the proximity of the esophagus to the heart and vessels permits high-quality imaging in nearly all patients undergoing TEE due to the use of a higher frequency transducer (7-9). Although the visualization of this structure is much clearer in TEE with a sensitivity of 100% and a specificity of 99%, TEE is semi invasive, uncomfortable to the patient and not without risks (8). Echocardiography assessment of LAA function was initially described by Suetsugu et al. (10) and by Pollick and Taylor (11) and has become an integral part of the routine TEE examination. Although TEE is considered the “gold standard” for excluding LAA thrombi, in some patients dense SEC and artifacts may hamper the identification or exclusion of thrombi (11). New echocardiographic modalities may improve current multplane 5- to 7.5- MHz TEE evaluation of LAA and other heart structures (12). Three-dimensional echocardiographic imaging should improve the delineation of LAA complexity and thus compensate for current limitations in the measurement of LAA ejection fraction by 2-D planimetry (13, 14). But both 2DTEE and 3DTEE are only slice techniques, visualizing only one plane at any given time, preventing comprehensive examination of the LAA and making it difficult to differentiate a clot from pectinate muscles in some patients (4, 15, 16).

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This limitation may be overcome by obtaining a 3D transthoracic image of the LAA. Once the LAA can be visualized from transthoracic images, it is possible to obtain a live/real time (RT) 3D image of the LAA. After a good quality image is acquired, it can be sectioned in any plane with any desired angulation, thereby increasing the confidence in accurately identifying the presence or absence of a thrombus and differentiating it from pectinate muscles especially if they are prominent or hypertrophied (17, 18). In particular, RT-3DTEE may represent the first-line approach because it can provide full view of the LAA because 2DTEE does not adequately allow complete spatial visualization of the LAA.

3. MATERIAL AND METHODS

We reviewed the data from 86 adult patients (50 males, 36 females; age range 43–86 years; mean age 71 ± 15 years). Forty-two patients were in atrial fibrillation and forty-two patients had atrial flutter. Four patients had paroxysmal atrial fibrillation. Forty-two patients were in atrial fibrillation and forty-four patients had sinus rhythm (Table 1). For both 2DTTE and 3DTTE, S5-2 and S3-1iE33 Philips, (Bothell, WA, USA) probe was used. For 2DTEE and 3DTEE a S7-2 MHz multplane probe, iE33 Philips ultrasound system has been used. On 3DTTE, attempt was made to visualize the LA and LAA using parasternal short-axis views (aortic-pulmonic or mitral-pulmonic planes) and apical views. Using the view where the LAA was best seen, the 3DTTE data set was captured in full volume. Subsequently, the 3D data set of the LAA was cropped manually online or offline with a proprietary Q-Lab software (version 4, Phillips Company, Bothell, WA, USA). The horizontal short-axis view at the base of the heart and the two-chamber longitudinal view of the left cavities has been used to image the LAA. A multiplane probe revolving around the cavity (0 to 180°) to improve the assessment of its frequently complex structure has been applied. The LAA was cropped systematically in a sequential manner using multiple long axis, short axis, and oblique cropping planes. While the LAA was sectioned, focus was placed on the number of lobes and the presence or absence of a clot and differentiating it from pectinate muscles. LAA max and LAA min were obtained visually and measured by planimetry, independent from the ECG cycle. The areas were measured by tracing a line from the top of the limbus of the upper-left pulmonary vein, along the whole appendage endocardial border. An average of five measurements was taken in patients with AF and three measurements for subjects with sinus rhythm. The percentage of the LAA area change (LAAAC%) was calculated using the formula: (LAA maximal area – LAA minimal area)/LAA maximal area × 100. The LAA flow measurements were obtained approximately 1 cm below the outlet of LAA cavity using pulsed-wave (PW) Doppler after suitable gain and filter adjustments. LAA emptying and filling velocities were measured. The LAA peak emptying flow velocity (LAA-E) was defined as the highest positive flow velocity that can be measured on pulse Doppler velocity time scale and the LAA peak filling velocity (LAA-F) was defined as the highest negative flow velocity. Measurements were taken from six consecutive cardiac cycles and averaged. Interobserver variability was assessed by reviewing the 3D data set of 50 randomly selected patients in a blinded manner. Statistical analysis was performed using MedCalc (Version 9.4.2.0; MedCalc, Mariakerke, Belgium) for calculating kappa value (K) for interobserver reproducibility.

4. STUDY RESULTS

In all patients studied, the LA and LAA could be visualized on 2DTTE, 3DTTE, 2DTEE and 3DTEE. From the 86 patients who underwent all procedures, no LAA thrombus was noted in 79 patients by all four modalities. Echo...
dense mass consistent with thrombus was noted by 2DTTEE in seven patients and these thrombi were also noted by 3DTTEE. In one patient, it was difficult to differentiate clearly a thrombus in the LAA by 2DTTEE, especially when viewing only one 2D plane of the LAA at any given time. However on 3DTTEE, and 3DTEE cropping the data set clearly showed this to be prominent rounded echo dense mass attached to the bordering LA/LAA segment of wall at 45 grade long axis (Figure 3). In the same patient was noticed the cardioversion from AF in sinu syndrome during the TEE procedure which was again reversed in AF by withdrawing the TEE probe. The same event took place three times, whenever the procedure was performed. Interobserver variability was also very low with a very high Kappa value of 1.0.

Evaluation of Spontaneous Echo Contrast and Thrombi

The presence of thrombus was diagnosed when an intracavitary echo-dense mass with an echocardiographic appearance different from the atrial, ventricular, auricular endocardium and the pectinate muscles was detected. The presence of SEC was diagnosed when dynamic, swirling intracavitary smoke-like echoes were detected, which were differentiated from white noise artifact by their characteristic swirling pattern and by careful attention to the gain settings. The severity of SEC was defined as follows: 0 = absence of echogenicity; 1+ = mild (minimal echogenicity detectable in only part of the left atrial, left ventricular, and LAA cavity with high gain settings); 2+ = moderate (denser swirling during the entire cardiac cycle); 3+ = severe (intense echo density and very slow swirling pattern in the cavity).

The LA and LAA SEC was present in all patients with mitral stenosis and LV SEC in very low EF patients. The severity of SEC (3+) was significantly higher in the mitral stenosis group than the other groups. Localization of the thrombi in LAA was in four patients in sinus rhythm and three patients in atrial fibrillation. LAA thrombus was detected in two mitral stenosis patients one with AF and the other in sinus rhythm. In 7 AF patients and 10 SR patients SEC in LAA, LA, LV was present. The cutoff values for the presence of LAA thrombi were 25% for the percent change of LAA, and 25 cm/sec for the LAA peak emptying velocity.

Descending aortic plaques (distance 25–45cm from incisive teeth) were detected in four AF patients and five SR patients.

5. DISCUSSION

An interesting aspect of our study was that the LAA could be visualized in all patients by combined 2DTTEE and 3DTTEE for the presence or absence of a thrombus in LAA. This was because all of these patients had good acoustic windows. This is particularly useful in very old and very ill patients, who do not undergo a TEE if an adequate quality echocardiographic study is obtained and LAA visualized. The stenographers have been trained to visualize the LAA during routine echocardiographic studies. In routine clinical practice, it has been estimated in the past that up to 20% of patients have suboptimal acoustic windows, but with the recent improvements in echocardiographic technology including the introduction of harmonic imaging, this number is considerably smaller (19, 20). Nevertheless, LAA would be expected to be visualized by 2DTTEE and 3DTTEE in the majority of patients studied, especially those patients in whom the LAA is larger and therefore more easily visualized by TTE. Also, our study showed an excellent correlation of combined 2DTTEE and 3DTTEE findings with 2DTEE and 3DTEE. All patients who had a clear LAA by 2DTEE and 3DTEE also had a clear LAA by 2DTTEE and 3DTTEE. Although, in seven patients who had a suspected clot on all modalities, 3DTEE offered an advantage over 2DTTEE only in one patient, providing clear information about the presence of echo dense mass and differentiating it as a clot. Clots may remain hidden because of the three-dimensional complexity of the LAA, and a false-positive diagnosis of thrombus may stem from false interpretation of a prominent pectinate muscles. Therefore, complete examination of the LAA requires careful manipulation of the multiplane TEE probe to bring the LAA to the center of the image sector and rotating the plane from 0° to 180°.22 Even then it may be difficult to ascertain if the visualized echo density represents a prominent pectinate muscle viewed in short axis rather than a thrombus. This underscores the unreliability of 2DTEE in accurately making a correct diagnosis of a clot within the LAA in some patients.
6. CONCLUSION

On the basis of our preliminary study, we would propose that for patients scheduled for 2DTEE for the evaluation of LAA thrombus, a combined 2DTEE and 3DTEE should be attempted first. If the LAA is well visualized by both 2DTEE and 3DTEE, then in this group of patients it may not be necessary to perform a 2DTEE and 3DTEE. However, if the LAA is not well visualized from the transthoracic approach, then a 2DTEE or 3DTEE would be warranted. Our preliminary study suggests that combined 2DTEE and 3DTEE has comparable accuracy to TEE in evaluating the LAA for a thrombus. 3DTEE may be particularly useful in differentiating a thrombus from prominent pectinate muscleatur in the LAA. Additionally, with the recent introduction of 3DTEE, the limitations of 2DTEE may be overcome (22).

REFERENCES