Impact of Body Weight Change on the Dose Distributions of Spot-scanning Proton Therapy for Pelvic Cancers

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Outline

**Background:** Bone marrow sparing spot-scanning (SS) proton therapy (PT) may be beneficial for pelvic cancer treatment.

**Issue:** Anatomical changes may degrade dose benefits due to range uncertainty.

**This study:**

**Method:** SS PT dose re-computed on weekly CT; weekly body weight changes noted.

**Results:** correlation between body weight change and target coverage by univariate analysis.
Background: 30%~50% of active bone marrow are located in the pelvic region.


Slide courtesy of Brandie Gross, CMD
Background

Severe hematologic toxicity may occur due to radiation damage of pelvic bone marrow.

This leads to lower progression-free and overall survival as well as lower quality of life [Nugent et al, 2010].

Methods to spare bone marrow during photon radiation treatment of pelvic cancer have been investigated [Mell et al, 2006, 2008, 2008; Liang et al, 2013].

At least one study using passive scattering proton therapy has been published [Song et al, 2010].
Univ. of Iowa is conducting a NIH-funded clinical trial on sparing *functional* bone marrow identified by FLT-PET in IMRT.

FLT is a thymidine analog that is incorporated into DNA during replication making it a good marker of proliferation.
Preliminary results suggest IMRT may not be effective enough in sparing functional bone marrow.

The red circle highlights the lack of bone marrow recovery in a region that received high radiation doses (≥ 35 Gy).

Slide courtesy of Sarah McGuire, PhD
Spot-scanning proton therapy is promising in further sparing bone marrow from radiation dose.


Presented at the AAPM Annual Meeting in Indianapolis, 2013.
BMS IMPT is robust under 3% systematic range error and 6 mm random setup errors.


Presented at the AAPM Annual Meeting in Indianapolis, 2013.
Issue: The robustness of IMPT under anatomical changes may be a bigger challenge.

Weight Gain:
Beam undershoots;

Weight Loss:
Beam overshoots.
**Methods:** computing dose on weekly CT for the original plan generated on Week 0, and perform *univariate analysis* between target coverage and weight change.

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<th>Week 0</th>
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<th>Week 3</th>
<th>Week 4/5</th>
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Weekly whole-body CT were collected as attenuation-correction CT for the FLT-PET scan in the same position and with immobilization device (VacLock) and under same CT scanner protocol. Bone-to-bone rigid registration was performed. The same ITV geometry was used.
Results: Body weight increase is significantly correlated to the decrease of target coverage in IMPT.

Pearson correlation coefficient: 
$R = -0.5537$
95% CI $[-0.7681, 0.3066]$ 

Two-tail $P = 0.0022$ (statistically significant!)

From GraphPad Prism v2.0
Increase of body weight reduces the probability of target coverage.

Survival analysis from GraphPad Prism v2.0
“Target coverage maintenance” defined as $D_{ITV95\%} \geq 95\%$ Rx dose
SFUD is much more robust to anatomical changes.
Increase of body weight reduces bone marrow dose in IMPT.

\[ y = -3.206x + 4.2461 \]

\[ R^2 = 0.6495 \]

Relative Body Weight vs. Relative Volume for Functional Bone Marrow V\(_{5\text{Gy}}\) with a trend line and data points.

Statistical significance:

\[ P < 0.0001 \]
IMPT is still of great interest because it spares much more functional bone marrow than SFUD.
Other Factors

Changes in bowel, bladder, and rectum

Bladder volume and rectum volume may be reasonably controlled in actual treatment.

Patient posture variation

The same overall body weight, but different amount of tissue at buttock; possibly due to the change of VacLock shape over time.
Conclusion

• Patient body weight *increase* is significantly ($p=0.0022$) correlated to the decrease of target coverage in bone-marrow sparing IMPT for pelvic cancers; a 2% increase in body weight drops the probability of target coverage to below 90%.

• Target coverage in SFUD is well maintained for patient body weight change in the range of -6.1% to +9.4%.

• Maintaining the robustness of IMPT is of great interest due to its superior ability of sparing functional bone marrow in the pelvic region.
Future Work

Studies on the effect of changes in bowel, bladder, and rectum.

- A multivariate analysis combining all quantifiable variables is on-going.

Seeking solutions to control some of variables

Water intake time and amount for bladder volume control;
Rectal balloon for rectal volume control;
Rigid immobilization device for posture control.
Establish action levels of weight change for re-scan and re-planning.
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References


