SCIENTIFIC RESEARCH

ASSESSMENT LEFT VENTRICULAR FUNCTION AND REGIONAL WALL MOTION BY 256-SLICE DUALSOURCE CORONARY CT ANGIOGRAPHY: A COMPARISON WITH 2D TRANSTHORACIC ECHOCARDIOGRAPHY

Lien Le Thi Thuy[1], Viet Nguyen Khoi[1], Hoa Hoang Van[1], Ngoc Phung Bao[1], Trang Nguyen Ngoc[1], Thoa Nguyen Thi[1], Tien Nguyen Cong[1], Phuong Phan Anh[1] Thong Minh Pham[1,2], Luu Vu Dang[1,2]

Objective: To compare the left ventricular (LV) function (dimensions, ejection fraction (EF), end-diastolic volume (EDV), end-systolic volume (ESV)), and regional wall motion analyzed by 256-slice Dual-source coronary angiography CT (DSCT) with 2D transthoracic echocardiography (TTE).

Materials and Methods: One-hundred twelve patients suspected of coronary artery disease underwent DSCT and 2D-TTE within 1 week for LV dimensions, EF, EDV, and ESV. Correlation between DSCT and 2D-TTE measurements was analyzed through linear regression and Bland-Altman analysis. Regional wall motion visually scored as 3 points scale (1, normal, 2, hypokinesia, 3, dysphagia, or akinesia).

Results: Average LVEF was 66,24± 13,52% (range 23-85%) on DSCT, compared with 65,72±11,31% (range 25-84%) on 2D transthoracic echocardiography. Evaluation of LVEF showed a good correlation between DSCT and 2D-TTE (r=0,715; p<0.001). Good correlations between DSCT and 2D-TTE were demonstrated for the assessment of LVEDV (r=0,732; P < 0.001) and LVESV (r= 0,841; P < 0.001). Mean differences (±SD) of 1,78 ± 24,10 mL (p <0 .05) and 0,766 ± 13,7 mL (p < 0.05) were observed between DSCT and 2D-echocardiography for LVEDV and LVESV, respectively. LVEF was slightly overestimated with DSCT (0.52 ± 9,59%; p < 0.05). Even the LVEF calculated by DSCT and echocardiography were similer but EDV and ESV from DSCT were statistically higher than those from 2D-TTE (p < 0.05). Agreement between DSCT and 2D-TTE in regional wall motion is 96,4%, k=0,840.

Conclusion: 256-slice DSCT can provide comparable results to those using 2D-TTE for LV function measurement include EF, EDV, ESV, and regional wall motion assessment in a heterogeneous population.

Keywords: *DSCT; Coronary Artery Disease; Left ventricular function; Echocardiography; Radiation*

[1] *Radiology Center, Bachmai hospital, Hanoi, Vietnam*

[2] *Department of Radiology, Hanoi Medical University, Hanoi, Vietnam*

INTRODUCTION

Left ventricular (LV) systolic function is an important indicator in the evaluation, monitoring, and prognosis of treatment of cardiovascular disease[1]. Accurate diagnosis of coronary heart disease and evaluation of left ventricular systolic function is essential towards effective treatment and reasonable prophylaxis. There are many methods to evaluate left ventricular systolic function such as ultrasound, MSCT, MRI .... Up now, ultrasound is still a popular method of assessing LV systolic function in the clinic because of its convenience, speed, economy, and absence of radiation[2]. However, it also has limitations depending on the proficiency of the ultrasound person and factors from the patient. MRI is considered the gold standard for assessing left ventricular systolic function, but the duration is long, not economical, and uncommon. Meanwhile, Multidetector Computed Tomography (MDCT) has many outstanding advantages as a non-invasive method that can accurately assess cardiac morphology, coronary artery and function at one time.

The purpose of this study was to compare LV systolic functional indexes measured by 256-slice DSCT with those measured by echocardiography.

MATERIALS AND METHODS

1. Patient population

This retrospective study enrolled 112 patients (43 males; mean age: 61,26 ± 11.68) suspected coronary artery disease or coronary artery disease known, underwent coronary artery DSCT and echocardiography up to 1 week apart. These patients were taken DSCT at Radiology Center- Bach Mai Hospital from June 2020 to October 2020. All patients had consent forms for their clinical and imaging data research.

Patients in the study must meet the following criteria: Patients indicated for coronary artery MSCT scan: according to ESC (European Heart Association 2019)

- Patients with atypical chest pain, preferring to detect coronary artery damage in the case of low and moderate likelihood of coronary artery disease.
- Patient is suspected of having coronary artery disease when other test results are available (ultrasound, stress test ...)
- Patients with risk factors for cardiovascular disease (hypertension, hyperlipidemia, diabetes mellitus, smoking, etc.)
- To identify anatomical abnormalities of the coronary artery system.
- To identify atypical cases of chest pain in patients with pre-insertion of Stents or Bridges.
- The above cases are accompanied by low heart rate, tachycardia, arrhythmia, not holding the breath well, not being taken by conventional MDCT.

Exclusion criteria: Patients with contraindications to intravenous contrast agents (allergy), renal failure (serum creatinine > 1.5 mg/dl), severe arrhythmias), inadequate image quality, and patient heterogeneity.

Research criteria

Clinical indicators: age, sex, risk factor characteristics (Family history). History of smoking tobacco (quit or smoking); Hypertension: systolic blood pressure (BP) ≥ 140 mmHg and/or diastolic BP ≥90 mmHg or having hypertension treatments; Diabetes: yes/no; Lipid disorder: disease patients being treated for blood lipid disorder or blood test results show blood lipid disorder (Total cholesterol ≥ 5.5 mmol / l and/or Triglicerid ≥ 1.73 mmol / l, HDL - Cholesterol <1, 03 mmol / l and/or, LDL - Cholesterol ≥ 1.8 mmol / l), Measure height, weight to calculate body mass index (BMI = Body mass index) based on WHO 2000 standard for people Asia, formula BMI = m / h2, with BMI ≥ 23 kg / m2: obesity, Chest pain: yes/no

The indicators on computed tomography: General parameters: • Image quality: from 1 to 4 points (based on Likert's scale) according to 15 circuit segments (classified by the American Heart Association), 4 large and common vascular branches for the coronary system (1: good; 2: fair; 3: average; 4: bad). • Average dose: calculated as mSv (DLP * 0.014). • Calcification score (Agatston scale). • Characteristics of left ventricular function on computed tomography - The left ventricular volume: measuring EF, EDV, ESV.

2. DSCT scanning protocol, reconstruction, and analysis

All patients use sublingual administration of 0.6 mg nitroglycerin before the examination. The administration of the contrast agent was controlled by the bolus-tracking technique. A region of interest was positioned into the aortic root, and image acquisition was started 7s after the density level reached the predefined threshold of 120 Hounsfield units (HU). For all CT examinations, a dual-head power injector was used to administer a three-phase bolus at the rate of 4.5 ml/s: first, 70–80 ml of iopromide (Omnipaque 370) was administered, followed by 45 ml of a 70–30% blend of contrast media and saline, and ending with 50 ml of saline. All CT examinations were performed using a DSCT scanner (Somatom Definition, Siemens Medical Solutions, Forchheim, Germany). DSCT for calcium scoring and CT coronary angiography was performed from 2 cm above the carina to the diaphragm in a craniocaudal direction, gantry rotation time, 330 ms. Before CT coronary angiography, an unenhanced CT scan of the coronary artery was performed for calcium scoring with ECG-based tube current modulation. The full tube current was applied at 70% of the R–R interval, and the tube current outside the 70% R–R interval was reduced to 4% of the nominal output. ECG-based tube current modulation was not implemented for CT coronary angiography. Images were acquired during an inspiratory breath-hold. A retrospective gating technique was used for data synchronization reconstruction with the ECG signal.

A mono segment reconstruction algorithm that uses data from a quarter rotation of both detectors was used for image reconstruction. Reconstruction parameters were as follows: image matrix was set at 512 x 512 pixels; field of view was adjusted according to the individual's structure to capture the heart exactly, and a medium-smooth convolution kernel B 26f. For functional analysis using the raw data, 10 transaxial data sets were reconstructed for every 10% (0–100%) of the cardiac cycle using a retrospective mono segment ECG gating algorithm; the specifications used were an effective slice thickness of 0.6 mm and reconstruction increment of 1.0 mm. The contrast-enhanced LV lumen was automatically segmented for all phases according to differences in attenuation values (HU).

To determine the LV volume, we selected the end-diastolic phase, the phase with the largest LV cavity, and the end-systolic phase, the phase with the smallest LV cavity among ten cardiac phases (0-100%), and then delineated the endocardial and epicardial LV contours with manual editing on the short-axis cine images. If there were severe artifacts on selected phases, we went back to the console box and performed ECG editing on that selected phase, and then re-transferred to the workstation. Papillary muscles were excluded during the computation of the LV volume by attenuation-based segmentation. LV end-diastolic volume (EDV), LV end-systolic volume (ESV), LVEF were calculated directly using the software. Analysis and measurement of LV function using the DSCT data sets were performed by two experienced radiologists who were blinded to all clinical information of patients and the results of 2D-TTE.

3. Two-dimensional transthoracic echocardiography

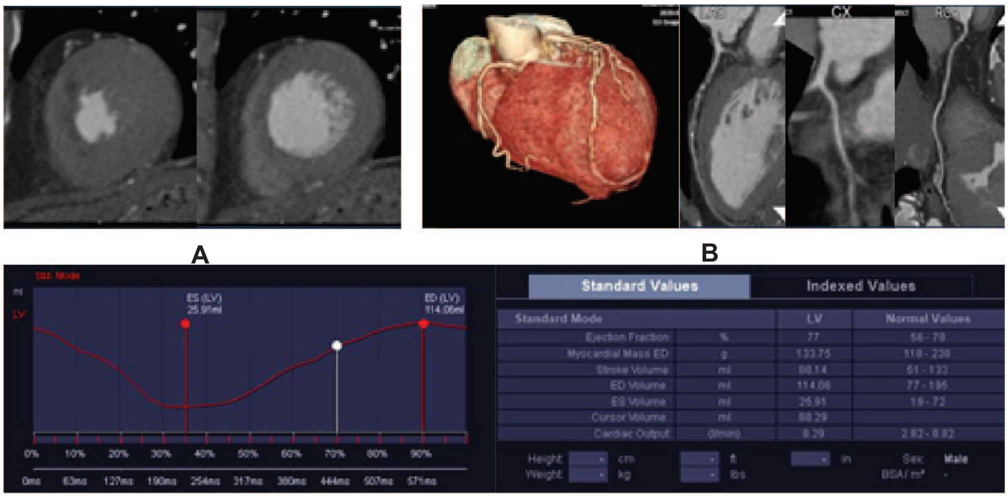
All patients underwent 2D-TTE using the standard protocol. Echocardiographic examinations were performed using a Philips (Phillips Anfinity 70G, US) by two experienced echocardiographers who were blinded to the CT results. Images were acquired in the standard apical and parasternal 2- and 4-chamber views using a 3.5 MHz transducer and all data sets were recorded on an S-VHS videotape following ASE and EACVI standard (2017). Chamber and wall dimensions were measured by consensus of two investigators using standard recommendations for chamber quantification. LVEF was calculated using the modified Simpson's method. For measurement of LV volume in end-systole and end-diastole, three beats were required to average the measurement of LV volume.

4. Data and statistical analysis

Continuous variables are presented as the mean (standard deviation). Considering 2D-TTE as the "reference standard", the statistical significance of the mean difference between the different modalities was tested using the Student's t-test for paired samples. P-value < 0.05 was considered statistically significant. Commercially available Windows-based software was used for statistical analysis (SPSS 25, SPSS, Chicago, IL, USA). Pearson's correlation coefficient and Bland–Altman analyses were performed to determine linear correlation and to calculate limits of agreement and systemic errors for each pair value of LV EDV, ESV, SV, and EF. Correlation was assessed as follows: poor, if r

= 0; slight, r = 0.01–0.20; fair, r = 0.21–0.40; moderate, if r = 0.41–0.60; good, r = 0.61–0.80; and excellent, if r = 0.81–1.00. Inter-observer agreement with regard to each parameter of LV global function obtained by the two DSCT readers was assessed with an intraclass correlation coefficient.

RESULTS



C

Fig. 1 A Short axis planes of the heart by cardiac CT in systole and diastole phases. B.VRT and MIP ouline coronary artery: LAD, LCX, RCA. C. Automate mesuerement by solfware : EF, EDV, ESV.

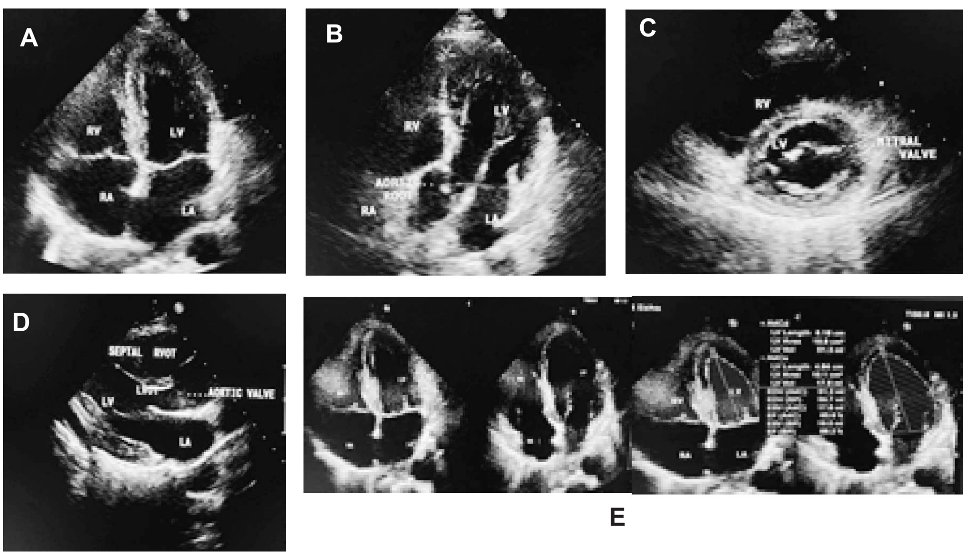


Fig. 2. Echocardiography technique. A, 2D echocardiography; apical 4-chamber view. B, 2D echocardiography; apical 5-chamber view. C, 2D echocardiography; parasternal short-axis view. D, 2D echocardiography; parasternal long-axis view., E, 4-chamber to measurement Simpsons methode during systole and diastole (RV, right ventricle; LV, left ventricle; RA, right atrium; LA, left atrium; RVOT, right ventricular outflow tract; LVOT, left ventricular outflow tract; AV, aortic valve; IVSd, interventricular septum thickness at end-diastole; LVIDd, left ventricular internal diameter in diastole; LVPWd, left ventricular posterior wall thickness at end-diastolic; IVSs, interventricular septum thickness at end-systole; LVIDs, left ventricular internal diameter at end-systole; LVPWs, left ventricular posterior wall thickness at end-systole)

Table 1. Patient characteristics

Characteristics	Mean±SD
Age (years)	61,26 ± 11,68
Bodyweight (kg)	59.96 ± 1.07
BMI	22.91 ± 3.49
HR (bpm)	78,18 ±15,42
Cardiovascular risk Factor	
Diabetes mellitus	14 (12.5%)
Hypertension	60 (53.6%)
Hyperlipidemia	54 (48,2%)
Smoking	31(27.7%)
Chest pain	88 (78.6%)
All data are expressed as mean ± SDs. (N =112 patients); BMI, Body Mass Index; HR, Heart rate; bpm, beat per minute;	

There were 60 hypertensive patients (53.6%), 31 patients who smoked cigarettes (27.7%), 14 patients with diabetes (12.5%), 54 patients with dyslipidemia (48.2%), 9 Patients with a history of coronary artery disease (8%), 13 patients with a family history of coronary artery disease (11.6%), 14 (12.5%) patients with variable diabetes waves (with Q and T waves)). 78.6% (88 patients) had clinical chest pain symptoms.

There are 54 (48.2%) patients who had good image quality, 32.1% good image quality, the remaining 21 patients (18.8%) with average image quality, and 1 patient had a poor quality picture of a patient with stenting and a high heart rate (113 bpm). Accordingly, the best image quality in the group of patients with low and medium heart rate N (55.5%) and low calcification score N (48.2%).

The mean effective X-ray dose of the study group was 3.78 ± 1.88 mSv equivalent to 270.55 ± 12.01 DLP.

Dimensions of LV

Relationship between left ventricular size index between DSCT and ultrasound: For all dimensions on DSCT and ultrasound, correlation index r > 0.5 with the left systolic and diastolic left ventricular diameters, the rest are the dimensions of the RV, R <0.5, with p <0.05, there is no difference. between ultrasound and DSCT. These indexes are all linearly correlated.

EF, EDV, ESV

Table 2. Comparison between DSCT and 2D echocardiography regarding LV ejection fraction, LV end-systolic volume, LV end-diastolic volume

	DSCT	Echocardiography	r	p - value
LVEF (%)	66,24± 1,35	65,72±1,13	0,715	0,482
ESV (ml)	41,13 ±4,32	38,60±3,12	0,841	0,617
EDV (ml)	97,47± 6,59	97,50±3,81	0,732	0,979

Relationship between left ventricular function index between DSCT and ultrasound: There is a correlation between DSCT and ultrasound in the assessment of LVEF, ESV, EDV index with high correlation coefficients (r = 0.715, 0.841, 0.732) with a difference of > 0.05, which means the 2 techniques have no difference.

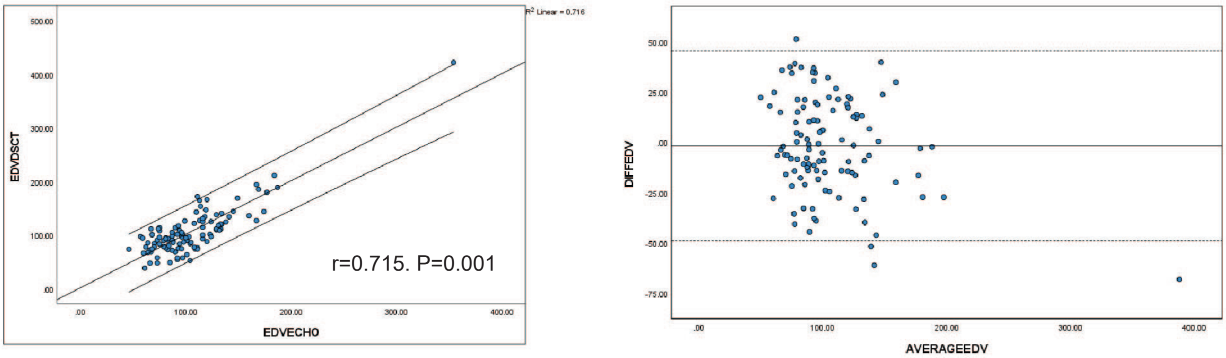
The EF value measured on DSCT was not significantly different than that of echocardiography.

The correlation between EF, EDV, and ESV on DSCT and echocardiography had a strong correlation with r > 0.7 with p < 0.001. The results showed that EDV and ESV on DSCT correlated well with the indicators on ultrasound. Correlation coefficients between EDV and ESV on DSCT and ultrasound are respectively: r = 0.84; r = 0.72.

Table 3. Correspondence between DSCT and echocardiography for regional wall motion

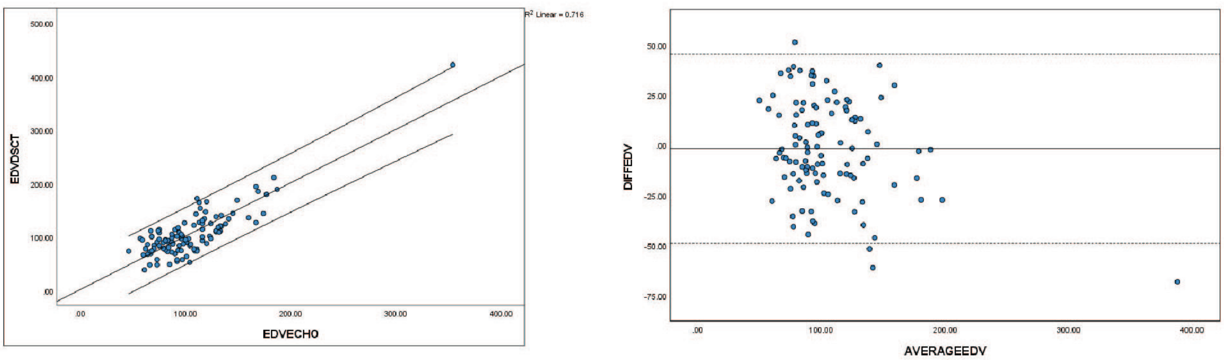
Echo / DSCT	Abnormal	Normal	Total
Abnormal	12	2	14
Normal	2	96	98
Total	14	98	112

Cohen'k Value = 0,84



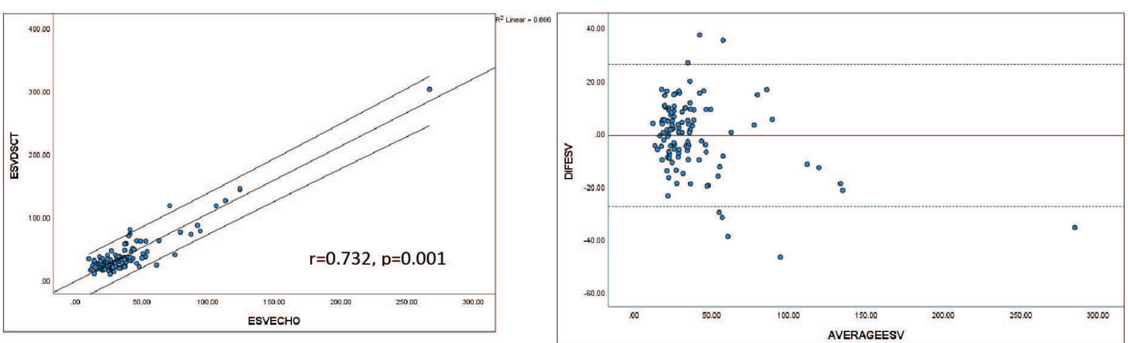
a b

Fig 3. a. Linear regression plot comparison between DSCT and 2D echocardiography assessment of LVEF. A positive correlation between LVEF as measured by DSCT and 2D echocardiography (r = 0.715, p = 0.001). b. Bland-Altman plot of LVEF shows the difference between EF by DSCT and 2D echocardiography plotted against the average value of them -0,517± 9,594% (p < 0.05) between MDCT and 2D echocardiography. The 95% limits of agreement ranged from 0,014± 0,073.



a b

Fig 4. a. Linear regression plot correlation. b Bland-Altman plot of LVEDV by MDCT and 2D echocardiography plotted against the average value of them (solid red line, mean value of difference; green line, mean value of differences ± 2 SDs)



a b

Fig 5. a Linear regression plot correlation. b Bland-Altman plot of LVESV by MDCT and 2D echocardiography plotted against the average value of them (solid red line, mean value of difference; green line, mean value of differences ± 2 SDs)

DISCUSSION

CT coronary scan is mainly performed to assess the condition of the coronary arteries. In addition, LV dimensions, total systolic function, and individual LV regions were also collected. The analysis of the above indicators makes an important contribution in the evaluation of specific cardiovascular diseases, thereby leading to the decision on treatment method. In our study, the LV diameter, volume, and function of the LV were compared between computed tomography and echocardiography with a close relationship, in which we used echocardiography as the reference method.

Regarding the indexes of LV diameter, on the DSCT, we evaluated diastolic, systolic, left diastolic, and systolic septal wall thickness, left diastolic and systolic left ventricular diameter, comparing with these indicators on echocardiography. As a result, there is a statistically significant difference between the two methods. This may be because 2D ultrasound is often imprecise in cutting short-axis perpendicular planes and often measures excess dimensions on DSCT images. In addition, since the differences in spatial and temporal resolution between the two methods are different, there is a difference between the systolic and diastolic sizes. In the study of Bak SH. et al, there was a moderate correlation between cardiac chamber size on DSCT and ultrasound[6]. In that study, patients had a high heart rate and received a heart rate lowering drug before CT scan. In our study, these sizes are correlated, albeit not closely, in which LV diameter tends to be lower than on DSCT, the rest indexes of wall thickness are higher than above. echocardiography. However, to add to the coronary artery condition, these sizes may also be reference indicators. Regarding the LV functions including total systolic function, each LV function, the results showed a high consensus between the two methods of DSCT and 2D-TTE. In assessing the ejection fraction index, the LVEF is a clinical index evaluating important information providing prognostic values and guiding clinical management. Numerous studies have evaluated ejection fraction index using 4-series, 8-series, 16-series, 64-series, and 2-power-source computer tomography and echocardiography.

LVEF on DSCT and ultrasound are highly suitable for cardiography, 2D -TTE, magnetic resonance, and radioisotope imaging[6]. In our study, the evaluation of EF using DSCT has a strong correlation with echocardiography. On the DSCT LVEFF tended to be higher with echocardiography (66.24 ± 1.35% with 65.72 ± 1.13%), the mean difference was (-0.517% ± 9.594%).

In our study, we found mean LVESV measured by DSCT was 41,13 ±4,32 ml slightly higher than that obtained by 2D echocardiography which was 38,60±3,12 ml. Evaluation of LVESV by linear regression analysis revealed good correlation r = 0.841, p-value < 0.05. Bland Altman plot showed good inter-technique agreement as it showed a mean value of the difference (± SD) of -0,7667± 13,70mL ($p < 0.05$). The 95% limits of agreement ranged from means ± (0,0674± -0,16325ml). Mean LVEDV measured by DSCT was 97,47± 6,59 ml equal to that obtained by 2D echocardiography which was 97,50±3,81ml. Evaluation of LVEDV by linear regression analysis revealed good correlation r = 0.732, p-value < 0.05. Bland-Altman plot showed good inter-technique agreement as it showed a mean value of the difference (± SD) of -1,7876± 24,10767 ml ($p < 0.05$). The 95% limits of agreement ranged from means ± (0,071± -0,18 ml). In this study, we found that EDV and ESV obtained by DSCT are equal to calculated by 2D echocardiography. The LV volume overestimation or underestimation may be due to inclusion or exclusion of the papillary muscle and due to operator people.

The endothelium assessed on the DSCT was fully automatic, closely related to echocardiography, while the muscle column and raft were also included in the left ventricular chamber on echocardiography. The ejection fraction index using magnetic resonance was different by excluding the papillary muscle column and raft in the calculation. Therefore, magnetic resonance is considered as the gold standard for evaluating ejection fraction, volume rating [2]. Regarding left systolic and diastolic volume indexes: DSCT and echocardiography were closely correlated (r = 0.71-0.84), similar to other studies on CT and echocardiography. The Bland-Altman equation shows the minimum difference between the two methods of evaluating left ventricular volume. High consensus and minimal difference mean that DSCT is a usable means to evaluate left ventricular function and volume, respectively. The function of each LV region: Due to being reproduced multiple times of cardiac cycle (0-100%), so DSCT can evaluate LV function. In the study of Stolzman et al. on DSCT in patients with various cardiovascular diseases when compared with magnetic resonance, the assessment has a strong correlation in the evaluation of regional motor (k = 0.81). Similarly, the regional motion on the 64-series MSCT with echocardiography was a good fit (75%, k = 0.61) in patients with heart failure compared with ultrasound [3]. Compared with magnetic resonance, the match was 90%, k = 0.78 in patients with acute myocardial infarction. In our study, the match was 96.4%, k = 0.840.

There was a good fit between regional t abnormality and ejection fraction, with p <0.05. Using ultrasound as the reference standard, we calculated that the compliance was 96.4%, with k = 0.840. On magnetic resonance, sensitivity and specificity are higher in the evaluation of regional motion (correlation 0.97, k = 0.88) [4].

Limitations of the study, CT is a 3D evaluation method, but compared with 2D ultrasound, the evaluation of the indicators is not accurate, so the comparison between CT and magnetic resonance is more encouraged. On the other hand, the clinical method is used more than 2D ultrasound. Some patients underwent an ultrasound and CT, not on the same day, so the hemodynamic may change.

CONCLUSIONS

DSCT scan is a useful modality for assessing LV systolic function and region wall motion and had a strong correlation with 2D echocardiography. There was no statistically significant difference in the evaluation of ejection fraction and LV volumes between DSCT and echocardiography. Evaluation of wall motion on the DSCT had good consensus coefficients with echocardiography, compliance 96.4%, k = 0.840.

REFERENCES

1. Lim SJ, Choo KS, Park YH, et al. Assessment of Left Ventricular Function and Volume in Patients Undergoing 128-Slice Coronary CT Angiography with ECG-Based Maximum Tube Current Modulation: a Comparison with Echocardiography. *Korean Journal of Radiology*. 2011;12(2):156-162. doi:10.3348/kjr.2011.12.2.156
2. De Graaf FR, Schuijf JD, van Velzen JE, et al. Assessment of global left ventricular function and volumes with 320-row multidetector computed tomography: A comparison with 2D-echocardiography. *J Nucl Cardiol*. 2010;17(2):225-231. doi:10.1007/s12350-009-9173-y
3. Stolzmann P, Scheffel H, Trindade PT, et al. Left Ventricular and Left Atrial Dimensions and Volumes: Comparison Between Dual-Source CT and Echocardiography. *Investigative Radiology*. 2008;43(5):284-289. doi:10.1097/RLI.0b013e3181626853
4. Asferg C, Usinger L, Kristensen TS, Abdulla J. Accuracy of multi-slice computed tomography for measurement of left ventricular ejection fraction compared with cardiac magnetic resonance imaging and two-dimensional transthoracic echocardiography. *European Journal of Radiology*. 2012;81(5):e757-e762. doi:10.1016/j.ejrad.2012.02.002
5. Ko S-M, Kim Y-J, Park J-H, Choi N-M. Assessment of left ventricular ejection fraction and regional wall motion with 64-slice multidetector CT: a comparison with two-dimensional transthoracic echocardiography. *BJR*. 2010;83(985):28-34. doi:10.1259/bjr/38829806.
6. Bak SH, Ko SM, Jeon HJ, Yang HS, Hwang HK, Song MG. Assessment of global left ventricular function with dual-source computed tomography in patients with valvular heart disease. *Acta Radiol*. 2012;53(3):270-277. doi:10.1258/ar.2011.110247.

1. Kim TH, Hur J, Kim SJ, et al. Two-Phase Reconstruction for the Assessment of Left Ventricular Volume and Function Using Retrospective ECG-Gated MDCT: Comparison with Echocardiography. *American Journal of Roentgenology*. 2005;185(2):319-325. doi:10.2214/ajr.185.2.01850319
2. Ryo Nakazato, MD, Ph.D., Balaji K. Tamarappoo, MD, Ph.D., Assessment of left ventricular regional wall motion and ejection fraction with low-radiation dose helical dual-source CT: Comparison to two-dimensional echocardiography. *Journal of Cardiovascular Computed Tomography.* 2011.Vol 5, No 3, May/June 2011.

Correspondent: Le Thi Thuy Lien. Email: drlienxqbm@gmail.com
Recieved: 10/10/2021. Assessed: 26/10/2021. Reviewed: 15/11/2021. Accepted: 20/11/2021