New Method to compensate angular dependency of QA devices in Intensity Modulated Arc Therapy

Junan Zhang, Ph.D. and Wolfram Laub, Ph.D.

Angular dependency of QA device

- Intensity modulated arc therapy (IMAT) is becoming the new standard of radiation therapy.
- A IMAT QA device is required to have minimal angular dependency.
- This study demonstrates a new method to compensate angular dependency of QA devices in IMAT.

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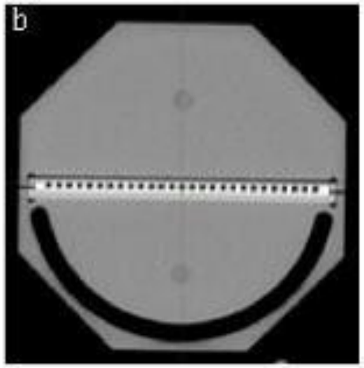
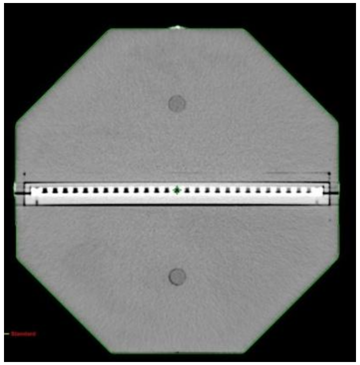
Existing method: Insert cavity to compensate angular dependence

- PTW QA system includes a Seven29 2D chamber array and two Octavius Phantoms (one for 2D array measurement and one for CT scanner and ion chamber measurement).
- A cylindrically symmetric compensation cavity corrects the anisotropic behavior of the 2D ion chamber measurements . The anisotropic behavior is reduced to less than 1.5%, except for the sidewise beam incidence (~3% for 6 MV, ~2% for 18 MV).

  (A. V. Esch, and et. al. October 2007, Medical Physics Volume 34, Issue 10, pp. 3825-3837)
- IMAT QAs are performed using the phantom with compensation cavity, but dose distributions are calculated using the solid phantom.



Used for QA measurement



Used for dose calculation

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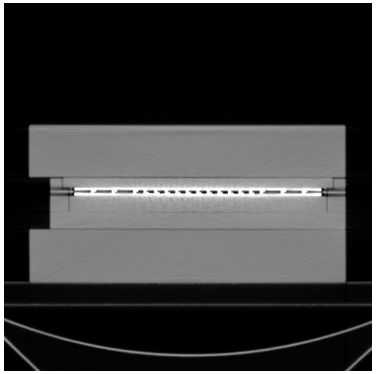
New method: Add virtual bolus into CT images to compensate angular dependence

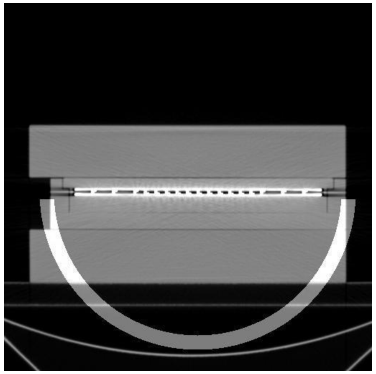
- A MapCheck device is placed inside an acrylic base with two 5-cm solid water pieces on the top and the bottom.

Two approaches:

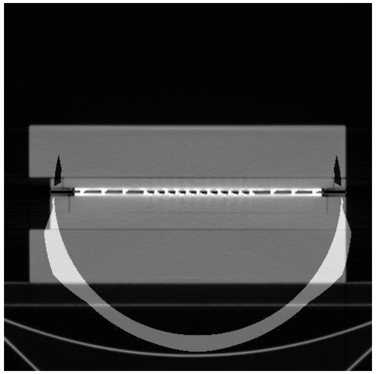
- A uniformly thick bolus is added into the planning CT image so that the TPS dose matches the measured dose for the posterior beam.
- A variably thick bolus is added the planning CT image so that the TPS dose matches the measured dose for all beam angles.



Used for QA measurement



Add uniformly thick bolus
Used for dose calculation



Add variably thick bolus
Used for dose calculation

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Measure angular dependence

- The angular dependency was measured by delivering 100MU (10x10cm 6MV) for every 15-degree gantry angles in a Varian Trilogy linear accelerator.
- Dose at the diode plane is calculated in Eclipse treatment planning system using AAA algorithm with heterogeneity correction.
- The measured dose plane is compared with the TPS dose plane to calculate average dose difference.

Add uniformly thick bolus into the CT image

- A halfpipe-shape bolus with uniform thickness is added into the 3D planning CT image.
- In Matlab, the HU number is increased by 1000 for all the pixels inside the bolus.
- The modified CT image was imported into Eclipse to calculate doses.
- The bolus thickness was chosen to match the TPS dose with the measured dose for the 180 degree beam angle.

Add variably thick bolus into the CT image

- A halfpipe-shape bolus with variable thickness is added into the 3D planning CT image.
- In Matlab, the HU number is increased by 1000 for all the pixels inside the bolus.
- The bolus thickness is determined for every 15 degrees.
- Because the thickness estimation does not include scattering and off-axis effects, TPS doses must be calculated for the new CT image to verify the effectiveness of the compensation.

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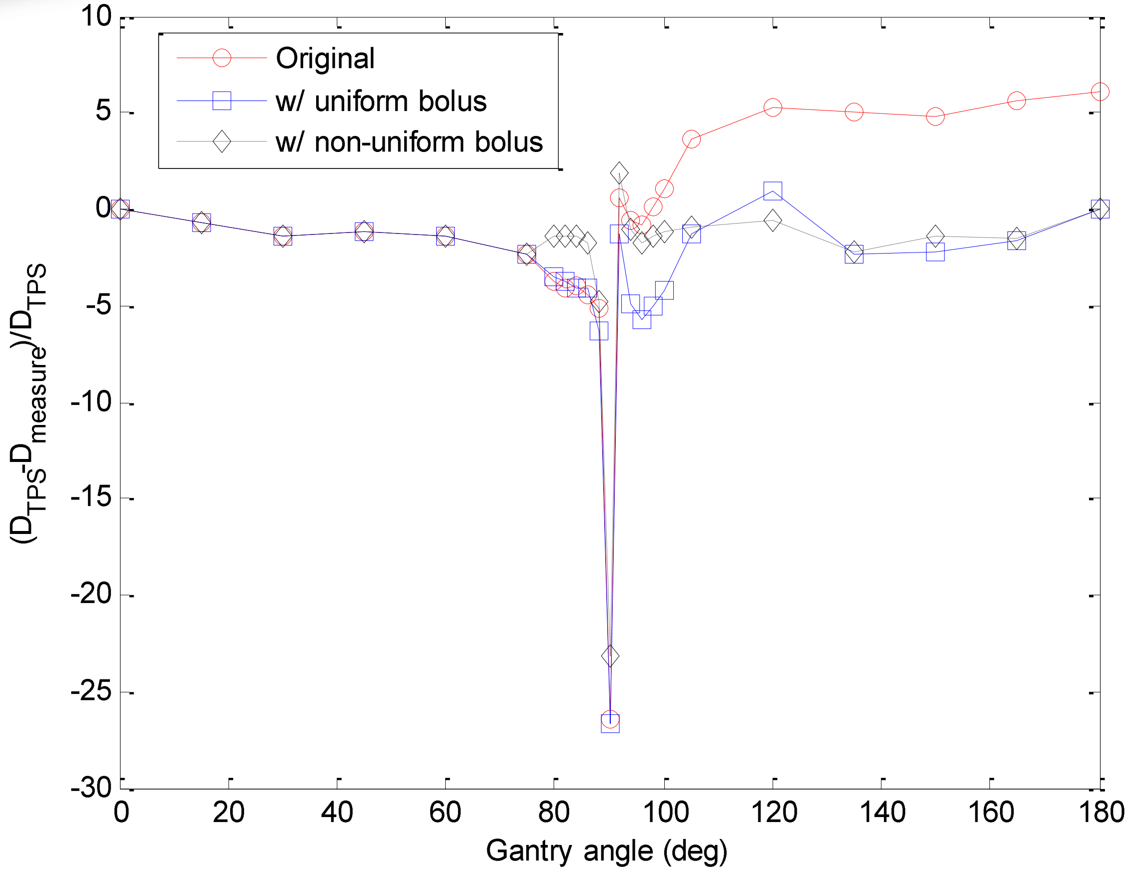
Angular dependence before and after uniformly and variably compensations



The 25% dose difference at the 90 degree angle is caused by the air space in the detector plane.

Angular dependence before and after uniformly and variably compensations

- For the original CT, the calculated dose is about 5% higher than the measured dose for most posterior angles (105 degree to 180 degree).
- It is probably due to angular dependence of the diode detector and metal artifact in the CT image.
- Both compensation methods reduce the dose difference for the posterior angles significantly,
- The angular dependency with variable compensation method was lower than the one with the uniformly compensation method (1.4% vs. 3.4% by the root-mean-square error).

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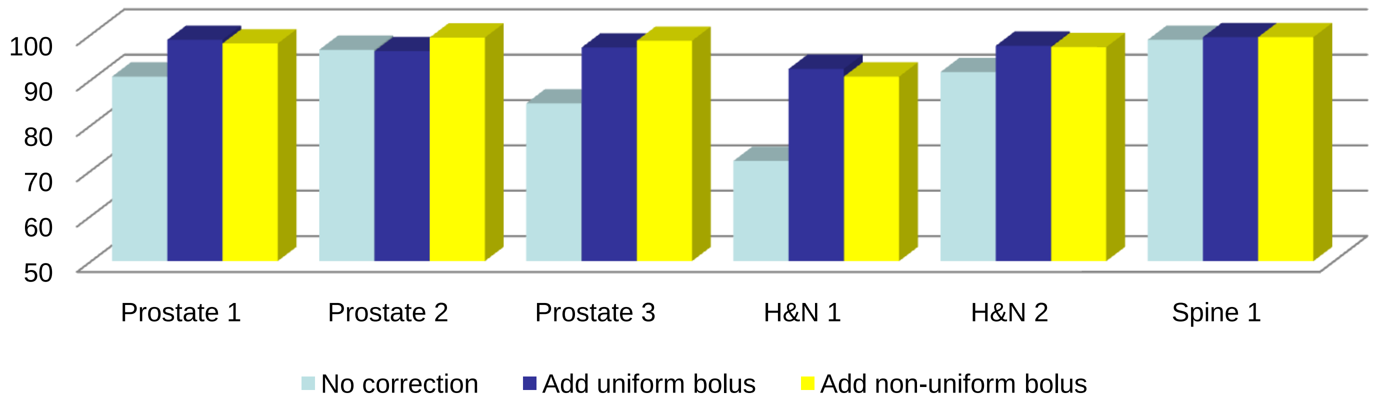
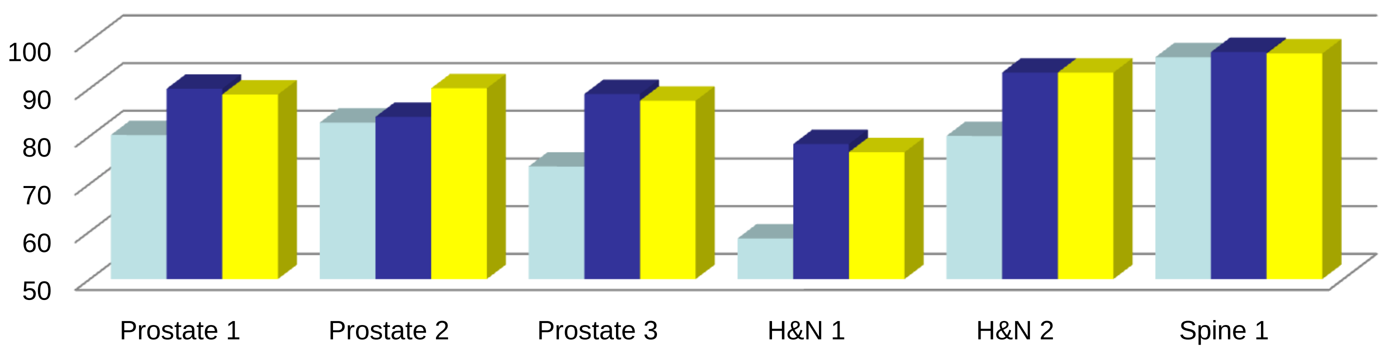
Gamma-index pass rate before and after uniformly and variably compensations

Criterion: top row 3%/3mm, bottom row 2%/2mm





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Result and Conclusion

- The two compensation methods improve gamma pass rate significantly. Failure rate of gamma analysis are reduced by 39% and 41% in average.
- However, the variable compensation method didn't show any advantage over the uniform compensation method. (p=0.87 and 0.95 for the two criterions, respectively).

Conclusion:

- The new method has been shown to be able to compensate angular dependency for MapCheck device.

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