# Using RapidPlan to Guide and Benchmark Monaco Treatment Planning for Malignant Pleural Mesothelioma

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**Clinical Impact: RapidPlan provides patient-specific dosimetric benchmarks for quality assurance and cross-platform benchmarking, enabling efficient implementation and validation of Monaco planning for malignant pleural mesothelioma**

## ABSTRACT

**Purpose:** Treatment planning for malignant pleural mesothelioma (MPM) is challenging due to target geometry and organ-at-risk sparing requirements. This study uses RapidPlan-predicted dose volume histograms (DVHs) to guide Monaco planning for TrueBeam and Versa delivery comparing dosimetric results across plans.

**Methods:** Twenty MPM patients were retrospectively selected. RapidPlan VMAT plans (2–4 arcs with contralateral lung avoidance) were generated in Eclipse V18.1 and re-planned in Monaco for TrueBeam and Versa delivery using constrained optimization, producing 60 plans. All plans used 6 MV beams with a prescription of 25 Gy in 5 fractions. Monaco optimization constraints were created using a physician-guided automation template. Dosimetric comparisons were performed using the Wilcoxon signed-rank test to evaluate plan quality, organ-at-risk sparing, target coverage, and delivery consistency across both treatment platforms clinically relevant.

**Results:** RapidPlans in Eclipse as well as plans in Monaco all met the dose constraints by generous margins of as much as 42% or 12.7 Gy depending on the dose constraint, while requiring 1–3 iterations from either a starting DVH estimation or template. For the same target coverage, total lung V12 Gy was lower (**p** < 0.001) for Monaco Versa plans at 32% (aim < 37%) while slightly higher at 34.5% for delivery on the TrueBeam with Monaco or Eclipse RapidPlan. Total and contralateral lung V3 Gy were comparable (aim < 80%), while heart mean and V18 Gy were within 1 Gy and 1% of each other on average. Similar trends were observed for liver, stomach, esophagus mean, ipsilateral kidney V10 Gy, and bowel maximum dose.

**Conclusion:** RapidPlan can help in quality assurance/benchmarking of mesothelioma plans when utilizing a new planning system to plan the same case, with both planning systems able to achieve the goals. Planning with constraint optimization helped prioritize and reduce low dose to the lung with other dosimetric tradeoffs.

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## INTRODUCTION

Malignant pleural mesothelioma (MPM) presents one of the most challenging disease sites for radiotherapy treatment planning because of its large, complex, annular target geometry and the need to spare the underlying ipsilateral lung and surrounding thoracic organs-at-risk (OARs). Achieving adequate target coverage while minimizing dose to the lungs, heart, esophagus, liver, kidneys, and bowel often requires multiple optimization iterations and remains highly planner dependent.

Knowledge-based planning (KBP) offers a mechanism for estimating patient-specific achievable dosimetry based on prior high-quality treatment plans. RapidPlan is a commercially available KBP system that predicts patient-specific dose-volume histograms (DVHs) to guide treatment planning. Although RapidPlan has been widely implemented within the Eclipse treatment planning system, its application as a **quality assurance and benchmarking tool** for evaluating treatment plans generated in other planning systems has not been investigated for mesothelioma.

We hypothesized that RapidPlan-generated DVHs could serve as **patient-specific, platform-independent dosimetric benchmarks** to guide and evaluate Monaco treatment planning for MPM, facilitating efficient implementation of standardized planning workflows across multiple treatment delivery platforms.

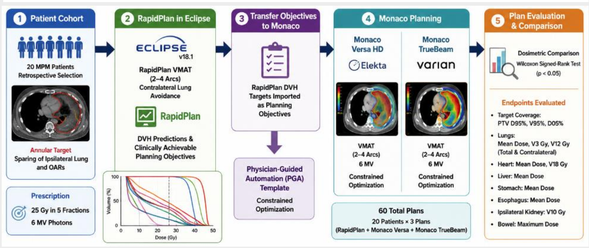
## METHODS AND MATERIALS

A previously developed **RapidPlan® (Varian Medical Systems)** knowledge-based planning model for malignant pleural mesothelioma (MPM) was retrospectively evaluated using **20 patients** previously treated with VMAT. RapidPlan-generated dose-volume histogram (DVH) predictions and clinically achievable planning objectives were used as benchmarks for treatment planning in Monaco.

For each patient, a **RapidPlan VMAT plan** was generated in **Eclipse V18.1** using **2–4 coplanar arcs** with contralateral lung avoidance. The same patients were subsequently replanned in **Monaco (Elekta)** for both **Versa HD** and **TrueBeam** delivery using a standardized **Physician-Guided Automation (PGA)** template, resulting in a total of **60 treatment plans** (RapidPlan, Monaco Versa, and Monaco TrueBeam). All plans utilized **6 MV photon beams** with a prescription dose of **25 Gy in 5 fractions**.

The Monaco optimization template incorporated constrained optimization with physician-defined planning objectives. Optimization cost functions and constraints were iteratively refined using RapidPlan-predicted DVHs to achieve clinically acceptable target coverage while minimizing dose to the lungs and other thoracic organs-at-risk.

Dosimetric endpoints included **PTV coverage (D95%, V95%, D05%)**, total and contralateral lung dose metrics (mean dose, V3 Gy, V12 Gy), heart mean dose and V18 Gy, liver mean dose, stomach mean dose, esophagus mean dose, ipsilateral kidney V10 Gy, and bowel maximum dose. Statistical comparisons among RapidPlan, Monaco Versa, and Monaco TrueBeam plans were performed using the **Wilcoxon signed-rank test**, with statistical significance defined as **p < 0.05**.




## RESULTS

**Table 1.** Dosimetric comparison of median doses with RapidPlan versus Monaco Versa (P1), RapidPlan versus Monaco TB (P2) and Monaco Versa versus TB (P3).

| | RAPIDPLAN, ECLIPSE TB | MONACO, VERSA | MONACO, TB | P1 | P2 | P3 |
|---|---|---|---|---|---|---|
| PTV D95% | 95% | 95% | 95% | N/A | N/A | N/A |
| PTV V95% | 95% | 95% | 95% | N/A | N/A | N/A |
| PTV D05% | 113.9% | 113.2% | 114% | 0.526 | 0.808 | 0.04 |
| TOTAL LUNG MEAN(Gy) | 9.71 | 9.14 | 9.34 | 0.005 | 0.108 | <0.001 |
| TOTAL LUNG V12Gy(%) | 34.6% | 32% | 34.4% | <0.001 | 0.121 | 0.001 |
| TOTAL LUNG V3Gy(%) | 57.8% | 53.32% | 56.90% | 0.079 | 0.794 | 0.03 |
| CONT LUNG MEAN(Gy) | 2.49 | 2.55 | 2.6 | 0.526 | 0.936 | 0.765 |
| CONT LUNG V12Gy | 0 | 0 | 0 | N/A | N/A | N/A |
| CONT LUNG V3Gy(%) | 24.98% | 21.20% | 26.77% | 0.079 | 0.737 | 0.023 |
| CORD MAX(Gy) | 21.13 | 20.52 | 20.93 | 0.044 | 0.314 | 0.067 |
| HEART MEAN(Gy) | 10.86 | 11.41 | 11.8 | 0.218 | 0.019 | 0.024 |
| HEART V18 Gy(%) | 19.09% | 19% | 18.09% | 0.433 | 0.737 | <0.001 |
| IPSI KIDNEY V10Gy(%) | 4.43% | 3.61% | 4.81% | 0.064 | 0.033 | <0.001 |
| LIVER MEAN(Gy) | 3.585 | 4.6725 | 3.1725 | 0.279 | <0.001 | <0.001 |
| STOMACH MEAN(Gy) | 6.11 | 5.45 | 5.804 | 0.001 | 0.008 | <0.001 |
| ESOPHAGUS MEAN(Gy) | 12.96 | 12.3 | 12.5 | <0.001 | 0.001 | <0.001 |
| BOWEL MAX(Gy) | 10.97 | 11.43 | 12.63 | 0.654 | 0.004 | <0.001 |

## RESULTS

**Target Coverage and Plan Quality:** RapidPlan (Eclipse) and Monaco-generated plans for both **Versa HD** and **TrueBeam** achieved comparable target coverage while meeting all clinical planning objectives. PTV **D95%**, **V95%**, and **D05%** demonstrated no clinically meaningful differences among the three planning approaches, with all plans satisfying protocol dose constraints. Furthermore, all plans met organ-at-risk dose constraints with margins of up to **42%** or **12.7 Gy**, depending on the dosimetric endpoint, while requiring only **1–3 optimization iterations**.

**Organ-at-Risk Sparing:** For equivalent target coverage, Monaco planning achieved organ-at-risk sparing comparable to RapidPlan across most evaluated structures. Mean doses to the heart, liver, stomach, and esophagus differed by less than **1 Gy** on average, while total and contralateral lung **V3 Gy** values remained within **5%** among all planning and delivery combinations. Similar agreement was observed for ipsilateral kidney **V10 Gy** and bowel maximum dose, demonstrating consistent dosimetric performance across treatment planning systems.

**Treatment Platform Comparison:** Among the evaluated delivery platforms, **Monaco plans optimized for Versa HD achieved the lowest total lung V12 Gy (32%)**, significantly lower than RapidPlan and Monaco TrueBeam plans (approximately **34.5%**, **p < 0.001**) while maintaining equivalent target coverage. This reduction in intermediate-dose lung exposure represents the primary dosimetric difference observed between delivery platforms, whereas all remaining target and organ-at-risk metrics were clinically comparable.

**Key Findings**
✓ All RapidPlan and Monaco plans satisfied clinical planning objectives.
✓ Monaco reproduced RapidPlan dosimetry while requiring only **1–3 optimization iterations**.
✓ **Versa HD** achieved the lowest total lung **V12 Gy (32%)** while maintaining equivalent target coverage (**p < 0.001**).
✓ RapidPlan successfully served as a **patient-specific benchmark** for cross-platform quality assurance and treatment planning in Monaco.

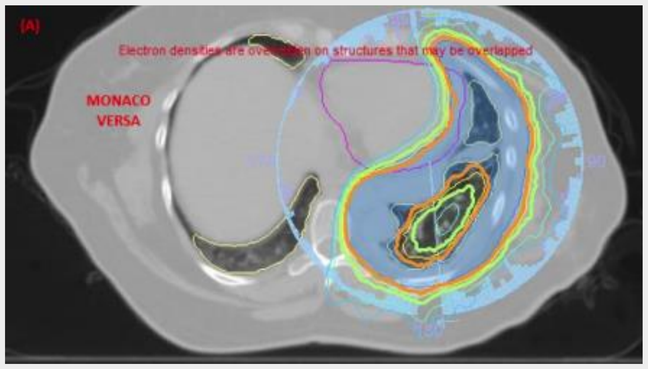



Figure 1. Dose Distribution in the Axial Plane for Monaco Versa Plan (A)

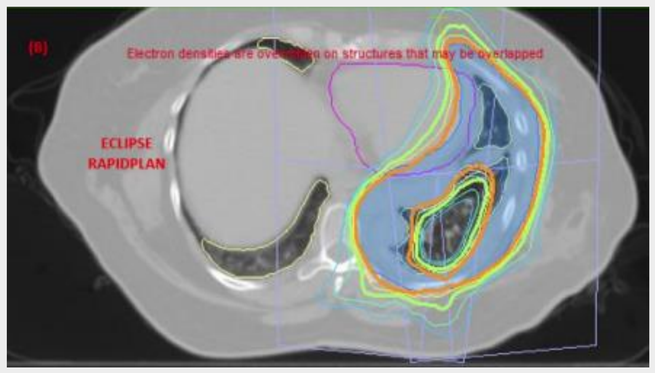



Figure 2 Dose Distribution in the Axial Plane for Eclipse RapidPlan (B)

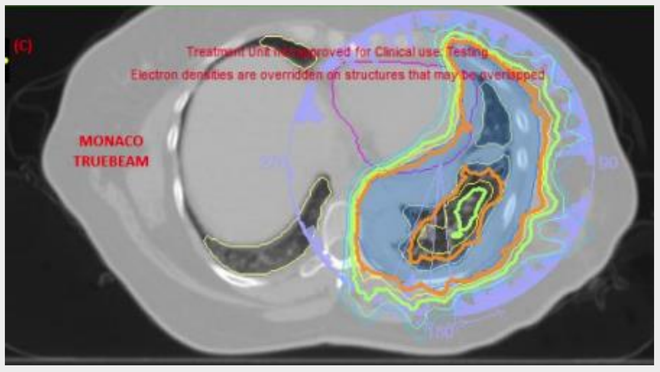
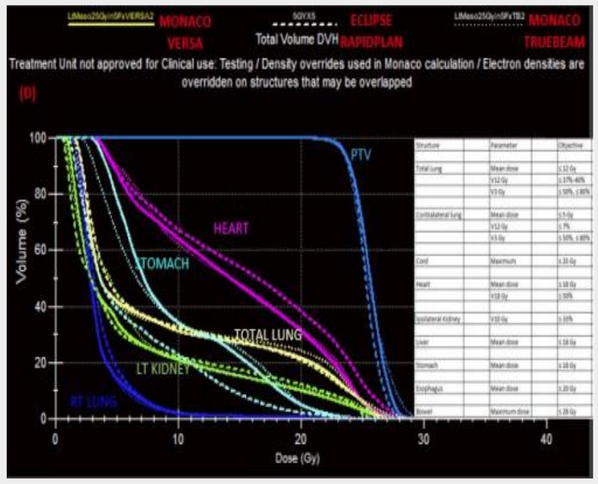



Figure 3. Dose Distribution in the Axial Plane for Monaco Truebeam Plan (C)

Figure 4. Dose Volume Histogram (DVH) comparisons of Monaco Versa plan (A), Eclipse RapidPlan (B) and Monaco Truebeam Plan (C)




## DISCUSSION

This study demonstrates that **RapidPlan-generated DVH predictions can serve as patient-specific dosimetric benchmarks for quality assurance and cross-platform treatment planning** in malignant pleural mesothelioma. Despite differences in optimization algorithms and delivery platforms, Monaco plans achieved target coverage and organ-at-risk sparing comparable to RapidPlan while consistently meeting all clinical planning objectives.

RapidPlan provided an estimate of **clinically achievable dosimetry** for each patient's anatomy, allowing Monaco optimization to be evaluated against patient-specific benchmarks rather than population-based planning goals alone. The physician-guided automation (PGA) template reproduced these planning objectives with only **1–3 optimization iterations**, demonstrating a streamlined and reproducible workflow for implementing mesothelioma planning in a new treatment planning system.

Although overall dosimetric agreement was excellent, Monaco plans optimized for **Versa HD** achieved significantly lower **total lung V12 Gy** compared with RapidPlan and Monaco TrueBeam plans while maintaining equivalent target coverage. This finding suggests that differences in optimization strategy and delivery platform may influence intermediate-dose lung exposure and could be leveraged to further improve treatment plan quality.

Even though limited by the retrospective design and relatively small cohort of 20 patients, this work represents the **first application of RapidPlan as a quality assurance and benchmarking tool for mesothelioma planning in Monaco**. These findings support the use of knowledge-based planning to facilitate implementation, standardization, and cross-platform validation of complex treatment planning workflows.

## CONCLUSIONS

**✓ RapidPlan provides patient-specific dosimetric benchmarks that can guide quality assurance and benchmarking of mesothelioma treatment plans across treatment planning systems.**
**✓ Monaco planning using a standardized Physician-Guided Automation (PGA) template achieved clinically acceptable target coverage and organ-at-risk sparing with high agreement to RapidPlan predictions.**
**✓ Constraint-based optimization consistently produced high-quality plans within 1–3 optimization iterations, supporting efficient and reproducible treatment planning.**
**✓ This approach has the potential to facilitate implementation, standardization, and validation of complex mesothelioma planning workflows across multiple treatment delivery platforms.**

## REFERENCES

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2. Clements M, Schupp N, Tattersall M, Brown A, Larson R. Monaco treatment planning system tools and optimization processes. *Med Dosim.* 2018;43(2):106-117. doi:10.1016/j.meddos.2018.02.005

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