Fluid Flow In The Human Small Intestine

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Abstract

Digestion is the process of breaking down food into smaller components, by mechanical and enzymatic action in the digestive tract, so that the smaller nutrient molecules can be more easily absorbed in the intestinal tract. Understanding the human digestive process could be useful for the food and health sectors in predicting the bio-availability of nutrients and pharmaceuticals. To study and analyze the human digestive process three different methodologies have been used in the past, namely in vivo feeding methods using human volunteers, in vitro gastrointestinal models, and advanced computational software. Though in vivo feeding studies provide accurate results, they are time-consuming and expensive. In the case of in vitro digestive studies, compromise is needed between the accuracy of the results and resources involved in developing/operating the in vitro model. The possibility of numerically analyzing the dynamics of food in the human gastrointestinal tract can enhance the understanding of the human digestive process.

The small intestine is the main site for digestion and nutrient absorption in the digestive tract. The objective of this study is to develop a fluid flow numerical model mimicking small intestinal geometry and motility. The small intestine is ~5 m long with an internal diameter of ~1.7 cm. The intestinal motility can be either peristalsis or segmentation. Peristalsis is progressive wavelike contractions that are responsible for the transport of intestinal content. Segmentation movement causes a forward and backward movement within a single region and is responsible for the mechanical breakdown of food particles and mixing of food and digestive enzymes. The flow field induced by peristaltic waves and segmentation waves is being analyzed in this study. COMSOL® Multiphysics (Version 5.2a) is being used to perform the numerical simulation. A two-dimensional axisymmetric model of a small section of small intestine (diameter: 1.73 cm and length: 10 cm) was developed to simulate the fluid flow using the Laminar Flow physics and the Moving Mesh physics. Based on the gut motility parameters obtained from the literature, the motility wave condition was imposed on the walls of the geometry. The preliminary result of velocity profile induced by a peristaltic wave and segmentation waves in a section of small intestine is shown in Figure 1. In the figure, the colors represent velocity levels, blue being the lowest and red being the highest. Using Particle Tracing for Fluid Flow physics the flow direction was observed. In the case of the peristaltic wave, the fluid flow was observed in the direction of the wave and in the case of segmentation waves, forward and backward flow was observed.

In future, this numerical model will be improved by simulating the entire geometry of the small intestine with multiple waves. The Transport of Diluted Species physics would be incorporated into this model to predict the digestion of food and nutrient diffusion through the walls. Numerically predicted results would be experimentally validated with in vitro studies that were carried out separately and then improved for accurate prediction of the human digestive process.

Figures used in the abstract

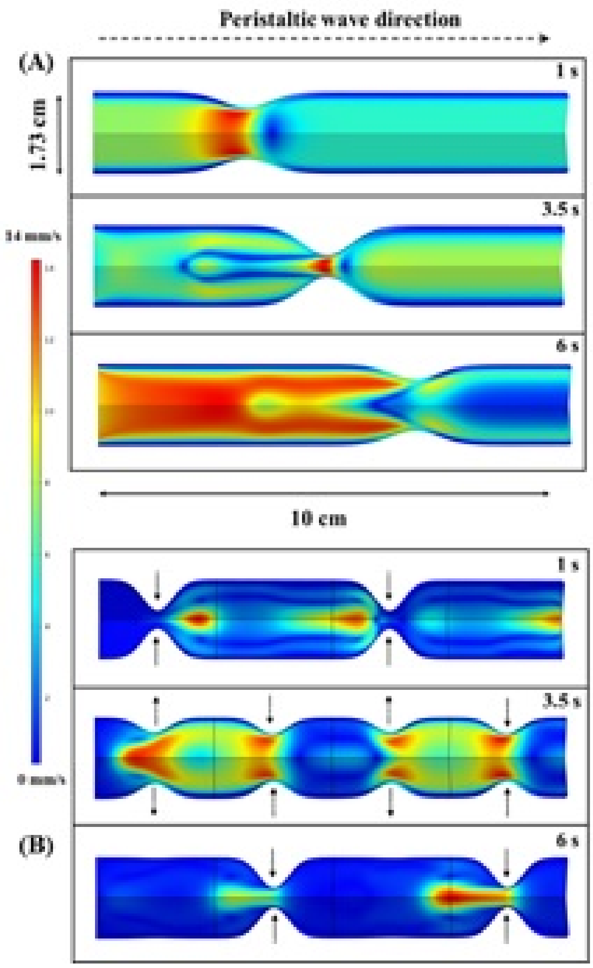

Figure 1 : Velocity profile induced by (A) A peristaltic wave and (B) Segmentation waves