MONTE CARLO DERIVED CORRECTION FOR A NON-WATER-EQUIVALENT BRACHYTHERAPY APPLICATOR MATERIAL

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VAGINAL-CUFF HIGH-DOSE RATE BRACHYTHERAPY

- HDR vaginal-cuff brachytherapy as an adjuvant or definitive treatment has been widely reported as providing excellent locoregional disease control.
- Some patients have irregular vaginal vaults such that standard cylindrical or dome applicators do not make good contact with the vaginal wall.
- Personalised or customised moulds can provide improved dosimetric plan quality and offer a high degree of freedom in terms of catheter configuration.

PERSONALISED APPLICATORS

- The customized moulds used at the Royal Brisbane & Women's Hospital are made from Fricotan, a vulcanising silicone product.
- The material is non-water-equivalent.
- For an ^{192}Ir source, Nilsson et al. measured a dose reduction of ~10% at depths of 1-2 cm, when compared to Virtual Water.

Nilsson S, Moutrie Z, Cheuk R, Chan P, Lancaster C, Markwell T, Dawes J, Back P (2015)
A unique approach to high-dose-rate vaginal mold brachytherapy of gynecologic malignancies.
Brachytherapy **14**(2): 267–272.

OBJECTIVES OF THE STUDY

1 **Perform Monte Carlo simulations** to determine dosimetric impact of non-water-equivalent material.

2 **Verify simulations with film** for confidence in Monte Carlo simulation results.

3 **Present methodology** to correct dose calculations for multiple dwell position treatments.

Fricotan composition

Elemental concentration was obtained with X-ray fluorescence analysis and inductively coupled plasma mass spectrometry.

Material definition

Material defined in a PEGS material definition file with ρ=1.35 g/cm^3, electron cut-off of 0.512 MeV, photon cut-off of 0.001 MeV.

Source parameters

Isotropically radiating ^{192}Ir line source of 0.36 cm length, 0 cm diameter (consistent with Elekta microSelectron HDR afterloader).

MONTE CARLO SIMULATION

Simulation geometries

DOSRZnrc used to model cylindrical Fricotan applicators of varying radii 0 – 5 cm, with length 10 cm; surrounded by water.

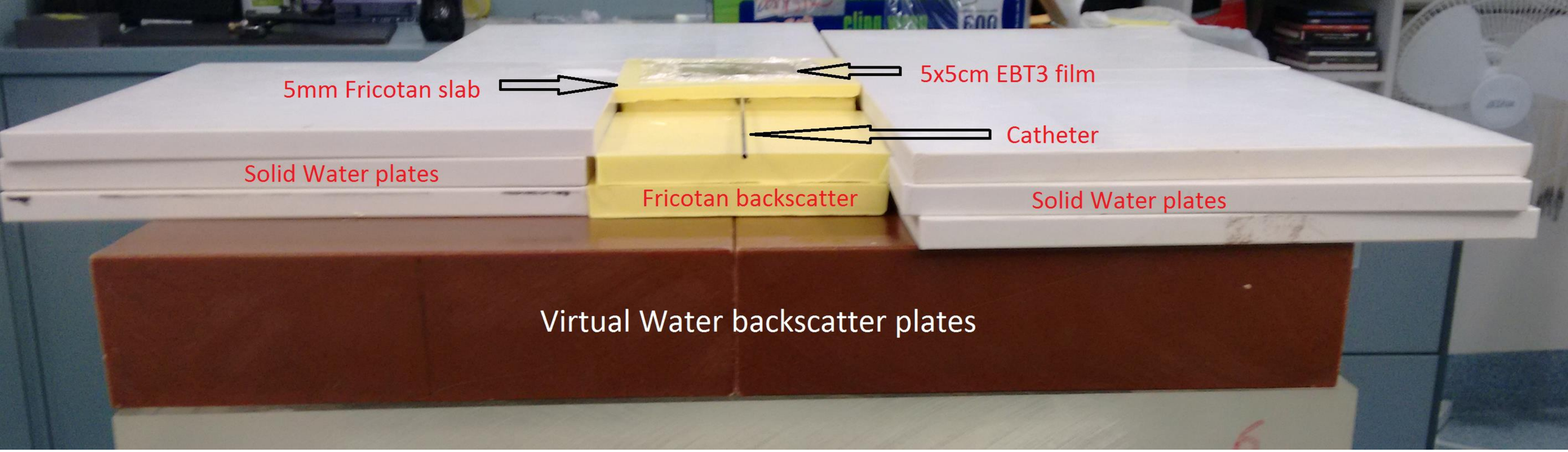
Dose calculations

Dose scored orthogonal to source, at distances 0, 0.5 and 1.0 cm from applicator wall. Resolution was 0.1 cm. DOSRZnrc uncertainty <0.04%.

TG-43 correction factors

$$f(r_f, r_w) = \frac{D(r_f, r_w)}{D_{water}(r_f, r_w)}$$

f is the correction, r_f applicator radius, r_w is distance in water.



VERIFICATION MEASUREMENTS

- 10×10 cm^2 slabs of Fricotan fabricated and QA performed with CT. Measurements performed in Virtual water for varying thicknesses of Fricotan slabs.
- EBT3 film measurements performed as verification, with deliveries of 1-2 Gy.
- Monte Carlo simulations repeated with a rectangular geometry, for comparison to film measurements.

TREATMENT CORRECTION FACTORS

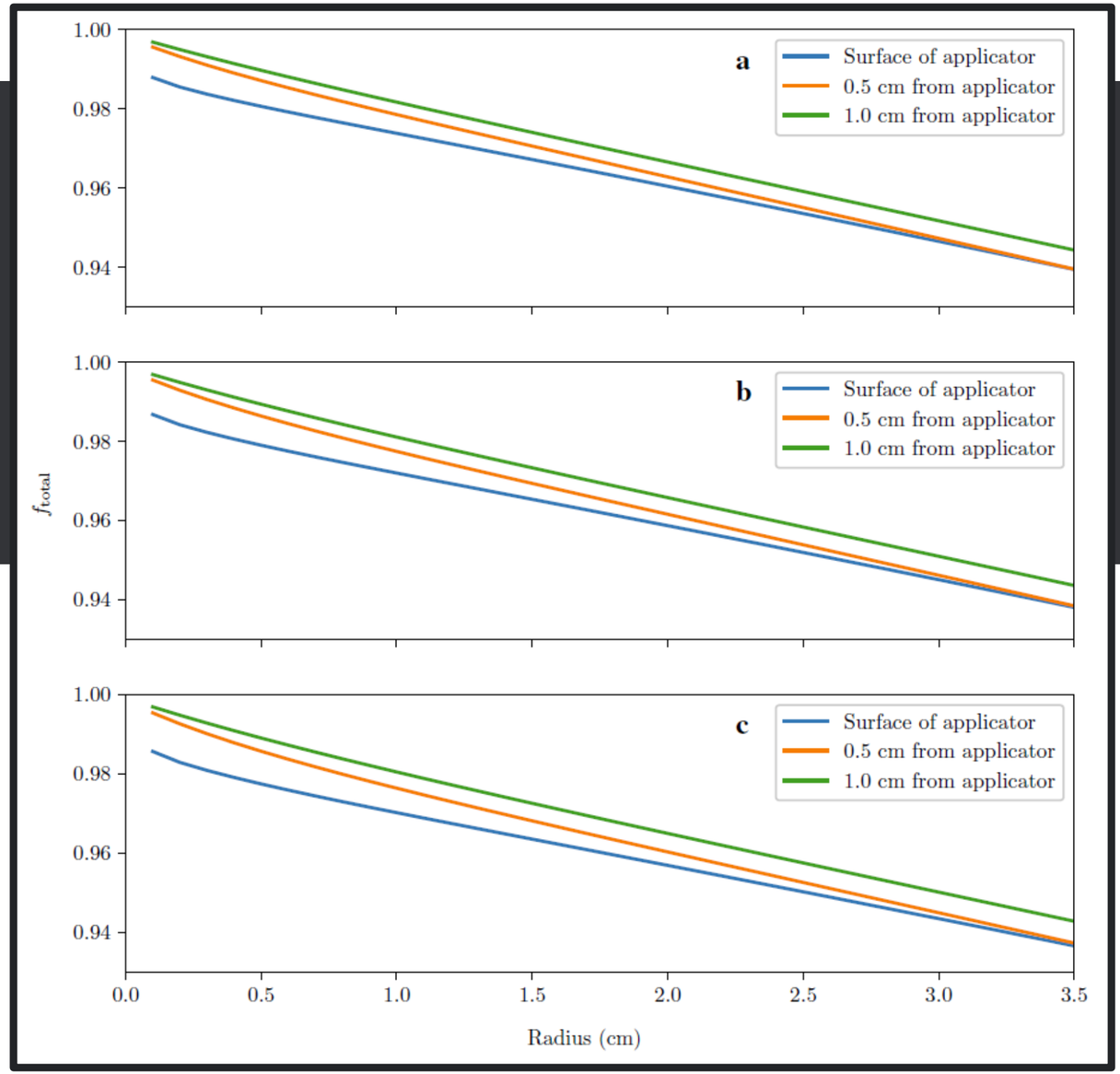
- Dose to a point in a patient is the sum of dose contributions from each dwell position.
- Total dose correction can be calculated by dividing sum of corrected dose values for each dwell position by total uncorrected dose values for each dwell position:

$$f_{\text{total}}(\text{P}) = \frac{\sum_{\text{dwell}}(f_{\text{dwell}}(r_f, r_w) \times D_{\text{dwell,water}}(r_f, r_w))}{D_{\text{total,water}}(P)}$$

- Individual dwell position corrections can be determined from earlier Monte Carlo simulation (with trigonometry and interpolation).
- Total dose corrections calculated for applicators of radii between 0.5 and 3.5 cm, for treatment lengths 4-6 cm, dwell position spacing of 0.25 cm, prescription depth 0, 0.5 and 1.0 cm from applicator surface.

RESULTS

- Total dose corrections for treatment lengths of 4, 5 and 6 cm, for (a), (b) and (c) respectively, with uncertainties of 2.4%.
- For typical moulds in RBWH department, the required correction varies from 1 to 4%.
- Monte Carlo results were consistent with film.



DISCUSSION / CONCLUSION

- For typical moulds at RBWH, required corrections vary from 1 to 4%.
- Proposed solution can provide idea of uncertainty, or be used to improve dose calculation accuracy in lieu of a treatment planning system dose calculation algorithm capable of modelling non-water-equivalent materials.
- Solution could be implemented for other moulding materials:
  - Material composition from vendors or elemental analysis
  - Single dwell position correction factors from Monte Carlo simulation
  - Verification against measurements
  - Single dwell corrections added to TG43 calculation, or otherwise total corrections generalised with simple clinical treatments

For more information: S. B. Crowe, Z. Pross, S. Nilsson, J. Dawes, T. Kairn, C. M. Lancaster. Characterisation of the radiological properties of a brachytherapy moulding material. *Australasian Physical and Engineering Sciences in Medicine* 41(3): 731-737, 2018