Non-Contact Scintillator Imaging Dosimetry for Total Body Irradiation in Radiotherapy

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Purpose: Current methods for monitoring patient dose in Total Body Irradiation (TBI) use OSLDs or TLDs. This requires careful handling to avoid mis-labelling the dosimeters which would report dose to incorrect anatomy. This process also requires time for the dosimeters to settle and be read. Together these factors mean that clinical teams won't have accurate dose monitoring for the first fractions of treatment. This is especially important with TBI as such treatments typically schedule fewer fractions and administer large doses (~2 Gy) in each fraction.

Non-Contact imaging dosimetry uses scintillators coupled with time gated cameras to report the dose administered to a patient[1]. After the scintillator responses have been calibrated, this method allowed for real-time dose readout.

Methods: Initial studies were completed on a flat tissue phantom that represented the color and dose buildup of soft human tissue. These studies also included bolus of varying thickness (Clearsight Bolus, Clearsight RT) and a 1cm thick Plexiglas spoiler and were done with EJ-240 (Eljen Tech) scintillators. The beam was set to 10MeV photon, with a 10x10 cm^2 beam area. Scintillation to dose linearity was assessed and compared with TLDs (TLD-100, Thermo Fisher Scientific).

Scintillator response was measured by a C-Dose (DoseOptics LLC) time gated camera. Average scintillator intensity was obtained using foreground and background marking techniques to generate a binary mask of the scintillator regions. The mask was then applied to the grayscale image and the mean values for each scintillator were recorded. This data was then compared to TLD dose at each location. Figure 1 demonstrates how the scintillator signal was isolated for processing.

Later studies used a Rescue Randy Manikin (Simulaids Ltd) to verify the techniques on human geometry which is shown in Figure 2. Scintillators were affixed to a wavelength shifter (EJ-284, Eljen Tech) to better match the emission spectrum with the camera's photocathode absorption spectrum to compensate for the increased SSD. The phantom was treated on a C-Arm LINAC (TrueBeam, Varian) at an SSD of 380cm, which is typical of TBI treatments. The beam parameters were again set to 10MeV photons, but the area was increased to 30x30cm^2. Three scintillators were placed on its forehead, chest, and umbilicus to report dose to the eyes, lungs, and intestines, respectively. TLDs were placed adjacent to scintillators and various prescriptions were delivered which produced dose response curves for the scintillators on human geometry.

Results: Tests performed with bolus and plexiglass were primarily focused on whether scintillators could be used in TBI treatments with relevant barriers (spoiler and/or bolus) in place. These tests showed that the signal to background ratio of individual scintillators decreased with spoiler presence and bolus thickness. While the barriers were transparent, so that the scintillators could be imaged on the other side, they still produced internal Cherenkov radiation to which the camera is sensitive, an example of which is shown in Figure 3. In addition, once the beams had penetrated the barriers the surface of the phantom was experiencing 80-95% of the percent depth dose for the treatment beam. This produced additional Cherenkov radiation on the surface of the phantom which further reduced the SBR for the scintillators. Table 1 shows the effect on SBR as different barriers were put in place. It is because of these results that the scintillators were affixed to wavelength shifters which later increased the signal output by a factor of 7.5.

Tests with TLDs on human geometry showed good dose-scintillation linearity at each region of interest (R^2=1). Individual regions of interest had their own response curve as shown in Figure 4.

Conclusions: Scintillators were detectable with typical TBI barriers at an SSD of 100cm but due to the complications posed by increasing the SSD to 380cm the scintillators needed to be affixed to wavelength shifters to increase their signal.

Scintillators at each location showed good linearity in their response to the dose administered. The dose scintillation curves differ by location which indicates the necessity to calibrate each scintillator in use. Calibration for room light intensity incident on each scintillator is currently being investigated.

Future work based on these results would be to determine the best camera/scintillator/wavelength shifter combination to increase SNR for image processing and to automate the process for clinicians.

Relevance to CIRMS: This work is relevant to the mission of CIRMS as it presents a new and faster means of quantifying surface dose to patients and provides clinicians real-time tools to improve the quality of treatments in a manner less susceptible to human error than previous methods.

Moving forward as a clinical physicist, CIRMS is relevant to my work in that it influences the protocols and standards that I will need to meet in the field. As this research hopefully moves forward, it would also mean that I would likely be more involved with CIRMS in establishing protocols for measuring external dose in this manner.

References:

1. P. Bruza, S. Gollub, J. Andreozzi, et.al, “Time-gated Scintillator Imaging for Real-time Optical Surface Dosimetry in Total Skin Electron Therapy,” *Phys Med Biol*. 2018 May 2; 63(9):095009.

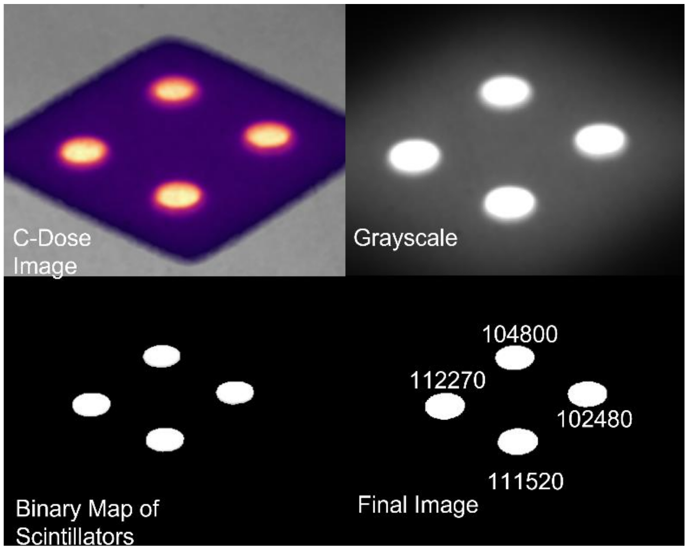

Figure 1. The composite C-Dose image was processed in MATLAB (MathWorks, USA) using foreground and background marking techniques to create a binary mask which isolated the scintillators. Each scintillator in the binary mask was eroded by a number of pixels based on camera-to-scintillator distance to remove signal from the painted sides of the scintillator. The mask was then applied to the original image.

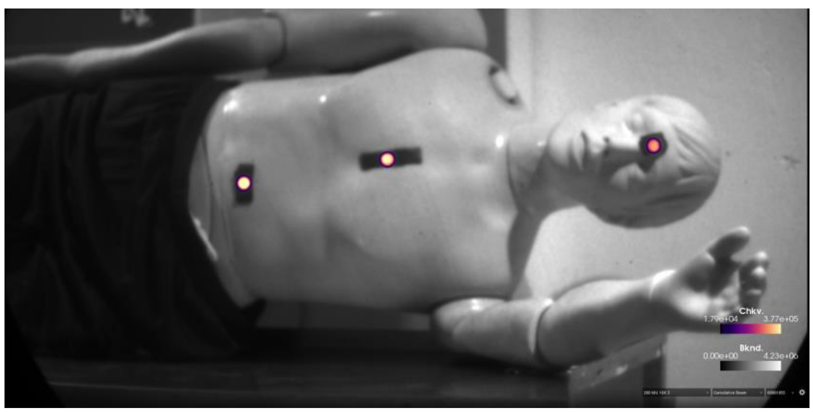

Figure 2. C-Dose image showing the locations and scintillation responses of the scintillators placed on the Rescue Randy Manikin.

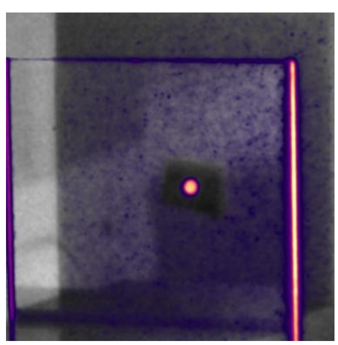

Figure 3. C-Dose image showing the internal Cherenkov speckle present within the plexiglass spoiler.

Table 1. SBR Across Varying Barriers

Barrier Type	SBR
No Barrier	3.62
3mm Bolus	3.29
3mm Bolus and Plexiglass	2.75
5mm Bolus	2.82
5mm Bolus and Plexiglass	2.07
10mm Bolus	1.99
10mm Bolus and Plexiglass	1.56

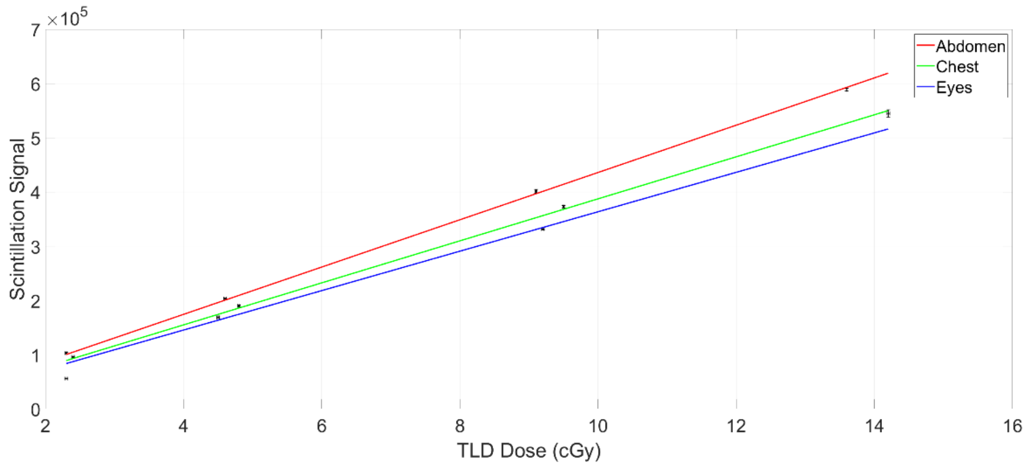

Figure 4. Dose-scintillation curves for the three regions of interest on human geometry.