Original Article

The influence of cardiac function on coronary arterial enhancement at coronary computed tomography angiography: A cross-sectional study

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Background: The purpose of this study was to evaluate the influence of ejection fraction (EF) on peak aortic time (PAT) and peak aortic enhancement (PAE) during coronary computed tomography angiography (CTA). **Materials and Methods:** One-hundred and twenty patients (64 men, 56 women) underwent measurement of coronary CTA with a measurement of EF within 3 months of coronary CTA. Pearson's correlation coefficient analysis was used to investigate the relationships between EF, PAT and PAE, and peak attenuation of all coronary arteries. **Results:** The range of EF was (25%–70%) (mean: 55 ± 7.7). The range of PAT and PAE of ascending aorta on bolus test was 13–31 s (mean: 19.3 ± 2) and 153–435 HU (mean: 235 ± 40.6), respectively. Mean peak attenuation of ascending aorta, right coronary artery, left coronary artery, left circumflex artery, and left anterior descending were (561 ± 119), (476 ± 109), (505 ± 108), (467 ± 113), and (473 ± 104), respectively. There was a negative correlation between EF and PAT ($r = -0.266$, $P = 0.003$); however, there was no significant correlation between EF and PAE ($r = -0.027$, $P = 0.767$).In addition, there was no significant correlation between EF and the peak attenuation of coronary arteries. **Conclusion:** PAT was related to EF, but there was no relationship between PAE and EF. One of the explanation is that the left ventricular EF used for our study was assessed with echocardiography which is used roughly estimation of EF with interval of 5%–10% and may cause confounding results.

Key words: Computed tomography, contrast enhancement, coronary artery, ejection fraction

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INTRODUCTION

Multidetector coronary computed tomography angiography (CCTA) is a highly accurate noninvasive method for the diagnosis of coronary artery disease. Advances in computed tomography (CT) allow us to acquire high-resolution images and reduced in time and contrast material needed to scan the target organs.[1-3]

Image quality is affected by different parameters included motion artifact,[4] coronary calcification,[5] and coronary arterial enhancement[6] which is related to the contrast material protocol and patients related factors.[6-8]

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Contrast enhancement protocol is determined by a variety of contrast medium-related factors, including contrast material dose, concentration, injection rate, injection duration, and the scan delay used after contrast material injection.[8-10] For determination of an optimal scanning delay time during computed tomography angiography (CTA), it is important to predict the aortic enhancement pattern - especially peak aortic time (PAT) and peak aortic enhancement (PAE) - after bolus injection of a contrast material for each patient.[11]

Multiple patient-related factors such as weight, height, heart rate, and cardiac output (CO) influence the condition of enhancement on the aorta and coronary arteries.[8,11,12] Among the patient factors, body weight has most important effect on contrast enhancement.[11-14] On the other hand, the most important factor affecting

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the timing of contrast material enhancement is cardiac function.[8,12]

It has been observed that reduced CO and cardiac function results in delayed and increased arterial enhancement.[8,12,15]

To the best of our knowledge, only a few reports have been published regarding relationship between cardiac hemodynamic parameters and coronary artery opacification, and no literature about influence of ejection fraction (EF) measured by echocardiography on the coronary arterial enhancement.

The purpose of this study was to investigate the effect of EF on coronary arterial enhancement in a group of patients with narrow range of body weight which is also received adjusted contrast material dose according to the body weight.

MATERIALS AND METHODS

Patients

This cross-sectional study was performed on 120 patients whom underwent coronary CT angiography for the evaluation of ischemic heart disease with a measurement of EF within 3 months of coronary CTA from 2014 to 2016 at AlZahra Hospital in Isfahan. Patients with stable angina pectoris, history of balloon angioplasty and recurrent symptoms after ballooning, atypical and typical chest pain, and high risk for coronary artery disease were included in our study. Clinical exclusions were renal insufficiency, unstable angina pectoris, acute myocardial infarction, history of allergy to an iodinated contrast material, high-grade heart failure, hemodynamic instability, and heart rate above 65 beats/min during CTA. Heart rate was obtained from an electrocardiogram on a monitoring screen. EF was measured using echocardiography within 3 months of coronary CTA. The study protocol was approved by the local Ethics Committee (Research Project Number: 395065).

Contrast material infusion and computed tomography protocols

All scans were performed with a 64-slice multidetector CT (MDCT) scanner (Medical health care GE Work Station RDW 4.3, GE, USA). Technical characteristics of MDCT were as following: 64 mm × 0.6 mm collimation, 350 ms gantry rotation time, kV of 120, and mAs of 600. Almost all patients were given 40 mg of metoprolol orally to achieve a resting heart rate < 65 beats/min. After calcium scanning, a bolus of 80–100 ml of nonionic iodinated contrast agent (Scanlux-370) followed by 50–60 ml of normal saline was injected by the way of an 18-gauge catheter at 4–6 ml/s. A dose of 15 ml of contrast was used during the bolus timing scan calculated (by the apparatus software) at the level of the ascending aorta (AA). The region of interest (ROI) was drawn in the AA at the level of the aortic root [Figure 1]. Five seconds were added to the calculated time to perform MDCT. Image acquisition was timed to peak contrast enhancement in the AA in the test bolus study. This time was the delay applied for coronary CTA.

Data collection

All data, including age, weight, height, heart rate, PAT, PAE and density of major coronary arteries (right coronary artery [RCA], left coronary artery [LCA], left anterior descending [LAD], and left circumflex artery [LCX]) and EF, were measured and recorded coronary arterial enhancement was measured at the aortic root, proximal of LCA, LAD, LCX, and RCA. Circular ROI as large as possible for the anatomic structure was used.

Statistical analysis

Images were evaluated by an experienced radiologist. Statistical analysis was performed with a statistical software package. Pearson's correlation coefficient analysis was used to investigate the relationships between EF, PAT and PAE, and peak attenuation (these parameters collected as continuous variables) of all coronary arteries. Pearson's correlation coefficient was also used to verify how a patient's heart rate, height, patient's body weight and time to peak attenuation, and peak attenuation of AA on test bolus affected PAE during coronary CTA. $P < 0.05$ was considered a statistically significant correlation.

RESULTS

A total of 120 patients (64 men, 56 women; mean age 57.61 ± 11 years; age range 28–80 years; mean weight 75.03 ± 3.7 kg; weight range, 70–79 kg) were included in the study. The mean age of the male patients was 57.63 ± 11.9 years, and the mean age of the female

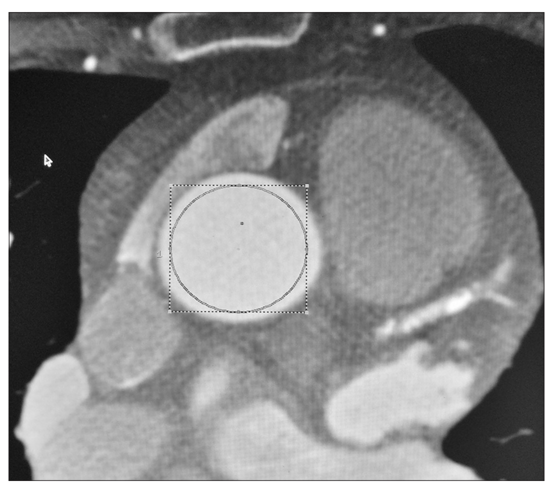

Figure 1: Transverse coronary computed tomography angiography showed placement of region of interests in ascending aorta at the level of aortic root

patients was 57.58 ± 11.25 years. The range of EF was (25%–70%) (mean: 55 ± 7.7). The range of PAT and PAE of AA on bolus test was 13–31 s (mean: 19.3 ± 2) and 153–435 HU (mean: 235 ± 40.6), respectively. Mean peak attenuation of the aorta, RCA, LCA, LCX, and LAD was (561 ± 119), (476 ± 109), (505 ± 108), (467 ± 113), and (473 ± 104), respectively [Table 1]. There was a negative correlation between EF and PAT ($r = -0.266$, $P = 0.003$) [Figure 2]; however, there was no significant correlation between EF and PAE ($r = -0.027$, $P = 0.767$) [Figure 3] also, there was no significant correlation between EF and the peak attenuation of coronary arteries (RCA, LCA, LCX, and LAD). There was a significant negative correlation between the patient body weight and PAE ($r = -0.255$, $P = 0.005$); however, there was no significant correlation between the patient body weight and PAT ($r = 0.081$, $P = 0.379$). There was no significant correlation between the heart rate and PAT ($r = 0.274$, $P = 0.101$) or PAE ($r = 0.349$ $P = 0.086$).

DISCUSSION

Optimal contrast enhancement of coronary arteries is crucial for achieving best image quality and more conclusive results and contrast density of 300–400 HU are preferable for CCTA.[7,11,16,17] By performing test bolus study, we can estimate PAT for adjusting main study according to it but unfortunately despite considering appropriate timing; suboptimal arterial enhancement was obtained. The most possible explanation is that the magnitude of enhancement in test is not usually under attention of technologist, and this enhancing magnitude could be influenced by some patient's related factors such as cardiac function. The previous studies[11-13,17] agree with the relationship between aortic and coronary enhancing time and magnitude with cardiac function, but CO measured by thermodilution as used by Sakai *et al.*[17] is invasive and difficult. Another study by Husmann *et al.*[15] used measured stroke volume and EF by reconstructed the image of CCTA. EF also could be measured by radionuclide technique, MDCT, cardiac magnetic resonance imaging composite valve graft. To the best our knowledge, there are no clear clinical studies in which the relationship between EF measured by echocardiography and aortic enhancement on CT has been investigated. We used echocardiography for estimating EF as a complete safety, noninvasive, available, and cost-benefit technique. In the other hand, echocardiographically reported EF could be a course estimator of CO[18] and

Table 1: Patient demographic data and attenuation of arterial coronary

Variable	Values
Age (years)	
28-80	57.61±11
Gender	
Men	64
Women	56
Body weight (kg)	
70-79	75.03±3.7
Height (cm)	
150-189	166.36±40
Heart rate (beats/min)	
53-65	60±3.4
Ejection fraction (%)	
25-70	55±7.7
Test bolus injection	
PAT (13-31 s)	19.3±2
PAE (153-435 HU)	235±40.6
PAE of coronary arteries	
RCA	476±109
LCA	505±108
LCX	467±113
LAD	473±104

PAT=Peak aortic time; PAE=Peak aortic enhancement; RCA=Right coronary artery; LCA=Left coronary artery; LCX=Left circumflex artery; LAD=Left anterior descending

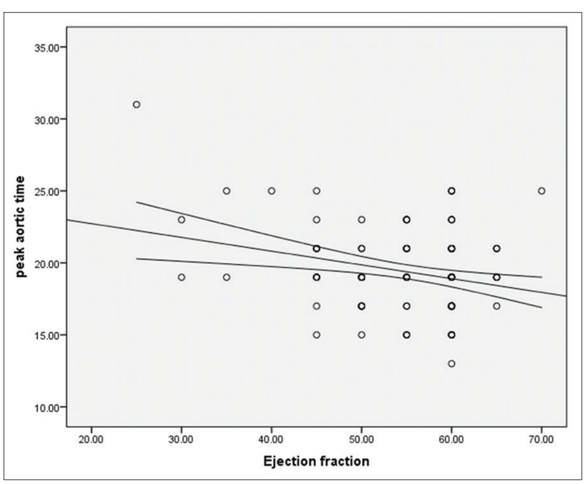

Figure 2: Scattergram shows the relationship between ejection fraction and peak aortic time. There was a negative correlation between two parameters ($r = -0.266$, $P < 0.003$)

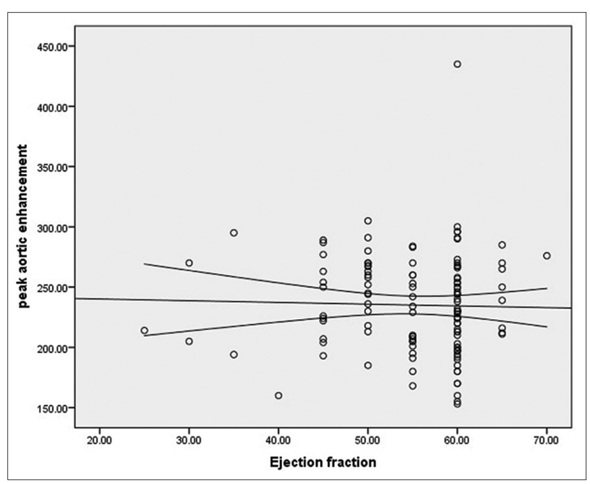

Figure 3: Scattergram shows the relationship between ejection fraction and peak aortic enhancement. There was no significant correlation between two parameters ($r = -0.027$, $P < 0.767$)

considering that it is available before starting the study, we aimed to test if any possible relationship between echocardiographically reported EF and result of aortic and coronary enhance timing and magnitude. EF in this study had a significant correlation with PAT as been expected according to the previous studies,[15,17] but no significant correlation was seen with peak attenuation in this study. Although the similar result was also reported by Husmann *et al*., but we had expected different result due to the larger study population. In addition, we limited our included cases in narrow weight range and relative narrow heart beat range in the purpose of subsiding their confounding effect as far as possible. One of the explanations of this nonsignificant correlation could be roughly estimating reported EF in reporting sheets of patient's echocardiography. Experienced echocardiographers usually estimate EF by looking at the overall size and contractility of the various segments of the LV walls without taking exact measurements and visually estimate EF in intervals of 5%–10%.[18]

In addition, we included patients with narrow weight and heart rate range for decrease their bias effect but maybe other parameters of patients, which was not taken into account had interfered with the attenuation measurements and might have been a confounding variable for result.

It is true that EF could also be measured precisely by postprocessing images of CCTA using dedicated software, but the cause that we choose echocardiogrphically to decide about adjusting protocol before its performance.

CONCLUSION

Despite PAT was related to EF but there was no relationship between PAE and EF one of the explanation is that the left ventricular EF used for our study was assessed with echocardiography which is used roughly estimation of EF with interval of 5%–10% and may cause confounding results.

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Nil.

Conflicts of interest

There are no conflicts of interest.

AUTHORS' CONTRIBUTION

MM contributed in the conception of the work, conducting the study, revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work, PH contributed in the conception of the work, drafting and revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work MM contributed in the conception of the work, drafting and revising the draft, approval of the final version of the manuscript, and agreed for all aspects of the work.

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