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Comparison of Computed Tomography and 2D Transthoracic Echocardiography in the Assessment of Left Ventricular Functional Parameters

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Abstract: Background and Aim: This study aimed to compare the results of 2D transthoracic echocardiography (TTE) and cardiac computed tomography (CT) in the evaluation of left ventricular function, and to determine the effectiveness of cardiac CT as well as whether it can serve as an alternative to TTE. **Materials and Methods:** A total of 29 patients who underwent cardiac CT for suspected coronary artery disease between June and August 2016 and also had TTE examinations were retrospectively analyzed. Measurements including ejection fraction (EF), end-diastolic volume (EDV), and end-systolic volume (ESV) were obtained using the modified Simpson method with both modalities. **Results:** The mean EF ($67.48 \pm 7.79\%$) and EDV (128.06 ± 28.34 mL) values obtained by CT were significantly higher than those measured by TTE ($63.64 \pm 3.86\%$ and 98.45 ± 27.98 mL, respectively) ($p = 0.018$ and $p < 0.001$, respectively). No statistically significant difference was observed between the two methods in ESV measurements (TTE: 36.13 ± 12.90 mL; CT: 39.96 ± 14.57 mL; $p = 0.430$). **Conclusion:** Although TTE remains the primary method for the evaluation of left ventricular function due to its accessibility, cardiac CT provides a valuable alternative by offering functional data, particularly in patients with limited acoustic windows.

Keywords: Echocardiography, Left Ventricle, Cardiac Computed Tomography.

1. Introduction

Heart failure (HF) is a global public health problem due to its high morbidity and mortality rates ^[1]. In the literature, left ventricular ejection fraction (EF) is accepted as the most fundamental variable determining survival and prognosis in patients with HF ^[2].

In clinical practice, 2D transthoracic echocardiography

(2D TTE) is the most commonly used method for the evaluation of ventricular function. However, due to its operator dependency, limited acoustic window, and insufficient delineation of endocardial borders, it may not provide optimal results in every patient ^[3]. Although magnetic resonance imaging (MRI) is considered the gold standard for the evaluation of ventricular function, its accessibility is limited due to high cost,



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long acquisition time, and restrictions in patients with metallic implants such as pacemakers. In this context, computed tomography (CT) has emerged as a strong alternative^[3,4].

Advances in CT technology have enabled not only the noninvasive evaluation of coronary arteries but also the detailed analysis of myocardial perfusion, valvular function, and left ventricular parameters^[5,6]. CT offers several distinct advantages, including direct voxel-based volumetric measurement instead of geometric assumptions, high spatial resolution, acquisition of the entire dataset within a single breath-hold, and safe use in the presence of cardiac implants^[5,7].

In this study, we aimed to compare left ventricular functional parameters (EF, EDV, and ESV) obtained by 2D TTE and cardiac CT in patients undergoing cardiac CT with a preliminary diagnosis of coronary artery disease, and to investigate the agreement between these two methods as well as the clinical utility of CT in this setting.

2. Materials and Methods

Study Design

In this retrospective study, 29 patients who underwent cardiac CT for suspected coronary artery disease (CAD) at our center between June and August 2016 and who also had transthoracic echocardiography (TTE) during the same period were analyzed. Ethical approval for the study was obtained from the Ethics Committee of Bakırköy Dr. Sadi Konuk Training and Research Hospital (protocol no: 2016/143). Due to the retrospective nature of the study, informed consent was not required.

Patient Selection

Patients older than 18 years of age without heart failure or arrhythmia, and with no history of coronary artery bypass grafting or prior cardiac surgery, were included in the study. Exclusion criteria were renal dysfunction (glomerular filtration rate <30 mL/min), pregnancy, lactation, contrast agent allergy, claustrophobia, and inability to hold breath.

In all patients, left ventricular ejection fraction (EF), end-diastolic volume (EDV), and end-systolic volume (ESV) were measured using both TTE and multidetector computed tomography (MDCT).

Cardiac CT Imaging Protocol and Data Analysis

CT examinations were performed using a 64-slice

scanner (Philips Brilliance 64; Philips Medical Systems, the Netherlands) with ECG gating. Acquisition parameters were as follows: collimation 64×0.625 mm, rotation time 0.4 s, field of view 220 mm, and matrix size 512×512 . Slice thickness was 0.9 mm with an increment of 0.45 mm. Tube voltage and current were set at 120 kV and 800 mAs per slice, respectively.

Patients with a heart rate > 65 beats/min received 50–100 mg oral metoprolol 1 hour prior to the examination, unless contraindicated. For left ventricular (LV) functional analysis, image reconstructions were obtained at 10% intervals between 0% and 95% of the cardiac cycle with a slice thickness of 2 mm. The images were transferred to a dedicated workstation (Extended Brilliance Workspace, Philips Medical Systems) and analyzed using specialized cardiac software (Comprehensive Cardiac Analysis, CCA; Philips Medical Systems). LV borders were automatically delineated by the software and manually adjusted, and end-systolic and end-diastolic phases were selected for each patient.

Echocardiographic Evaluation

2D TTE examinations were performed by an experienced cardiologist using a 3.5 MHz transducer in accordance with the criteria of the American Society of Echocardiography (ASE). LV volumes and EF values were calculated from apical two- and four-chamber views using the modified Simpson method.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) software, version 22.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean \pm standard deviation. Normality of data distribution was assessed using the Shapiro–Wilk test. Comparisons between transthoracic echocardiography (TTE) and computed tomography (CT) measurements were performed using the paired samples t-test for normally distributed variables and the Wilcoxon signed-rank test for non-normally distributed variables. Correlations between TTE- and CT-derived measurements were evaluated using Pearson's or Spearman's correlation coefficients, as appropriate. Agreement between the two imaging modalities was assessed using Bland–Altman analysis. A *p* value < 0.05 was considered statistically significant.

3. Results

Left ventricular functional parameters (ESV, EDV,

and EF) obtained by both methods in all patients are presented in **Table 1**.

Table 1. Comparison of left ventricular function parameters obtained by both methods.

| PATIENTS | EF% | | EDV (mL) | | ESV (mL) | |
|----------|--------|------|----------|--------|----------|-------|
| | 2D TTE | CT | 2D TTE | CT | 2D TTE | CT |
| 1 | 65.4 | 65 | 54.6 | 91.96 | 18.9 | 32 |
| 2 | 69.25 | 80 | 108 | 147.83 | 31.8 | 30.18 |
| 3 | 59.8 | 76 | 90.6 | 130.62 | 34.9 | 31.92 |
| 4 | 63.2 | 62 | 149 | 121.6 | 54.8 | 45.65 |
| 5 | 69.85 | 81 | 125 | 134.43 | 58.4 | 25.55 |
| 6 | 62.4 | 65 | 93.2 | 195.4 | 35 | 68.4 |
| 7 | 63.6 | 65 | 104 | 157.16 | 37.9 | 54.25 |
| 8 | 66.8 | 55 | 73.6 | 162.14 | 24.4 | 73.57 |
| 9 | 63.8 | 83 | 198 | 191.68 | 71.6 | 32.75 |
| 10 | 64.9 | 71 | 104 | 83.47 | 36.5 | 24.57 |
| 11 | 68.3 | 67 | 78 | 91.49 | 24.7 | 30.08 |
| 12 | 69 | 59 | 84.9 | 123.12 | 26.3 | 50.44 |
| 13 | 57.5 | 57 | 130 | 145.64 | 55.2 | 62.66 |
| 14 | 62.7 | 59 | 68.3 | 127.45 | 25.5 | 52.67 |
| 15 | 59 | 72 | 90.5 | 125 | 34.5 | 30 |
| 16 | 69 | 76 | 104 | 145.7 | 31 | 27.4 |
| 17 | 58 | 60 | 107 | 118.2 | 52 | 43.4 |
| 18 | 59.2 | 75 | 90 | 130 | 34.5 | 31.5 |
| 19 | 65 | 57.3 | 83.4 | 127 | 25 | 52.7 |
| 20 | 65 | 73.7 | 106 | 140 | 27 | 24 |
| 21 | 67 | 62 | 80 | 85 | 32 | 26 |
| 22 | 65 | 67 | 55 | 90.7 | 20 | 28.8 |
| 23 | 61.3 | 63 | 97 | 118.4 | 55 | 44.6 |
| 24 | 58.7 | 64 | 91.2 | 130 | 31 | 65 |
| 25 | 61 | 58 | 95 | 90 | 40 | 28 |
| 26 | 65 | 70 | 110 | 148.2 | 42 | 48.6 |
| 27 | 61 | 73 | 112 | 130 | 28 | 30.2 |
| 28 | 68 | 67 | 81.8 | 102 | 25 | 32 |
| 29 | 57 | 74 | 91 | 129.5 | 35 | 32 |

The mean EF measured by TTE was $63.64 \pm 3.86\%$, whereas the mean CT-derived EF was $67.48 \pm 7.79\%$. CT-derived EF values were significantly higher than those obtained by TTE ($p = 0.018$). The mean EDV measured by TTE was 98.45 ± 27.98 mL, while the mean CT-derived EDV was 128.06 ± 28.34 mL,

demonstrating significantly higher EDV values with CT ($p < 0.001$). The mean ESV values were 36.13 ± 12.90 mL for TTE and 39.96 ± 14.57 mL for CT, with no statistically significant difference between the two methods ($p = 0.430$) (**Table 2**).

Table 2. Comparison of TTE and CT measurements of EF, EDV, and ESV

| Parameter | TTE (mean \pm SD) | CT (mean \pm SD) | Statistical test | p value |
|-----------|---------------------|--------------------|---------------------------|-------------|
| EF (%) | 63.64 ± 3.86 | 67.48 ± 7.79 | Paired t-test | 0.018* |
| EDV (mL) | 98.45 ± 27.98 | 128.06 ± 28.34 | Wilcoxon signed-rank test | $< 0.001^*$ |
| ESV (mL) | 36.13 ± 12.90 | 39.96 ± 14.57 | Wilcoxon signed-rank test | 0.430 |

Statistically significant difference at $p < 0.05$.

Correlation analysis revealed no significant correlation between TTE- and CT-derived EF values ($r = 0.142, p = 0.461$). A moderate positive correlation was observed between EDV measurements obtained

by TTE and CT (Spearman's $\rho = 0.432, p = 0.019$). However, no significant correlation was found between TTE- and CT-derived ESV measurements (Spearman's $\rho = 0.031, p = 0.873$) (**Table 3**).

Table 3. Correlation between TTE- and CT-derived left ventricular functional parameters.

| Parameter | Correlation test | Correlation coefficient | p value |
|-----------|---------------------|-------------------------|---------|
| EF | Pearson correlation | $r = 0.142$ | 0.461 |
| EDV | Spearman's rho | $\rho = 0.432$ | 0.019* |
| ESV | Spearman's rho | $\rho = 0.031$ | 0.873 |

Correlation is significant at the 0.05 level (two-tailed).

Bland–Altman analysis demonstrated a mean difference of -3.83% , with wide limits of agreement for EF, with 95% limits of agreement ranging from -19.88% to 12.22% . For EDV, the mean difference was -29.60 mL, with limits of agreement between -84.07

mL and 24.87 mL. For ESV, the mean difference was -3.82 mL, with 95% limits of agreement ranging from -41.39 mL to 33.75 mL (**Figure 1**). Agreement analysis was primarily illustrated for EF, the clinically most relevant parameter, while volumetric measurements were summarized in tabular form (**Table 4**).

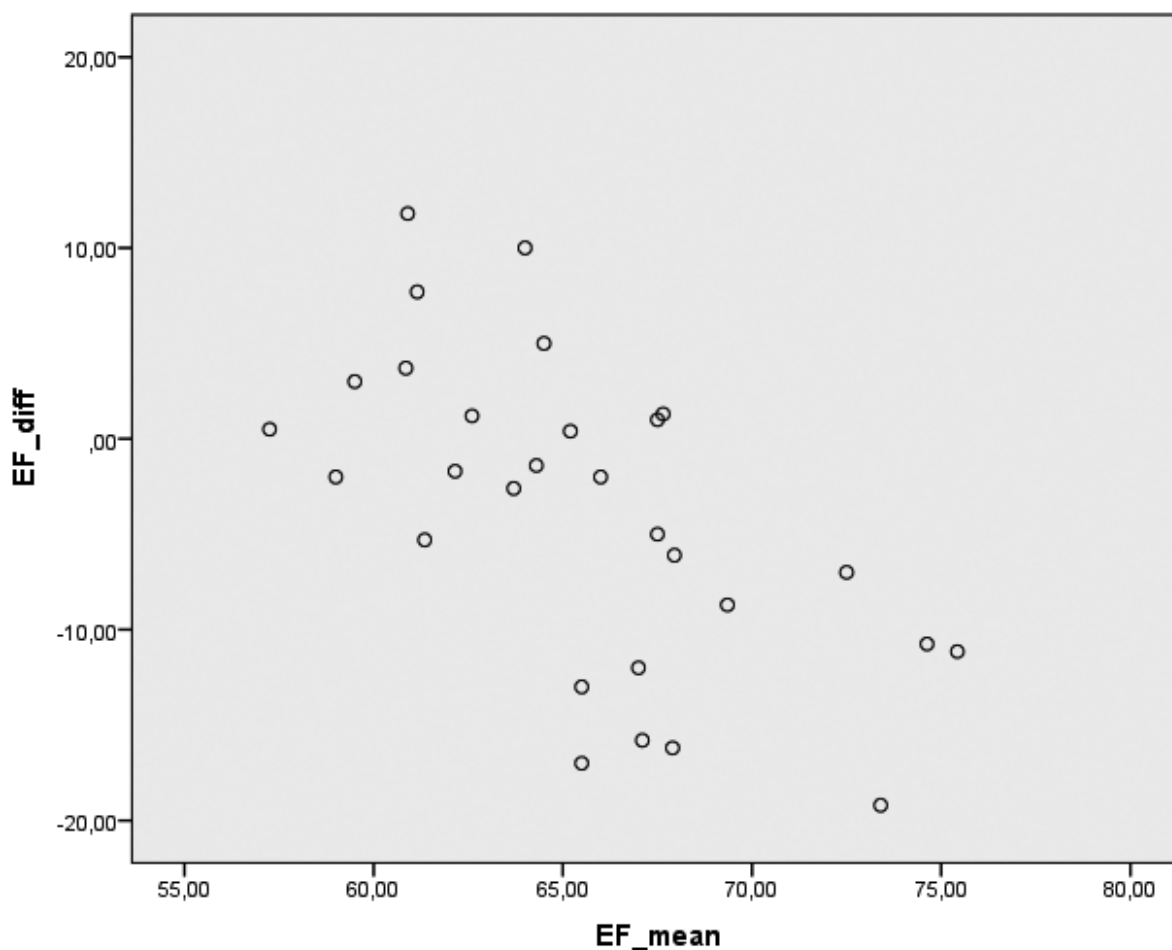


Figure 1. Bland–Altman plot comparing TTE- and CT-derived left ventricular ejection fraction

Table 4. Bland–Altman analysis of TTE- and CT-derived left ventricular functional parameters.

| Parameter | Mean difference (bias) | Lower limit of agreement | Upper limit of agreement |
|-----------|------------------------|--------------------------|--------------------------|
| EF (%) | -3.83 | -19.88 | 12.22 |
| EDV (mL) | -29.60 | -84.07 | 24.87 |
| ESV (mL) | -3.82 | -41.39 | 33.75 |

Mean difference was calculated as *TTE* – *CT*. Limits of agreement were defined as mean difference ± 1.96 standard deviations.

Representative examples demonstrating variability between the two measurement methods are shown in **Figures 2 and 3**.

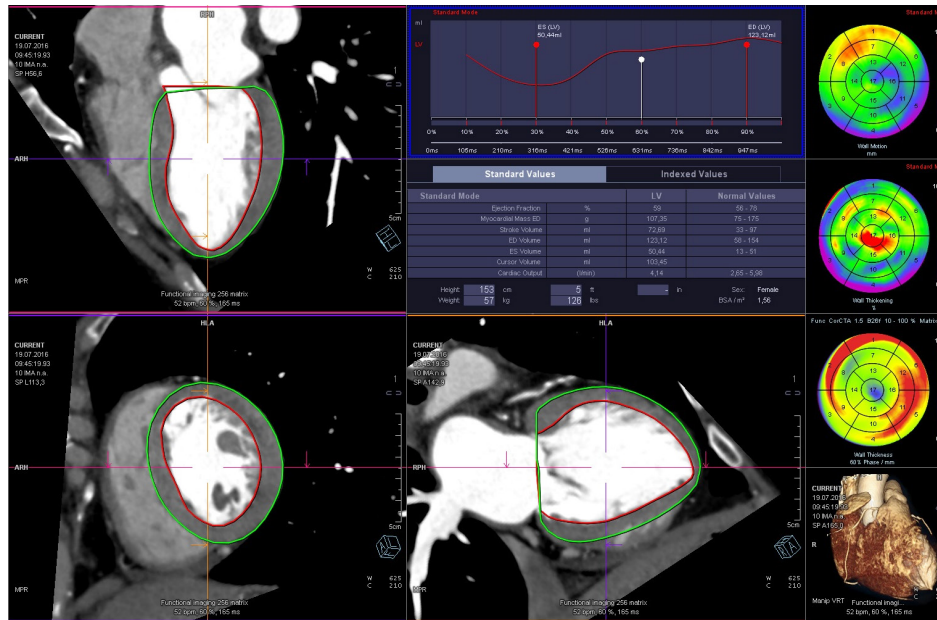


Figure 2. In a 42-year-old male patient, 2D TTE and cardiac CT showed no significant difference in ESV, while EF and EDV differed (EF: 69.25%/80%; ESV: 31.8/30.18 mL; EDV: 108/147 mL).

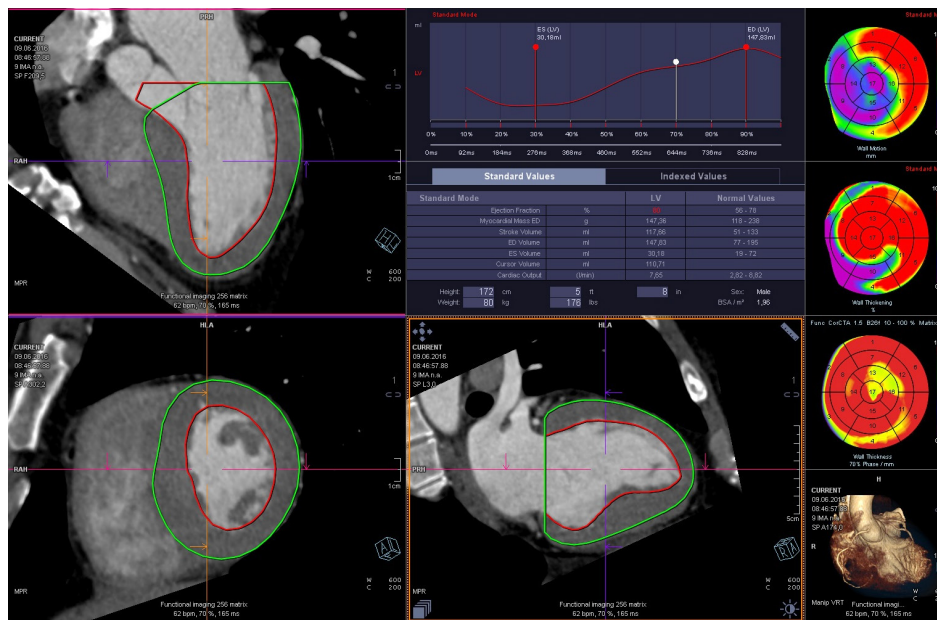


Figure 3. In a 48-year-old female patient, significant differences were observed in left ventricular functional measurements between 2D TTE and cardiac CT (EF: 69%/59%; ESV: 26/50 mL; EDV: 85/123 mL).

4. Discussion

In this study, we compared left ventricular functional parameters obtained by TTE and CT, focusing on EF, EDV, and ESV measurements. Our results demonstrated that CT-derived EF and EDV values were significantly higher than those measured by TTE, while no significant difference was observed for ESV.

Although CT-derived EF values were significantly higher, correlation analysis showed no significant association between EF measurements obtained by the two modalities. This finding suggests that despite similar mean values, EF measurements derived from TTE and CT may not be interchangeable at the individual patient level.

For EDV, a moderate and statistically significant correlation was observed between TTE and CT measurements, indicating that both modalities demonstrate a similar trend in estimating ventricular size. However, Bland–Altman analysis revealed a considerable systematic bias, with CT consistently yielding higher EDV values compared to TTE. This discrepancy may be attributed to differences in image acquisition, temporal resolution, and geometric assumptions inherent to each modality.

In contrast, ESV measurements showed neither a significant difference nor a meaningful correlation between TTE and CT. The wide limits of agreement observed in Bland–Altman analysis further suggest substantial inter-method variability, limiting the interchangeability of ESV measurements between the two techniques.

Overall, while CT and TTE show moderate agreement for EDV measurements, the observed systematic biases and lack of consistent correlation for EF and ESV indicate that these modalities should not be used interchangeably for comprehensive left ventricular functional assessment.

Several studies in the literature have evaluated the agreement between cardiac CT and TTE. De Graaf et al.^[10] reported excellent agreement in EF measurements and found that CT yielded higher values in volumetric assessments. Similarly, Krawczyk-Ozóg et al.^[11] demonstrated that CT produces higher volumetric measurements due to its superior delineation of endocardial borders. In a recent study, Lange et al.^[12] showed that functional data obtained during coronary

CT angiography demonstrated excellent correlation with cardiac MRI, which is considered the gold standard.

The tendency of cardiac CT to measure higher left ventricular volumetric values observed in our study is consistent with several previous reports in the literature^[11,13,14]. The main reasons for this discrepancy can be summarized as follows. First, 2D TTE relies on geometric assumptions such as the Simpson method for volume calculation; however, the heart, particularly in pathological conditions, may deviate from this idealized geometric shape. In contrast, CT provides direct voxel-based volumetric measurements by more clearly delineating endocardial borders and trabecular structures, owing to its high spatial resolution^[11,13].

A second reason is the phenomenon of apical foreshortening in echocardiographic examinations, which may occur due to probe angulation. This leads to underestimation of the true long-axis length of the left ventricle and consequently to systematic underestimation of ventricular volumes. As emphasized by Chuang et al.^[15], these differences arise not from the imaging modality itself, but from the methodological distinction between two-dimensional modeling and three-dimensional volumetric analysis.

The most important limitation of CT remains its temporal resolution. The 20–50 ms temporal resolution required to accurately capture end-systolic phase cannot yet be fully achieved with modern CT systems (approximately 75–150 ms on average)^[16]. This limitation may lead to errors in ESV measurements and consequently to deviations in EF calculations.

Studies using next-generation multidetector CT systems (≥ 320 slices) have demonstrated that improved temporal resolution increases agreement with TTE and MRI^[12]. However, as in our study, it should be noted that in retrospective analyses and with lower-slice CT scanners, CT tends to yield higher volumetric measurements and sometimes more variable EF values. In addition, although beta-blockers administered prior to CT scanning reduce heart rate and improve image quality, they may also affect left ventricular contractility, potentially leading to differences in functional parameters compared with TTE^[17,18].

The primary limitations of this study are the relatively small sample size, its retrospective design, and the lack of comparison with cardiac MRI, which is regarded

as the reference standard. Furthermore, the inherent operator dependency of TTE may have introduced variability and potentially affected the standardization and reproducibility of the measurements. Another limitation is the lack of core laboratory adjudication for the echocardiographic data, as measurements were performed by institutional operators, which may introduce inter-observer variability.

5. Conclusion

Left ventricular functional analysis using cardiac CT provides valuable additional information in patients undergoing coronary CT without the need for extra procedures. However, caution should be exercised when using EF and EDV values obtained from TTE and CT interchangeably. In clinical follow-up, continuing assessments with the same imaging modality appears to be a more reliable approach to minimize measurement variability.

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