Out-of-Field Photon and Neutron Dose Distributions in Breast Cancer Radiotherapy: Dosimetric Considerations

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Background
Conventional treatment planning systems (TPS) often fail to estimate out-of-field dose distributions accurately. The current investigation applies Monte Carlo (MC) simulations to evaluate photon and neutron dose distributions in breast cancer radiotherapy comprehensively. In addition, to quantify dose estimation reliability uncertainty maps are evaluated.

Methods
An Elekta Precise linear accelerator (LINAC) operating at low and high energy photons was simulated through the GATE MC code. To compare dose distribution variations, two anthropomorphic, Rando and XCAT phantoms, were used. Eight radiotherapy treatment plans were generated and validated. Dose Volume Histograms (DVH) for Organs At Risk (OARs) were extracted and compared for MC simulations and TPS calculations. Photon and neutron doses in out-of-field organs were further validated against thermoluminescent dosimeter (TLD) measurements. Dose uncertainty maps were generated and analyzed for a range of treatment conditions.

Results
Monte Carlo simulations demonstrated high agreement with experimental and TPS data for in-field regions, with gamma passing rates exceeding 90% for 3D gamma criteria (4 mm, 6% for Rando; 3 mm, 4% for XCAT). Out-of-field photon dose comparisons between MC and TLD measurements showed discrepancies below 10%. Neutron dose variations between MC and TLD measurements were attributed to the inability of TLDs to detect fast and epithermal neutrons. Uncertainty maps highlighted dose variations at field edges and out-of-field regions, emphasizing the impact of patient anatomy and treatment parameters on dose estimation accuracy.

Conclusion

Monte Carlo simulations provide a robust method for assessing out-of-field dose distributions, considering secondary cancer risk estimation. The uncertainty maps offer a more precise understanding of dose variability, underscoring the necessity of advanced dosimetric evaluations to improve radiotherapy planning and minimize unintended exposure.

Keywords: Radiotherapy, Out-of-Field Dosimetry, Monte Carlo Simulation, Photon and Neutron Dose, Breast Cancer, Secondary Cancer Risk, Uncertainty Analysis

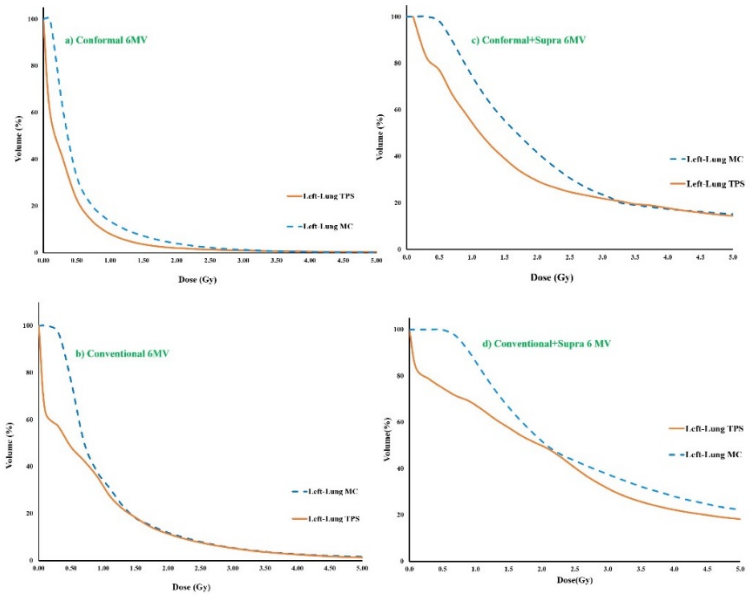

Figure 1. Dose Volume Histograms for conventional and Conformal breast radiotherapy with and without Supraclavicular fields

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