Title: Simultaneous MV-kV imaging for intra-fractional motion management during Volume Modulated Arc Therapy (VMAT) delivery on the Varian TrueBeam.

Innovation/Impact: This abstract investigates accuracy of a new method for obtaining intra-fractional MV-kV pairs. As simultaneous MV-kV imaging methods become clinically available, they may provide an efficient and accurate method for monitoring intra-fractional motion.

Methods: Intra-fractional kV images (~11 fps) were acquired during VMAT using a standard TrueBeam programmed imaging template. Because TrueBeam functionality currently prohibits simultaneous MV-kV intra-fractional imaging, MV images (~9.5 fps) were acquired by deploying the EPID and passively collecting images using Varian proprietary software, iTools Capture. MV and kV images were paired temporally and a further comparison of the MV image MLC shape with that in the plan served as final verification of the MV gantry angle. 3D localization accuracy was assessed using a Rando phantom with 3 gold markers inserted near the mid-thoracic vertebra. A typical VMAT 360 degree arc was delivered in TrueBeam Developer mode using custom XML files. Intra-fractional patient motion was simulated by programming couch movements into the XML file, thereby moving the phantom during delivery. Prostate and respiratory motions were simulated using a Calypso and a sinusoidal trace. This simulation method takes advantage of the high positional accuracy of the couch and relative ease of later correlating the images with the couch/phantom motion, gantry and MLC positions. Maximum excursions were 0.48 cm and 1.0 cm for prostate and respiratory motion, respectively. For both motion scenarios, delivery was repeated, varying total MU (180 to 600) and gantry speed (1 to ~0.3 rpm). For image registration, DRRs at 1 deg. intervals were created from CT data using ROIs limited to ~0.5 cc volumes centered on each marker. After applying a Sobel filter, each image was registered to its corresponding DRR using automatic registration (normalized cross-correlation with simplex minimization) when possible and manual registration otherwise. To improve image quality, MV frame averaging (5 frames) was performed prior to registration (Fig 1).

Results: 130 to 390 MV-kV pairs were acquired for each delivery. ≥ 1 marker was visible in 99% of MV images. Images without visible markers occurred with large instantaneous motion or low MV dose (< ~ 0.25 MU/frame). Mean difference between planned and measured 3D marker positions for prostate was ≤ 0.03 cm (± 0.03) in each direction. Neither gantry speed nor total MU significantly impacted accuracy. For respiratory motion, mean difference between planned and measured 3D position was ≤ 0.04 cm with an average SD of 0.06 cm. With large motion and lower MU, the SD increased to 0.12 cm. Overall, MV image quality and approximations in MV image gantry angle determination were the primary sources of inaccuracy.

Planned and measured BEV-view marker traces from (a) MV and (b) kV images with respiratory motion. (c) Differences between measured and planned positions in the room coordinate system.