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Analysis of Left Ventricular Function by Dual Source MDCT in Patient with Ischemic Heart Disease in Comparison with ECHO

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Abstract:

Background: To evaluate left ventricular function in patients with ischemic heart disease (IHD) by dual source CT (DSCT) in comparison to Echocardiography (ECHO). **Material and Methods:** This cross-sectional comparative study included 60 cases who were examined by echocardiography. They underwent DSCT coronary angiography followed by left ventricle global and regional segmental functions evaluation by two experienced radiologists with ten years of experience in cardiac imaging. We used the Pearson correlation test to estimate the correlation between the functional parameters of DSCT and ECHO. Moreover, we assessed the agreement between the functional parameters and regional wall motion abnormality (RWMA) using Altman bland test and Fleiss Kappa tests, respectively. **Results:** Mean left ventricular ejection fraction (LVEF), end diastolic volume (EDV), end systolic volume (ESV) and stroke volume (SV) were 53.21%, 181.52 ml, 85.99 ml and 95.22 ml, respectively on DSCT and 53.79 %, 171.15 ml, 82.3 ml and 93.55 ml respectively in ECHO with statistically significant positive correlation (r=0.98, 0,99, 0,96 and 0.99 / p < 0.001) respectively. Using a Bland-Altman analysis, EF was slightly underestimated in DSCT compared to ECHO, while both EDV and ESV were slightly overestimated in DSCT but with statistically non-significant differences between both techniques. However, regarding RWMA, by using binary scoring, there was good agreement between both modalities (K=0.86 and p < 0.001). **Conclusions:** DSCT can be an alternative option to ECHO in LV function assessment in patients with IHD with strong positive correlation between both techniques.

Keywords: Dual source CT; Ejection fraction; Echocardiography; Regional wall motion abnormality.

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Introduction

Diagnosis of cardiac diseases depends on its function evaluation and its pump activity [1]. Decreasing LV function by less than 40% is considered heart failure in ability to pump blood effectively with subsequent cardiac output decreasing [2]. Trans-oesophageal ECHO is considered as an initial test for ventricular ejection fraction, end systolic and end diastolic volume evaluation, but it is operator dependant technique and may lead to either under or over estimation of the ejection fraction [3]. By special technique of cardiac CT in the form of ECG gating either prospective or retrospective study with reconstruction of the images, special axes and special considerations can facilitate evaluation of the function [1]. Introduction of a new CT generation (Dual source CT) for left ventricular function evaluation, enabling covering the entire heart volume in one beat, so the previous limitations of cardiac CT can be overcomed [3]. New generation, is characterized by gantry rotation, time reduction and temporal resolution increasing with subsequent improving both end systolic and diastolic phases identification [3]. So cardiac CT is used not only for coronary artery diseases evaluation but also for evaluation of myocardium, pericardium, heart valves and left ventricular function in the form of stoke volume, end systolic, end diastolic and ejection fraction for patient with ischemia or other types of cardiomyopathies [1]. However, the gold standard for the examination in patient with newly diagnosed ischemic cardiomyopathy is cardiac MRI because of good tissue characterization and myocardial fibrosis detection by late Gd enhancement which gives worse prognosis, but it has several limitations as its high cost, obesity, claustrophobia, patients with cochlear implant and decrease image quality by motion artefact and cardiac arrhythmia [3]. Semi-automatic segmentation for all 10 cardiac phases after filling the lumen by IV contrast is done for global function assessment [4]. The most universal tool to evaluate the left ventricular function is the EF estimation which is considered diagnostic and prognostic marker for treatment decision [5]. Cine CT has also a good role for providing information about wall motion if there is regional wall motion abnormality (RWMA), the myocardial contraction and relaxation throughout whole cardiac cycle can be visualized from reconstructed cine-loop images. So cardiac CT can be used as coronary artery supplement assessment for coronary artery stenosis significance establishment by different CT techniques for cardiac function evaluation [6]. This study aimed to assess the role of DSCT in left ventricular function assessment compared to ECHO**.**

Material and methods

Before the study began, all patients signed written consents, and the study was approved by the Institutional Review Board (IRB) of our institution {Reference No: M.D.15.4.2023} and the study followed Helsinki declarations.

Study design and population:

This cross-sectional comparative study was done at CT unit –Radiology department of the National Cardiac Institute from May 2023 to May 2024 included 60 patients (38 males and 22 females) with mean age of 52 years ranging from 26 to 74 years, with suspicion of ischemic heart disease. Referral of the patients was from the cardiology out-patient clinics for coronary artery disease evaluation by DSCT coronary angiography. The study examination was done by DSCT after ECHO which was done within the same day or one day before. Any patient with any age and sex with ischemic heart disease, clinical diagnosed of ventricular impairment and approved to do both cardiac MDCT as well as ECHO were included. Patients with hemodynamics and respiratory instability, their ejection fraction less than 35%, renal failure (estimated GFR <60 ml/min) or patient refused to do any cardiac MDCT or ECHO were excluded.

Technique of DSCT and ECHO

Patient preparation

Patients had to fast 4-6 hours before the examination, receiving sub lingual nitrates 0.4 mg, trained on Valsalva maneuver and observation of the patient compliance and heart rate changes was done during this trial. Patient positioning was supine with fixation of three traditional sites of ECG leads.

Scan protocol and parameters

CT angiographic examinations was done by DSCT, using Somatom Force, Siemens Medical Solution, Syngo.via workstation with the following parameters of 2 x192 x 0.6 mm detector collimation, 250 ms gantry rotation time, 0.18 pitch and 400-600 mA tube current at 90-120 KV.

First, scanogram was done in both AP and lateral views extending from the root of the neck down to 1 cm below diaphragm. **Then**, Calcium scoring was done.

Image acquisition was performed by retrospective ECG gating with no dose modulation. ECG was recording simultaneously throughout scanning. Injection of 50 ml contrast was done by cannula of 18-gauge through right antecubital vein using a dual head power injector pump using 350-370 mg /ml Ultravist with an injection rate of 6 ml /s immediately followed by 40 to 50 ml saline bolus flush. Volumetric data set was acquired in a cranio-caudal fashion during breath hold, using smart prep technique to detect the enhancement peak automatically in the descending aorta with about 200 HU threshold level in a single breath hold.

MDCT image analysis

All images were analyzed and interpreted by two experienced radiologists with ten years of experience in cardiac imaging who were blinded to the ECHO findings. First, they evaluated the coronary vessels for CAD as follows: Considering the phases of 75% and 40% of R-R interval are ideal for native arteries assessment and grafts. However, if the images were not satisfying or sufficient, further phases of cardiac cycle were used. Combination of both axial and reconstructed images. Evaluation was performed first by the axial source then curved MPR images. Second, they assessed the **global left ventricular function analysis:** Reconstruction of the images was done at 0, 30, 40, 45, 50, 60, 70, 75, 80 & 90 % phases of the R–R interval. Post-processed images were achieved at workstation at all 10 phases. Assessing global LV function was done automatically at both end systolic and end diastolic phases, delineation of endocardial LV contours with manual editing and papillary muscles exclusion then LVEF, LVED and ES volumes are calculated directly by using software. Finally, **regional left ventricular function analysis was done:** Assessing wall motion abnormality was done by cini loops of the short axis slices (basal, mid cavity and apical) as well as two & four chambers orientation and then grading using a 17 –segment LV model regarding to the American heart association (AHA) [7]. If the left ventricular systolic wall thickness increases 40% it considered normal, if the increase was less than 30% considered hypokinesia, considering akinesia, if it was less than 10%. However outward motion was considered as dyskinesia and images are scores as follows, normal = 0, hypokinesia =1, akinesia =2 and dyskinesia =3. Wall motion abnormality was also matched to its corresponding segment [8].

Echocardiography

Asking patients were done for left lateral decubitus lying for the examination using (Vivid-7; GE-Vingmed, Milwaukee Wis) machine and a of 3.5 megahertz (MHz) curvilinear transducer. Imaging was done at both systole and diastole and obtaining three dimensional images by Simpson method. Tracing the outlines of the LV endocardium was done and calculated the following parameters LVEDV, LVESV and LVEF. For regional LV function evaluation, two and four chamber long axis as well as short-axis views at following levels, apical level, papillary muscle and mitral valve were obtained and recorded. Scoring each segment was done as CT. The exam was done by a blind expert cardiologist (doesn't know the DSCT findings).

Statistical analysis

Using Microsoft Excel software to collect and submit data for statistical analysis. The data were analyzed after being imported, using the social sciences software statistical package (IBM crop. Released 2020. IBM SPSS statistics for windows, version 27.0. Armonk, NY: IBM crop). Representation of the qualitative data was by number and percentage while using mean ± SD for quantitative data, the mean of each EF, EDV, ESV and stroke volume (SV) were used for statistical analysis, the data from them were expressed as mean ± SD by using the paired two- tailed Student's t test and compared. Agreement and correlation of the LV function and volumes by DSCT and ECHO were determined by Bland Altman analysis and Pearson correlation test respectively. The 95% limits of agreement were defined as range of value ± 2SD s from the mean value of differences. The Fleiss kappa test was utilized to estimate the agreement between both modalities regarding RWMA. A p value less than 0.05 was considered statistically significant.

Results

This current study included 60 patients who had ischemic heart disease and performed ECHO at the same day or a day before. Mean age of the studied patients was 52.1 ± 11.4 years with 38 of them were males.

Frequency distribution of CAD-RADS among the studied patients

As shown in **table 1**, The most prevalent recorded category was CAD RADS 5 in 35% followed by CAD-RADS 4A and CAD-RADS 3 (26.7% and 18.3%, respectively).

Global LV function of the following parameters (LVEF, LVEDV, LVESV& LVSV)

The mean EF measured by DSCT was 53.21 ± 9.07, slightly lower than the 53.79 ± 9.03 observed using ECHO. The mean LVEDV was 181.52 ± 41.03 ml by DSCT, compared to 176.15 ± 40.57 ml by ECHO. Similarly, the mean LVESV was 85.99 ± 29.02 ml with DSCT, compared to 82.3 ± 28.18 ml measured by ECHO. Finally, the mean LVSV was 95.22 ± 23.31 ml with DSCT, closely matching the 93.55 ± 22.79 ml obtained by ECHO, **(Table 2).**

Correlation and agreement between DSCT and ECHO in EF estimation

The mean EF is slightly lower than that obtained by ECHO but with no statistically significant difference. Using Pearson correlation test, LVEF evaluation showed strong positive correlation between DSCT & ECHO ($r=0.98$, $p < 0.001$). Furthermore, the Bland–Altman plot showed excellent agreement analysis with mean value of difference of -0.58 % and 95% limits of agreement ranging from -1.58 to 0.42 %**.**

Correlation and agreement between DSCT and ECHO in LVEDV estimation.

The mean LVEDV is slightly higher than that obtained by ECHO, but with no statistically significant difference. Using linear regression analysis for LVEDV evaluation showed excellent correlation between DSCT and ECHO as ($r=0.99$, $p < 0.001$). Bland Altman plot shows excellent inter technique agreement with mean value of difference of 5.2 ml and 95% limits of agreement ranging from -2.2 to 12.6 ml**.**

Correlation and agreement between DSCT and ECHO in LVESV estimation

The mean LVESV is slightly higher than that obtained by ECHO, but with no statistically significant difference. Using linear regression analysis for LVESV evaluation showed excellent correlation between DSCT and ECHO as (r=0.96, p

< 0.001). Bland Altman plot shows excellent inter technique agreement with mean value of difference of 3.7 ml and 95% limits of agreement ranging from -2.2 to 9.4 ml.

(Figure 1). A 63-year-old male patient suffered from acute chest pain, patient undergo CABAG as well as stent, he underwent RIMA to LCX, non-opacified distal segment and anastomotic site with poor distal opacification as well as occluded stent at proximal segment of RCA and attenuated distal run off**. (I) for global function assessment by DSCT (A&B)** short axis views of the left ventricle by obtaining short axis views of the left ventricle, while **(B&D)** are for **ECHO** images by biplane Simpson method at both end systolic and end diastolic phases respectively giving the **following parameters for EF, EDV, ESV and SV of about:** 53%, 187ml, 87.3ml 99.7 ml in DSCT and 54.3%, 182 ml, 83 ml and 99 ml in ECHO respectively. **(II) for segmental function assessment by DSCT.** Basal (A & B), mid-cavity (C & D), apical (E & F) short axis and apex (G & H) left ventricular out flow tract (LVOT) long axis reformations of the heart at end Diastolic (A, C, E, G) & end systolic (B, D, F, H) phases show, diastolic and systolic LV myocardial thinning involving, the basal (inferior and infero-lateral) walls, (segments 4 & 5), mid cavity inferior wall, segment 10 and apex, segment 17 due to previous myocardial infarction. **In cine images** there were systolic akinesia in segment 4, and hypokinesia in segments 5&17. Regular systolic contraction of anterior and septal LV myocardium, **while ECHO findings** regarding segmental function: systolic akinesia at segments 4&5, hypokinesia at segments 10, 11&17 respectively.

(Figure 2). A 59-year-old male patient suffered from acute sever chest pain, who had moderate restenosis of a long LAD stent. **(I) for global function assessment by DSCT** (A&B) short axis views of the left ventricle by obtaining short axis views of the left ventricle, while **(B&D)** are for **ECHO** images by biplane Simpson method at both end diastolic and end systolic phases respectively giving the **following parameters for EF, EDV, ESV and SV of about:** 37%, 216.7ml, 136.5ml & 80.2 ml in DSCT and 37.9%, 233.2 ml, 144.6 ml and 88.6 ml in ECHO respectively.**(II) for segmental function assessment by DSCT,** Basal (A & B), mid-cavity (C & D), apical (E & F) short axis and apex (G & H) left ventricular out flow tract (LVOT) long axis reformations of the heart at end Diastolic (A, C, E, G) & end systolic (B, D, F, H) phases show, diastolic and systolic LV sever myocardial thinning involving the basal (anterior, antro-septal & infero-septal) walls, (segments 1, 2& 3), mid cavity (anterior and antro-septal) walls (segments 7 & 8), apical (anterior and septal) walls (segments 13 & 14) due to previous myocardial infarction as well as scar at the anterior and septal walls. **In cine CT images**, systolic akinesia in segments (1, 7, 8, 13& 14), and hypo kinesia in segments 2, regular systolic contractions of both inferior and lateral LV myocardium. **While ECHO findings** regarding RWMA are: systolic akinetic segments of all anterior and septal LV walls (1, 2, 3, 7, 8, 13& 14).

Segmental analysis

There was statistically significant good agreement between DSCT and ECHO and MDCT in detection of RWMA. Detection of normal segments was the best agreement followed by a kinetic segment and the hypokinetic segments detection was the least with (K =0.834 and p <0.001) **(Table 3).**

Diagnostic accuracy of DSCT in left ventricle RWMA detection in comparison with ECHO, as ECHO is a standard:

The DSCT sensitivity, specificity and accuracy were about 80.4%, 100% & 94.5 % respectively as ECHO is a gold standard **(Table 4)**.

Table 1. CAD-RADS categorization among the study group.

Patients' complaint	**(n=60)**	
	No	**%**
CAD-RADS 0 (No coronary artery stenosis)	2	3.3
CAD-RADS 3 (50-69% stenosis)	11	18.3
CAD-RADS 4A (≥ 70% stenosis in one or two vessels)	16	26.7
CAD-RADS 4B (≥ 70% stenosis in three vessels or ≥ 50% stenosis in Left Main coronary artery)	10	16.7
CAD-RADS 5 (Occlusion)	21	35

Table 2. Comparison between ECHO and new dual source MDCT regarding left ventricular global function measurements.

Variable	**ECHO (n=60) mean ± SD (Range)**	**MDCT (n=60) mean ± SD (Range)**	**Test**	**P**
EF (%)	53.79 ± 9.03 (35.4 - 75.5)	53.21 ± 9.07 (35-75)	T 0.25	0.81 NS
LVEDV (ml)	176.15 ± 40.57 (89 - 300)	181.52± 41.03 (97.4-313)	T 0.51	0.61 NS
LVESV (ml)	82.3 ± 28.18 (37.2 – 143.1)	85.99 ± 29.02 (40.5-153.4)	W 0.49	0.62 NS
SV (ml)	93.55±22.79 (47.1-156.9)	95.22±23.31 (51.5-159.6)	T 0.28	0.78 NS

t: Paired t test W= Wilcoxon test U test. NS Non significant (p>0.05).

Moreover, there was no statistically significant difference between ECHO and DSCT regarding EF%, LVEDV, LVESV and SV.

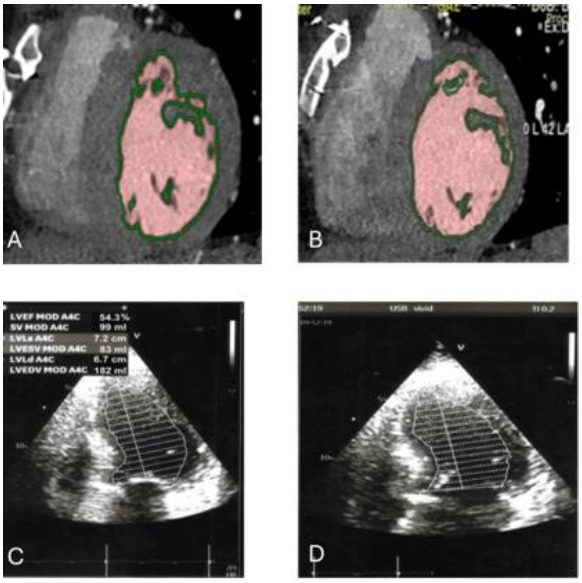
Table 3. Agreement between ECHO and DSCT in detection of RWMA according to three-point scoring system.

All segments		ECHO **(1)** **No. (%)**	ECHO **(2)** **No. (%)**	ECHO **(3)** **No. (%)**	Kappa	p-value
MDCT	**1**(normal motion) **(790)**	734 (72%)	56 (5.5%)	0 (0.0%)	**0.834**	**<0.001 ****
	2(hypo-kinesia) **(180)**	0 (0.0%)	168 (16.5%)	12 (1.2%)		
	3(akinesia) **(50)**	0 (0.0%)	0 (0.0%)	50 (4.9%)		
	Total (1020)	**734**	**224**	**62**		

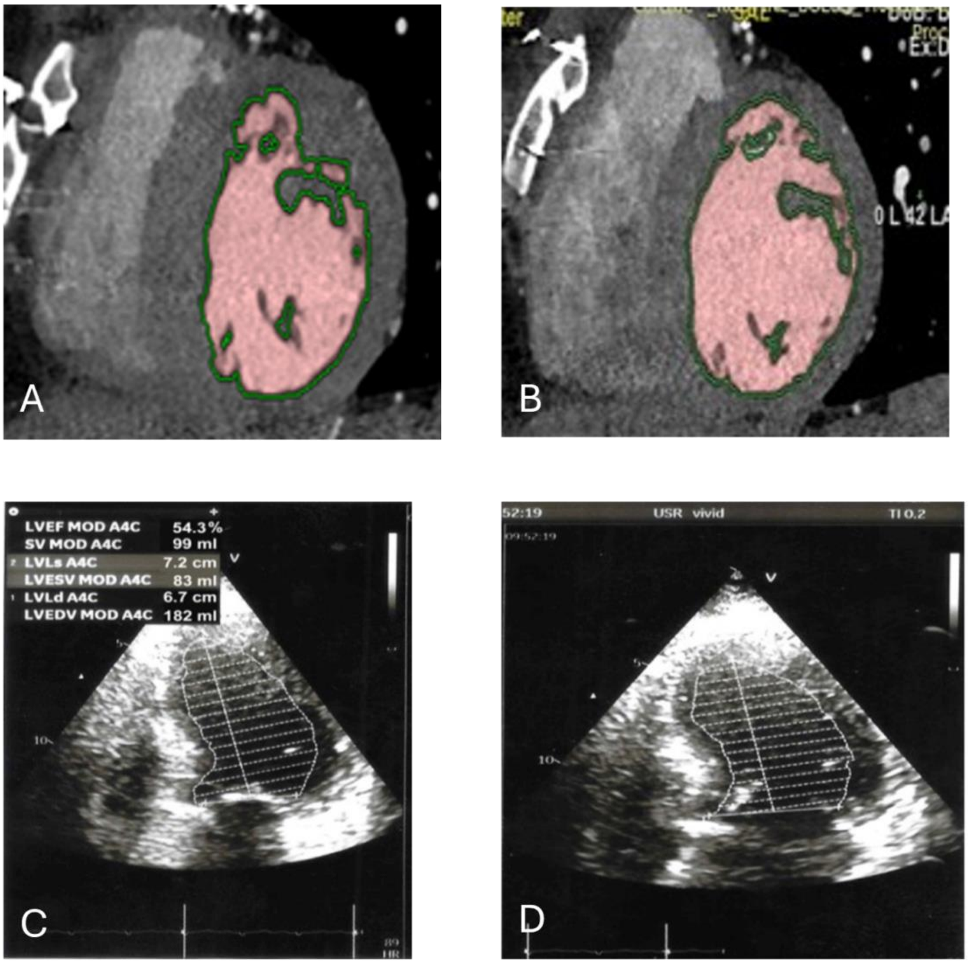
Kappa: Kappa agreement test **: Highly significant (P<0.001).

Table 4. Diagnostic accuracy of new dual source MDCT in detection of RWMA of the left ventricle comparing to ECHO, as ECHO is a standard.

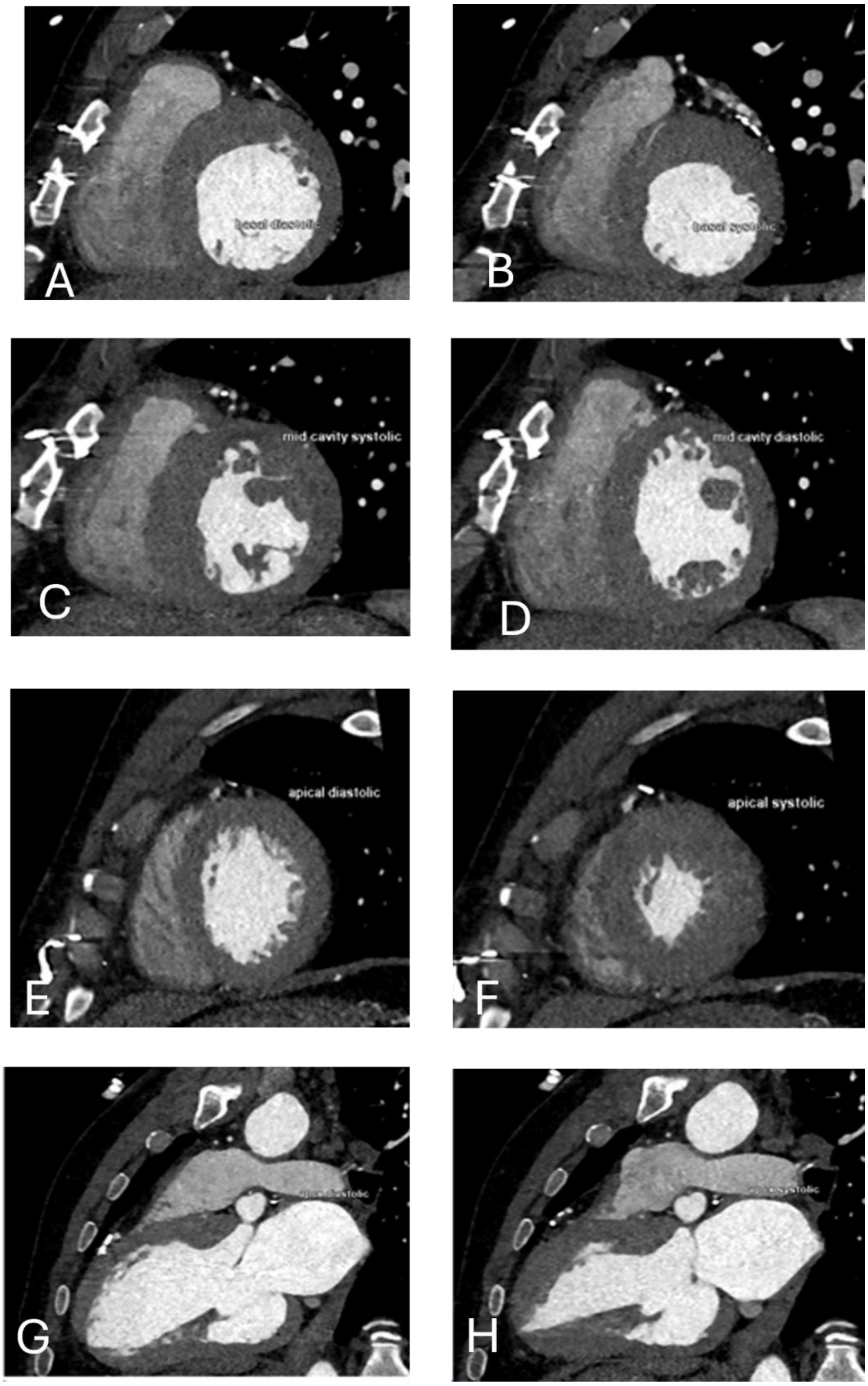
Variable	Sensitivity	Specificity	PVP	PVN	Accuracy
Binary score	80.4%	100%	100%	92.9%	94.5%


A
B
LVEF MOD A4C 54.3%
SV MOD A4C 99 ml
LVLs A4C 7.2 cm
LVESV MOD A4C 83 ml
LVLd A4C 6.7 cm
LVEDV MOD A4C 182 ml
C
D

(I)

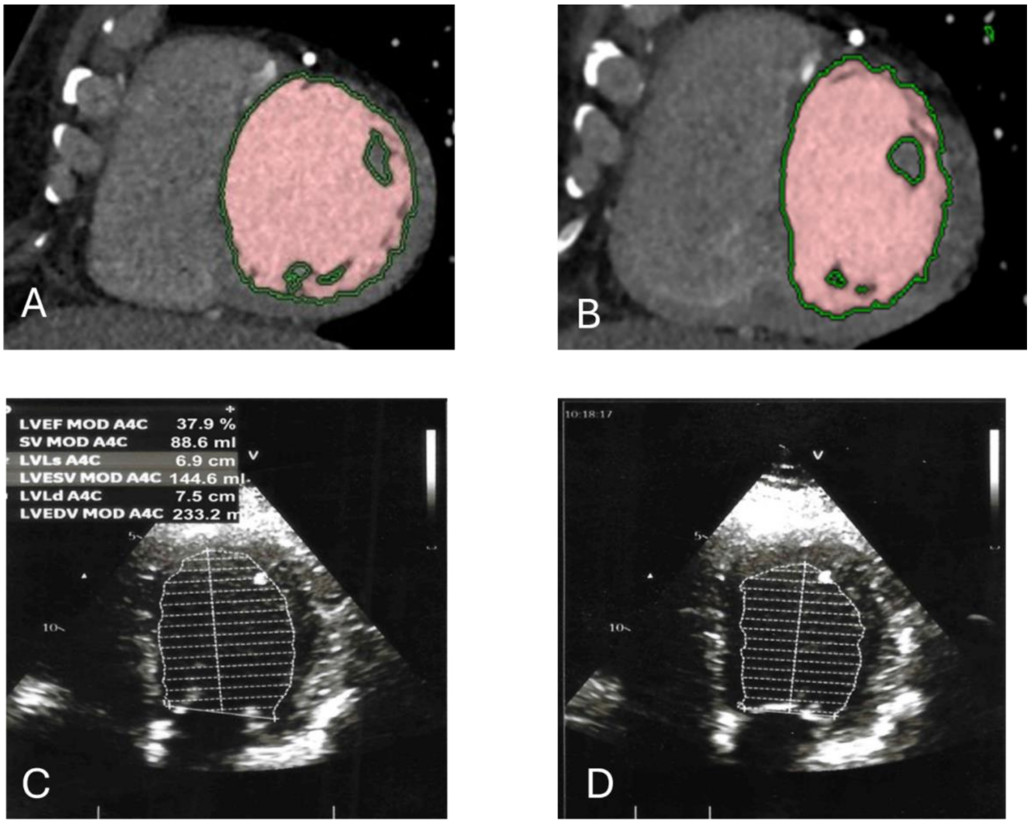

A
B
LVEF MOD A4C 54.3%
SV MOD A4C 99 ml
LVLs A4C 7.2 cm
LVESV MOD A4C 83 ml
LVLd A4C 6.7 cm
LVEDV MOD A4C 182 ml
C
52:19 USR vivid TI 0.2
D

(I)

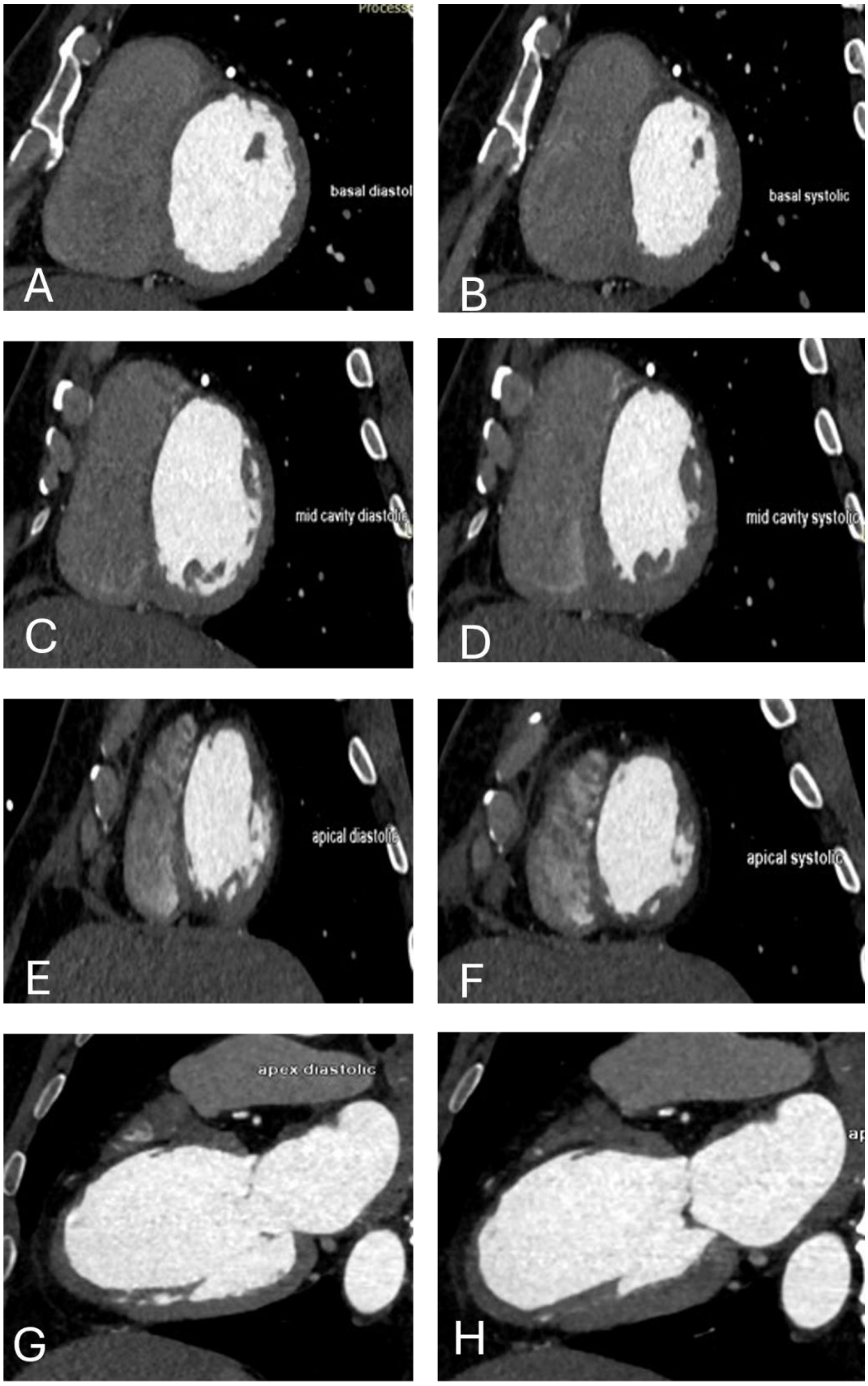


(II)

Figure1. (I & II): for global and segmental functions assessment respectively.

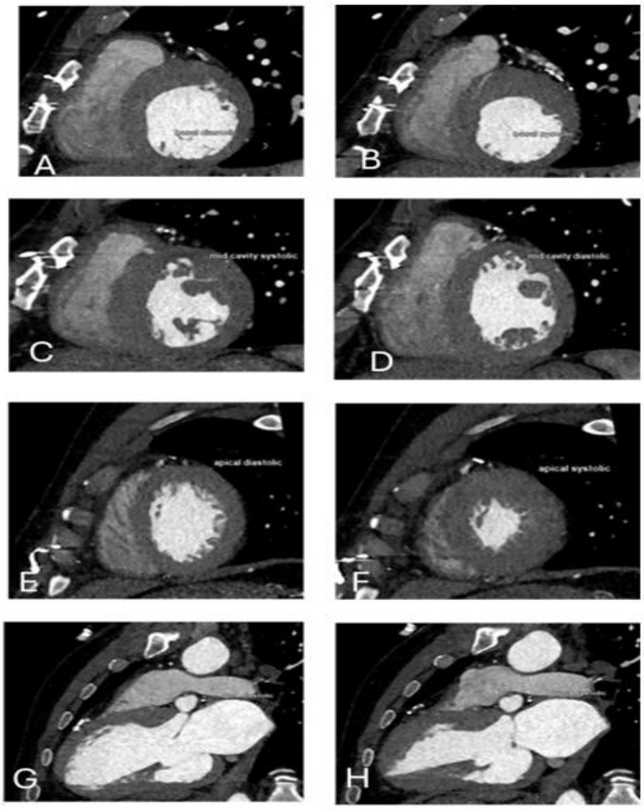

A
B
LVEF MOD A4C 37.9 %
SV MOD A4C 88.6 ml
LVLs A4C 6.9 cm
LVESV MOD A4C 144.6 ml
LVLd A4C 7.5 cm
LVEDV MOD A4C 233.2 ml
C
D

(I)



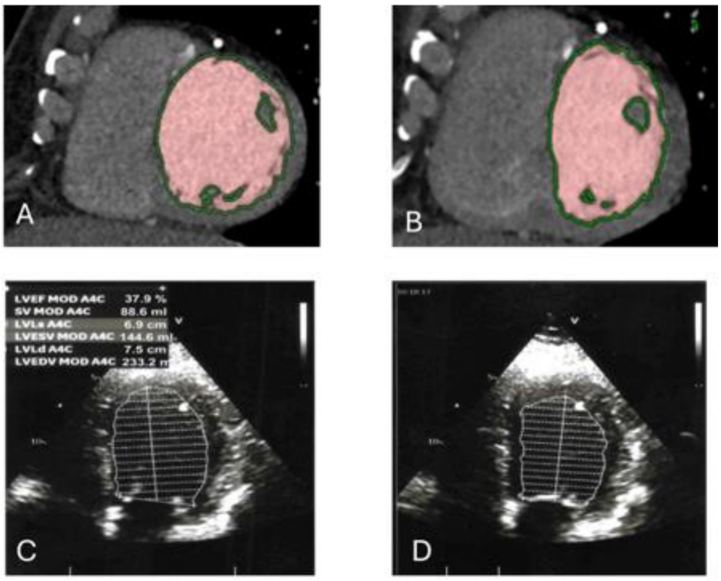
II) (

Figure2. (I&II): for global and segmental functions assessment respectively.

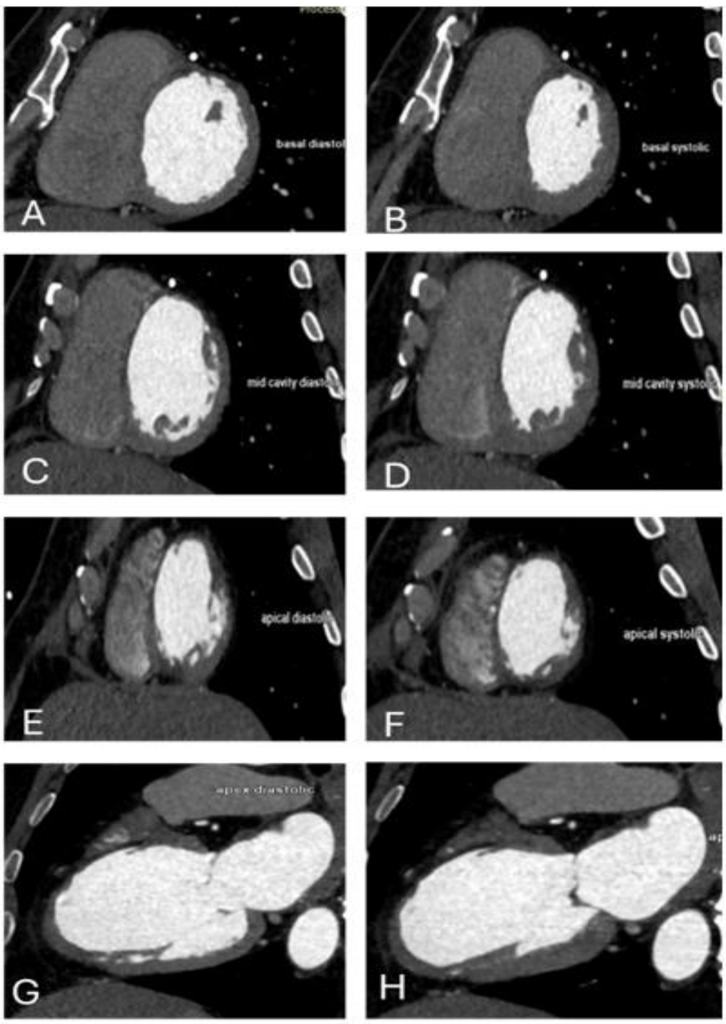


(II)

Figure1. (I & II): for global and segmental functions assessment respectively



(I)



(II)

Figure 2. (I&II): for global and segmental functions assessment respectively.

Discussion

Assessment of both global and regional LV functions is cardiac disease indicator; beside coronary artery disease accurate diagnosis; it provides important information about clinical diagnosis, risk stratification for patients, monitoring treatment prognosis [9]. ECHO is a popular method; however, it is an operator dependent. Although cardiac MRI gives more accurate left ventricular functional assessment but has several contraindications [10]. Introduction of new dual source CT can achieve high temporal resolution by using low tube voltage with a low radiation dose powerful post processing software gives a good opportunity for both global and regional LV dysfunction assessment if any limitations faced either echocardiography or CMR [11].

This study included 60 patients; 52.1 years old was the mean age, 63.3% of them are males. CAD-RADS 5 was the most prevalent category of about 35%. In the present study, we compared global and regional LV function by using DSCT in patients having ischemic heart disease with 2DSE which is considered as the reference standard. Excellent agreement was noticed between DSCT and 2DSE in global LV function analysis and good agreement was detected regarding regional analysis. Several studies [4, 10, 12] described excellent correlation between two modalities who used 128 MDCT and DSCT [9, 13, 14].

This was enrolled 60 patients and reported excellent correlation between two modalities in calculation of EF, LVEDV and LVESV (r = 0.97, 0.93 & 0.96 / P < 0.001 respectively). Their results were consistent with our results regarding slightly underestimation of the EF a mean value of differences of -1.8 % and the 95% limits of agreement ranging from -6.9 % to 3.3%, and slightly over estimation of both LVEDV & LVESV with a mean value of differences of 11.3 ml and 9.1 ml at 95% limits of agreement ranging from -27.4 to 50.1 ml and from -21.2 to 39.53 ml respectively [4].

Also, [9] recorded a significant positive correlation between DSCT and ECHO (r = 0.715, 0.841 and 0.732) of LVEF, ESV and EDV respectively, P < 0.001).

However, [1] who used 128 row MDCT on 50 patients, they showed moderate correlation in EF between two modalities regarding LVEF (r = 0.345, P < 0.05) with good correlation regarding both EDV & ESV (r = 0.84 and 0.8 respectively and P < 0.05). This study is not in line with our results regarding underestimation of the left ventricular volumes at MDCT in relation to ECHO, this is because it is an operator dependent technique, or because they included the papillary muscles in ECHO. Furthermore, they depended on M mode not global estimation that may cause fallacies.

Moreover, [11] studied 48 patients on DSCT, their study was not in line with ours as they reported fair to moderate correlation between both techniques regarding the EDV of (r= 0.395, P <0.005), they overestimated the LVEDV in DSCT in comparison to ECHO significantly. This discrepancy may be attributed to several factors such as acquisitioning of high-quality 3D reconstructed images in DSCT that can limit the error related to endocardial border delineation, left ventricular apex foreshortening & reduction of the endocardial definition by myocardial trabeculations results in LV volume underestimation by ECHO as well as different respiratory phases variable intra thoracic pressures (inspiration for CCTA Vs ECHO free breathing) [15]. They were inconsistent with our study regarding that significant overestimation of LVEDV in DSCT, this may be because difference in sample sizes, non-using of an effective B blocker before our study. Papillary muscles, either inclusion or exclusion can lead to either under or over estimation of the volume. The papillary and trabecular muscles constitute some LV mass and volume percentage.

In this study, comparing DSCT with ECHO which is the most available and the most used imaging modality in clinical practice for LV function estimation. Without dose modulation we performed retrospective gating DSCT to provide a systolic phase high-quality image that enabled accurate endocardial delineation as well as careful papillary muscles exclusion with avoiding much overestimation avoidance of DSCT values.

We did not examine the patients by CMR in this study, so that we could not compare DSCT with CMR. Previous studies [16, 17 and 18] demonstrated an excellent correlation between both techniques. On the other hand, Simpson method was only included in our study without 3D segmentation method. The 3D segmentation method was performed in studies done by [4] as well as lacking of quantitative method for RWMA evaluation, that can be done by measurement of the myocardial thickness of the left ventricle at both end systolic & diastolic phases, after that calculate and estimate the systolic wall thickening degree.

Conclusions

Dual source CT can be used as an alternative good option for LV function evaluation when other imaging techniques are not available or inadequate. By using a lower radiation dose and very good temporal resolution simultaneously provides information not only for coronary artery disease and vessels assessment, but also for function evaluation with a strong positive correlation between MDCT and ECHO and no statistically significant difference in between especially in global function estimation.

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