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DYNAMICS OF NANO PARTICLES IN PATIENT SPECIFIC BLOOD VESSELS

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ABSTRACT

In the treatment and imaging of diseases, as such cancer and cardiovascular, nano-sized delivery vehicles (particulate system) are emerging as powerful tools [1]. These are made up of a central core, carrying drug molecules or imaging contrast agents, and an external coating with precise physicochemical properties, and are injected within the blood stream at the systemic level. The great advantage of particulate systems over freely administered molecules is their "engineerability:" their size, shape and surface properties can be optimized to increase the probability of reaching the desired biological target [2,3]. An "optimally" designed particulate system should be able to navigate into the circulatory system, recognize preferentially the target vasculature and there adhere firmly to the vessel walls resisting to the hydrodynamic dislodging forces or, if sufficiently small, leave spontaneously the vasculature and diffuse into the extravascular space. The dynamics of a particulate system within the blood vessels, however, is not only influenced by its intrinsic properties (size, shape and surface properties) but it is also dramatically affected by (i) the hydrodynamic conditions at the site of adhesion or extravasation, (ii) the authentic structure and (iii) physiological properties of the vasculature and (iv) the rheology of blood. Notably, the points (i)-(iv) are disease specific, patient specific and would change over time as the disease progresses.

Recently, the Isogeometric Analysis concept has been extended to simulate fluid-structure interaction problems with biomedical applications [4,5]. Isogeometric analysis encompasses and generalizes the finite element method, simplifying mesh refinement and improving the functional representation of the geometry and the solution [6]. The increased geometrical flexibility obtained with isogeometric methodology, as well as the smoothness of the geometrical description, allows for the accurate representation of patient-specific vascular geometries with fewer degrees of freedom. An efficient parallel-solution strategy has been implemented and thoroughly tested in the Texas

Advanced Computing Center (TACC) high-performance computing systems. This efficiency, combined with the robustness and accuracy of the numerical procedures, permits the inclusion of several non-linear physical phenomena in a single simulation framework. This combination has allowed more realistic simulation of relevant biomedical problems, such as drug delivery [4], the analysis of flow patterns in cerebral and abdominal aneurysms and the growth-and-remodeling process by which healthy arterial-wall tissue degenerates into an aneurysm.

The aim of this work is to develop within the Isogeometric Analysis concept, a numerical framework to analyze (i) the distribution of particulate systems, treated as diffusing/advecting scalars, within authentically complex (patient specific) vascular systems; and (ii) their adhesive interaction with the walls of the vessels. The effect of the permeability of the vessels to both the particulate systems and the plasma will be addressed as well as the contribution of the non-Newtonian properties of blood.

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