Original Article

Qualitative indices and enhancement rate of CT pulmonary angiography in patients with suspected pulmonary embolism: Comparison between test bolus and bolus-tracking methods

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Abstract

Background: The aim of the present study was to assess the qualitative indices and enhancement rate of computed tomographic pulmonary angiography (CTPA) in patients with suspected pulmonary embolism using Test bolus and Bolus-tracking techniques.

Materials and Methods: Fifty-two patients with suspected pulmonary embolism that passed informed consent were randomly divided in the two groups. In each group, demographic characteristics, qualitative indices, and enhancement rate of CTPA were recorded.

Results: The diagnostic result obtained in majority of the participants in the two groups (88.5 % in Test bolus group *vs.* 73.1% in the Bolus tracking group). In the case of quantitative variables, no statistically significant differences were found between the groups ($P > 0.05$). The only statistically significant difference between the two groups is average of "X-ray dose".

Conclusion: The results of our study show that there is no statistically significant difference between the Bolus Tracking and Test Bolus techniques for producing more homogeneous enhancement.

Key Words: Bolus-tracking, Computed tomographic pulmonary angiography (CTPA), pulmonary embolism, test bolus

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INTRODUCTION

Pulmonary embolism (PE) is a frequent and common lethal disorder in adults.[1] PE happens when venous thrombosis, usually from the deep veins of the proximal legs, moves to the lungs. Thromboemboli also could come from pelvic, renal, or upper extremity veins; the right heart; central venous catheter sites; and vena caval filters that cause a series of outcomes, including dyspnea, chest pain, hypoxemia, and sometimes death.[2-4] PE probably accounts for 100,000 to 200,000 deaths per year, making it the third most prevalent cause of death among Americans.[5,6] PE can occur in patients without any identifiable predisposing factors; nevertheless, one or more of these factors are usually identified.[7] Predisposing risk factors affect thrombus formation through their involvement of one

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or more elements of Virchow's triad, defined as venous stasis, hypercoagulability, and vessel wall injury. Other risk factors for thromboembolic disease consist of congestive heart failure, aging, cigarette smoking, and the oral contraceptive usage.[8] Nowadays, CTPA has widely been applied to assess suspected pulmonary embolism because of its accuracy in defining embolism to the level of segmental pulmonary arteries.[4,9-12] Although the CTPA is the major diagnostic imaging procedure in patients suspected to pulmonary embolism (PE) and its application is increasing, but is often strongly dependent on the examiners' expertise, type and dose of contrast material, and the amount of radiation.[13,14] Bolus tracking (BT) and test bolus (TB) are the most frequently used techniques for the determination of scan delay in clinical routine.[15] In a study comparing the TB and BT techniques for intravenous contrast material administration at 16-detector row computed tomographic (CT) coronary angiography, it has been suggested that bolus-tracking causes more homogeneous enhancement than TB technique.[16] Investigating on the effects of a TB protocol contrast medium administration on diagnostic image quality in CTPA revealed that the TB contrast administration should be used as an optimal protocol.[4] A homogeneous enhancement of the pulmonary arteries and adequate overall image quality was attained using both the BT and TB techniques with significant lower contrast doses compared to conventional contrast material injection protocols.[17] Another study indicated that there were no statistically significant differences between the TB and the BT methods concerning vessel attenuation or overall image quality also expressed that sufficient image quality can be achieved with either BT or TB techniques.[15] So, from the aforesaid studies it can be inferred that there is no consensus in the diagnosis of pulmonary embolism by CTPA and justifies the necessity of the present study to evaluating these two methods in our community. The purpose of our study was to assess the qualitative indices and enhancement rate of CT pulmonary angiography in patients with suspected pulmonary thromboembolism using TB and BT techniques.

MATERIAL AND METHODS

The present comparative analytical study was conducted during 2012 in Al-Zahra Hospital in Isfahan, Iran. Before initiation, the study protocol was approved by the official review board, and written informed consent was obtained from all participants after the modality of the process had been exactly clarified.

Fifty-two patients with suspected pulmonary embolism that passed informed consent entered the study. In this study, the sample size was determined using the Krejcie and Morgan table for determining sample size. Non-probability consecutive sampling method was used.

After the enrolment, all patients were randomly divided either into a TB cohort (n = 26) or into a BT cohort (n = 26). Random assignment of patients performed by Random Allocation Software into one of two groups.[18] In group TB, the Test-bolus technique and in group BT, the Bolus-tracking technique was applied.

Exclusion criteria were as follows: Previous allergic reaction to iodinated contrast material, pregnancy, respiratory impairment, and unstable clinical status.

Examinations were performed using a 64-multislice CT scan (Light Speed 64 CT; GE Medical Systems, Milwaukee, WI, USA) while patients were positioned in the supine and scanned in a craniocaudal direction from lung apices to lung bases.

The following parameters were applied for diagnostic image acquisition: 0.6-mm slice thickness, X-ray tube 120 kV, 300 mAs effective with automatic exposure control (CARE Dose 4D, Siemens Healthcare). For vascular enhancement, 100 cc of contrast material Iodixanol (Visipaque 320; Amersham Health, Princeton, NJ) was injected through a 180-gauge needle with 4 ml/sec injection rate.

The volumes of contrast material and injection rate, respectively, were 20 mL and 4 mL/sec for the TB and for the main angiographic bolus 100 mL and 4 mL/sec (total injection time, 25 seconds). We measured densities of pulmonary a arteries based on Hounsfield unit (HU).

In each group, indices of CT pulmonary angiography and demographic characteristics such as patient age, gender, and body weight were recorded.

The data are presented as Mean ± SD for continuous variables and Number (Percent) for categorical ones. The X-ray doses are expressed as Median (25th and 75th percentile). Because the number of patients in each group was smaller than 50, we used the Shapiro-Wilk test for normality. Statistical differences among studied groups were assessed by Independent-Samples T-test, Mann-Whitney, Pearson chi-square, and Fisher's exact procedures. All analyses were done using Statistical Package for Social Sciences version 20 (SPSS Inc., Chicago, IL, USA) and P values less than 0.05 were considered significant.

RESULTS

Fifty-two patients (17 males and 35 females) entered the study. Their ages ranged from 26 to 92 years, with a mean age of 54.5 ± 17.6 and a median age of 56 years. Ten of the 52 patients had the suboptimal result (three cases in TB group and seven cases in BT. group). The demographic and clinical characteristics of the study population categorized by group are shown in detail in Table 1.

As shown in Table 1, the age and sex structure of the studied groups is well distributed, as well as their weight.

The diagnostic result obtained in majority of the participants in the two groups (88.5% in TB group *vs* 73.1% in the BT group); and there is no statistically significant differences between them (Chi-Square = 1.98; P = 0.159).

In the case of quantitative variables, no statistically significant differences were found between the groups (P > 0.05). As can be seen from the data, the only statistically significant difference between the two groups is average of "X-ray dose".

Table 1: Comparison of demographic characteristics and CT pulmonary angiography indices in 52 patients with suspected pulmonary embolism in the two studied groups

	Group		*P* Value
	Test Bolus (*n* = 26)	Bolus Tracking (*n* = 26)	
Age (year)	51±16.4	58±18.3	0.153
Gender (Male / Female)	10/16	7/19	0.375
Weight (kg)	70.4±14.7	74.8±12.3	0.278
Aorta (HU)	123.12±86.76	106.24±82.83	0.481
PA trunk(HU)	329.77±72.49	343.72±91.22	0.547
mPA (HU)	329.38±69.15	335.70±92.35	0.783
Rt PA (HU)	330.23±72.38	333.76±94.06	0.881
Lt PA(HU)	328.54±67.64	337.64±92.23	0.689
RUL (HU)	328.27±69.38	333.64±93.512	0.816
RML (HU)	328.77±71.64	337.56±93.281	0.707
RLL (HU)	327.88±68.76	336.68±94.41	0.705
LUL (HU)	325.23±67.73	329.64±90.60	0.844
LLL(HU)	326.38±67.43	332.04±91.65	0.802
Suboptimal result (artifact)	3 (11.5)	7 (26.9)	0.159
Motion / Structural	2/1	5/2	0.708
Diagnostic result	23 (88.5)	19 (73.1)	0.159
X-ray dose	553.5 [519.2-593.7]	469.8 [407.7-585.5]	0.012*

PA trunk: Pulmonary Artery trunk; MPA: Main Pulmonary Artery; Rt PA: Right Pulmonary Artery; Lt PA: Left Pulmonary Artery; RUL: Right Upper Lobe; RML: Right Middle Lobe; RLL: Right Lower Lobe; LUL: Left Upper Lobe; LLL: Left Lower Lobe; Data are Mean ± SD; Median [IQR] and *N* (%); *P* values derived from *T*-test; Mann-Whitney; Chi-square and Fisher's Exact Test; *Statistically significant

DISCUSSION

The present investigation was designed to assess the qualitative indices and enhancement rate of CT pulmonary angiography in patients with suspected pulmonary embolism, comprising the TB and BT techniques.

Our results indicate that among all CT angiography indices, the X-ray dose was the only characteristic that had a significant difference between the TB and BT technique. The median of X-ray dose in BT group was lower than TB group (469.8 [407.7-585.5] *vs.* 553.5 [519.2-593.7], respectively).

Some studies had compared the TB and BT techniques. Rodrigues *et al*. in 2011 compared 50 patients underwent computed tomography pulmonary angiography (CTPA) via a TB protocol with 50 patients undergoing CTPA using a standard BT protocol (both at 120 kVp). They assessed the attenuation, signal-to-noise ratio (SNR), and contrast-to-noise ratio (CNR). The TB protocol indicated significantly higher attenuation, SNR, and CNR in the pulmonary vasculature down to the segmental level in comparison to BT CTPA (P < 0.0001). They expressed that the TB contrast administration should be applied as an optimal protocol. In contrast, our results indicate that there is no statistically significant difference and is in accordance to the Henzler *et al*. They assigned 60 patients into two groups (TB and BT) and measured the overall image quality and attenuation profiles in different vascular segments to estimate the timing techniques. They found no statistically significant difference between TB and BT techniques concerning vessel attenuation or overall image quality and suggested that a homogeneous opacification of the different vascular territories and the pulmonary parenchyma as well as a satisfactory image quality can be attained with either BT or TB techniques.

Unlike to all aforesaid studies, Cademartiri *et al*. in 2003 in their study stated that the BT cohort had better synchronization among contrast material administration and scanning. They measured the attenuation in three main vessels: Ascending aorta, descending aorta, and main pulmonary artery. They expressed that BT yields more homogeneous and steady enhancement does than the TB technique. Moreover, significantly higher attenuation in the BT group for left coronary artery and its main branches was attained. They subsequently implied that BT causes more homogeneous enhancement at coronary CT and that the TB technique will probably present parallel bolus geometry in an additional delay usage. Unlike the result given by Cademartiri *et al*., our results about the contrast material administration and attenuation rate between TB and BT groups were not significantly different. It is noteworthy that their investigation was carried out using a 16-detector row CT coronary angiography with 12 detectors, compared to the 64-multislice CT scanner in our study. Nevertheless, the present results are in accommodation with those of Kerl *et al*., in 2011 who suggested that a homogeneous opacification of the pulmonary arteries and sufficient image quality can be attained with both the BT and TB. In their study, they assigned 80 patients into two groups (TB and BT) and measured the overall image quality and attenuation profiles in the pulmonary trunk and on segmental level as well as in the ascending aorta to assess the timing techniques. No statistically significant difference between TB and BT was found concerning attenuation of the pulmonary arteries or overall image quality.

A potential limitation of our study is that the conclusion is based on a relatively small number of related studies. There is a marked lack of studies investigating qualitative indices on CT pulmonary angiography examining in patients with suspected pulmonary embolism to compare with the results of the present study. Small sample size is another limitation of present study that could be considered in future surveys.

In conclusion, it seems that there is no statistically difference between the BT and TB techniques for producing more homogeneous enhancement.

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