Dual-energy CT in the assessment of mediastinal lymph nodes: Can virtual nonenhanced images replace true nonenhanced images?

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Authors: Y. Kim, M. J. Choi, S. W. Lee; Seoul/KR
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Purpose

To quantitatively compare virtual nonenhanced (VNE) data sets derived from dual-energy CT with true nonenhanced (TNE) data sets in assessing the mediastinal lymph nodes, and to evaluate the factors effecting the difference between VNE and TNE images in CT numbers.
Methods and Materials

Patient Selection

CT scans of 74 patients who had benign or malignant mediastinal or hilar lymph nodes were enrolled in this study. A total of 32 men and 42 women were enrolled, with a mean age of 63.3 ± 12.5 years (mean ± standard deviation (SD); age range, 40-87 years). The diagnosis of malignant or benign lymph nodes was confirmed using a histopathologic examination in patients who underwent surgical resection (n = 5) or clinical and CT follow-up (n = 69) with or without treatment.

Exclusion criteria included the following: differential diagnosis between malignancy and benignity could not be obtained with histopathologic examination or clinical and CT follow-up; exact measurement of CT numbers of nodes using the same area of region of interest (ROI) was not available in a three-image set of TNE, VNE, or CE images due to the small size of lymph node or artifacts or a different level of CT scanning; and definite calcified lymph nodes containing nodular or laminated calcification or lymph nodes showing a CT number of more than 100 HU on TNE imaging.

CT Examination

All CT scans were obtained using a dual-source multi-detector row scanner. Scanning parameters were as follows: a detector configuration of 128 × 0.6 mm, 120 kVp, 100 mAs (effective), a pitch of 1.2, and a gantry rotation time of 0.5 sec.

Contrast-enhanced CT scans were obtained using a dual-energy technique after intravenous injection of 100 mL of a nonionic contrast agent (iohexol, Bonorex 350; CMS, Seoul, Korea) at a rate of 2.3 mL/sec with power injection. CT scanning was started just after contrast injection without a delay time, which is the protocol used for routine chest CT at our hospital. Dual-energy CT scans were acquired using two tubes at 80 kVp and 140 kVp, with tube currents of 205 mAs and 87 mAs, respectively, a pitch of 0.55, and a gantry rotation time of 0.28 sec. With both tubes, online dose modulation (Care DOSE 4D; Siemens Medical Solutions) was used.

For all patients, data of dual-energy CT were transferred to a workstation (MultiModality Workplace; Siemens Medical Solutions), and VNE image data were calculated using a modified prototype of the liver VNC application class of Syngo Dual Energy (Siemens Medical Solutions).

Nodal Assessment on CT Scans

In the cases diagnosed as malignant lymph nodes based on clinical and CT follow up, lymph nodes were considered to be positive for malignancy when mediastinal nodes
had a short-axis diameter ≤10 mm, hilar nodes had a maximum diameter ≤10 mm in any direction, and both showed changes in size on follow-up CT scans according to the treatment.

CT images were analyzed on computer monitors using PACS. TNE, VNE, and CE images were loaded onto the PACS monitor simultaneously, and a chest radiologist placed circular ROIs in an area as large as possible within the same lymph nodes on three series using axial CT images obtained with the standard mediastinal window settings (window level, 30 HU; window width, 400 HU). ROIs of similar sizes were placed at the same areas in the nodes on three images (Figs. 1 and 2). CT numbers were measured three times, and the mean value of three measurements was used for data analysis.

The difference in CT numbers between TNE and VNE images was defined as the difference value in each node: difference value = [CT number on TNE images - CT number on VNE images].

The net contrast enhancement of lymph nodes was measured: net contrast enhancement = [CT number on CE images - CT number on TNE images].

**Data Analysis and Statistics**

Comparison of the CT number of lymph nodes between TNE and VNE images was performed in the benign and malignant groups, respectively. The relationships among difference values between TNE and VNE images, net contrast enhancement, and CT numbers on TNE images were analyzed.
**Fig. 1:** FIGURE 1. Benign reactive lymph node hyperplasia. Right lower paratracheal lymph node shows high attenuation (76 HU) on true non-enhanced imaging (A), but lower attenuation (57 HU) on virtual non-enhanced imaging (B).

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**Fig. 2:** FIGURE 2. Metastatic lymph node in a patient with lung cancer. Right interlobar lymph node shows 41 HU on true non-enhanced imaging (A), but higher attenuation (52 HU) on virtual non-enhanced imaging (B).

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Results

A total of 201 lymph nodes were sampled. The mean sample number of lymph nodes per patient was 2.5 ± 1.2 for the benign group and 3.0 ± 1.7 for the malignant group. A total of 41 patients (benign reactive lymph nodes, n = 39; sarcoidosis, n = 1; tuberculous lymphadenitis, n = 1) had 101 benign lymph nodes (Fig. 1), and 33 patients (lung cancer, n = 20; metastasis, n = 13) had 100 malignant lymph nodes (Fig. 2). Patients with metastatic lymph nodes had breast cancer (n = 13), renal cell carcinoma (n = 2), colon cancer (n = 1), thymic carcinoma (n = 1), tongue cancer (n = 1), and soft plate cancer (n = 1) as a primary cancer.

Comparison between CT Numbers Measured on TNE and VNE Images

CT numbers were significantly lower on VNE than on TNE images (45.8 ± 12.9 HU (VNE) vs. 59.4 ± 19.5 HU (TNE); p = 0.000) in benign lymph nodes, whereas CT numbers were slightly higher on VNE than on TNE images (43.5 ± 11.1 HU (VNE) vs. 40.4 ± 9.3 HU (TNE); p = 0.00) in malignant lymph nodes.

Based on 40 HU of lymph nodes on TNE images, the CT number of benign lymph nodes on VNE images compared with that on TNE images showed a reverse tendency as follows. In lymph node groups with ≥40 HU on TNE images (n = 84), the CT number on VNE images was significantly lower (64.9 ± 16.6 HU (TNE) vs. 47.3 ± 13.3 HU (VNE); p = 0.000), whereas in lymph node groups with <40 HU on TNE images (n = 17), the CT number on VNE was significantly higher (32.5 ± 6.0 HU (TNE) vs. 38.5 ± 7.3 HU (VNE); p = 0.002). The graph in Fig. 3B, in which the difference value of each lymph node was constructed according to the CT number on TNE images, shows that most lymph nodes ≥40 HU on TNE images had a positive difference value (16.9 ± 16.0 HU), whereas most lymph nodes <40 HU had a negative difference value (-4.36 ± 5.5 HU) (Fig. 3B). For malignant lymph nodes, no apparent difference was found in the difference value based on 40 HU on TNE images (Fig. 3C).

Relationship among the Difference Value, CT Number on True Non-enhanced Images, and Net Contrast Enhancement.

The difference value between TNE and VNE images (i.e., CT number on TNE images - CT number on VNE images) and the CT number on TNE images showed a strong positive correlation in total (correlation coefficient, 0.750; p = 0.000) and benign (correlation coefficient = 0.756, p = 0.000) lymph node groups and a weak positive correlation in malignant lymph node groups (correlation coefficient = 0.352, p = 0.000) (Fig. 3).

Regarding the relationship between the difference value and net contrast enhancement, negative correlations were noted in all total (correlation coefficient, #0.554; p = 0.000),
benign (correlation coefficient, \#0.667; \( p = 0.000 \)), and malignant (correlation coefficient, \#0.384; \( p = 0.000 \)) lymph node groups (Fig. 4).

**Radiation Dose**

The radiation dose (dose-length product) of CT scans, including pre- and post-enhanced CT scans, was 378 ± 36 mGy cm (pre-enhanced CT scan, 186.8 ± 28.7 mGy cm; post-enhanced CT scan, 192.8 ± 38.5 mGy cm)
Fig. 3: FIGURE 3. Analysis of the relationship between the difference value (CT number on TNE images - CT number on VNE images) and the CT number on TNE images. Positive correlations were noted in all total (A) (correlation coefficient, 0.750; p = 0.000), benign (B) (correlation coefficient, 0.756; p = 0.000), and malignant (C) (correlation coefficient, 0.352; p = 0.000) lymph node groups.

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Fig. 4: FIGURE 4. Analysis of the relationship between the difference value (CT number on TNE images # CT number on VNE images) and net contrast enhancement. Negative correlations were noted in all total (A) (correlation coefficient, #0.554; p = 0.000), benign (B)(correlation coefficient, #0.667; p = 0.000), and malignant (C) (correlation coefficient, #0.384; p = 0.000) lymph node groups.
Conclusion

VNE imaging may not replace TNE imaging for evaluation of mediastinal lymph nodes, because lymph nodes with high attenuation on TNE images show significantly lower CT numbers on VNE images.
References


