Al-Kindy College Medical Journal (KCMJ)

Research Article

Comparative study on Various Tube Voltages and Contrast Media Doses in CT Pulmonary Angiography to detect Pulmonary Thromboembolism

Shaymaa Khalid Abdul-Qader[1*], Atheer Adnan Fadhil[2]

[1] Al-Kindy college of Medicine, University of Baghdad, Baghdad, Iraq
[2] Radiology Department, Baghdad Teaching Hospital, Medical City Complex, Baghdad, Iraq
* Corresponding author: shaymaa.k@kmc.uobaghdad.edu.iq

Article history:
Received 8 March 2022
Accepted 17 September 2022
Available online 30 December 2022

https://doi.org/10.47723/kcmj.v18i3.808

Keywords: pulmonary thromboembolism, computed tomography for pulmonary angiography, contrast media.

ABSTRACT

Background: Lowering the amount of iodinated contrast material and tube voltage may increase pulmonary artery opacification and thrombus identification without compromising picture quality.

Objectives: To explore the efficiency of using lower tube voltage and a lower contrast medium dose for conducting computed tomography for pulmonary angiography (CTPA) aiming to increase its accuracy in detecting pulmonary thromboembolism (PTE).

Subjects and Methods:100 patients scheduled for CTPA with a preoperative diagnosis of PTE were grouped into two: group A, (50 patients) got 1 mL/kg at 120 kV and group B, (50 patients) received 0.5 mL/kg at 80 kV.The technique of bolus tracking was implemented.Values of midpoint of multiple pulmonary artery divisions were used to assess attenuation.Significant values are those that exceed 300 Hounsfield units (HU). The dosage of radiation received by the patient, defined as the effective dose, was compared between groups.

Results: Total mean attenuationdata for the pulmonary arteries have shown to be substantially greater in group-B compared to group-A (39110.4HU vs. 335.97.9HU, P=0.001). Moreover, total dose length product (DLP) values were substantially lower in group-B (934.9 mGy.cm vs. 384.443 mGy.cm, P=0.001). While effective dose values have shown to be significantly lower in group-B (2.90.3 mSv vs. 13.21.8 mSv, P 0.001).

Conclusion: Low-kilovoltage technique and low quantity of iodinated contrast are useful in conducting (CTPA) with high accuracy in detection of pulmonary thromboembolism.

Introduction

Pulmonary thrombo-embolism (PTE) is a frequent consequence of deep venous thrombosis and is regarded as third most common acute cardiovascular illness after stroke and myocardial infarction(1). CTPA is often used to test individuals clinically assumed of having pulmonary embolism (PE) in order to confirm or rule-out this diagnosis (2).

Narrow slices and high number of cross-sections in multi-detector computed tomography (MDCT), implies higher radiation dosage;however, by reducing the kV value, the radiation dose may be lowered without compromising the diagnostic accuracy of PTE(3).

Apart from radiation risk, anotherpoint of concern is injectable intravenous contrast media needed for CTPA. Because of potential contrast medium-induced nephropathy, its usage is troublesome in individuals suffering compromised renal function(4).

Unfortunately, the majority of patients liable to develop pulmonary embolism are old with several coexisting diseases that raise the risk of contrast medium-induced nephropathy (5).

Thus, lowering the iodine load in such patients may effectively avert contrast-induced nephropathy. Additionally, lower CM volume is beneficial in individuals having compromised right ventricular function, since even low osmolar CM will draw fluid from interstitium during its venous return, resulting in right ventricle volume overload(4)

Low-voltage protocols for pulmonary CT angiography may result in significant dose reductions. The mean reduction would reach 40% as setting is reduced from 120 down to 80kVp. It is most likely due to the enhanced vascular enhancement caused by the greater weakening of iodinated contrast material at low tube voltage. This would increase the pictures contrast/noise ratio. Second, reducing tube voltage, would improve vascular enhancement, since at low tube voltage, the attenuation of iodinated contrast medium rises (6).

Reduced tube voltage, on the other hand, increases noise while boosting picture contrast. As the relative increase in noise is greater than the equivalent rise in picture contrast, the signal-to-noise ratio (SNR) would decrease(7).

When low kV is utilized, image noise might significantly rise. This is especially critical in parts of the body with a large surface area, for instance abdomen. Low kilovoltage applications in lungs, on the other hand, do not pose a problem due to the large density difference between interstitium of alveoli and the vasculature. The attenuation and absorption of x-ray in alveoli are quite low. This improves visibility of adjacent vascular and parenchymal structures(8).

Aim of Study

Investigate whether MDCT may be utilized to examine pulmonary arteries (pas) in individuals suspected of having PTE by utilizing low dose CM and low tube voltage.

Subjects and Methods

CT pulmonary Angiography Image Acquisition: This cross-sectional study was carried out in Medical City at Baghdad Teaching Hospital, Department of Radiology.

The study extended for 6 months from September 2018 to February 2019. CT pulmonary angiography examination was carried out using 64–slice CT scan (Brilliance 64: Philips medical system corporation, best, the Netherland), the tube voltage was 120 KV for group-A, and 80 KV for group-B.

The other parameters kept constant as the following:

- Tube current: 200 mAs
- Collimation: 0.6 mm
- Slice increment: 0.5 mm
- Pitch: 0.891
- Rotation time: 0.5 sec
- FOV: 350 mm
- Scan time: 5 seconds
- Bolus tracking threshold: 150
- Post threshold delay: 6 sec
- Window level of CTPA: 80
- Window width of CTPA: 700
- Window level of parenchyma: 600

Window width of lung parenchyma: 1200For CTPA scans, iopromide (Ultravist; Bayer Schering Pharma AG, Germany) wasutilized at a dosage of 370/100 mg/ml administered at a rate of 5 ml/s.

The CTPA examination was initiated automatically utilizing thebolus tracking approach; this method initiates image acquisition when the augmentation in the major pulmonary artery reaches a predefined threshold.

Patients Population: CT pulmonary angiography requested for 115 patients with clinical suspicion of pulmonary embolism to confirm their provisional diagnosis. All patients signed a written informed consent, (age range 15-85 years, mean age = 49.1 year), 15 patients are precluded from the study 5 patients had a known allergy to contrast media, 10 patients had impaired renal function (serum creatinine more than 1.5 mg/dL), the other exclusion criteria were pregnancy and respiratory distress.

The study group subdivided into Group-A (50 patients) received 120 kV value and 1 ml/kg contrast media, and group-B (50 patients) received 80 kV value and 0.5 ml/kg contrast media, the examination was carried out at the end inspiration in supine position, in cranio-caudal orientation extending from thoracic inlet down to adrenals.

The density of several pulmonary arterial segments was determined from their centers. More than 300 HU values were considered significant. All pulmonary arterial segments had appropriate attenuation values for diagnosis.

Objective Image Quality Assessment: The attenuation values from main and lobar pulmonary segments in HU were computed by centering a circular region of interest (ROI) on the center of these vessels and adjusting the size of the circular area to vessel diameter, up to 2 cm. To determine the HU of the peripheral arteries, measurements have been taken in several segmental and sub-segmental branches in the basal and apical branches. Seven arteries were separately analyzed, (main pulmonary artery, Rt and Lt pulmonary arteries. The apical section was chosen between the upper and lower aortic arch boundaries. The basal segment was defined as the area situated in-between the inferior pulmonary veins and the diaphragm. The highest attenuation value estimated from the peripheral vessels takenwas done solely in axial plane due to their small caliper.

After the sections were obtained, the PA attenuation value, sufficiency of image quality, and radiation dose received by the patients have been estimated. The CT scan results were read by two consultant radiologists who check the exam separately. The examining radiologists documented radiological findings from the CTPA examination, including thrombus location, consolidation, pleural effusion, the existence of pulmonary embolism, and assessments of PAs density. As PTE is an emergency case, CTPAs are often made in an emergency situation. As a result, our research excluded patients' weight, height, and body mass index.

Subjective Image Quality: All studied cases exams are assessed by two specialist radiologists separately.They evaluated the image quality of each exam subjectively and recorded their observations on evaluation sheets which is prepared for this purpose. They scored the image quality in three main scores:

1. Very high to outstanding quality: That enables accurate identification of even tiny structures.
2. Adequate quality: The enhancement was less than score 1, but still sufficient for diagnosis.

3. Inadequate quality: Where there is sub-optimal opacification that could not be used for diagnosis.

Radiation Exposure: The dosage-length product was automatically determined by the CT equipment, and the effective dose for CTPA was estimated using the quality standards for CT established by the European research group (18).

The effective dose was estimated using this approach by multiplying dose length product (dose divided by length of anatomical region inspected; dose length product (DLP), mGy.cm) by the anatomical chest area conversion factor (k = 0.017mSv.mGy-1.cm-1).

Ethical consideration and official approvals: verbal permission was taken from each patient preceding data collection, and the details were kept anonymous, administrative approvals were conceded from: The council of Arab Board of Health Specialization, Baghdad teaching hospital in Medical City.

Statistical Analysis: The collected data were introduced into Excel sheet and loaded into IBM-SPSS V24 software to be used in statistical analysis.Descriptive statistics were presented through tables and graphs.Two samples independent T-test, Chi-square test were used to find out significance of differences between continuous numerical variables and associations between categorical variables. P-value less than 0.05 was considered for discrimination between levels of significance.

Results

In this cross-sectional study, 100 patients with provisional diagnosis of pulmonary embolism enrolled the study, the range of age (15-85 years old), mean age of studied cases was 49.14±16 years. Group-A; mean age 48.3±14.5 years, group B; mean age 49.9±17.4 years, there is no significant difference between both groups in age according to independent 2 sample T-test, p-value 0.637.

Males constituted 38% of studied cases, females constituted 62%. Group-A: males=17, females =33, Group-B: males=21, females=29, there is no significant association between gender and the group of study, P- value=0.410

Pulmonary arterial thrombosis was revealed in seventeen patients (17%) in both Groups, 7 patients had central thrombosis (7%), and 10 had segmental and sub segmental thrombosis (10%).The pleural effusion: Found in 25 patients, 25%. Consolidation: Found in 25 patients, 25%. Dilatation of the main pulmonary artery and increased in the aorto-pulmonary ratio present in 4 patients, 25%

Objective Image Quality:

The attenuation values of pulmonary arterial tree were taken from each case in both groups:

1. The main PA
2. The right main PA
3. The left main PA
4. The right-left apical PA
5. The right-left basal PA Segments.

The attenuation value of pulmonary arterial segments was significantly higher in group-B where low contrast and low kv given to the patient in contrast to group-A where the ordinary dose given.The attenuation value of main pulmonary artery in group-B = 411 ±78 HU, while in group-A, was 347±60 HU, the percentage of difference is 15.6%, which is significant P-value is less than 0.001.The density of Rt and Lt pulmonary arteries in group-A were 342±60 HU and 339±53 HU respectively, while in group-B the readings were 396±89 HU and 389±87 HU respectively, percentage

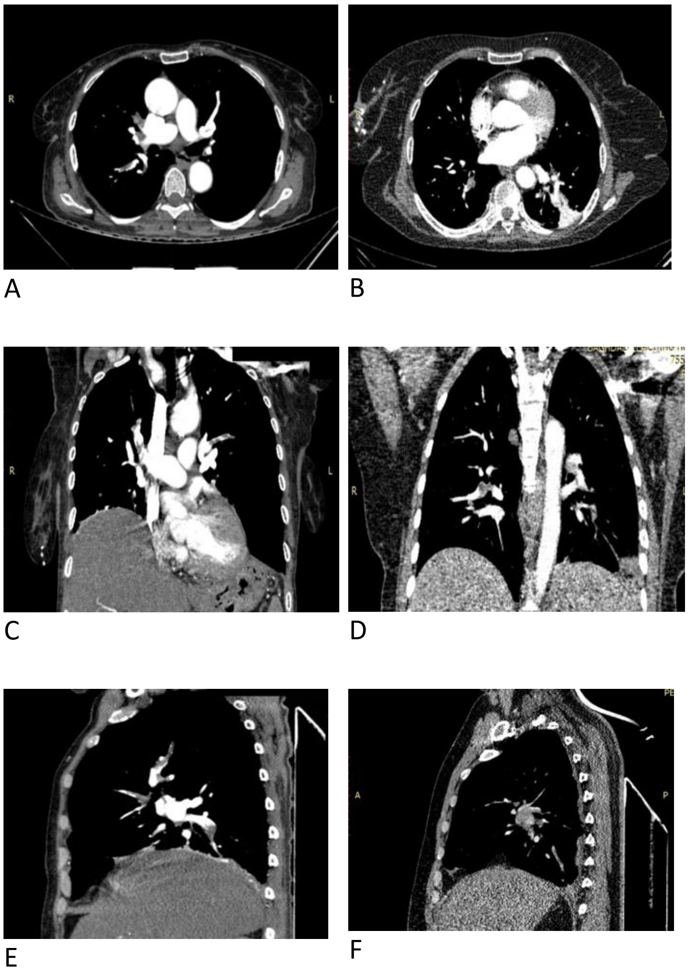

Figure 1: Pulmonary CTA performed using the conventional protocol (a,b,c) and the evaluated low-voltage, low contrast medium protocol (d,e,f).Axial images (a,d), reformatted coronal images (b, e), and reformatted sagittal images (c, f). The study performed with the conventional pulmonary CTA technique. A similar example is shown in the study obtained with the 80 kV protocol demonstrated segmental PE.

of difference is 13.7% in right pulmonary artery and 12.7% in Lt pulmonary artery, which is statistically significant. P-value of all cases was less than 0.001. The peripheral pulmonary arteries density values also found to be significantly higher in group-B.

The attenuation values and percentage of difference between both groups are shown in table (1) and figure (1& 2).

.

Subjective Image Quality

There was inter observer agreement between two radiologists regarding the image quality who evaluate the images separately. The vast majority of exams where low voltage protocol used (80 KV) and low dose of contrast media (0.5 ml/kg) given was scored as 1 – very good to excellent image quality, few cases scored as 2 where the enhancement was inferior to score 1 but still suitable to sufficient diagnosis.

Onlyone case shows inadequate opacification and poor arterial enhancement so scored as 3

Table 1: Two sample t-tests showed differences between means of attenuation values of different pulmonary arterial segments according to the tube voltage exposure of patient

Pulmonary arteries	KV value	Mean	% Of difference	Std. Deviation	P value
MPA	120kv	347.3700	15.6%	60.5	0.001
	80kv	411.9200		78.2	
RMPA	120kv	342.5000	13.7%	60.7	0.001
	80kv	396.9400		89.2	
LMPA	120kv	339.9200	12.7%	53.7	0.001
	80kv	389.6300		87.16	
RAPA	120kv	327.2300	15.1%	57.6	0.001
	80kv	385.6000		79.8	
LAPA	120kv	326.9600	15.4%	55.7	0.001
	80kv	386.9100		67.7	
RBPA	120kv	330.7300	13.6%	65.2	0.001
	80kv	382.8600		82.1	
LBPA	120kv	336.7000	12.1%	70.5	0.004
	80kv	382.9400		85.9	
Average of all data	120kv	335.9	14.1%	7.9	0.001
	80kv	391		10.42	
DLP	120kv	384.44	-313.4%	43.4	0.001
	80kv	93		4.9	
Effective dose	120kv	13.2	-355.2%	1.8	0.001
	80kv	2.9		0.3	

.

The Patients Radiation Dose:

By statistical analysis: patients in group-B received lower radiation dose than group-A.The mean value of total dose length product of group-A was 384 mgray.cm-1, while in group-B was 93 ml gray.cm-1, which is significantly lower in group-B with P value less than 0.001.

The effective dose also was significantly lower in group-B 2.9 than group-A which is 13.2 with p- value less than 0.001.

Discussion

In our study: the most fundamental feedback is that the use of new protocol of CTPA including low kv value and smaller amount of contrast media results in better enhancement of pulmonary arterial segments including central and peripheral branches. The new protocol that we used provided diagnostic dependability that was not substantially different from our standard protocol and yet significantly decreasedDLP and effective dose between two groups with P value 0.001, implying that the effective dose decreased by 300% in group-B as compared to group-A.

Because both CTPA methods have produced comparable rates of pulmonary embolism and adequate subjective image quality, the slightly inferior objective picture quality owing to noise appears to be irrelevant in practice.Our study were in line with many previous studies of the same purpose, such as the study done by Mustafa Kara et al who examined by 80 and 120 kv protocol. They found significantly higher attenuation of the different pulmonary arterial segments with changing tube voltage from 120Kv to 80Kv (as in our study) and also decreased the amount of contrast media given to the patient by 60%, thus,lessening the risk of contrast media nephrotoxicity, and associated allergic reactions, in addition to less effective dose (3).

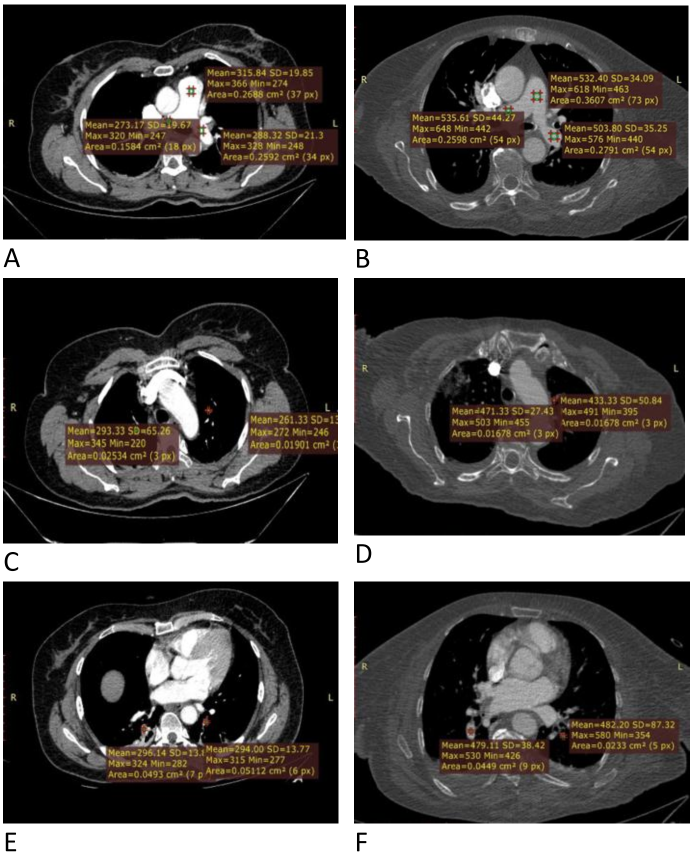

Figure 2: A, Mean attenuation values of group A; main pulmonary artery 315 HU, right pulmonary artery 273 HU, left pulmonary artery 288 HU. B, Mean attenuation. Values of group B; main pulmonary artery 532 HU, right pulmonary artery 535 HU, left pulmonary artery 503 HU. C, Mean attenuation values of group A; right upper zone pulmonary artery branch 293 HU, left upper zone pulmonary artery branch 261 HU. D, Mean attenuation values of group B; right upper zone pulmonary artery branch 471 HU, left upper zone pulmonary artery branch 433 HU. E, Mean attenuation values of group A; right lower zone pulmonary artery branch 296 HU, left lower zone pulmonary artery branch 294HU. F, Mean attenuation values of group B; right lower zone pulmonary artery branch 479 HU, left lower zone pulmonary artery branch 482 HU.

Note/ group-A: where conventional protocol used and group-B: where the studied low Kv and low contrast used

Viteri-Ramirez et al. conducted another research in which they compared the two aforementioned CTPA methods. The author evaluated 70 individuals with a preliminary diagnosis of PTE in this study. Patients were placed into two groups: A (80 kV/60 mL) and B (100 kV/80 mL). The mean attenuation values were 362.4-100.2HU for group-A and 262.4 -134.3HU for group-B, with a P-value less than 0.001 in both central and peripheral arteries. Additionally, the total DLP and effective dosage values were decreased, and the reductions were statistically significant (P=0.001) (9).These findings are compatible with our study.

Viteri-Ramírez G the author have changed the tube voltage from 120 kv down to 80 kv(9) (as our study), and the amount of contrast from 80ml to 60 ml, in our study we give the patients halved the standard dose 0.5ml/kg instead of 1ml/kg), and in spite of this decrement, the attenuation value of central and peripheral pulmonary segments has been increased.

Other studies, such as Leithner Det al., reduced only the tube voltage and observed the effect on contrast attenuation in the vessels and exposure dose. They discovered significantly greater attenuation values at 90 kV compared to 120 kV in central and peripheral Pas (10).

Conclusion:

Pulmonary CTA protocol which performed using 80 KVP and 0.5 ml/kg iodinated contrast media produces high attenuation of central and peripheral pulmonary arteries and thus produces the same diagnostic accuracy as the traditional method in confirming or excluding the diagnosis of pulmonary embolism.

Study Limitations

Lack of patient information's about body mass index, since the CTPA is an emergency condition and most of patients are tired. Additionally, we didn't compare the two separate kV values and two contrast media protocols intra individually because it will be unethically to expose the same patient to extra dose of radiation.

Funding

This research did not receive any specific fund.

Conflict of Interest

No conflict of interest.

References

[1] Mayo J, Thakur Y. Pulmonary CT angiography as first-line imaging for PE: image quality and radiation dose considerations. American Journal of Roentgenology. 2013;200(3):522-8.

[2] Crawford F, Andras A, Welch K, Sheares K, Keeling D, Chappell FM. D dimer test for excluding the diagnosis of pulmonary embolism. Cochrane Database of Systematic Reviews. 2016 (8).

[3] Mustafa K, Kayan M, Cetinkaya G, Turkoglu S, Kayan F. Investigating the use and optimization of low dose KV and contrast media in CT Pulmonary angiography examination. Iranian Journal of Radiology. 2018;15(3)

[4] Newhouse JH, RoyChoudhury A. Quantitating contrast medium-induced nephropathy: controlling the controls. Radiology. 2013;267(1):4-8.

[5] Rezaei Y, Khademvatani K, Rahimi B, Khoshfetrat M, Arjmand N, Seyyed-Mohammadzad MH. Short-Term High-Dose Vitamin E to Prevent Contrast Medium–Induced Acute Kidney Injury in Patients With Chronic Kidney Disease Undergoing Elective Coronary Angiography: A Randomized Placebo-Controlled Trial. Journal of the American Heart Association. 2016;5(3):e002919.

[6] Zhao L-q, He W, Li J-y, Chen J-h, Wang K-y, Tan L. Improving image quality in portal venography with spectral CT imaging. European journal of radiology. 2012;81(8):1677-81.

[7] Kayan M, Köroğlu M, Yeşildağ A, Ceylan E, Aktaş AR, Yasar S, et al. Carotid CT-angiography: low versus standard volume contrast media and low kV protocol for 128-slice MDCT. European Journal of Radiology. 2012;81(9):2144-7.

[8] Scharm SC, Schaefer-Prokop C, Willmann M, Vogel-Claussen J, Knudsen L, Jonigk D, et al. Increased regional ventilation as early imaging marker for future disease progression of interstitial lung disease: a feasibility study. European Radiology. 2022:1-12.

[9] Viteri-Ramírez G, García-Lallana A, Simón-Yarza I, Broncano J, Ferreira M, Pueyo JC, et al. Low radiation and low-contrast dose pulmonary CT angiography: comparison of 80 kVp/60 ml and 100 kVp/80 ml protocols. Clinical radiology. 2012;67(9):833-9.

[10] Leithner D, Gruber-Rouh T, Beeres M, Wichmann JL, Mahmoudi S, Martin SS, et al. 90-kVp low-tube-voltage CT pulmonary angiography in combination with advanced modeled iterative reconstruction algorithm: effects on radiation dose, image quality and diagnostic accuracy for the detection of pulmonary embolism. The British Journal of Radiology. 2018;91(1088):20180269.

To cite this article: Abdul-Qader SK, Fadhil AA. Comparative study on Various Tube Voltages and Contrast Media Doses in CT Pulmonary Angiography to detect Pulmonary Thromboembolism . Al-Kindy College Medical Journal. 2022;18(3):185–89.