Case Report: 3D-Printed Model for Surface Mould Preparation on a Patient with Down's Syndrome

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INTRODUCTION

For patients with Down syndrome, administering adjuvant radiotherapy for conditions like Dermatofibrosarcoma protuberans (DFSP) poses challenges due to anesthesia-related complications [1]. To address this, we present a novel approach using a 3D-printed model of the patient's head for brachytherapy treatment planning. By avoiding prolonged sedation, the 3D-printed model allows for efficient and precise applicator preparation. We achieved a significant reduction in anesthesia sessions, delivering the same Equivalent Dose of 44.69 Gy in just five brachytherapy sessions, thereby minimizing anesthesia risks for the Down syndrome patient population.

OBJECTIVES

Utilize 3D printing technology to fabricate a custom brachytherapy applicator for a patient with Down syndrome and Dermatofibrosarcoma protuberans (DFSP), eliminating the need for general anesthesia during applicator preparation. Brachytherapy was chosen as the treatment for this patient as it offers several advantages [2,3]: rapid dose fall-off, fewer number of fractions, and a mould applicator can be made around an irregular/curved surface. There have been many cases where brachytherapy was administered to treat DFSP in patients with an irregular anatomy.

Evaluate the accuracy and suitability of the 3D-printed brachytherapy applicator in conforming to the patient's unique anatomy and tumor location. By achieving these objectives, the study aims to demonstrate the potential of 3D printing technology in improving treatment planning for DFSP in Down syndrome patients, minimizing anesthesia-related risks, and enhancing the overall treatment experience.

METHOD

Treatment Setup:

Prepared surface brachytherapy applicator on the patient using a thermoplastic mask with embedded catheter tubes on dental wax. CT scan performed under sedation using propofol and ketamine to avoid general anesthesia risks. Lesion boundaries marked with wires by the radiation oncologist before CT scan.

3D-Printing:

Patient's head contour and Clinical Target Volume (CTV) delineated and 3D-printed with a 5 mm thickness covering frontal, occipital, and temporal regions. Used ProJet MJP 3600 Max printer with UV-light for resin material curing. Printed material, VisiJet M3 crystal, CT scanned for CT number analysis (300 HU) and post-processed using vegetable oil to dissolve support material (wax). Assembled three printed parts using male-female plugs and super glue.

Brachytherapy Mould Applicator:

Thermoplastic mask prepared on 3D-printed model, allowing convenient catheter placement due to integrated CTV. Dental wax sheets (2 mm) used for attenuation, 11 applicator mould probes (Varian) sandwiched between wax sheets with 1cm space between each of them, marked from 1 to 11. Fitted mould applicator tested on the patient, and a second CT scan performed under sedation for planning. Ultrasound gel with cotton gauze placed inside applicator to minimize air gaps.

Brachytherapy Planning:

Prescription for brachytherapy: 32.5 Gy in 5 fractions (EQD2: 44.69 Gy) with TG-43 volumetric optimization on ECLIPSE planning station. Each channel manually reconstructed from metal markers in CT scan. Final plan delivered 95% of prescribed dose to 95% of target volume, with CTV 5 mm into patient's skin, 7.5 cm long, and 10 cm wide. Treatment time on initial day: 16 minutes with Ir-192 source (7.474 Ci strength), QA plan ensured clearance for all channels before daily treatment delivery.

RESULTS

1. **Avoidance of General Anesthesia:** By utilizing brachytherapy and 3D-printing, the need for general anesthesia in a patient with Down's Syndrome was successfully avoided. General anesthesia in such patients poses significant risks, including respiratory infections, airway blockage, and atlanto-occipital dislocation.

2. **Unrushed Applicator Preparation:** The 3D-printed model allowed for a more relaxed and unhurried environment during applicator preparation. Unlike conventional methods that require general anesthesia and limited sedation time, the 3D-printed model enabled precise and neat placement of catheter probes on the patient's head surface.

3. **Improved Catheter Placement:** The presence of the Clinical Target Volume (CTV) on the 3D-printed model facilitated better catheter placement, ensuring even distribution and optimal coverage beyond the CTV region.

4. **Satisfactory Applicator Fitting:** The fitting of the brachytherapy mould applicator on the patient's head, verified before the treatment planning CT scan, was found to be satisfactory. The use of ultrasound gel minimized air gaps, ensuring accurate dose delivery.

5. **Challenges of Sedation:** While the sedation approach was well-tolerated, increasing dosage was required on subsequent treatment days. In contrast, prolonged external beam treatment would have necessitated excessively high sedation dosage by the end of the treatment.

6. **Time and Resource Requirements:** A drawback of 3D-printing was the time-intensive process of printing the head model (approximately 22 hours). Additional time was also needed for anatomy preparation and post-processing of the 3D-printed model.

CONCLUSIONS

There are two rare conditions in this case: DFSP and Down's Syndrome. Since there are several complications with general anesthesia for a patient with Down's Syndrome, it is best to avoid general anesthesia and provide sedation with minimal dosage and minimal sessions. Brachytherapy is an excellent option to reduce the number of fractions and hence the number of anesthesia sessions. We used a 3D-printed model to prepare the mould applicator, significantly reducing the sedation during radiotherapy simulation. 3D-printing a patient's anatomy is an excellent option to prepare mould applicators for surface brachytherapy. It can greatly reduce potential risks from anesthesia, improve patient comfort and allow relaxed environment for the preparation of the applicator.

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