BIOMECHANICS OF THE HUMAN STOMACH AFTER BARIATRIC SURGERY

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ABSTRACT
This work compares the dynamics of stress-strain development in the human stomach before and after bariatric surgery. Results of numerical simulations demonstrate that significant changes in propulsive activity of the organ develop after sleeve gastrectomy. It is shown that anatomical variability of the human stomach also contributes to postsurgical motility.

Keywords: biomechanics, computer simulation, human stomach, bariatric surgery.

INTRODUCTION
The prevalence of obesity has increased in recent decades, and is considered to be a major public health concern worldwide. However, there are currently no truly effective pharmacological agents to treat morbid obesity. These patients commonly undergo various bariatric surgical procedures which are aimed at reducing the size of the stomach and diverting food transport. The procedures are defined as: 1) restrictive - sleeve gastrectomy (SG), vertical banded gastroplasty (VBG), adjustable gastric band (AGB), 2) malabsortive – Roux-en-Y-gastric bypass (RYGBP), and 3) combined – sleeve gastrotomy with Roux-en-Y-gastric bypass. Studies on postoperative problems associated with bariatric procedures have been concerned mainly with diabetes, hyperlipidemia, hypertension and obstructive sleep apnea, and only a few have addressed the question of postoperative motility of the organ. The aim of the study was to determine the impact of different types of bariatric surgery on stress-strain distribution and motility of the human stomach.

METHODS
The mathematical model of the human stomach was constructed. It was based on detailed anatomical, morphological, electrophysiological and biomechanical data obtained from in vivo and in vitro experiments. The organ was represented as a thin deformable soft biological shell. The effect of anatomical variability in the shape – bull horn, fish hook and intermediate - of the stomach on postsurgical outcomes was examined by choosing various initial configurations of the organ. The excitatory input to the system and the generation of electromechanical processes were supplied by the intramural myenteric nervous plexus and its spatially distributed ganglia.

RESULTS
The results of simulations of the intact human stomach under static loading resembled patterns of stress-strain distribution recorded experimentally. The anatomical variation in the initial configuration of the organ showed differences in the development of total forces in the

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Fig. 1- Stress-strain distribution in the normal human stomach and after gastric band and sleeve gastrectomy surgery cardio-fundal region and along the lesser curvature of the stomach. The maximum total force in the longitudinal direction was $\max T_l = 1.3$ mN/cm and in the circumferential – $\max T_c = 1.9$ mN/cm. The organ showed greater extensibility circumferentially ($\lambda_c = 1.18$) compared to the axial direction ($\lambda_l = 1.05$). The bariatric procedure, namely SG, significantly restricted deformations of the stomach circumferentially ($\lambda_c = 1.05$) and did not affect the axial deformation ($\lambda_l = 1.04$). Total forces produced by the modified organ were also reduced compared to the norm: $\max T_l = 0.8$ mN/cm and $\max T_c = 1.0$ mN/cm. By contrast, VBG and AGB procedures stretched the organ longitudinally ($\lambda_l = 1.2$) and circumferentially ($\lambda_c = 1.13$). There was a concomitant rise in the total force: $\max T_l = 2.2$ mN/cm and $\max T_c = 1.2$ mN/cm. Three dimensional views of the human stomach and stress distributions in the longitudinal $T_l$ (top rows) and circumferential $T_c$ (bottom rows) in the normal organ and after AGB and VBG procedures are shown in fig. 1. The activation of the myenteric nervous plexus and the development of active forces of contraction led to peristalsis. It was decreased after SG and sustained its effectiveness after VBG and AGB.

**CONCLUSION**

The computer simulation and biomechanical analysis of the dynamics of stress-strain distribution in the human stomach before and after different types of bariatric surgical procedures revealed significant alterations in motility and propulsive activity in the organ that underwent SG and not AVG and VBG. Post-surgical complications, e.g., gastroesophageal reflux, dumping syndrome and conditions related to over-distension of the remnant organ are expected to be more common amongst patients who have undergone SG.