

Single-Isocenter Online Adaptive Radiotherapy for Multi-Lesion Lung Cases: Dosimetric Gains and Time Efficiency

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STUDY OVERVIEW

Clinical Motivation

Lung cancer cases frequently involve multiple lesions, creating a need for reliable, efficient treatment workflows that maintain target coverage without substantially increasing treatment time.

Study Focus

This study evaluates CBCT-guided online adaptive radiotherapy for multi-lesion lung cases treated using a single-isocenter multi-lesion (SIML) approach.

Comparison

SIML was compared with single-isocenter single-lesion (SISL) delivery for target coverage and treatment time per lesion.

Key Findings

Online adaptation improved SIML target coverage to levels comparable with SISL. SIML reduced treatment time per lesion, while scheduled-plan coverage loss increased with lesion distance from isocenter.

INTRODUCTION

Lung cancer cases frequently involve multiple lesions, and treating each lesion with a separate isocenter can increase the time required for online adaptive workflows. A single-isocenter multi-lesion (SIML) approach may improve efficiency but may also be more sensitive to geometric uncertainty from inter-fraction motion, intra-fraction motion, and setup variation.

CBCT-guided online adaptive radiotherapy (ART) can potentially mitigate part of this uncertainty by accounting for inter-fraction motion and setup variation before treatment delivery.

Objective: To compare CBCT-guided online ART for SIML and single-isocenter single-lesion (SISL) lung treatments in terms of target coverage, treatment time per lesion, and lesion-to-isocenter distance effects.

METHODS AND MATERIALS

Study Cohort

- Retrospective analysis of 25 lung cancer patients with ≥2 lesions.
- A total of 152 treatment fractions were delivered on a CBCT-guided adaptive platform (Varian Ethos).

Treatment Approaches

- SIML: 92 fractions, comprising 227 lesion-fraction evaluations.
- SISL: 60 fractions.
- PTV margins ranged from 3–7 mm, typically 5 mm.

Lesion Geometry

- In the SIML cohort, lesion-to-isocenter distance ranged from 0.03 to 16.68 cm.

Dosimetric Analysis

- PTV V100% was compared between scheduled and adapted plans.
- Scheduled-plan coverage degradation was defined as:
100% – scheduled-plan PTV V100%.

Efficiency Analysis

- Treatment time per lesion was defined as session duration divided by number of lesions treated per plan.
- Treatment time per lesion was compared between SIML and SISL using the Mann–Whitney U test.

RESULTS

- Scheduled SIML plans showed lower and more variable PTV V100% than SISL:
84.7 ± 17.0% vs 91.6 ± 8.7%.
- After online adaptation, PTV V100% was comparable between SIML and SISL:
96.0 ± 2.1% vs 95.1 ± 1.3%.
- In SIML treatments, scheduled-plan coverage degradation increased with lesion-to-isocenter distance..
- SIML significantly reduced treatment time per lesion compared with SISL:
26.6 ± 8.4 min vs 50.5 ± 15.8 min; p < 0.001

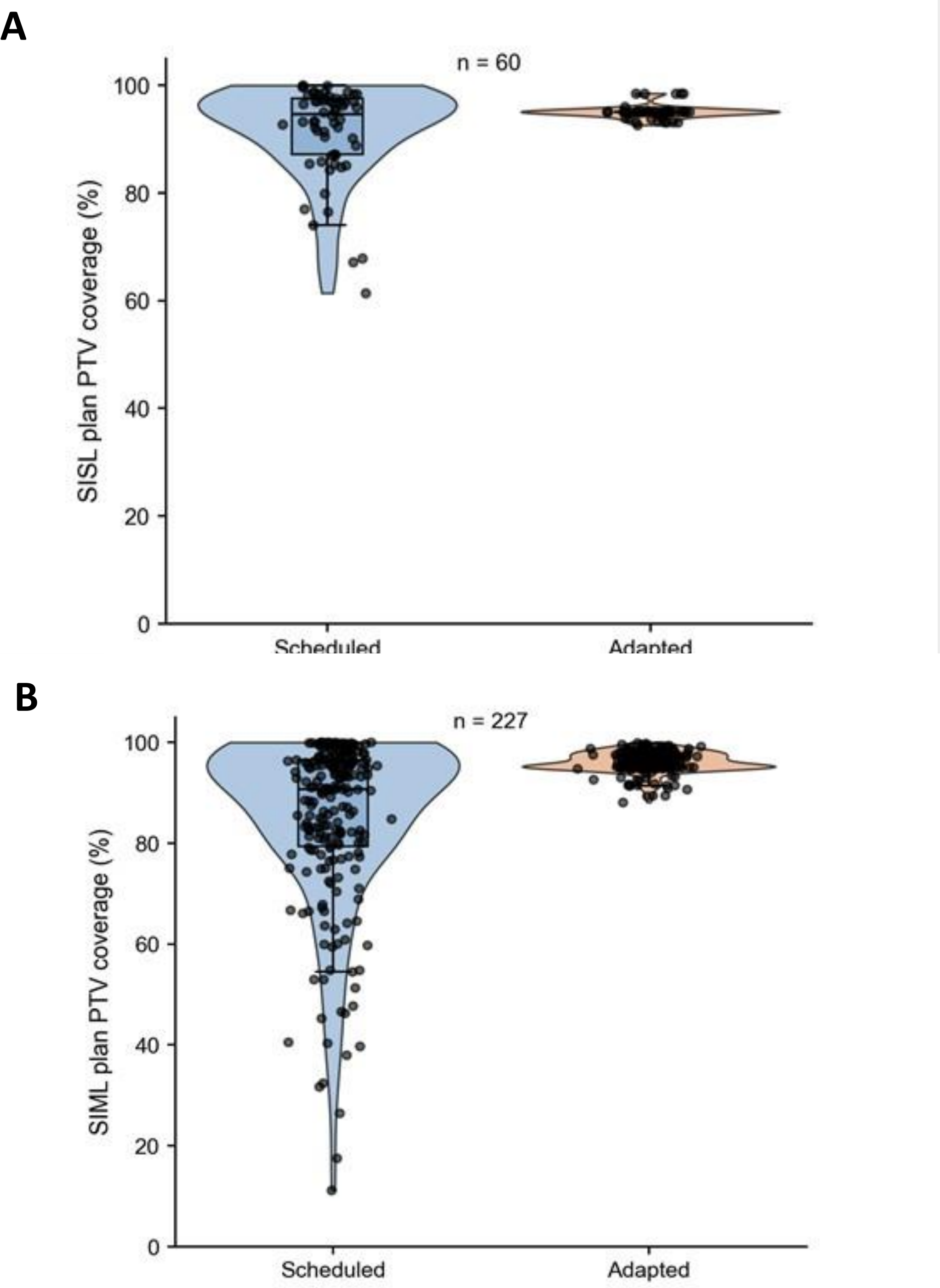


Figure 1. Comparison of PTV V100% between scheduled and adapted plans. A: SISL plans. B: SIML plans.

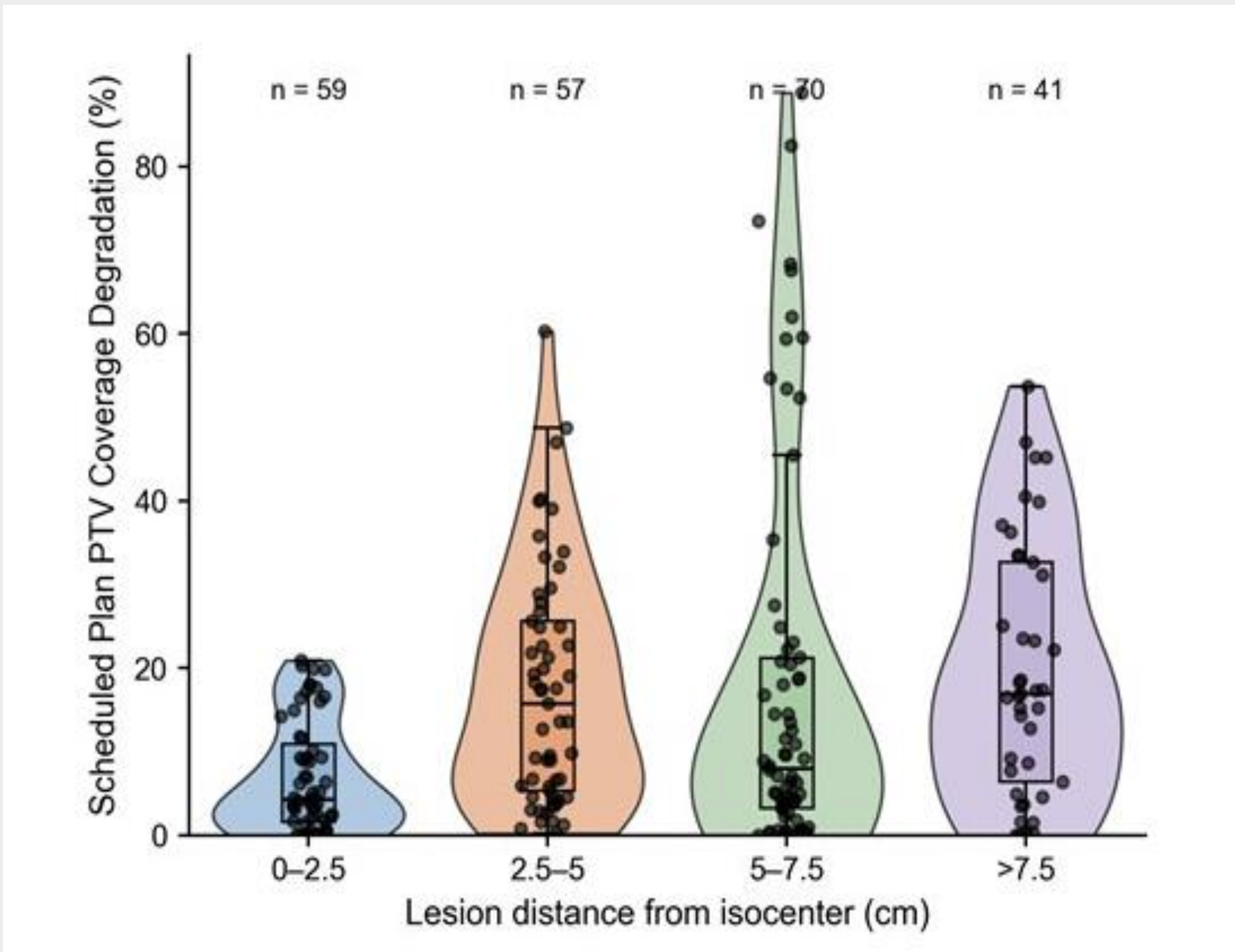


Figure 2. Scheduled-plan PTV coverage degradation, defined as 100% – scheduled-plan PTV V100%, versus lesion-to-isocenter distance in SIML treatments.

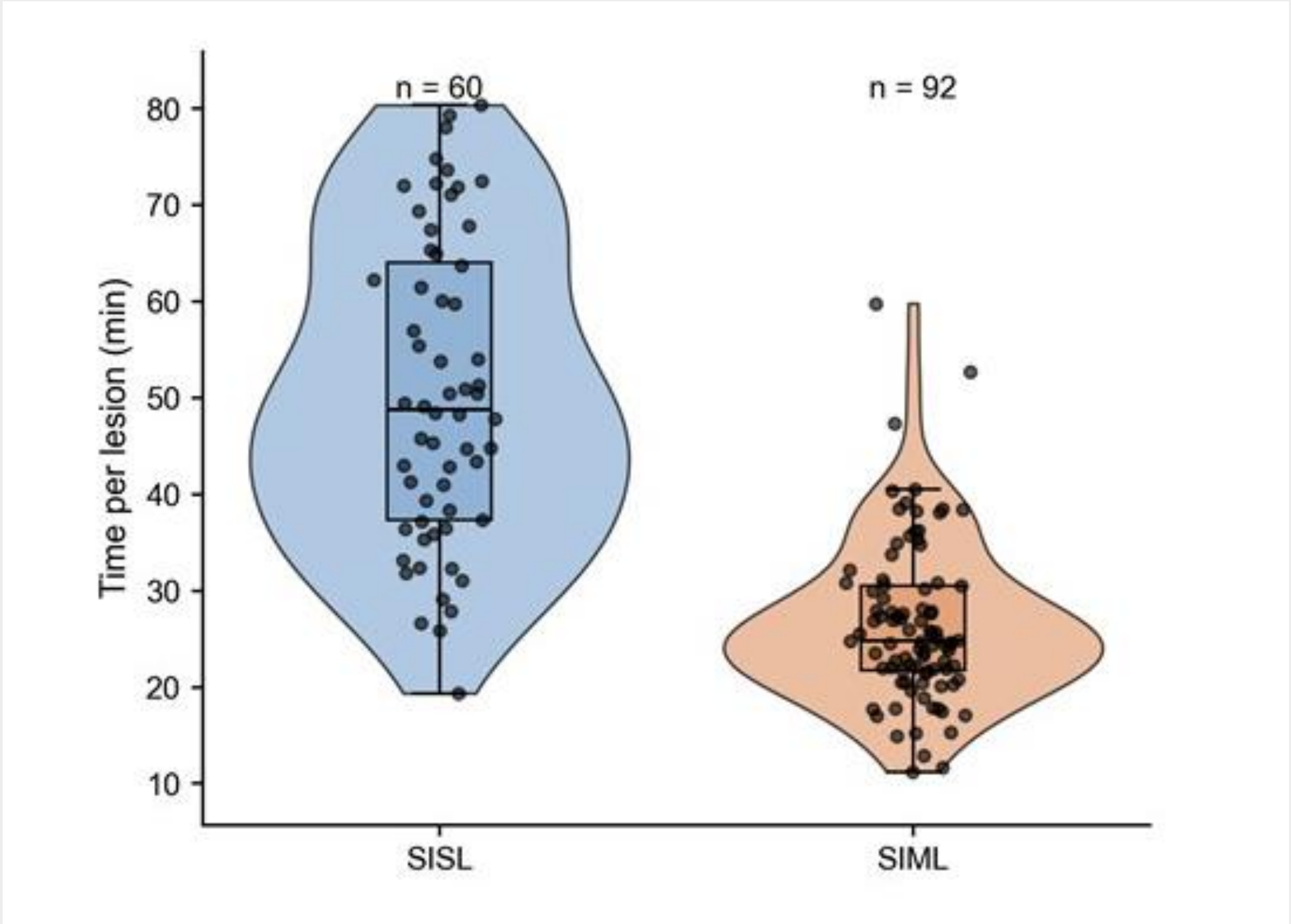


Figure 3. Treatment time per lesion was significantly shorter for SIML than SISL: 26.6 ± 8.4 min vs 50.5 ± 15.8 min; Mann–Whitney U test, p < 0.001.

DISCUSSION

- Scheduled SIML plans showed lower and more variable target coverage, consistent with increased sensitivity to motion and setup uncertainty in SIML delivery.
- Online adaptation restored PTV V100% to approximately 96%, suggesting that CBCT-guided ART can compensate for coverage loss observed in scheduled plans.
- Coverage degradation increased with lesion-to-isocenter distance, indicating that lesion geometry remains an important consideration for SIML case evaluation.
- SIML significantly reduced treatment time per lesion, supporting its potential role in efficient multi-lesion adaptive treatment.

CONCLUSIONS

- CBCT-guided online ART enabled SIML lung treatments to achieve adapted-plan target coverage comparable to SISL.
- Scheduled-plan coverage degradation increased with lesion-to-isocenter distance, highlighting greater vulnerability in some non-adapted SIML plans.
- SIML significantly reduced treatment time per lesion, supporting efficient online adaptive workflows for selected multi-lesion lung cases.

REFERENCES

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