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Abstract

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Spinal Cord Dose Tolerance for Reirradiation

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Jimm Grimm [1], Olusola Obayomi-Davies [2], Michael LeCompte [3], Kristin J. Redmond [4], James Welsh [5], Mark McLaughlin [1], Lawrence R. Kleinberg [3], Dwight E. Heron [6]

1. Radiation Oncology, Wellstar Health System, Marietta, USA 2. Radiation Oncology, Wellstar Kennestone Hospital, Marietta, USA 3. Radiation Oncology, Johns Hopkins University School of Medicine, Baltimore, USA 4. Radiation Oncology and Molecular Radiation Sciences, Johns Hopkins University School of Medicine, Baltimore, USA 5. Radiation Oncology, Hines VA, Chicago, USA 6. Radiation Oncology, Bon Secours Mercy Health, Youngstown, USA

Corresponding author: Jimm Grimm, jimmgrimmjr@yahoo.com

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Abstract

Purpose
Repeat irradiation of spinal metastases with radiosurgery in 1-5 fractions is increasingly used after prior radiation but the dose-time recovery factors remain uncertain. To address these uncertainties, a preliminary cumulative normal tissue complication probability (NTCP) model was developed based on existing published data, incorporating the essential recovery factors.

Methodology
A simple raised exponential function is used to model dose-time recovery for reirradiation with two parameters: the MaximumRecovery, accounting for the residual dose effect that may not fully recover, and the RecoveryHalftime, which is the time required to reach 50% recovery.

A PubMed search using the terms (myelopathy OR neuropathy) AND (reirradiation OR re-irradiation) in October 2024 identified 306 evaluable cases of spine stereotactic body radiation therapy (SBRT) reirradiation from 13 studies. All initial and reirradiation spinal cord maximum point doses were converted to biological effective dose (BED) using the linear quadratic (LQ) model with an alpha/beta of 2 Gy. Prior doses were then multiplied by the recovery time discount factor. Maximum likelihood parameter fitting was used to estimate the optimal MaximumRecovery, RecoveryHalftime, and the logistic model's 50% risk Tolerance Dose (TD50) and slope parameter.

Results
The maximally likely RecoveryHalftime for this dataset was estimated to be less than 2 years, to reach 50% recovery. Since the percent recovery continued to increase beyond two years, modeling of long-term data suggests that MaximumRecovery is 80% of the original treatment BED asymptotically at the longest time intervals. However, due to the limited availability of data, these parameters were conservatively set to 2 years and 80%, respectively, for subsequent analyses. Therefore, the RecoveryHalftime shorter than 2 years or an MaximumRecovery exceeding 80% was not used until further high-quality data becomes available for validation. As a clinical example, including the dose-time recovery factor for a spine SBRT reirradiation 2 years after the initial course, the model estimates risk of myelopathy of 1-2% for cumulative spinal cord maximum point dose BED up to about 100 Gy. Similar models for other fractionations were also attempted but we have only observed this rapid rate of recovery for SBRT. Other fractionations with larger volumes of spinal cord exposure will require additional investigation to predict risk.

Conclusions
Preliminary evaluation of published data provides a conservative estimate of RecoveryHalftime and MaximumRecovery dose-time parameters of radiation tolerance for spinal cord reirradiation. Many caveats and limitations will be discussed, along with a roadmap of future work including reporting standards to better estimate risk in a broader group of scenarios.