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Improvement of Contrast Media Enhancement in CTA Evaluating Pulmonary Embolism by Utilizing 'Delayed' Bolus Tracking in the Descending Aorta

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Summary

Background: As standard bolus triggering in the pulmonary trunk sometimes fails to achieve sufficient enhancement in the pulmonary arteries, the study investigates an alternative, 'delayed' position of the tracking ROI in the descending aorta.

Material/Methods: Retrospective analysis of 143 patients suspected of pulmonary embolism investigated with 3 different scanners (16 to 80 rows) in clinical routine. Bolus triggering with 120 hounsfield units (HU) was performed using the pulmonary trunk (n=70) or descending aorta (n=73) after application of 70 to 120 mL of contrast agent, Iomeprol 300. Student's t-test was applied to compare vascular enhancement. Additional factors were analysed by a regression analysis.

Results: Positioning of the tracking ROI in the descending aorta achieved a significantly higher contrast enhancement in the pulmonary trunk with a mean increase of 63 HU ($p<0.001$).

Conclusions: In CTA, delayed acquisition by using the descending aorta for bolus triggering can improve the enhancement of the pulmonary trunk to investigate a pulmonary embolism. Furthermore, the scan protocol simultaneously allows to rule out aortic pathologies as an alternative cause for a similar clinical condition.

MeSH Keywords: Contrast Media • Multidetector Computed Tomography • Pulmonary Embolism

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Background

Especially in critically ill patients undergoing computed tomography angiography (CTA) to rule out or detect a pulmonary embolism, we observed cases of diminished contrast enhancement in the pulmonary arteries although a diagnostic standard of bolus tracking with a region of interest (ROI) placed in the pulmonary trunk was used [1]. CTA with modern multi-slice scanners is connected with several pitfalls like short-term effects of breath-hold manoeuvres [2,3], thus reliable examination protocols are of high interest to the radiologists. Unfortunately, literature reports that about 6.1% of all scans investigating pulmonary embolism lack sufficient enhancement of the pulmonary vasculature resulting in a non-diagnostic image quality [4]. However, a transfer to alternative imaging methods (e.g. lung scintigraphy) is time-consuming or not readily available while repeated scans with further application of contrast media (CM) potentially increase the risk of contrast-associated renal insufficiency [5].

This retrospective study seeks to investigate a potential improvement in vascular enhancement within the pulmonary trunk after altering our clinical standard. Here, we utilized a 'delayed' position of the bolus tracking ROI in the descending aorta (also known as thoracic CTA) while maintaining all other scan parameters of three multi-slice scanners.

Material and Methods

Patient cohort

We examined 143 consecutive patients that were referred to our department for the investigation of a pulmonary

Table 1. Patient data and CTA parameters comparing both groups.

	Group A, PT tracking	Group B, AO tracking	*p*-value
All patients*	n=70	n=73	
Female	n=40	n=35	
Male	n=30	n=38	0.18
Mean age ±SD in years	66.6±15.6	67.5±15.1	0.75
Major pulmonary embolism detected	n=17	n=22	0.46
Contrast injection parameters*			
Mean CM volume ±SD in ml	90.6±7.7	95.1±8.8	0.13
Mean CM injection rate ±SD in ml/s	3.2±0.5	3.4±0.4	0.47

* χ^2 or Student's t-Test.

embolism suspected on the basis of clinical symptoms. A total of 75 females and 68 males were included.

All 143 patients included had a mean age of 67.0±15.3 years (range 17–95 years). Examinations were performed with scanners used in clinical routine, with 16 rows (n=59), 64 rows (n=49), and 80 rows (n=35). Bolus tracking was positioned initially in the pulmonary trunk in 70 patients and later on in the descending aorta in 73 patients.

Multi-slice CTA

Three different multi-slice CT scanners were used in clinical routine: with 16 rows (Aquillion 16®, Toshiba Medical Systems, Neuss, Germany), 64 rows (Somatom Definition AS®, Siemens Healthcare Diagnostics, Eschborn, Germany), and 80 rows (Aquillion Prime®, Toshiba Medical Systems, Neuss, Germany). The settings were as follows: 120 kV tube voltage and modulated tube current.

If the patient was clinically stable and oriented, informed consent to a contrast-enhanced scan was obtained and an intravenous cannula (at least 20 GA, preferable 18 GA) was placed. Intubated emergency patients typically had a central venous catheter with a distal lumen of at least 18 GA capable of high-pressure injections.

After positioning of the patient in the CT scanner and acquisition of an axial slice slightly below the aortic arc, the region of interest (ROI) to track the CM bolus was set. After initially using the central pulmonary trunk (group A), we sequentially altered the clinical standard in favour of the descending aorta (group B) within the same slice.

The contrast agent used in all patients was Iomeprol at a concentration of 300 mg iodine per mL (Imeron 300®, Bracco Imaging, Konstanz, Germany). The injection flow was selected in concordance with the available central or peripheral catheter with a mean rate of 3.3 mL/s, and a flush with 30 mL of saline followed at the same rate. The volume of the contrast medium was adjusted to the patient's body mass, i.e. 1 mL/kg within a range of 70 mL to 150 mL.

When achieving a peak of at least 120 HU within the ROI, the CTA scan was initiated after a single breath-hold manoeuvre. Primary image reconstruction in all scanners included axial 5-mm and 1-mm slices. If required, secondary coronary or sagittal reconstruction was performed individually on a workstation (Infinitt® PACS, Infinitt Healthcare Europe, Frankfurt/Main, Germany).

Assessment of contrast enhancement

Subsequent image analysis for the study included the measurement of the minimum, mean and maximum density (HU) within a representative ROI set to the pulmonary trunk (primary variable) as well as the descending aorta. Additionally, presence of attenuation of at least 150 HU was used as a reference for diagnostic image quality [6].

Besides, we recorded the diagnosis of pulmonary embolism as well as other differential diagnoses.

Statistical analysis

All measurements were entered into a database using SPSS 21.0 (IBM®, New York, USA). Apart from descriptive statistics, primary analysis was performed using the Student's t-test for ROI measurements presented as means ± standard deviation (SD) and range.

A stepwise linear regression included the total volume of contrast medium administered, injection rate, patient age and sex to investigate potential cofactors for vascular enhancement.

The frequency of attenuation of at least 150 HU was compared using the Chi-Square test.

Results

Patients and scan details

A mean contrast medium volume of 92.9±8.6 mL (range 70–120 ml) was administered at a mean injection rate of 3.3±0.5 mL/s (range 2–4). In 39 patients (27%), a major pulmonary embolism compromising the main branches of

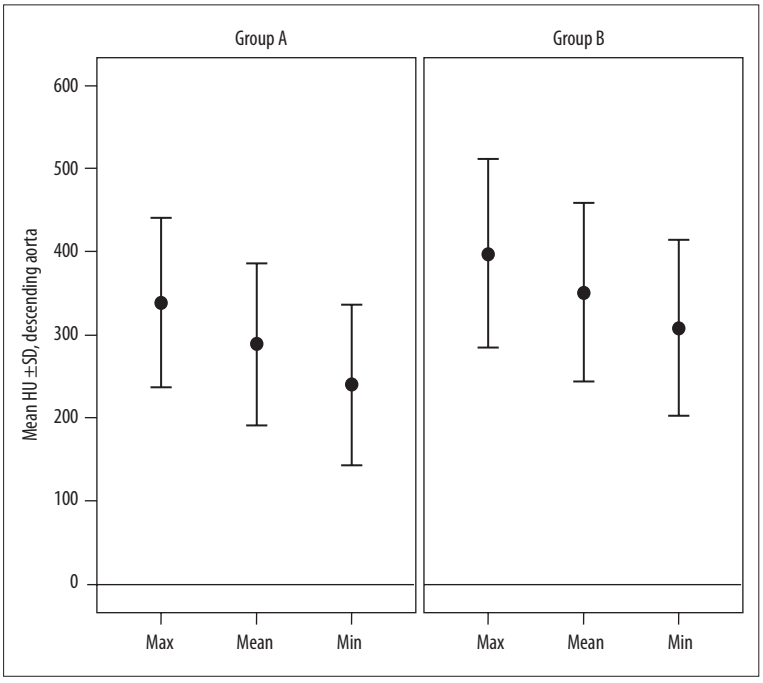

Figure 1. Enhancement of the pulmonary trunk depending on the bolus tracking spot.

the pulmonary arteries was diagnosed (group A, n=17 *vs.* group B, n=22, p=0.46). Other, relevant diagnoses for the clinical condition were found in 2 patients of group B (left atrial thrombosis, n=1; insufficiency of an aortic anastomosis after reconstruction surgery, n=1).

Gender and age showed no significant differences (p=0.18 and p=0.75, respectively) between both groups. Neither the injection rate (mean 3.2 *vs.* 3.4 mL/s) nor the contrast medium volume (mean 90.6 *vs.* 95.1 mL) had any significant influence on the density reached in the pulmonary trunk (p=0.47 and p=0.13, respectively) (Table 1). Furthermore, a higher contrast medium enhancement was not associated with a specific type of CT scanner (p=0.14).

Pulmonary trunk enhancement

Minimum, mean and maximum density within a representative ROI was measured for each patient and the means were calculated (Figure 1). The positioning of the tracking ROI within the pulmonary trunk (group A, n=70) resulted in a mean density of 289±97 HU with a mean maximum of 340±101 HU and a mean minimum of 241±95 HU. A significantly higher (p<0.001) density was achieved in the scans using the descending aorta (group B, n=73) as a tracking spot with a mean of 352±107 HU, a maximum of 398±113 HU and a minimum of 309±106 HU.

A mean enhancement below 150 HU was found in 2 scans of group A and 1 scan of group B. Within this small number of cases (2% of all patients), no significant difference in frequency was found (p=0.6).

Aortic enhancement

As tracking ROI in the pulmonary trunk (group A, n=70) leaves little time for the contrast medium bolus to reach the aorta, only a mean density of 197±66 HU was achieved (maximum 243±65 HU, minimum 150±71 HU). In contrast, the tracking spot in the descending aorta (group B, n=73) ensured a significantly higher enhancement (p<0.001) which was seen with a mean density of 301±90 HU (maximum 344±92 HU, minimum 258±91 HU) (Figure 2). Correspondingly, a significantly higher difference between the mean enhancement in the descending aorta and the pulmonary trunk was observed in group A (93 *vs.* 51 HU; p=0.008).

Higher opacification of the aorta compared to the pulmonary trunk was found in 22 examinations, occurring significantly more frequent after bolus tracking in the descending aorta (p=0.01). In total, 17 scans (23%) had an intermittent reduction of contrast medium enhancement of the pulmonary trunk in comparison to the aorta and central veins after bolus tracking in the descending aorta (group B) while only 5 exams (7%) showed such an effect after tracking in the pulmonary trunk (group A).

Regression analysis

Linear regression was used on potential cofactors influencing the enhancement of the pulmonary trunk (Table 2*)*. In the univariate step, only age (p<0.001) and scanner type (p=0.033) indicated a significant influence besides the bolus tracking position (study groups, p<0.001). Correlations revealed a significantly better contrast enhancement for patients at higher age (r=0.29) and suggested a dependence on the scanner type (r=0.18). Those initially significant factors underwent a multivariate regression analysis further on. Here, the scanner type failed to show any influence (p=0.34) as nearly all patients examined with an 80-row scanner belonged to group B and were thus linked to better results, as proven by a highly positive correlation (0.34, p<0.001).

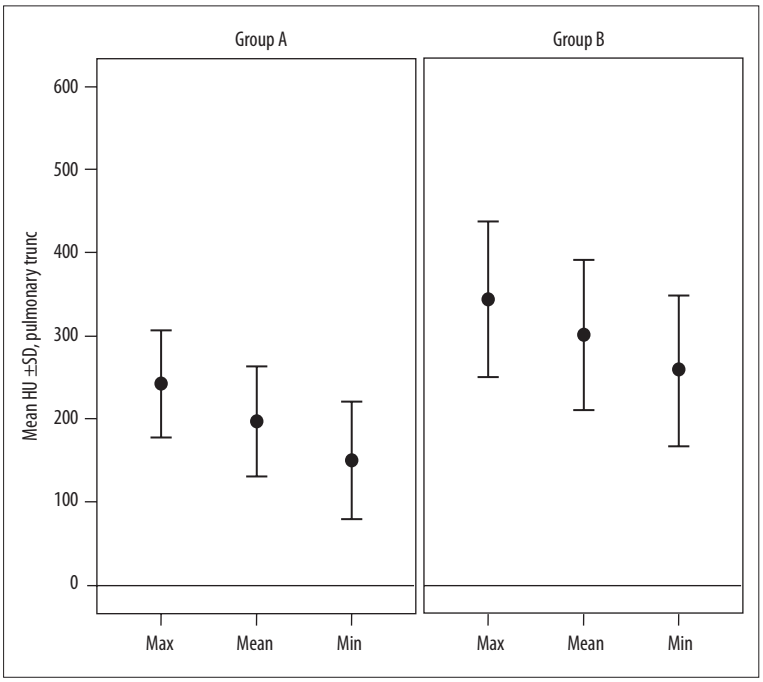

Figure 2. Enhancement of the descending aorta depending on the bolus tracking spot.

Table 2. Regression analysis, factors influencing the enhancement of the pulmonary trunk.

Regression analysis	N or mean ±SD	*r*-value**	*p*-value
Univariate analysis			
Sex			
Male	n=68		
Female	n=75	0.03	0.70
Age in years	67.0±15.3	0.29	<0.001*
CM volume in ml	92.9±8.6	–0.03	0.70
CM injection rate in ml/s	3.3±0.5	0.09	0.26
Bolus tracking			
PT tracking (Group A)	n=70		
AO tracking (Group B)	n=73	0.30	<0.001*
Scanner type			
16-row (Toshiba)	n=59		
64-row (Siemens)	n=49		
80-row (Toshiba)	n=35	0.18	0.033*
Multivariate analysis*			
Age		0.29	<0.001
Bolus tracking		0.18	0.002
Scanner type		0.30	0.34

* Including factors p<0.1 in the univariate analysis; ** correlation coefficient.

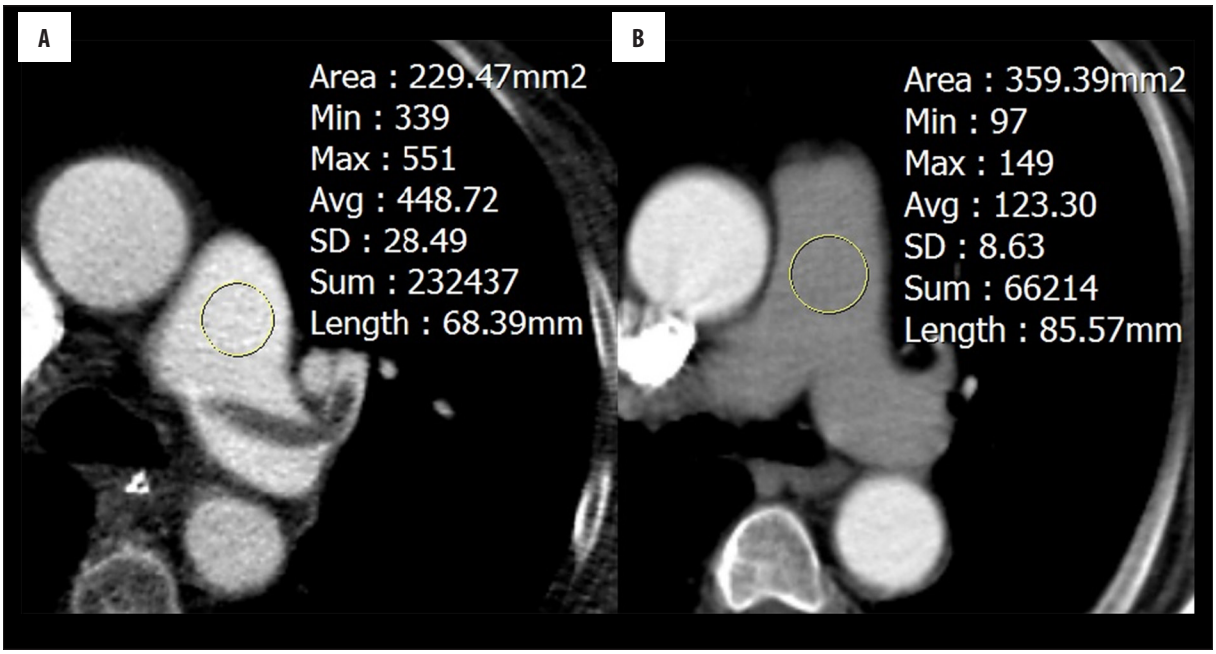

Figure 3. ROI measurement in the pulmonary trunk following bolus tracking in the descending aorta yielding sufficient opacification (**A**) with confirmation of a large thrombus in the left main pulmonary artery and upper lobar artery. Spared opacification in the pulmonary trunk after bolus tracking at this particular point (**B**) despite sufficient contrast enhancement in the aorta, mainly due to a deep inspiration.

In summary, only the tracking position ($p=0.002$) and the patients' age ($p<0.001$) were confirmed as factors influencing the pulmonary trunk enhancement.

Discussion

Value of CTA protocols

Suitable strategies for the pulmonary CTA are still being discussed. Conflicting cases, also seen in our study (Figure 3), emphasize the demand for further investigations.

Examinations with a relatively low, yet diagnostic contrast enhancement were actually found in both groups of our study. Regarding a substantial number of scans, our protocol alteration presented an improvement of diagnostic quality in comparison to the standard method of bolus tracking in the pulmonary trunk [1].

We also examined cases where pulmonary embolism was not the cause of the patient's condition while the additive diagnostic contrast enhancement of the aortic arch revealed a severe pathology (e.g. dissection, active bleeding after aortic valve replacement as demonstrated in Figure 4). Thus, our protocol offers a possibility to assess pulmonary or aortic pathologies in cases where not only the pulmonary embolism might be the cause of a certain clinical condition.

Another key difference to 'early' tracking positions in the right atrium or pulmonary trunk is the enhancement of the pulmonary veins which complicates identification of the pulmonary arteries but on the other hand enables assessment of venous and left atrial thrombosis.

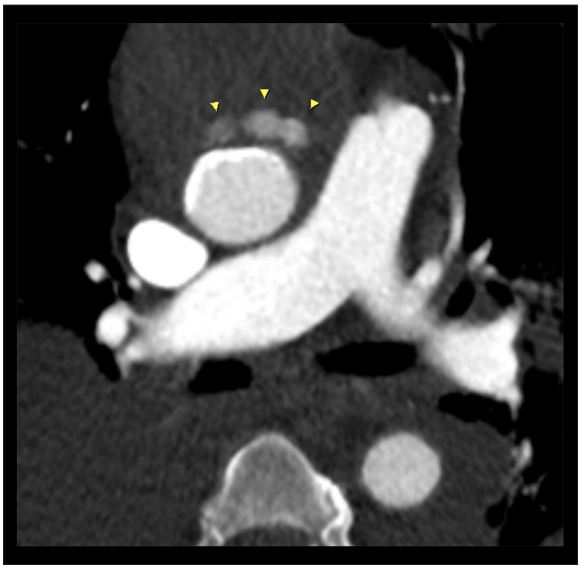

Figure 4. CTA using the descending aorta for bolus tracking in clinical routine. The patient was readmitted to the emergency department after aortic valve replacement demonstrating dyspnea and circulatory instability. Postoperative pulmonary embolism was suspected, yet an insufficiency of the aortic suture with consecutive hematoma was present as clearly shown by a diagnostic contrast in the thoracic aorta.

Moreover, our study investigated the relationship of vascular enhancement and key parameters of contrast medium application. The injection rate and CM volume, both confounding factors for vascular enhancement, had no significant influence on the opacification of the pulmonary vessels. Although the contrast medium administration was adjusted to the patient's body mass resulting in

a total volume of up to 120 mL (300 mg Iodine per mL), a reduction of contrast medium volume might be possible as seen in cases with only 70 ml of contrast medium applied, resulting in a high opacification. As already investigated by Hunsaker et al., 75 mL of contrast medium with a higher density of 370 mg Iodine per mL may be adequate [9]. Other authors suggest that even the application of only 40 mL with 320 mg Iodine per mL might be sufficient for a diagnostic pulmonary contrast enhancement [10].

Finally, bolus tracking in the descending aorta showed similar results in scanners with 16 to 80 physical rows which underlines its reliability in shorter and longer acquisition times.

Limitations

First of all, our study is a retrospective observation with sampling and indication bias. We could rule out differences in certain aspects of contrast media application (e.g. injection flow rate, overall volume), yet the vessel calibre and catheter position (e.g. antecubital, central) were not sufficiently reported in our database. Furthermore, a fixed amount of 30 mL saline was used to flush the contrast medium out of the afferent peripheral veins as well as central lines. Although no important influence on arterial enhancement in other regions is shown [11], the effect of saline flushes and different intravenous access devices on pulmonary artery enhancement is still unknown.

The positive influence of shallow breathing as reported by Renne et al. was neglected as all patients were examined during inspiration as a clinical routine [2]. It is described that a deep inspiration may lead to an increased flow of unopacified blood from the inferior vena cava to the right ventricle which results in an interruption of contrast medium enhancement in the pulmonary trunk [12]. A diminished enhancement of the pulmonary trunk compared to both aorta and central veins might therefore indicate an increased blood flow from the lower body as seen in 17 examinations (23%) after bolus tracking in the descending aorta. Regarding this substantial number, further studies using shallow breathing or expiration should investigate possible benefits of thoracic CTA.

As non-diagnostic scans appeared in only 3 cases (2% of all patients) both protocols presented in our report are at least consistent as regards diagnostic quality with previous studies [4]. When necessary, additional scans after diagnostic failure were conducted sufficiently by repeating the initial technique.

Interestingly, the regression analysis revealed a significant influence of the patient's age on the enhancement of the pulmonary trunk. Especially older patients showed better opacification, possibly due to a reduced physical capability for deep inspiration and therefore less frequent influence of the aforementioned mechanism of reduced contrast medium inflow to the right ventricle.

Conclusions

We believe that bolus tracking in the descending aorta with a relatively low trigger of 120 HU will achieve a high vascular opacification within the pulmonary vessels. Especially in the presence of other clinical conditions than pulmonary embolism, our alteration of the standard bolus tracking in the pulmonary trunk can yield a diagnostic benefit.

As the number of non-diagnostic scans remains the most important quality standard, further studies should investigate such protocol alterations in a prospective or even randomised setting.

Conflict of interest

The authors of this manuscript declare no relationships with any companies whose products or services may be related to the subject matter of the article.

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References:

1. Hach-Wunderle V: [Interdisciplinary S2 guidelines. Diagnosis and therapy in bone and deep venous thrombosis and pulmonary embolism]. Hamostaseologie, 2005; 25: 219–36; quiz 237–38 [in German]
2. Renne J, Falck CV, Ringe KI et al: CT angiography for pulmonary embolism detection: The effect of breathing on pulmonary artery enhancement using a 64-row detector system. Acta Radiol, 2014; 55(8): 932–37
3. Hallett RL, Fleischmann D: Tools of the trade for CTA: MDCT scanners and contrast medium injection protocols. Tech Vasc Interv Radiol, 2006; 9: 134–42
4. Stein PD, Fowler SE, Goodman LR et al: Multidetector computed tomography for acute pulmonary embolism. N Engl J Med, 2006; 354: 2317–27
5. Trivedi H, Foley WD: Contrast-induced nephropathy after a second contrast exposure. Ren Fail, 2010; 32: 796–801
6. Kay FU, Macedo AC, Chate RC et al: Reduction of poor contrast enhancement of the pulmonary artery in computed tomography angiography using an alternative respiratory maneuver. J Thorac Imaging, 2014; 29(2): 107–12
7. Gruettner J, Henzler T, Sueselbeck T et al: Clinical assessment of chest pain and guidelines for imaging. Eur J Radiol, 2012; 81: 3663–68
8. Ripley DP, Uddin A, Greenwood JP: CT triple rule-out examination: Higher radiation dose without clinical benefit. BMJ, 2013; 347: f5118
9. Hunsaker AR, Oliva IB, Cai T et al: Contrast opacification using a reduced volume of iodinated contrast material and low peak kilovoltage in pulmonary CT angiography: Objective and subjective evaluation. Am J Roentgenol, 2010; 195: W118–24
10. Wu CC, Lee EW, Suh RD et al: Pulmonary 64-MDCT angiography with 30 mL of IV contrast material: Vascular enhancement and image quality. Am J Roentgenol, 2012; 199: 1247–51
11. Takeyama N, Ohgiya Y, Hayashi T et al: Comparison of different volumes of saline flush in the assessment of perivenous artefacts in the subclavian vein during cervical CT angiography. Br J Radiol, 2011; 84: 427–34
12. Wittram C, Yoo AJ: Transient interruption of contrast on CT pulmonary angiography: Proof of mechanism. J Thorac Imaging, 2007; 22: 125–29