Feasibility of Using Simultaneously Acquired MV/kV Images to Monitor Spine Target Position during SBRT Delivery: A Phantom Study

Qiang Liu, Jian Liang, Shupeng Chen, Doug G. Drake and Di Yan. Beaumont Health, Royal Oak, Michigan, USA

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INTRODUCTION

Due of the proximity of target to critical organs (e.g., cord and esophagus) and the high dose per fraction delivered in spine SBRT, even a few millimeters patient shift may lead to potential adverse outcomes. Intra-fraction target position monitoring is therefore considered an indispensable safety component.

Megavoltage (MV) portal image generated with treatment beam itself has been pervasively used in radiation oncology to verify field placement. It provides target position information in beam's eye view, the most dosimetrically relevant direction for photon radiotherapy. MV imaging combined with kV imaging had been explored to monitor 3D target position during lung and prostate treatments. The aim of this study was to investigate the feasibility of using combined MV/kV imaging to determine spine position during spine SBRT.

METHOD

Experiment was performed with an anthropomorphic body phantom on an Elekta LINAC. Small translational couch shifts (~4 mm) were introduced along three directions. Pre- and post-shift CBCTs were obtained and registered to the reference CT to determine the ground-truth shifts. Post-shift MV and kV images were acquired using the electronic portal imaging device (6 MV, 10×10 cm field size and 4 MUs) and the gantry-mounted kV imaging system (120 kV and 6.4 mAs).

Each paired orthogonal MV/kV images were registered to their corresponding kV projections of pre-shift CBCT based on mutual information (MI) to determine 2D shifts. The following image processing steps were applied before image registration: 1) center corrections for both MV/kV images to compensate source/detector shift related to gantry sag; 2) image filtering to MV image to reduce noise and enhance contrast; 3) histogram matching to improve image similarity between MV and reference kV projection. The 2D shifts for each MV/kV pair were then used to triangulate 3D shifts. Residual registration errors, defined by the differences between the ground-truth and the calculated shifts, were used to assess the accuracy of this approach.

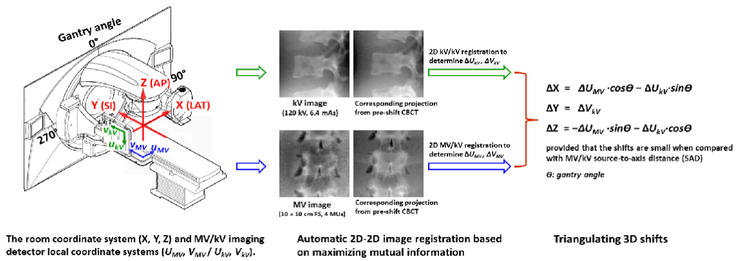

Figure 1: A schematic of using combined MV/kV imaging to determine 3 dimensional spine shifts.

RESULTS

Image quality of MV portal image was greatly improved after simple image processing steps, leading to reliable automatic cross-modality image registration.

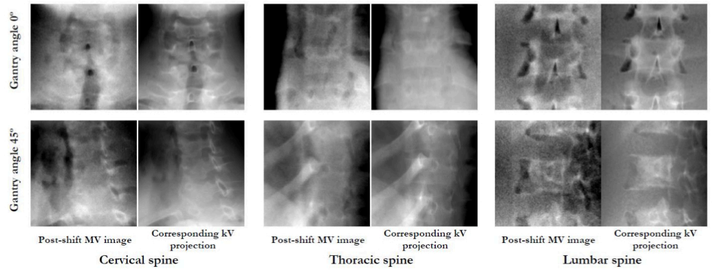

Figure 2: Examples of MV image and corresponding kV projection image of pre-shift CBCT (not co-registered). The following image processing steps were performed before image registration: 1) center correction for both MV/kV ; 2) edge preserving filtering to reduce image noise, contrast-limited adaptive histogram equalization (CLAHE) to MV image to enhance contrast; 3) histogram adjustment of MV image to match histogram of corresponding kV projection.

For a total of 24 MV/kV image pairs, i.e., 8 gantry angles and 3 spine sites (cervical, thoracic, and lumbar), the mean and standard deviation of residual errors were 0.23 ± 0.16 mm for lateral (range 0.01–0.54 mm), 0.55 ± 0.10 mm for longitudinal (0.39–0.71 mm) and 0.31 ± 0.26 mm for the vertical direction (0.02–0.99 mm).

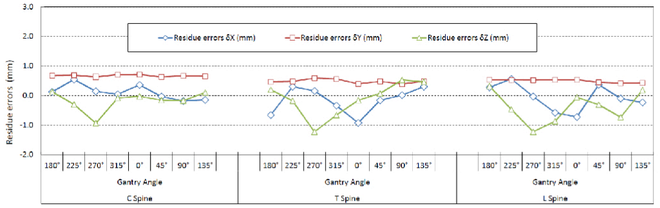

Figure 3: Summary of residual registration errors for 8 gantry angles and 3 spine sites.

DISCUSSION AND CONCLUSIONS

Results from this phantom study suggest it is possible to achieve sub-millimeter accuracy using combined MV/kV imaging approach to determine spine position. It could be a simple alternative to mid-treatment CBCT for intra-fraction target verification during spine SBRT delivery.

We propose the following methods to clinically implement this imaging technique for periodic intra-fraction imaging during spine SBRT delivery: 1) in a static manner, i.e., briefly pause the treatment, image and verify, then resume the treatment; or 2) in a continuous manner, i.e., incorporate a few small "open" MV imaging fields or arcs into IMRT or VMAT treatment delivery and capture the MV/kV images without interrupting the treatment delivery. Considering the small MUs used for taking the MV portal images, their corresponding dose should be easily taken into account during plan optimization without significant deteriorating the plan quality.

REFERENCES

1. Jenny Bertholet et al., Real-time Intrafraction Motion Monitoring in External Beam Radiotherapy, Phys Med Biol 2019
2. Mao et al., Image-guided Radiotherapy in Near Real Time With Intensity-Modulated Radiotherapy Megavoltage Treatment Beam Imaging, Int J Radiat Oncol Biol Phys 2009
3. Zhang et al., Optimizing fiducial visibility on periodically acquired megavoltage and kilovoltage image pairs during prostate volumetric modulated arc therapy, Med Phys 2016
4. Hunt et al., Simultaneous MV-kV Imaging for Intrafractional Motion Management During Volumetric-Modulated Arc Therapy Delivery, J Appl Clin Med Phys 2016

CONTACT INFORMATION

qiang.liu@beaumont.org