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Contrast monitoring techniques in CT pulmonary angiography: An important and underappreciated contributor to breast dose

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ABSTRACT

Objective: The aims of our study were to evaluate the contribution of contrast-monitoring techniques to breast dose in pregnant and non-pregnant women, and to investigate the effect of a reduced peak kilovoltage (kV) monitoring scan protocol on breast dose and Computed Tomography Pulmonary Angiography (CTPA) diagnostic quality.
Materials and methods: Single center retrospective study of 221 female patients undergoing a reduced kV 80 kV contrast-monitoring CTPA protocol compared to 281 patients using the conventional 120 kV contrast-monitoring protocol (Siemens Somatom Definition AS+). 99 pregnant patients analyzed separately. ImPACT dosimetry software was used to calculate dose. Group subsets were evaluated to assess CTPA diagnostic quality.
Results: The contrast-monitoring component of a CTPA study constituted 27% of the overall breast dose when using a standard 120 kV protocol compared to only 7% of the overall breast dose in the 80 kV study group. The dose to the breast from the contrast-monitoring component alone was reduced by 79% in the non-pregnant patients (0.36mGy ± 0.37 versus 1.7mGy ± 1.02; $p < 0.001$), and by 88% in the pregnant population (0.25 mGy ± 0.67 versus 2.24mGy ± 1.61; $p < 0.001$). There was no statistical difference in CTPA diagnostic quality or timing.
Conclusion: Despite a short scan length and relatively small DLP, contrast-monitoring techniques (test-bolus or bolus-tracked) set at 120 kV can account for 27% of the overall breast dose accrued from a CTPA study. By decreasing the kilovoltage of the contrast-monitoring component, a significant reduction in breast dose for pregnant and non-pregnant female patients can be achieved without affecting CTPA quality or timing.

1. Introduction

Computed Tomography Pulmonary Angiography (CTPA) is the current standard of care for detecting pulmonary embolism (PE) in the non-pregnant population [1,2]. Even though there have been significant recent improvements in CT technology, radiation exposure to the breast during CTPA remains a concern, especially for young female patients. In fact it is mainly due to concerns with breast dose that lower limb venous ultrasound and/or perfusion scintigraphy, rather than CTPA, have been advocated as preferred investigations in the pregnant patient suspected of having a PE [3–6]. While the debate on the best investigation in pregnancy continues, it is important that when the CTPA technique is used it is optimized with regards to radiation dose. There are several well documented and proven methods to optimize CTPA technique to reduce patient dose, including reducing the kilovoltage, using iterative reconstructive techniques, reducing the field of view and others, however these are directed at the diagnostic component of the CTPA study.

A typical CTPA study comprises three components: a patient topogram, a contrast-monitoring scan and a diagnostic scan. The role of the contrast-monitoring scan is to determine the optimum timing between the injection of contrast material and CT data acquisition in order to obtain adequate pulmonary arterial contrast enhancement. In practice the contrast monitoring component

Abbrevations: AA, ascending aorta; BMI, body mass index; CNR, contrast to noise ratio; CTDIVOL, CT dose index volume; CTPA, CT pulmonary angiography; CXR, chest X-ray; DLP, dose length product; ED, effective dose; HU, hounsfield unit; kV, peak kilovoltage; LD, latissimus dorsi muscle; mA, tube current; MPA, main pulmonary artery; PE, pulmonary embolism; RA, right atrium; ROI, region of interest; SD, standard deviation; SNR, signal to noise ratio.

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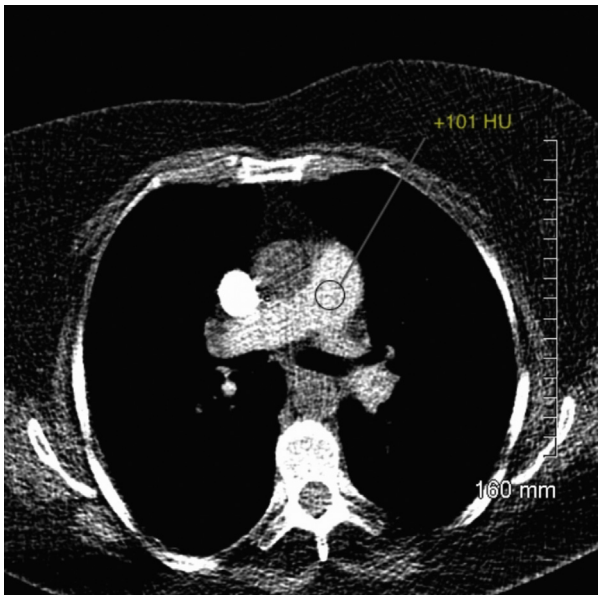

Fig. 1. Bolus-tracking image with ROI drawn overlying the pulmonary trunk.

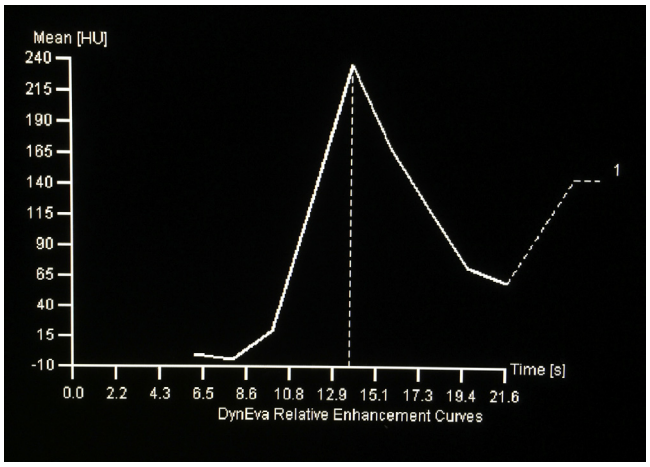

Fig. 2. Time-enhancement curve used in Test-bolus Technique.

entails the continuous imaging of the pulmonary trunk after contrast injection has begun, which can either trigger the diagnostic scan at a predetermined Hounsfield level (i.e. bolus-tracking) or can be used to accurately time a separate diagnostic study (i.e. test-bolus timing).

While contrast-monitoring techniques contribute little to the total Dose Length Product (DLP) of an examination, due to the short scan length, the technique does require repetitive scanning through breast tissue when monitoring the pulmonary trunk. We hypothesized that contrast-monitoring techniques are significant but under-appreciated contributors to breast dose during CTPA examinations. If confirmed this would be an important additional target for technique optimization that could significantly reduce breast dose without compromising the quality of the diagnostic scan.

The aims of our study were to evaluate the contribution of contrast-monitoring techniques to breast dose and to investigate the effect of using a reduced kV monitoring scan protocol on breast dose and CTPA diagnostic quality.

2. Materials and methods

The authors have no conflicts of interest. Ethics review board approval waived the requirement for informed patient consent, because of the retrospective nature of patient data analysis.

2.1. CTPA and contrast monitoring techniques

All CTPAs were performed on two 128 slice CT systems (Somatom Definition AS+, Siemens Healthcare, Forchheim, Germany) in a single tertiary referral center. The diagnostic scan utilized automatic exposure control (CARE Dose 4D; Siemens Healthcare) with a reference tube current of 90 mAs. A topogram was performed at 100 kV, which determined the kV selection of the diagnostic study (CARE kV; Siemens Healthcare). Importantly, CARE kV did not automatically adjust the kV for the contrast-monitoring scan. 60 ml of non-ionic iodinated contrast (Iopamidol, Isovue 370; Bracco Diagnostics Inc., USA) was injected at 4–5 ml/s via a dual-headed pump injector (Swiss Medical Care, Lausanne, Switzerland) with a 20 ml saline flush. The diagnostic scan was performed in the craniocaudal direction with the following parameters: pitch 1.4, and rotation time of 0.33-s. All CTPA images were constructed with a sinogram-affirmed iterative reconstruction algorithm (SAFIRE, Siemens Healthcare, Forchheim, Germany). The strength of the SAFIRE was set at 3 as recommended by the manufacturer.

Automated breathing instructions were provided to ensure a shallow inspiration breath-hold. For pregnant patients, a reduced scan range was performed from the aortic arch to the dome of the diaphragm.

Two contrast monitoring techniques were utilized, both of which image over the level of the pulmonary trunk with the following parameters: 10 mm slice thickness, rotation speed 0.33 s and fixed 20 mAs. All "standard" techniques were performed using the manufacturer's default setting of 120 kV. In January 2015, our department introduced a "reduced dose" 80 kV protocol after analysis of our standard technique suggested dose savings could be obtained during the contrast-monitoring component of our CTPA examinations. The type of contrast-monitoring technique (bolus-tracking or test-bolus) used during CTPA exams is not stipulated in our departmental protocol and was decided by the technologist based on technical experience and patient factors (inadequate vascular opacification with one technique typically prompted the technologist to scan using the alternate technique).

The bolus-tracking technique involved repeated single slice acquisitions at 1.2-s intervals, following an initial 8-s delay from the time of injection of the contrast medium. The diagnostic scan was triggered when the manually drawn region of interest (ROI) over the main pulmonary trunk achieved a threshold of +100HU(see Fig. 1). The inter-scan delay was set at 5-s.

The test-bolus technique consisted of injection of 20 ml of contrast at 4–5 ml/s. Acquisition of the dynamic monitoring images started 6 s after the beginning of the test-bolus injection at 1.2-s intervals. A ROI within the pulmonary trunk was used to generate the time-enhancement curve (see Fig. 2) using DynEVA software (Siemens Medical Solutions, Forchheim, Germany).

2.2. Patient groups

All female patients who had undergone standard 120 kV contrast monitoring CTPA examinations over a four-month period from September 1, 2014 through December 31, 2014 were compared with all female patients who had undergone reduced dose 80 kV contrast-monitoring examinations from February 1, 2015 through May 31, 2015. To enrich the proportion of pregnant patients in the standard 120 kV group, data from CTPA studies performed on pregnant women dating back to September 2012 (using the same CTPA