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Dosimetric Analysis of Lymphopenia After Lung Cancer Proton Irradiation and Modeling the Probability of Normal Tissue Complications

Mengyao Li[*,2], Shuting Wang[1], Weijie Li[2], Xiaoying Fan[2], Yin Yong[2], Tianyuan Dai[2]

[*, 1] Department of Graduate, Shandong First Medical University, China, [2] Department of Radiation Oncology Physics and Technology, Shandong Cancer Hospital and Institute, China

Objectives

Decreased lymphocytes increase the risk of infections and other problems. Radiation exposure can cause the development of severe lymphopenia. In this study, we used a dynamic blood flow model to simulate the irradiation process to obtain the circulating blood dose under proton therapy, to determine the relationship between the occurrence of SRIL and blood dose, and to establish a normal tissue complication probability (NTCP) model.

Methods

We retrospectively analyzed data from 39 lung cancer patients, recording their absolute lymphocyte counts before, during, and after treatment. SRIL was diagnosed when an event occurred during the course of treatment with an absolute lymphocyte count (ALC) < 500 μL. The histogram of circulating blood dose was simulated using a time-dependent calculation framework called hematological dose. Statistical analysis was performed using SPSS 27 software. NTCP modeling in response to blood dose was performed using the Lyman-Kutcher-Burman model of generalized equivalent dose.

Results

Patients developed varying degrees of lymphopenia during treatment. There were no statistically significant differences between the groups with/without SRIL in terms of gender, age, fractionated prescription dose, pretreatment ALC level, tumor stage, chemotherapy regimen, or treatment modality. Patients' mean ALC decreased consistently during treatment (rate, -0.047 per day) (Figure 1(a)). The median mean blood dose for all patients was 2.842 Gy (RBE) (range, 1.408-3.720 Gy (RBE)). Patients experiencing SRIL received significantly higher mean blood doses ($p<0.006$) (Figure 1(b)). The Dn% for SRIL had correlations. Of these, D80% had the strongest correlation with SRIL (UVA, ratio = 4.982, $p < .011$). NTCP modeling of lymphopenia after lung irradiation using circulating blood doses. When applying the developed NTCP model to predict SRIL, the area under the receiver operating characteristic curve and Brier score values were 0.77 and 0.18, respectively (Figure 2).

Conclusions

Circulating blood dose is associated with ALC depletion in radiation therapy. The NTCP model established in this study regarding SRIL provides a reference for optimizing the radiation dose for subsequent treatment planning, which is beneficial for the maintenance of the patient's immune system.

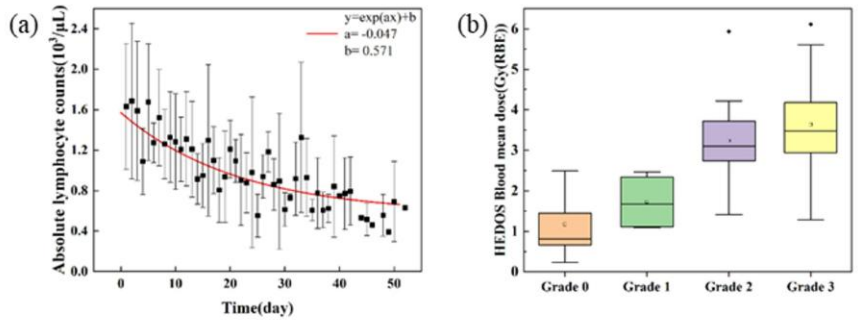

Figure 1 (a) Plot of exponential change in ALC over the course of treatment as a function of the number of days of treatment. (b)Box plots of mean circulating blood dose corresponding to each RIL classification

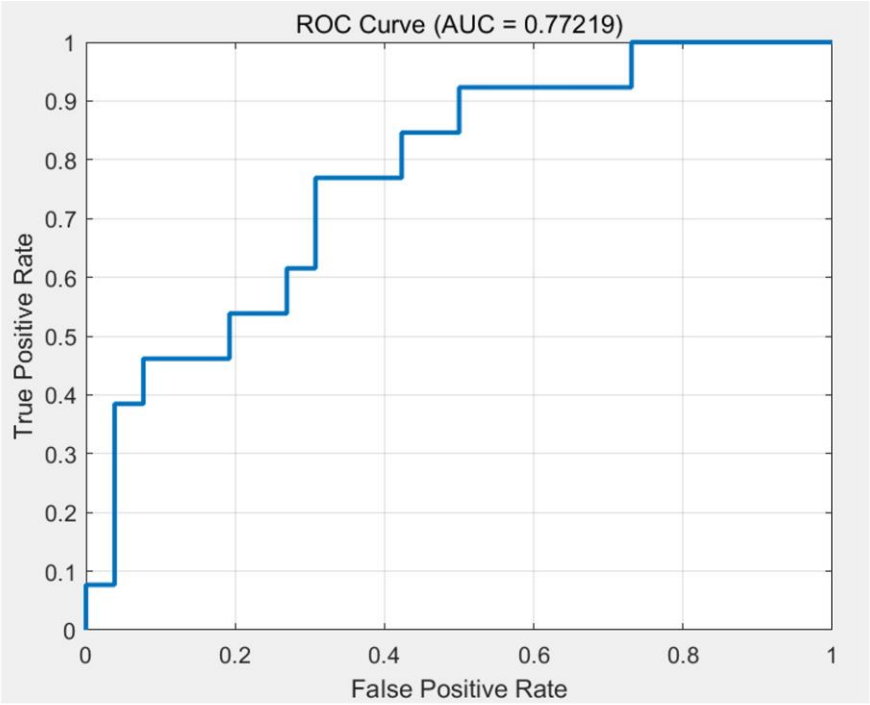

Figure 2 Receiver operating characteristic curve with the area under curve (AUC) values for normal tissue complication probability models.