ORIGINAL ARTICLE

The Comparison of Image Quality of Systole and Diastole Phases in Dual Source CT (DSCT) to Evaluate a Myocardial Bridge on Tachycardia

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ABSTRACT

Introduction: Cardiovascular diseases (CVD) has the highest prevalence of death worldwide. A myocardial bridge, an anomaly of a coronary artery that is one of the causes of CVDs, are better visualized by Dual Source CT (DSCT) and Coronary Computed Tomography Angiography (CCTA) with > 90% sensitivity and specificity. The CCTA challenge is about tachycardia in a patient who is unresponsive using beta-blockers and produce poor image quality. This study aims to compare the image quality between the systole and diastole phases in DSCT to evaluate the myocardial bridge on patients with tachycardia based on image processing and the size of the bridge between the systole and diastole phases. **Methods:** ROI was placed along coronary artery lumen and background to obtain quantitative image quality measurement (SNR and CNR). The length, the depth, and the diameter of the myocardial bridge were measured in CPR format. There were 22 samples, consisting of 12 men and ten women. **Results:** There were significant differences in the SNR, depth, and diameter. Meanwhile, there were no significant differences in the CNR and length between the systole and diastole phases. **Conclusion:** There was no significant difference in image quality between systole and diastole phases in patients with a myocardial bridge and tachycardia. The length and diameter of the lumen on the diastole phase was greater than that on the systole one. In the other hand, the myocardial bridge on systole phase is deeper than that on the diastole one.

Keywords: Myocardial bridge, Diastole, Systole, Tachycardia

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INTRODUCTION

Cardiovascular Disease (CVD) is the leading cause of death in the world. In 2016, there were 17.9 million people died due to CVD, representing 31% of the entire cause of death. More than three-quarters of the death occurred in countries with lower-middle-income economies. In Indonesia and Vietnam, CVD is also the primary cause of death with a percentage of 35% and 31%, respectively (1).

One of the causes of CVD is a myocardial bridge which is an anomaly of the coronary arteries. This abnormality can be evaluated through CCTA (Coronary Computed Tomography Angiography) and it is highly recommended to use DSCT with an image quality ranging from 95.86% with a sensitivity of 93.8%, a specificity 99.61%, a PPV (Positive Predictive Value) of 95.31% and an NPV (Negative Predictive Value) of 99.48% (2). However, the challenge in scanning and reconstructing DSCT images in tachycardic patients (heart rate > 65 beats / min) is the possibility of the occurrence of motion artifacts on high image results, so the reconstruction results are less optimal especially in coronary arteries (3). Beta-blockers in CCTA preparation are used to reduce heart rate to optimize the image quality. However, the use of the drugs in patients with tachycardia must be monitored by a cardiologist and it is often less effective in lowering the heart rate (4).

Heyer et al, (2007) mentions that the primary physical parameters that determine the quality of the image quantitatively is the SNR (signal to noise ratio) and CNR (contrast-to-noise ratio). Obtaining a high-quality image requires the right phase selection so that the length, the compression diameter, and the depth of a myocardial bridge can be evaluated comprehensively (5). Generally, the diastole phase is taken at a stable heart rate between 60-65bpm (2). According to research on DSCT Siemens Definition, Siemens Medical Solutions, Forcheim Germany, Araoz et al. (2009) explains that the best sharpness of the image of the low heart rate can be found in the diastole phase, while the the high one can be observed during the systole phase (6). According to Seifarth et al. (2007) the optimal position of the reconstruction window in the systole phase is 30-35%, while the one in the diastole phase is 70-75% (7).

In the CCTA of a myocardial bridge case, the image quality is compared by giving ROI to the myocardial bridge to get the Signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR) in which CNR is the physical parameter that best describes the quality of CT-Scan images with classifications as follows : CNR value>8 refers to the optimum image quality, CNR value 4-8 contributes to the medium image quality, and CNR<4 indicates poor image quality (8) . Besides, the dimension of the myocardial bridge that include the length, the depth, and the diameter is also measured to determine differences of the size of a myocardial bridge between systole and diastole phases (9). Therefore, this study is entitled "The Comparison of Image Quality of Systole and Diastole Phases in Dual Source CT (DSCT) to Evaluate a Myocardial Bridge on Tachycardia based on the Image Processing" with the main objective of figuring out the appropriate phase to obtain the optimal image quality.

MATERIALS AND METHODS

Patients

The study involved 22 patients consisting of 12 males and 10 females. There were 5 (five) patients (22.7%) with a heart rate of 66-74 bpm, 13 patients (59.1%) with a heart rate of 75-95 bpm, and 4 patients (18.2%) with a heart rate > 95 bpm. The lowest heart rate was 66 bpm and the highest one was 117 bpm. A CCTA test with a myocardial bridge was conducted from November 2018 to January 2019 in Unit of Radiology, Department of Outpatient, Bach Mai Hospital, Hanoi, Vietnam.

CT scan

CT Scanner used was Siemens SOMATOM Definition Flash 256 Slice with prospective ECG-triggering, detector type: Ultrafast ceramic, detector thickness: 0.6 mm, z- coverage per gantry rotation: 19.2 mm, Gantry rotation time: 330ms, contrast injection media technique by bolus test, tube voltage: 120 kV, tube current 45 mA, and scanning time 10,5 seconds. Contrast inject ion volume was 10-20 ml with 40 ml saline flushing when peak enhancement time was shown. Then, ROI was placed in the ascending aorta as high as carina. When the time to peak graph was shown, contrast ± 65 ml and 40 ml saline was injected with flow rate of 6 ml/sec. Reconstruction by medium soft-tissue kernel and the data were processed by CPR (Curved Planar Reformation) and MPR (Multi Planar Reformation) format.

Statistical Analysis

ROI was placed 4 (four) times on the lumen of the coronary arteries and background to generate the signal intensity values (mean) and noise (SD) used to calculate SNR and CNR. Data were processed by using SPSS version 25. The normality test used was saphiro-wilk and the significance test used was paired t-test and Wilcoxon.

RESULTS

Patient Characteristics

In this study, the myocardial bridge was located on the LAD (Left Anterior Descendent) and it was not found in other coronary artery segments. Based on the equation 1 and 2, the average SNR and CNR values are shown in Table I while the calculation of the length, the depth and the diameter of the myocardial bridge are shown in Table II. The results of the data distribution are shown in Figure 1.

$$SNR = \frac{Sa}{Na} \qquad \text{(Equation 1)}$$

Remark: Sa = Signal intensity in the ROI area
Na : Noise in the ROI area

Table I : The mean of SNR and CNR values in the systole and diastole phases

	Systole	Diastole
SNR	18.27 ± 6.32	23.09 ± 7.59
CNR	29.45 ± 11.53	30.38 ± 14.82

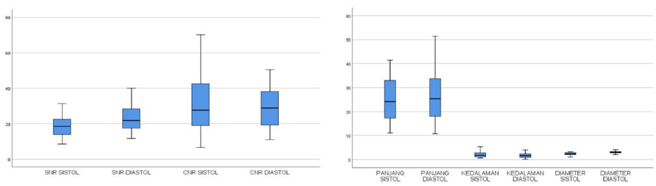

Figure 1 : (A) The comparison value of the SNR and CNR during systole and diastole phase in a myocardial bridge with tachycardia. (B) The comparison values of length, depth and diameter of systole and diastole phase in a myocardial bridge with tachycardia.

Table II : Test Results of Paired T-test and Wilcoxon on the SNR, the CNR, the length, the depth, and the diameter of the myocardial bridge

	SNR Systole-Diastole	CNR Systole-Diastole	Long Systole-diastole	Systole-Diastole Depth	Systole-Diastole Diameter
Asymp . Sig. (2-tailed)	0.019	.771	.272	0.003	0,000

$$CNR = \frac{(Sa\text{-}Sbg)}{Nbg} \qquad \text{(Equation 2)}$$

Remark: Sa = Signal intensity in the ROI area
Sbg = Intensity in the background area
Nbg = Noise in the background area

Based on the normality test using the Shapiro-Wilk method, the significance values of the SNR, the CNR, the length and the diameter of the myocardial bridge during the phases of systole and diastole was > 0.05. It indicated that the data distribution was normal and, as a result, the significance test of the values of the SNR, the CNR, the length and the diameter of the myocardial bridge used the paired t-test method. Meanwhile, the significance values of the depth of the myocardial bridge during the phases of systole and diastole was <0.05. It indicated that the depth value of the myocardial bridge during the phases of systole and diastole was not normally distributed and, thus, the hypothesis test used the Wilcoxon method.

The results of significance test in Table II indicated that the significance values of the SNR, the depth, and the diameter of the myocardial bridge during the phases of systole and diastole showed p value <0.05, and, thus, there was a significant difference between the phases of systole and diastole on the values of SNR, the depth, and the diameter. Meanwhile, the significance values of the CNR and the length of the myocardial bridge during the phases of systole and diastole showed p value > 0.05, indicating that there was no significant difference between the phases of systole and diastole on the CNR values and the length of the myocardial bridge.

DISCUSSION

SNR and CNR values

The image quality is assessed from SNR values by identifying the increase and decrease of SNR values. SNR is closely associated with the intensity of the signal and noise, in which the SNR values are directly proportional to the intensity value of the signal and noise. Increasing the intensity values of signal and noise will increase the SNR values, increasing the image quality. Therefore, the higher the SNR value, the more optimal quality of the image. Furthermore, CNR is the ratio of the difference of the signal intensity from two parts of the ROI, namely the object and the background of an image. Based on Chian et al. (2017), the CNR value on the CCTA of the myocardial bridge during the systole and diastole phases in this study was considered to be an optimal image quality because it showed a value of>8. However, the qualitative evaluation of the comparison of the image quality between the two phases should be based on the increase and decrease of the CNR values. The higher the CNR values, the more optimal the image quality (8). According to Nguyen et al. (2019), the high and low signal intensity is influenced by the attenuation of the organs that have HU (Hounsfield Unit) values on the CT-Scan (10). Generally, the HU values for diagnostics is>326 HU in the proximal coronary arteries and decreases gradually in the distal coronary arteries. Bae in Zhu, (2012:1562) explains that the factors affecting the values of the attenuation or contrast enhancement is divided into three categories, namely: patient factors, contrast medium (dose), and CT-Scan protocol (the rate of contrast flow). Patient factors that influence the attenuation values are body weight and cardiac output (CO). Normally, the comparison of the amount of contrast that is used in the CT-Scan examination is 1: 1 (1 ml/kg weight body). It is essential for, especially, children and patients with obesity because organs with much fat are less vascularized than the visceral and muscular organs. Thus, the distribution and the mixture of contrast media in the blood decrease. This is also related to the flow rate (contrast drug flow rate). The number of contrast media used in this study was the same in every patient, which was 65ml with a contrast flow rate of 6ml/sec. Zhu et al. (2012) states that, among three variations of the flow rate used in their research, there is no significant difference of the attenuation values in the DSCT-CCTA (11).

The additional factor associated with the condition of the patient is cardiac output (CO) (10,11). Cardiac output is the blood volume that is pumped by the heart per minute. Cardiac output is measured by using an echocardiography. The higher the patient's cardiac output, the lower the HU values of an organ, decreasing the attenuation values. In relation to contrast injection, the faster the injection speed, the higher the attenuation values of the organ. Furthermore, Tang (2011) in Zhu (2012) states that during the acquisition of CCTA data with DSCT, an increase in heart rate decreases attenuation values (11). In this study, the placement of ROI and the calculation of SNR and CNR values are in accordance with the research of Nguyen et al. (2019) and Chian et al. (2017). The range of heart rate of the samples is 66-117 bpm and DSCT is able to produce optimal image quality because DSCT has a high temporal resolution. The increase of the heart rate also increases the cardiac output but lowers the attenuation values. However, this study did not control the range of the value of the cardiac output of a patient so that there was the possibility that the range of the HU values of the results of the ROI (mean/SD) was lower than 326 HU in some patients. As a result, results between SNR and CNR were not directly proportional. In this case, cropping, zooming, and windowing settings have no effect on the HU values generated (8,11).

Regarding the heart rate, in patients with low heart rate, the end-diastole phase is longer and the coronary artery movement is slower than that in the end-systole phase (6). End- diastole phase is a good moment to capture the image of CCTA due to minimal motion artifact. When the heart rate increases, the end-diastole shortens and the movement of coronary arteries becomes more rapid. This study is in accordance with the previous studies on 64-slice CT scans by Leschka et al. (2006) and a separate study of DSCT also by Leschka et al. (2008) which states that the diastole is a perfect phase for the reconstruction of the CCTA in both low and high heart rates although the studies found out that the artifacts due to the increase in the heart rate in the phases of systole and diastole were almost the same. The optimal phase reconstruction is also associated with CT-scan tool systems that are used. This study used a 256-Slice DSCT so that it is able to scan heart images in tachycardic patients with speeds reaching 737 mm/s (12,13).

Commonly, the length of a myocardial bridge on CCTA is 10-50 mm (14). In this study, the myocardial bridge in the phase of diastole was longer than the one in the phase of systole with an insignificant difference (p value <0.05). This is based on the research conducted by Leschka et al. (2008) , Kim et al. (2011) , Niu et al. (2013) , and Shabestari et al. (2016) which state that there is no relationship between the length of the myocardial bridge and dynamic compression during the systole phase (14,15,16,17). However, it is different from the research conducted by Ma, et al. (2013) and Yu et al. (2017) which show that the greater the compression of the systole at the heart, the longer the myocardial bridge (18,19).

The Length, Depth, and Diameter of Myocardial Bridge
In depth measurement, this study shows that in the phase of systole, the myocardial bridge was deeper than the one of diastole with the significant difference (p value <0.05). Based on the results of this study, the depth in the systole phase belongs to the deep myocardial bridge group (> 2mm), whereas, in the diastole phase, it is classified as superficial (> 1-2mm). In the phase of systole, the heart contracts, resulting in systole compression of coronary arteries by the muscular heart which led to the lumen of the artery coronary narrowing (stenosis) (13,117,18,19). According to Ma et al (2013), stenosis on a myocardial bridge is so dynamic that the assessment is based not only on the morphology, but also on the decrease of the diameter from diastole to systole (17). In this study, the diameter of the phase of systole is smaller than that of diastole by the difference in an average decrease of 0.66 ± 0.05. This is consistent with the research of Ma et al. (2013) (Table III) and Shabestari et al. (2016) (17,18). The abnormal data distribution and different normality values in the length, the depth, and the diameter were supposedly caused by the anomaly itself'. Thus, the study set a limitation on the fact that the researchers did not consider the cardiac output of the patients. Although the number and the flow rates of media contrast of every patient were the same, but the cardiac output affected the signal intensity of the coronary arteries, especially in phase of diastole.

CONCLUSION

There is no significant difference in the quality of the image in both the phases of systole and diastole in patients with a myocardial bridge and tachycardia. Therefore, the reconstruction of CCTA of systole and diastole phases can be performed. Furthermore, the length of the myocardial bridge in the diastole phase was greater than the length of the systole with no significant difference. The height in the myocardial bridge in the systolic phase is deeper than in the diastole phase with a significant difference. At last, the diameter of the diastole phase is bigger than the systole phase with a significant difference.

Table III : The Comparison Results of the Measurement of the Length, the Depth and the Diameter of Myocardial Bridge by Ma et al. (2013)

	This Study			Research Ma et al. (2013)		
Quantification	Systole	Diastole	Change	Systole	Diastole	Change
Length (mm)	26.46 ± 11.26	26.98 ± 11.92	0.53 ± 0.47	17.8 ± 5.6	15.5 ± 5.2	2.3 ± 1.1
Depth (mm)	2.20 ± 1.23	1.77 ± 1.06	0.42 ± 0.12	4.0 ± 1.0	2.7 ± 0.7	1.2 ± 0.4
Diameter	2.41 ± 0.62	3.07 ± 0.69	0.66 ± 0.05	1.5 ± 0.3	2.6 ± 0.5	1.1 ± 0.4

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