Can Radiation Dose Burden of CT Angiography be Reduced While Still Accurately Diagnosing Etiology of Acute Chest Pain?

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Abstract: ***Background:*** **Multidetector-row computed tomography is often used as a first-line test in the diagnostic evaluation of cardiovascular diseases including aortic dissection, coronary artery disease and pulmonary embolism. This study evaluated the impact of reducing the tube potential from 120 kVp to 100 kVp in a selected group of patients presenting to the Emergency Room with acute chest pain. The primary end point was how the reduction of radiation dose affected image quality.** ***Methods:*** **The current study was performed over a period of 2 years between July, 2016 and July, 2018. This study included patients who presented to the Emergency Room or to an outpatient clinic and were suspected to have a coronary, a pulmonary (pulmonary embolism), or an aortic (aortic dissection) etiology. Suspicion was determined by the medical provider based on clinical picture, EKG, and lab results when available. All patients were referred for computed tomography angiography (CTA) testing as part of their diagnostic evaluation. A total of 84 patients were involved in the study. Seventy of the patients underwent the low acquisition Kvp technique (100 Kvp - Group I). In the remaining 14 patients, the standard acquisition technique (120-140 Kvp - Group**

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II) was utilized. *Results:* This study showed the feasibility of using low energy CTA to significantly reduce the patient's radiation exposure without markedly affecting the image quality and diagnostic accuracy. *Conclusion:* The use of low energy CTA protocols in cases of acute chest pain revealed no major difference regarding the image quality with marked reduction of the radiation dose received by the patient. (Curr Probl Cardiol 2021;46:100766.)

Background

Multidetector-row computed tomography (MDCT) is often used as a first-line test in the diagnostic evaluation of cardiovascular diseases including aortic dissection, coronary artery disease (CAD) and pulmonary embolism.[1] CT angiography (CTA) uses MDCT for rapid, continuous scanning. A series of vascular images can be obtained through multiplanar and 3D CT reconstruction. The addition of detector rows has significantly improved the spatial resolution and scanning speed of MDCT, which allows MDCT to accurately diagnose CAD.[2]

Although there has been continuing improvements in CTA technology, there is still a concern regarding patient radiation exposure. The effective patient radiation dose averages between 10 and 15 mSv when performing a 64-slice coronary CT angiogram (CCTA). This is dependent on the scanning technique, CT system utilized, as well as patient related factor.[3] Radiation dose varies approximately with the square of the voltage under a constant tube current. Thus, reducing the voltage has a greater impact on patient dose than reducing the tube current.[4]

This study was designed to detect the impact of reducing the tube potential from 120 kVp to 100 kVp in a selected group of patients presenting with acute chest pain looking specifically at subsequent image quality.

Methods

The current study was performed over a period of 2 years between July 2016 and July 2018. This study included patients who presented to the Emergency Room or to an outpatient clinic and were suspected to have a coronary (CAD), a pulmonary (Pulmonary Embolism), or an aortic (aortic dissection) etiology. Suspicion was determined by the medical provider based on clinical picture, EKG, and lab results when available. All patients were referred for CTA testing as part of their diagnostic evaluation. A total of 84 patients were involved in the study. Seventy of the patients underwent the low acquisition Kvp technique (100 Kvp - Group I). In the remaining 14 patients, the standard acquisition technique (120-140 Kvp - Group II) was utilized.

Inclusion criteria for the study was any patient who presented to a medical provider with acute chest pain and subsequently received a CTA in the diagnostic evaluation. Obese patients, pregnant patients, and patients known to have a severe allergy to contrast material were excluded from the study.

Patient Preparation

Detailed explanation of imaging procedure, including practicing breath holds was provided to all patients. Insertion of a (18-20 g) IV cannula was done (right arm). Beta-blockers were given to lower the heart rate below (70-65 b/min) with C examinations. Nitroglycerine was given 4 minutes prior to the CCTA studies. The studies took about 5-10 minutes to acquire images.

Procedure

All patients were subjected to a history and an imaging study. These studies included CCTA (CCTA), pulmonary CTA or CT aortography. Imaging was done using a General Electric (GE) Optima 64 MDCT scanner or a Siemens somatom definition dual source CT scanner. After adequate preparation, imaging was performed with slice thickness 0.625 mm, pitch 1.3, rotation time 0.5 second, tube current 200-400 milliamperes and tube voltage 80-100 kilovolt. The patients were then given IV contrast (1 mL/1 kg) by injector (4-5 mL/sec) and postcontrast imaging was taken for maximum intensity projections, MPR (multiplanar reconstruction), and 3D reconstruction. Results were analyzed according to imaging quality and radiation dose.

Qualitative Image Evaluation

Two experienced radiologists were blinded to the reconstruction low Kvp CTA technique applied. Both radiologists independently evaluated each data set by using axial sections and standard CTPA window settings. All CTA reconstructions were rated according to a 5-point scale (1 indicating worst through to 5 indicating best) for subjective image quality, subjective image noise, and blotchy image appearance using evaluation criteria published previously. The obtained 5-point scoring system is described in Table 1.[5]

TABLE 1. Five-point scoring system of different image quality characteristics for observer study

Score	Subjective image quality	Subjective image noise	Blotchy image appearance
5	excellent image quality, no artifacts, full diagnostic confidence	no perceived noise	no blotchy appearance
4	good image quality, minor artifacts, not affecting diagnostic confidence	minor noise	minor blotchy appearance
3	moderate image quality, increased artifacts, impairment of diagnostic confidence	moderate noise	moderate blotchy appearance
2	reduced image quality, substantial artifacts, limited diagnostic confidence	extensive noise	increased blotchy appearance
1	poor image quality, major artifacts, no diagnosis possible	major noise	major blotchy appearance

Quantitative Image Evaluation

All data sets were transferred to a dedicated workstation. Maximum intensity projections and curved planar reformations were generated for each study.

To evaluate objective image quality on axial CT images, intravascular attenuation was measured in the pulmonary trunk, right and left main pulmonary arteries, ascending and descending aorta, aortic arch, left ventricle, right coronary, and left anterior descending arteries. The measurements were averaged to derive a mean intravascular attenuation. The attenuation of the adjacent muscle and the noise within subcutaneous fat (standard deviation of the CT attenuation) were also measured to calculate signal-to-noise ratio (SNR), contrast-to-noise ratio (CNR), objective image noise, and average vascular attenuation of each arterial segment. The image noise was defined as the mean value of the standard deviation in subcutaneous fat. The attenuations were measured in a region of interest within the vessels which was defined to be the largest diameter segment while avoiding calcifications and stenotic regions. The SNR and CNR were calculated as follows[6]:

- SNR = attenuation of the vessel lumen/SD of subcutaneous fat.
- CNR = (attenuation of the vessel lumen - attenuation of muscle)/SD of subcutaneous fat.
- Objective image noise = the mean of the SD's of the CT-N.
- Average vascular attenuation = the mean of the CT-N of the arterial segments.

Estimation of Radiation Dose

The volumetric CT dose index and dose-length product (DLP) were recorded for each patient. Effective radiation dose (ED) was estimated by multiplying the DLP by a conversion factor of 0.014 mSv/(mGy × cm).[7] The effective radiation dose (ED) also considers the biological effects of radiation. The European guidelines for Quality criteria for CT (2000) suggested a simple method converting the DLP to ED using conversion coefficients (e-value). The conversion coefficients vary for different parts of the body depending on the radiation sensitivity of the tissue. The conversion coefficients of the head, thorax, abdomen, and pelvis are well-established (Table 2).[8]

TABLE 2. Conversion coefficients

Exam type	Conversion coefficient
CT head	0.0023
CT thorax	0.017
CT abdomen	0.015
CT pelvis	0.019

TABLE 3. Showing demographic distribution, type of examination, and received radiation dose

Demographic data		No. = 84
Age	Mean ± SD	56.40 ± 13.49
	Range	21-87
Gender	Females	48 (57.1%)
	Males	36 (42.9%)
Examination	Pulmonary angiography	52 (61.9%)
	Aortic angiography	20 (23.8%)
	Coronary angiography	12 (14.3%)
Dose linear product (mGY/cm)	Median (IQR)	250.0 (203-423)
	Range	123-1964
Radiation dose (mSV)	Median (IQR)	4.2 (3.4–7.1)
	Range	2-33.3

Results

The current study was a prospective study performed over a period of 2 years between July 2016 and July 2018. Eight-four patients were included in the study. Seventy patients underwent the low Kvp technique (100 Kvp - Group I) and 14 patients underwent the standard technique (120-140 Kvp - Group II). All patients underwent CT angiographic examinations (Tables 3 and 4).

TABLE 4. Comparison between the low energy group (I) and standard group (II) in dose linear product and radiation dose

		Group I (100 Kilo voltage)	Group II (120 Kilo voltage)	Test value*	P-value	Sig.
		No. = 70	No. = 14			
Dose linear product (mGY/cm)	Median (IQR)	236 (201-366)	1209 (379-1841)	−4.682	0.000014	HS
	Range	123-650	329-1964			
Radiation dose (mSV)	Median (IQR)	4 (3.4-6.2)	20.5 (6.4-31.2)	−4.686	0.000014	HS
	Range	2-11	5.5-33.3			

P-value type = "Other">0.05: Nonsignificant (NS); *P*-value <0.05: Significant (S); *P*-value<0.01: highly significant (HS).
*Mann-Whitney test.

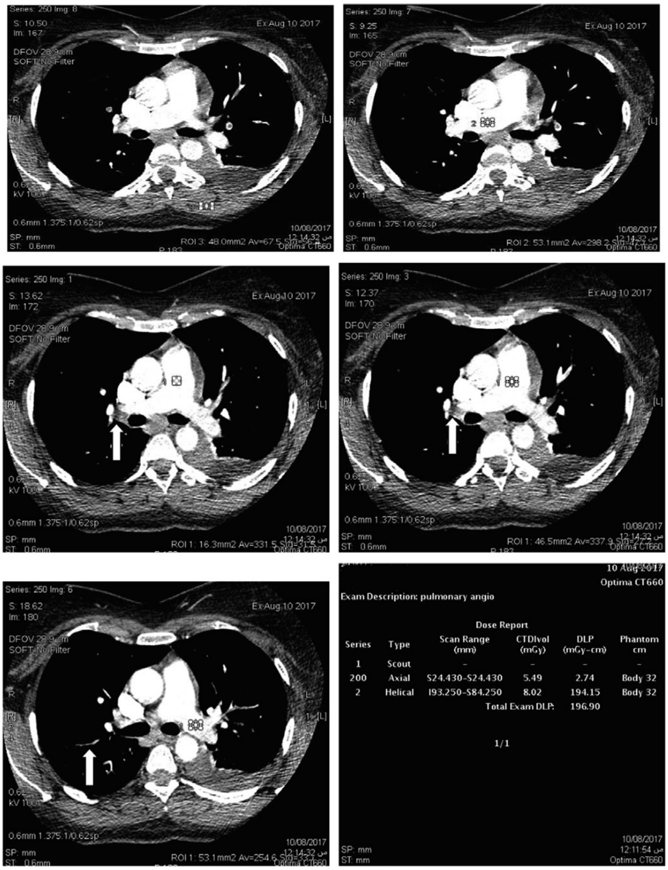


FIG 1. A 45 years old female patient, presented to the ER with acute chest pain and tachypnea, ECG was performed revealed no evidence of significant abnormality, chest x-ray performed and reported normal, blood sample for D-Dimer revealed mildly elevated levels. CT pulmonary angiography was requested **Pulmonary** CTA findings: Bilateral filling defects of the 3rd and 4th order divisions of the pulmonary arteries **(white arrow) .Kilovoltage** = 100 Kvp **. Effective radiation dose** DLP × chest conversion factor = 196 × 0.017 = 3.3 mSV**. SNR** = 19.3**. CNR** = 15.6**. Five point scoring system** = 4 (good image quality, minor artifacts, not affecting the diagnostic confidence).

There was a highly significant difference between the two groups in the received radiation dose (4 mSV for group I and 20.5 mSV for group II) (Figs 1−4).

There was a significantly higher SNR in the standard group (II). There was no significant difference in the CNR between the 2 groups (Table 5).

There was no significant difference between the 2 groups in the quality of the obtained images (Table 6).

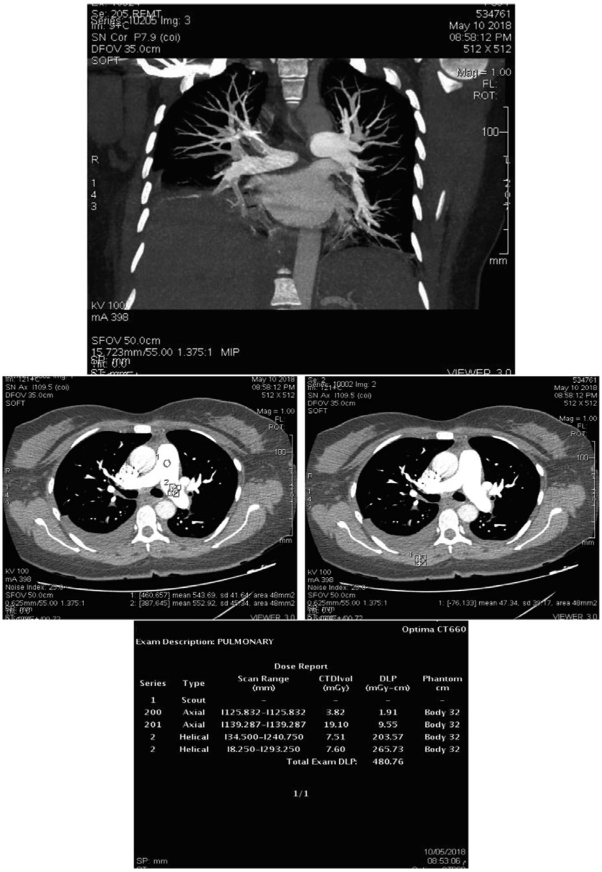


FIG 2. A 39 years old female patient, presented to the ER with acute chest pain and dyspnea, ECG was performed revealed nonspecific ischemic changes, D-dimer levels were mildly elevated, pulmonary CTA was requested .**Pulmonary CTA findings:** Bilateral filling defects of the 3rd and 4th order divisions of the pulmonary arteries more at the right side. **Kilovoltage** = 100 Kvp. **Effective radiation dose** DLP × chest conversion factor = 203 × 0.017 = 3.4 mSV. **SNR** = 19.9 **CNR** = 18.0 **. Five-point scoring system** = 4 (good image quality, minor artifacts, not affecting the diagnostic confidence).

There was no significant difference between the 2 groups in the average attenuation and the average noise of the obtained images (Table 7).

Discussion

The risk of radiation-induced cancer has become a major public concern with the increasing use of computed tomography angiography (CTA). This includes CCTA, pulmonary CT angiography, and chest CTA for the diagnosis of cardiac and pulmonary causes of chest pain and

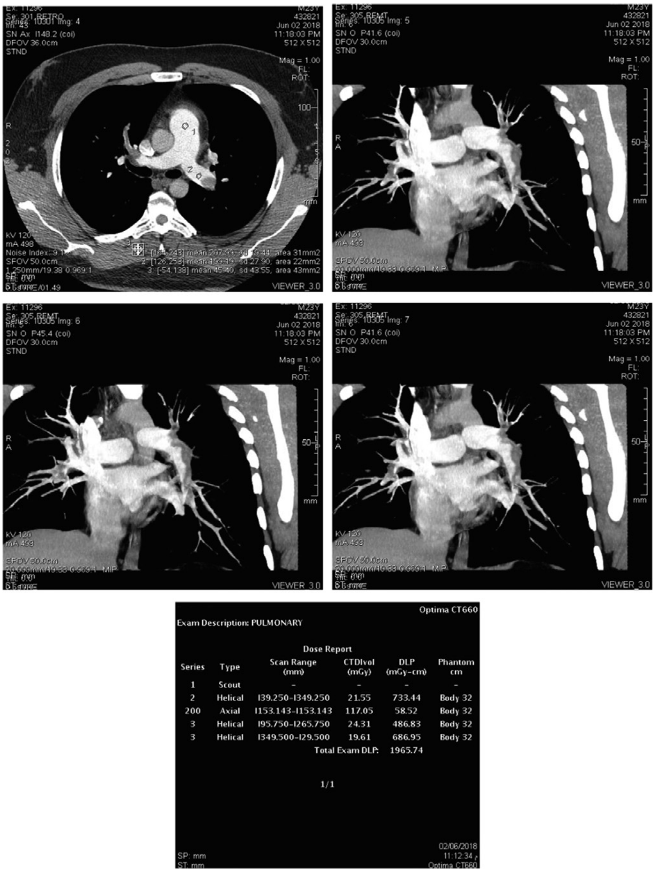
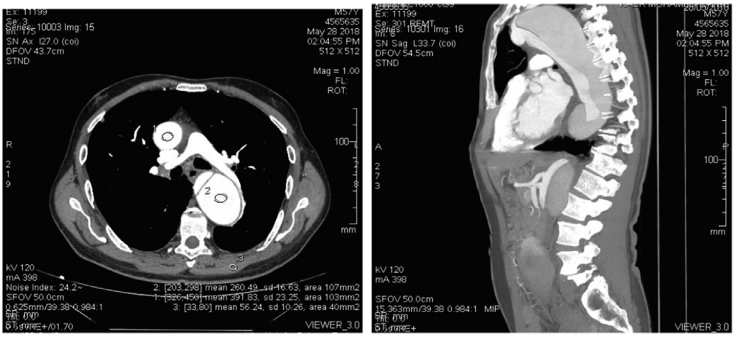
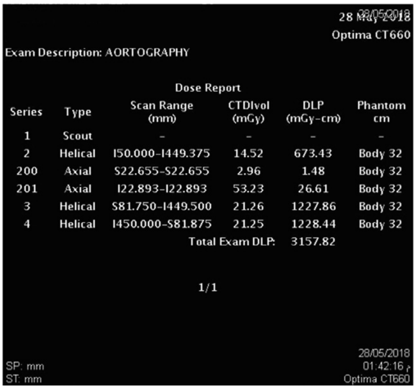


FIG 3. A 61 years old male patient, presented to the ER with recurrent acute chest pain, ECG was performed revealed nonspecific ischemic changes, CT coronary angiography was requested . **Coronary CTA findings:** Minor insignificant atherosclerotic calcified and noncalcified plaques . **Kilovoltage** = 120 Kvp .**Effective radiation dose** DLP × chest conversion factor = 1841 × 0.017 = 31.2 mSV **SNR** = 41.5 **CNR** = 36.8. **Five point scoring system** = 5 (excellent image quality, No artifacts, full diagnostic confidence).

shortness of breath. Although the absolute risk of carcinogenesis associated with this radiation exposure has yet to be determined, there is nevertheless a need to minimize radiation dose while maintaining diagnostic image quality for CTA examinations.[9,10] Therefore, CT protocols should be properly planned and carefully applied in order to achieve the highest amount of reliable information while still using the lowest radiation dose achievable. This is especially important as the risk of radiation-induced cancer from CT examinations has been reported as significant.[9,11]





28 May 2018
Optima CT660

Exam Description: AORTOGRAPHY

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	I50.000-I449.375	14.52	673.43	Body 32
200	Axial	S22.655-S22.655	2.96	1.48	Body 32
201	Axial	I22.893-I22.893	53.23	26.61	Body 32
3	Helical	S81.750-I449.500	21.26	1227.86	Body 32
4	Helical	I450.000-S81.875	21.25	1228.44	Body 32
			Total Exam DLP:	3157.82	

1/1

SP: mm
ST: mm

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01:42:16
Optima CT660

FIG 4. A 69 years old male patient, presented to the ER with acute chest pain radiating to the back, ECG was performed revealed no abnormality, aortic CTA was requested. **Aorta CTA findings:** Dissecting thoracoabdominal aortic aneurysm. **Kilovoltage** = 120 Kvp . **Effective radiation dose** DLP $\times$ chest conversion factor = 1227 $\times$ 0.017 = 20 mSV . **SNR** = 32.8 **CNR** = 27.2 **Five point scoring system** = 5 (excellent image quality, No artifacts, full diagnostic confidence).

TABLE 5. Comparison between the low energy group (I) and the standard group (II) in SNR and CNR

		Group I (100 Kilo voltage)	Group II (120 Kilo voltage)	Test value*	*P*-value	Sig.
		No. = 70	No. = 14			
SNR	Mean ± SD	21.96 ± 7.97	27.90 ± 7.61	−2.566	0.012	S
	Range	3.5-53.2	17.8-41.5			
CNR	Mean ± SD	19.54 ± 7.71	23.69 ± 7.01	−1.864	0.066	NS
	Range	2.9-51.6	16.3-36.8			

P-value >0.05: Nonsignificant (NS); *P*-value <0.05: Significant (S); *P*-value <0.01: highly significant (HS).
*Independent *t* test.

TABLE 6. Comparison between the low energy group (I) and the standard group (II) in subjective evaluation of the image quality according to the 5-point scale

Four points scale	Group I (100 Kilo voltage)		Group II (120 Kilo voltage)		Test value*	*P*-value	Sig.
	No.	%	No.	%			
Reduced quality	4	5.7%	0	0.0%	3.953	0.412	NS
Adequate	6	8.6%	0	0.0%			
Moderate	4	5.7%	0	0.0%			
Good	30	42.9%	6	42.9%			
Excellent	26	37.1%	8	57.1%			

P-value >0.05: Nonsignificant (NS); *P*-value <0.05: Significant (S); *P*-value<0.01: highly significant (HS).
*Chi-square test.

TABLE 7. Comparison between the low energy group (I) and the standard group (II) regarding average attenuation and average noise

		Group I (100 Kilo voltage)	Group II (120 Kilo voltage)	Test value*	*P*-value	Sig.
		No. = 70	No. = 14			
Average attenuation	Mean ± SD	406.71 ± 130.40	344.29 ± 88.65	1.710	0.091	NS
	Range	200-799	202-499			
Average noise	Mean ± SD	28.94 ± 7.17	25.64 ± 8.68	1.518	0.133	NS
	Range	16-48	10-35.4			

P-value >0.05: Nonsignificant (NS); *P*-value <0.05: Significant (S); P-value <0.01: highly significant (HS).
*Independent *t* test.

The initial radiation dose reduction strategies for CT focused on decreasing tube current as there is a corresponding linear reduction in radiation dose. Mayo et al reported in 1995 a threefold decrease in radiation dose by decreasing tube current from 400 to 140 mA without a significant deterioration in image quality or diagnostic utility.[12] Subsequent interest has focused on reduction in tube kilovoltage. Lowering the tube voltage represents the most widely reported technique for reducing the radiation dose in body CTA. This approach allows a significant radiation dose reduction as the dose decreases with the square of the tube voltage.[11] Therefore, a potentially larger reduction in radiation dose can be achieved with this strategy.[12]

In this study, the tube voltage was lowered from the standard 120 kV used in our institution to 100 kV for pulmonary, aortic, and CCTA examinations. This technique resulted in a significant decreased radiation dose to the patient and a nonsignificant change in the image quality. These results are similar to previous studies conducted by Fanous et al, Ripsweden et al, and Zhang et al.[1,11,13] There was no significant difference as regards the 5-points scale system between the 2 groups in evaluating the quality of the obtained images in terms of excellent image quality (37.1% for group I and 57.1 % for group II) and good image quality (42.9 % for both groups). There was a mildly significant difference in SNR with SNR for group II higher (*P* value 0.012). There was no significant difference in CNR between the 2 groups (*P* value 0.066). There was also no significant difference in average attenuation or average noise between the two groups (*P* value 0.091 and 0.133, respectively. Similar findings were reported by Chen et al, Kim et al, and Zhang et al.[1,14,15]

The major limitation of the study is the small number of study participants in the context of other related trials.

Conclusions

The use of MDCT in the evaluation of acute chest pain has increased in frequency. This includes cardiac CTA, pulmonary CTA, and chest CTA in evaluation of aortic dissection. Cardiac CTA is gaining favor as a first-line diagnostic test for acute chest pain. As evaluated in this study, the use of low energy CT angiography protocols was associated with similar image quality and a marked reduction of the radiation dose received by the patient. This decrease in radiation dose to the patient can lower their long-term risk of cancer.

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