Intrafraction Imaging: Simultaneous kV Image Acquisition during MV Treatment Delivery to Monitor Patient and Target

UC DAVIS COMPREHENSIVE CANCER CENTER Radiation Oncology

JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING EASTERN TIME [GMT-4]

L. SENSOY[1], A.M. HERNANDEZ[2], D. HERNANDEZ[1], Y. RONG[1], and S. BENEDICT[1]

[1]Department of Radiation Oncology; University of California Davis, Sacramento, CA, United States

[2]Department of Radiology; University of California Davis, Sacramento, CA, United States

INTRODUCTION

- One of the main challenges in radiation therapy is tumor motion.
- As the internal patient anatomy constantly alters due to cardiac, respiratory, gastrointestinal, skeletal muscular, and urinary movements, significant displacements of the tumor during the treatment becomes possible.
- Therefore, intrafraction motion monitoring, and any issues regarding its reliability need to be well understood and addressed in order to both keep target conformality and spare surrounding healthy tissue as much as possible.
- So far, only a limited number of studies has been conducted on Elekta's intrafraction kV cone beam computed tomography (CBCT) imaging feature.[1-2]

AIM

- To examine the Elekta intrafraction imaging feature for both image quality and ease of use in a clinical setting for adaptation into the routine workflow.
- To quantitatively investigate possible image deterioration with varying treatment field conditions such as beam energy and monitor units (MU).

METHOD

Intrafraction Phantom Imaging:

VMAT treatment fields for the Anderson Rando anthropomorphic phantom (Radiology Support Devices Inc., Long Beach, CA) were planned and exported to the oncology information system for treatment delivery. The start and end angles of the gantry were set to 182 and 178 degrees, respectively, for both treatment and intrafraction kV imaging.

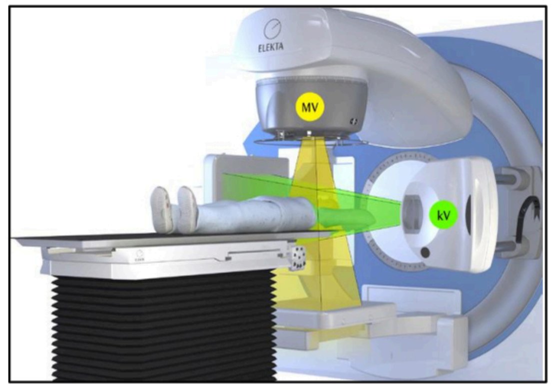

Figure 1. An animated description for the simultaneous kV imaging during patient treatment. Image courtesy of Elekta.

Image Quality Evaluation:

CBCT reconstructions of the Rando phantom were evaluated by comparing line profiles comparing the mean HU value and variance within ROIs extracted in homogenous soft tissue and lung parenchyma regions for the following four conditions:

1) No MV beam
2) 200 MU for 6 MV beam
3) 2000 MU for 6 MV beam
4) 2000 MU for 15 MV beam

Figure 2. Anderson Rando phantom was used for planning, delivery and simultaneous imaging.

RESULTS

Qualitative Assessment

- Axial slices through the Rando phantom (Figure 3) demonstrate satisfactory image quality for the purpose of ensuring the treatment beam was delivered as prescribed.
- While some artifacts are present with MV on (see yellow arrows) they do not obscure the visibility of the carina and bony vertebral structure as shown in the inset zoomed images.
- These very modest differences, although detectable, are not consequential as a major concern for purposes of assessing whether the treatment was delivered in accordance with expectations.

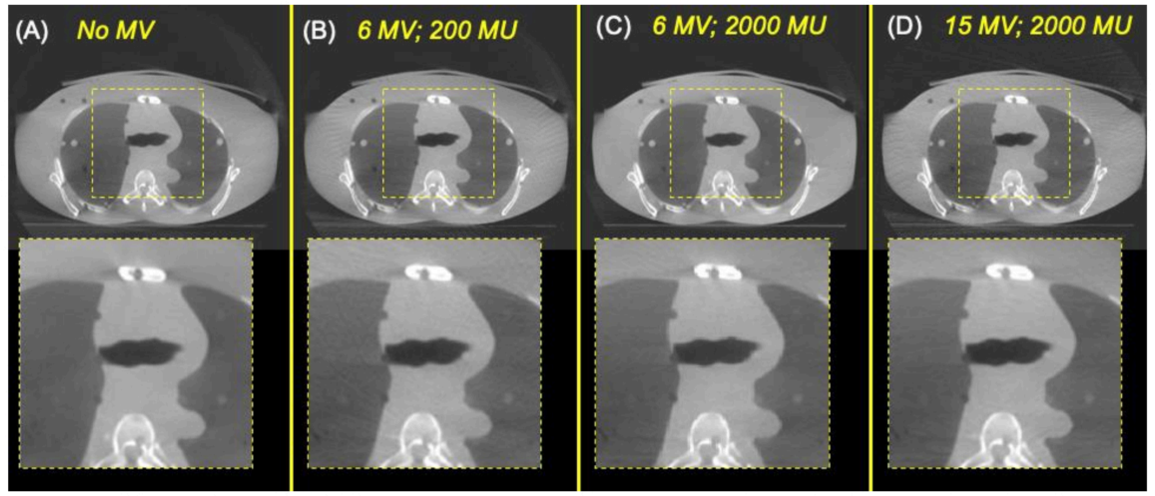

Figure 3. Axial slices at the carina level of the CBCT reconstructions without any treatment beam (a), with 200 MU of 6 MV (b), with 2000 MU of 6 MV (c), and 2000 MU of 15 MV fields (d) simultaneously treating.

CT number consistency and image noise

- Line profiles shown in Figure 4 indicate good correspondence between the relative contrast CT for the various materials within the line profile and consistent CT number uniformity across the field-of-view.
- The homogenous soft tissue and lung parenchyma regions used for generating VOIs are indicated in the top panel of Figure 5. For the thicker effective diameter axial slice, the variance was consistently higher for all three MV "on" conditions in comparison to MV "off" as expected (Figure 4; bottom panel). In addition, the CT numbers for lung and soft tissue were within 20 HU and 60 HU, respectively.

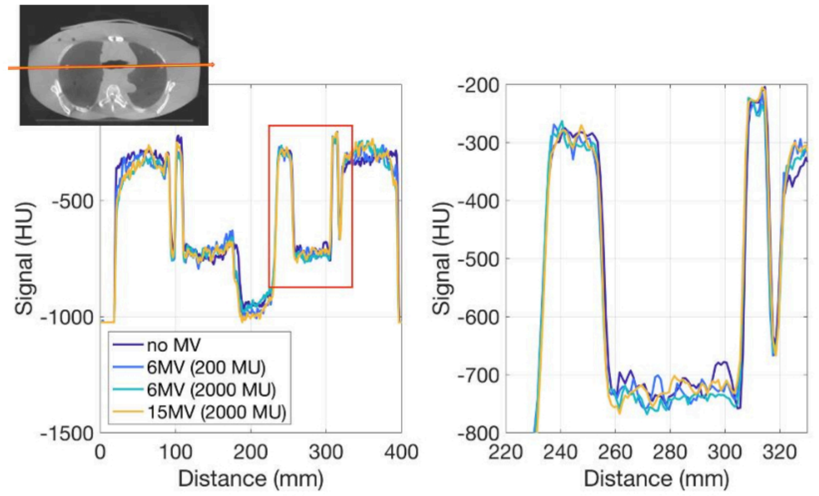

Figure 4. Line profiles taken along the lateral direction through the thickest region of the Rando phantom as indicated in the inset image.

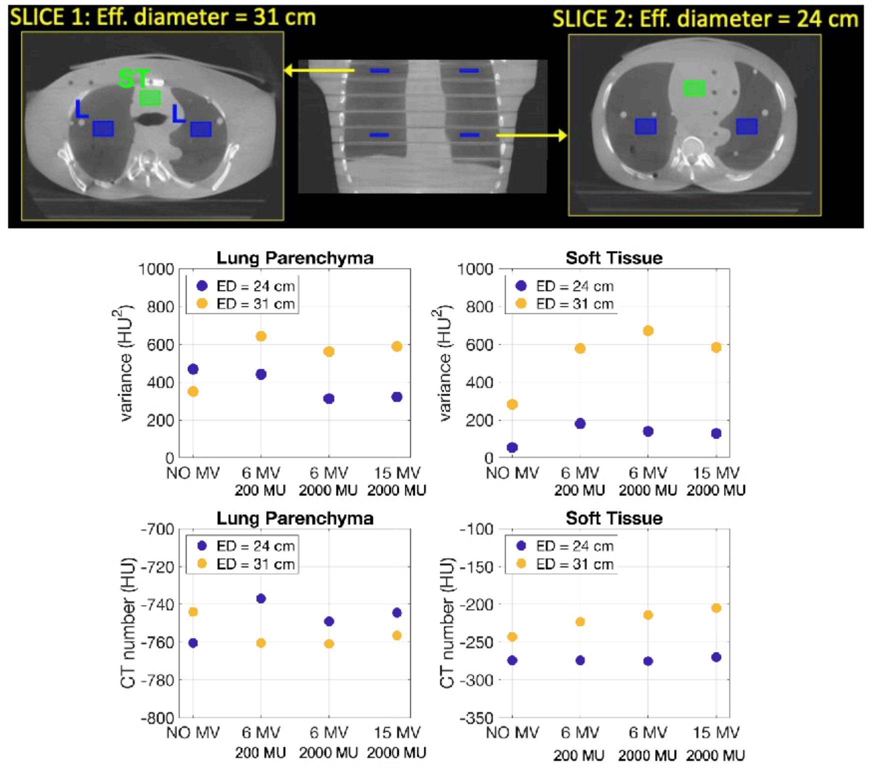

Figure 5. [Top] Example axial slices through the superior and inferior regions of the Rando phantom with effective diameters of 31 cm and 24 cm, respectively. [Bottom] Variance and CT number measured for the lung parenchyma and soft tissue ROIs indicated in the top panel.

CONCLUSIONS

- Intrafraction kV imaging during MV treatment delivery was demonstrated on an Elekta Linac. Preliminary image quality evaluation using the Rando anthropomorphic phantom indicates that the MV beam introduces only a modest change in the noise characteristics and presence of artifacts in reconstructed CBCT volume data sets.
- This feature enables the users to document 3D imaging of actual beam delivery.
- The Intrafaction kV imaging feature is relatively easy to use; adding an intrafraction procedure to the kV imaging procedures list follows the same steps as generating presets for the regular CBCT image protocols in the XVI system.
- Improvements to Elekta's Intrafaction kV imaging feature, such as planar imaging and live feedback, will make the this tool even more instrumental and enable the users to react to a significant shift in patient or target during the treatment delivery.

ACKNOWLEDGEMENTS

This research was partially supported by Elekta.

REFERENCES

[1] Liang, J., Lack, D., Zhou, J., Liu, Q., Grills, I., & Yan, D. (2019). Intrafraction 4D-cone beam CT acquired during volumetric arc radiotherapy delivery: KV parameter optimization and 4D motion accuracy for lung stereotactic body radiotherapy (SBRT) patients. *Journal of Applied Clinical Medical Physics, 20*(12), 10-24. doi:10.1002/acm2.12755

[2] Cao, D., Jermoumi, M., Mehta, V., & Shepard, D. (2016). SU-F-J-30: Application of Intra-Fractional Imaging for Pretreatment CBCT of Breath-Hold Lung SBRT. *Medical Physics, 43*(6Part9), 3412-3412. doi:10.1118/1.4955938

CONTACT INFORMATION

Levent Sensoy, Ph.D.

Department of Radiation Oncology | University of California Davis

sensoy@ucdavis.edu