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Small Intestine Peristaltic Motion Simulator

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Extended Abstract

The small intestine (or small bowel) is the part of the gastrointestinal tract following the stomach and followed by the large intestine, and is where much of the digestion and absorption of food takes place. Human small intestine alone measures around six meters and it has a surface area of over 200 meters. The muscles, which encircle this tube, constrict about seven to twelve times a minute to move the food back and forth, to churn it, knead it, and to mix it with gastric juices. The wavy motion of the small intestine generates waves that move the food forward, but these are usually weak and infrequent to allow the food to stay in one place until the nutrients can be absorbed.

Capsule endoscopy is a way to record images of the digestive tract for use in medicine. The capsule is the size and shape of a pill and contains a miniature camera. After a patient swallows the capsule, it takes pictures of the inside of the gastrointestinal tract. The primary use of capsule endoscopy is to examine areas of the small intestine that cannot be seen by other types of endoscopy such as colonoscopy or esophagogastroduodenoscopy (EGD). The technique was approved by the U.S. Food and Drug Administration (FDA) in 2001. In early 2014, FDA approved a new swallowable pill camera, 'PillCam Colon' by Given Imaging from Israel, which takes high-speed photos over an eight hour tour in the innards and transmits the images to a receiver on a belt. It is also considered very safe method to determine unknown cause of Gastrointestinal bleeding. Capsule usually passes through feces within 24-48 hours.

The capsule, in addition to image capturing, provides temperature, pressure activity, pH and other parameters. Rather than following the development and testing of the new capsules through rather expensive and time consuming animals tests, we proposed and developed an in-vitro small intestine (SI) motility simulator.

We tested the SI motility with PillCam SB 3 capsule (Given Imaging Ltd.). PillCam® SB is the most widely used, patient-friendly too for directly visualizing the small bowel to detect, diagnose and monitor abnormalities. This procedure is the standard of care for small bowel evaluation, helping healthcare practitioners determine the presence and source of obscure GI bleeding and providing a valuable perspective for improving patient outcomes. With PillCam SB, physicians can visualize the entire small bowel without putting their patients through a lengthy, uncomfortable procedure or having them undergo sedation. By simply swallowing a vitamin-sized capsule, physicians may detect and monitor lesions, ulcers, tumors, and bleeding within the small bowel. We have also tested the simulator with SmartPill® (Given Imaging Ltd.) for pressure measurements of the SI model peristaltic motion.

The SI simulator is based on circular inflating units of about 1 cm width that were assembled consecutively. Inflating membrane is made from 0.4-mm thick silicone. Pressurized air is supplied to the unit and causes circular inflation and orifice closing. Each inflation unit connected to inflation controller

separately. Both peristaltic velocity and peristaltic intensity could be managed by the operator, and the number of simultaneously inflated units (compression width) could be changed. The SI model itself is an independent elastic tube which is loaded inside the inflating units in a concentric manner.

We tested two SI models: 1) Penrose drain tube of 15-mm diameter and 1-mm thickness; 2) section of porcine SI. For the second case, a preservation procedure was applied before ex vivo test. Measurements performed in the SI simulator were compared to in-vivo recordings from human adults.

Our experiments show that the proposed simulator ensures small intestine model contractions and capsule movement similar to that in-vivo. Images taken by the capsule indicate excellent similarity of the SI insides to that taken in-vivo. Pressure recordings measured with the SmartPill show similarity in the pressure wave morphology, yet with higher amplitude in the SI simulator. This higher amplitude is accounted to the material properties of the silicone in the inflating units.

Overall the SI simulator shows great potential for in-vitro testing of capsule endoscopy products, enables reduction in number of animal tests, and improves the R&D procedure.

References

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