Technical Note

Optimization of image quality in pulmonary CT angiography with low dose of contrast material

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Abstract

Aim: The aim of this study was to compare objective image quality data for patient pulmonary embolism between a conventional pulmonary CTA protocol with respect to a novel acquisition protocol performed with optimize radiation dose and less amount of iodinated contrast medium injected to the patients during PE scanning.

Materials and Methods: Sixty- four patients with Pulmonary Embolism (PE) possibility, were examined using angio-CT protocol. Patients were randomly assigned to two groups: A (16 women and 16 men, with age ranging from 19-89 years) mean age, 62 years with standard deviation 16; range, 19-89 years) - injected contrast agent: 35-40 ml. B (16 women and 16 men, with age ranging from 28-86 years) - injected contrast agent: 70-80 ml. Other scanning parameters were kept constant. Pulmonary vessel enhancement and image noise were quantified; signal-to-noise ratio (SNR) and contrast-to-noise ratio (CNR) were calculated. Subjective vessel contrast was assessed by two radiologists in consensus.

Result: A total of 14 cases of PE (22 %) were found in the evaluated of subjects (nine in group A, and five in group B). All PE cases were detected by the two readers. There was no significant difference in the size or location of the PEs between the two groups, the average image noise was 14 HU for group A and 19 HU for group B. The difference was not statistically significant (p = 0.09). Overall, the SNR and CNR were slightly higher on group B (24.4 and 22.5 respectively) compared with group A (19.4 and 16.4 respectively), but those differences were not statistically significant (p = 0.71 and p = 0.35, respectively).

Conclusion and Discussion: Both groups that had been evaluated by pulmonary CTA protocol allow similar image quality to be achieved as compared with each other's, with optimize care dose for both protocol and contrast volume were reduced by 50 % in new protocol comparing to the conventional protocol.

Key words: pulmonary embolism; signal to noise ratio; contrast to noise ratio; contrast volume; image quality.

Introduction

Multidetector computed tomography (MDCT) is the reference standard for the diagnosis of pulmonary embolism (PE) [1-4]. It is reported that the pulmonary embolism is the third most common acute cardiovascular disease, after myocardial infarction and stroke, and results in an estimated 200,000-300,000 hospitalizations and 37,000-44,000 deaths per year in the United States [5]. Recent studies have shown the sensitivity of thin-slice "MDCT PE" to be 90-100% and the specificity to be 89-94% for the detection of pulmonary emboli to the level of the subsegmental arteries [6-10], using pulmonary angiography as the gold standard.

Several studies had revealed an overuse of CT angiography (CTA) to exclude PE, which increase in effective dose per patient [11-12], there is a need for reduction of radiation dose. Therefore the recent studies of pulmonary CTA have conducted important updates on optimizing protocols that restrict the amount of iodinated contrast media thus decreasing the risk of contrast medium-induced nephropathy particularly in people suffering from certain diseases such as diabetes and high blood pressure disease [13-15]. Thus, low radiation dose by using 128 MDCT scanning , low contrast medium volume CTA protocols may be potentially advantageous both to reduce radiation-derived risks and to prevent contrast medium-induced adverse event.

Material and Methods

Subjects

This study was held by Al Najah University Hospital in Nablus city, Palestine. Each individuals referred for pulmonary CTA for clinical suspicion of PE exam. To be eligible for the study patients had to have normal renal function. Patients with a personal history of allergy to iodinated contrast material, or impaired renal function (creatinine >1.2 mg/dl) were excluded from the study. Patients were divided in two groups: A (16

women and 16 men, with age ranging from 19-89 years) - injected contrast agent: 35-40 ml. B (16 women and 16 men, with age ranging from 28-86 years) - injected contrast agent: 70-80 ml.

Pulmonary CTA protocol

All pulmonary CTA examinations were performed using 128 MDCT system (Somatom Definition, Siemens Healthcare, Forchheim, Germany). For group A the acquisition parameter were: pitch = 1, low contrast medium volume = 35-40 ml; flow rate = 4; bolus tracking technique with Hounsfield attenuate threshold = 75-85 HU and delay scan time after the contrast triggering in bolus-tracking technique is 3 second without breathing instruction before data acquisition. For group B the acquisition parameters were: pitch = 0.8; contrast = 60-80 ml; flow rate = 4; HU predefined attenuation threshold with delay scan time after the contrast triggering in bolus-tracking technique is 5 second with breathing instructions before data acquisition, bolus tracking with the region of interest placed in the main pulmonary artery. Pure, undiluted iodinated contrast medium was used for both groups (Iomeron 300), other parameters were kept constant for both groups (slice thickness is 3 mm, kVp =100 and care dose were selected for both group).

Quantitative analysis of pulmonary CTA images

All images were evaluated by two observers with 1 and 3 years of experience in CTA evaluation, blinded to the clinical history and pulmonary CTA protocol. Each study was subjectively classified as diagnostic or non-diagnostic by each reader. 3 mm slice thickness source images were employed for quantitative analysis.

The signal intensity for the central pulmonary arteries (SI vessels), given in HU, was defined as the attenuation measured by placing circular regions of interest (ROIs) in the centre of these vessels. The ROI size was adapted to the diameter of the vessel, reaching up to 80 to 90 mm^2 in the central arteries. The main arteries were analysed by select the main pulmonary artery, left and right. In order to minimize bias, each artery was measured at three different locations. The mean of these values was used for further calculations.

The attenuation in the peripheral pulmonary arteries was ignored because unable to use the ROI method for assessing the signal intensity due to their small calibre.

To define the image noise, the standard deviations of HU measured in ROIs of at least 100 mm^2 drawn in three different regions outside the patient body (middle, left, and right sides) were averaged.

The signal-to-noise ratio (SNR) was defined as SI vessel/ Noise. The contrast-to-noise ratio (CNR) was defined as (SI vessel - SI background)/Noise). These two parameters were calculated separately for the central pulmonary arteries.

For statistical analysis the SPSS software version 16.0 (SPSS Inc. Chicago, IL, USA) were applied and the independent sample t-test was employed to compare continuous variables. A two-sided p-value <0.05 was considered to indicate a statistically significant difference.

Results

All subjects in this study with suspected PE underwent pulmonary CTA, without complications. No significant differences were observed in age, weight, and gender between individuals included in groups A and B. Patient data are represent in **Table 1**. All studies were considered to have enough image quality to detect PE (**Figure 1**). A total of 14 cases of PE (22.5%) were found in the evaluated of subjects (nine in group A, and five in group B). All PE cases were detected by the two readers. There was no significant difference in the size or location of the PEs between the two groups.

The average image noise was 14 HU for group A and 19 HU for group B. The difference was not statistically significant (p = 0.09). Overall, the SNR and CNR were slightly higher on group B (24.4 and 22.5 respectively) compared with group A (19.4 and 16.4 respectively), but those differences were not statistically significant (p = 0.71 and p = 0.35, respectively).

Table 1. Structure of population, patient characteristics, signal intensity for the central pulmonary arteries and image quality in study groups data.

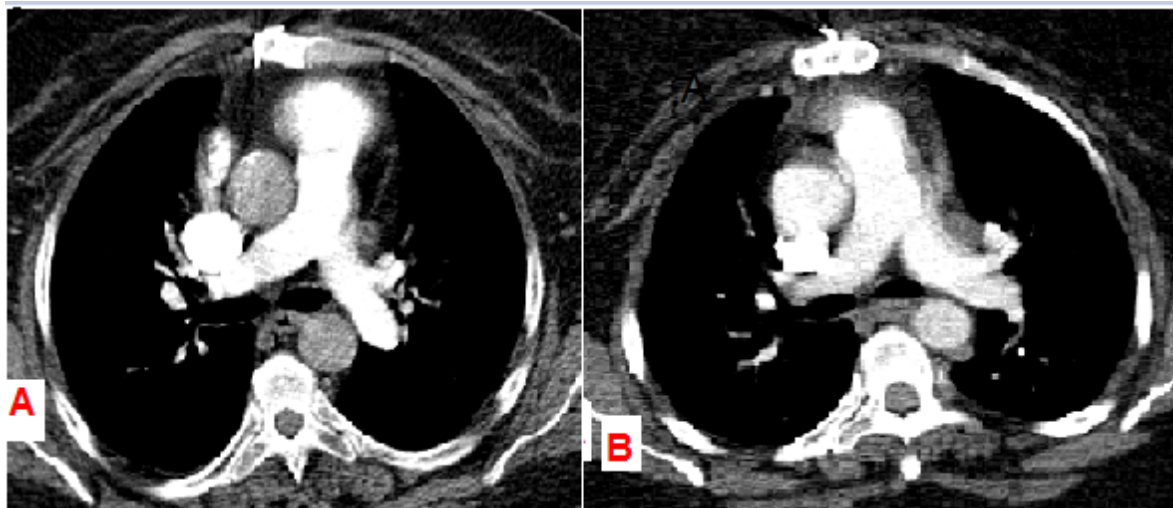|	Group A	Group B	P Value
Male	16	16	
Female	16	16	
Weight (kg)	80.4	85.6	0.82
Vessel attenuation (HU)	286	297	0.815
Noise	14	19	0.075
SNR	19.4	24.4	0.71
CNR	16.2	22.5	0.35

Figure 1. Exemplary 3 mm-thick transverse CTPA images at 100 kVp from the present patient collective. A. Image scan with protocol A (contrast volume 35-40 cc and pitch =1). B. Image scan with protocol B (contrast volume 80-100 cc and pitch= 0.8). For better comparison, the window level was set at 50 HU and the window width at 350 HU for all images. See the reduced beam hardening and streak artifact in image A.

Discussion and Conclusions

In the present study, the two groups were matched by gender, age, and weight, thus exclude possible variations between the groups in the vessel enhancement secondary to a different body habitus. Conversely, volume, concentration, injection rate, and duration of iodinated contrast medium administration are factors directly associated with pulmonary artery enhancement. As shown, the reduction in acquisition times achieved with the newest CT equipment avoids the need for long-duration contrast medium administration protocols, as the injection duration critically affects both the magnitude and timing of contrast enhancement [16-25]. This study used 128 MDCT Siemens machine during pulmonary scanning it managed to reduce injection period to less than 60% during CT scanning and this in turn reduce the size of the contrast medium to less than 50% of the value used in the classical pulmonary scanning protocol.

The most relevant finding of this study is that in individuals average weighing 80 kg, a pulmonary CTA protocol with relatively small volume of iodinated contrast medium (35 ml) results in pulmonary CT angiograms with lower injection period than using a conventional pulmonary CTA protocol (**Figure 1**). The novel protocol proposed here yielded a diagnostic confidence of PE that was not significantly different from the standard protocol, but using 50% less intravenous contrast medium. This optimization of a standard pulmonary CTA protocol may have been achievable this is due to the latest technology, such as thin collimation and shortened study time provided by the new MDCT equipment, the use of automatic initiation of the examination by the bolus tracking technique, and the infusion of a saline flush immediately following the contrast medium which increase peak aortic enhancement through pushing into the cardiovascular system contrast material that otherwise would be left in the injection tubing. The saline flush also minimizes streak artifact from dense contrast which increases SNR of the pulmonary CTA [17,18].

It is known that both normal and CT pulmonary angiography involve the injection of intravenous radiographic contrast under pressure and this injection may develop cardiopulmonary arrest after contrast injection [6]. The reduction of the amount of the contrast to 50% undoubtedly will reduce the likelihood of cardiac arrest, thus in turn will improve the use of CTA in diagnostic PE in a large scale. The reduction of the amount of contrast injection will also reduce beam hardening and streak artifact (see **Figure 1**), obscuring vessels especially in the area of the superior vena cava during the scan.

On order to spare participants from the double dose exposure, data existing in the database in the hospital (for previously used CTA screening protocol) were compared with results obtained for the new protocols, that use reduction of the contrast medium volume combined with high injection rate. This may influence the final results. In order to avoid any bias during comparing between two scanning protocols, the authors recommend the data to be collected for the same subjects on both protocols.

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