# An Introduction to Radionuclide-Based Brachytherapy for Superficial Targets

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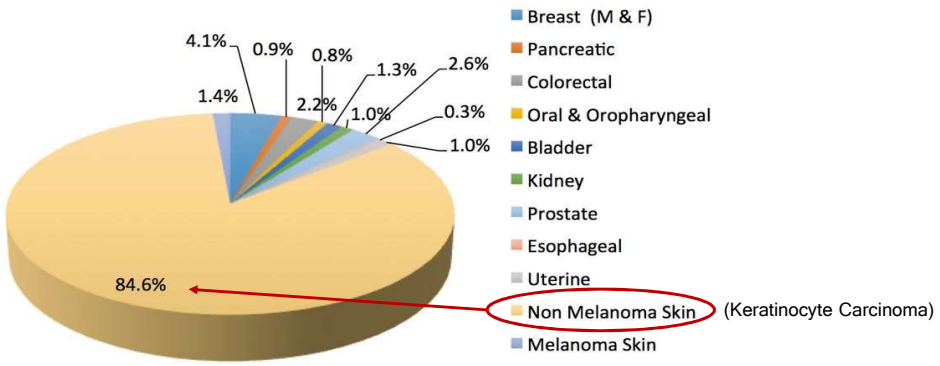
## Introduction

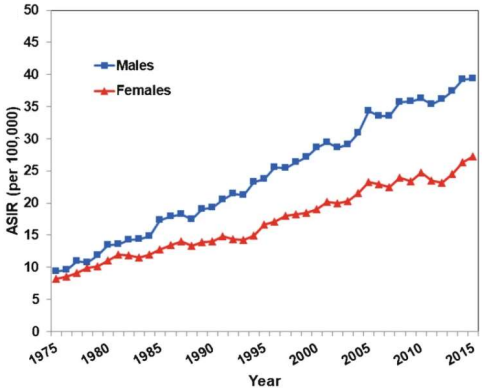
Skin cancer is one of the most common cancers worldwide



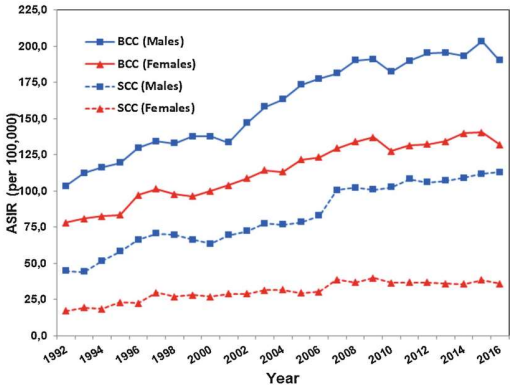

Gareau, *et al.* Biomed Opt Express (2017) 8(8):3807-3815

# 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

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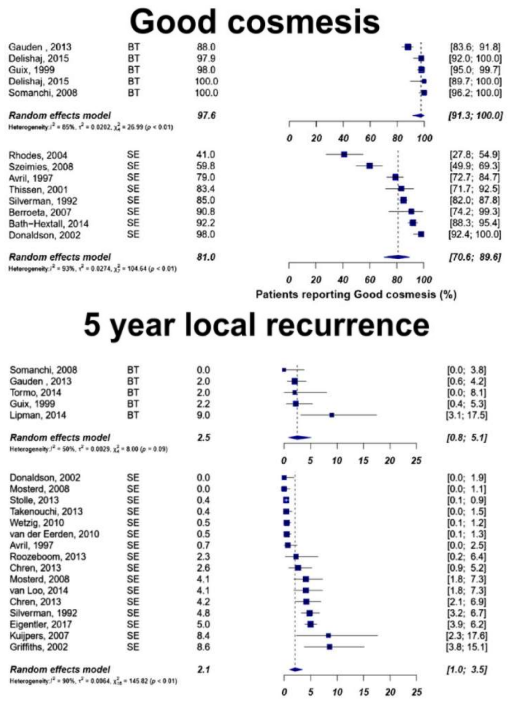
# Surface Brachytherapy

Advantages of HDR over EBRT

- Hypofractionated treatment
- Shorter overall treatment times
- Fast dose falloff – lower doses to surrounding normal tissues
- Excellent cosmetic outcomes

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Lee *et al.* (2019) Cancer, 125(20):3582-3594

# When is surface brachytherapy appropriate?

## Contraindications

- Bony invasion
- Deep extension
- Young age

## Patient selection

- See ABS consensus guidelines for skin brachytherapy (Ouhib *et al.* Brachytherapy (2015) 14(6):840-58 and Shah *et al.* Brachytherapy (2020) 19(4):415-426)
- Margins should be **3-20 mm**
- Treatment depth **≤ 5 mm**

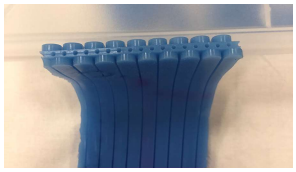


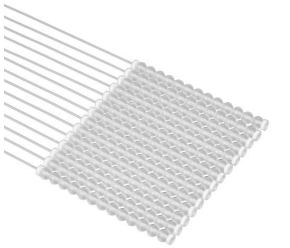
# Available HDR Surface Applicators

- Flaps
- Leipzig-style
- Valencia
- Custom molds

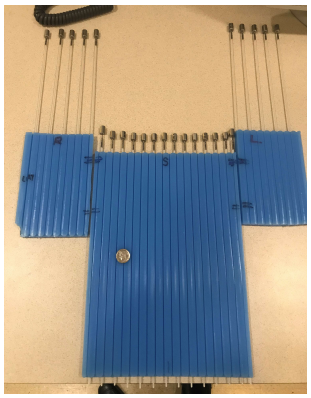
# Available Applicators: Flaps

- 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





https://www.elekta.com/products/brachytherapy/documents/Brachytherapy-Applicator-Guide.pdf



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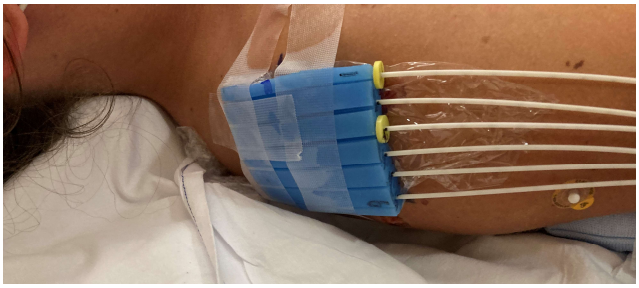
# Available Applicators: Flaps

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



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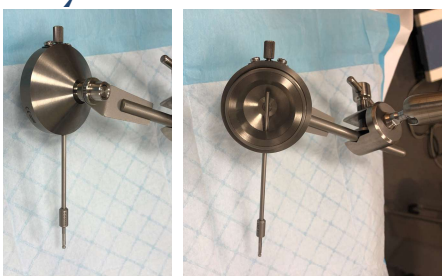
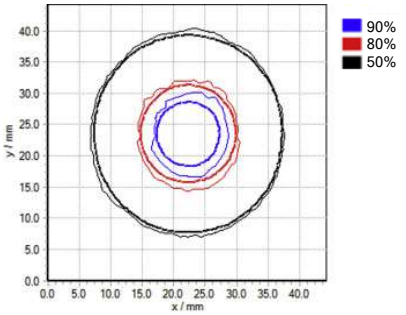
# Available Applicators: Leipzig-style

- 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 (Iftima, *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






Tien, *et al.* (2020) Brachytherapy 19(4):532-543

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# Available Applicators: Leipzig-style

Typical fractionation reported in the literature

- See Table II in Shah *et al.* Brachytherapy (2020) 19(4):415-426
- 42 Gy in 6 to 7 fractions
- 40 Gy in 5 fractions
- Sensitive areas: 40-50 Gy in 8-10 fractions

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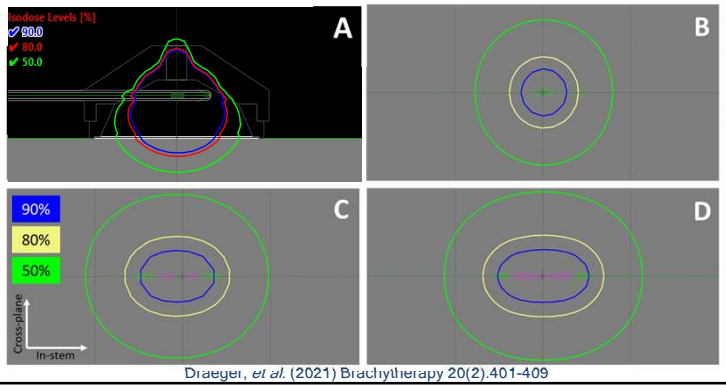
# Available Applicators: Leipzig-style

Multiple dwell positions within a Leipzig-style applicator has been investigated (Draeger, *et al.* (2021) Brachytherapy 20(2):401-409 and Tien, *et al.* (2020) Brachytherapy 19(4):532-543)

- Treatment area increased from ~10 mm diameter to 20.9×12.4 mm$^2$ at 3 mm depth
- May increase the utility of this applicator for more elongated lesions
- Has yet to be used clinically




Draeger, *et al.* (2021) Brachytherapy 20(2):401-409

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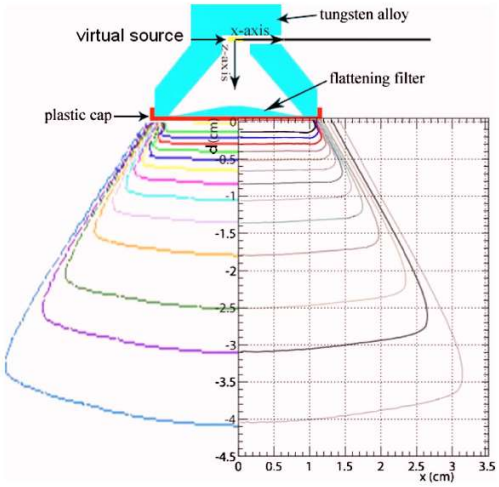
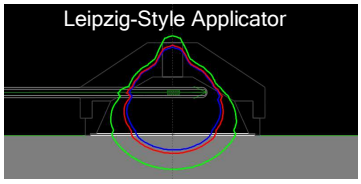
# Available Applicators: Valencia

- Very similar to the Leipzig applicator but contains a **flattening filter** to help flatten out the dose distribution
  - Can increase clinically useful treatment area
  - Flattening filter reduces dose rate by up to 50-64% (Granero, et al. Med Phys (2008) 35:495-505 and Jeraj, et al. PMB (2001) 47:723-735)
  - Not available from all vendors




Rivard, *et al.* (2009) Med Phys 36(6):1968-75

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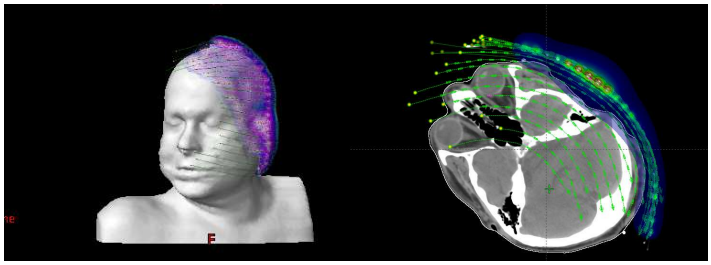
# Available Applicators: Custom Molds

- 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

Fulkerson, *et al.* Med Phys (2020) 47(10):e951-e987



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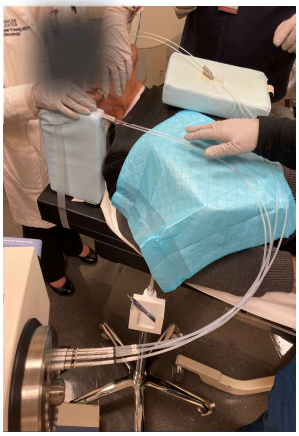
# Additional Considerations

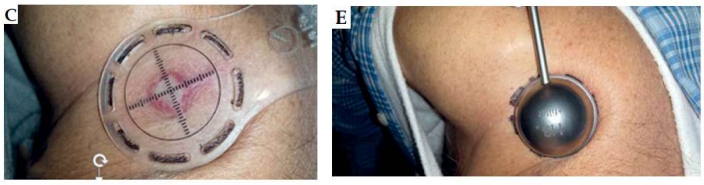
Applicator setup reproducibility

- Mark patient/applicator/immobilization device to ensure proper orientation/location for each fraction
- Templates can help ensure reproducible setup of Leipzig and Valencia applicators (Villalba, *et al.* (2016) J Contemp Brachytherapy 8(4):344-8)

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






Villalba, *et al.* (2016) J Contemp Brachytherapy 8(4):344-8

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# 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 accurate 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, MBDCA 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
  - GEC-ESTRO ACROP recommendations in skin brachytherapy (Guinot *et al.* Radiotherapy and Oncology (2018) 126(3):377-385)
  - American Brachytherapy society consensus statement for skin brachytherapy (Shah *et al.* Brachytherapy (2020) 19:415-426)
- For more information on clinical considerations, workflows, and quality management programs see
  - Surface brachytherapy: Joint report of the AAPM and the GEC-ESTRO Task Group No. 253 (Fulkerson *et al.* Med Phys (2020) 47(10)e951-e987)
  - TG-186: Model-based dose calculation techniques in brachytherapy (Beaulieu *et al.* Med Phys (2012) 39(10):6208-6236)