Improved Planning Efficiency with RapidPlan^{PT} in Proton Breast Cancer Therapy

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ABSTRACT

PURPOSE

To evaluate the clinical efficacy and planning efficiency of RapidPlan^{PT} for proton beam breast cancer treatment planning.

BACKGROUND

Prior RapidPlan studies focused mainly on photon planning or on head and neck and prostate proton planning [1,2]. Proton planning must balance physical dose, robustness, and biological dose. Because RapidPlan^{PT} optimizes only physical dose, its efficacy and usefulness on proton breast planning was not known.

METHODS

A RapidPlan^{PT} (RP) model was built in the Eclipse Treatment Planning System for whole-breast proton treatment: 40.05 Gy to the breast plus a 48.00 Gy boost over 15 fractions. It was trained on 72 historical plans from 2022–2024 (64% left-sided, 36% right-sided), validated on 35 plans, and then used prospectively on 107 plans. For each prospective use, dosimetrists recorded whether the RP output shaped the final plan, any modifications made, and the estimated time saved.

RESULTS

Predicted and achieved DVHs agreed closely, and RP plans lowered brachial plexus dose compared to historical plans. Although RP optimizes only physical dose, biological dose to the brachial plexus met constraints in 91% of validation cases. Validation highlighted OARs that would likely need further optimization, and this was confirmed through the questionnaires.

Of the 107 prospective cases, 27 (25%) were ready for physician review right after RP optimization. Plans saved about 1 day (8 hrs) each, totaling 105 days' worth of time since implementation. The lung and left anterior descending artery (left-sided cases) most often needed re-optimization, with iterations ranging from 0 to 15 (median 3). Dosimetrists found RapidPlan^{PT} most useful for setting an optimization starting point and creating comparison plans for insurance authorization.

METHOD: DATA & VALIDATION

- Cohort: Patients treated with 4005cGy to the whole breast with a 4800cGy boost in 15 fractions between 2022-2024
- Training/Validation: 72/35 plans (64% left-sided, 36% right-sided)
- Beam Arrangement: 25-degree contralateral tipped beam, 40-degree tipped en-fac beam, and a 105-degree posterior tangential beam (Beam arrangement was adjusted patient-to-patient to account for anatomy, setup, and clinical considerations.)

Table 1:Validation results

OAR	DVH Metric	Number of plans	Lower than prediction	Within prediction	Higher than prediction
Thyroid	D1cc [cGy]	32	84%	13%	3%
Brachial Plexus	D0.03cc [cGy]	33	79%	9%	12%
Humeral Head	D1cc [cGy]	33	79%	9%	12%
Esophagus	D1cc [cGy]	33	70%	30%	0%
Humeral Head	D0.03cc [cGy]	33	67%	30%	3%
Cord	D0.03cc [cGy]	33	55%	42%	3%
Heart	Mean [cGy]	35	54%	43%	3%
Lung	V5Gy [%]	35	23%	66%	11%
Esophagus	D0.03cc [cGy]	33	15%	73%	12%
L Ant Dec A	D0.03cc [cGy]	22	9%	68%	23%
Lung	V40% [%]	35	9%	57%	34%
R Coronary A	D0.03cc [cGy]	13	8%	54%	38%

Works well

Needs adjustments

DOSIMETRY QUESTIONNAIRE RESULTS

Q: HOW MUCH TIME DID YOU SAVE?

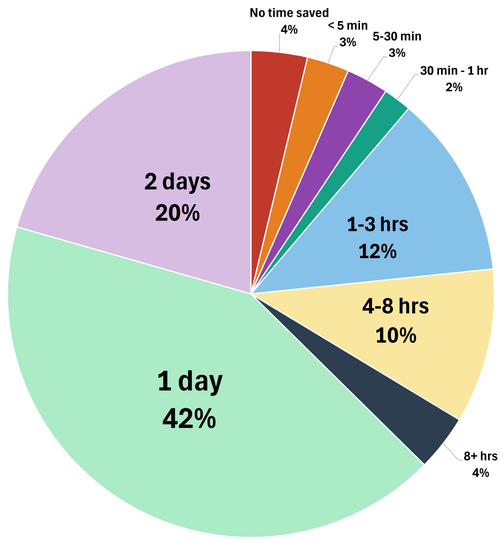

Figure 1: Estimated time saving reported by dosimetrist

Q: WAS THE OUTPUT USED FOR FINAL PLAN?

Table 2:Usefulness of the RapidPlan output

Response	Count	Percentage
Yes	93	87%
No	9	8%
Unanswered	5	5%
Total Responses	107	

Q: INDICATE THE RESULTS AFTER 1ST OPT

Table 3: State after 1st Rapid Plan optimization

Response Option	Count	Percentage
Ready to show MD	27	25%
Re-opt: Hot spots	67	63%
Re-opt: Cold spots	61	57%
Re-opt: OAR constraints	65	61%
Total Responses	107	

Q: INDICATE WHICH OAR NEEDED RE-OPT

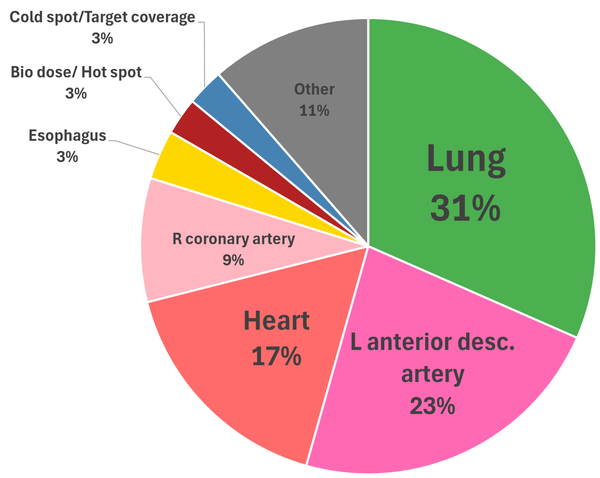

Figure 2: OAR constraints causing re-optimization

DISCUSSION

- RapidPlan^{PT} demonstrated strong agreement between predicted and achieved DVHs, supporting its use as a reliable starting point for proton breast planning.
- RapidPlan^{PT} also improved workflow efficiency. Although only 25% of plans were ready for physician review after the first optimization, overall planning time decreased by approximately one day per case. Dosimetrists found the model highly valuable for initial optimization and for generating comparison plans for insurance authorization. When paired with photon RapidPlan, comparison plans for insurance review or appeals were generated at least 2 hours faster than traditional workflows.
- However, the results also highlight important limitations. Structures such as the heart, left anterior descending artery, right coronary artery, and lungs showed less consistent agreement with predictions. This is likely related to boost location, heart position/anatomy, lung volume, and variation in free breathing between patients, which can significantly impact calculated dose. In addition, RapidPlan^{PT} DVH predictions are relatively coarse, particularly in low-dose regions common in proton breast planning, and maximum dose predictions may be less accurate. These structures were also sensitive to beam arrangement, presence of tissue expanders, range uncertainty, and robustness objectives, introducing geometric and tradeoff complexities that are difficult for the model to generalize.
- Skin was not explicitly modeled as involvement is highly patient-dependent, with some cases requiring coverage and others prioritizing skin sparing. This variability is difficult to model and would've required manual adjustment beyond the model predictions.
- Overall, RapidPlan^{PT} is most effective as a planning accelerator rather than a fully automated solution. It provides a clinically meaningful starting point and improves efficiency, but expert-driven refinement remains essential, particularly for low-dose OARs and anatomically variable structures.

CONCLUSIONS

RapidPlan^{PT} can substantially improve proton planning efficiency for breast cancers, even without explicit modeling of biological dose. RapidPlan^{PT} does not eliminate the need for planner intervention and expertise.

REFERENCES

1. Delaney, A. R., et. al. "Evaluation of an Automated Proton Planning Solution." *Cureus*. 2018. https://doi.org/10.7759/cureus.3696
2. Johnson, C. L, et al. "Advancing knowledge-based intensity modulated proton planning for adaptive treatment of high-risk prostate cancer." Medical Dosimetry. 2023.