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Dosimetric Comparison of Cervix boost RT with CBCT-Based Adaptive versus non-adaptive instead of brachy boost

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ABSTRACT

High-dose-rate (HDR) brachytherapy is the standard boost modality for locally advanced cervical cancer; however, it is not feasible for all patients because of anatomical, medical, or resource-related limitations. Online adaptive radiotherapy (ART) has emerged as a potential external beam alternative by accounting for daily anatomical changes using cone-beam CT (CBCT). In this study, we retrospectively compared CBCT-based adaptive and non-adaptive external beam cervix boost plans generated on the Varian Ethos platform. Adaptive plans were re-optimized using the anatomy of the day and compared with scheduled (non-adaptive) plans using cumulative EQD2 target coverage and organ-at-risk dose metrics. Adaptive planning consistently improved target coverage while reducing bladder and rectal dose, with the greatest benefit observed in patients exhibiting substantial inter-fraction anatomical variation. Although adaptive external beam radiotherapy cannot replicate the dosimetric advantages of image-guided brachytherapy, it demonstrated superior dosimetric performance compared with non-adaptive planning and may represent a promising boost strategy for patients in whom brachytherapy cannot be performed.

INTRODUCTION

High-dose-rate (HDR) brachytherapy is an integral component of definitive radiotherapy for locally advanced cervical cancer because it enables highly conformal dose escalation while minimizing dose to surrounding organs at risk (OARs). Numerous studies, including the EMBRACE trials, have demonstrated superior local control and favorable toxicity profiles with image-guided adaptive brachytherapy. However, brachytherapy may not be feasible in all patients due to limited institutional resources, unfavorable anatomy, medical contraindications, or patient refusal. External beam boost techniques have been investigated as alternatives but are susceptible to inter-fraction anatomical changes, including variations in bladder filling, rectal distension, and target position, which may compromise target coverage and increase OAR dose. Online adaptive radiotherapy (ART) provides the ability to re-optimize treatment based on daily cone-beam CT (CBCT), potentially improving dosimetric accuracy by accounting for these anatomical variations. The purpose of this study was to compare the dosimetric performance of CBCT-based adaptive and non-adaptive external beam cervix boost plans using cumulative EQD2 metrics for target coverage and OAR sparing.

PURPOSE

High-dose-rate (HDR) brachytherapy is the standard boost modality for locally advanced cervical cancer because of its ability to deliver highly conformal dose escalation while sparing surrounding organs at risk (OARs). However, brachytherapy is not feasible for all patients due to limited availability, anatomical constraints, or medical contraindications. This study evaluated whether cone-beam CT (CBCT)-based online adaptive radiotherapy (ART) improves the dosimetric quality of external beam cervix boost treatments compared with non-adaptive planning.

METHODS AND MATERIALS

Eight cervical cancer patients previously treated with external beam radiotherapy were retrospectively replanned using the Varian Ethos adaptive platform. For each treatment fraction, an online adaptive plan was generated using the anatomy of the day, while a scheduled (non-adaptive) plan was recalculated on the same CBCT dataset for direct comparison. Target coverage and OAR doses were accumulated and converted to EQD2 using deformable image registration.

RESULT

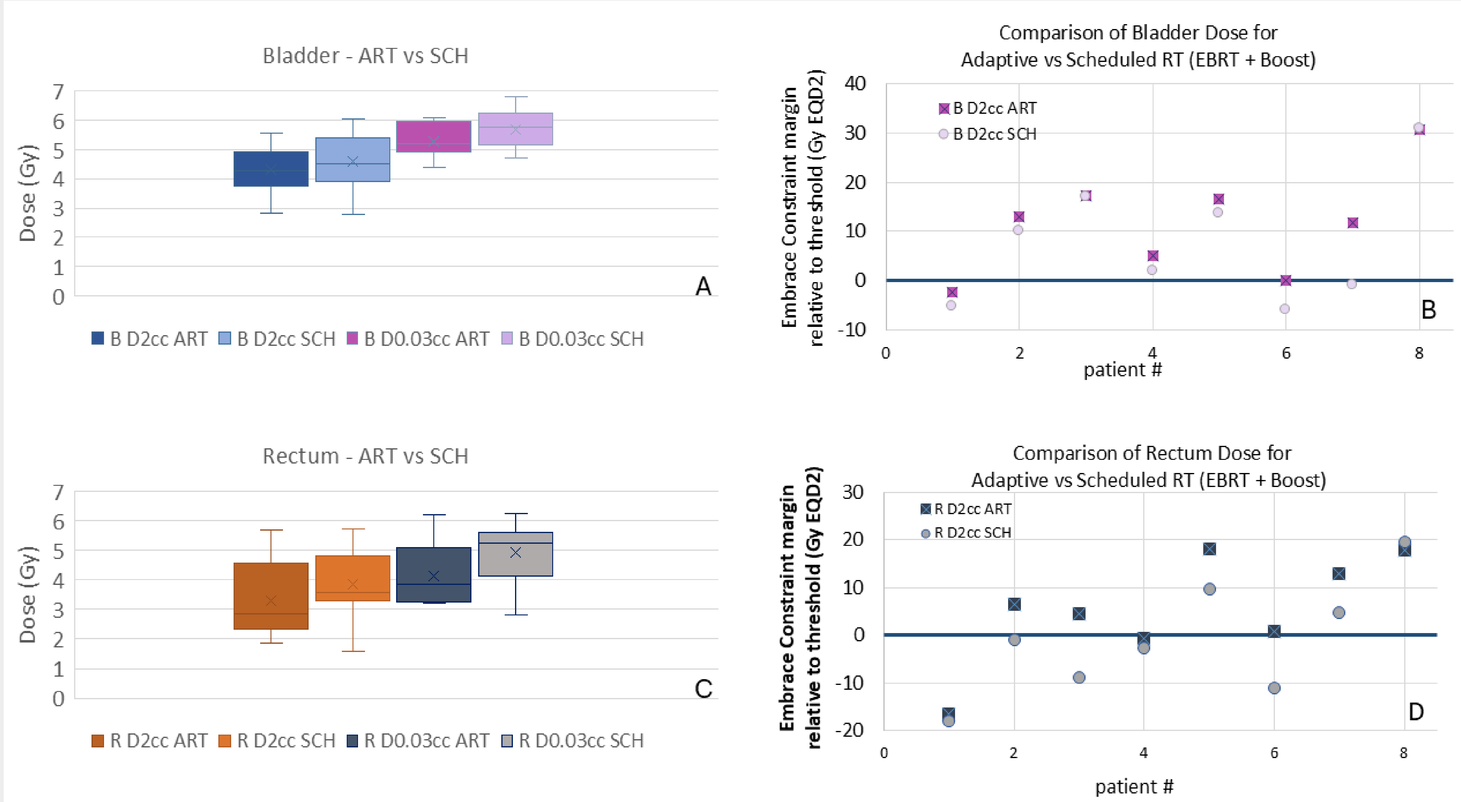
CBCT-based adaptive planning maintained or improved target coverage while reducing bladder and rectal doses compared with scheduled plans. The greatest dosimetric benefit was observed in fractions exhibiting substantial inter-fraction anatomical variation, demonstrating improved plan robustness under changing anatomy.

CONCLUSIONS

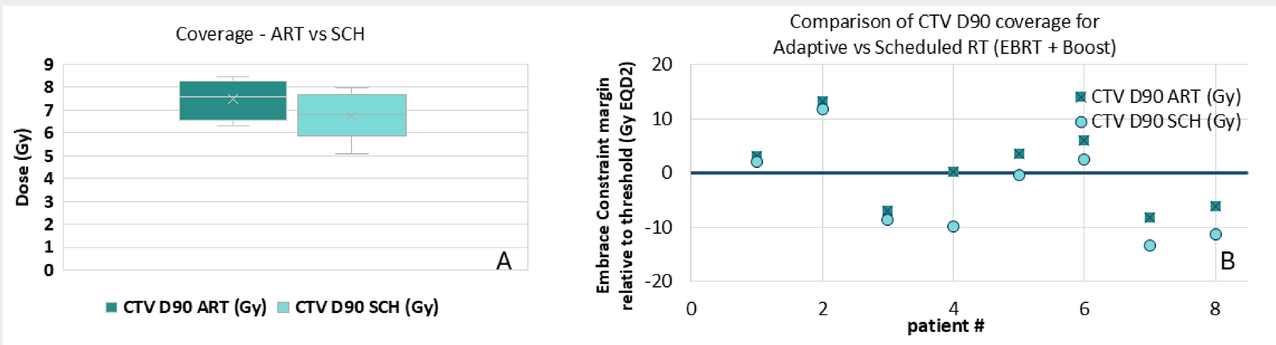
Online CBCT-guided adaptive radiotherapy provides superior dosimetric performance compared with non-adaptive external beam boost planning. Although it does not replace image-guided brachytherapy, ART may serve as a valuable external beam boost strategy for patients in whom brachytherapy cannot be performed and warrants further clinical investigation.

DISCUSSION

CBCT-based adaptive radiotherapy demonstrated improved target coverage and reduced bladder and rectal dose compared with non-adaptive planning. These improvements are attributable to online plan re-optimization, which compensates for daily anatomical variations such as changes in bladder filling, rectal distension, and target position that cannot be addressed with conventional scheduled plans. Although HDR brachytherapy remains the standard boost modality for locally advanced cervical cancer because of its superior dose conformity and established clinical outcomes, it is not feasible for every patient. In these situations, adaptive external beam radiotherapy may provide a dosimetric advantage over conventional non-adaptive boost techniques by improving the therapeutic ratio while maintaining treatment efficiency. This study is limited by its retrospective design and small patient cohort, and only dosimetric outcomes were evaluated. Future studies with larger patient populations and clinical outcome data are needed to determine whether these dosimetric improvements translate into improved local control and reduced treatment-related toxicity.



Positive values indicate satisfaction of the clinical constraint, while negative values indicate violation. Comparison of adaptive radiotherapy (ART) and scheduled radiotherapy (SCH) for target coverage and organ-at-risk dose following EBRT and boost summation. (A) Distribution of bladder dose metrics (D2cc and D0.03cc) for ART and SCH plans. (B) Patient-specific bladder constraint margins relative to clinical thresholds (0 Gy EQD2). (C) Distribution of rectum dose metrics (D2cc and D0.03cc) for ART and SCH plans. (D) Patient-specific rectum constraint margins relative to clinical thresholds (0 Gy EQD2). For all margin plots, positive values indicate satisfaction of the corresponding clinical constraint, while negative values indicate violation. Each marker represents an individual patient.



Positive values indicate satisfaction of the clinical constraint, while negative values indicate violation.
(A) Distribution of CTV D90 dose for ART and SCH plans.
(B) Patient-specific CTV D90 constraint margins relative to the prescription threshold (0 Gy EQD2).

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