# Dosimetric Comparison of Proton Therapy Plans for Breast Cancer Between Eclipse and CuraProton

Zihan Lu[1], Yifeng Yang[2], Hao Chen[1], and Yuanshui Zheng PhD[1]

[1] Guangzhou Concord Cancer Center, Guangzhou, China; [2] Raynaissance Technology Co., Ltd, Hefei, China

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广州泰和肿瘤医院
GUANGZHOU CONCORD CANCER CENTER

## ABSTRACT

**Purpose**: Proton therapy for breast cancer presents unique dosimetric challenges due to frequent use of range shifters and potential proton penetration into lungs. The study aims to compare dosimetric results between a novel proton treatment planning system (TPS) with an established one, and develop a hybrid workflow that integrates the new TPS calculated plan into our existing TPS and beam delivery platform for improved planning quality and efficiency.

**Methods**: CuraProton(V1.0, Raynaissance Technology Co., Ltd) was beam-modeled for Varian ProBeam system using identical measured beam data as Eclipse. 11 breast cancer cases were planned with both Eclipse and CuraProton V1.0. Plans created by CuraProton V1.0 were exported to Eclipse for final dose calculation and clinical beam delivery. Dose coverage for CTV, OAR doses, and planning time were compared between plans generated by the two systems.

**Results**: CuraProton-optimized plans demonstrated comparable target coverage and robustness, with superior sparing for most OARs compared to Eclipse-optimized plans. The ipsilateral lung V5 was reduced from 28.84% ± 11.23% to 16.50% ± 7.11%, and V20 decreased from 8.20%±6.19% to 3.86%±2.96%(both p<0.01); heart Dmean decreased from 33.89±43cGy to 13.02 ± 22.93cGy(p<0.01); esophagus D0.1cc decreased from 2376.92±1583.36cGy to 2114.22 ± 1484.4cGy(p<0.02). No statistically significant difference was observed in skin D0.1cc between the two systems (p = 0.898).On average, the time for treatment planning per case using CuraProton was approximately 30% less than Eclipse. To date, over 20 patients have been successfully treated using the hybrid workflow.

**Conclusion**: The CuraProton–Eclipse hybrid workflow enables accurate MC-guided optimization and efficient clinical delivery within existing proton therapy infrastructures. For breast cancer proton therapy, this approach provides substantial improvements in lung and heart sparing, reduced treatment planning time, while maintain similar target coverage, and skin dose, representing a practical pathway to translate advanced TPS capabilities into routine clinical practice.

## CONTACT

Yuanshui Zheng PhD DABR

Guangzhou Concord Cancer Center
No. 9, Ciji Road, Huangpu District,
Guangzhou, Guangdong, China
yuanshui.zheng@ccm.cn
+86 19864851118

## INTRODUCTION

- Proton therapy is increasingly used for breast cancer patients due to its potential better sparing of heart, lung and other organs near the tumor. However, due to the use of range shifter for shallow tumor and proton beam's long penetration in low density lung shallow, optimal treatment planning for breast cancer patients using intensity modulated proton therapy (IMPT) could be challenging.
- A newly developed planning system, CuraProton, was installed at our center. The purpose of this study was to compare CuraProton with Eclipse for breast proton planning and assess whether a CuraProton-Eclipse hybrid workflow could improve organ-at-risk sparing and planning efficiency without relaxing target or robustness requirements.

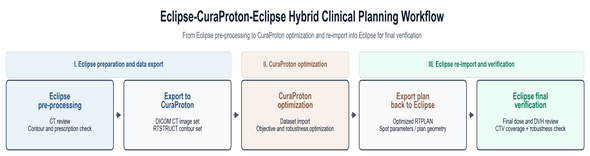


**Figure 1.** Hybrid Eclipse-CuraProton-Eclipse Workflow for Breast Proton Plan Optimization

## METHODS AND MATERIALS

- CuraProton V1.0 was beam-modeled for the Varian ProBeam proton therapy system using the same measured beam data as the Eclipse model.
- 11 breast cancer cases were studied, including 8 right-sided and 3 left-sided cases. 10 patients received 4005 cGy, and 1 received 5000 cGy.
- Target configurations included breast-only, breast plus supraclavicular nodal, chest wall plus supraclavicular nodal, and chest wall plus internal mammary and supraclavicular nodal irradiation.
- The comparison was designed as a practical implementation test, so planning quality, export reliability, and downstream clinical usability were evaluated together rather than as isolated software functions.
- For each case, plans were generated in both Eclipse and CuraProton. CuraProton plans were then exported to Eclipse for final dose calculation and delivery integration.
- Nominal plan acceptability required CTV V100% >= 99%. Robustness was evaluated in 12 scenarios combining 5-mm setup shifts in six directions with +/- 3% range uncertainty. The worst-case requirement was CTV V95% >= 95%.
- Primary OAR endpoints were ipsilateral lung V5 and V20, heart mean dose, esophagus D0.1cc, skin D0.1cc, and planning time.
- Dosimetric values are reported as mean +/- standard deviation and compared using paired Wilcoxon signed-rank tests.

## RESULTS

- All plans met the predefined target criteria. Nominal CTV V100% was at least 99%, and worst-case CTV V95% remained at least 95% across the 12 robustness scenarios.
- CuraProton reduced ipsilateral lung dose compared with Eclipse. Ipsilateral lung V5 decreased from 28.79 +/- 11.16% to 16.50 +/- 7.11% (p = 0.001), and ipsilateral lung V20 decreased from 8.11 +/- 6.02% to 3.86 +/- 2.96% (p = 0.002).
- Mean heart dose also decreased, from 33.46 +/- 42.01 cGy to 13.02 +/- 22.93 cGy (p = 0.001). Although absolute cardiac doses were low, the reduction is relevant for left-sided or nodal breast proton planning.
- Esophagus D0.1cc decreased from 2376.92 +/- 1583.36 cGy with Eclipse to 2114.22 +/- 1484.40 cGy with CuraProton (p = 0.014).
- Skin D0.1cc was essentially unchanged, with values of 4344.10 +/- 338.99 cGy and 4344.40 +/- 336.84 cGy, respectively (p = 0.898). Thus, improved lung, heart, and esophageal sparing was not accompanied by a measurable increase in the reported high-dose skin metric.
- Average planning time was approximately 30% shorter with CuraProton, and more than 20 patients have been treated using the hybrid workflow.

**Raw dosimetric data for paired Eclipse and CuraProton breast proton plans**

Values are shown per case using the original metrics from the planning comparison table.

| | Eclipse | | | | | CuraProton | | |
|---|---|---|---|---|---|---|---|---|
| Rx (cGy) | Lung V5 (%) | Lung V20 (%) | Heart Dmean (cGy) | Esophagus D0.1cc (cGy) | Skin D0.1cc (cGy) | Lung V5 (%) | Lung V20 (%) | Heart Dmean (cG |
| 4005 | 23.4 | 3.6 | 2.1 | 2919 | 4248 | 13.7 | 2.6 | 0.2 |
| 4005 | 18.7 | 2.8 | 55.7 | 0 | 4216 | 11.7 | 1.2 | 14.7 |
| 4005 | 42.2 | 18.1 | 119.2 | 3969 | 4285 | 24.0 | 7.0 | 46.7 |
| 4005 | 39.7 | 13.3 | 90.2 | 4045 | 4296 | 28.2 | 7.5 | 68.4 |
| 4005 | 15.3 | 3.0 | 3.0 | 2949 | 4259 | 13.4 | 3.5 | 0.2 |
| 4005 | 27.0 | 6.5 | 1.8 | 3414 | 4192 | 14.0 | 4.3 | 0.9 |
| 4005 | 35.1 | 9.6 | 0.7 | 3228 | 4201 | 14.2 | 3.5 | 0.2 |
| 4005 | 32.7 | 7.7 | 1.7 | 3147 | 4274 | 16.7 | 2.2 | 1.3 |
| 4005 | 23.3 | 5.3 | 3.7 | 2 | 4246 | 11.3 | 1.0 | 1.1 |
| 5000 | 46.1 | 18.2 | 30.2 | 2431 | 5361 | 28.0 | 9.4 | 4.8 |
| 4005 | 13.1 | 1.3 | 59.8 | 42 | 4207 | 6.4 | 0.2 | 4.8 |

vraclavicular nodes; CW, chest wall; IMN, internal mammary nodes.
the original table values; normalization was used only for the comparative boxplot panel.

**Figure 2.** Details the individual dosimetric parameters for all 11 cases across different lateralities and prescriptions.

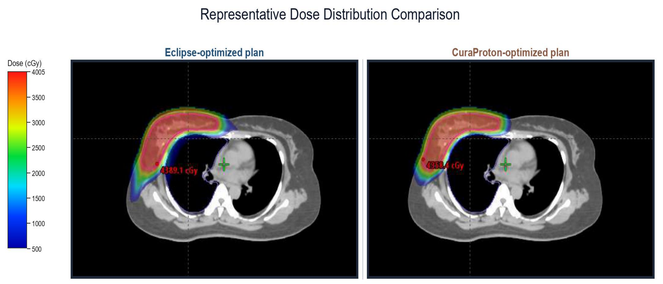


**Figure 3.Representative Axial Dose Comparison Between Eclipse- and CuraProton-Optimized Breast Proton Plans**

## DISCUSSION

- CuraProton demonstrated dosimetric advantages within predefined clinical coverage and robustness constraints, suggesting that the observed organ-at-risk sparing was not achieved at the expense of target adequacy.
- The hybrid workflow is clinically practical because CuraProton can be used for optimization while Eclipse remains responsible for final dose calculation, documentation, quality assurance, and Varian ProBeam delivery integration. This approach may facilitate implementation of a new optimizer within an established proton therapy program.
- Limitations include the small single-institution cohort and the absence of patient-specific QA, toxicity, cosmesis, and long-term outcome data. Future studies should integrate robustness metrics, delivery parameters, and QA results.

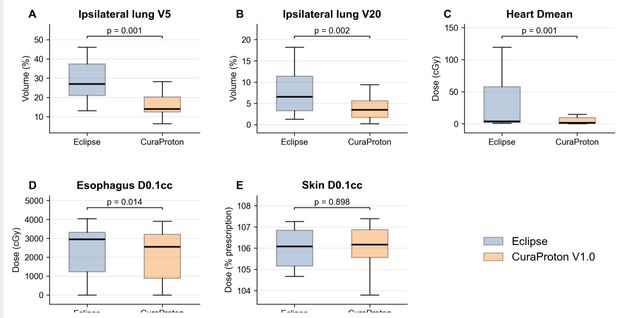


Figure 4: OAR dosimetric comparison between CuroProton and Eclipse TPS for breast cancer proton therapy (N=11) .

## CONCLUSIONS

- The CuraProton-Eclipse hybrid workflow provides a feasible strategy for integrating CuraProton optimization into breast proton therapy planning.
- CuraProton significantly reduced ipsilateral lung V5, ipsilateral lung V20, heart mean dose, and slightly reduced esophageal D0.1cc compared with Eclipse, while skin D0.1cc and target coverage remained similar.
- CuraProton has a better planning efficiency with planning time approximately 30% shorter
- Further validation including larger cohorts, patient-specific QA endpoints, and delivery efficiency metrics are underway.