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Real-time 3-dimensional transesophageal echocardiography assessment of left ventricular shape and function after surgical remodelling

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ABSTRACT

Background
Real-time three dimensional transoesophageal echocardiography (RT 3D-TEE) may better reflect left ventricle (LV) shape and function than cconventional 2D-TEE. The goal of this study was to evaluate the advantages of 3D analysis in shape assessment and to quantify the LV volume by ejection fraction (EF) measurement, after LV surgical remodelling.
Methods
In a prospective manner, twenty consecutive coronary surgery patients with LV anteroapical aneurysm and functional mitral regurgitation were analyzed by 2D- and thereafter by 3D- TEE before and after surgery. The key intraoperative inclusion criteria was a LVEF < 30% confirmed by intraoperative 3D-TEE immediately before surgical remodeling.
Results
Before surgery, the geometry of post infarction aneurysm shows negative curvatures of the antero-basal and infero-apical segment and the apex of LV is shifted clockwise, towards the mitral valve. Surgery had significantly reduced the LV volumes and the LVEF had increased by 13.3% as recorded by 2D-TEE and by 18.3% as assessed by 3D-TEE quantification (p < 0.001 for both). Accordingly, the longitudinal plane had been shortened, the apex was now shifted anti-clockwise towards the aorta and the inferior region had taken a more important function of the LV. Significantly lower values were observed in the EF measurement with 3D- vs 2D-TEE before remodelling (22.3 vs. 29.7%, p = 0.048).
Conclusion
Improvement of LV function occurred due to the increased systolic contraction of the inferior region after remodelling in patients with postinfarction aneurysm.

Key words: intraoperative transesophageal echocardiography (TEE), real-time three dimensional TEE (RT-3D TEE), left ventricle, cardiac surgery

INTRODUCTION

Real-time three dimensional transoesophageal echocardiography (RT 3D-TEE) is founded on a new matrix technology which consists of 512 piezzoelectric crystals in three planes, making a total of 4096 lines, by which we can reconstruct a live 3D pyramidal and full volume image of the heart (1, 2). A "multiplane" probe generated image during a TEE examination shows the two standard plane views of the heart (longitudinal and transverse) whereby using the 20 standard diagnostic TEE views, a complete analysis of the heart can be obtained (3). This complexity of a standard 2D TEE analysis can be simply replaced by a single RT 3D-TEE generated image, which as is the case in all other digital diagnostic techniques (RTG, CT, MRI), can portray the heart with a full volume image and in the real anatomical position. Due to a lack of a standard 3D-TEE perioperative protocol, the focus of the 3D-TEE is most often a specific intraoperative cardiac pathology, rather than a routine examination (4).
3D quantification of volume and left ventricle (LV) function is a more precise and more reproducible method than te conventional 2D method in cardiac surgery (5, 6). After a myocardial infarction, the normal shape of the LV begins to dilate and becomes more spherical. Such a change in LV shape cannot be adequately portrayed with 2D echo. In this setting, 3D-TEE imaging provides a unique intraoperative visualisation of LV shape and volume (7).
The goal of the study was to establish the advantages of 3D analysis in shape assessment and to quantify the LV volume by ejection fraction (EF) measurement, after LV surgical remodelling.

PATIENTS AND METHODS

In a prospective manner, 23 consecutive cardiac surgery patients were included in this investigation, which was conducted at the Department of Cardiac Anaesthesia and Intensive Care, of the Clinical Department of Anesthesiology, Reanimatology and Intensive Care, University Hospital Dubrava. Inclusion criteria were as follows: significant triple vessel disease of the coronary arteries and/or left main stenosis, LV anteroapical aneurysm with a functional mitral regurgitation and severe LVEF impairment. The key intraoperative inclusion criteria was a LVEF < 30% confirmed by intraoperative 3D TEE immediately before surgical procedure commencement. From 23 consecutive patients, in 3 patients we found a 3D LVEF > 30% prior to surgery so they were consequently excluded from this investigation. Routine intraoperative TEE assessment was conducted according to protocol for all of the patients and ethical approval was obtained from the institution's Ethics committee. After left ventricular surgical remodelling, all of the patients received inotropic support with dobutamine in the range from 2 to 2.5 μg/kg/min with glyceril-trinitrate in the dose of 0,5 μg/kg/min. No other vasoactive drugs were administered.

From the 23 patients, 20 patients (58.3 ± 11.1 yrs, 15 male, 15 pts with LV dysfunction, 17 pts with functional mitral regurgitation 2/3) who met the inclusion criteria, were first analyzed by 2D- and thereafter by 3D- TEE before and after surgery, using a Philips iE33 ultrasound system with TEE S7-2omni transducer (Philips Ultrasound, WA, US).

Before and after left surgical remodelling in a full-volume acquisition, based on the direct 3D volumetric method, we evaluated the change in LV shape and quantified the LV end-diastolic (EDV), end-systolic volume (ESV) and EF. The 3D imaging data set was stored to allow a late analysis from the same recordings by Philips QLAB Advanced Quantification 4.2.1 software (Philips Ultrasound, WA, US).

STATISTICAL ANALYSIS

Statistical anaysis was carried out using the software program Statistica 10.0 (StatSoft, Inc., www.statsoft.com). The W Shapiro-Wilk test was applied to assess normal data distribution. The data in each group possess non-Gaussian distribution. To compare data, the non-parametric Kruskal Wallis and post-hoc Mann Whitney U tests were performed and also, the Wilcoxon matched paired test was applied for dependent variables.

Numerical data of the analysis are shown in Table 1 and 2. Data are expressed as median and interquartile range. P-value <0.05 was considered statistically significant.

Table 1. 2D and 3D-TEE quantification of LV volumes and EF measurement (n = 20), expressed by median and interquartile range

LV parameter (mL)	Before remodelling	After remodelling	Statistics† P
	2D-TEE		
EDV	183.6 (119.3)	110.0 (50.0)	<0.001
ESV	123.8 (113.3)	65.0 (24.0)	<0.001
LVEF (%)	29.7 (32.5)	43.0 (29.0)	<0.001
	3D-TEE		
EDV	190.8 (105.4)	116.6 (77.3)	<0.001
ESV	139.4 (75.6)	69.8 (32.0)	<0.001
LVEF (%)	22.3 (14.9)	40.6 (24.3)	<0.001

Abbreviation: LV – left ventricle; EDV – end diastolic volume, ESV – end systolic volume, EF – ejection fraction
†Comparison between groups with Wilcoxon matched paired test

Table 2. 2D vs 3D-TEE LV parameters before and after surgical remodelling, (n =20), expressed by median and interquartile range

LV parameter (mL)	2D-TEE	3D-TEE	Statistics‡ P
	Before remodelling		
EDV	183.6 (119.3)	190.8 (105.4)	0.293
ESV	123.8 (113.3)	139.4 (75.6)	0.038
LVEF (%)	29.7 (32.5)	22.3 (14.9)	0.048
	After remodelling		
EDV	110.0 (50)	116.6 (77.3)	0.200
ESV	65.0 (24.0)	69.8 (32.0)	0.992
LVEF (%)	43.0 (29.0)	40.6 (24.3)	0.147

Abbreviation: LV – left ventricle; EDV – end diastolic volume, ESV – end systolic volume, EF – ejection fraction
‡Comparison between groups with Mann Whitney U test

RESULTS

Out of 20 patients who underwent LV surgical remodelling, sixteen patients also underwent coronary surgery, while eleven also had a mitral valve annuloplasty. Preoperative 3D assessment of left ventricular shape showed a spherical left ventricle with an aneurysmatic apex. Geometry of such a post infarction aneurysm shows negative curvatures of the antero-basal and infero-apical segment. The apex is shifted clockwise, towards the mitral valve (Figure 1). After surgical remodelling, the apex is shifted anti-clockwise, towards the aorta. Surgery has shortened the longitudinal plane while the transversal width remained the same and the sphericity of the LV in diastole increased. As opposed to the unchanged antero-basal curvature, the inferior region takes the function of the antero-apical region and has a smaller end-systolic and end-diastolic curvature (Figure 2).

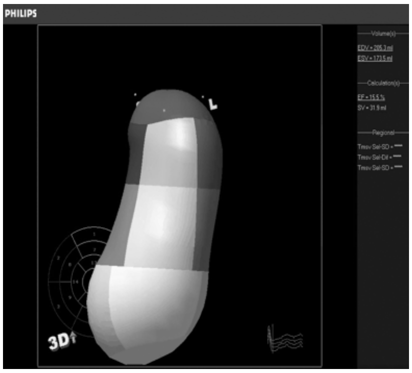

Figure 1. RT 3D-TEE image of left ventricular shape before surgery remodelling

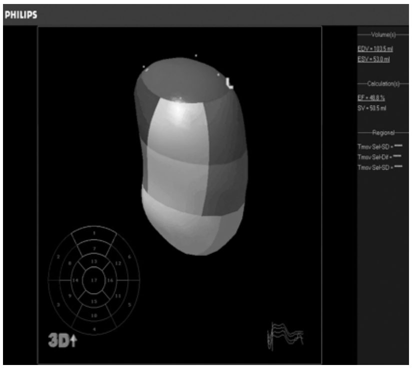

Figure 2. RT 3D-TEE image of left ventricular shape after surgery remodelling

Quantification of LV volumes and EF measurement with 2D- and 3D-TEE before and after left ventricular surgical remodelling is shown in Table 1. Significant differences were observed with 2D- and 3D-TEE measurement in every tested combination, in patients after sugical remodelling ($p < 0.001$). After remodelling, in comparison to before surgery, the LVEF was higher by 13.3% as recorded by 2D-TEE and was also higher by 18.3% as assessed by 3D-TEE quantification ($p < 0.001$ for both).
Table 2. shows 2D- vs 3D-TEE LV parameters before and after left ventricular remodelling. Although LV volumes were continuously higher by 3D-TEE analysis before and after remodelling, compared with 2D-TEE quantification, the significance was only in ESV ($p = 0.038$). Significantly lower values were observed in the LVEF measurement with 3D- vs 2D-TEE before remodelling (22.3 vs. 29.7%, $p = 0.048$).

DISCUSSION

Assessment of LV remodelling has conventionally been performed with 2D-TEE derived LV volumes. It is well known, that as LV function worsens, ventricular size increases and the ventricle becomes more spherical than elliptical (8). In this study, it has been suggested that RT 3D-TEE imaging of the LV endocardium may better reflect global and regional LV shape. Namely, before surgical remodelling, the geometry of such a post infarction aneurysm shows negative curvatures of the antero-basal and infero-apical segment and the apex of LV is shifted clockwise, towards the mitral valve. Surgery, in which a volume of approximately 70 -80 ml of aneurysmatically changed apical myocardium was resected, had significantly affected the LV volume values. The longitudinal plane had been shortened, the apex was now shifted anticlockwise towards the aorta and the inferior region had taken a more important function of the LV. Improvement of LV function occurred due to the contraction of the inferior region. The sphericity index was shown as an accurate predictor of LV remodelling in patients after an acute myocardial infarction (9). Studies have shown that Simpson's biplane calculation of EF can vary up to 4.1% between clinicians. This variability is due to the complex geometric assumptions and problems with 2D-images (10). Consequently, cardiac magnetic resonance imaging (MRI) has been proposed as a more warranted alternative for LV assessment, especially in clinical trials because of its good image quality and high spatial resolution (11). 3D volume quantification and LV ejection fraction calculation, has become a standard technique due to high efficiency in comparison with cardiac MRI and radionuclide ventriculography (12, 13). In this study, the LV volumes were significantly higher in 3D-TEE imaging compared with 2D-TEE, especially the ESV before remodelling ($p = 0.038$). On average, the LVEF was 7,4% smaller before surgery and 2,4% smaller after surgery in 3D-TEE quantification, compared to conventional 2D-TEE imaging. Online measurement of 3D LV volumes is achievable and more accurate than with 2D (14).
Contrary to 2D-TEE imaging, a 3D image, after a live image reconstruction, can allow an analysis of all 17 segments, once a wide image is harvested and includes the outer border of the LV. 3D quantification of the LV is based on a semiautomated endocardial border detection which creates a dynamic cast of the LV endocardial cavity. For this point of view, no studies have been published on the use of RT 3D-TEE for the assessment of left ventricular shape and global function after surgical remodelling. When comparing 3D-TEE with 2D-TTE in LV volume quantification, RT 3D-TEE is more reproducible and has a high test correlation (2). 3D-TEE is now the gold standard and echocardiographic measurement of choice for the accurate calculation of LV volumes and EF (15).

CONCLUSIONS

3D TEE yielded important information regarding LV shape and function after surgical remodelling in patients with postinfarction aneurysm. Enhancement of LV function occurred due to the increased systolic contraction of the inferior region. Because of the opportunity of spatial reconstruction, intraoperative 3D gives a new insight into the complex LV geometry after surgical remodelling.

Conflict of Interest: None to declare.

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