Patient Case Study:
3D Printed Surface Brachytherapy Applicator for Treatment of the Scalp Vertex

ROYAL NORTH SHORE HOSPITAL
Northern Sydney Cancer Centre
Sydney, Australia

Overview

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

The following case demonstrates the clinical application of a 3D printed high dose rate (HDR) surface brachytherapy applicator for the scalp. The treatment was planned in Elekta's Oncentra Brachy 4.5.3 treatment planning system (TPS). The applicator was prepared by importing the DICOM RT structure and CT data set from the TPS into Adaptiiv's software. The final applicator structure was exported from Adaptiiv's software for 3D printing.

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Patient History & Description

A 64-year-old male was diagnosed with cutaneous melanoma of the scalp vertex. The patient's general practitioner initially resected a 8 mm-thick non-ulcerated amelanotic BRAF-negative melanoma lesion with focally involved peripheral margins and a close (0.3 mm) deep margin. The mitotic rate was high at 15 per mm². PNI (perineural invasion) was also present at the periphery of the tumour, and further wide local excision was recommended 4.5 weeks after initial resection. A final specimen of 48 mm x 33 mm x 8 mm to the level of periosteum was removed and disclosed two completely resected satellite melanoma nodules (BRAF-negative) measuring 1.5 mm and 0.7 mm, respectively, with the latter involving an unnamed nerve. Surgical margins were again close at 0.5 mm. The patient's primary defect was closed with a scalp rotation flap with good healing.

Treatment Planning

The patient's 4-week post-operation positron emission tomography (PET) scan revealed no suspicious uptake locally or regionally. After a consultation at North Coast Cancer Institute, the patient was referred to Northern Sydney Cancer Centre (NSCC) for treatment. During the consultation, the oncologist explained that the treatment regime included a 3D printed applicator. The treatment regime was a tumour reference dose of 30-40 Gy in 10 fractions, bi-daily for 5 days (an EQD2 of approximately 35Gy at depth and 50 Gy on the skin surface).

Before the patient's computerized tomography (CT) scan, the radiation oncologist (RO) outlined the clinical target volume (CTV) on the patient's scalp, and a CT marker wire was placed along the CTV. The patient was positioned in an inclined position on a breast board with a cushion to support the patient's neck. The CT scan of the whole head was completed with a high resolution 1 mm slice thickness and 1024x1024 pixel matrix.

The patient's CT scan was imported into the Oncentra brachytherapy TPS; the radiation therapist (RT) contoured the body, skull, and brain. The CTV was delineated based on the CT marker wire, extending the target volume to the depth of the skull (Figure 1).

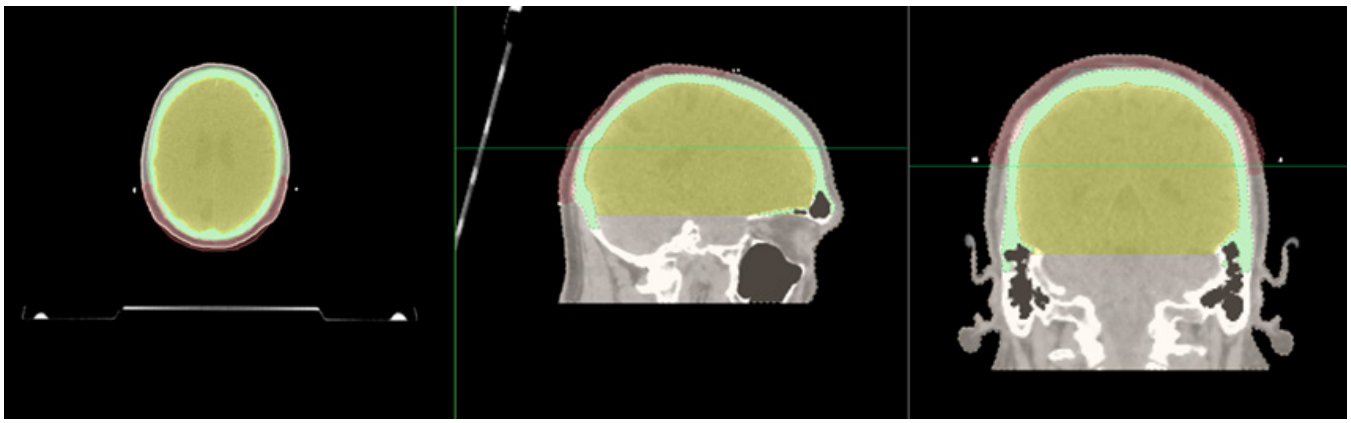

Figure 1. CT scan was imported into Oncentra; the body, skull, brain, and CTV were contoured.

Using the AAPM TG-43 dose algorithm, several different standoff and catheter separation values were tested to achieve the prescribed dose of 34 Gy in 10 fractions with coverage constraints of CTV D98min > 90% at depth, CTV D90=100% and CTV 2cc max <125% at the scalp surface. The optimal plan was achieved using 12 mm standoff and 12 mm between catheters (Figure 2).

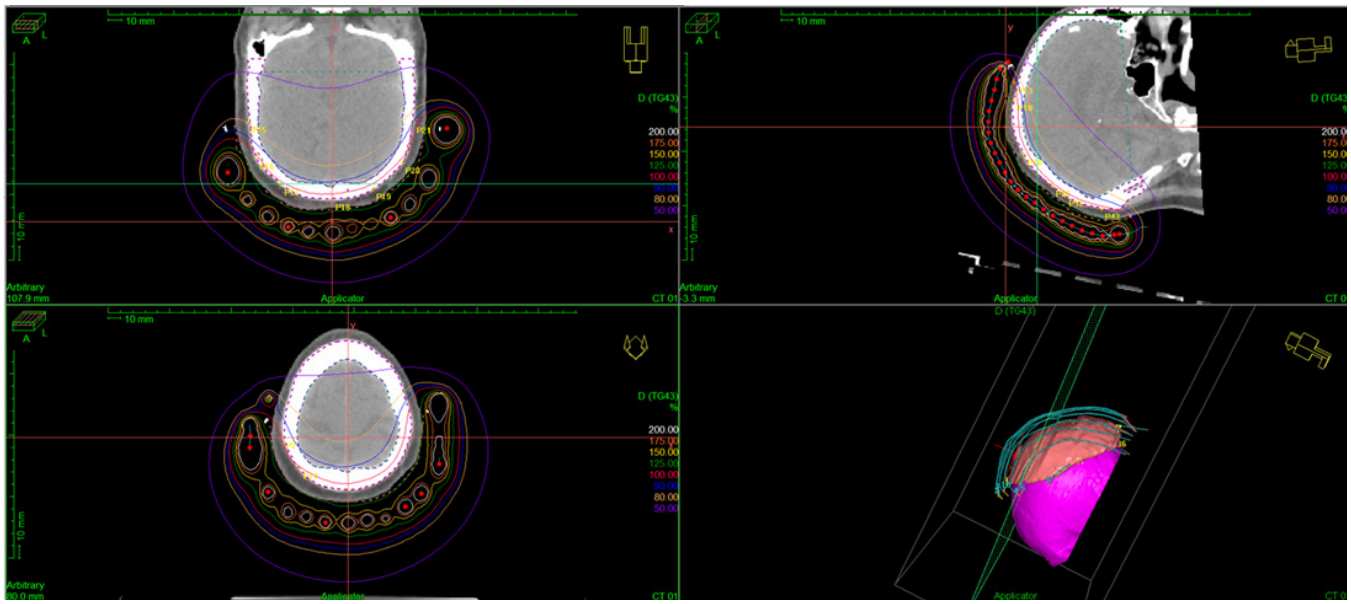

Figure 2. Several different standoff and catheter separation values were tested to successfully achieve an optimal dose delivery.

Treatment Planning

The final applicator was created with a 17 mm thickness to provide 5 mm of backscatter and 12 mm of standoff. The trade off between having adequate backscatter to reduce the dose deficit at the skin surface created by an incomplete scatter environment and ensuring the weight of the final applicator would not be too heavy was considered.

The DICOM structure set was then imported into the Adaptiiv software. The user selected the scalp's surface contour and the applicator structure. Next, the following trajectory criteria were customized; inter trajectory distance (12 mm), the number of trajectories, surface distance (12 mm), and tunnel radius (Figure 3). For the 6F flexi-implant catheters, 4 mm diameter channels were found to be the smallest that prevented source obstructions due to the nature of the curved surface of the mould.

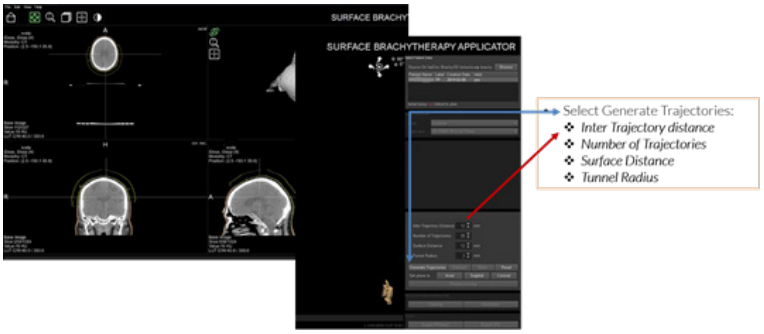

Figure 3. Adaptiiv software allows users to customize trajectories.

Once the catheter trajectories were generated, each was checked and edited where required. As shown in Figure 4, highlighted red sections on trajectories indicate locations with a small curvature radius, which could potentially be too tight for the source to traverse. These sections were smoothed by simply clicking and dragging the red nodes on the yellow highlighted trajectory, turning them blue.

After the trajectories were adjusted, the structure was imported into the TPS to verify that the catheter positions were equivalent to the initial treatment plan (Figure 5). The final structure was exported from Adaptiiv for 3D printing.

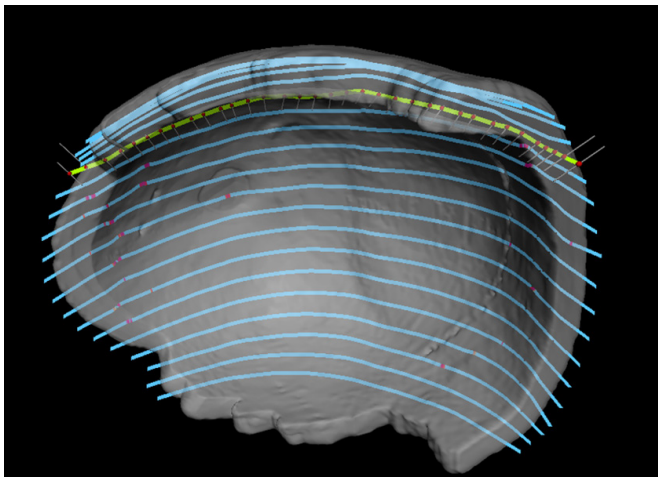

Figure 4. Catheter tunnel trajectories with small curvature radius can be smoothed or straightened by a simple point-and-click function in Adaptiiv's software.

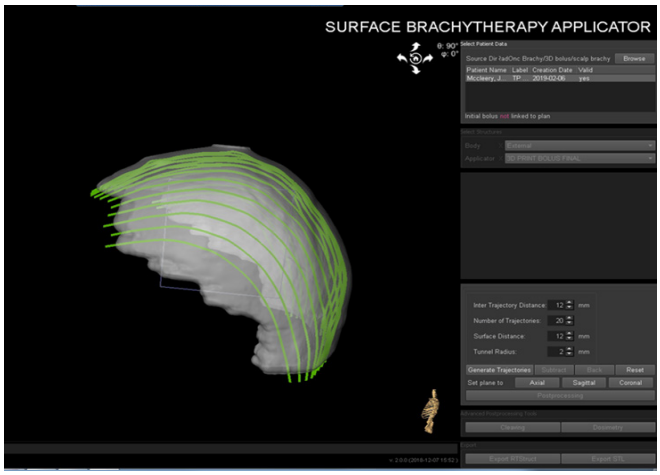

Figure 5. Catheter tunnel trajectories can be checked in Adaptiiv software for equivalence to plan generated in TPS and amended if required, then the file can be exported seamlessly from the software to 3D printing slicing software to prepare print-ready file.

Results

The Northern Sydney Cancer Centre at Royal North Shore Hospital demonstrated that producing an HDR surface brachytherapy scalp mould is possible using the Adaptiiv software solution. The centre noted that special care should be taken during treatment planning to create a surface applicator to achieve the RO's prescription. Consideration should be given to the trade off between backscatter material and the weight of the mould. The centre found that using Adaptiiv software to design and 3D print a surface applicator was less time-consuming than other brachytherapy surface mould methods previously used.

Summary

1. It is viable to produce a 3D printed HDR surface applicator for the scalp using Adaptiiv.
2. Customizing and fabricating the brachytherapy applicator scalp mould was less time-consuming than traditional methods.

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Adaptiiv Medical Technologies Inc.
1969 Upper Water Street, Suite 906
Halifax, NS B3J 3R7

info@adaptiiv.com
adaptiiv.com

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