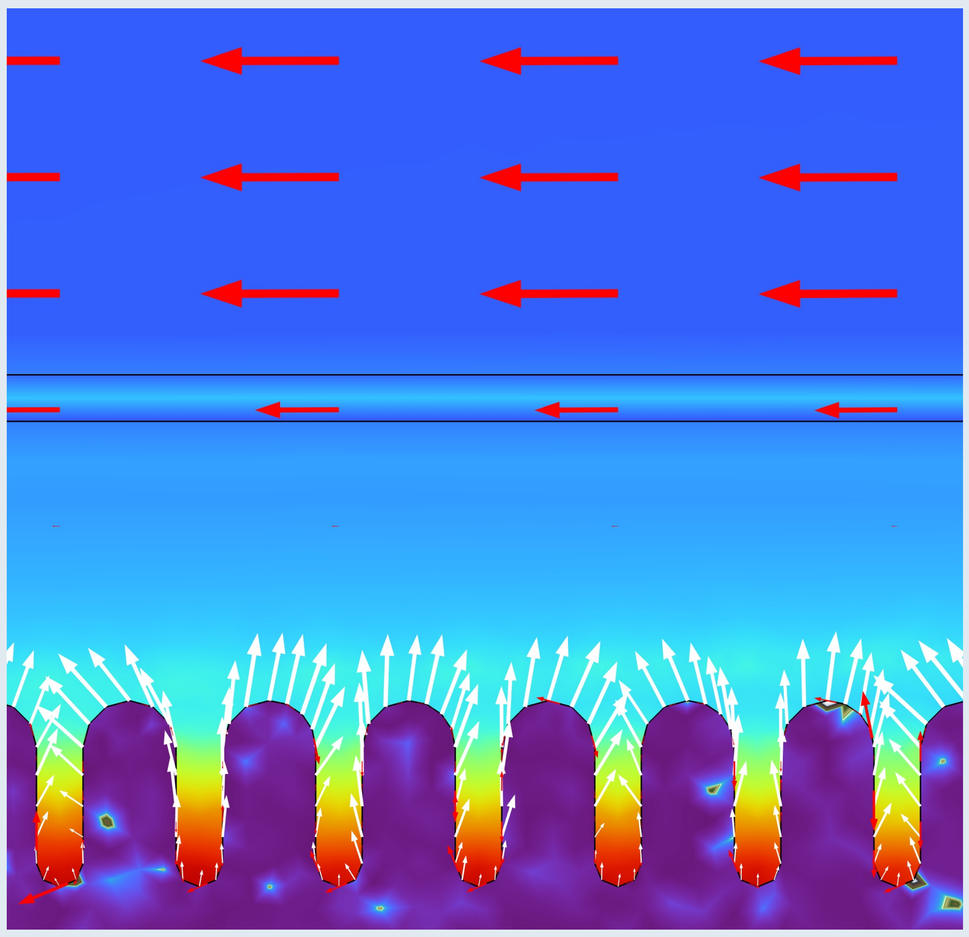

A Multifaceted Model Exploring the Role of Mucus and Shear Stress in Intestine

All cells generate and respond to mechanical forces. It is becoming more evident that, mechanical forces play a role in physiology. This work investigates how healthy and diseased intestinal mucus may change the mechanics of the tissue.

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Abstract

The goblet cells throughout the intestine secrete the intestinal mucus as a dynamic barrier. One of the important functions of the mucus is to protect the tissue from mechanical forces during the motility. Under low shear conditions, the mucus retains its solid-like properties, acting as a physical barrier, while under high shear forces, it transitions into a more fluidic state, allowing the passage of food or peristaltic movements without structural breakdown[1].

Current models lack a detailed understanding of how mucus rheology and shear stress interact with epithelium, particularly in pathological states. We developed a computational model to predict the shear transfer to the epithelium in healthy and inflamed intestinal states. Our findings suggest that the damaged mucus layer may increase the shear stress and disrupt the motility.

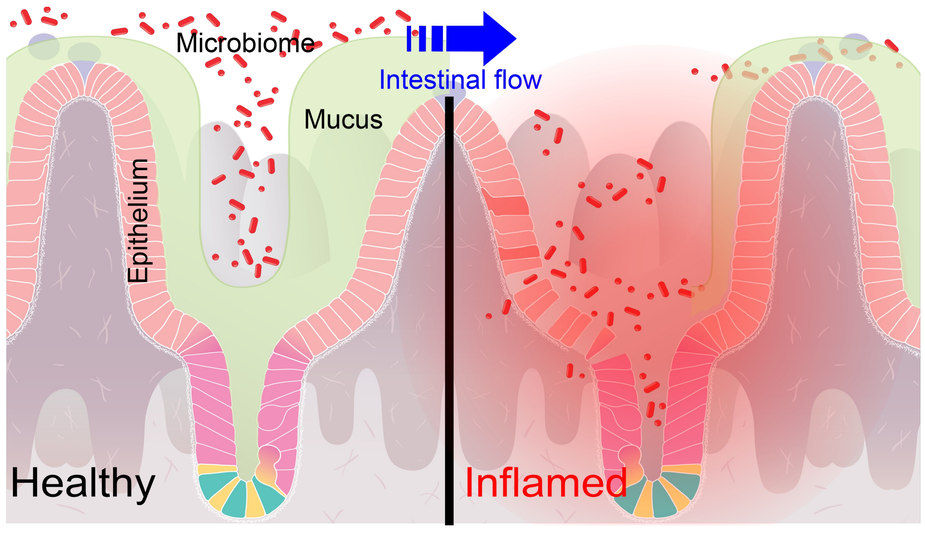

FIGURE 1. Intestinal epithelium in healthy and inflamed conditions

Methodology

Using histological human samples, a 2D ternary-phase field model (feces, mucus bilayer) was constructed for a section of the intestine (5x3 cm). Material properties of mucus and feces were adapted from rheological studies[2]. Mucus thickness was varied in the healthy model from 100 – 800 µm and mucus was absent in the inflamed model.

Fecal flow was achieved by incorporating a pressure wave using clinical pressure values. Fluid-structure interaction coupling was used to study the force transmission to the epithelium.

Results

The pressure wave guiding the fecal flow showed similarity to clinical pressure wave measurements. The flow velocity in mucosal models was significantly higher than in the inflamed model, which impacted the cumulative fecal output.

The resulting shear profile indicated a spatiotemporal variation and significant differences in shear magnitude between healthy and inflamed models. These differences were conserved in physiologically relevant sites of the epithelium and may take a role in tissue function.

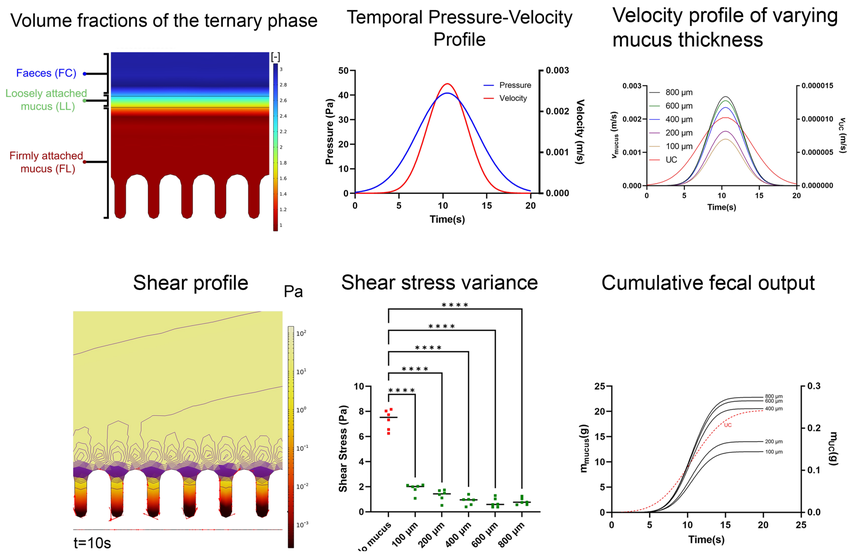

FIGURE 2. The shear stress varies along the epithelium and mucus regulates the magnitude

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