RELIABILITY OF ECHOCARDIOGRAPHIC LEFT VENTRICULAR VOLUME MEASUREMENTS IN PATIENTS WITH DILATED VENTRICLE

M. M. J. MOHAMMED*
G. VIJAYARAGHAVAN**
A. M. YOUSOF**
T. ABRAHAM**
N. HAYAT**
G. CHERAIN**

SUMMARY: Left ventricular volume indices (LVVI) were measured in fifty patients with chronic mitral and/or aortic regurgitation. Their age ranged from 12 to 71 (mean ± SD, 38 ± 15) years. End-diastole (ED) and end-systole (ES) frames were selected from video replay of two dimensional echocardiograph (TDE) recorded from apical long axis view. LVVI were calculated using the ellipsoid formula. The data compared LVVI measured from left ventricular angiography (LVA) done within one week of TDE study. The mean end-diastolic volume index (EDVI) for all 50 patients was 215 ± 111 ml (mean ± SD) was not different from the single plane angiographic value of 221 ± 68 m1 (r = 0.94). The mean end-systolic volume index (ESVI) of 111 ± 77 ml was also not significantly different from the angiographic value of 118 ± 77 ml (r = 0.94). The average TDE and angiographic ejection fraction (EF) values of 51 ± 11 and 52 ± 12 were not different (r = 0.904). The excellent correlation between the two techniques is due to better endocardial delineation and smoothening of the trabeculae in dilated ventricles. LVVI and EF estimated by TDE are adequate for follow up and surgical decision making in patients with mitral and/or aortic regurgitation.

Key Words: Echocardiography, Left ventricular volume

INTRODUCTION

Left ventricular function is one of the most important factors for the prognostic assessment and follow up of heart disease. The standard method for evaluating left ventricular volume is an invasive technique that uses ventricular outline traced from cineangiograms (1). Several non invasive techniques have shown that ejection fraction (EF) and left ventricular volumes (LVV) correlated well with EF and LVV derived from X-ray cineangiograms (2-5). Calculations of LVV and EF by standard time-motion (M-Mode) echocardiography have compared reasonably well with measurements obtained by contrast ventriculography in patients with

*From Department of Physiology, Faculty of Medicine, Jordan University of Science and Technology, Jordan.
**From Department of Cardiology, Faculty of Medicine, Kuwait University, Kuwait.

Figure 1: Two-dimensional four chambers echocardiographic view with focus on the left ventricle in end-systole (above) and end-diastole (below). The cardiac apex is at the top and the atria are at the bottom of each apical photo. The mark on the ECG indicates the approximate timing for obtaining end-systolic and end-diastolic images.

symmetrically contracting ventricles (6-7). Other studies reported poor correlation between M. Mode measurement and angiographic calculation in patients with segmental wall motion abnormality (2,8). EF and LVV estimated by TDE have revealed high correlation with values determined by cineventriculography (2,3,9,10). Other studies have shown that TDE can yield volume measurements and EF with an accuracy comparable to that of radiological methods (11,12). While third group of workers have shown that TDE appear to underestimate left ventricular volumes. Transoesophageal TDE had also been used for measurement of LVV and EF, and the results showed good correlation with values estimated by radionuclide angiography (13). The purpose of the present study was to analyze left ventricular volumes and ejection fraction from TDE apical long axis view and to compare these measurements with contrast cineangiographic determinations of left ventricular volume and EF.

MATERIALS AND METHODS

Fifty eight patients with various valvular heart diseases underwent examination by TDE and cardiac catheterization during the same hospitalization. Fifty patients had satisfactory studies with both techniques. In four patients left ventricular angiograms were not suitable for analysis because of ectopic beats and in two patients there was inadequate specification of the left ventricle. One had pericardial effusion and another patient had poor echo window. In the fifty patients with good quality cineventriculgram and TDE, 41 were males, 9 were females. The mean age (± SD) was 38.1 ± 14.6 (range 12-72 years). All patients had valvular heart disease, 10 with aortic regurgitation. 2 had mitral regurgitation, 2 with aortic stenosis, 1 had mitral stenosis and 35 had combined valvular disease. Patients had cineventriculography done within one week of the TDE.

Echocardiographic study

Two dimensional echocardiography was performed using a commercially available equipment, (Advanced Technology Laboratories, In. Bottle, Wash) using a mechanical transducer having a frequency of 2.25 MHZ. Cardiac images used in this study were recorded from the cardiac apex with the patient in the left lateral decubitus position, to optimize image quality. The transducer was placed at the cardiac apex to obtain four chambers view, and then rotated clockwise to get the apical long axis view including aortic root. Echocardiographic images were stored on video tape recorder and played back on a video computer system (American song cooperation). End-systole and end-diastole were defined from the ECG at the end of T wave and at R wave of the QRS respectively. Endocardium was identified and traced from the posterior leaflet of the mitral valve (papillary-muscles were excluded), through the lateral wall to the apex and then through the ventricular septum to the anterior leaflet of the mitral valve (Figure 1) using a light pen as a digitizing pad. The major long axis was taken from the apex to the center of mitral annulus. Long axis length of the end-systolic and end-diastolic apical images and area were then measured. End-systolic and end-diastolic volumes were calculated by ellipsoid formula, and ESVI, EDVI and ejection fraction were estimated. All the data calculated by TDE were compared with volume indices and EF measured by left ventricular angiography performed within one week of TDE.

Cardiac catheterization and ventriculography

Cardiac catheterization was performed, from the right groin using the seldinger technique. Ventriculography was done in the 30 degree right anterior oblique (RAO) projection. A vanguard motion analyzer (Vanguard Instrument Corporation, Melville, New York) was utilized to draw the systolic and diastolic outline and corrected for magnification factors. With the aid of Hewlett Packard 5600m computer (Hewlett Packard, Waltham Massachusetts). LV volumes and EF were obtained from single-plane cineangiocardiography using area length formula (14).

All measurements were done by two independent observers. Each calculation were repeated by the same operator on another day.

Statistical analysis

The two dimensional echocardiographic volume indices were compared with determination of volume indices by cineventriculography. Linear regression analysis was performed using one way analysis of variance, and standard error of the estimate was calculated.

RESULTS

End-diastolic left ventricular volume index (EDVI)

The mean of the estimated value of EDVI by TDE was 215 ± 111 ml (±SD) which was not significantly different from the mean angiographic EDVI of 221 ± 118 ml (±SD) ($p<0.001$, $r = 0.94$) (Figure 2). The correlation coefficient (r) between TDE left ventricular end-diastolic volume index and cineangiographic end-diastolic volume index in the 50 patients was 0.94. The following linear regression equation showed the relationship between the echocardiographically derived data and the angiographic data:

EDVI echo = EDVI cine X 0.879 + 20.4.

End-systolic left ventricular volume index (ESVI)

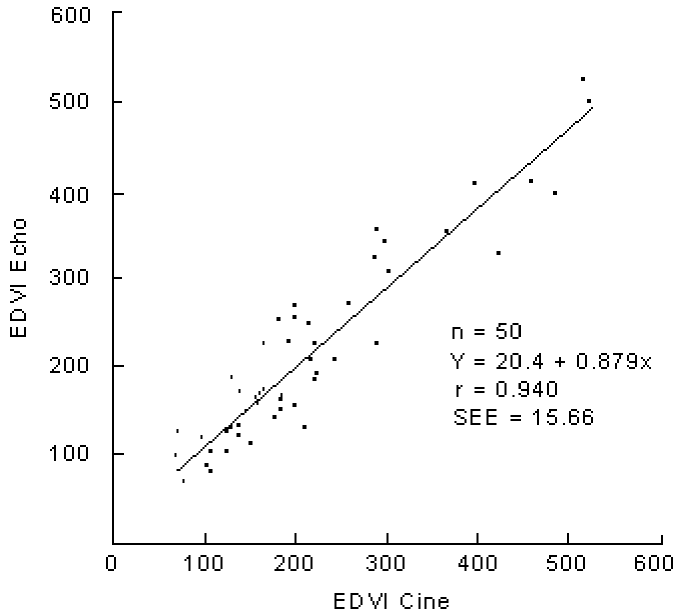
The mean value of the estimated ESVI by the TDE was 111 ± 77 ml (±SD) which was not significantly different from the mean value by angiographic ESVI of 118 ± 77 ml (±SD) ($p<0.001$, $r = 0.94$) (Figure 3). The correlation coefficient (r) between echocardiographic left ventricular end-systolic volume index in 50 patients was 0.94. The relationship between the echocardiographically derived data and the angiographic data is described by the following linear regression equation:

ESVI echo = ESVI cine X 0.874 + 12.3.

Left ventricular ejection fraction (LVEF)

The mean echocardiographic ejection fraction was 51 ± 11 (±SD) which was not significantly different from the mean angiographic ejection fraction of 52 ± 12

Figure 2: Correlation of echocardiographic left ventricular end-diastolic volume index (EDVI) is plotted for the 50 patients against the single-plane cineangiographic values. Linear regression yield an r value of 0.94 and a standard error of estimate (SEE) of 15.66 cc.



(±SD) ($p<0.001$, $r = 0.91$) (Figure 4). The range of the calculated value of ejection fraction by left ventricular angiography was (22-76). Therefore the overall accuracy of the echocardiographic method was not significantly different from that of angiographic method over a wide range of ejection fraction value (9). The correlation between ejection fraction calculated from the echocardiographic end-systolic and end-diastolic volume and that measured by angiographic value in the 50 patients was very good ($r = 0.904$).

The relationship between the echocardiographically derived data and the angiographic data is described by the following linear regression equation:

EF echo = EF cine X 0.837 + 7.23.

Reproducibility of the data

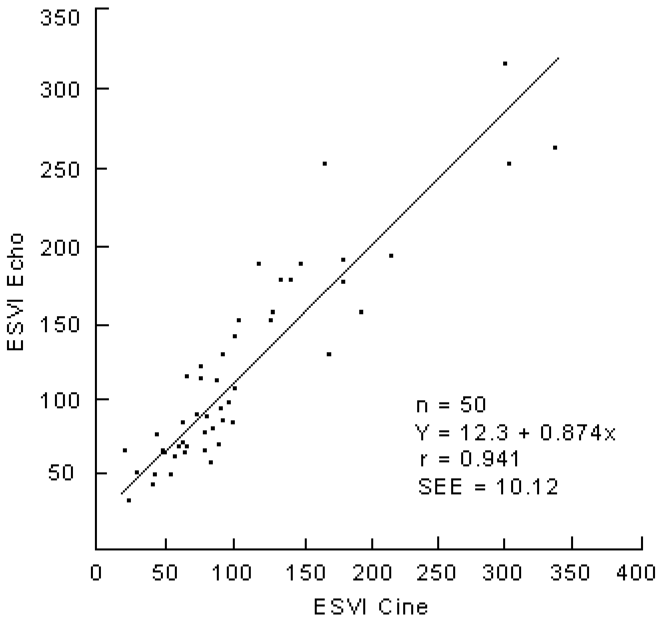
The inter observer variability in echocardiographic EDVI, ESVI and EF was negligible ($r = 0.98$, 0.97 and 0.97, respectively). The intra observer variability was also negligible ($r = 0.98$) for all the parameters.

DISCUSSION

The use of a non invasive technique to measure the left ventricular dimension would provide valuable information regarding ventricular function and ventricular volumes. Angiocardiographic method has proven its validity and is generally considered the gold standard for comparison, therefore all non invasive methods, TDE, radionuclide and Magnetic Resonance Imaging (MRI) are assessed by comparing them to the standard cineangiography. TDE is simple to perform in the outpatient department and takes only short time and does not need any injection or radioactive substance and it is completely harmless to the patient. TDE can be used to determine left ventricular volume with high correlation compared with analysis estimated by cineangiography.

Our data indicate that TDE can determine ESVI, EDVI and EF of the left ventricle with high accuracy compared with the values calculated from cineangiography. The correlation coefficient between the two tech-

Figure 3: Correlation of echocardiographic left ventricular end-systolic volume index (ESVI) is plotted for the 50 patients against the single-plane, cineangiographic values. Linear regression yield an r value of 0.94 and a standard eror of estimate (SEE) of 10.12 cc.

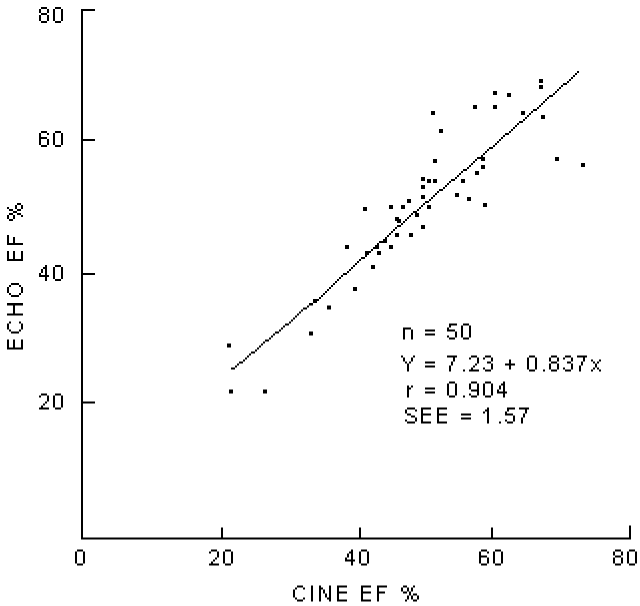


niques was 0.94, 0.94 and 0.904 respectively. Erbel *et. al.* (15) and Wyalt *et. al.* (12) showed accurate but slight underestimation of left ventricular volume by TDE compared with cineventriculography performed simultaneously. Erbel *et. al.* (15) have reported correlation coefficient of 0.907, 0.938 and 0.803 for EDVI, ESVI and EF respectively. Jenni *et. al.* (16) have reported correlation coefficient for both volumes of 0.90. Starling *et. al.* (3) reported correlation coefficient of 0.80, 0.88 and 0.90 for EDVI, ESVI and EF respectively. Their data indicated that the echocardiography underestimates left ventricular EDVI and ESVI. Explanation of the underestimation by echocardiography could be the more pronounced trabeculation especially in small volume of the left ventricle during systole, thereby increasing the difference in outlining left ventricular contour by TDE and cineventriculography. Silverman *et. al.* (17) showed in children that TDE was a good predictor of the angiographic end-diastolic volume but overestimated slightly the angioraphic end-systolic volume. Because the end-systolic volume is smaller in absolute value than the end-diastolic volumes so an error in the measurement of the end-systolic volume caused by frame selection would lead to a greater percentage of error than would a similar error in end-diastolic frame selection.

Other non invasive methods as nuclear angiograpy (10,18) showed correlation coefficient of 0.88 for the EF estimated by nuclear ventriculography with that calculated by cineangiography. This technique needs injection of radioactive substance and long time to be performed. While Magnetic Resonance Imaging (MRI) methods showed a correlation coefficient of 0.65-0.98 for EF estimated by MRI using single slice imaging and multiple contiguous slice imaging compared with calculated data by ventriculography (5).

The excellent correlation of our data between the TDE and contrast ventriculography is due to better endocardial delineation and smoothening of the trabeculae in dilated ventricles. TDE is a non invasive method

Figure 4: Correlation of echocardiographic left ventricular ejection fraction (EF) is plotted for the 50 patients single-plane cineangiographic values. Linear regression yield an r value of 0.904 and a standard error of estimate (SEE) of 1.57.



for predicting angiographic volumes and EF. There is no change in ventricular volume or function caused by radiographic contrast material or ectopic beats related to a cardiac catheter. Because it is non invasive, TDE is ideally suited for studying the natural history of heart diseases and the effect of medical and surgical intervention on left ventricular performance which can be evaluated even in infant and young children, as often as it is required.

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Correspondence:
M. M. J. Mohammed
Department of Physiology
and Biochemistry,
Faculty of Medicine,
Jordan University of Science
and Technology.
P.0. Box 3030, Irbid,
JORDAN.