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Mosaic attenuation pattern in non-contrast computed tomography for the assessment of pulmonary perfusion in chronic thromboembolic pulmonary hypertension

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ABSTRACT

Background: Chronic thromboembolic pulmonary hypertension (CTEPH) is difficult to diagnose as patients rarely present with specific symptoms. However, a mosaic attenuation pattern (MAP) in chest computed tomography (CT) suggests CTEPH. Areas of increased attenuation are not always visible using default CT settings for the lung. Thus, we examined the utility of non-contrast CT imaging with new settings focusing on MAP (CT_{Mosaic}) for the assessment of pulmonary perfusion in patients with CTEPH. The regional perfusion defects visualized using CT_{Mosaic} and single-photon-emission CT with fusion of CT images (SPECT/CT) were compared.

Methods: Twenty-seven patients with CTEPH (20 women; aged 62.8±7.9 years) underwent imaging with non-contrast CT and SPECT/CT. We converted non-contrast mediastinal CT images into various CT window settings to identify the MAP, and the CT window setting that could most easily identify the MAP was defined as CT_{Mosaic}. We then scored and

Abbreviations: CO, cardiac output; CT, computed tomography; CTEPH, chronic thromboembolic pulmonary hypertension; CT_{Mosaic}, non-contrasted CT images in the CT window setting for the mosaic attenuation pattern; CTPA, computed tomography pulmonary angiography; dPAP, diastolic pulmonary arterial pressure; HU, Hounsfield units; MAP, mosaic attenuation pattern; mPAP, mean pulmonary arterial pressure; PAH, pulmonary arterial hypertension; PAP, pulmonary arterial pressure; PAWP, pulmonary artery wedge pressure; PE, pulmonary embolism; PEA, pulmonary thromboendarterectomy; PH, pulmonary hypertension; PVR, pulmonary vascular resistance; RHC, right-heart catheterization; SPECT, single-photon-emission computed tomography; SPECT/CT, single-photon-emission CT with fusion of CT images; V/Q, ventilation/perfusion; WL, window level; WU, wood units; WW, window width

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Non-contrast computed tomography

compared lung segments depending on the degree of perfusion on CT_{Mosaic} and SPECT/CT. *Results:* CT_{Mosaic} was identified as the CT window setting in which the window level was −800 Hounsfield units (HU), and the window width was 200 HU. Using CT_{Mosaic}, MAP was detected in 366 of 486 segments (75.3%). The agreement between CT_{Mosaic} and perfusion defects on SPECT/CT was 84.9%. Weighted kappa statistics demonstrated a good agreement between the two examinations (κ=0.605, 95% confidence interval, 0.502–0.707). *Conclusions:* The CT_{Mosaic} setting can easily identify an MAP in CTEPH patients. Therefore, this may be useful as a simple and cost-effective evaluation method for blood distribution in patients with CTEPH.

1. Introduction

Chronic thromboembolic pulmonary hypertension (CTEPH) is a type of pulmonary hypertension (PH) caused by both non-resolving thromboembolism of the pulmonary arteries and pulmonary vascular remodeling [1]. A ventilation/perfusion (V/Q) scan is used to differentiate CTEPH from other diseases. Single-photon-emission computed tomography (SPECT) can also reveal detailed images of blood distribution in the lungs. Moreover, SPECT together with computed tomography (CT) (SPECT/CT) offers improved diagnostic performance for the imaging of pulmonary embolism (PE) [2]. However, perfusion scintigraphy and SPECT/CT cannot always be conducted as they require the administration of a radioactive isotope and exposure to radiation; moreover, they are expensive. CT is widely performed in patients with respiratory symptoms and diseases, and CT pulmonary angiography (CTPA) is essential for the detection of thrombi in the pulmonary arteries of patients with CTEPH. CTPA can distinguish CTEPH from idiopathic pulmonary arterial hypertension (PAH), facilitate evaluation of underlying lung disease, and help to identify rare causes of PH [3].

A mosaic attenuation pattern (MAP) in the lungs revealed by CT imaging is characterized by areas of ground-glass attenuation with hyperperfused vascular segments, intermingled with areas of low attenuation with hypoperfused vascular segments. MAP is regarded as a typical finding of CTEPH and reflects the maldistribution of blood flow to the lungs [4,5]. Although an MAP can be observed in PH of various etiologies [6], pulmonary infiltrative disease, and small airway disease [7], MAP in a lung field is observed in 77%–100% of patients with CTEPH [8]. Furthermore, MAP has been correlated with pulmonary arterial pressure (PAP) and pulmonary vascular resistance (PVR), and is a prognostic indicator of pulmonary thromboendarterectomy (PEA) [8]; however, because an MAP can be very subtle in patients with CTEPH [4], it is sometimes overlooked.

We hypothesized that adjusting the CT window settings, such as the window width (WW) and window level (WL), would enable the clear visualization of an MAP using non-contrast CT. Therefore, the aims of this study were to identify a non-contrast CT setting that could be used to reliably evaluate blood distribution in patients with CTEPH, and to compare the findings of this setting with those of SPECT/CT.

2. Patients and methods

2.1. Study population

The study group comprised consecutive patients who underwent non-contrast CT, SPECT/CT, and right-heart catheterization (RHC), between November 2010 and June 2016, due to a high clinical suspicion of CTEPH. Diagnosis of CTEPH was confirmed by PEA. For comparison, patients with PAH who underwent non-contrast CT, SPECT/CT, and RHC during the same period were also included. This study was approved by the ethics committee of Chiba University, Japan (approval date: June 01, 2009; approval number: 826). Written informed consent was obtained from each patient before participation. Patients with complications, including severe chronic obstructive pulmonary disease [Global Initiative for Chronic Obstructive Lung Disease (GOLD) stages III–IV] and/or severe interstitial pneumonia and/or other lung diseases (e.g., infectious pneumonia), were excluded, as it is difficult to detect lung segments in these patients. In addition, patients in whom CT was performed more than 2 weeks apart from SPECT/CT were also excluded.

2.2. Computed tomography

All CT scan results were obtained retrospectively. Within 2 weeks of SPECT/CT, CT (Aquillion ONE, Toshiba Medical, Tokyo, Japan) was performed in the supine position at full inspiration. None of the patients were given contrast medium. The CT scan parameters were as follows: collimation, 0.5 mm; 120 kV (kV); 200 mA (mA, CT-auto exposure control); gantry rotation time, 0.5 s; beam pitch, 0.83. All images were reconstructed using a standard reconstruction algorithm with a slice thickness of 0.5 mm and a reconstruction interval of 0.5 mm. The voxel size was $0.63 \times 0.63 \times 0.5$ mm.

2.3. Perfusion single-photon-emission computed tomography with fusion of computed tomography images

After intravenous injection of 100–120 megabecquerels of technetium-99 m macroaggregated albumin (Techne, MAA Kit, FUJIFILM RI Pharma, Tokyo, Japan) and with each patient in the supine position, a whole-body scan and six-view images were acquired using a dual-head camera during tidal breathing. In all patients, SPECT/CT (Infinia Hawkeye 4, GE