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Intravenous contrast material administration at high-pitch dual-source CT pulmonary angiography: Test bolus versus bolus-tracking technique

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ABSTRACT

Purpose: To compare test bolus and bolus tracking for the determination of scan delay of high-pitch dual-source CT pulmonary angiography in patients with suspected pulmonary embolism using 50 ml of contrast material.

Materials and methods: Data of 80 consecutive patients referred for CT pulmonary angiography were evaluated. All scans were performed on a 128-channel dual-source CT scanner with a high-pitch protocol (pitch 3.0, 100 kV, 180 mA s). Contrast enhancement was achieved by injecting 50 ml of iomeprol followed by a saline chaser of 50 ml injected at a rate of 4 ml/s. The scan delay was determined using either the test bolus ($n = 40$) or bolus tracking ($n = 40$) technique. Test bolus required another 15 ml CM to determine time to peak enhancement of the contrast bolus within the pulmonary trunk. Attenuation profiles in the pulmonary trunk and on segmental level as well as in the ascending aorta were measured to evaluate the timing techniques. Additionally, overall image quality was evaluated.

Results: In all patients an adequate and homogeneous contrast enhancement of more than 250 HU was achieved in the pulmonary arteries. No statistically significant difference between test bolus and bolus tracking was found regarding attenuation of the pulmonary arteries or overall image quality. However, using bolus tracking 15 ml CM less was injected.

Conclusion: A homogeneous opacification of the pulmonary arteries and sufficient image quality can be achieved with both the bolus tracking and test bolus techniques with significant lower contrast doses compared to conventional contrast material injection protocols.

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1. Introduction

Computed tomographic pulmonary angiography (CTA) is widely used to evaluate patients who are clinically suspected of having pulmonary embolism to either confirm or rule out this diagnosis. Over the last decade advances in multidetector CT have led to improved spatial resolution, detection of small emboli on subsegmental level by enabling delineation of the peripheral pulmonary arteries and therefore increasing sensitivity and specificity in the diagnosis of pulmonary embolism [1,2]. Beside the developments in CT technology considerable effort is being directed at optimizing injection parameters for contrast-enhanced CT applications in general [3,4] and for the diagnosis of pulmonary embolism (PE) in particular [5,6] in order to ensure high, homogenous and consistent vascular attenuation.

Since the introduction of the second generation of dual-source CT (DSCT), a new era in CT acquisition speed has started. Compared with older CT systems, the second generation of DSCT has two detector systems, each acquiring 128 slices [7]. In single-source CT, the pitch factor is limited to a maximum of approximately 1.5 to ensure gapless volume coverage. In the new-generation DSCT system, a high-pitch data acquisition mode allows for pitch values of up to 3.4 resulting in an increased acquisition speed [8]. Therefore it is possible to image the entire thorax within under 1 s [9].

However, beside the advantages of high-pitch CT acquisition an optimization of contrast injection protocols for the evaluation of the pulmonary arteries is needed. As the data acquisition takes only approximately 1 s there is place for a reduced contrast material volume protocol that ensures the bolus timing only in this very moment. Excluding a fixed empirical delay, bolus tracking (BT) and test bolus (TB) are the most frequently used techniques for the determination of scan delay in clinical routine [10].

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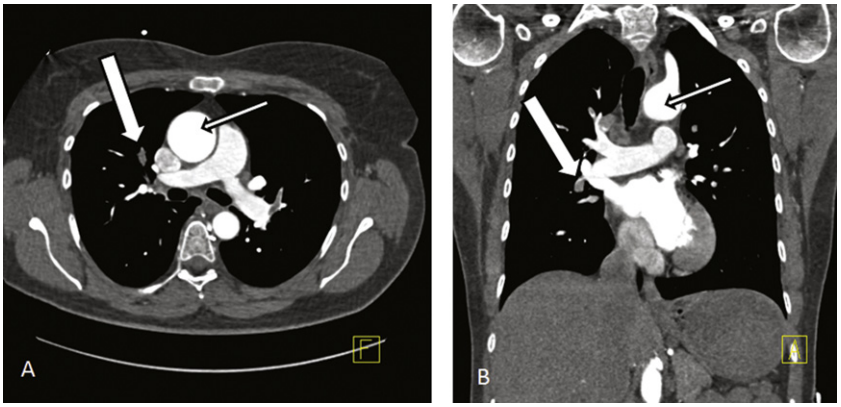

Fig. 1. Transverse (A) and coronal (B) CT sections acquired with high-pitch dual source CT to rule out pulmonary embolism. For the estimation of the optimal contrast timing test bolus technique was used. The bolus timing allowed for the diagnosis of a bilateral pulmonary emboli (white arrow). Additionally, sufficient enhancement could be observed in the ascending aorta to rule out aortic dissection.

Thus, the purpose of our study was to compare both intravenous contrast media administration techniques with regard to pulmonary arterial enhancement and image quality of CTPA with high-pitch.

2. Materials and methods

2.1. Patients

The human research committee of our hospital approved this retrospective analysis and waived the need for informed patient consent. We retrospectively analyzed data of 80 patients who had undergone clinically indicated contrast-enhanced multi-detector row CT angiography of the pulmonary arterieson a DSCT scanner of the second generation between August and December 2010. At our institution, CT angiography is the first-line examination for patients suspected of having pulmonary embolism (PE). In group 1 ($n = 40$) the test-bolus technique was used, while in group 2 ($n = 40$) bolus tracking for the determination of scan delay was used.

2.2. CT acquisition protocol

All CT examinations were performed on the same dual-source CT device of the second generation (Somatom Definition Flash, Siemens Healthcare, Forchheim, Germany) in high-pitch dual-source mode. A tube potential of 100 kV with a reference tube current-time-product of 180 mA s and a collimation of 128mm × 0.6 mm was used on both tube-detector-units. The pitch was set to 3.0 at a gantry rotation time of 0.28 s. By spatial restrictions inside the gantry, the field of view (FOV) of the second detector is limited to 32 cm while the first detector supports a regular FOV of up to 50 cm.

All examinations were performed by using the same non-ionic low-osmolar contrast material (CM) (iopamidol, Imeron 400, Bracco Imaging, Konstanz, Germany) injected through an intravenous antecubital catheter at a rate of 4 m/s.

In group 1, a test bolus (TB) consistent of 15 ml CM followed by a 30 ml saline chaser bolus was used for the evaluation of the scan delay during the acquisition of a series of dynamic low-dose monitoring scans (100 kV, 20 mA s) at the level of the pulmonary trunk. Region of interests (ROIs) were placed within the pulmonary trunk to calculate the enhancement/time curve. Acquisition of the monitoring scans started 5 s after the beginning of the injection. The delay between each monitoring scan was set to 1 s. The peak enhancement during that attenuation curve was assumed to be the optimal scan delay with an additional delay of 8 s. The actual image acquisition was performed in free breathing using 50 ml CM and a saline chaser bolus of 50 ml.

In group 2, the bolus tracking (BT) technique was performed by using dedicated software (CARE bolus, Siemens). 50 ml CM were injected followed by a saline chaser bolus of 50 ml. Real-time low-dose monitoring scans (100 kV, 20 mA s) of the contrast material were performed 5 s after the beginning of the injection. The delay between each monitoring scan was set to 1 s. The ROI was placed within the pulmonary trunk with a trigger threshold of 100 HU above the baseline. The scan was then started with a delay of 8 s.

CTPA images were reconstructed at a slice thickness of 1.0 mm with 0.5 mm increment in angiographic window (center: 100 HU; width: 700 HU) with a medium-soft convolution kernel (B26f).

2.3. Image analysis

One observer (____ with 1 year of experience reading chest CT scans) who was blinded to the scan protocol performed attenuation measurements in regions of interest (ROI) by using transverse sections on a medical workstation (Syngo Multimodality Workplace; Siemens). In each patient and for each target structure, three regions of interest were prescribed on three consecutive transverse sections depicting the respective target structure. For the pulmonary arteries, these measurements were performed in the bifurcation of the pulmonary trunk and in the artery of segments 1 and 10. Region of interest size was adjusted to encompass the entire contrast-enhanced vessel lumen, avoiding the inclusion of the vessel wall or embolus. For the enhancement in the ascending aorta (AA) and superior vena cava (SVC), the level of the aortic root was used. For the enhancement of the subclavianvein (SV), the measurements were performed in the middle part of the vessel. Regions of interest were as large as possible and were placed in such a fashion that soft tissue structures were avoided. The mean attenuation (in Hounsfield Units) ± the standard deviation (SD) in the regions of interests on three consecutive sections was calculated for each target structure (Figs. 1 and 2).

Two observers (____ with 3 and 5 years of experience reading cardiovascular CT scans, respectively) who were blinded to the scan and injection technique rated separately each scan in random order on a medical workstation (Syngo Multimodality Workplace, Siemens) and assessed image quality according to a 5-point scale: 1 = excellent; 2 = good; 3 = moderate; 4 = fair; 5 = poor.

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