Osmangazi Tıp Dergisi
Osmangazi Journal of Medicine 2023;

Research Article / Araştırma Makalesi

Review of Factors Contributing to the Imaging of the Coronary Arteries in Coronary Computed Tomography Angiography and Implications for Imaging Practice

Koroner Bilgisayarlı Tomografik Anjiografide Koroner Damarların Görüntülenmesine Katkı Sağlayan Faktörlerin Gözden Geçirilmesi ve Bunların Çekim Pratiğine Yansıması

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Abstract

We aimed to review factors affecting the opacification of the coronary arteries in coronary computed tomography angiography (CTA) and evaluate their reflections on imaging practices. Coronary CTA images were retrospectively evaluated. The measurements performed from the central part of the left main coronary artery (LMCA) were divided into two groups optimal CTA (in the range of 300-400 Hounsfield units) and non-optimal CTA. Weight, heart rate, tube current, amount of contrast agent, region of interest (ROI), the short axis diameter of the left ventricle at the midventricular line in the end-diastolic phase, the field of view (FOV), and contrast + saline injection time were compared between the two groups. P<0.05 was accepted as the statistical significance limit. Eighty-three patients were included in the study, and their mean age and standard deviation were 58±18.56 years. In the study, 35 patients (42.3%) had non-optimal CTA and 48 (57.8%) had optimal CTA according to LMCA density. Patient weight (p<0.05), amount of contrast (p<0.01), FOV (p<0.05), and contrast + saline injection time (p<0.01) were significantly higher and tube current was significantly lower (p < 0.05) in the optimal CTA group compared to the non-optimal CTA group. As a result of the logistic model established with independent variables that affected the non-optimal CTA scan, tube current and amount of contrast agent were found to be significant. To bring coronary CTA to a more optimal level, radiologists should work on a patient basis, revising contrast agent protocols and adapting them to each patient.
Keywords: Coronary Computed Tomography Angiography, Computed Tomography, Coronary Arteries, Imaging of Coronary Arteries, Coronary Artery Contrast Enhancement

Özet

Koroner bilgisayarlı tomografik anjiografide (BTA) koroner damarların opasifikasyonuna etki eden faktörlerin gözden geçirilmesi ve bunların çekim pratiğine yansımalarını değerlendirmeyi amaçladık. Retrospektif olarak koroner BTA çekimleri değerlendirilmiş olup sol ana koroner arter (LMCA) santral kesiminden yapılan ölçümlere göre 300-400 Hounsfield Unit aralığında yapılan ölçümler optimum kabul edilip, bunun dışındakiler optimum olmayan grup olarak kabul edildi. İki grup kilo, kalp atımı, tüp akımı, kontrast miktarı, region of interest (ROI), end diastolik fazda midventriküler hatta sol ventrikül kısa aks çapı, Field of View (FOV), kontrast+ serum fizyolojik (SF) verilme süresi kıyaslandı. İstatistiksel anlamlılık sınırı olarak p<0,05 kabul edildi. Çalışmaya 83 hasta dahil edilmiş olup hastaların yaş ortalamaları ve standart sapması 58 ± 18.56 yıl olarak saptandı. Çalışmada LMCA dansitesine göre 35 hasta (42.3%) optimum olmayan grupta olup, 48 hasta (57.8%) optimum olan gruptaydı. Çalışmada LMCA dansitesine göre 48 hasta (57.8%) optimum olan grupta olup, 35 hasta (42.3%) optimum olmayan gruptaydı. Koroner BTA çekimi optimum olan hastalarda optimum olmayan hastalara göre kilo değerleri (p<0.05), kontrast madde miktarı (p<0.01), FOV değerleri (p<0.05), kontrast+SF verilme süresi değerleri (p<0.01) anlamlı düzeyde yüksek, tüp akımı (p<0.05) anlamlı düzeyde düşük olarak saptandı. Optimum olmayan BTA tetkikine etkili bağımsız değişkenlerle oluşturulan logistik regresyon modeli sonucunda; tüp akımı ve kontrast madde miktarı anlamlı bulunmuştur. Koroner BTA çekimlerini daha optimal düzeye taşıyabilmek için hasta bazlı çalışılmalı, kontrast protokollerini değiştirerek hastaya uyarlamalıyız.
Anahtar Kelimeler: Koroner Bilgisayarlı Tomografi Anjiyografi, Bilgisayarlı Tomografi, Koroner Arterler, Koroner Arter Görüntüleme, Koroner Arter Kontrastlanması

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Received 22.04.2022 Accepted 24.10.2022 Online published 28.10..2022

Aydin N, Review of Factors Contributing to the Imaging of the Coronary Arteries in Coronary Computed Tomography Angiography and Implications for Imaging Practice, Osmangazi Journal of Medicine, 2023;45(1): 88-93 Doi: 10.20515/otd.1107186

1. Introduction

Coronary computed tomography angiography (CTA) is a leading non-invasive test for imaging the coronary arteries, diagnosing stenosis, and planning the treatment of patients (1). Coronary CTA is performed with different protocols, including retrospective and prospective electrocardiogram (ECG) triggering, depending on the suitability of the patient and the availability of equipment (2-4). The adequate contrast enhancement of the coronary arteries during coronary CTA is important since it affects the diagnostic performance in the evaluation of coronary plaques and stenosis caused by these plaques (5). Plaque stenosis cannot be optimally visualized in imaging performed below <300 or above >500 HU in the coronary arteries (5-7). Variables such as contrast volume, injection time, flow rate, saline infusion, and tube kilovoltage affect contrast enhancement (8-12).

In this study, we aimed to provide solutions that can be integrated into imaging practices by comparing the coronary CTA images with and without optimal contrast enhancement according to the measurements performed from the central part of the left main coronary artery (LMCA).

2. Materials and Methods

Patient Population

Ethics committee approval was obtained prior to the study (approval number: E-25403353-050.99-192715, decision number: 15, decision date: 01.06.2021), and patients were retrospectively screened. Eighty-three coronary CTA examinations undertaken in our hospital between 2019 and 2021 were included in the study. The amount of contrast agent given to the patients was determined retrospectively. Manual measurements were performed from the proximal central part of LMCA, as much central as possible, by placing regions of interest (ROI) and excluding the arterial wall. In the measurements, the scans obtained in the range of 300-400 HU were considered optimal while those outside this range were considered non-optimal. The two groups were compared in terms of weight, heart rate, tube current (milliampere(mA)), amount of contrast, ROI, the short axis diameter of the left ventricle at midventricular line in the end-diastolic phase, the field of view (FOV), and contrast + saline injection time. Before the procedure, 50 mg beta-blocker (Metoprolol, AstraZeneca) was orally given to the patients with a heart rate of >75 beats/minute. Patients whose heart rate did not decrease after medication and/or those with a heart rate of >90 beats/minute were excluded from the study.

Imaging and Contrast Protocol, and CTA Imaging Analysis

Coronary CTA examinations were retrospectively performed with a 128-slice device (GE, Revolution EVO, USA) triggered by ECG, and the images of the patients were evaluated by a radiologist (N.A. with 10 years' experience). The radiologist evaluated the contrast protocol blindly. Coronary CTA parameters were as follows: slice thickness: 0.625 mm, window level/window width: 100/800, phase: 75%, and matrix size: 458x458. The coronary arteries were assessed on AW Server version 3.2 Ext. 1.2 and software (CardIQ Xpress). Contrast agents were given to the patients at the same standards (Opaxol 350 mg/ml; Iohexol). We use biphasic injection protocol with volume ranging from 65 to 110 mL followed by a 20-30 mL saline (13). The amount of contrast agent was increased in overweight patients. Real-time monitoring was undertaken with SmartPrep during the CTA scan. The bolus tracking method was used. ROI was placed in the descending aorta, and a 200 HU value was used as the cut-off (Figure 1). In drug injection, the flow rate was applied as 5 mL/s. CTA was performed at 120 kilovolt (kV) in overweight patients and in patients with a normal weight.

Statistical Analysis

Mean, standard deviation, median, minimum, and maximum values were obtained as descriptive statistics for continuous data, and percentages for discrete data. The Shapiro-Wilk test was used to examine the conformity of continuous data to a normal distribution. In the comparison of continuous data between two groups, the t-test was used for normally distributed data, and the Mann-Whitney U test for data without a normal distribution. Risk factors for non-optimal coronary CTA were analyzed with the multivariate logistic regression analysis. IBM SPSS Statistics v. 20 was used in the statistical analyses, and $p < 0.05$ was accepted as the statistical significance limit.

3. Results

Eighty-three patients were included in the study, and their mean age and standard deviation were 58 ± 18.56 years. According to LMCA density, 48 (57.8%) were in the optimal CTA group and 35 patients (42.3%) were in the non-optimal CTA group. The descriptive statistics of the patients are given in Table 1.

Table 1. Descriptive statistics of the study data

	Mean ± SD	Median (Min-Max)
Age (year)	58 ± 18.56	61 (34-82)
Weight (kilogram)	79.73 ± 12.93	80 (53-124)
Heart rate (beats/minute)	64.35 ± 7.47	64 (50-87)
Tube current (milliAmpere)	503.23 ± 51.87	504 (249-559)
Amount of contrast agent (milliliter)	89.58 ± 12.52	90 (65-110)
ROI*(square millimeter)	0.61 ± 0.14	0.6 (0.4-0.9)
Left ventricular short axis diameter (millimeter)	45.78 ± 6.67	46 (31-66)
FOV* (centimeter)	24.71 ± 8.64	19 (17-42)
LMCA* density (Hounsfield Unit)	371.59 ± 67.40	363 (224-540)
Contrast + saline injection time (second)	39.92 ± 2.50	40 (35-44)

ROI, region of interest; FOV, field of view; LMCA, left main coronary artery

When the two groups were compared in terms of the investigated parameters, patient weight ($p < 0.05$), amount of contrast agent ($p < 0.01$), FOV ($p < 0.05$), and contrast + saline injection time ($p < 0.01$) were significantly higher and tube current was significantly lower ($p < 0.05$) in the optimal CTA group compared to the non-optimal CTA group. There was no significant difference between the two groups in relation to the heart rate, ROI, and left ventricular short axis diameter values ($p > 0.05$ for all). The detailed data are presented in Table 2.

Table 2. Comparison of the Optimal CTA and Non-optimal CTA groups

	Optimal CTA Group (n = 48)	**Non- optimal CTA Group** (n = 35)		***P*-value**
	Mean ± SD Median (Min-Max)	Mean ± SD Median (Min-Max)		
Weight (kilogram)	82.13 ± 12.55 80.5 (58-124)	76.46 ± 12.91 78 (53-105)	t = -2.007	0.048
Heart rate (beats/minute)	65.31 ± 7.18 64 (53-87)	63.03 ± 7.78 63 (50-83)	t = -1.382	0.171
Tube current (milliAmpere)	493.08 ± 60.10 504 (249-559)	517.14 ± 33.93 524 (400-559)	U = 620.0	0.042
Amount of contrast agent (milliliter)	92.71 ± 11.94 90 (70-110)	85.29 ± 12.18 85 (65-110)	t = 2-.773	0.007
ROI* (square millimeter)	0.61 ± 0.14 0.60 (0.40-0.90)	0.62 ± 0.15 0.60 (0.40-0.90)	U = 799.5	0.704
Left ventricular short axis diameter (millimeter)	46.29 ± 4.89 46 (36-59)	45.09 ± 8.56 45 (31-66)	t = -0.749	0.457
FOV* (centimeter)	26.19 ± 9.33 19 (17-42)	22.69 ± 7.23 19 (17-39)	U = 628.0	0.046
Contrast + saline injection time (second)	40.54 ± 2.39 40 (36-44)	39.06 ± 2.44 39 (35-44)	U = 559.0	0.008

ROI, region of interest; FOV, field of view

In the examination of the risk factors for the non-optimal measurement of LMCA density on CTA, the independent variables that were found to be significant in the univariate analysis (weight, heart rate, tube current, amount of contrast agent, FOV, and contrast + saline injection time) were included in the multivariate logistic regression analysis. The multivariate logistic regression model was obtained using the backward stepwise method. The results showed that tube current and amount of contrast agent were significant parameters affecting LMCA measurements. An increase in the mA values of the patients by 1 unit increased non-optimal LMCA measurements by 1.018 times, while an increase of 1 unit in the amount of contrast agent reduced it by 1.063 times (Table 3).

Table 3. Logistic regression model for factors affecting a Non-optimal CTA scan

	Regression coefficient (SE)	OR	95% CI		*P*-value
Tube current (milliAmpere)	0.018 (0.008)	1.018	1.002	1.034	0.025
Amount of contrast agent (milliliter)	-0.061 (0.021)	1.063	1.020	1.109	0.004

CTA, computed tomography angiography; CI, confidence interval; SE, standard error

4. Discussion

Coronary CTA is one of the important tests used for the imaging of the coronary arteries, and the quality of imaging directly affects the evaluation of these structures. In our study, the imaging parameters of optimal and non-optimal CTA scans were compared according to the measurements performed from LMCA. The mean weight of the patients, amount of contrast agent, FOV, and contrast + saline injection time were determined to be significantly higher, and tube current was found to be significantly lower in the optimal CTA group compared to the non-optimal CTA group. The logistic regression model created with independent factors that affected LMCA density values not being measured optimally revealed tube current and amount of contrast agent to be significant variables.

In the literature, it has been stated that insufficient contrast enhancement is obtained at injection times below 10 seconds, while there are streak artifacts in the right atrium at injection times above 20 seconds. Therefore, it is recommended to keep the injection time in the range of 10-20 seconds (14). Since the automatic injection in our hospital has a single outlet, we created a biphasic protocol for the injection of contrast and saline There is also triphasic injection protocol in the literature that contains an undiluted contrast, followed by a diluted contrast media and finally salin chaser. The diluted of contrast media can be varied. The triphasic injection protocol provides a better evaluation of the right heart compared to the biphasic protocol (15). In our study, as the amount of contrast agent increases, the contrast injection time will also increase, which may explain the differences between the optimal and non-optimal CTA groups.

Applying a single standard protocol in CTA scans by disregarding the characteristics of each patient, such as height and weight can cause serious problems in imaging practices. In the literature, systems with dedicated contrast protocol software have been used, and patient-related parameters used in our study were mostly determined with manual adjustments (16).

In our study, optimal images being obtained in overweight patients can be attributed to increased contrast volume applied in these patients. In a study by Mihl et al., adequate contrast enhancement was obtained in all patient groups in which contrast protocol software was used, while no contrast enhancement was detected in coronary CTA in overweight patients in the control group in which this software was not utilized (16). In our study, we increased the contrast agent volume in overweight patients to a certain extent and obtained optimal images in these patients without using the software. Thus, it can be concluded that it is important to apply a contrast protocol to each patient considering their characteristics. Coronary CTA is a dynamic test rather than a standard scan. Therefore, patient characteristics should be taken into account in imaging practices. However, while increasing the contrast volume in patients, the risk of contrast-induced nephropathy (CIN) should not be overlooked. While evaluating the patient in terms of CIN, attention should be paid to the glomerular filtration rate, presence of severe heart disease, presence of dehydration, diabetes mellitus, and multiple contrast uptake in less than 24 hours (17).

As the FOV value increases, the dose taken by the patient also increases. The imaging area is a parameter that can vary from patient to patient. In a study by Muenzel et al., the use of small and large FOV values were compared in 256-slice multidetector computed tomography, and the authors reported that the diagnostic image quality did not change according to FOV (18). A small FOV can naturally be selected in patients with a body-mass index of <30 kg/m^2 (19). In the current study, the FOV value was significantly higher in patients with optimal CTA compared to the non-optimal group. This may be related to the higher rate of overweight patients in the optimal CTA group. In routine practice, radiologists should use the minimum FOV value to include all the coronary arteries in the image. And also radiologists should adjust this parameter according to the patient's body mass index.

According to the logistic regression model obtained from our study, a 1-unit increase in the mA values of the patients increased the non-optimal LMCA measurements on CTA by 1.018 times. When the literature is examined, it is observed that the use of low kV, close to a K-edge value of 33 keV, can both reduce the contrast dose and help obtain images with better quality (20). This result can be attributed to the 33 keV K-edge value as the mA will decrease as the dose value decreases. So better image quality can be achieved.

In a study by Wang et al. 80 kV was used for coronary CTA for non-obese patients, and Wang et al. reduced the radiation and iodine dose without compromising image quality (21). In our study, we evaluated tube current values for optimization in coronary cta.

In a previous study, there was no significant difference in contrast enhancement between the weight-adjusted (1.0 mL/kg) and fixed (80 mL) contrast dose protocol groups in measurements performed with a 64-slice multidetector computed tomography device, but the mean visual score for beam-hardening artifacts were significantly lower in the weight-adjusted- than the fixed-iodine-dose protocol (22).

In our study, an increase of 1 unit in the contrast agent volume reduces non-optimal LMCA measurements by 1.063 times. This suggests that increased contrast dose can result in better images in certain patient populations.

There are several limitations to this study. First, the body mass index values of the patients were not evaluated because the height values of the patients could not be reached due to the retrospective design of the study. Second, measurements from the proximal were considered sufficient, and those from the distal coronary segments were not included in the evaluation. Lastly, kV values not being evaluated can be considered a limitation.

5. Conclusion

To bring coronary CTA scans to a more optimal level, we should work on a patient basis, revising and adapting contrast protocols according to each patient. The logistic regression model obtained from the current study showed that decreased mA value and increased amount of contrast agent resulted in more optimal CTA scans.

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Ethics
Ethics Committee Approval: The study was approved by Eskişehir Osmangazi University Noninterventional Clinical Research Ethical Committee (Number: 15, Date: 01.06.2021).
Informed Consent: The author declared that it was not considered necessary to get consent from the patients because the study was a retrospective data analysis.
Authorship Contributions: Surgical and Medical Practices:none. Concept:NA. Design:NA. Data Collection or Processing:NA. Analysis or Interpretation:. Literature Search:NA. Writing:NA.
Copyright Transfer Form: Copyright Transfer Form was signed by the author.
Peer-review: Internally peer-reviewed.
Conflict of Interest: No conflict of interest was declared by the author
Financial Disclosure: The author declared that this study received no financial support.