Dual-energy CT Can Evaluate Both Hilar and Mediastinal Lymph Nodes and Lesion Vascularity with a Single Scan at 60 Seconds after Contrast Medium Injection

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Rationale and Objectives: The aim of this study was to investigate whether 80-kVp and weighted-average 120-kVp computed tomographic (CT) images scanned at 60 seconds after contrast material injection using a dual-source CT scanner could substitute for conventional 120-kVp images obtained at 30 and 100 seconds.

Materials and Methods: Eighty-three consecutive patients with suspected lung cancer were enrolled. Images were obtained in dual-energy mode (80 and 140 kVp) at 60 seconds and conventional 120-kVp mode at 30 and 100 seconds after contrast injection. The CT numbers of the pulmonary artery, pulmonary vein, hilar zone lymph nodes, and pulmonary lesions were measured. Contrasts between the pulmonary artery/pulmonary vein and lymph nodes and beam-hardening artifacts were visually evaluated using five-point and four-point scales, respectively. The degree of enhancement was evaluated on 30-second 120-kVp, 100-second 120-kVp, and 60-second weighted-average 120-kVp images.

Results: The mean differences in attenuation between the pulmonary artery/pulmonary vein and lymph nodes on the 30-second 120-kVp, 60-second 80-kVp, and 60-second weighted-average 120-kVp images were 184/155, 130/140, and 84/92 Hounsfield units, respectively (all *P* values <.001). The mean contrast scores for the hilar/mediastinal lymph nodes were 4.5/4.7, 3.7/4.2, 3.3/3.6, and 2.4/2.5 for these three and for 100-second 120-kVp images, respectively (all *P* values <.01). The mean artifact scores of the four images were 1.2, 3.4, 3.6, and 4.0, respectively. On 60-second weighted-average 120-kVp images, 55 of 60 lesions (92%) showed higher enhancement than on 100-second conventional 120-kVp images.

Conclusions: Dual-energy CT images scanned 60 seconds after contrast injection show excellent vessel–lymph node contrast and enhancement of lesions and can replace dual-phase scan protocols.

Key Words: Dual-energy CT; DECT; chest; enhanced CT; lymph nodes; injection time.

Evaluation of metastases to regional lymph nodes (LNs) is very important to predict the prognoses of patients with lung cancer and to establish treatment strategies. Contrast-enhanced (CE) computed tomographic (CT) imaging is the standard modality for this purpose. It has been reported that scanning soon after contrast material injection (eg, 30 seconds) is appropriate for clearly depicting the hilar and mediastinal LN (1–5). However, this is too early to evaluate the contrast enhancement of pulmonary lesions such as neoplasms, inflammations, and tuberculomas. At our institution, therefore, postcontrast scans have been performed twice: at an early phase (30 seconds) to evaluate the LNs and at a late phase (100 seconds) to evaluate the vascularity of lesions. However, it is desirable that both demands be fulfilled with a single scan.

With a dual-energy (DE) CT scanner, images at low and high tube voltages can be obtained at one time. Using a low tube voltage, the contrast between iodinated contrast medium and surrounding tissues becomes larger because iodine provides greater x-ray attenuation, caused by the increase in its relative atomic number ($Z = 53$) upon exposure to reduced x-ray energy (6–14). The photoelectric effect in x-ray attenuation increases at lower tube voltages, particularly in scans of structures with high effective atomic numbers. Because of Compton scattering, most x-rays interact to

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a lesser extent with soft tissue as tube voltage increases. Therefore, tube voltage reduction leads to an increase in the attenuation of calcified structures and iodinated contrast material as the photoelectric effect increases and Compton scattering decreases. Consequently, as the k-edge of iodine is closer to the reduced voltage, beam attenuation is increased, and higher attenuation readings are obtained (6–14). It has been reported that chest multi–detector row CT scans at low tube voltages can reduce radiation dose, with images showing improved contrast enhancement (11). On the other hand, CT images scanned at low tube voltages result in reduced quality by increasing the level of noise and artifacts. Increases in image noise with the use of lower tube voltages lead to a direct reduction in photon flux (7,10,14), but no significant differences have been reported in image noise and radiation dose between single-energy acquisition and weighted-average 120-kVp DE images generated from a combination of 80-kVp and 140-kVp images (15).

In a previous study (16), we examined DE CE CT imaging at a late phase (100 seconds) after contrast material injection and attempted to evaluate the contrast between pulmonary vessels and LNs and the enhancement of lesions simultaneously. We postulated that 80-kVp and weighted-average 120-kVp images on DE CE CT imaging obtained at 100 seconds might show increased contrast between pulmonary vessels and LNs and good enhancement of lesions. However, the enhancement of pulmonary vessels decreased according to the scan delay, and the contrast on late-phase 80-kVp images was not always adequate. Therefore, it was suggested that shorter scan timing would be appropriate to evaluate both pulmonary artery (PA)/pulmonary vein (PV)–LN contrast and enhancement of solid lesions. In this study, we investigated whether the DE CT images (80-kVp and weighted-average 120-kVp images) scanned with a shorter scan delay time of 60 seconds could substitute for the usual 120-kVp dual-phase scan protocol.

MATERIALS AND METHODS

Study Design

This was a prospective study to evaluate the optimal scan protocols for CE CT of the chest using a DE scanner. Eligibility criteria were as follows: (1) clinically suspected lung cancer on chest radiography, (2) no contraindication to iodinated contrast material administration, and (3) no history of thoracic surgery. The study period was set as April 2009 to July 2010. The local institutional review board approved the study, and informed consent was obtained from all patients before the examination.

Patients

During the period, 83 eligible patients were accrued, 62 men and 21 women. Their age ranged from 39 to 84 years, with a median age of 68 years. Their disease proved to be primary lung cancer in 61, lung metastases in three, inflammatory disease in 15, and hamartomas in four. Sixty and 23 patients had solid pulmonary lesions and partly solid pulmonary nodules on CT imaging, respectively. All patients completed scheduled scans without complications.

CT Scanning

CT examinations were performed using the DE mode of a Somatom Definition (Siemens Medical Solutions, Forchheim, Germany) with a 512 × 512 pixel matrix, 14 × 1.2 mm collimation, tube current–time products of 116 mAs at 140 kVp and 493 mAs at 80 kVp, a pitch of 0.5, and a rotation time of 0.33 seconds. The images were reconstructed into slices 3 mm in thickness and interval using a D30f kernel that was suitable for interpreting soft tissues, including hilar and mediastinal structures. After performing unenhanced scans, 100 mL of a 300 mg I/mL nonionic iodinated contrast material and 50 mL of saline were simultaneously injected into an antecubital vein at rates of 2 and 1 mL/s, respectively, using a dual injector. Images were obtained in conventional 120-kVp mode at delays of 30 seconds (early phase) and 100 seconds (late phase) and DE (80 and 140 kVp) mode at a delay of 60 seconds (intermediate phase). By combining the 140-kVp and 80-kVp data with a weighting factor of 7:3, weighted-average images (ie, calculated imitation 120-kV images) was automatically generated. These weighted-average images were the reference images for DE-mode scanning. We set the dose for DE scanning at 60 seconds to be similar to that of the 30-second and 100-second conventional scans by fixing the standard deviation of CT attenuation of the images.

Evaluation of Images

Endpoints of this study were the differences in CT numbers between the PA or PV and LNs and in scores of visual evaluation of contrast between them, the degree of enhancement of the lesions, and artifacts. The CT numbers of pulmonary lesions among the 30-second conventional, 60-second weighted-average, and 100-second conventional images were also compared to assess the enhancement of the lesions on 60-second 80-kVp images. Hilar and mediastinal structures on transaxial images were evaluated using a Totoku 2M viewer (Totoku Electric Co, Ltd, Tokyo, Japan). As an objective evaluation, CT numbers of the pulmonary vessels and LNs were measured on the four images; a region of interest of 3 to 10 mm in diameter was placed in the slice with minimal beam-hardening and motion artifacts from pulsation on the bilateral PA just distal to the pulmonary trunk, inferior PV just distal to the left atrium, and bilateral hilar zone (main bronchial and interlobar) LNs, and two measurements were averaged. LNs < 3 mm in short-axis diameter were excluded. The evaluated hilar zone LNs were 3 to 20 mm in short-axis diameter (n = 327), and most of the hilar zone LNs were not enlarged and were <10 mm