Design of Custom, 3D-Printed Surface Brachytherapy Applicators

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JULY 12–16 2020 VIRTUAL JOINT AAPM | COMP MEETING

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EASTERN TIME [GMT-4]

INTRODUCTION

- Superficial photon or electron beams are typically used when treating skin cancer with radiation therapy.
- Treatment with these modalities is most consistent when the patient contour is normal to the treatment beam.
- If the treatment area is large or there is more than one lesion, multiple fields may be required to obtain adequate target coverage.
- Planning and treating many targets on a patient's sloping body contour can be particularly problematic.
- Additionally, the treatment of patients over several fractions creates another layer of complexity.

AIM

- The purpose of this work is to design and fabricate patient-specific, surface HDR brachytherapy applicators for the treatment of multiple complex targets with a simple daily set up.

METHOD

- An 80-year-old patient presented with bilateral basal cell carcinoma on his shins – three lesions on the right shin, two on the left. The targets were prescribed 40 Gy in 15 fractions with HDR surface brachytherapy.
- The patient's initial CT simulation was used for applicator design, with the targets wired by the physician, as shown in Figures 1 (a) and (b).
- The CT dataset was imported into the Eclipse TPS (Varian Medical Systems). Individual applicators for each shin were created as "bolus" structures, using the patient's external body contour.
- Care was taken to control the applicator dimensions so that it would **fit on the 3D-printer plate**, would be **shorter than the brachytherapy catheters**, and would **not need to be cleaved** and then reattached to be placed onto the patient.
- The Eclipse structures were imported into the brachytherapy module of 3D Bolus (Adaptiv Medical Technologies) to take advantage of its **automatic tunneling feature** to design the catheter trajectories (see Figure 1 (c)).

- The applicator designs were exported from 3D Bolus and printed with a Lulzbot® TAZ 5 3D-printer (Aleph Objects).
- Flexible 6F catheters were inserted through the tunnels and fastened in place with buttons to allow the HDR source to travel reliably through the applicator.
- A second CT simulation (see Figure 2) of the patient, with the completed applicators and radiopaque markers inserted, was required to:
  - Ensure proper fit
  - Verify print quality
  - Create reference marks for daily setup on the patient
  - Enable catheter reconstruction for treatment planning
- The patient was planned in Oncentra Brachy (Elekta), with two treatment plans – one for each shin.

Figure 1: (a) Initial simulation for applicator design, with radiopaque wires outlining the CTVs. Two lesions on the right shin were combined into one, resulting in two CTVs per shin. (b) Body contour that was used to model the applicators for 3D-printing. (c) Applicator and catheter trajectory model for the right shin in 3D Bolus.

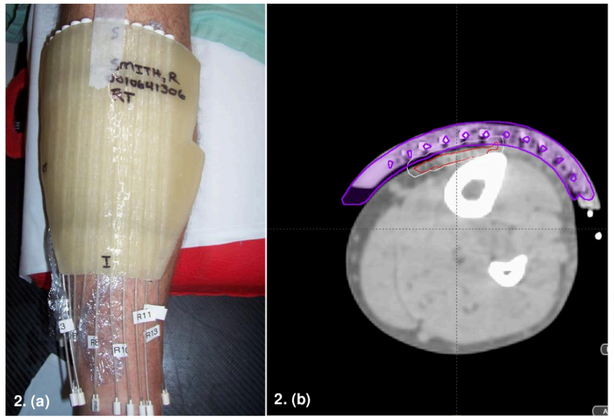

Figure 2: (a) 3D-printed applicator on right shin. (b) CT of patient with completed applicator. CTV is in red, PTV in white and designed applicator in purple.

RESULTS

- Each applicator required 13 catheter tunnels to encompass the CTVs in all directions, with at least one catheter tunnel lateral to the wired targets.
- After minor adjustments during the second CT simulation, the applicator fit the patient's body contour and matched the modelled applicator well, as show in Figure 2.
- The first CT dataset was co-registered to the second dataset to allow contouring (from the wired mark-ups on the first CT scan) and planning (with the radiopaque markers and completed applicators on the second CT scan) to occur on the second set of simulation images.

- The CTVs were designed to treat to a 3 mm depth, with a 3 mm PTV margin in the lateral and superior-inferior directions to account for daily setup variations.
- The resulting plan was able to cover greater than 98% of the PTV with 100% of the prescription, and mostly contained the 150% isodose to the applicator, minimizing the volume of target that receives the high dose (see Figure 3).

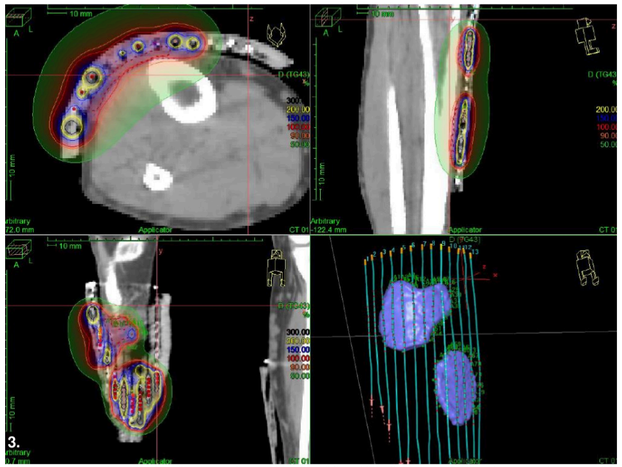

Figure 3: Dose distribution in three planes for the right shin. The prescription dose conforms well to the PTV, with dose greater than 150% confined to the applicator.

CONCLUSIONS

- 3D-printed surface brachytherapy applicators can be successfully used to treat patients with bilateral shin skin cancers.
- The 3D-printed applicator provided excellent fit to the patient's contour and was easy to use for treatment.

CONTACT INFORMATION

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