Purpose: Small-volume biologically effective (BED) dose limits are critical to safe spinal stereotactic body radiotherapy (SBRT) delivery. However, due to mismatch in spatial location of dose hot spots from non-uniform dose distributions inherent to SBRT, for repeat treatment courses they cannot be simply added by assuming a uniform dose distribution. This study aims to develop a probability-based biological equivalent dose formula to solve this problem.

Methods: A generalized biological equivalent dose (gBED) was formulated via computing damaging or survival probability of repeat spine SBRT treatments. Parameters from the linear-quadratic model such as a/β = 2 Gy for the spinal cord were applied for the gBED calculations. The derived method was applied to both simulated and clinical treatment cases to demonstrate its applicability and usefulness for assessing spinal cord dose limits for repeated SBRT treatment courses.

Results: The gBED formula allows direct superposition of dose within a small volume of spinal cord from a non-uniform dose distribution of varying dose fractionation schemes of SBRT. From the studied examples, traditional BED calculations even with full voxel-by-voxel tracking calculations resulted in inconsistent BED values and can underestimate the biological dose to a small-volume spinal cord by as much as 20%. Such an error tends to increase rapidly with increasing volume of interests such as from 0.1 mL to 2.0 mL.

Conclusions: When assessing spinal cord tolerance for repeat spinal SBRT treatments, consistent surrogates such as gBED are needed to avoid potential underestimation of treatment-induced complications.