

Multi-Institutional Benchmarking of Stereotactic Targeting Accuracy Using Multi-Target Winston–Lutz Analysis

Chester R. Ramsey¹, Elijah Clay Nordhorn², John Paul Anthony Dieffenthaler³, Brett A. Miller³ and Alexander V. Usynin²

(1)Covenant Health Cancer Center, Knoxville, TN, (2)Covenant Health Radiation Therapy, Knoxville, TN, (3)University of Tennessee Medical Center, Knoxville, TN

Innovation: This work extends established Multi-WL testing by applying per-field, geometry-resolved analysis for multi-institutional, multi-vendor benchmarking. Unlike traditional approaches based on a single 3D displacement value, this method characterizes distributional and geometry-dependent errors, revealing clinically relevant behavior that may otherwise be obscured by aggregate metrics.

INTRODUCTION

Multi-target Winston–Lutz (Multi-WL) testing has emerged as an important stereotactic QA technique for single-isocenter, multi-lesion SRS/SBRT. Conventional Winston–Lutz analysis often summarizes performance with a single 3D isocenter displacement metric, potentially obscuring geometry-specific targeting errors. This study benchmarked targeting accuracy across multiple institutions and linac platforms using geometry-resolved Multi-WL analysis.

METHODS AND MATERIALS

- A Multi-WL plan was delivered on 10 clinical linacs (Varian and Elekta) at 7 different facilities
- The SNC MultiMet phantom and SNC software were used for Multi-WL acquisition and analysis
- Imaged using 8 gantry, couch, and collimator combinations for 48 fields per linac
- Targets included one isocenter and five off-axis positions
- Field-target coincidence was evaluated for each field and target
- Mean, median, RMS, p95, and maximum coincidence errors were calculated
- Couch-kicked (90°/270°) and non-kicked deliveries were compared using bootstrap confidence intervals

RESULTS

- Across all measurements, mean/median/RMS coincidence errors were 0.697/0.600/0.862 mm, with 17.3% of fields exceeding 1.0 mm
- Couch-kicked deliveries showed larger errors than non-kicked deliveries (0.879 vs 0.637 mm), with a mean difference of 0.242 mm (95% CI: 0.119–0.369)
- Isocenter targeting was only slightly better than off-axis targeting (0.641 vs 0.708 mm)
- Considerable inter-linac variability was observed, with mean coincidence ranging from 0.425 to 1.564 mm
- Although 9 of 10 linacs had 3D isocenter vectors <1 mm, several demonstrated clinically relevant field-target errors >1 mm, illustrating limitations of relying solely on a 3D summary metric (Figure 1)
- The highest-error unit had 64.6% of fields >1 mm, while the lowest-error unit had 0% exceeding 1 mm

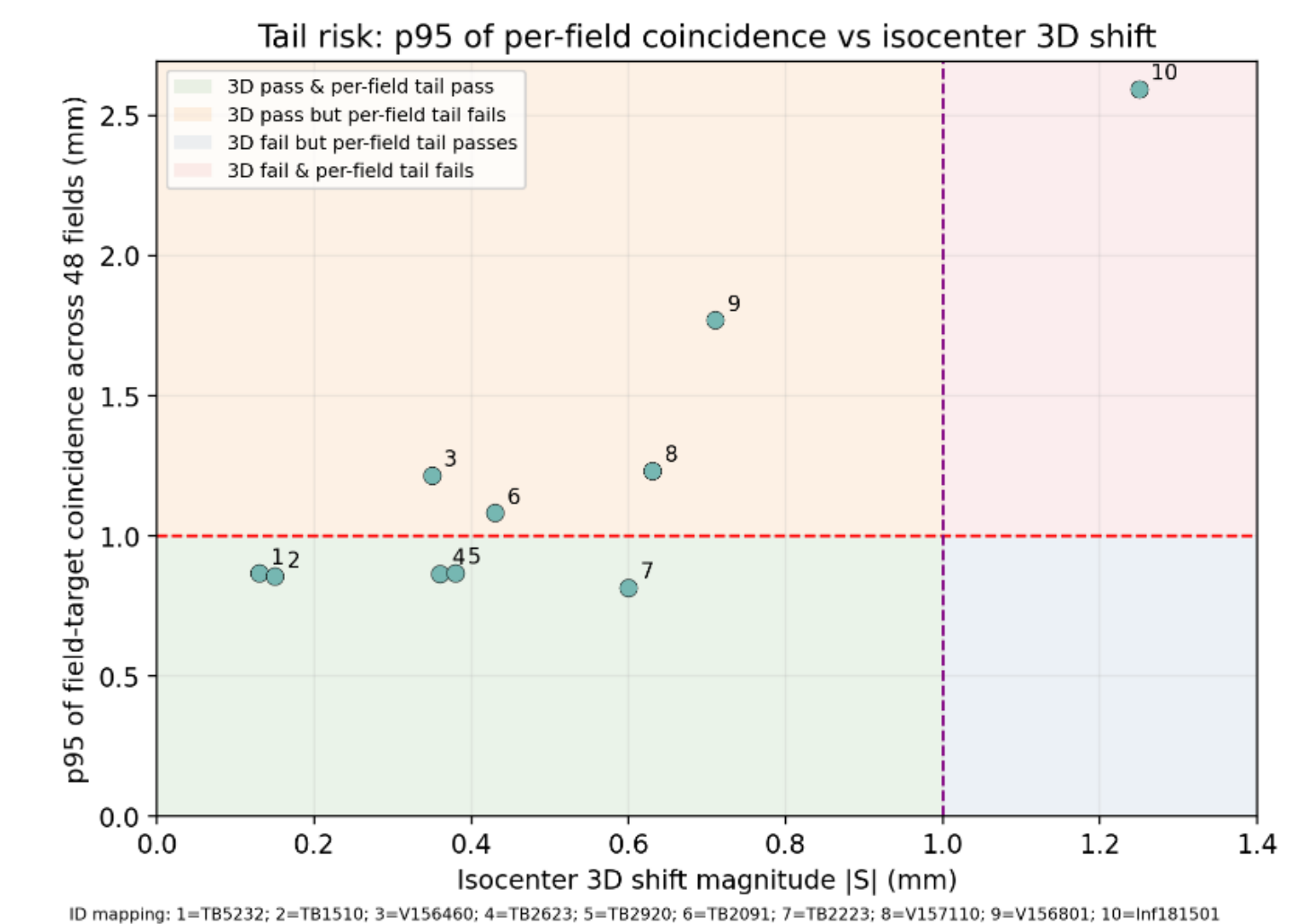
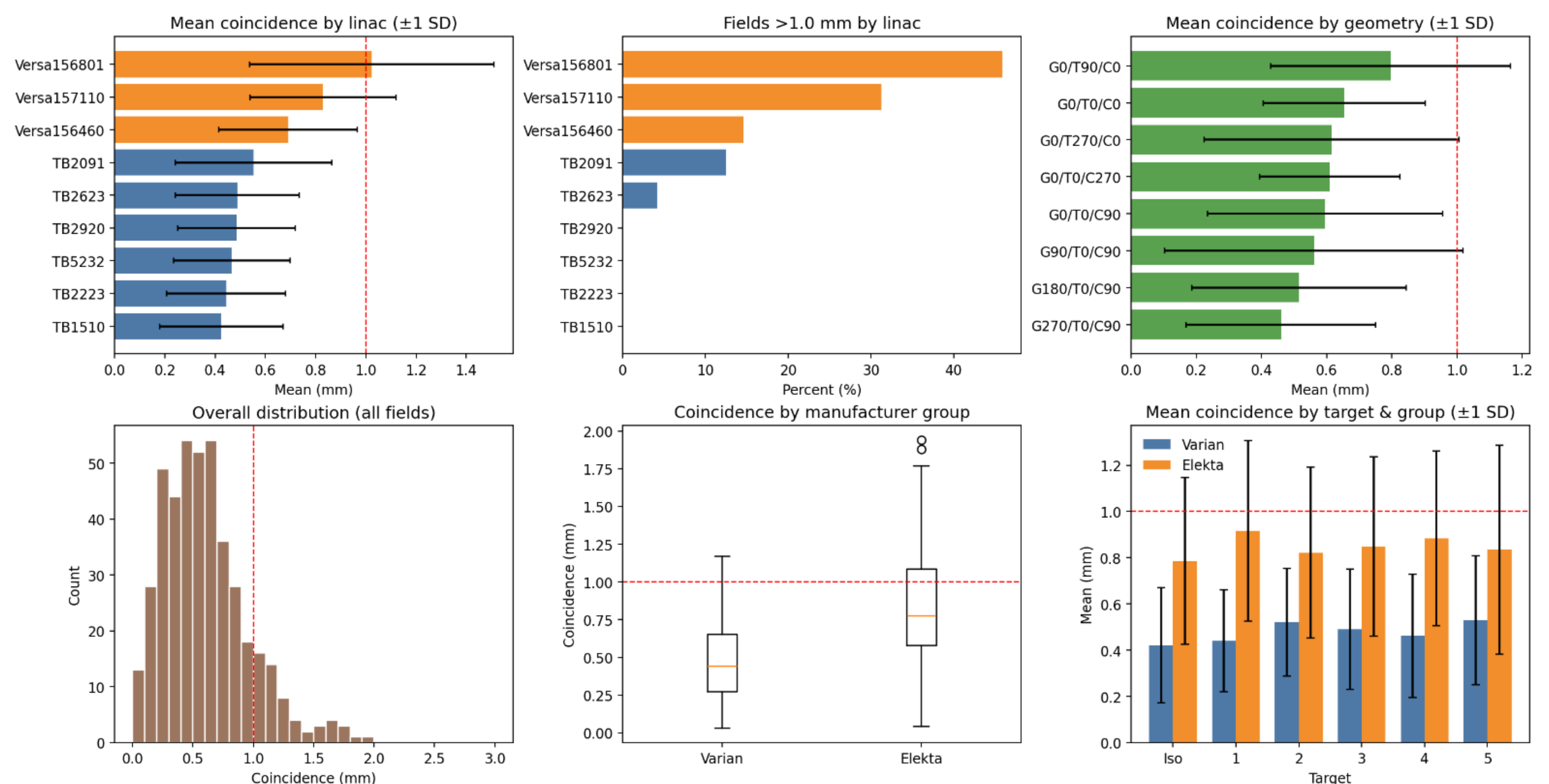


Figure 1. Scatter plot of the isocenter 3D displacement versus the 95th percentile of field-target coincidence across all 48 fields. Shaded regions indicate pass/fail combinations using 1.0-mm thresholds. Points in the upper-left quadrant illustrate cases where the 3D summary passes while clinically relevant per-field errors exceed tolerance.



CONCLUSIONS

Multi-WL testing enabled practical benchmarking of stereotactic targeting performance across multiple institutions and linac platforms. Couch-rotation geometries were associated with increased targeting error, and geometry-specific analysis revealed clinically relevant variation not captured by conventional 3D isocenter metrics alone. Reporting per-field and geometry-resolved results may support targeted investigations of mechanical performance and improve stereotactic QA.

CONTACT

Chester Ramsey
cramsey@covhlth.com
www.covenanthealth.com/our-services/cancer-care/covenant-health-proton-center/