A Multi-Channel Plastic Scintillator for Real-Time VMAT TBI Dosimetry

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INTRODUCTION

- VMAT TBI is a complex treatment delivery technique with as many as 7+ isocenters and field junctions that includes a patient rotation from head-first supine to feet-first supine.[1]
- It is essential to verify accurate treatment delivery, particularly at complex junction regions, for successful bone marrow transplants and overall survival while minimizing unnecessary toxicity.
- We performed validation measurements using a multi-channel plastic scintillator [2] to measure delivered VMAT TBI doses in real-time. This dosimeter has been comprehensively characterized [3,4] and exhibits minimal energy, dose rate, angular, and temperature dependencies that are common to other real-time in-vivo dosimeters such as diodes and MOSFETS. [5]
- We present a multi channel plastic scintillator dosimeter that provides accurate real-time dose verification during VMAT TBI delivery when using the treatment planning system (TPS) as the predicted dose. This is especially important in high uncertainty regions such as at the field junctions.

MATERIALS AND METHODS

- The HYPERSCINT RP-200 with the 4-channel FLEX Series plastic scintillator dosimeter system (Medscint Inc., Quebec, QC., Canada) was used to measure VMAT TBI fields delivered by a TrueBeam Linac on both Solid Water (Gammex, Middleton, WI, USA) and custom Rando (RSD, Gardena, CA, USA) phantoms.
- The scintillator was calibrated (**Figure 1**) for absorbed dose (cGy) under known reference conditions in "TBI Reference Geometry" and verified with ionization chamber measurement and TPS dose calculations. A Varian TrueBeam LINAC was used.
- Bolus for surface dose measurements were used to ensure full buildup at the scintillator, reducing both the scintillator measurement uncertainty and calculated dose uncertainty in the TPS when using the TPS as the predicted dose.
- For Solid Water measurements, twenty-five VMAT fields and eighteen static-dynamic TBI fields were delivered to a single scintillator channel positioned at the field center beneath a 1.5 × 3.0 × 3.0 cm^3 bolus.
- The scintillator/bolus assembly was placed on top of a 30 × 30 × 30 cm^3 Solid Water phantom at 85cm SSD (gantry 0°) using a 6 MV photon beam for Solid Water measurements.
- To evaluate dosimetry at TBI field junctions, an additional ten VMAT and six static-dynamic TBI fields were delivered to a Rando phantom with custom fiberboard legs **(Figure 2).**
- AlignRT (VisionRT, London, UK) surface guidance was used to accurately place four scintillator/bolus pairs at four junction locations **(Figure 3).** The boluses were contoured in the TPS and included in the body for bolus matching with AlignRT.
- AAA v15.6 in the Eclipse TPS with bolus/phantom modeled was used for the expected predicted dose.
- Uncertainty related dose variation with scintillator placement was also quantified.

SETUP

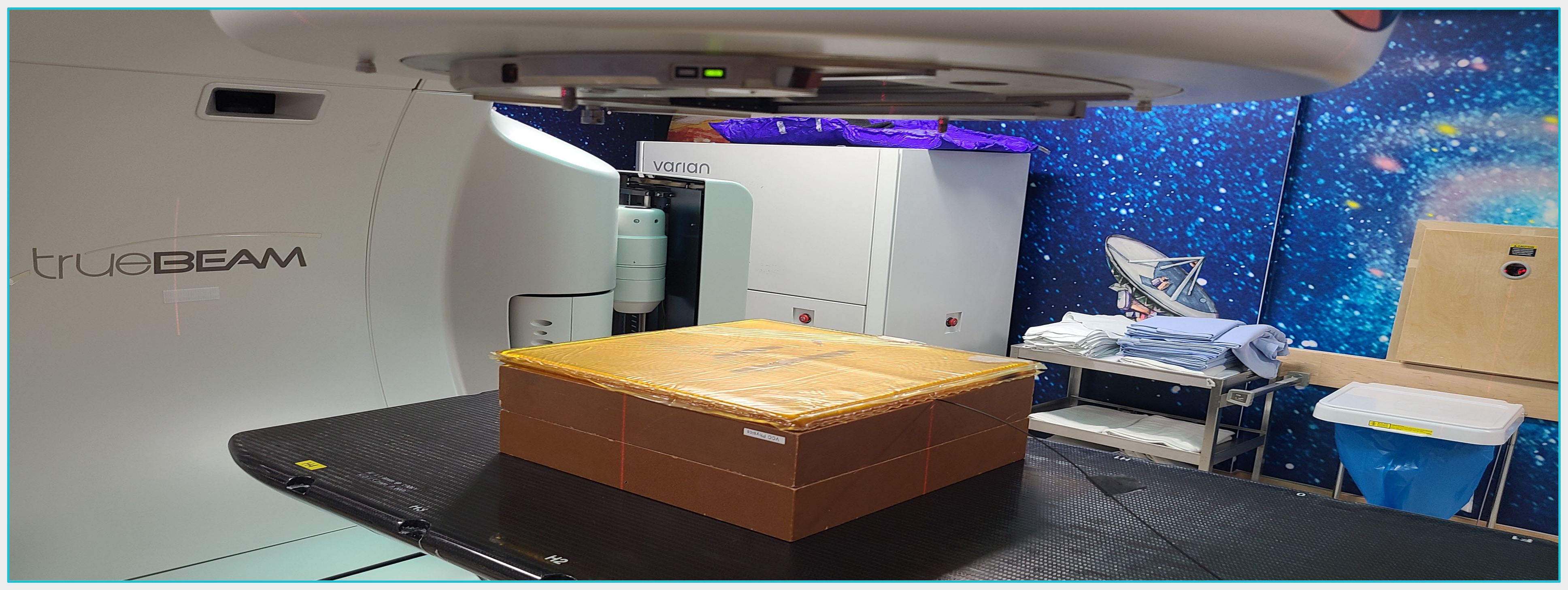

Figure 1. An absorbed dose calibration (cGy) was performed in "TBI Reference Geometry" to match the VMAT TBI treatment geometry as close as possible to correct for detector response. A 6 MV beam was used with a dose rate of 300 MU/min, a 5 x 5 cm^2 field size, and an 85 cm SSD to have reference conditions simulate as close as possible to what the scintillator response would see during treatment. The scintillator was placed at a depth of d_{max} (1.5 cm) under bolus in the center of the field, with 10 cm of Solid Water backscatter.

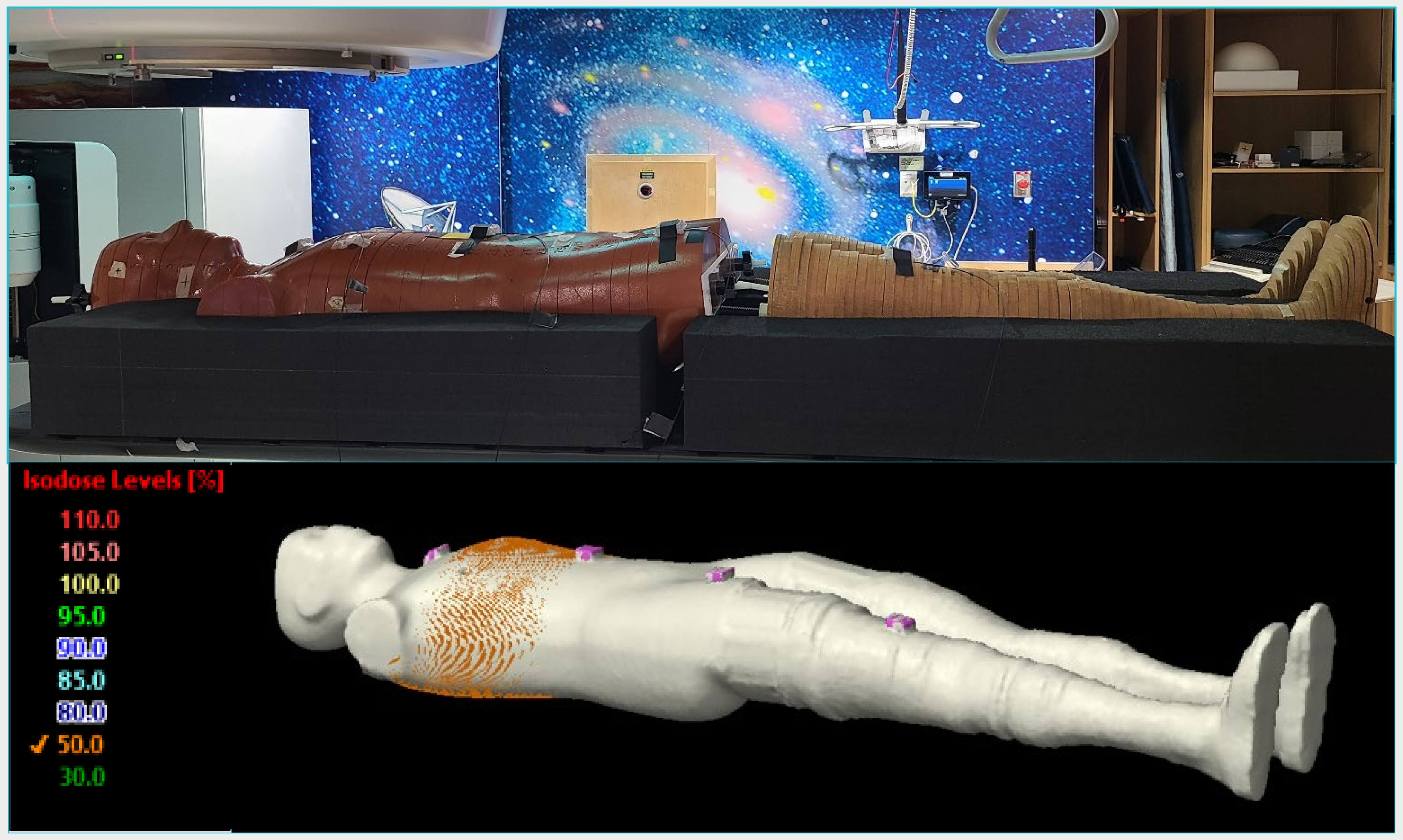

Figure 2 (Top). Rando phantom with custom fiberboard legs inside foam immobilization. Four scintillators are under bolus (under black tape) placed at TBI junctions between adjacent overlapping fields. **(Bottom)** CTsim of phantom body contour in Eclipse TPS with four boluses (purple) contoured. A combination of VMAT plans (thorax, abdomen, pelvis) and dynamic static fields (head, legs) were delivered. The 50% isodose level is illustrated (orange) for the chest field with boluses modeled at superior and inferior field borders. Predicted doses in TPS measured directly under boluses.

Figure 3: Using Surface Guidance with AlignRT to position the bolus on the Rando phantom. The top superior square within the Green ROI is the correct bolus position from the TPS, and the bottom inferior square is the real-time live positioning of the bolus. Correct bolus positioning is achieved when both bolus squares overlap.

RESULTS

- Solid Water measurements had a mean dose difference between scintillator and TPS of 1.6%, with a maximum difference of 3.3%.
- A 1 cm mispositioning in scintillator position at the center of the field produced up to a 10% change in measured dose.
- For junction measurements on the custom Rando phantom, mean and maximum percentage dose differences were 2.9% and 8.7%, respectively, when surface guidance was used to verify bolus/scintillator placement.
- A 1 cm mispositioning at junction locations produced dose deviations of up to 15%.
- Under TBI setup conditions, AlignRT surface guidance enabled bolus/scintillator placement on the Rando phantom with a setup accuracy within 3 mm, corresponding to an estimated dose uncertainty of approximately 4.5%.

CONCLUSIONS

- A multi-channel plastic scintillator positioned with surface guidance provided reliable real-time dose monitoring of VMAT TBI LINAC dose deliveries.
- This will enable real-time VMAT TBI treatment verification, especially in high uncertainty regions such as at field junctions.

REFERENCES

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