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BIOMECHANICS OF THE BOLUS PROPULSION IN THE COLON

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ABSTRACT

The mathematical model of a segment of the human colon based on real anatomical and electrophysiological data has been used to investigate the effect of the viscous and dry friction on the dynamics of propulsion of the bolus. The results of simulations of movement patterns resembled those recorded experimentally and provided quantitative insights into the spatio-temporal patterns of changes in configuration, the distribution of contact forces over the bolus, and also predicted the average velocity of colonic transit. Thus a reciprocal relationship in the contraction of the longitudinal and circular smooth muscle was necessary to guarantee the "mixing" type of movements. Strong conjoint contractions of both muscle layers were necessary to expel the pellet from the gut. In cases of increase/decrease in the viscous and dry friction diabetes, there are significant changes in colonic transit.

Keywords: a segment of the human colon, thin shell, viscous and dry friction, bolus, propulsion.

INTRODUCTION

The primary functions of the large intestine (colon) are to store, process and expel fecal mass residues. These require sustained contractile activity in the organ. Patterns of contractions produced by the colon are associated with non-propagating and high amplitude propagating mass movements. The disparity between mechanical and propulsive activities caused by anatomical and/or neuropathological changes in the organ result either in constipation, obstructed defecation or diarrhea. The severity and the diversity of the clinical symptoms, relative inaccessibility and the complexities posed by the presence of solid or semi-solid fecal masses, make it difficult to formulate hypotheses of underlying pathophysiological mechanisms and thus design effective treatments.

The aim of this study is to investigate numerically the propulsion of the intraluminal content (bolus), to assess the dynamics of stress-strain distribution and changes in the shape and configuration of the colon and to analyze the effect of the viscous and dry friction on bolus propulsion.

RESULTS AND CONCLUSION

The mathematical model of a segment of the gut with an enclosed bolus was used to run simulations [1]. The colon was represented as a thin deformable soft biological shell with the bolus modelled as a non-deformable solid sphere. The bolus in motion was subjected to dry and viscous friction, and the inertia forces were neglected. Propagating electromechanical waves triggered contractions and the movement of the sphere.

The results of simulated movement patterns resembled those recorded experimentally. These provided quantitative insights into the space-temporal patterns of changes in configuration and the distribution of contact forces over the bolus. The average velocity of colonic transit was also predicted. A reciprocal relationship in the contraction of the longitudinal and circular smooth muscle was necessary to guarantee the "mixing" type of movements. Strong conjoint contractions of both muscle layers were necessary to expel the bolus from the gut.

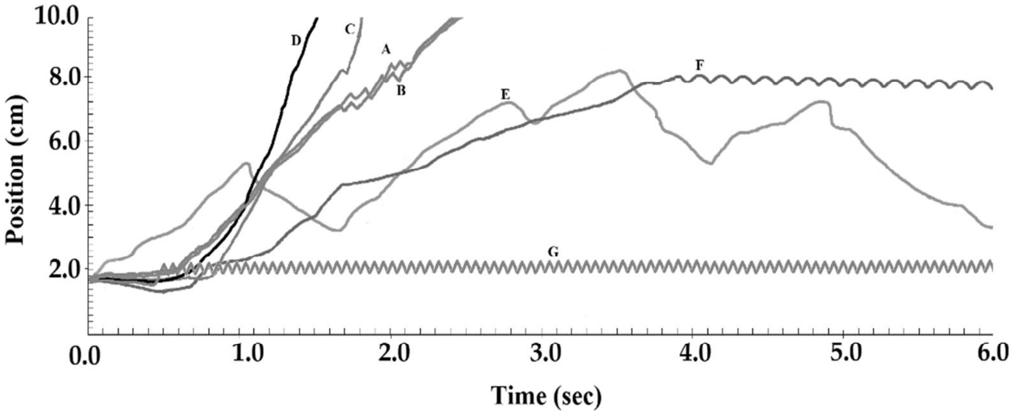

Fig. 1 - The effect of the viscous (μ) and dry (F_d) friction on propulsion of the bolus in a segment of the colon. A: μ = 230 Ns/m; F_d = 20 N. B: μ = 230 Ns/m; F_d = 2 N. C: μ = 200 Ns/m; F_d = 20 N. D: μ = 90 Ns/m; F_d = 450 N. E: μ = 230 Ns/m; F_d = 450 N. F: μ = 1200 Ns/m; F_d = 20 N. G: μ = 230 Ns/m; F_d = 800 N.

The dynamics of stress-strain distribution demonstrated the rise in intensity of active propulsive forces in the circular smooth muscle layer throughout the entire phase of propulsion of the bolus. Viscous, as compared to dry, friction had a marked effect on the average velocity of colon transit. Thus the addition of osmotic and rapidly acting lubricant laxatives intraluminally significantly reduced the time required for expulsion of the bolus (Figure 1).

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