Lung Perfusion with Dual-energy Multidetector-row CT (MDCT):

Feasibility for the Evaluation of Acute Pulmonary Embolism in 117 Consecutive Patients[1]

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Rationale and Objectives. To investigate the accuracy of dual-energy computed tomography in the depiction of perfusion defects in patients with acute pulmonary embolism (PE).

Materials and Methods. One hundred seventeen consecutive patients with clinical suspicion of acute PE underwent dual-energy multidetector computed tomographic (CT) angiography of the chest with a standard injection protocol. Two radiologists evaluated, by consensus, the presence of endoluminal clots on (1) transverse "diagnostic" scans (contiguous 1-mm-thick averaged images from tubes A and B) and (2) lung perfusion scans.

Results. Seventeen patients showed CT features of acute PE, with the depiction of 75 clots within the lobar (n = 15), segmental (n = 43) and subsegmental (n = 17) pulmonary arteries. A total of 17 clots were identified as complete filling defects (ie, obstructive clots), located within segmental (12 of 17) and subsegmental (5 of 17) arteries. Fourteen of the 17 obstructive clots were seen with the concurrent presence of corresponding perfusion defects, whereas cardiac motion and/or contrast-induced artifacts precluded the confident recognition of perfusion abnormalities in the remaining two segments and one subsegment. Four subsegmental perfusion defects were depicted without the visualization of endoluminal thrombi within the corresponding arteries. Perfusion defects were identified beyond five nonobstructive clots.

Conclusion. Simultaneous information on the presence of endoluminal thrombus and lung perfusion impairment can be obtained with dual-energy computed tomography.

Key Words. Pulmonary arteries; acute pulmonary embolism; lung perfusion; dual-source computed tomography.

Since the introduction of multidetector-row computed tomography with high spatial and temporal resolution, computed tomographic (CT) angiography (CTA) has become the reference standard for diagnosing acute pulmonary embolism (PE), with sensitivity and specificity varying between 83% and 100% and 89 and 97%, respectively (1–3). Although the depiction of endoluminal clots within central pulmonary arteries is an easy task, it may be more difficult to identify filling defects within small-sized pulmonary arteries. This potential limitation of CTA could be theoretically compensated for by the detection of ischemic lung zones beyond the level of obstructive clots, provided both morphologic and functional information can be derived from the same data set. Moreover, despite the availability of high-resolution images of pulmonary

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arteries, CTA does not allow the analysis of lung perfusion impairment after acute PE, which is especially valuable in patients with underlying respiratory disease.

On the basis of single-source computed tomography, two approaches have been investigated for the detection of perfusion abnormalities, one using color-coded maps of lung density in humans (4–6) and the other a subtraction technique using pre- and postcontrast conventional CT images in experimental animal studies (7,8). Although both approaches have demonstrated the detectability of perfusion defects on computed tomography, the feasibility of these approaches in clinical practice have substantial limitations pertaining to scanning times and levels of radiation exposure to patients. The recent availability of dual-source computed tomography and the subsequent possibility to scan patients with dual energy offers another alternative for lung functional imaging. Preliminary experiences have shown that this technique could be applied to the analysis of lung perfusion, with radiation doses below the legally required levels (9). The purpose of this study was to investigate the detectability of perfusion defects with dual-energy computed tomography in the clinical context of acute PE.

MATERIALS AND METHODS

Population

Between January and June 2007, 136 consecutive patients with clinical suspicion of acute PE were referred to our institution to undergo chest CTA. Since the availability of dual-energy computed tomography in the Department of Radiology (ie, January 2007), all CTA indicated for suspicion of acute PE was performed with this technology because of its potential to provide not only the diagnostic information of standard CTA of the chest but also complementary information on lung perfusion for radiation doses below the legally required levels (calculated dose–length product [DLP] for dual-energy chest computed tomography, 229 mGy · cm [9]; reference dose value defined by the European Communities for routine chest computed tomography, 650 mGy · cm [10]). The study protocol was approved by our institutional ethics committee. No patient's informed consent was required to perform dual-energy computed tomography using a commercially available product. This retrospective analysis was possible with a waiver of patients' informed consent.

The exclusion criteria for dual-energy CTA were (1) an inability to maintain apnea for 12 to 15 seconds (ie, the average duration for the survey of the entire thorax using this technology) and (2) an inability to position the arms above the shoulders (data acquisition with the arms positioned alongside the body may cause artifacts at the level of the lower lung zones because of bony structures). Over this 6-month investigation, these criteria led to the exclusion of 18 patients. The final study group included 118 patients (73 men, 44 women; mean age, 57.4 ± 17.1 years; range, 21–88).

Scanning Protocol

CT examinations were performed using a Somatom Definition scanner (Siemens Medical Systems, Forchheim, Germany) in dual-energy mode using a scanning protocol similar to that in routine clinical practice at our institution. Tube voltages were set at 80 and 140 kV, with the tube current for the 80-kV tube adjusted to six times that of the 140-kV tube (ie, 330 and 50 mA, respectively) to compensate for the lower photon input at the lower voltage. Collimation was 32 × 0.6 mm with z-flying spot, enabling the reconstruction of 64 slices per rotation; the gantry rotation time was 0.33 seconds; and the pitch value was 0.5. The acquisitions were acquired from the top to the bottom of the chest. The injection protocol was similar to that for standard CTA performed with a single energy source using the same equipment (120 mL of 35% contrast agent at a flow rate of 4 mL/s). The scan was initiated by bolus tracking within the ascending aorta, with a threshold of 100 Hounsfield units (HU) to trigger data acquisition. These examinations were systematically obtained with an automatic angular (x, y) modulation of the milliamperage (Care Dose 2D; Siemens Medical Systems).

Reconstructed Scans

From each data set, 2 categories of images were reconstructed: the diagnostic scans and the lung perfusion scans. The diagnostic scans corresponded to contiguous 1-mm-thick transverse CT scans of the chest, generated from the raw spiral projection data of tubes A and B. The averaged images of both tubes (60% from the acquisition with tube A and 40% from the acquisition with tube B), used for diagnostic reading by the radiologists, consisted of lung and mediastinal images, reconstructed with standard reconstruction kernels (B20f for mediastinal images and B50f lung images), with a field of view adapted to the patient's size. Because the averaged images of both tubes had never been used for the depiction of endoluminal clots, the information provided by the diagnostic