Brainlab Novalis Circle
9th International Conference 2023

Prediction of Radiation Necrosis for Brain Metastases Treatment

Karen Manger[1,5] | Guillaume Landry[2] | Sylvia Garny[2] | Michael Reiner[2] | Jan Hofmaier[2] | Katia Parodi[2] | Claus Belka[2] | Oliver Hayden[3] | Raphael Bodensohn[4] | Maximilian Niyazi[4]

[1] Physics Department, Technical University Munich, Garching, Germany; [2] University Hospital, Ludwig-Maximilians-Universität München, Munich, Germany;
[3] Heinz-Nixdorf Chair of Biomedical Electronics, CIT, Technical University Munich, Munich, Germany; [4] University Hospital, Universitätsklinikum Tübingen, Tuebingen, Germany; [5] Brainlab AG, Munich, Germany

Purpose

Accurate dose distribution modeling and accounting for dose heterogeneity in Stereotactic Radiosurgery (SRS) is important for minimizing adverse effects and predicting symptomatic radionecrosis (RN) risk. However, limited evidence exists for RN risk prediction in multiple metastases (MM). While previous studies have correlated RN risk with V10 and V12, these metrics do not account for dose heterogeneity. Niyazi et al. demonstrated the correlation between Equivalent Uniform Dose (EUD) and RN risk, suggesting its incorporation into Normal Tissue Complication Probability (NTCP) modeling to improve RN risk prediction in SRS treatment planning [1]. Although initially limited to proton therapy, we aim to explore the applicability of the EUD-based NTCP proton model to SRS and develop a methodology for calculating EUD for MM. Applying the EUD-based NTCP proton model to our data sets aims to answer the question: "Can EUD predict RN for SRS of single lesions and brain metastases?"

Materials and Methods

Single Lesion (SL): 65 patients treated with LINAC-based single-fraction SRS for metastatic brain lesions were analyzed. EUD and NTCP were calculated for the healthy brain (HB) using EUD-based NTCP proton model parameters. RN probabilities were compared with the SL data set to investigate correlations between RN prediction and RN occurrence and to verify the proton model on the SL photon modality.

Multiple Metastases (MM): 127 patients with 525 metastases treated with LINAC-based single-fraction SRS for multiple brain metastases were analyzed. A new methodology was developed, using binary masks and distance transforms for voxel assignment of individual metastatic areas to calculate local and global EUD for MM. RN's local and global probability was calculated using the EUD-based NTCP proton model parameters.

Results

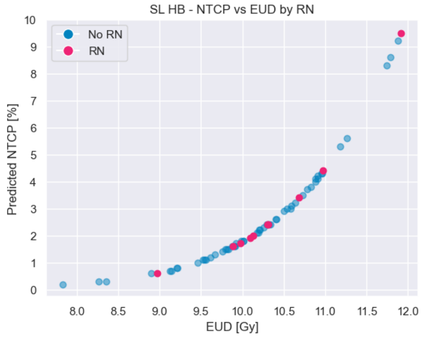
SL: HB EUD and NTCP calculations of SL resulted in a mean EUD of 10.17 Gy. 15.4% of all patients had RN. Graphical result visualization in Figure 1a showed increased NTCP with increasing EUD values.

MM: The MM methodology allowed calculating EUD, NTCP, V10/V12, minimum and maximum dose for individual metastatic areas, and HB. 16 of 127 patients (12.6%) showed RN. Global HB risk showed NTCP values of 0-9% and a mean EUD of 10.13 Gy. Individual local metastatic risk showed NTCP values from 1% to 55% and a mean EUD of 11.03 Gy. An increase in NTCP showed increased V10/V12 volume for global HB and local metastatic risk.

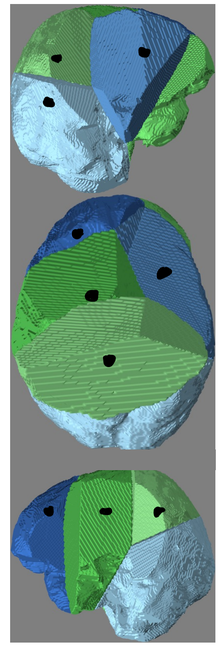
Figure 1: EUD and NTCP analysis for SL and MM.

a) Patients' SL HB EUDs versus corresponding NTCPs; b) Methodological HB separation into local areas around metastases; c) Patients' MM HB and MM single metastasis EUDs versus corresponding NTCPs.

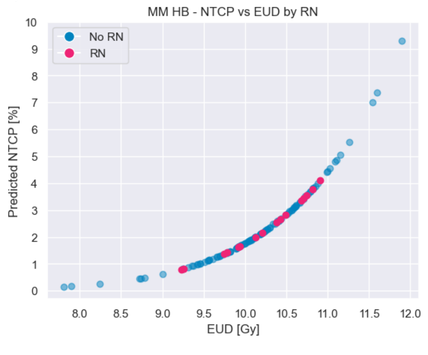
a)

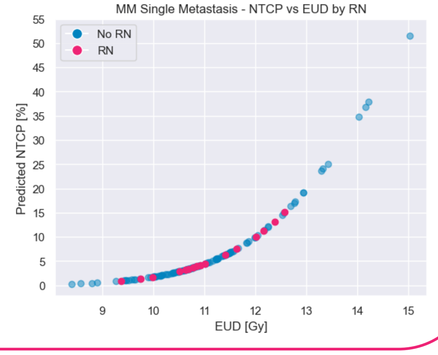


b)



c)





Conclusion and Outlook

SL: The EUD-based NTCP model parameters showed limited correlations in the data set, with no alignment with RN cases. The correlation with RN and the statistical significance of the model parameters will be further investigated by collecting additional SL data to increase the data size.

MM: Successful implementation of a new methodology to calculate EUD and NTCP for MM, considering HB and individual metastases, allowing EUD use for biological modeling of custom data sets. Further correlation analysis of MM results and EUD/NTCP parameters will be performed. In addition, preliminary statistical results show signs of a Dmax-dependent RN risk.

References

[1] M.Niyazi, A. Niemierko, H. Paganetti, et al., Volumetric and actuarial analysis of brain necrosis in proton therapy using a novel mixture cure model, Radiotherapy and Oncology, https://doi.org/10.1016/j.radonc.2019.09.008