ORIGINAL ARTICLE

Qualitative evaluation of pulmonary CT angiography findings in pregnant and postpartum women with suspected pulmonary thromboembolism

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Background: Considering the importance of using more appropriate imaging technique for accurate diagnosis of pulmonary thromboembolism (PTE) with less side effects, we aimed to evaluate the quality of pulmonary 64-multidetector computed tomographic (MDCT) angiography in pregnant and postpartum women with suspected PTE in Isfahan. **Materials and Methods:** In this descriptive study, radiological findings of pregnant and postpartum women with suspected PTE who underwent pulmonary 64-MDCT angiography were evaluated. Prevalence of PTE in pregnant and postpartum women, mean of pulmonary arteries density for right and left pulmonary arteries, and their lobar and segmental branches, diagnostic quality of the pulmonary arteries density and their scoring, frequency of diagnostic and nondiagnostic images, mean of radiation dose and mean of bolus time, and the correlation between the quality of the vascular density with the peak density of the pulmonary artery were determined. **Results:** In this study, 44 pregnant and postpartum women with suspected PTE were selected. The overall prevalence of PTE was 9.1% (4/44). PTE was diagnosed in 1 (3.7%) pregnant and 3 (17.5%) postpartum women ($P = 0.14$). Mean density of pulmonary trunk was 278.81± 108.16 Hounsfield unit (HU) and 308.41 ± 59.30 HU in pregnant and postpartum women, respectively. Mean of bolus timing, kilovoltage peak (kVp), tube current, and dose length product (DLP) were 12.53 ± 2.36 s, 105.22± 45.71 milliamperage (MA), 382.9 ± 173.5 MA, and 317.98 ± 78.92 mGy/cm, respectively. The rate of nondiagnostic images was 4.5%. **Conclusion:** Our findings indicated that pulmonary 64-MDCT angiography is an appropriate imaging method for diagnosing PTE in pregnant and postpartum women with suspected PTE. It seems that, using fast CT systems (64-MDCT), in accordance with high flow rate, high contrast medium concentration and low kVp could explain the obtained appropriate quality of images more efficiently than computed tomographic pulmonary angiography (CTPA).

Key words: Computed tomographic pulmonary angiography (CTPA), diagnosis, postpartum, pregnancy, pulmonary thromboembolism (PTE)

How to cite this article: Moradi M, Jalali Monfared L. Qualitative evaluation of pulmonary CT angiography findings in pregnant and postpartum women with suspected pulmonary thromboembolism. J Res Med Sci 2015;20:1088-93.

INTRODUCTION

Pulmonary thromboembolism (PTE) is one of the major causes of maternal death during pregnancy and postpartum period.[1] It is estimated that 1-2 cases of 1,000 pregnancies may be complicated with PTE.[2] The rate is higher in postpartum period than in pregnancy period.[3]

There is a paradox in the diagnosis of PTE in a way that it tends to be both under-and overdiagnosed due to the lack of specific diagnostic algorithm for diagnosis of PTE in suspected pregnant and postpartum women.[4] Both positive and negative false diagnoses of PTE could have serious consequences including potential risk of radiation for the mother and fetus, anticoagulant therapy and its long- and short-term complications, and higher mortality rate related to misdiagnosis of PTE.[4]

Access this article online	
Quick Response Code:	Website: www.jmsjournal.net
	DOI: ****

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Received: 24-04-2015; **Revised:** 28-07-2015; **Accepted:** 09-11-2015

Diagnosis of PTE in mentioned high-risk periods is the most challenging issue for both clinicians and radiologists.

Physiologic changes during pregnancy that mimic the signs and symptoms of PTE complicated the clinical diagnosis of PTE among these groups of population.[5] Moreover, there are limitations of using the Wells' criteria[6] and Genova score[7] for predicting of clinical probability of PTE during pregnancy and postpartum period.

Regarding the utility of different radiologic approaches for diagnosis of PTE in pregnancy and postpartum period, there are controversies. Though the first recommended diagnostic method for PTE is Doppler ultrasound, recently the use of computed tomographic pulmonary angiography (CTPA) in patients with suspected PTE has increased because of its higher accuracy.[8] The most frequently reported pitfalls of CTPA are its limitations in image quality mainly as a result of motion artifact and poor contrast enhancement.[9] Using multislice CTPA has improved the quality of mentioned imaging test.[10]

The British Thoracic Society and Fleischner Society have recommended CTPA as the first-line imaging modality for PTE detection in the general adult population.[8,11] The utility of this test during pregnancy and postpartum period has not been clearly investigated.[12] Some recent studies have evaluated the quality of this radiologic modality in pregnancy and puerperium.[13-15] Evidences indicated that the image enhancement is poor during pregnancy because of the hemodynamic effects of pregnancy.[16] Reports have demonstrated that using low kilovoltage peak (KVP) technique as well as the fastest available scanners during the procedure for these groups of population could substantially improve the contrast enhancement.[12]

Though there were concerns about the fetal radiation exposure and its consequences, recent studies showed that the radiation dose of CTPA is lower than the accepted radiation threshold level. However, the risk of radiation by this imaging method could increase the risk of breast cancer in women.[5]

The precise diagnosis of PTE during pregnancy and postpartum period is crucial for preventing its related morbidity and mortality as well as preventing unnecessary treatments and its related complications for both the mother and fetus. In addition, using appropriate imaging technique for providing high-quality images for accurate diagnosis of PTE with fewer side effects is an important issue in this regard. So considering recommended protocols by previous studies with the purpose of enhancing image quality in these women, we aimed to evaluate qualitative indices, results, and radiation dose of pulmonary 64-MDCT angiography in our population. However, our findings could provide valuable information both for radiologists to reassess adequacy of images by modified protocols and for clinicians to improve decision to select patients who are actually appropriate candidate.

MATERIALS AND METHODS

In this descriptive study, radiological findings of pregnant and postpartum women with suspected PTE who underwent CTPA were evaluated.

The protocol of study was approved by the regional ethics committee of the Isfahan University of Medical Sciences (research project number 393856).

During this study, consecutive pregnant and postpartum women who underwent CTPA in Al-Zahra Hospital, affiliated to Isfahan University of Medical Sciences, from March 2012 to December 2014, were identified retrospectively and their radiological files were evaluated. Those who underwent CTPA using a 64-slice multidetector-row CT machine were included. Reviewing the medical files of the selected patients, those with a history of cardiorespiratory disease were excluded.

According to the report of CTPA, the following parameters were collected in a checklist by an expert radiologist; the parameters were as follows: Prevalence of PTE in pregnant and postpartum women, mean of pulmonary arteries density for right and left pulmonary arteries and their lobar and segmental branches, diagnostic quality of the pulmonary arteries density and their scoring, frequency of diagnostic and nondiagnostic images and mean of radiation dose, and mean of bolus time. The correlation between the quality of the vascular density and the peak density of the pulmonary artery was also evaluated.

Selected 64-MDCT angiography images were evaluated by experienced radiologist for detecting or any important thoracic finding that could explained patients' symptom.

Also qualitative and quantitative index of image were evaluated by objective and subjective incidences.

According to the subjective and objective criteria, the diagnostic or nondiagnostic images were distinguished.

Imaging method and evaluation

CT pulmonary angiography was performed in selected patients in supine position and craniocaudal direction during suspended inspiration. During the imaging, the arms were suspended above the head. The image evaluations were performed from the lung apices to the level of the diaphragm.

For contract enhancement, a bolus intravenous (IV) injection of 50 cc of iodinated contrast medium (visipaque 320 mg/dL) was given at a rate of 4.5 mL/s via an IV cannula (at least an 18 gauge) into the antecubital vein with 10 mL test bolus injected prior to the main injection. Immediately after that 30 mL of normal saline was injected at the same rate.

The scans were performed using a 64-MDCT scanner using LightSpeed VCT SYS, model Ge64 device (General Electric, Wisconsin).

The images were reconstructed in the axial plane in .6 mm intervals.

For a 64-slices imaging, the following protocol was used: 100-120 kVp, pitch 1, rotation time 0.5-0.6 s, and detector width of 64 × 0.6 mm.

Diagnosis of PTE in pregnant and postpartum women was confirmed based on observation of filling defect in pulmonary arteries and its branches.

The diagnostic quality of the images was evaluated objectively and subjectively.

For objective quality evaluation, pulmonary arteries vascular opacification was measured in the pulmonary trunk, right and left pulmonary arteries, and lobar and segmental branches by measuring Hounsfield units (HU) of each arterial segment of interest at a specific site using a circular region of interest cursor that has chosen to be half the diameter of vessels.

Aortic opacification was also measured in ascending aorta.

For subjective evaluation of enhancement of main pulmonary arteries, lobar, segmental, and subsegmental branches of a four-graded scoring system [from 1 (nondiagnostic) to 4 (excellent)] was used. The details were described earlier.[14]

According to subjective and objective criteria, we distinguished that the study was diagnostic or nondiagnostic.

Time of peak enhancement after test bolus was measured and recorded in the questionnaire.

Image noise was assessed subjectively by two point scoring systems (1: No noise and 2: Significant noise).

We also import technical factors as kVp and milliamperage (MA).

Radiation dose is also determined according to the data of MDCT system (CTD vol and DLP).

Statistical analysis

Data were analyzed using Statistical Package for the Social Sciences (SPSS) version 22 (SPSS Inc., Chicago, IL, USA) software. Mean (SD) and frequency of studied variables between pregnant and postpartum women were compared using *t*-test and chi-square test. The correlation between the quality of the vascular density with the peak density of the pulmonary artery was evaluated using spearman correlation tests. $P < 0.05$ was considered statistically significant.

RESULTS

In this study, 44 pregnant and postpartum women with suspected PTE were selected. The group included of 27 pregnant and 17 postpartum women.

The overall prevalence of PTE was 9.1% (4/44). PTE was diagnosed in 1 (3.7%) pregnant woman and 3 (17.5%) postpartum women ($P = 0.14$).

In postpartum women, PTE was detected in segmental, subsegmental, and lobar branches.

Mean density of pulmonary trunk in all studied population was 293.59 ± 81.54 HU. Mean of bolus timing, kVp, tube current, and DLP were 12.53 ± 2.36 s, 105.22 ± 45.71 MA, 382.91 ± 73.5 MA, and 317.98 ± 78.92 mGy/cm, respectively. The rate of nondiagnostic images was 4.5%.

Imaging characteristics of pregnant and postpartum women with suspected PTE are presented in Table 1.

Pearson correlation test did not indicate any significant relationship between the studied variables. There was only negative significant relationship between density of pulmonary trunk ($P = 0.02$, $r = –0.350$) and right main pulmonary artery ($P = 0.033$, $r = –0.322$) with bolus time.

DISCUSSION

In this study, we evaluated the quality of CTPA imaging in pregnant and postpartum women using 64-MDCT. The findings of current study indicated that the quality of images using 64-MDCT angiography were appropriate and mean of contrast media dose was also acceptable.

As mentioned earlier, CTPA is an appropriate imaging method for detection of PTE with a sensitivity and specificity of 83-100% and 89-97%, respectively.[17-19] Its use in pregnant women has also been recommended in the recent guidelines.[20]

In this study, we used CTPA using 64-MDCT. The advantages of this method are its shorter duration of procedure and its

Table 1: Imaging characteristics of pregnant and postpartum women with suspected PTE underwent pulmonary 64-MDCT angiography

Variables	Pregnant women *N* = 27 (%)	Postpartum women *N* = 17 (%)	*P* value
Age (years)	30.22±4.31	26.00±4.86	0.007
Sign and symptoms [*n* (%)]			
Dyspnea	26 (96.3)	7 (41.2)	<0.01
Palpitation	0 (0)	8 (47.1)	<0.01
Cardiopulmonary arrest	0 (0)	1 (5.9)	0.38
Dyspnea and palpitation	1 (3.7)	1 (5.9)	1.0
Objective image quality (HU)			
Density of pulmonary trunk	278.81±108.16	308.41±59.30	0.30
Density of right pulmonary artery	260.48±92.64	296.47±57.91	0.16
Density of left pulmonary artery	258.25±88.49	299.47±64.05	0.10
Density of right upper lobe	245.51±107.52	250.88±74.82	0.85
Density of right middle lobe	225.96±89.89	254.47±77.04	0.28
Density of right lower lobe	237.29±74.37	269.88±57.09	0.13
Density of left upper lobe	229.40±87.35	261.47±54.18	0.18
Density of left lower lobe	253.03±89.67	289.76±54.58	0.13
Density of aorta	154.18±103.90	151.35±71.11	0.92
Bolus timing (s)	12.00±2.20	12.11±2.54	0.87
Peak kilovoltage (kVp)	109.25±48.43	101.17±42.85	0.49
Tube current (MA)	380.18±115.22	385.58±60.20	0.85
DLP (dose length product) (mGy/cm)	303.55± 98.74	333.12± 61.38	0.27
Other radiologic findings [*n* (%)]			
Atelectasia	2 (7.4)	1 (5.9)	1.0
Pleural effusion	3 (11.1)	0 (0)	0.27
Lung infarction	0 (0)	2 (11.8)	0.14
Alveolar infiltration	1 (3.7)	0 (0)	1.00
Normal variation	0 (0)	1 (5.9)	0.38
Pericardial effusion	1 (3.7)	0 (0)	1.00
Dilated vein in thoracic cage	1 (3.7)	0 (0)	1.00
Scoliosis and vertebral anomaly	1 (3.7)	0 (0)	1.00
Non diagnostic [*n* (%)]	1 (3.7)	1 (5.9)	0.62
Image noise [*n* (%)]	4 (14.8)	3 (17.6)	0.55

accuracy to depict peripheral segmental and sub segmental pulmonary arteries.[21] Shortened duration consequently could improve the image enhancement and decrease the contrast media volume.[21]

Considering the higher rate of insufficient diagnostic examinations among pregnant women, the CT protocols during pregnancy have been modified and some techniques have been introduces recently to reduce the higher rate of nondiagnostic examination. The recommended techniques are bolus triggering with short start delays, high flow rates or high contrast medium concentration, preferential use of fast CT systems, and the use of low KVP CT techniques. In this study, we used the recommended techniques for obtaining more accurate results.[12]

In this study the objective quality of the CTPA using a 64-MDCT scanner was similar in pregnant and postpartum women. The density of pulmonary artery in pregnant and postpartum women was 278.81 HU and 308.41 HU, respectively. Obtained results regarding the quality of images were similar to previous studies. Density of pulmonary artery in the study of Browne *et al*. was 270.54 HU in the pregnant group and 277.53 HU in the puerperium group.[15] They did not report any significant difference in diagnostic quality of CTPA among pregnant, postpartum women, and control groups. They concluded that the imaging method could be an appropriate technique for evaluation of these groups of patients with suspected PTE.[15]

In the study of Andreou *et al*., the mean pulmonary arterial densities were 259.79 ± 59.31 HU and 371.88 ± 60.63 HU in pregnant and nonpregnant patients, respectively. The enhancement was significantly lower in pregnant women than control nonpregnant women.[22]

In the study of U-King-Im *et al.* in the UK, among 40 pregnant patients using CTPA by 16-MDCT and 64-MDCT scanners, densities of pulmonary artery in pregnant and nonpregnant women was 241 HU and 286 HU, respectively.[14]

In literature review, there was only one study that similarly carried out CTPA by only a 64-MDCT scanner.[15] Reminder studies in this field mostly used small sample size of patients and different techniques of MDCT. Most of the studies compared pregnant women with control nonpregnant ones.[13,14]

It seems that the density of studied arteries, in our study was similar to those in the study of Browne *et al.* and higher than those in the study of U-King-Im *et al*. It is suggested that performing CTPA by a 64-MDCT improves the quality of images in pregnant and postpartum women.

In our study, subjective evaluation of the images indicated that only one case in each group had nondiagnostic quality (4.5%). This rate in the study of Browne *et al*. was one in pregnant women and none in postpartum group. The rate of undiagnosed cases in our study was similar to the results of Browne *et al*.[15] Whereas this rate was higher in other studies. Andreou *et al*. in UK retrospectively analyzed the CTPA examinations used 4MDCT among 16 pregnant and 16 nonpregnant women suspected of having PTE. They reported a 62.5% of nondiagnostic or borderline-for-diagnosis rate.[22] The rate was 27.5% in another study in Cambridge, UK, among 40 pregnant patients on whom CTPA performed by 16-MDCT and 64-MDCT scanners.[14] Shahir *et al.* in the USA have reported a nondiagnostic rate of 4% by evaluating 106 CTPA using an 8-MDCT, or 16-MDCT, or 64-MDCT scanner.[23]

Image noise is found in 15.9% of our population that was similar to findings of previous studies.[15,16,22]

Mean delay time in our study was 12 s and we use test bolus. In the study of Andreou *et al*., this time was 20 s and they do not using test bolus.[22]

Mean level of kVp in this study was in the accepted range recommended by previous studies. There were evidences that optimizing the procedure by reducing kVp from 140 to 100 would improve the quality of the image and consequently the diagnosis process.[24,25] The mean of kVp in this study were 109 and 101 for pregnant and postpartum women, respectively.

The mean of tube current in this study was higher than the standard range of 200 MA.[26] Mean of tube current in our study was similar to the study of Hurwitz *et al*.[27] In reminder studies, the MA was lower than that in our study.[13-15]

The mean DPL in our study was 303.55mGy/cm for pregnant women and 333.12 mGy/cm for postpartum women. It was lower than that reported by Browne *et al*. They reported mean DPL of 397.54 mGy/cm and 456.04 mGy/cm for pregnant and postpartum women, respectively.[15] In the study of Andreou et al., the mean DPL was 324.8 mGY/cm in pregnant women and 379.6 mGY/cm in control nonpregnant women.[22] Mean of DPL in our study was in the recommended dose for the fetus and mother.

Shahir *et al*. have reported that reduced scan range (*z*-axis) in CTPA among patients aged 18-40 years would result in a 69% DPL reduction.[28]

In this study, PTE was diagnosed in 1 (3.7%) pregnant woman and 3 (17.5%) postpartum women. The rate of PTE was 4.7 fold higher in postpartum women than in pregnant women, which was similar to the results of previous studies.[3]

Browne et al. in Ireland have evaluated the image quality of 70 pregnant, 54 postpartum, and 124 control nonpregnant women who underwent CTPA using a 64-MDCT scanner and were suspected to have PTE. The results indicated that PTE was positive in 1 (1.4%) pregnant woman and 5 (9.3%) postpartum women.[15]

The rate of positive PTE in suspected pregnant women was 0% in the study of U-King-Im *et al*. in the UK.[14]

The limitations of this study were the retrospective design of the study, low sample size, and lack of control group.

In sum, the findings of current study indicated that pulmonary 64-MDCT angiography is an appropriate imaging method for diagnosing PTE in pregnant and postpartum women with suspected PTE. It seems that, using fast CT systems (64-MDCT), in accordance with high flow rate, high contrast medium concentration, and low KVP, could explain the obtained appropriate quality of images than CTPA.

Though the findings of our study in accordance with the reports of previous studies indicated that the fetal radiation dose using this method could not have serious effect on fetus development, yet considering the low proportion of cases diagnosed with PTE and those with suspected sign and symptoms of PTE and also risk of breast cancer it is recommended to use this method with caution in these groups of patients, especially pregnant ones. Further studies with consideration of mentioned limitations are warranted to obtain more conclusive results.

Acknowledgments

This study was supported by Isfahan University of Medical Sciences, Isfahan, Iran (research project number; 393856).

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

AUTHOR'S CONTRIBUTION

All authors contributed in the study design, conducting the study and drafting the manuscript. All authors approved the final version for submission and take the responsibility for the manuscript content.

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