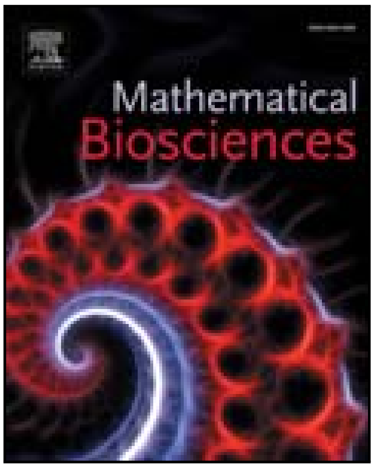

Variation of pressure from cervical to distal end of oesophagus during swallowing: Study of a mathematical model

Sanjay Kumar Pandey , Gireesh Ranjan ,
Shailendra Kumar Tiwari , Kushagra Pandey

PII: S0025-5564(17)30178-5
DOI: 10.1016/j.mbs.2017.03.010
Reference: MBS 7929

To appear in: *Mathematical Biosciences*

Received date: 29 March 2016
Revised date: 12 December 2016
Accepted date: 31 March 2017

Variation of pressure from cervical to distal end of oesophagus during swallowing: Study of a mathematical model

Sanjay Kumar Pandey[a,*] **, Gireesh Ranjan**[b]**, Shailendra Kumar Tiwari**[a] **and Kushagra Pandey**[a]

[a] Department of Mathematical Sciences, Indian Institute of Technology (BHU), Varanasi, INDIA
[b] School of Medical Science and Technology, Indian Institute of Technology, Kharagpur, INDIA

Abstract

The investigation is an attempt to explore the cause that generates high pressure in the distal oesophagus compared to that in the proximal part. We observe through computer simulation that peristaltic waves of even slightly but progressively increasing amplitude can generate high pressure near the distal end. This is illustrated through exponential growth in the wave amplitude, which represents the dependence of the rate of growth of amplitude on its current magnitude. This may be physically interpreted that the generation of high pressure in the lower oesophagus ensures complete bolus delivery to stomach through the cardiac sphincter. This finding may prove to be a very prominent result towards creating a prosthetic oesophagus. Some more conclusions with regard to progressive exponential increase in amplitude are also drawn. The pressure falls to zero invariably in the proximal half of every bolus, whereas for constant amplitude, zero pressure is located exactly at the midpoints of the boluses for Newtonian flows. Backward flow of fluid takes place in a smaller region if amplitude increases. Circular muscles contract more in the lower oesophagus to generate higher pressure in the distal oesophagus. In a sharp contrast to the case of constant-amplitude, pressure is neither uniformly distributed in a wave, nor is of identical shape for all boluses in the case of train wave propagation. Pressure distribution along the axis of the oesophagus differs in shape and magnitude both when a single wave propagates.

Keywords: Oesophagus; Peristalsis; Bolus transport; High pressure zone; waves with increasing amplitude.

1 Introduction

Exploration of peristalsis towards enhancing knowledge of the phenomenon as well as for physiological and engineering applications has been a crusade of the mankind for over four decades. Much has been revealed about it through numerous investigations reported through these years. However, a strong bond between theoretical investigations and clinical/experimental observations has been lacking. The main purpose of theoretical studies in biomechanics is, no doubt, to facilitate and meet the clinical demands. An attempt has been made in this report to mathematically formulate experimental observations pertaining to swallowing in oesophagus.

Having been masticated with teeth, food is rolled into a bolus and is then pushed through the cervical sphincter to oesophagus. Peristalsis is the only pumping mechanism that propels a food-bolus down the stomach through the cardiac sphincter. The mechanism involves contraction followed by relaxation of oesophageal wall, which thus creates a progressive transverse wave-motion. Oesophageal wall motion which causes peristaltic flow in oesophagus has generally assumed as sinusoidal motion of constant amplitude. (Burn and Parkes [1], Shapiro et al.[2], Fung[3], Fung and Brown[4], Takabatake et al.[5]). Li and Brasseure [6] made a modification in the conventional sinusoidal equation which produces contraction and relaxation up to the natural boundary to match the real movement of oesophagus to some extent. However, the model need to adjust the wave-amplitude in order to keep the volume of the fluid within one wave fixed. Misra and Pandey [7] designed a bit modified model that incorporates contraction and relaxation

----

*Corresponding author. Tel: +919450533132