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Mathematical modeling of innate immune response dynamics in early-stage inflammation

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Innate immune cells respond to infections by triggering an acute inflammatory reaction that restores tissue homeostasis and promotes subsequent repair. Their activation must be tightly regulated to prevent tissue damage, organ dysfunction, or even death. This study presents a new set of mathematical models to analyze the dynamics of the innate immune response to tissue damage and to improve our understanding of its role in early-stage inflammation. Various damaged cell production functions are introduced to account for secondary tissue damage caused by the immune system. Stability and bifurcation analysis reveal a critical threshold parameter that can be regulated to prevent chronic inflammation and ensure successful healing. Numerical simulations further support the theoretical findings and highlight the medical relevance of the proposed model.