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Sutter Health

Electron Backscatter Dose Reduction Using 3D-Printed Aluminum

Gevork S. Gevorkyan, PhD[1]; Garett Roe, MS[1]; Chris J. Tunnicliff, CMD[1]; Christopher U. Jones, MD[1]; Kelly Hosier, MS[1]

[1]Sutter Medical Foundation Department of Radiation Oncology

ABSTRACT

Purpose: Aluminum (Al, 2.7 g/cc) can be used with internal lead shielding to reduce backscattered dose to superficial targets, particularly in superficial lip cancers. Cutting and molding an Al sheet to comfortably fit inside the mouth of the patient is a challenge. This work tests the electron backscatter reduction efficacy of aluminum-polylactic acid filament (Al-PLA, 1.45 g/cc), which can be 3D-printed to conform to the patient dental contour.

Methods: The Al-PLA sheets of 1.0 mm, and 2.2 mm were produced, matching the solid Al sheet thickness. For dosimetry, Gafchromic film was calibrated with 9 MeV electrons. Backscatter reduction was tested on both Al and Al-PLA sheets with thicknesses of 1.0 mm, 2.2 mm, and a combined 3.2 mm, measuring the upstream-of-lead and downstream-of-lead dose for water-equivalent thicknesses (WET) between 1.0 cm to 2.0 cm for 6 MeV electrons and 2.5 cm to 3.5 cm for 9 MeV electrons with lead thicknesses of 4.0 mm and 4.8 mm respectively.

Results: For 6 MeV electrons at WET depths of 1.0 cm, 1.5 cm, and 2.0 cm, the average backscatter dose reduction with [1 mm, 2.2 mm, 3 .2mm] Al was [16%, 25%, 29%] and Al-PLA was [8%, 18%, 23%]. For 9 MeV electrons at WET depths of 2.5 cm, 3.0 cm, and 3.0 cm, the average backscatter dose reduction with [1 mm, 2.2 mm, 3 .2mm] Al was [18%, 27%, 30%] and Al-PLA was [12%, 19%, 26%]. Downstream dose was consistently below 1 cGy.

Conclusions: The same thickness of Al-PLA did reduce the backscattered dose to half the efficacy of Al, requiring roughly double the thickness. The filament can be used for patient-specific shielding using the patient contours acquired from simulation, however challenges remain with the consistency of printing using commercially available 3D printers and limitations of space in the oral cavity where internal shielding will be used.

CONTACT

Gevork S. Gevorkyan
Sutter Medical Foundation – Radiation Oncology
2825 Capitol Ave, Sacramento, CA., USA, 95816
Gevork.Gevorkyan@Sutterhealth.org

INTRODUCTION

Internal lead shielding is commonly used with 6~9 MeV clinical electron beams for treating superficial lip and cheek lesions.

Lead increases upstream electron backscatter, requiring a lower-density material like aluminum to reduce mucosal dose.

Conventional aluminum is difficult to shape for patient-specific treatments, and 3D-printable Al-PLA could be an alternative.

Figure 1. Aluminum 6061 Filamet™ from Virtual Foundry, Inc., printed using the Bambu Labs H2D Pro dual nozzle printer.

Figure 2. Lead sheet **(A)**, solid aluminum sheet **(B)**, and Aluminum-PLA sheet **(C)**.

METHODS AND MATERIALS

Printed 1.0 mm and 2,2 mm Al-PLA sheets using a commercial 3D printer to compare against solid aluminum of the same thicknesses. The upstream and downstream doses were measured using EBT4 Gafchromic Film.

Beam setup:
- 6 MeV (4.0 mm Pb)
- 9 MeV (4.8 mm Pb)
- 10 x 10 cm2 field
- 100 cm SSD
- 200 MU

Tested Al/Al-PLA thicknesses:
- 0 mm (no aluminum)
- 1.0 mm
- 2.2 mm
- 3.2 mm

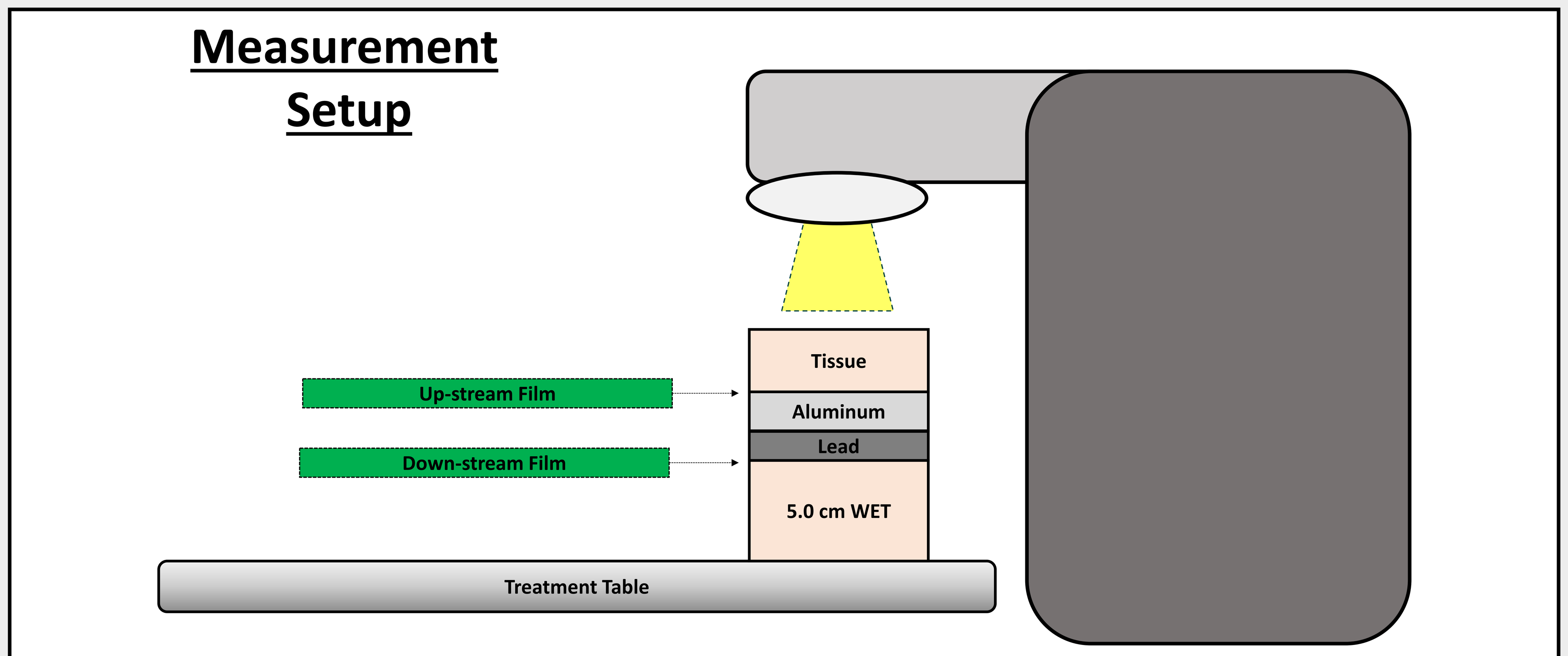

Figure 3. Experimental geometry used to measure upstream backscatter reduction and downstream transmission.

RESULTS

Down-stream dose measurements consistently showed < 1.0 cGy for all setups tested.

Table 1. Shielding results of 6 MeV measurements.

Dose relative to expected PDD (%)	1.0 cm WET	1.5 cm WET	2.0 cm WET	Average
0.0 mm Al	155.1 %	161.5 %	161.2 %	**159.3 %**
1.0 mm Al	138.8 %	130.3 %	130.9 %	**133.3 %**
2.2 mm Al	119.4 %	117.4 %	119.1 %	**118.6 %**
3.2 mm Al	109.2 %	115.4 %	113.2 %	**112.6 %**
1.0 mm Al-PLA	146.4 %	149.2 %	142.8 %	**146.1 %**
2.2 mm Al-PLA	136.2 %	129.7 %	126.3 %	**130.8 %**
3.2 mm Al-PLA	128.1 %	120.0 %	117.8 %	**121.9 %**

Table 2. Shielding results of 9 MeV measurements.

Dose relative to expected PDD (%)	2.5 cm WET	3.0 cm WET	3.5 cm WET	Average
0.0 mm Al	162.4 %	170.5 %	175.4 %	**169.4 %**
1.0 mm Al	140.0 %	142.2 %	136.5 %	**139.6 %**
2.2 mm Al	122.7 %	123.9 %	123.2 %	**123.3 %**
3.2 mm Al	115.4 %	122.0 %	119.5 %	**119.0 %**
1.0 mm Al-PLA	148.3 %	149.7 %	149.8 %	**149.3 %**
2.2 mm Al-PLA	140.0 %	137.1 %	131.8 %	**136.3 %**
3.2 mm Al-PLA	128.0 %	127.1 %	120.4 %	**125.1 %**

CLINICAL IMPACT AND FUTURE WORK

- **Al-PLA reduced electron backscatter, but approximately 2 × thickness was needed compared to solid aluminum.**
- Patient-specific 3D printing may improve shielding conformity and comfort for oral treatments.
- Print consistency remains a practical challenge with software-locked printers.
- A more reliable printing method needs to be explored.

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