Fluxion_DDS: A Targeted Aspirin Delivery System Using Chitosan-Coated Magnetite Nanoparticles under Magnetic and Electric Field Control with a Model of Nanoparticle Behavior in Pulsatile Blood Flow for Thrombosis Treatment

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Abstract

Thrombotic disorders are a major contributing factor to stroke and cardiovascular diseases, which remain among the leading causes of mortality worldwide. Conventional pharmacological therapies are limited by their inability to achieve precise drug delivery while minimizing adverse effects on healthy tissues. Therefore, this study investigated the effect of chitosan concentration (0, 0.125, 0.250, 0.375, and 0.500 mg/mL) onthe stability of aspirin-loaded magnetite nanoparticles synthesized via co-precipitation, as well as the relationships between nanoparticle linear velocity and the applied magnetic field and between aspirin release rate and the applied electric field. ATR-FTIR analysis confirmed the interaction of magnetite nanoparticles with chitosan and aspirin. Nanoparticles coated with 0.250 mg/mL chitosan exhibited the greatest stability ($p < 0.001$), with an average particle diameter of 86.7 ± 14.9 nm, a polydispersity index (PDI) of 0.470, a zeta potential of 39.8 ± 1.4 mV, and the highest aspirin loading capacity of 39.8 ± 0.6 mg/mL. Nanoparticle transport under an applied magnetic field was consistent with the Magnetophoresis model ($R^2 = 0.9251$, $p < 0.001$). Likewise, aspirin release under an applied electric field was consistent with the Nernst–Planck model ($R^2 = 0.9768$, $p < 0.001$). These findings demonstrate that the developed aspirin delivery system, together with a physics-based molecular dynamics model implemented in LAMMPS to predict nanoparticle behavior under pulsatile blood flow in PBS-based simulated physiological conditions, supports the development of targeted aspirin delivery systems for thrombosis treatment. Nevertheless, further validation under physiological conditions is required before practical application.

Keywords: Magnetite nanoparticles, Chitosan, Aspirin delivery system, Pulsatile blood flow, Thrombosis