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GRAVITATIONAL EFFECTS ON RENAL CALCULI SIZE DISTRIBUTIONS IN THE NEPHRON

Abstract

Renal stone disease is not only a concern on earth but can conceivably pose as a serious risk to the astronauts' health and safety in Space. In this work, a Population Balance Equation (PBE) model of the nephron is developed to assess the risks of renal stone development for astronauts during space travel. The model treats the nephron as a continuous crystallizer and includes the effects of nucleation, growth and agglomeration on the renal stone size distributions developed in 1g and microgravity. Furthermore, the PBE model is coupled to a Computational Fluid Dynamics model for flow of urine and transport of Calcium and Oxalate in the nephron. Simulations using the coupled PBE-CFD model are used to parametrically isolate the effects of growth and agglomeration and to predict the impact of gravity on the stone size distributions. Results presented for realistic 3D tubule geometry clearly indicate that agglomeration is the primary mode of size enhancement in both 1g and microgravity. Preliminary 3D numerical simulations seem to further indicate that there will be an increased number of smaller stones developed in microgravity that will likely pass through the nephron in the absence of wall adhesion. However, upon reentry to a gravitational field the renal calculi can lag behind the urinary flow in tubules that are adversely oriented with respect to the gravitational field and grow/agglomerate to near critical sizes. This is an important consideration for future planetary explorations envisioned by NASA where, for example, in a Mars mission, transition from long-duration microgravity during the travel to 3/8g after landing could have serious renal stone implications for the astronauts.