Assessment of Positional Accuracy of Ring Applicators Following Source Exchange

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ABSTRACT

Purpose:
Ring applicators are widely used in high-dose-rate (HDR) brachytherapy, where accurate source positioning is essential for achieving dosimetric precision. Following each radioactive source exchange, positional accuracy is routinely verified; however, clinical experience suggests that the necessity of verification after every exchange may warrant reassessment. This study evaluates the reproducibility of dwell position accuracy in ring applicators following source exchange and examines whether repeated verification is clinically justified.

Methods:
Positional verification was performed after source exchange and compared with the original commissioning planning template. Ring applicators were affixed to Gafchromic film, which was initially irradiated using 12 MeV electrons to 700 monitor units to create a reference outline of the applicator geometry. The applicators were then connected to an HDR afterloader. A test plan consisting of nine dwell positions spaced 1 cm apart was delivered to the film. Films were scanned and analyzed to determine measured dwell positions, which were compared to commissioning values to assess positional accuracy and reproducibility. Dosimetric impact was evaluated using previously treated patient plans by applying measured positional shifts and comparing resulting dose metrics to the unshifted clinical plans.

Results:
Measured dwell positions demonstrated variability of up to 3 mm relative to initial commissioning. Dosimetric analysis revealed a maximum change of 3.3% in high-risk clinical target volume (HR-CTV) D90 for evaluated patient plans.

Conclusion:
Measurable positional variations in ring applicator dwell positions following source exchange were observed. However, clinical use of 5 mm dwell spacing, rather than 1 cm, may mitigate the dosimetric impact of these variations. Ongoing work will further characterize the effect of positional variability on dosimetric quality across a broader patient cohort.

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INTRODUCTION

Ring applicators are widely used in high-dose-rate (HDR) brachytherapy, where accurate source positioning is essential for achieving dosimetric precision. Following each radioactive source exchange, positional accuracy is routinely verified; however, clinical experience suggests that the necessity of verification after every exchange may warrant reassessment. This study evaluates the reproducibility of dwell position accuracy in ring applicators following source exchange and examines whether repeated verification is clinically justified.

METHODS AND MATERIALS

Two different ring applicators were assessed using the Varian© Bravos system post source exchange.

Part 1: Create Reference Applicator Geometry

1. Secure the ring applicator directly onto a sheet of Gafchromic film.
2. Place the film and applicator setup in the electron treatment field and irradiate the film with 12 MeV electrons using 700 monitor units (MU).
3. Connect the ring applicator to the HDR afterloader.
4. Create a test treatment plan containing nine dwell positions with 1 cm spacing.
5. Deliver the HDR test plan to the film.
6. Remove and label the irradiated film for analysis.

Part 2: Film Analysis and Positional Verification

1. Scan the Gafchromic film and import images into the Brachyvision software.
2. Align the HDR film with the reference applicator template and identify the center of each measured dwell position on the HDR film.
3. Compare the measured dwell positions with the corresponding dwell positions from the original commissioning planning template.
4. Calculate positional deviations for each dwell position.

Part 3: Dosimetric Impact Assessment

1. Using a previously treated patient HDR plans for evaluation, introduce the measured dwell position shifts into each patient plan.
2. Recalculate the plans using the shifted dwell positions.
3. Compare and quantify the dose metrics between shifted and unshifted plans.

RESULTS

Measured dwell positions demonstrated variability of up to 3.5 mm relative to initial commissioning (Figure 1). Dosimetric analysis revealed a maximum change of 3.3% in high-risk clinical target volume (HR-CTV) D90 for evaluated patient plans (Figure 2). Statistical analyses were not performed due to small sample size (n=2 for each ring dwell position distance and source exchange combination). Examples of ring template commissioning and subsequent registration post-irradiation is shown in Figure 3.

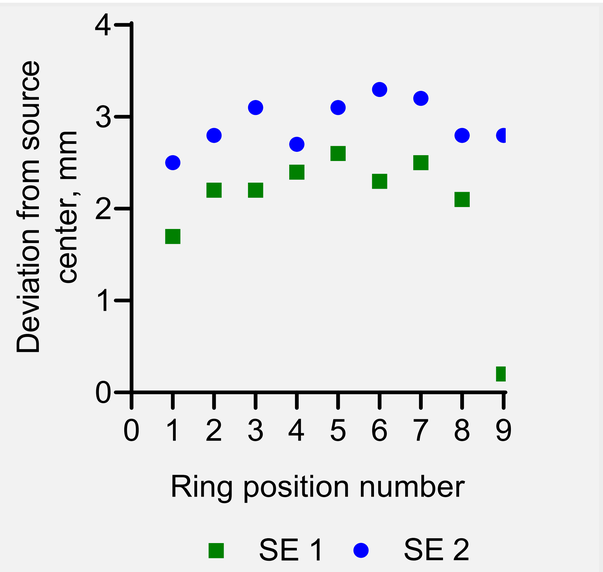

Figure 1: Distance from center of source to clinical commissioning template as measured after film irradiation, import and analyses in Brachyvision. n=1 per source exchange (SE).

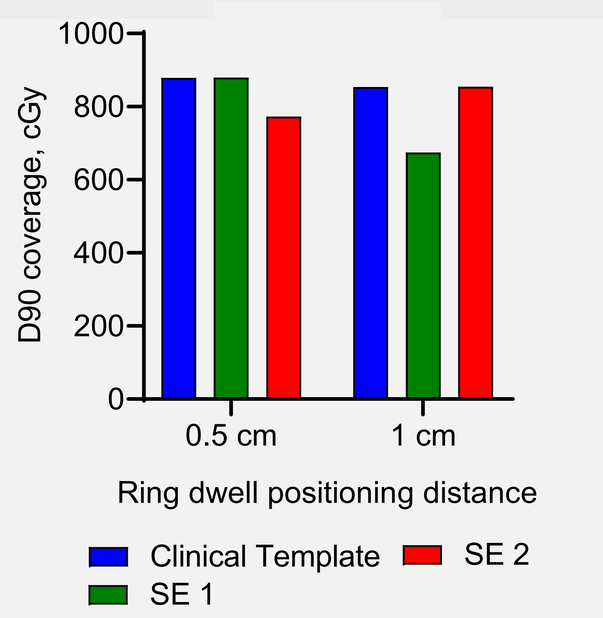

Figure 2: Dosimetric impact on D90 by applying positional shifts from clinical commissioning template. This was evaluated using previously treated patient plans and comparing resulting dose metrics to the unshifted clinical plans (n=1 per SE).

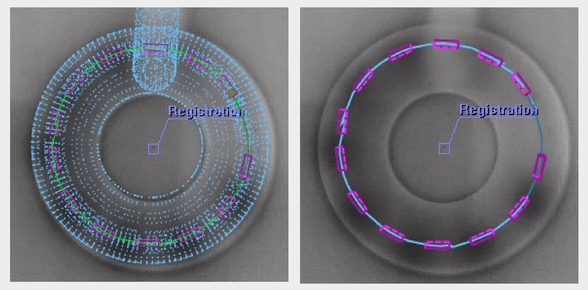

Figure 3. 45 degree ring template commissioning in Brachyvision (left). Example of registration of irradiated/exposed ring in Brachyvision (right).

DISCUSSION

Measured dwell position shifts of up to 3 mm were observed following source exchange, demonstrating that positional variability can occur relative to initial commissioning. Despite these differences, dosimetric analysis showed a maximum change of only 3.3% in HR-CTV D90 for the patient plans evaluated, indicating a limited clinical impact in this cohort. The use of 5 mm dwell spacing in routine clinical treatments, compared with the 1 cm spacing used in the verification test plan, may reduce the dosimetric consequences of small positional shifts by providing greater overlap between adjacent dwell positions. While these findings suggest that routine verification after every source exchange may have limited clinical benefit, additional investigation is needed. Ongoing analysis of a larger patient cohort will further evaluate the relationship between dwell position variability and clinically relevant dose metrics to determine whether current quality assurance practices can be optimized.

CONCLUSIONS

Ring applicator dwell position variations were observed following source exchange but produced limited dosimetric impact in the cases evaluated. These findings suggest that current clinical practice may be robust to small positional deviations. Further evaluation across a larger patient cohort, additional source exchanges, and multiple clinical sites is underway to determine the reproducibility of these results and assess whether current source exchange quality assurance practices can be safely optimized.

REFERENCES

1. None.