An Introduction to Radionuclide-Based Brachytherapy for Superficial Targets

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Introduction
Skin cancer is one of the most common cancers worldwide


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Introduction

Incidence of melanoma in the US

Incidence of keratinocyte carcinoma in Scotland

Leiter et al. (2020) Advances in Experimental Medicine and Biology, vol 1268

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Treatment Options for Skin Cancer

Major treatment options include

- Surgery
- Cryosurgery, electrodessication and curettage (EDC), and chemical peels
- Radiotherapy

Melanoma

- Primary treatment option is surgery
- Adjuvant external beam radiotherapy used to decrease risk of recurrence

Keratinocyte Carcinoma

- Primary treatment option is surgery
- Cryosurgery, EDC, and chemical peels often used for low-risk disease
- Radiotherapy used when patient not a surgical candidate or when surgery may lead to functional loss or poor cosmetic outcome

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Radiotherapy Treatment Options for Skin Cancer

External Beam Radiotherapy (EBRT)
- Used as adjuvant treatment for melanoma, or for non-surgical keratinocyte carcinoma patients
- Includes orthovoltage x-rays, electrons, and MV photons
- Will be discussed further by Dr. Hogstrom

Brachytherapy
- Used for non-surgical keratinocyte carcinoma patients
- Options include
  - HDR, PDR, LDR, and electronic brachytherapy
  - Surface applicators (treatment depth ≤5 mm) and interstitial brachytherapy (treatment depth >5 mm)
  → focus of this presentation will be on radionuclide-based HDR surface brachytherapy

Advantages of HDR over EBRT
- Hypofractionated treatment
- Shorter overall treatment times
- Fast dose falloff - lower doses to surrounding normal tissues
- Excellent cosmetic outcomes

Surface Brachytherapy

Lee et al. (2019) Cancer, 125(20):3852-3894
When is surface brachytherapy appropriate?

Contraindications
• Bony invasion
• Deep extension
• Young age

Patient selection
• Margins should be 3-20 mm
• Treatment depth ≤ 5 mm

Available HDR Surface Applicators
• Flaps
• Leipzig-style
• Valencia
• Custom molds
Available Applicators: Flaps

- Flexible silicon applicator that can be molded to irregular surfaces
- Can be sewn to masks or immobilization devices for more reproducible setup
- Flaps can cover a large area or be cut/modified to cover smaller or irregularly shaped lesions
- Source to surface distance of 5 mm
- Channel spacing 5-10 mm
- Treatment depth up to 5 mm
- Applicators available from all major vendors

Typical fractionation reported in the literature

- see Table II in Shah et al. Brachytherapy (2020) 19(4):415-426
- 40-50 Gy in 10-12 fractions
- 42 Gy in 6 or 7 fractions
- Sensitive areas: 60-70 Gy in 30-35 fractions
- Postoperative: 30-40 Gy in 10 fractions
Available Applicators: Leipzig-style

- Tungsten shell with horizontally or vertically oriented stem
  - Applicators with vertically oriented stems show dips in dose near the central axis of up to 20%, with high dose region 8-10 mm from the central axis (Ilhan, et al. JACMP (2016) 17:231-248)
- Range of collimation available (10-45 mm diameter)
  - Even with largest collimator, due to rapid dose falloff, 90% isodose line limited to ~10 mm diameter area at 3 mm depth (Fulkerson, et al. Med Phys (2014) 41(2):022103)
- Source to surface distance 12.5 mm
- Lesion treated with single, centered dwell
- Treatment depth 3-4 mm
- Applicators available from all major vendors

Available Applicators: Leipzig-style

Typical fractionation reported in the literature

- 42 Gy in 6 to 7 fractions
- 40 Gy in 5 fractions
- Sensitive areas: 40-50 Gy in 8-10 fractions
Available Applicators: Leipzig-style


- Treatment area increased from ~10 mm diameter to 20.9×12.4 mm² at 3 mm depth
- May increase the utility of this applicator for more elongated lesions
- Has yet to be used clinically

Available Applicators: Valencia

- Very similar to the Leipzig applicator but contains a flattening filter to help flatten out the dose distribution
  - Can increase clinically useful treatment area
  - Not available from all vendors
Available Applicators: Custom Molds

- Can be made of wax, rubber, silicon, thermoplastic material, or can be 3D printed
- Custom formed to patient’s skin to accommodate irregular surfaces
- Catheters ideally parallel and <10 mm apart, with source to surface distance ideally 5 mm
- Can adjust thickness of material to change dose distribution
- Fractionation similar to flaps

Additional Considerations

Applicator setup reproducibility

- Mark patient/applicator/immobilization device to ensure proper orientation/location for each fraction

Source guide tube placement

- Minimize contact of source guide tubes with patient - use blocks/cushions/etc to hold catheters off of patient
- Minimize running guide tubes over patient to the extend possible

Model-Based Dose Calculation Algorithms

- Dose calculations for brachytherapy generally completed using TG-43/TG-43U
  - This algorithm assumes water-equivalent applicator and patient
  - Invalid for surface brachytherapy due to air interface
  - Some applicators (Leipzig/Valencia) also made of high-Z material (tungsten)
  - Need to use a model based dose calculation algorithm to accurately calculate dose in these applicators and model applicator geometry and scatter
- AAPM TG-186 reviews available MBDCAs, and gives recommendations for dose specification, CT imaging and patient modeling, MBDA commissioning, and uncertainties and limitations in the use of MBDCAs (Beaulieu et al. Med Phys (2012) 39(10):6208-6236)

Summary

- Surface brachytherapy is suitable for the treatment of keratinocyte carcinomas with depths ≤5 mm
- Several applicators are available for HDR treatments, including: flaps, Leipzig-style, Valencia, and custom molds
- Surface brachytherapy requires the use of model-based dose calculation algorithms for accurate dose calculations
- For more information on treatment guidelines see
- For more information on clinical considerations, workflows, and quality management programs see