Apply Field-Of-View Extension And Deformable Image Registration To Improve HDR-EBRT Cumulative Dose Estimation In Cervical Cancer Patients

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ABSTRACT

Accurate dose accumulation in cervical cancer radiotherapy combining external-beam radiotherapy (EBRT) and high-dose-rate (HDR) brachytherapy requires reliable deformable image registration (DIR) between two drastically different planning CTs. Truncated field-of-view (FOV) in HDR-CT limits anatomical context and may increase uncertainty in organ-at-risk (OAR) dose estimation. This study evaluates a workflow combining HDR-CT FOV extension and DIR to improve anatomical alignment and cumulative dose assessment.

A retrospective cohort of 32 cervical cancer patients treated with EBRT followed by HDR brachytherapy was analyzed. HDR-CTs with truncated FOV were extended using a locally trained CropGAN model. Rigid, intensity-based DIR, and contour- and intensity-hybrid DIR methods were applied to register HDR-CT to EBRT-CT. Registration accuracy was evaluated using DICE similarity coefficient, Mean Distance to Agreement, and qualitative artifact assessment. Deformation vector fields were used to map HDR dose distributions onto EBRT-CT geometry for cumulative DVH analysis.

FOV extension improved intensity-based DIR performance, increasing mean DICE from 0.52 to 0.59, compared with 0.43 using rigid registration. The contour- and intensity- based hybrid DIR algorithm achieved a mean DICE of 0.81 for both extended and unextended HDR-CT inputs. Qualitative assessment showed that FOV extension reduced deformation artifacts, including bone elongation and excessive organ stretching. In one representative patient, more accurate DIR resulted in higher cumulative D2cc estimates for bladder and rectum.

This study demonstrates that addressing HDR-CT FOV limitations before DIR can improve registration accuracy and may substantially affect cumulative OAR dose estimation in cervical cancer EBRT + HDR brachytherapy.

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INTRODUCTION

Background: Cervical cancer radiotherapy combines EBRT and HDR brachytherapy. Calculating cumulative dose requires aligning planning CTs using deformable image registration (DIR).

Problem: HDR-CTs often have a truncated field-of-view (FOV). The missing anatomy causes DIR inaccuracies and deformation artifacts, leading to unreliable organ-at-risk dose estimates (e.g., D2cc).

Study Objective: To evaluate whether extending truncated HDR-CT images before DIR improves anatomical alignment and supports more reliable cumulative dose assessments.

METHODS AND MATERIALS

- **Cohort:** 32 cervical cancer patients (EBRT + HDR).
- **Intervention:** Compared registrations using original truncated HDR-CTs versus FOV-extended HDR-CTs (generated by locally trained CropGAN model).
- **Registration Methods:** Rigid, intensity-based DIR, and contour-intensity-hybrid DIR.
- **Alignment Evaluation:** Assessed bladder and rectum alignment using the DICE similarity coefficient and qualitative artifact review.
- **Dose Accumulation:** Mapped HDR doses to the EBRT-CT geometry to calculate accumulated D2cc for OARs.

RESULTS

FOV Extension Improved Anatomical Plausibility

Figure 1 shows DIR results. Unextended HDR-CTs produced non-physical deformations (Figure 1a), while CropGAN-extended inputs yielded anatomically plausible registrations with improved skeletal and OAR alignment (Figure 1b). Yellow labels are bladder, purple labels are rectum, and green/cyan colored labels are bowels.

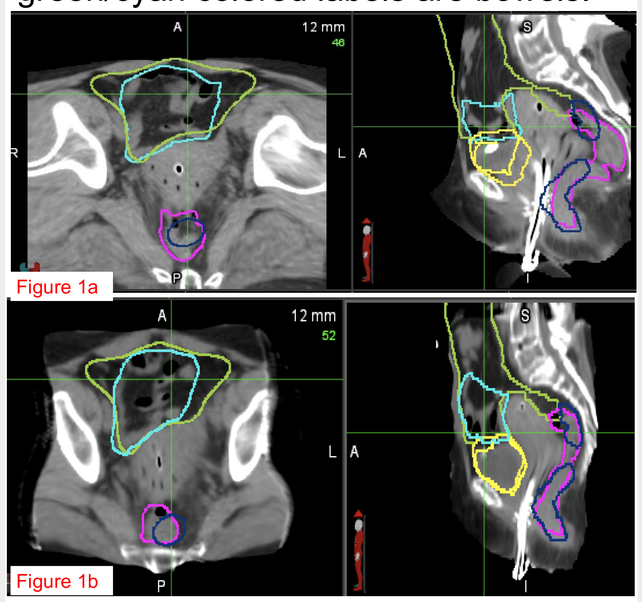

Figure 1. Deformable registration wo/w volume extension

FOV Extension Improved Intensity-Based DIR Accuracy

As shown in **Figure 2**, mean DICE scores were **0.43** for rigid registration and **0.52** for intensity-based DIR (improving to **0.59** with FOV extension). The hybrid DIR achieved the highest score (**0.81**) regardless of extension.

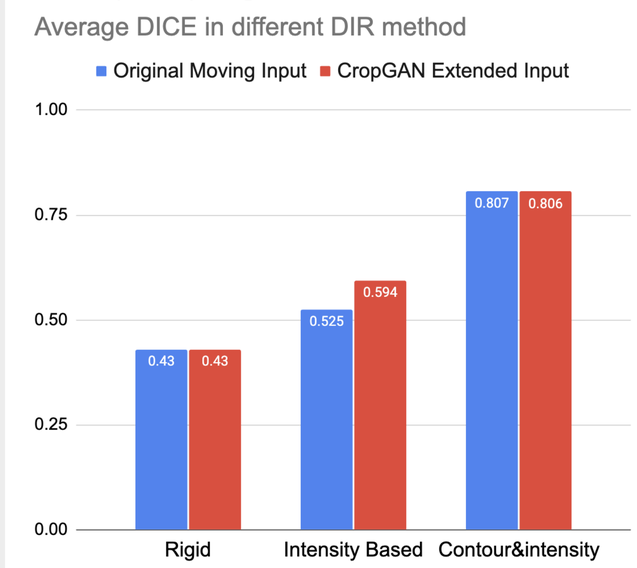

Figure 2. DICE coefficient of different DIR methods. Blue column is unextended HDR< red column is CropGAN-extended HDR

DISCUSSION

- **Improved Registration:** FOV extension improved intensity-based DIR by providing external anatomical context.
- **Reduced Artifacts:** Even with the high DICE scores in hybrid DIR, FOV extension was necessary to reduce non-physical deformation artifacts (indicating DICE alone is insufficient for judging anatomical plausibility).
- **Dosimetric Impact:** Cumulative dose estimation is sensitive to registration quality. One representative patient (Figure 3) shows that FOV extension increased D2cc for both the bladder (+2.65 Gy) and rectum (+2.48 Gy).
- **Next Steps:** Cohort-level DVH analysis is required to determine if these dose increases are a systematic trend.

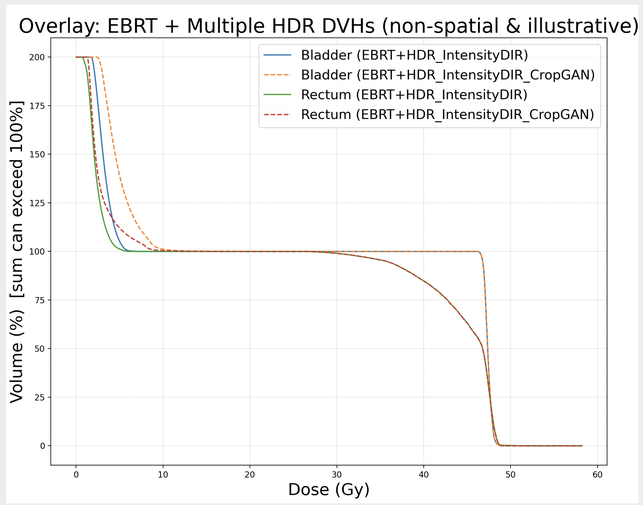

Figure 3. Example accumulated DVH for pelvic OARs (bladder and rectum); Solid line represents unextended HDR-CT after DIR, and the dashed line corresponds to extended HDR-CT after DIR.

CONCLUSIONS

Extending truncated HDR-CT images prior to registration restores anatomical context, improves DIR accuracy and reduces deformation artifacts. This method supports more reliable cumulative OAR dose assessments in combined EBRT and HDR brachytherapy, warranting further cohort-level validation.

REFERENCES

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