HDR Brachytherapy Quality Assurance: Ensuring Accuracy and Safety in Dose Delivery

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ABSTRACT

Purpose: Routine quality assurance (QA) is vital for precise delivery of HDR prostate brachytherapy for prostate cancer. This study aimed to confirm system accuracy and identify areas for improvement in quality-control and real-time treatment monitoring.
Methods: Initial QA testing was performed using the CIRS Model 053S prostate phantom, with volume reconstruction performed on the Vitesse ultrasound-guided brachytherapy planning system. Reconstructed volumes were compared to the known phantom volume, confirming system accuracy within the 5% error threshold recommended by AAPM Task Group 128. To characterize a reproducible image discontinuity observed during probe zeroing, the stepper probe was rotated at fast, medium, and slow speeds with the zero point positioned at mid-gland, and the resulting reconstruction gap measured using the Vitesse system. Following QA confirmation, a retrospective comparative analysis was conducted between pre-treatment MRI and day-of-treatment transrectal ultrasound (TRUS) prostate volumes, with data retrieved from the Mosaiq and Velocity databases at Fox Chase Cancer Center (FCCC). Only cases from 2024-2025 in which MRI and TRUS were performed within a three-week interval were included.
Results: Patients were grouped by treating physician into three cohorts (n=14, 24, and 15). The mean percent volume changes between MRI and TRUS were +24.6%, +0.5%, and -0.4% for the three physicians, respectively, demonstrating substantial inter-physician variation in prostate volume assessment. Regarding image discontinuity evaluation, faster probe rotation produced larger discontinuities, with measured gaps of 3.4 mm (fast), 2.3 mm (medium), and 1.8 mm (slow).
Conclusions: These findings suggest a notable physician-dependent influence on prostate contouring that may impact treatment planning and dose-delivery accuracy in brachytherapy. Further investigation is warranted to identify sources of discrepancies and reduce inter-physician volume variability, ensuring consistent and precise patient outcomes.

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INTRODUCTION

High-Dose Rate (HDR) Brachytherapy is an established method for the treatment of prostate cancer. Both transrectal ultrasound (TRUS) and MRI imaging are crucial for the accurate planning and delivery of radiation. Therefore, it is necessary to do routine quality assurance (QA) of the ultrasound system to ensure it is providing accurate imaging to maintain high standards of clinical performance and patient safety. After confirming system accuracy, this study investigates the consistency of prostate volume measurements across treating physicians using pre-treatment MRI and day-of-treatment TRUS imaging.

METHODS AND MATERIALS

- To test TRUS accuracy, a CIRS model 053S gel-based phantom was used
- Using known phantom dimensions, volume reconstruction on the Vitesse software confirmed system accuracy
- A retrospective analysis was then conducted using the Velocity and Mosaiq software to compare prostate volumes from pre-treatment MRI and day-of-treatment TRUS
- Only 2024–2025 cases with imaging within a three-week interval were included. Patients were grouped by physician into three cohorts (n = 14,24,15)

RESULTS

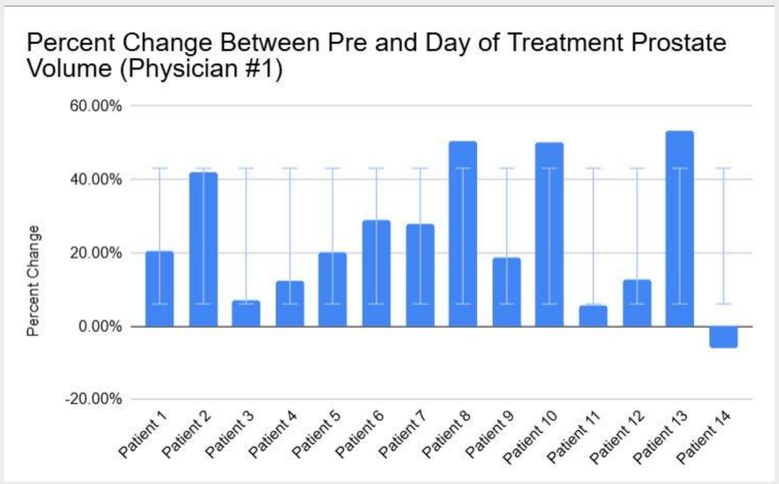

Figure 1: Percent change of prostate size between imaging modalities for treating physician #1 patients

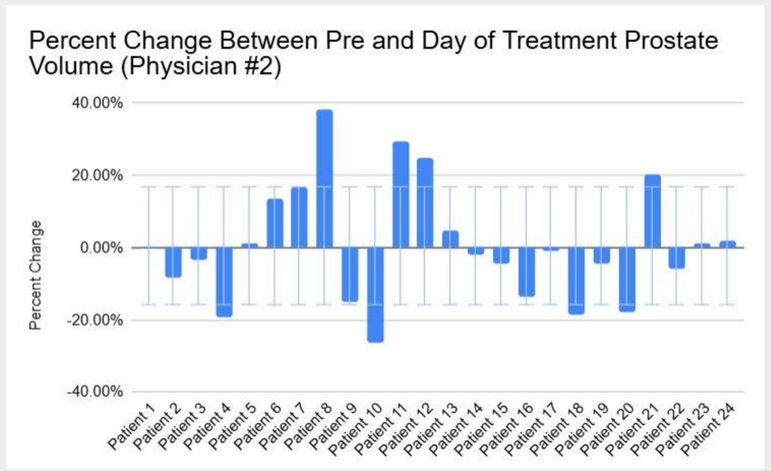

Figure 2: Percent change of prostate size between imaging modalities for treating physician #2 patients

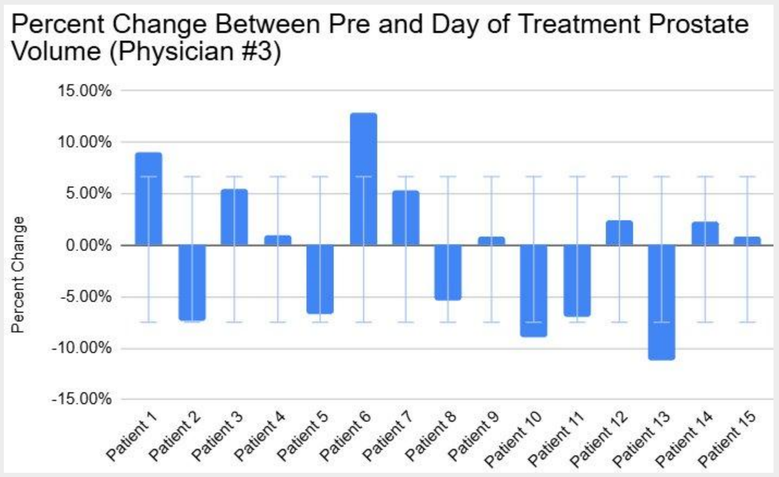

Figure 3: Percent change of prostate size between imaging modalities for treating physician #3 patients

DISCUSSION AND FUTURE DIRECTIONS

- The mean percent volume changes of +24.6%, +0.5%, and -0.4%, respectively, suggest a notable influence of physician-dependent factors on prostate contouring. This variability may affect treatment planning and the accuracy of dose delivery in HDR brachytherapy

- QA testing on the TRUS used the 5% error threshold recommended by AAPM Task Group 128, confirming system accuracy

- Further investigation is warranted to identify the underlying causes of these discrepancies and to reduce inter-physician volume variability, ensuring consistent and precise patient outcomes

REFERENCES

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Full reference list available by request