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Image-guided Motion Management

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I recently cared for a 55-year-old man we'll call Mr. Franklin. At the outset, he had respiratory wheezing, shortness of breath, and a non-productive cough. Chest x-ray detected both a 4 cm right upper lobe lung lesion and a 2 cm right lower lobe lung lesion. A 2-[18F] fluoro-2-deoxy-D-glucose positron emission tomography (FDG-PET) and computed tomography (CT) scan declared hypermetabolic activity in the right upper lobe lung lesion (standard uptake value [SUV] 10.3) and in the right lower lobe lung lesion (SUV 8.0). Navigational bronchoscopy with biopsy confirmed squamous cell carcinoma. After multidisciplinary conference attended by thoracic surgeons, medical oncologists, and radiation oncologists, definitive radiochemotherapy treatment was recommended for Mr. Franklin. Radiation was to target the two lung lesions independently. Subsequent radiation therapy planning brought up image-guided motion management,a topic for commentin this issue of the Journal of Radiology.

Image-guided motion management accounts for intrafraction and interfraction variability in tumor motion occurring because of respiration, heartbeat, swallowing, and rectal and bladder fillings. Mr. Franklin's two lung lesions present key challenges for respiratory motion management.

When simulating Mr. Franklin in radiation treatment position on a fast multislice scanner, tumor image acquisition occurs during an arbitrary respiratory cycle phase. Captured images project'instantaneous' tumor positional information, and perhaps not true tumor hysteresis resulting from quiet breathing. One method of seizing patient-specific tumor motion throughout the entire respiratory cycle utilizes synchronized image acquisition to generate 4D CT data sets [1]. Here, multiple individual CT data sets, usually 10 sets for 10 respiratory phases, are acquired, reconstructed for phase of the respiratory cycle, and contoured for gross tumor volume (GTV). Newer post-imaging software may reconstruct a Maximum Intensity Projection (MIP) 4D CT data set [2]. The MIP displays the most intense voxel values for a target obtained during the entire breathing cycle of the 4D CT scan. A single MIP data set can be used to contour the image-guided internal target volume (ITV), rather than contouring on the usual 10 CT data sets. In Mr. Franklin's case, the right upper lobe lung lesion was simulated using a 4D CT scan. Radiation planning allowed comparison of the MIP ITV to the actual position of the GTV at 0% and 50% respiratory cycle extremes; the MIP ITV approximated the GTV extremes well. Radiation treatment planning was done using the Average Intensity Projection (AIP) CT data set. For this case, the planning tumor volume was the MIP ITV with 5-millimeter expanded margins.

Mr. Franklin's right lower lobe lung lesion underwent radiation therapy planning using a multiphase inspiratory/expiratory breath-hold CT scan acquired on a separate simulation day. Here, free-breathing, end-inspiration, and end-expiration breath-hold images were obtained. Post-imaging software allowed fusion of GTV contours encompassing the 'extremes' of target motion in the respiratory cycle into a single image-guided ITV [2]. Radiation treatment planning was conducted on the free-breathing CT data set, with the ITV expanded all around by 5-millimeters for a planning tumor volume.

As you can see, image-guided motion management is labor intensive for the patient and the radiation therapy team. To accurately account for the respiratory motion of Mr. Franklin's two lung lesions, multiple CT data sets were needed-all of which expose him to small-scale radiation dose from the image acquisition process [3]. Alternative techniques for image-guided motion management are needed. One solution may be FDG-PET images superimposed upon CT images to create an image-guided ITV [4]. This approach assumes that the time-dependent detection of FDG tracer sequestered in targeted cancer cells can be used as a surrogate for patient-specific tumor motion. See, FDG-PET images are taken during quite breathing over a 3 to 5 minute bin time. The resultant image reports a FDG signal smear approximating tumor hysteresis during the respiratory cycle. But what image threshold settings for the FDG-PET signal should be used to define the ITV? A 40% threshold has been studied previously [4]. In Mr. Franklin's case, the 40% threshold ITV captured the same respiratory motion as the 4D scan did for the right upper lobe lung lesion and as the inspiratory/expiratory breath-hold scan did for the right lower lobe lung lesion. The lightning rod moment in this single case may be that FDG-PET images adequately reproduce tumor hysteresis, lower image acquisition-related radiation dose exposure, and aid radiation therapy planning more so than 4D CT or multiphase inspiratory/expiratory breath-hold scans. Formal study is needed.

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