Case Study: Clinical Applications of 3D Printing in Radiotherapy

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Overview

Adaptiiv Medical Technologies Inc. (Adaptiiv) provides cancer centres with the hardware, software, and materials to develop low cost, high performing medical devices that supersede existing conventional technologies. The following case illustrates the application of our technology used in clinical radiation oncology through the creation of 3D bolus for modulated electron radiotherapy (MERT). This case is a great example of how Adaptiiv's software can be effectively used to create an optimized bolus to allow for the modulation of the electron fluence to spare distal structures. More details can be found in the published article listed below.[1]

Patient History

A 67-year-old female patient was treated at the Nova Scotia Health Authority with mycosis fungoides of the forehead, eyelid and nose.

Description

This case study illustrates a clinical application of 3D printing in radiation oncology through the creation of a bolus for modulated electron radiotherapy (MERT) to treat the patient with mycosis fungoides of the forehead, eyelid and nose. The plan was to treat her disease with two separate electron fields: a superior field, with an anterior beam, was intended to cover the lesions in the regions of the bilateral eyebrows, eyelids, glabella, and nasal bridge; and a right lateral field, used to cover the right malar and cheek area. The application of bolus was necessary to deliver the prescribed dose to the skin surface.

A uniform thickness material would not be suitable for the superior field, due to marked surface irregularities and complex curvatures of the body contours. 3D printing was therefore used to create an optimized bolus for the superior field, allowing modulation of the electron fluence to spare distal structures (see Figures 1 and 2). Adaptiiv software was used to determine the shape of the anterior bolus surface, whereby the thickness of the bolus modulated the electron fluence and energy.

[1] *Zhao et al 2017 – Clinical applications of 3-dimensional printing in radiation therapy. Medical Dosimetry 42 (2017) 150-155. https://www.meddos.org/article/S0958-3947(17)30032-8/ppt*

Fabrication and Treatment

The bolus was designed with the aim of achieving dose distributions sparing tissues distal to the target volumes. The width of the bolus was intended to cover the PTV with 20mm margins. DICOM images of the bolus were converted to a stereolithography file. The end product was fabricated with a LulzBot TAZ5 3D printer, using NinjaFlex TPU. The printing duration was approximately 23.5 hours. The patient received 25Gy over 20 fractions @ 12 MeV.

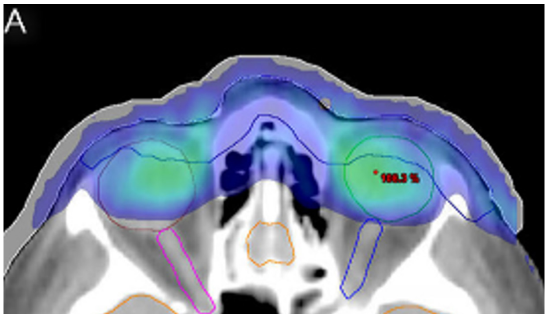

Figure A.

Patient with mycosis fungoides of the forehead, eyelid and nose. Standard bolus provides coverage of the PTV, however, a high dose to underlying OARs and normal tissue is evident.

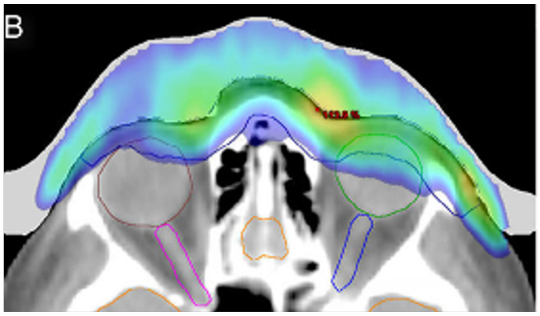

Figure B.

Adaptiiv's Modulated Electron Bolus is customized, changing the surface shape to allow for tailoring of dose distribution.

Results / Findings

The custom bolus was optimized by Adaptiiv software and was modulated to be thicker over the ocular structures, allowing adequate delivery of the dose to the eyelids, but relative sparing of the eyes and optic nerves. It was relatively thinner in the periphery of the electron field, accounting for the lateral constriction of the higher level isodose lines. The inferior aspect of the 3D printed TPU bolus was conformal to the patient's complex and uneven upper facial surface anatomy. Based on the treatment planning CT, the size of the largest air gap at the interface of the 3D printed structure was 2mm. An acceptable treatment plan was obtained (90% isodose to 92.5% of PTV) and compared with a plan with a uniform thickness bolus, the plan achieved relative sparing of all OARs distal to the target volume, while maintaining similar target volume coverage. The 3D printed bolus was rigid and could be reproducibly placed at the times of planning CT and daily treatments, without causing discomfort.

Summary

1. 3D printing can be implemented effectively in the clinical setting to create highly conformal bolus for Modulated Electron Radiation Therapy (MERT).
2. 3D printing's accuracy and high resolution make it best suited for MERT bolus, allowing precise dose modulation.
3. The customized 3D printed bolus could be reproducibly placed at the times of planning CT and daily treatments, without causing discomfort.