Implementation of a New Treatment for Skin Cancer using HDR Brachytherapy

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Introduction

Radiotherapy is commonly used in the treatment of non-melanoma skin cancers (NMSC) and can be delivered using electrons or low energy x-rays using a kilovoltage (kV) x-ray unit. The kV unit in the Radiotherapy department at Aberdeen Royal Infirmary was decommissioned almost 15 years ago. Electron treatments are not suitable for small lesions, therefore patients' only treatment option has been surgery. Brachytherapy is a well established technique for the treatment of many cancers and is available in most radiotherapy centres accounting for approximately 10% of their work load. Until recently Aberdeen Royal Infirmary provided Brachytherapy for patients with gynaecological cancers only, but treatment for NMSC is now provided using Varian surface skin applicators (Fig 1). Brachytherapy can deliver a superficial dose to the skin similar to that of a kV x-ray unit and evidence demonstrates cost efficiencies and improved cosmesis compared to surgical intervention. Projected patient numbers are 12-15 per year and will predominantly be used for those patients not suitable /refuse surgery, elderly, or have skin cancers in anatomically complex positions – affecting future cosmesis.

Figure 1: Brachytherapy skin applicators. A range of collimator sizes are available.

Commissioning Model Based Dosimetry Algorithms

Since 1995 the dominant dose calculation algorithm in brachytherapy has been the TG-43 model based on assuming a source with radial symmetry existing in a medium of pure water. However, in a situation such as with a tungsten shielded applicator, the TG-43 model is incapable of accounting for the presence of the tungsten and will model the dose incorrectly; a new approach is therefore required.

Varian has developed a model based dose calculation algorithm (MBDCA) that solves the linear Boltzmann transport equation (LBTE) explicitly. This model (Acuros) is commercially available as part of Varian's BrachyVision treatment planning system.

To commission this model for clinical use it is important to complete a number of tests as laid out in TG-186 [1]. These checks involve performing dose calculations with TG43 and Acuros and comparing them to a gold standard Monte Carlo calculation.

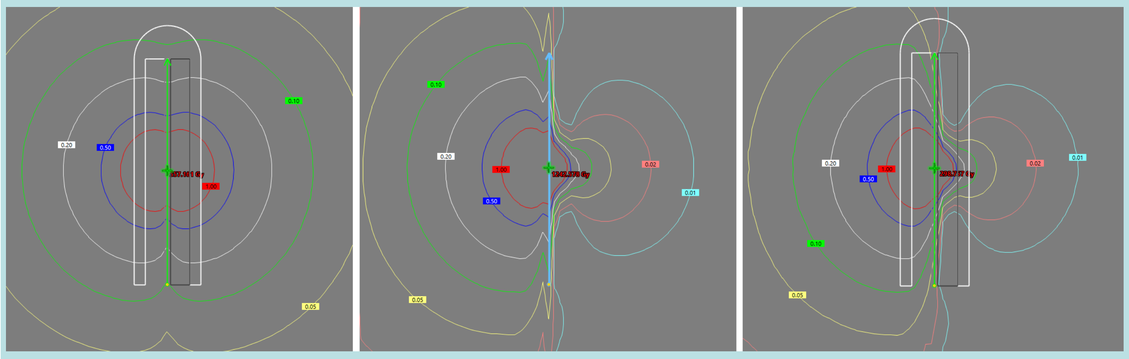

Figure 2: Comparison of dose algorithms for shielded applicator with single dwell position in centre. Applicator is from [2] and has tungsten on right side. Left: TG43, Middle: Monte Carlo MCNP6, Right: Acuros BV 1.7. MCNP6 data from [3].

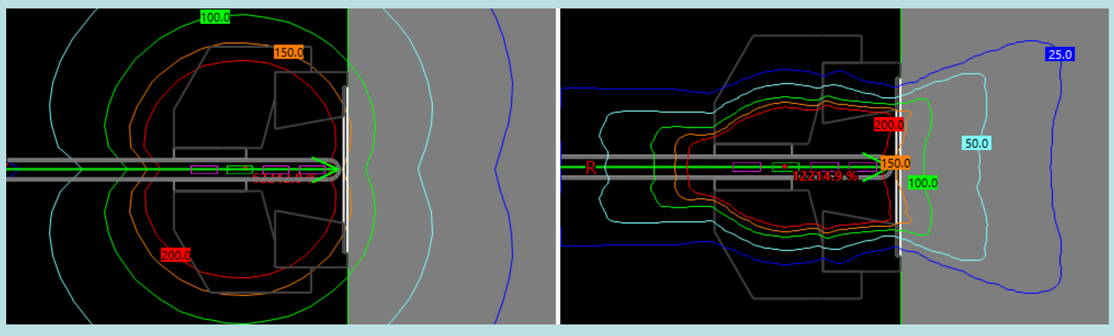

Figure 3: Side by side comparison of shielded skin applicators on a water phantom using the TG43 dose calculation (left) and Acuros BrachyVision (right). TG43 is unable to account for the tungsten shielding and so does not model the attenuation of dose correctly

Film measurements and Monte Carlo modelling

It is necessary to independently verify the output of the treatment planning system to ensure that patients will receive the correct radiation dose. Two suitable methods were chosen: measurement using radiochromic film and independent simulation using EGSnrc, a Monte Carlo algorithm.

All three methods of assessing the dose showed good agreement relative to the uncertainties involved, increasing our confidence in the technique. Some minor differences were observed at the field edges and at the skin surface.

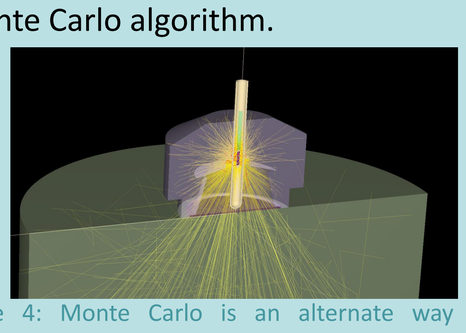

Figure 4: Monte Carlo is an alternate way of calculating radiation dose

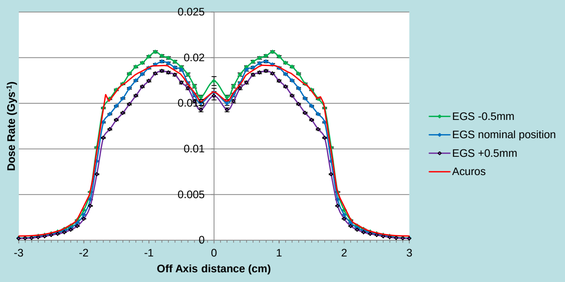

Figure 5: This shows how the dose rate at 3mm deep varies when the source is moved 0.5mm vertically within the 30mm applicator

Using Monte Carlo also allowed us to assess the variation in the treatment that would be caused by small changes in the radioactive source position. Knowledge of these uncertainties allow us to make better decisions regarding the selection of applicators for treatment

First patient

We treated the first patient in January 2019. The patient had been diagnosed with a 14mm diameter nodular BCC with estimated thickness <3mm on their scalp, and preferred a non surgical treatment option.

Patient was prescribed 40 Gy in 8 fractions to be delivered over four weeks as per the GEC-ESTRO guidelines on skin brachytherapy [4]. To ensure adequate coverage a PTV margin of 5mm was added and so a 25mm diameter applicator was used. To ensure maximum patient immobilisation and consistency of treatment, the patient was fitted with a thermoplastic shell with the area around the tumour and face cut out as seen below in Figure 5. The skin applicator fixed by a clamp and treatment times were typically <10 minutes.

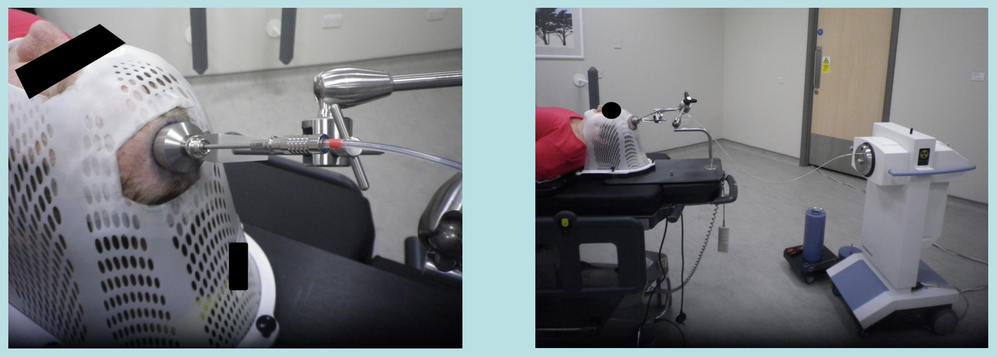

Figure 6: Left, close up showing thermoplastic shell and skin applicator applied to the surface of the lesion. Right, the entire treatment setup including the brachytherapy unit and transfer tube.

Shown below are images of the lesion as treatment progressed and at their first follow-up appointment two months after the final fraction. From fraction 5 onwards patient developed erythema (RTOG grade 1) to the surrounding tissue. Shrinkage of the tumour is apparent and a complete response to treatment is expected.

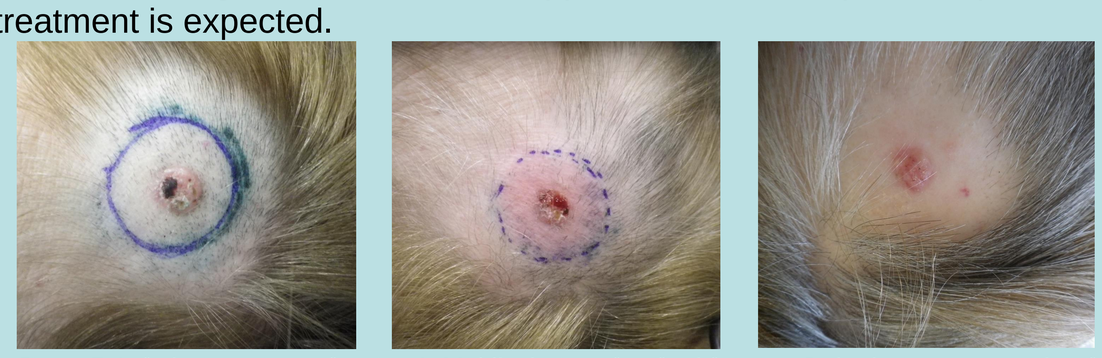

Figure 7: Left, lesion prior to fraction 1. Middle, lesion after final fraction. Right, lesion two months after conclusion of treatment.

References

[1] L. Beaulieu *et al*, "Report of the Task Group 186 on model-based dose calculation methods in brachytherapy beyond the TG-43 formalism: Current status and recommendations for clinical implementation", Med. Phys. **39** (10), 2012.

[2] Y. Ma *et al*, "A generic TG-186 shielded applicator for commissioning model-based dose calculation algorithms for high-dose-rate 192 Ir brachytherapy", Med. Phys. **44** (11), 2017.

[3] Model Based Dose calculations, http://rpc.mdanderson.org/rpc/BrachySeeds/Model_calculations.htm, Accessed March 2018.

[4] J.L. Guinot *et al*, "GEC-ESTRO ACROP recommendations in skin brachytherapy", Radiother. Oncol. **126**(3), 2018.