A Fully-Automated Field-in-Field Algorithm for Rectal Cancer

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Introduction

- The most common treatment technique for rectal radiotherapy is three-dimensional conformal radiotherapy (3DCRT).[1,2]
- In our clinic, a 3DCRT plan typically uses 3-field geometry consisting of a posterior-anterior (PA) beam and two opposed laterals.
- Due to asymmetries in human anatomy in the anterior-posterior direction, hotspots occur in the posterior region of the body.
- To circumvent this, hotspot reduction planning technique such as field-in-field (FiF) has been routinely used in clinic. However, the process is repetitive and time-consuming.

Aim

- Develop an algorithm to automatically produce 3D conformal radiotherapy treatment plans for rectal patient.
- The algorithm can reduce hotspots while maintaining adequate and homogeneous dose coverage to target volume using wedge and FiF technique.
- The algorithm should be customizable to changes in clinical practices and independent of treatment planning system.
- Automatically generated plans will be scored as clinically acceptable by a radiation oncologist.

Methods

- We created an algorithm using Python that automates the clinical workflow for creating plans with wedges and FiFs.
- As shown in Figure1, the algorithm automatically identifies a hotspot volume, creates a subfield, calculates dose, and optimizes beam weight without user intervention. This process is repeated until the hotspot is sufficiently reduced.

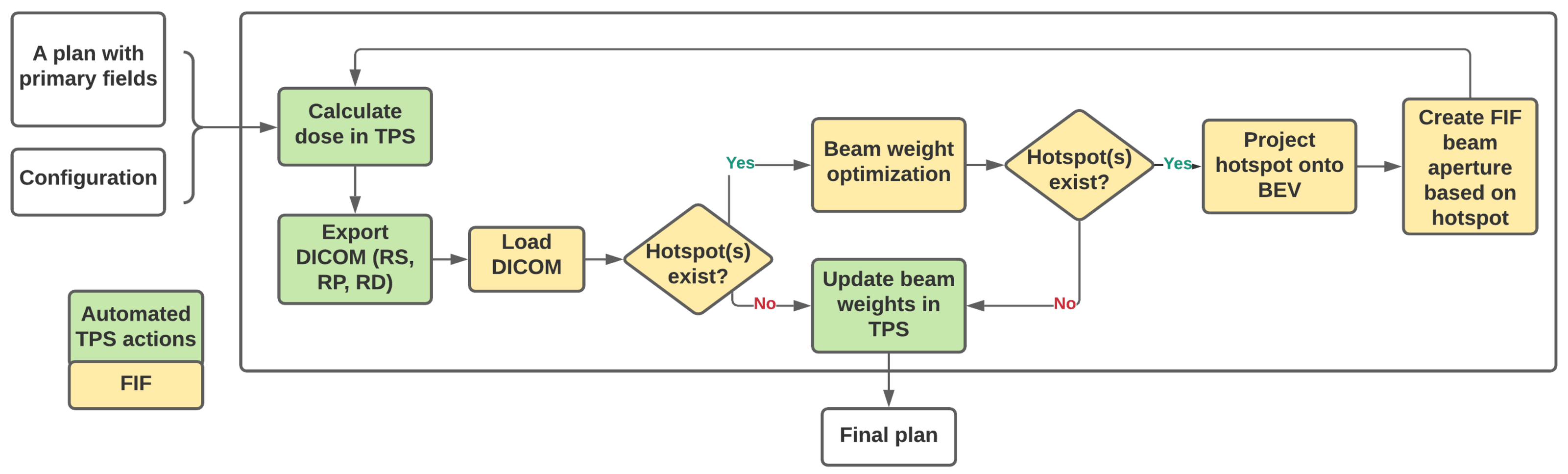

Figure 1: The flow chart of the FiF algorithm. The green and yellow boxes indicate steps performed in treatment planning system (TPS) and FiF algorithm, respectively.

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Methods

- Configurable parameters include the definition of hotspot, the target volume, the maximum number of subfields, the minimum MU per field, and the optimization solver.
- The beam weights are optimized based on user-configured physical constraints for DVH coverage and least-squared cost functions (Eq 1). For target volumes, only the voxels lower than Rx will be penalized. For OARs, only the voxels higher than the specified tolerance dose would be penalized.

$$f = \sum_{m}^{M} \omega_m \sum_{i}^{I} \left(\sum_{j}^{J} \alpha_j B_{ij} - D_m^{Rx} \right)^2$$

$$minMU \leq \alpha_j \leq maxMU$$

Eq 1: m is the m^{th} ROI. i represents the i^{th} voxel in the ROI. j represents the j^{th} number of beam. α_j is the beam weight for the j^{th} beam. B_{ij} is the beam dose (Gy) for a specific voxel. D_m^{Rx} (Gy) is the prescription dose for the specific ROI.

- We tested four configurations (Table 1) on 20 rectal patients.

Config	Wedge	Definition of hotspot
A	45-deg	107%Rx
B	60-deg	107%Rx
C	No wedge	107%Rx
D	45-deg	106%Rx

Table 1: shows different configurations tested on 20 rectal patients treated with 3-field 3DCRT. All plans were normalized so that 99% of the PTV was covered with the prescription dose.

- The following planning metrics were recorded before and after FiF algorithm for comparison: percentage V107 hotspot and hotspot percentage. Physician evaluation and scoring followed 5-point scale (Table 2).

Score	Acceptability
5	Acceptable, Use-as-is
4	Acceptable, Minor edits that are not necessary accounting for stylistic differences
3	Unacceptable, Minor edits that are necessary
2	Unacceptable, Major edits
1	Unacceptable, Unusable

Table 2: Scoring rubrics

Results

- For each patient, at least one plan was acceptable.
- The best performing configuration was B for most patients with 85% acceptability.

	Counts per score					Acceptability percentage	
Configuration	5	4	3	2	1	Acceptable	Unacceptable
A	12	5	2	1	0	85%	15%
B	13	4	2	1	0	85%	15%
C	2	8	10	0	0	50%	50%
D	8	9	2	1	0	85%	15%

Table 3: The results of physician review for each configuration

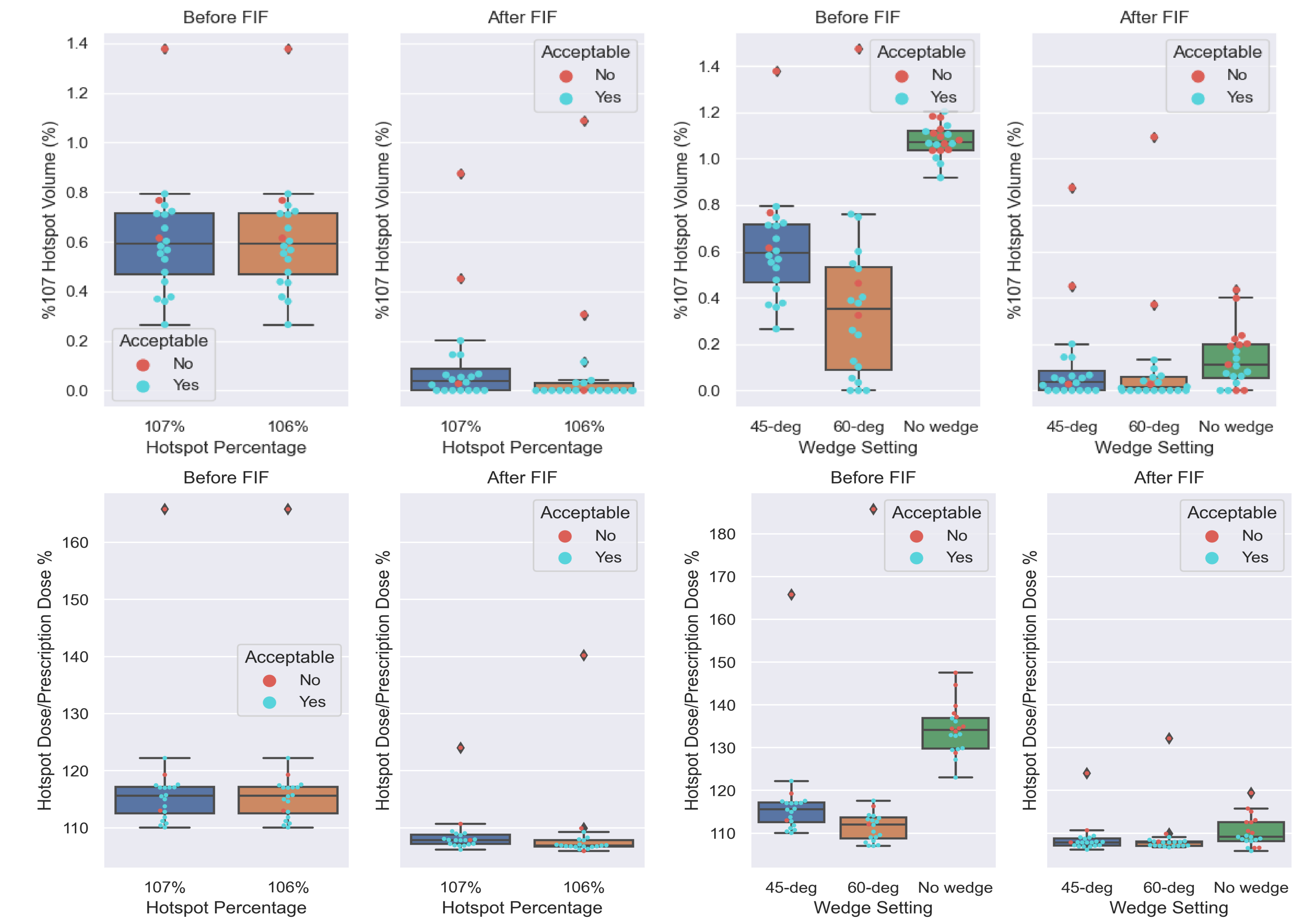

Figure 2: Top row: Boxplots for volume exceeding 107%Rx for (top left) different hotspot percentage settings, and (top right) different wedge settings. Bottom row: Boxplots for percentage hotspot dose of plans before and after FIF for (bottom left) different hotspot percentage settings, and (bottom right) different wedge settings.

Conclusion

We have automated the clinical workflow for generating FIF to reduce hotspots in 3-field 3D conformal plans for rectal cancer.

References

1. Hong, T. & Das, P. Radiation therapy for gastrointestinal cancers. (2017).
2. Wo, J. Y. et al. Radiation Therapy for Rectal Cancer: Executive Summary of an ASTRO Clinical Practice Guideline. Pract. Radiat. Oncol. 0, (2020).

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