

Customized Bolus Is More Effective Than Standard Bolus to Mitigate the Increase in Exit Dose During MRI-Guided Radiation Therapy

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Purpose:

To compare customized boluses with Superflab bolus to reduce the increased skin dose at the beam exit side due to the electron return effect for MR-image guided radiation therapy (MR-IGRT) systems.

Methods:

Three silicone phantoms mimicking simple anthropomorphic geometries were molded in the shapes of a hemisphere, flat cube, and adult hand. The phantoms were designed to incorporate 2x2 cm² EBT-3 film pieces on the beam exit surface (the non-flat surface). Custom 1cm-thick 3D printed PLA boluses and 1cm-thick eXaSkin boluses were created from CT images and molded directly onto each phantom, respectively, for comparison with 1cm-thick Superflab bolus. PLA and eXaSkin boluses were also tested in combination with ultrasound gel (UG) to remove any small air gaps. Each phantom-bolus combination was irradiated with a preclinical 7 MV MR-linac and a 6 MV linac with gantry angle 180° and 10x10 cm² fields. Each film was read out using an Epson flatbed scanner prior to irradiation and 24 hours post-irradiation; the optical densities were converted to a relative dose for comparison.

Results:

For **irradiations in the MR-linac**, surface doses using the Superflab, PLA, eXaSkin, PLA+UG, eXaSkin+UG on the hemisphere/cube/hand phantom were decreased by 20%/26%/28%, 7.2%/0.4%/20%, 10.9%/2.5%/26%, 21.2%/26%/23%, and 7.8%/29%/33%, respectively, relative to the “bare” scenario with no bolus added.

In contrast, **irradiations in the linac** (no magnetic field) resulted in minimal differences with the addition of the different bolus materials. The surface doses on the hemisphere/cube/hand phantom changed -0.2%/0.3%/0.2%, -2%/0%/0%, 0.3%/+0.4%/-1.3%, 0.3%/0%/-2.3%, and -1.7%/-0.5%/-0.8%, respectively.

Conclusion:

Our findings suggest that the Superflab and PLA+UG bolus materials reduced the skin dose at the beam exit surface in the MR-linac the most, indicating that the ERE for the beam exit was moved to the bolus surface from the phantom surface for irradiations in a strong magnetic field.

Innovation/Impact: At tissue-air interfaces, a strong magnetic field (B_0) influences secondary electrons to curl back into the air interface deposition a hot spot of radiation dose, also called the electron return effect (ERE). This can result in elevated radiation doses to the skin at the exit end of the beam in an MR-linac. The results of this study enabled us to assess which bolus will reduce the skin dose at the beam exit surface the most significantly as the ERE is shifted from the phantom “skin” surface into the bolus material.

Key Results: The hemisphere phantom bolus comparison (**Figure 1**) indicates that PLA+UG reduced the dose at the skin surface the most for the MR-linac whereas the eXaSkin and PLA barely reduces the relative dose. PLA alone had some air gaps between the bolus and phantom and required the addition of UG to remove the gaps, **whereas eXaSkin had minimal air gaps (minimal differences when compared to eXaSkin+UG)**. The bolus comparison for the cube phantom (**Figure 2**) resulted in the most reduced surface dose using PLA+UG and superflab. The bolus comparison for the hand phantom (**Figure 3**) shows that the eXaSkin+UG decreased the relative dose for the MR-linac the most. In comparison, when irradiated in a **conventional linac (0 T), the different bolus materials resulted in minimal differences in changes to the phantom surface dose from each other.**

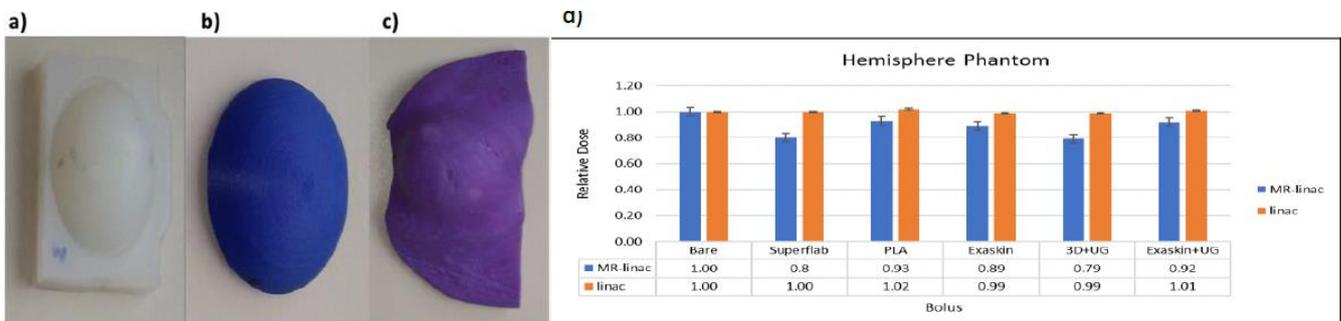


Figure 1: a) Silicone hemisphere phantom, b) 3D printed PLA bolus, c) molded eXaSkin bolus, and d) relative surface doses for each bolus material in comparison to “bare” (no bolus) for irradiations in an MR-linac (1.5 T) and conventional linac (0 T).

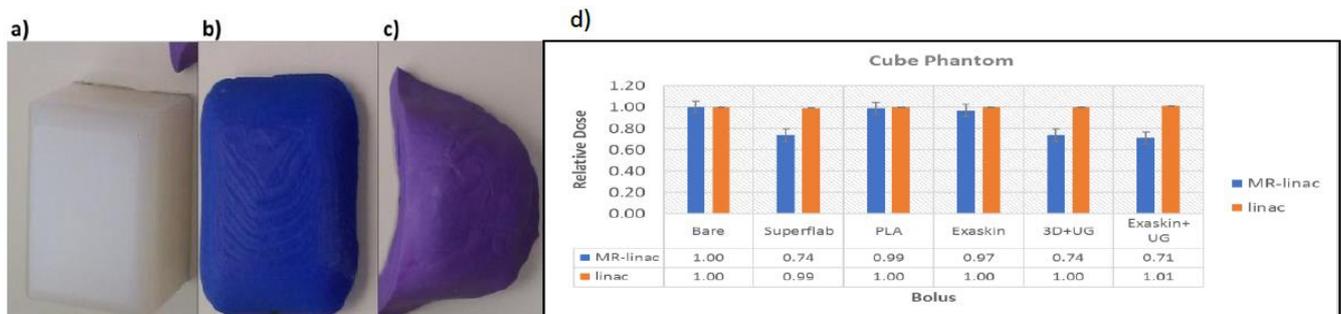


Figure 2: a) Silicone cube phantom, b) PLA bolus, c) eXaSkin bolus, and d) relative doses

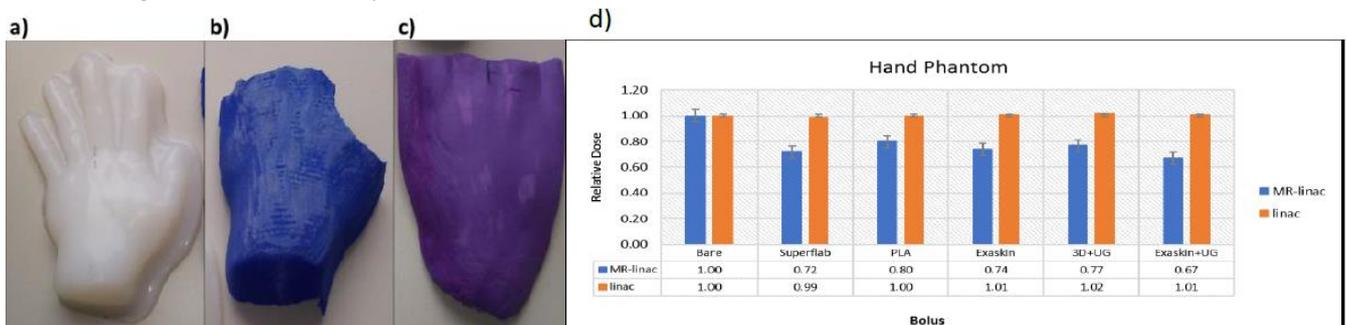


Figure 3: a) Silicone hand phantom, b) PLA bolus, c) eXaSkin bolus, and d) relative doses