Clinical evaluation of generalized optimization for reference-free direct-to-unit prostate radiation therapy

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ABSTRACT

Purpose:
To explore utilization of a generalized planning template to enable reference-free direct-to-unit treatment for prostate cancer.

Methods:
Direct-to-unit workflows bypass acquisition of a CTSim, often by using diagnostic imaging. For reference-free treatments, personalization occurs through an adaptive process once the patient arrives for treatment. This necessitates a generalized approach to reference plan generation. Plans for 20 prostate patients (60 Gy/20 fx, 9 or 12 field IMRT) were reviewed for further investigation. A generalized planning template was created using a weighted averaged order of dose goals across all original clinical plans. This class solution was then used to generate a new plan for each patient. These plans were compared for non-inferiority in target coverage and OAR sparing using Wilcoxon signed rank tests. To assess clinical feasibility, reference-free plans were compared to clinical plans by four experts, one dosimetrist and three radiation oncologists, using a structured survey.

Results:
No statistically significant differences were found between personalized and generalized plans for PTV, CTV, and nearby OAR metrics. For 95% of cases (n=19), at least half of the expert panel expressed either no preference or a preference for the generalized plan over the clinical plan. For 8 out of 20 cases, the entire panel reported no preference or a preference for the generalized plan over the established clinical plan.

Conclusion:
Statistical analysis found that plans did not differ significantly despite careful optimization and personalization of clinical plans. Detailed review by experienced experts supported these results, indicating no underlying clinical differences. A reference-free procedure could be incorporated into the clinical workflow for straight forward prostate treatment, reducing overall plan preparation and reducing site visits. Further personalization of the plan may be achieved with other ART techniques, such as daily imaging and contouring which is used to adapt plans to changes in daily anatomy.

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INTRODUCTION

Treatment planning is a fundamental part of the radiation therapy workflow. It involves personalized optimization for each patient and dedicated time to shape the dose distribution, followed by detailed review and approval. For online adaptive radiation therapy, oART, the need for a personalized reference plan creates a barrier for direct-to-unit workflows as it requires imaging prior to arrival at the unit.

This work explores the utilization of a class solution for reference-free direct-to-unit treatment for prostate cancer, enabling use of the same starting point (reference plan) for all patients. The hypothesis is that adaptive plans created from a workflow that only considers the patient-specific anatomy once the on-couch adaptive session begins are non-inferior to plans that come from a personalized clinical reference plan and optimization template. This workflow has the potential to improve efficiency of treatment planning by reducing the time clinicians spend on developing and reviewing individualized reference plans. This is also a crucial step in unlocking direct-to-unit workflows that bypass initial imaging and treatment planning, steps that can take up to two weeks.

METHODS AND MATERIALS

Treatment planning fan-beam CT's were obtained for 20 anonymized patients previously treated for prostate cancer. The prescription was 60 Gy/20 fx to the prostate only and plans involved 9 or 12 fixed-field IMRT beams. A common generalized planning template was created using a weighted averaged order of both target and OAR dose goals across all original clinical plans.

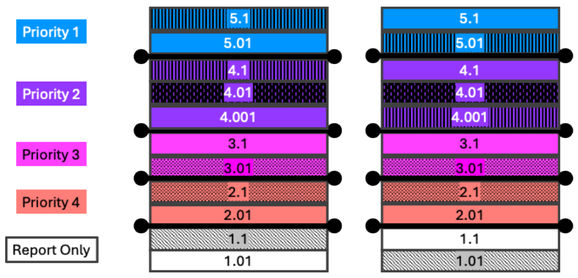

Figure 1. Illustration demonstrating the weighting done to find the averaged order of dose goals.

This class solution template was used as a physician's intent in Ethos[1] Treatment Management to generate a new plan for each patient. These generalized plans were then compared to the clinically-approved personalized plans for non-inferiority in target coverage and OAR sparing using Wilcoxon signed rank tests. To assess clinical feasibility, reference-free plans were compared to the original clinical plans by four experts, one dosimetrist and three radiation oncologists, using a structured survey.

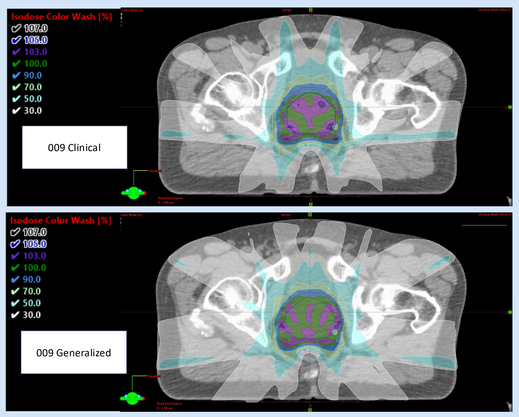

Figure 2. Dose wash of Patient009 . Clinical plan (top) and Generalized plan (bottom)

RESULTS

No statistically significant differences were found in plan metrics for PTV, CTV, and nearby OAR (bladder, rectum, and bowels) when values were compared across generalized and clinical plans using a signed Wilcoxon rank test. For 95% of cases (n=19), at least half of the expert panel expressed either no preference between the two plans or a preference for the generalized plan over the clinical plan. For 40% of cases (n=8), the entire panel reported no preference or a preference for the generalized plan over the established clinical plan.

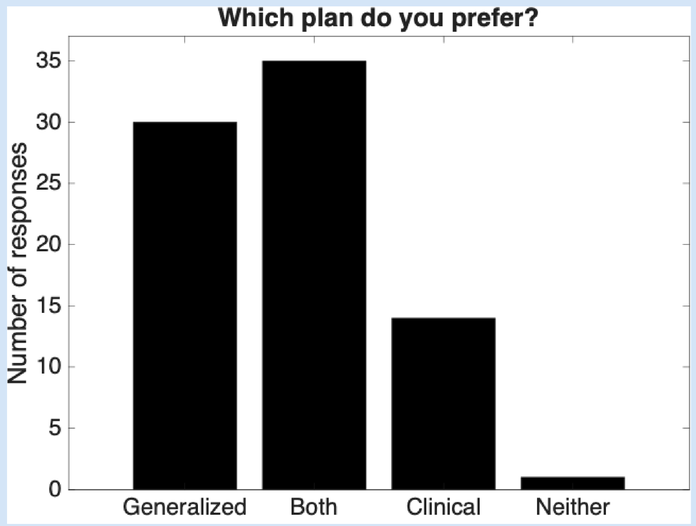

Figure 3. Bar graph showing the distribution of responses for the blinded survey. Thirty (37.5%) responses indicated the generalized plan was preferred, thirty-five (43.8%) responses indicated no preference, fourteen times (17.5%) the clinical plan was preferred, and 1 (1.3%) time neither plan was chosen.

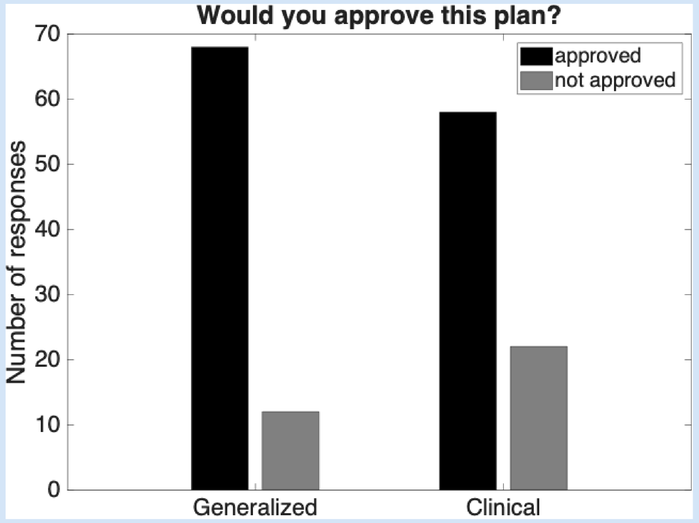

Figure 4. Approval rates for the generalized and clinical plans. Responses indicated that the generalized plans would not be approved 12 times out of 80 (15%). The clinical plans would not have been approved 22 times out of 80 (27.5%).

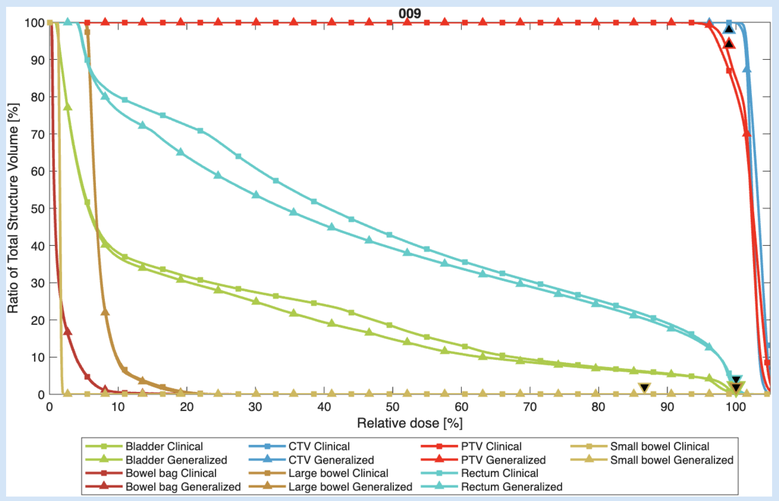

Figure 5. Dose-Volume Histogram (DVH) for Patient 009 comparing the personalized clinical plan (Clinical) and the automated workflow (Generalized). Black triangles represent specific dose constraints used for optimization and evaluation.

DISCUSSION

The purpose of daily ART with the use of plan generation is to create plans for the patient that are optimal for their treatment goals in a condensed timeline. The use of daily images allows for the plan to reflect any anatomical changes that have occurred since time of initial planning. This relies on the generalized plans being clinically acceptable. The 20 generalized plans in this work are not significantly different from plans used clinically, and review from clinical professionals did not reveal a general preference for the clinical plans over the generalized plans. (Figure 3 and figure 4)

Implementation of this method in a clinical workflow would consist of patient set up and imaging followed by: assessing/editing contours, plan re-optimization and calculation, and then quality assurance. Previous work evaluating a template-based automated solution to plan generation found that the time spent using the template-based solution was much faster than creating the plans manually[2]. In the workflow proposed in this work, human input time is minimal as the physician's intent template has already been created. Plan generation and calculation times are also very swift, on the order of 10 minutes. Should the user wish to re-generate a plan after evaluation and making changes, the time spent is unlikely to surpass the time spent manually creating plans.

CONCLUSIONS

The generalized and clinical plans do not differ significantly from one another despite careful optimization and personalization of each clinical plan by an experienced clinician. Detailed review by experienced experts supported these results, indicating no underlying consistent clinical differences. A reference-free procedure could be incorporated into the clinical workflow for straight forward prostate treatment, reducing overall plan preparation and reducing site visits. Daily imaging, recontouring, and plan adaptation to changes in daily anatomy may be used in conjunction with this method to add personalization, as necessary.

REFERENCES

1. Varian Medical Systems, Palo Alto, CA
2. Cilla, S. et al. (2020). Template-based automation of treatment planning in advanced radiotherapy: a comprehensive dosimetric and clinical evaluation. Scientific Reports, 10(1), 423. DOI 10.1038/s41598-019-56966-y