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Development of multiple dwell techniques in horizontally-oriented Leipzig-style applicators for surface brachytherapy guided by a model-based dose calculation algorithm.

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INTRODUCTION

- Leipzig-style surface applicators (Figure 1) are conventionally used for small, circular lesions with a single, centered source dwell position
- Using single dwell position may not adequately cover the target, we report the feasibility and quantify results from using multiple dwells
- Due to the tungsten shell and air cavity, model based dose calculation algorithm (MBDCA) is necessary [1,2]
- We produced a set of templates and resultant dose coverage dimensions to be considered by those without access to a MBDCA

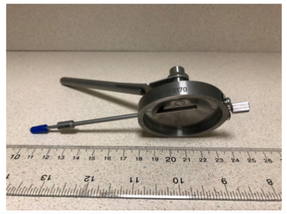

Figure 1: Leipzig-style applicator, showing the interior of the shell and the stem.

METHODS

- Commercial treatment planning system used to model Leipzig-style applicator
- Plans evaluated based on size of 80% and 90% isodose lines (IDLs) in the in-stem and cross-plane dimensions at 3 mm depth
- Templates created for prescription dose of 6 Gy:
  - Template A: conventional, single-dwell at center of applicator (Figure 2a)
  - Templates B/C: two dwells at 130.00 cm and 128.50 cm (Figure 2b)
  - Template D: two dwells at 130.00 cm and 129.00 cm (Figure 2c)
  - Template E: two dwells at 130.00 cm and 129.50 cm
  - Template F: single-dwell at 128.50 cm, applicator rotation of 180°, additional single-dwell at 128.50 cm (Figure 2d)
- Uncertainty in applicator rotation determined by defining PTV from 80%/90% IDLs and reducing these isotropically by 1-4 mm to create GTVs. Angular offsets added to plan (0°-10°) and dosimetric impact quantified using $V_{100\%}$, $D_{95\%}$, and D_{min}.

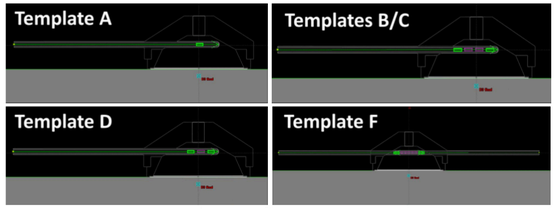

Figure 2: Examples of template plan designs and source orientations.

RESULTS

- Dwell positions and times for template plans illustrated in Table 1
- Largest treatment area obtained using Template F which gave in-stem (cross-plane) dimensions of 20.9 (12.4) mm, compared to a single dwell with dimensions of 9.4 (9.7) mm (Figure 3)
- Treatment coverage increased with increasing dwells from 80% IDL coverage of a 15.2 cm long lesion with a single-dwell to 95% IDL coverage with Template F (Figure 4)
- For rotational uncertainty analysis (Figure 5), smallest margins (largest GTV) illustrated maximum changes of 2.0%, 1.8%, and 8% in $V_{100\%}$, $D_{95\%}$, and D_{min}, respectively. The largest margins (smallest GTV) show maximum changes of 1.3%, 1.9%, and 7.5% in $V_{100\%}$, $D_{95\%}$, and D_{min}.

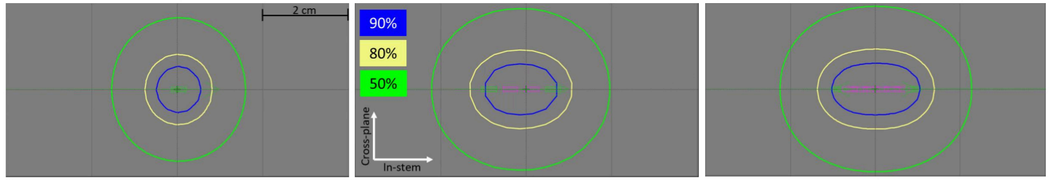

Figure 3: Increase in isodose coverage from a single-dwell (left), to multiple dwells (middle), and multiple dwells with an applicator rotation (right).

Table I: Dwell positions, dwell times, and 80% and 90% isodose line sizes for all template designs.

Plan ID	Dwell 1			Dwell 2			D90% dimensions [mm]		D80% dimensions [mm]	
	Position [cm]	Time [s]	Rotation	Position [cm]	Time [s]	Rotation	In-stem	Cross-plane	In-stem	Cross-plane
Single-dwell	129.4	125.2	-	-	-	-	9.4	9.7	15.3	15.7
Template B	130.0	76.6	-	128.5	76.6	-	16.6	11.3	23.7	17.9
Template C	130.0	85.6	-	128.5	66.5	-	15.9	11.3	23.1	17.8
Template D	130.0	69.0	-	129.0	69.0	-	12.4	10.6	18.8	16.7
Template E	130.0	67.4	-	129.5	67.4	-	12.8	10.3	18.0	16.3
Template F	128.5	81.3	-	128.5	81.3	180°	20.9	12.4	27.5	18.8

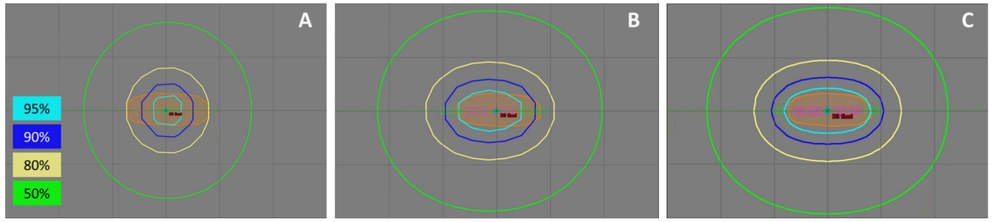

Figure 4: Illustration of increased dose conformity with multi-dwell plans. Panel A shows a conventional single-dwell treatment of an elongated lesion (orange) with the 80% IDL. Panel B shows coverage with Template B, while panel C shows coverage with Template F.

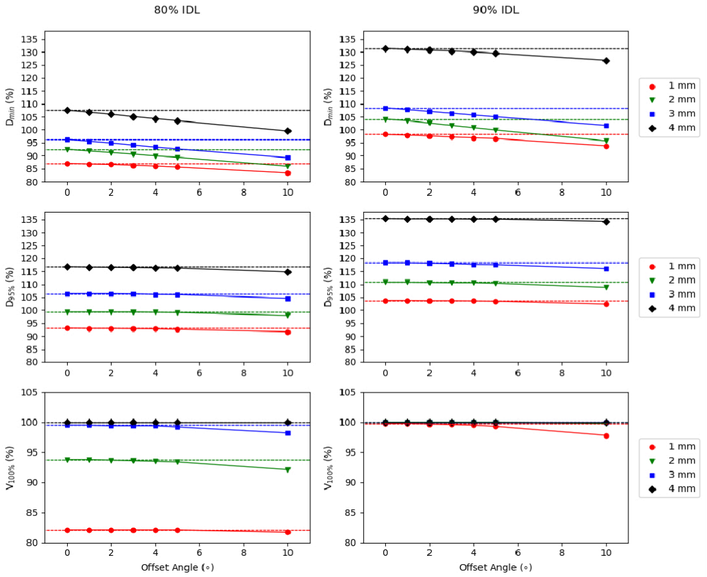

Figure 5: Uncertainties associated with incomplete applicator rotation.

CONCLUSIONS

- Optimized template plans demonstrated significant increases in viable treatment area, with the 90% (80%) isodose line increasing from 9.4×9.7 (15.3×15.7) mm^2 for a single-dwell to 20.9×12.4 (27.5×18.8) mm^2 in the largest treatment plan.
- Multi-dwell plans also offered increased dose conformity for elongated targets.
- Template plans may be utilized by users without MBDCAs to explore the use of multi-dwell treatments in Leipzig-style brachytherapy.

REFERENCES

[1]Beaulieu, L., et al. Med Phys 39(10) 6208-6236, 2012.

[2]Tien, C.J., et al. "Feasibility of using multiple-dwell positions in ^{192}Ir Leipzig-style brachytherapy surface applicators to expand target coverage and clinical application." Brachytherapy, E-pub ahead of print., 2020.

CONTACT INFORMATION

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