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The influence of inspiratory effort and emphysema on pulmonary nodule volumetry reproducibility

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AIM: To evaluate the impact of inspiratory effort and emphysema on reproducibility of pulmonary nodule volumetry.

MATERIALS AND METHODS: Eighty-eight nodules in 24 patients with emphysema were studied retrospectively. All patients had undergone volumetric inspiratory and end-expiratory thoracic computed tomography (CT) for consideration of bronchoscopic lung volume reduction. Inspiratory and expiratory nodule volumes were measured using commercially available software. Local emphysema extent was established by analysing a segmentation area extended circumferentially around each nodule (quantified as percent of lung with density of −950 HU or less). Lung volumes were established using the same software. Differences in inspiratory and expiratory nodule volumes were illustrated using the Bland–Altman test. The influences of percentage reduction in lung volume at expiration, local emphysema extent, and nodule size on nodule volume variability were tested with multiple linear regression.

RESULTS: The majority of nodules (59/88 [67%]) showed an increased volume at expiration. Mean difference in nodule volume between expiration and inspiration was +7.5% (95% confidence interval: −24.1, 39.1%). No relationships were demonstrated between nodule volume variability and emphysema extent, degree of expiration, or nodule size.

CONCLUSION: Expiration causes a modest increase in volumetry-derived nodule volumes; however, the effect is unpredictable. Local emphysema extent had no significant effect on volume variability in the present cohort.

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Introduction

Pulmonary nodule volumetry applications have played a central role in the nodule management algorithms of several European lung cancer screening trials.[1–4] Semi-automated nodule volumetry offers benefits compared to manual electronic calliper diameter measurements as it is more reproducible.[5,6] Superior reproducibility is of paramount importance if true nodule growth is to be distinguished from spurious measurement imprecision. Furthermore, volumetry can be used to calculate nodule volume doubling times (VDT) on serial computed tomography (CT) examinations. Recently, volumetry and VDT have been integrated into clinical guidelines for the investigation of pulmonary nodules issued by the British Thoracic Society.[7]

Reproducible pulmonary nodule volumetry requires successful nodule segmentation, a process that relies, in part, on predefined density thresholds.[8] Segmentation is, therefore, potentially affected by the density of the lung tissue surrounding a nodule, a factor that is in turn inevitably influenced by inspiratory level and the presence of any emphysema adjacent to the nodule[9]; however, there are few data concerning the effects of inspiratory effort and local emphysema on nodule volumetry reproducibility. Furthermore, the limited data that are available, particularly regarding inspiratory effort, are conflicting,[10–12] and this has resulted in calls for further clarification.[13]

The aim of the present study was to assess inter-scan variability by testing the ability to detect the absence of nodule growth between two scans performed on the same day, in which any perceived difference in nodule volume can be attributed to imperfect reproducibility (i.e., inter-scan variability). Specifically, the effect of inspiratory effort on volumetry reproducibility was investigated by comparing nodule volumes on full-inspiratory versus end-expiratory CT images. Whether the degree of variability was influenced by the presence of emphysema local to the nodule was also investigated.

Materials and methods

Patient selection

This retrospective study had institutional review board approval and patient consent was not required. Baseline full-inspiratory and end-expiratory CT, undertaken on the same attendance for patients with severe emphysema under consideration for bronchoscopic lung volume reduction as part of a bronchoscopic lung volume reduction trial, were reviewed retrospectively. CT examinations in which lung nodules were reported were selected for the study. The final study population comprised 88 nodules in 24 patients with emphysema (mean age: 64 years; range: 49–79 years; 20 [83%] male).

Image acquisition

Full-inspiratory and end-expiratory examinations were undertaken on the same attendance. Patients remained supine on the scanner between acquisitions. All scans were performed without contrast media on a 128-detector-row CT system (Somatom Definition Edge, Siemens, Erlangen, Germany). CT examinations were acquired using 120 kVp tube voltage, 70–110 mAs according to body habitus (patients weighing $<$50 kg received 70 mAs; 50–90 kg received 90 mAs; $>$90 kg received 110 mAs) with dose modulation turned off, 0.5 s rotation time, 128$\times$0.6 mm collimation, pitch of 0.8. Images were reconstructed using a medium kernel (B40f), 1 mm section thickness, and 1 mm increment.

Nodule volumetry

CT images were analysed by a radiologist using the Oncology package on SyngoVia version VA30A (Siemens, Erlangen, Germany). Using the inspiratory axial dataset, non-calcified solid pulmonary nodules identified in the CT report were confirmed and measured by a radiologist and any additional solid non-calcified nodules $\geq$15 mm ^{3} were also recorded and measured. Nodules were individually recorded by section number and lobe. Nodule size was evaluated using semi-automatic nodule volumetry, requiring the radiologist to place a “seed point” within the nodule. This provided an inspiratory nodule volume (mm^3). Corresponding nodules were identified on the expiratory series and expiratory nodule volumes were similarly calculated. Nodules where segmentation was judged to be unsatisfactory on inspiratory CT were excluded.

Local emphysema calculation

Local emphysema calculation was performed by a radiologist using the inspiratory dataset, also employing SyngoVia Oncology package (Siemens, Erlangen, Germany). A segmentation region of interest was manually drawn

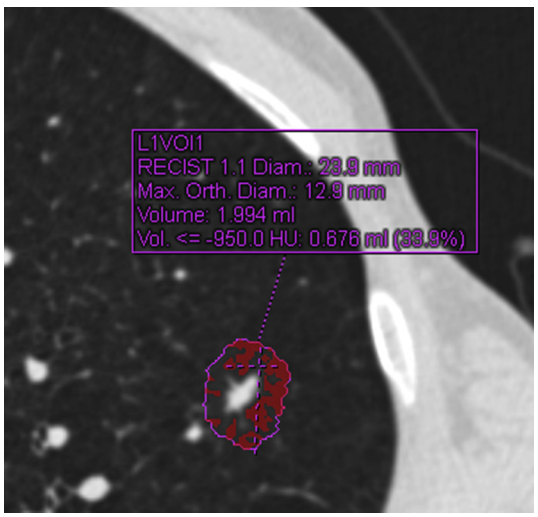

Figure 1 Local emphysema extent was calculated by extending a segmentation area circumferentially around each nodule by approximately 1 cm, and using the “Hounsfield Unit Statistics” function within the Oncology application on SyngoVia Oncology package (Siemens, Erlangen, Germany) to calculate the percentage of surrounding lung with density of −950 HU or less.

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