Comparative evaluation of respiratory motion-corrected cone-beam CT images derived from treatment-day vs. simulation-day respiration-correlated CT scans

Innovation/Impact: We have previously developed a method of correcting respiratory motion-induced blur and artifacts in CBCT images, using a patient-specific model derived from a respiration-correlated CT (RCCT) [1]. This approach assumes that respiration-induced organ deformations at simulation, when RCCT scans are normally acquired in the clinical process, are still valid at treatment. The statement is clinically relevant since it has impact on accuracy of motion-corrected CBCT for image-guided treatment.

In an IRB-approved study, lung cancer patients receive an RCCT on a CT simulator and a respiration-gated kV CBCT and a 1-minute CBCT on a linac. In all scans respiration is recorded with an external monitor that reflects anterior chest motion. Motion correction of the 1-minute CBCT uses the motion model that is derived from a principal component analysis that relates 3D deformations, obtained from deformable image registration between RCCT images, with the motion of the diaphragm or fiducials in the RCCT. In the gated CBCT scan, the linac is programmed to enable gantry rotation and kV image acquisition within a gate of 25-30% duty cycle around end expiration. The gated CBCT serves as ground truth for comparison to the CBCT with motion correction using the treatment-day RCCT (MC-CBCT\textsubscript{tx}) and using the simulation-day RCCT (MC-CBCT\textsubscript{sim}).

Fig. 1 compares coronal views of a lung tumor in one patient. The tumor in both gated and MC-CBCT\textsubscript{tx} image sets has similar shape and contrast whereas in MC-CBCT\textsubscript{sim} images the tumor is elongated and blurred. Lung tumor image quality comparison is quantified using tumor-to-background contrast ratio (TBCR) values. Following rigid registration to align the tumor, delineations of lung tumor and surrounding background tissue in the gated CBCT are transferred to each MC-CBCT images and TBCR values are measured. As can be seen in Fig. 2, TBCR is higher in MC-CBCT\textsubscript{tx} in 4 out of 5 patients, implying that the RCCT\textsubscript{tx} deformation field (taken on same day as CBCT) is likely closer to that in the CBCT. This is further supported by Fig. 3 which compares motion extent (end expiration to end inspiration) of the tumor and diaphragm in the RCCT\textsubscript{sim} and RCCT\textsubscript{tx} image sets. One can see the tumor motion relative to diaphragm changes between image sets, indicating that the deformation patterns, and hence the model-predicted tumor motion, have changed. This in turn affects motion-corrected CBCT. The one exception is patient 4, which exhibits small tumor motion (2mm), thus motion correction has little impact and TBCR is similar (see Fig. 2). The preliminary findings require confirmation with a larger number of patients. Data from additional patients will be presented.