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**Four-dimensional multislice helical CT of the lung: Comparison of retrospectively gated and static images in an ex-vivo system**

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Motion-adapted radiotherapy with gated irradiation or tracking of tumor positions requires dedicated imaging techniques such as four-dimensional (4D) helical computed tomography (CT) for patient selection and treatment planning. The objective was to analyse the image quality of respiratory-gated 4D helical CT and to evaluate the reproducibility of spatial information for small objects on 4D CT using computer-assisted volumetry of lung nodules in a ventilated ex vivo system.

Five porcine lungs were inflated inside a chest phantom and prepared with 55 artificial nodules (mean diameter,  $8.4 \text{ mm} \pm 1.8$ ). The lungs were respirated by a flexible diaphragm and scanned with 40-row detector CT (collimation:  $24 \times 1.2 \text{ mm}$ ; pitch: 0.1; rotation time: 1 s; slice thickness: 1.5 mm; increment: 0.8 mm). Dynamic images (regular respiration at 8/min) and static images (w/o respiration) at 0/25/50/75 and 100% of maximum inspiration were reconstructed. Image quality on multi-planar reformations was evaluated. Partial projection artifacts, stepladder-artifacts and noise were compared for upper, middle and lower parts of

the lung and different respiratory phases (scores 0–3 for absent, minimal, moderate and diagnostically relevant artifacts). The reproducibility of nodule volumetry (three readers) was assessed using the variation coefficient (VC).

Partial projection effects were limited to dynamic scans (mean score 1.33). Stepladder artifacts predominated in dynamic series compared to static series (mean score 0.55 versus 0.1;  $p < 0.001$ ). Image noise was not related to lung motion (mean scores 0.68–0.81). All artifacts predominated close to the diaphragm compared to the upper and middle parts of the lung ( $p < 0.001$  to  $p = 0.02$ , respectively). Partial projection and stepladder artifacts were less in endinspiration and end-expiration than within the respiration ( $p < 0.001$  and  $p = 0.17$ , respectively). Diagnostically relevant artifacts were noted 9 times (9/9 close to diaphragm, 7/9 partial-projection). The mean volumes from the static and dynamic inspiratory scans were equal (364.9 and 360.8 mm<sup>3</sup>, respectively,  $p = 0.24$ ). The static and dynamic end-expiratory volumes were slightly greater (371.9 and 369.7 mm<sup>3</sup>, respectively,  $p = 0.019$ ). The VC for volumetry (static) was 3.1%, with no significant difference between 20 apical and 20 caudal nodules (2.6% and 3.5%,  $p = 0.25$ ). In dynamic scans, the VC was greater (3.9%,  $p = 0.004$ ; apical and caudal, 2.6% and 4.9%;  $p = 0.004$ ), with a significant difference between static and dynamic in the 20 caudal nodules (3.5% and 4.9%,  $p = 0.015$ ). This was consistent with greater motion-related artifacts and image noise at the diaphragm ( $p < 0.05$ ). The VC for interobserver variability was 0.6%.

Even in ideal realistic conditions, helical 4D-CT produced tolerable artifacts which could be overcome by radiologists. Residual motion-related artifacts had only minimal influence on volumetry of small solid lesions. This indicates a high reproducibility of spatial information for small objects in low pitch helical 4D-CT reconstructions.