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CHALLENGES AND ADVANCES IN MODELING GASTROINTESTINAL TRACT MOTILITY AND TRANSPORT PHENOMENA

Clément de Loubens

Univ. Grenoble Alpes, CNRS, Grenoble INP, LRP, 38000 Grenoble, France

Background

The gastrointestinal (GI) tract encompasses several biological, chemical, and physical phenomena crucial for the absorption of nutrients from our food. There is a burgeoning interest in unravelling the intricate connections between GI tract motility and transport phenomena, as several critical processes depend on them: the spatiotemporal organization of the microbiota, the response of the immune system, the breakdown of food or the delivery of drugs.

The aim of this talk is to provide fresh insight into the modelling of biomechanical phenomena that govern transport and mass transfers in the GI tract.

Recent Advances

The recent development of high-resolution mapping of the active intestine under ex-vivo conditions [1] made it possible to develop computational fluid dynamics (CFD) models that incorporate the spatio-temporal coordination of circular and longitudinal smooth muscles under various mechanical stimuli. These models [2,3] reveal the relative role of coordinated or uncoordinated circular and/or longitudinal contractions on mixing near the mucosa and in the lumen of the small intestine, Fig. 1a.

High-resolution motility mapping techniques are also beginning to quantify the motility of the villi of the small intestine, the finger-like structures that line the mucosa [4]. These advances stimulate the development of CFD models [5,6] showing that villi motility plays a major role in mixing at short- and long-time scales, Fig 1, c & d.

In addition, the complex rheology of digesta is also incorporated into the models. Interestingly, the CFD models show phase segregation for semi-diluted suspensions in the small intestine [7], as well as a strong interaction between muscle motility and emptying rate during defecation of soft faeces [8].

Future directions

While certain insights have immediate applications in clinical practices [8], the primary challenges lie in enhancing our understanding and modeling of the relationships between muscle motility and the passive folding of the mucosa to integrate motility at both micro- and macro-scales. Additionally, efforts are underway to develop experimental methods for quantifying mixing phenomena within the lumen at both macro- and micro-scales [9].

Clément de Loubens is a CNRS researcher based at the University of Grenoble Alpes. He earned his Ph.D. in the modeling of biomechanical phenomena governing stimuli release during chewing and swallowing (2007-2011). Then, he conducted a post-doc (2011-2013) on intestinal motility and flow in the group of Prof. Lentle at Massey University (New Zealand). At Aix-Marseille Université (2013-2016), he investigated the dynamics of biomimetic soft particles in flow. Joining CNRS in 2016, his research focus on the rheology and modelling of biological systems, with a particular emphasis on the digestive tract. He is leading an interdisciplinary research project funded by ANR on the multi-scale modelling of transport in the gastrointestinal tract. He is an author of 32 publications in peer-reviewed journals

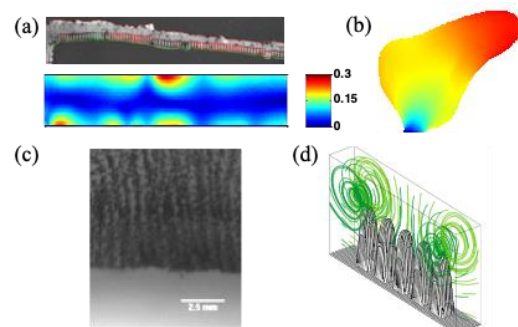


Figure 1: (a) Motility mapping of the small intestine and shear rate distribution in the lumen [2], (b) Pressure field during rectal emptying of a neostool [7], (c) Villi organization (black lines) that resulted from folding of the mucosa [4], (d) CFD model of mixing induced by villi motility [5].

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