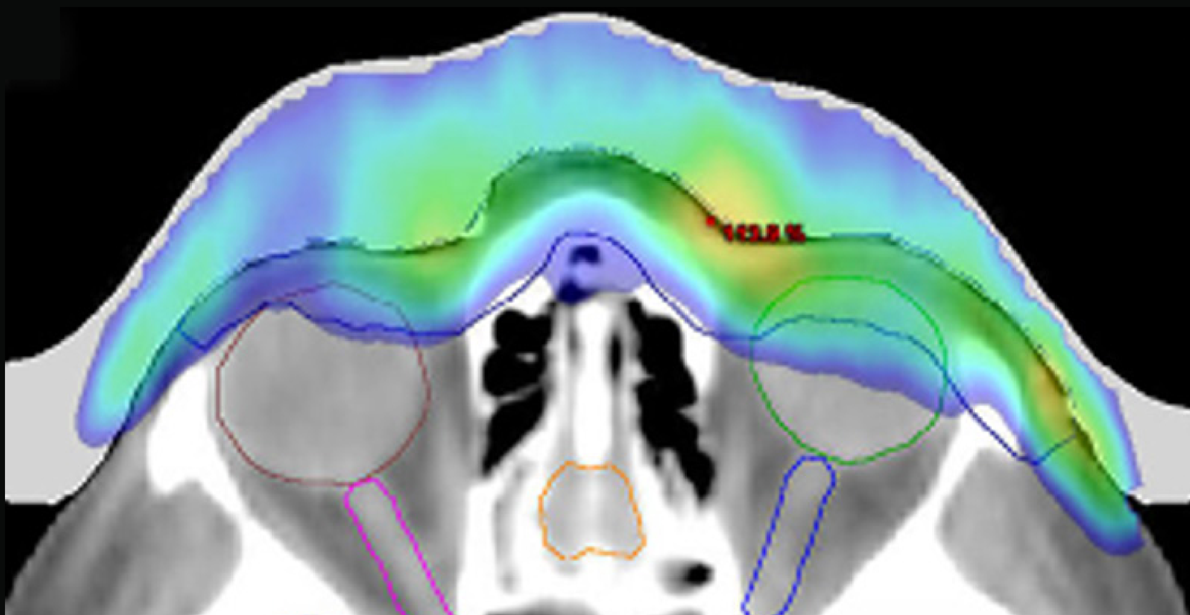

Patient Case Study:
Clinical Applications of 3D Printed Modulated Electron Bolus in Radiotherapy

NOVA SCOTIA HEALTH
Halifax, Nova Scotia
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Overview

Adaptiiv Medical Technologies Inc. (Adaptiiv) provides cancer centers with regulatory cleared software to design patient-specific radiotherapy accessories that can be 3D printed.

This case study illustrates a clinical application of 3D printing in radiation oncology through a personalized bolus for modulated electron radiotherapy (MERT). The patient was treated for mycosis fungoides of the forehead, eyelid and nose. The modulation allowed for optimization of the dose and an increase of dose to the skin surface while sparing the critical eye and optical nerve structures distal to the planned treatment volume compared to the planned treatment of a uniform thickness bolus.[1]

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

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Patient History

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

Description

The initial treatment plan consisted of two separate electron fields. The first was a superior field with an anterior beam used to cover the lesions in the regions of the bilateral eyebrows, eyelids, glabella, and nasal bridge. The second was a right lateral field covering the right malar and cheek area. The bolus was necessary to assist in delivering the prescribed dose to the skin surface.

A vinyl sheet bolus was deemed unsuitable for the superior field due to marked surface irregularities, complex curvatures of the body contours, and the risk of dose to the critical underlying surface structures. A 3D printed bolus allowed the bolus structure to easily conform to the patient's irregular skin surface and the nose's extreme curvature. It was decided to use a modulated bolus for the superior field. The modulation of the electron fluence allowed sparing of distal structures and significantly reduced dose to the eyes compared to the uniform thickness bolus (see Figures A and B). 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.

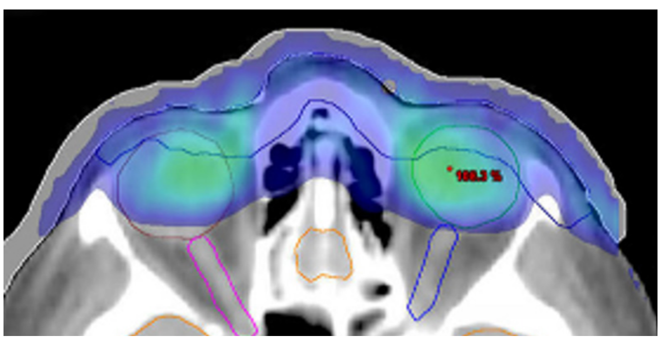

Figure A. Standard bolus provides coverage of the PTV and a high dose of underlying OARs and normal tissue is evident.

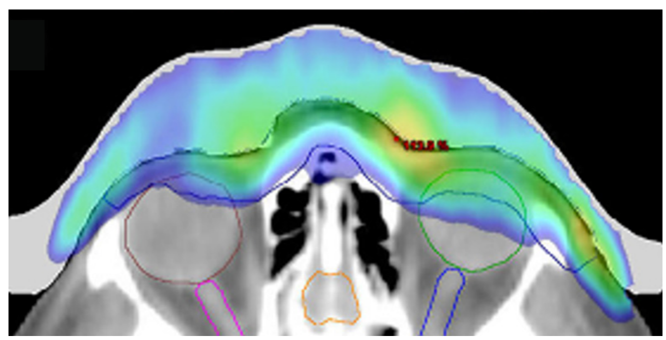

Figure B. The MEB allowed a significantly reduction of dose to the eye while, increasing the dose to the eyelid and skin surface.

Fabrication and Treatment

The modulated bolus was used to achieve dose distributions sparing tissues distal to the target volumes. The width of the bolus was intended to cover the PTV with 20 mm margins. DICOM images of the bolus were converted to a stereolithography file (STL). The finished bolus model was 3D printed with a LulzBot TAZ5 3D printer, using NinjaFlex TPU. The printing duration was approximately 23.5 hours. The patient received 25 Gy over 20 fractions at 12 MeV.

Results

The personalized MEB was designed in Adaptiiv software. The bolus was optimized to be thicker over the ocular structures for modulation of the electron field, in an effort to spare the eyes and optical nerve. The MEB allowed an adequate build-up of dose to the eyelids and 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.

Results (cont.)

The inferior aspect of the 3D printed TPU bolus was conformal to the patient's complex 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 2 mm.

An acceptable treatment plan was obtained (90% isodose to 92.5% of PTV) after comparison to a uniform thickness bolus. Testing of the uniform thickness bolus revealed dosing of 108% to the underlying eye structures. The MEB 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 when planning CT and daily treatments without causing discomfort.

Summary

1. A personalized 3D printedbolus allowed for a conformal fit of the patient's complex surface structures compared to a sheet bolus.

2. A modulated electron bolus, optimized in Adaptiiv software, allowed for sparing of the distal organs at risk; in this case, there was a significant reduction in dose to the eye and optical nerve when using MEB in comparison to a uniform thickness bolus.

3. 3D printing can be implemented effectively in the clinical setting to create a conformal bolus for modulated electron radiation therapy (MERT).