Purpose: A growing number of early-stage lung malignancies identified in low-dose CT raises a challenge for thoracic surgeons to accurately localize subpalpable nodules, increasing the potential for erroneous resection or unnecessarily large margins. We investigate combining minimally invasive video-assisted thoracic surgery (VATS) with intraoperative image guidance using a mobile C-arm for cone-beam CT (CBCT).

Method and Materials: Studies were performed on a C-arm prototype equipped with a flat-panel detector enabling high-quality CBCT. Lung nodule detectability was assessed in three pig models using solid lung nodules (~50 HU) simulated by ~6 mm polyethylene spheres inserted into the lung. Scans were performed at inhale, exhale, and complete deflation to assess visualization of tumors within the deflated lung and identify minimum-dose limits. A cadaveric torso provided first experience in CBCT guidance of VATS in cooperation with a thoracic surgeon. Experiments employed an in-house guidance system combining pre- and intraoperative images, surgical planning, trackers, and thoracoscope video augmentation.

Results: Simulated lung nodules were conspicuous in low-dose scans (0.41 mSv) for the inhale and exhale states by virtue of high contrast within the air-filled parenchyma. Nodule visibility in the deflated lung required higher dose (1.63 mSv) for confident visualization and suggested a valuable means of intraoperative localization. For the cadaveric torso, preoperative CT and planning were registered to CBCT using deformable registration methods, with error ~3-10 mm in soft-tissue registration error. Real-time tracking of thoracoscopy allowed valuable augmentation of the video stream with image and planning data.

Conclusion: C-arm CBCT integrated with tracking, registration, and video augmentation promises to advance the safety and precision of VATS, showing potential for improved tumor targeting and normal tissue sparing. CBCT image quality was sufficient for direct visualization of solid nodules in the inflated and collapsed lung, and registration with thoracoscopic video provided significant improvement to visualization and workflow.

Funding Support, Disclosures, and Conflict of Interest:

Research supported by National Institutes of Health R01-CA-127444 and collaboration with Siemens Healthcare (Erlangen Germany).