Impact of range uncertainties on robust mixed electron-photon beam radiation therapy

Veng Jean Heng [1] Marc-André Renaud [2] Monica Serban [3] Jan Seuntjens [3]

[1]Medical Physics Unit, McGill University, Montréal, QC, Canada [2]Gray Oncology Solutions, Montréal, QC, Canada
[3]Princess Margaret Cancer Centre, Radiation Medicine Program, University of Toronto, Toronto, ON, Canada

Introduction & Background

Mixed electron-photon beam radiation therapy (MBRT) is an emerging technique that combines both external electron and photon beams to leverage the dosimetric characteristics of each particle.

Due to their charged nature, electrons are more sensitive to changes in tissue density than photons. For this reason, it has been established that MBRT plans must be optimized robustly to setup errors. Dose distributions are calculated in artificially shifted positioning scenarios to allow the optimizer to account for dose degradation under setup errors.

Another source of uncertainty is the assignment of mass densities when converting CT images to a phantom. For charged particles, this translates to an uncertainty on the beam's range.

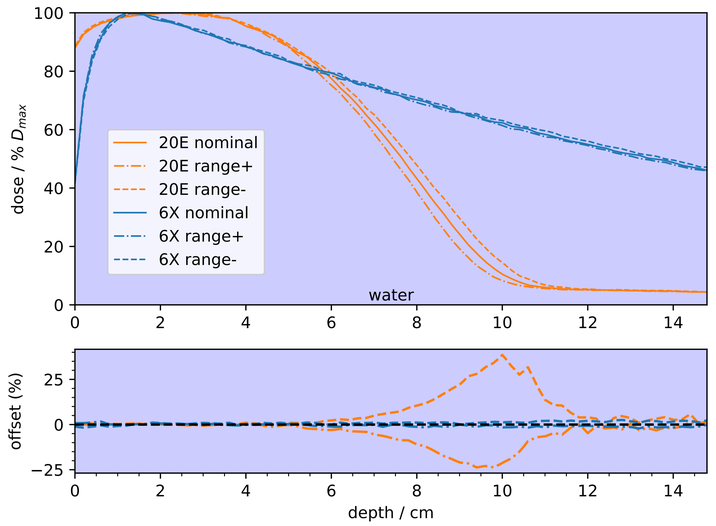
This study aims to investigate the impact of this range uncertainty in the context of MBRT.

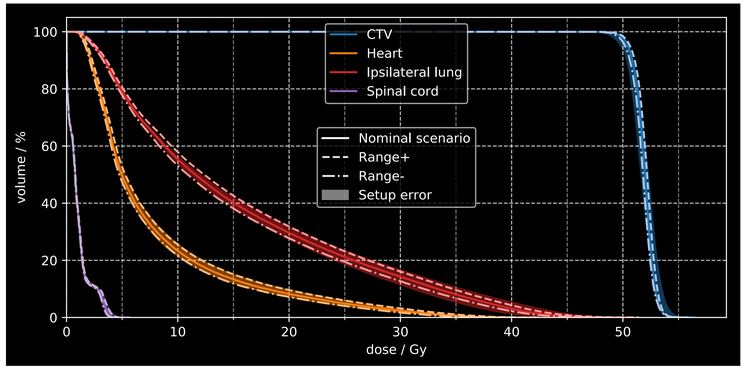
Methods

PDD curves for a 20 MeV electron and a 6 MV photon beams are calculcated in a homogeneous water phantoms. Two phantom copies are additionally generated with downscaled/upscaled mass densities by ±**3.5%** to mimic range uncertainties. The calculation is performed by Monte Carlo using EGSnrc to a type-A uncertainty of less than 0.5%.

2 MBRT plans were robustly optimized on chest wall patients to compare the dose deviations due to range vs. setup errors. To calculate range scenarios, phantoms were generated by upscaling/downscaling CT numbers by 3.5% prior to their conversion to mass density.

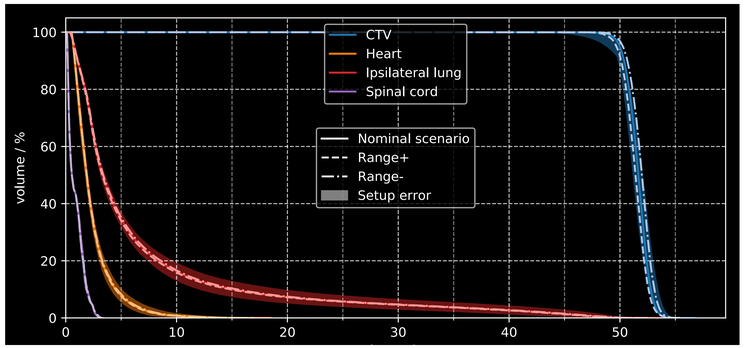
Results





Deviations from the nominal scenario of up to 38% are observed in the 20 MeV PDD. For the 6 MV beam, deviations remained within 2%.

The first MBRT plan (left) used a larger proportion of electrons: mean CTV electron dose of 37.3 Gy. For this plan, range scenarios had similar deviations as the worst setup scenarios. In the second plan (right), less electrons were used: mean CTV electron dose of 9.8 Gy. As such, the range scenarios had mostly negligible impact on the DVH.



Conclusions

Depending on the fraction of electron used in MBRT plans, range uncertainties can have dose degradations on similar order of magnitude as setup uncertainties. They should be accounted for when performing robust optimization of treatment plans.

Acknowledgements

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