Continuous Time Markov Chain to Progression of Pediatric Low-Grade Glioma Cancer

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1. Abstract

Pediatric Low-Grade Glioma (PLGG) is the most common central nervous system tumor in children, characterized by a heterogeneous and often chronic disease course. While overall survival is favorable, a significant subset of patients requires multiple treatments, leading to substantial long-term morbidity. Traditional survival analysis fails to capture the full complexity of this multi-stage journey. This research presents a comprehensive Continuous-Time Markov Chain (CTMC) framework, built upon a large clinical cohort from the German SIOP-LGG 2004 study (Goebel et al., 2019). We define a 7-state CTMC, representing distinct clinical intervention states from diagnosis to death and use an optimization procedure to find the generator matrix Q that best fits the observed state probabilities at 5 years after diagnosis probabilities. Leveraging this fitted model, we compute critical prognostic metrics, including expected sojourn times and time to absorption (death), using three distinct methods: direct matrix inversion, convolution of exponential distributions, and phase-type distribution theory. Our analysis includes a comparative visualization of the mean time to death for patients starting in different states, providing stark, quantitative evidence of how initial disease progression impacts long-term survival. This CTMC model offers a dynamic, refined, and personalized tool for prognosis, enabling the identification of high-risk patient groups and furnishing a robust, quantitative foundation for clinical decision-making and patient counseling.