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Enhancement of Surface Dose In Electron Beams Using a Partial Shielding Technique with Water-Equivalent Material and Oil-Based Modeling Clay

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ABSTRACT

Electron beam therapy is widely used for the treatment of superficial tumors; however, low-energy electron beams typically deliver a surface dose that is 20% lower than the maximum dose.

Although the application of a bolus can increase the surface dose, it also shifts the percentage depth dose (PDD) curve toward the surface, thereby reducing the effective treatment depth.

This study investigates a partial shielding technique using different bolus materials to optimize the dose weighting between non-bolus and bolus fields, aiming to improve insufficient superficial dose while maintaining an unchanged treatment depth.

INTRODUCTION

Electron beam therapy is a commonly used modality in radiotherapy for superficial tumors. Compared with conventional photon beams, electron beams exhibit a rapid dose fall-off beyond the target, providing a distinct clinical advantage. However, for low-energy electron beams in the range of 6–12 MeV, the surface dose is typically only about 70–80% of the maximum dose, which limits their clinical effectiveness. Therefore, bolus materials are often applied to increase the surface dose.

The use of a bolus, however, is a double-edged sword: while it enhances the surface dose, it also reduces the penetration depth of the electron beam. To overcome this limitation, this study aims to simulate the partial shielding technique proposed by Duncan M. et al., and to employ a highly conformable oil modeling clay as a bolus material that can closely match the patient's surface contour. By adjusting the dose contribution with and without the bolus, this approach seeks to improve the dose delivered to superficial target regions without significantly altering the therapeutic depth, while also enhancing dose uniformity within the target volume.

METHODS AND MATERIALS

PDD curves of a 6 MeV electron beam were measured using a 3D water scanning system. Partial shielding technique was first simulated with water as bolus, and the optimal monitor unit (MU) weighting for the composite field was determined to be 8:2 for the non-bolus and bolus fields.(**Figure 1**)

Experimental measurements were subsequently performed using a solid water phantom with either water-equivalent bolus or an oil modeling clay bolus placed on the surface.

Depth ionization measurements were acquired using a Markus chamber (PTW Freiburg), and percentage depth dose (PDD) curves were analyzed to evaluate surface dose.

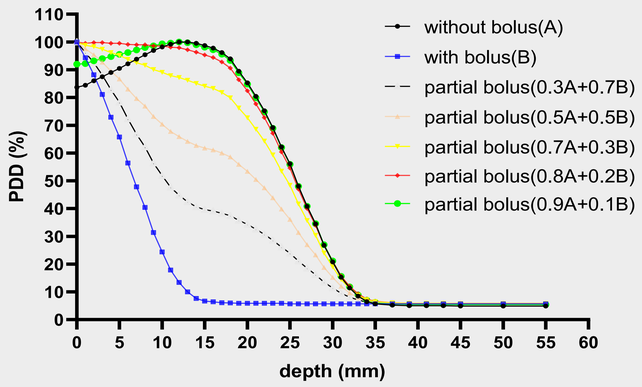

Figure 1. PDD of a 6MeV electron beam in water tank with different weighted composite fields.

RESULTS

The results of 6MeV electron beam showed that a weighting of 0.8 (non-bolus) and 0.2 (with 2cm water-equivalent bolus) effectively compensated for surface dose deficiency, achieving more than 90% PDI from the surface to the depth of maximum dose.(**Figure 2**)

Furthermore, a custom-made 1 cm high-density oil modeling clay bolus for 6MeV electron beam demonstrated improved performance. With an MU weighting of 7:3, the partial shielding technique achieved a PDI exceeding 97% within the first 10 mm depth. (**Figure 3**)

Similarly, partial shielding techniques using 3cm water-equivalent bolus or 1.5cm oil modeling clay bolus for 9MeV electron beam can also increase PDI before 20mm depth. (**Figure 2,3**)

In addition, we converted partial shielding PDI reading to PDD based on the TG 21 water/air stopping-power ratio to meet clinical needs. After converting PDI to PDD, the water-equivalent bolus, combined with the partial shielding technique, achieved PDD of 92% and 100% for the 6 MeV and 9 MeV electron beams, respectively. And the oil modeling clay bolus reached PDD of 100% for 6E and 97.1% for 9E. Furthermore, the overall trends of the PDI and PDD curves demonstrated high consistency across both materials.(**Figure 4.5**)

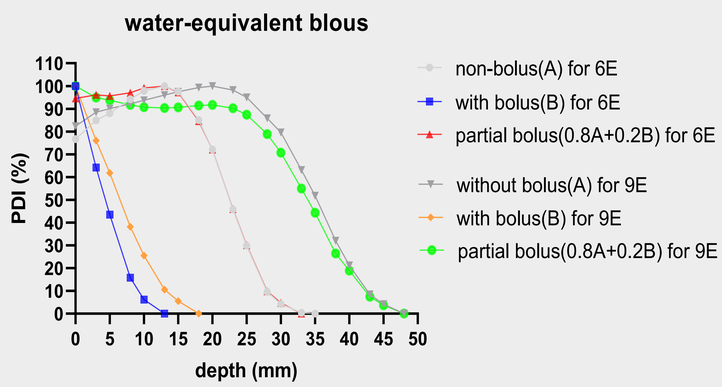

Figure 2. PDI obtained by using the water-equivalent bolus for 6MeV and 9MeV electron beam.

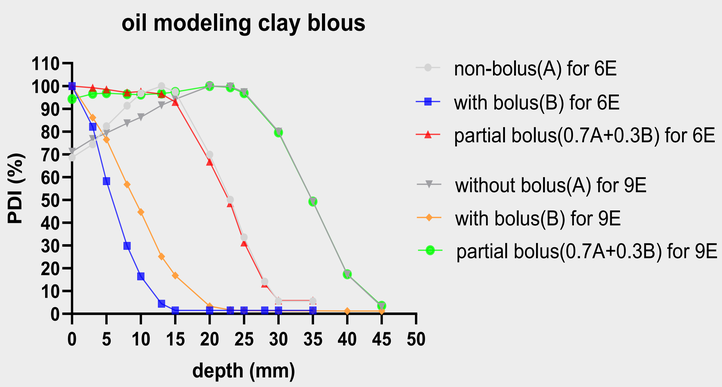

Figure 3. PDI obtained by using the oil modeling clay bolus for 6MeV and 9MeV electron beam.

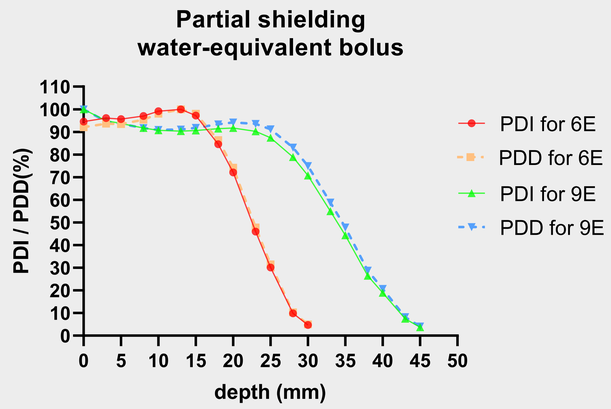

Figure 4. PDD obtained by TG21 stopping power ratio for partial shielding techniques of water-equivalent bolus .

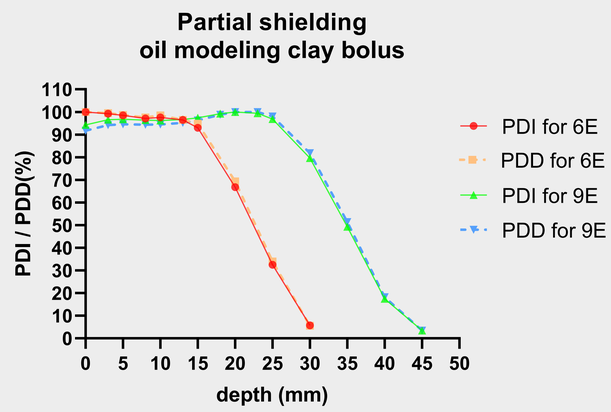

Figure 5. PDD obtained by TG21 stopping power ratio for partial shielding techniques of oil modeling clay bolus .

DISCUSSION

We found that oil modeling clay has the advantages of being readily available and resistant to cracking, making it a suitable material for bolus.

We also measured the CET (Coefficient of Equivalent Thickness) of the oil modeling clay at 6 MeV and 9 MeV electron beams, finding it to be 1.88 and 1.90 cm, respectively.

CONCLUSIONS

These findings indicate that the partial shielding technique can enhance surface dose while preserving sufficient treatment depth, providing a practical alternative to increasing electron beam energy and potentially reducing bremsstrahlung production.

REFERENCES

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2. AAPM TG-21 (1983) A Protocol for the Determination of Absorbed Dose from High-Energy Photon and Electron Beams. Medical Physics, 10, 741-771.

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