Relation between pulmonary embolus volume quantified by multidetector computed tomography and clinical status and outcome for patients with acute pulmonary embolism

Kei Nakada · Takemichi Okada · Hisato Osada
Norinari Honda

Abstract

Purpose. The aim of this study was to determine whether pulmonary embolus volume (PEV) obtained with multidetector row computed tomography is related to clinical status and outcomes.

Materials and methods. Subjects comprised 48 patients with acute pulmonary embolism (PTE). PEV was measured by tracing the contours manually and compared between sets of two groups divided by clinical status. Correlations of PEV to blood gases and D-dimer levels were investigated. PEV was tested as a predictor of clinical probability of acute PTE using Wells’ criteria and as a predictor of survival after PTE by logistic regression analysis.

Results. The PEV was greater in groups with respiratory symptoms ($P < 0.001$), PTE as pretest clinical diagnosis ($P = 0.027$), and heart rate $>100$ beats/min ($P < 0.001$). It was smaller in subjects with concurrent malignancy ($P = 0.02$). It was correlated with PaCO$_2$ ($P = 0.04$, $\rho = -0.37$) and the D-dimer level ($P = 0.002$, $\rho = 0.46$); it was not a predictor of clinical probability of acute PTE or survival after PTE. The survival rate did not differ between groups with $PEV > 10$ ml (8/9) or $\leq 10$ ml (32/36).

Conclusion. The PEV in acute PTE may relate to the presence of respiratory symptoms, hypocapnia, and tachycardia. The PEV was smaller in patients with malignancy. It did not contribute to mortality in this study.

Key words Pulmonary embolus volume · Quantitative measurement · Pulmonary thromboembolism · MDCT

Introduction

Pulmonary thromboembolism (PTE) is a disease in which the pulmonary arteries become occluded by dislodged thrombi formed acutely or chronically in the venous system, usually from the deep veins of the lower limbs. It has typically been diagnosed using pulmonary angiography. However, the development of multidetector row computed tomography (MDCT) with narrow collimation and the ability to perform multiplanar image reformation via a workstation has led to computed tomography pulmonary angiography (CTPA) becoming the first choice for diagnosing PTE.

Comparison of the degree to which pulmonary artery obstruction correlates with patients’ outcome has previously been investigated using pulmonary angiography. Few reports have compared outcomes and the degree of obstruction according to MDCT. Qanadli et al. described a semiquantitative CT obstruction index for CT angiography. Wu et al. and Pech et al. compared survival rates and outcomes for acute PTE using the CT obstruction index. However, the results of those two studies are conflicting. The purpose of the present study was thus to test whether embolus volume, a quantitative index, is related to symptoms and patient outcomes. To the best of our knowledge, no previous studies have reported relationships between embolus volume and patient outcome.
Materials and methods

Study population

All study protocols were approved by the institutional review board. The need for written informed consent from the patients was waived owing to the retrospective design of the study. The radiological database from December 2005 to August 2008 identified 76 consecutive patients with acute PTE who were eligible for the study. Diagnosis was based on the presence of a filling defect in the pulmonary arteries on CTPA as identified by board-certified radiologists. Among the 76 examinations, 28 were excluded because of inappropriate section thickness (>3 mm) (n = 10), hydrothorax (n = 7), extensive consolidation/ground glass opacity (n = 3), pneumothorax (n = 1), extensive postoperative lung distortion (n = 1), multiple metastases (n = 1), and past history of PTE (n = 5).

Examinations from a total of 48 patients (16 men, 32 women; mean age 65 years; outpatients/inpatients 24/24) were thus entered into the study. History included cancer in 16 patients, collagen disease in 2, fracture in 1, benign tumor of the female pelvis in 2, inflammatory bowel disease in 1, and puerperium (≤6 weeks after delivery) in 8. Seven patients had a history of cardiopulmonary disease (postoperative state after thoracic aortic aneurysm, n = 1; arrhythmia, n = 2; coronary heart disease, n = 1; old myocardial infarction with coronary-aorta bypass graft, n = 1; hypertension, n = 1; and past history of local lung surgery, n = 1). Heart function was normal with the left ventricular ejection fraction >60% on echocardiography.

CT imaging

All CTPA-CT venography (CTV) studies were performed using either an 8- or 16-MDCT scanner (Light Speed Ultra, GE Yokokawa, Tokyo, Japan; or Emotion 16, Siemens, Erlangen, Germany). For both 8- and 16-MDCT scanners, the automatic bolus trigger was used, with a region of interest placed over the main pulmonary artery, triggering the scanner at an enhancement level (i.e., increase in CT value of 100 HU). CTV was obtained 150 s after injection of contrast material. For all studies, 100 ml of nonionic iodinated contrast medium (Iopamiron 370, Nippon Bayer Pharmaceuticals, Tokyo, Japan; or Omnipaque 300, Daiichi-Sankyo, Tokyo, Japan) was administered intravenously at an injection rate of 3 ml/s using a power injector. Omnipaque 300 was usually employed, but Iopamiron 370 was used for patients weighing over 65 kg.

Scanning parameters used for the 8- and 16-detector-row scanners were, respectively: detector-configuration 8.0 × 1.25 mm and 16 × 0.75 mm; section thickness 1.25 mm and 1.5 mm; pitch, 1.0 and 0.7; rotation time 0.5 and 0.8 s, with 120 mA/120 kVp, and 512 × 512 matrix. Reconstruction section thickness and intervals for scanners were 1.25 mm/0.625 mm (for 8-row MDCT) and 1.5 mm/1.0 mm (for 16-row MDCT) for diagnosis and multiplanar image reformation (MPR).

Images of CTV for the pelvis and lower extremities were reconstructed with 10-mm section thickness and 10-mm intervals. All images were reviewed and interpreted on a PACS workstation (Virtual Place Lexus; AZE, Tokyo, Japan) for image analysis and on a DICOM viewer (i-PACS viewer; Konica-Minolta, Tokyo, Japan) for diagnosis of PTE and deep vein thrombosis (DVT).

Measurement of embolus volume

The data set of 1.25 or 1.5 mm thick sections with an interval of 0.625 or 1.0 mm was transferred to the workstation. Volume measurement was performed using a window width of mean CT value of the main pulmonary artery and ascending aorta on the workstation. The window level was set 100–150 HU. After identifying a filling defect as far as visually recognizable down to subsegmental arteries, contours were defined manually on several transverse sections by one of the authors (K.N.). The workstation automatically interpolated contours between these selected sections and calculated the pulmonary embolus volume (PEV) based on the number of the voxels within the contours. If multiple emboli were found, the sum of each volume was used for the PEV. The defined contours were confirmed from multiple angles using the multiplanar reformation capability of the workstation.

We evaluated inter- and intraobserver reproducibility of the PEV measurement. For this analysis, we selected 20 patients based on random numbers between 1 and 48 generated by a software program (Ranpo, http://www.vector.co.jp/soft/win95/util/se123548.html). The PEV was measured on the 20 patients for defining intraobserver reproducibility by one of the authors (K.N.) 9 months after completion of the serial measurements on the 48 patients. Another author (T.O.) measured the PEV independently for defining interobserver reproducibility on a different set of 20 patients selected as described above.

Data analysis

Interobserver and intraobserver reproducibility was analyzed by linear regression analysis and Bland-Altman...