Numerical analysis of bariatric configurations after endoscopic surgery

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***Abstract*—Bariatric surgery is the most effective intervention for severe obesity, which is one of the most serious health problems. Laparoscopic Sleeve Gastrectomy is one of the principal techniques. Nonetheless, major complications are frequent, and weight-loss is not always successful. Non-optimal intervention design and general anesthesia are the principal cause of this situation. A novel approach is required, integrating bioengineering and medical competences, aiming to engineering design the procedure, to improve efficacy and safety.**

Preliminary outcomes have been reported from activities that are under development in the research field of stomach mechanics and bariatric surgery. The results pointed out the potentiality of computational methods for the investigation of stomach functionality and the planning of bariatric surgery procedures and techniques.

***Keywords*—Obesity, finite element model, endoscopy, bariatric surgery.**

I. Introduction

OBESITY is a growing health problem associated with high Body Mass Index (BMI) value (>30) and shortened life expectancy. It is a condition that occurs in conjunction with multiple co-morbidities, increasing risks of showing metabolic and cardiovascular diseases, some cancers, musculoskeletal disorders and psychosocial impairments. The World Health Organization estimates that its prevalence is nearly tripled between 1975 and 2016, affecting 650 million people worldwide in 2016 [1]. This upward trend entails huge healthcare costs due to obesity [2].

The use of bariatric surgery in the treatment of obesity is increasingly applied throughout the world and has proved to be the most effective treatment with respect to pharmacological or life-style interventions in inducing excess weight loss. However, beyond the periprocedural complications of surgery, other risks can compromise surgery success: weight regain, anatomic complications and micronutrient deficiencies [3]. To deepen the influence of the type of bariatric procedure on the stomach functionality, computational analyses have been undertaken. Different stomach conformations have been considered in order to compare the Laparoscopic Sleeve Gastrectomy (LSG) and the Endoscopic Sleeve Gastroplasty (ESG). Furthermore, numerical investigations have allowed to consider new possible scenarios regarding bariatric surgery, with particular regard to novel endoscopic approaches to SG and hybrid procedures between Adjustable Gastric Banding and endoscopic SG. The undeformed physiological conformation of the stomach experimentally and numerically investigated [4] has been evaluated as term of comparison.

II. Materials and Methods

A. FE model

A finite element model of the stomach developed by [4]-[5] has been involved in the analyses. The numerical model was developed considering hysto-morphological parameters and data about the gastric tissue mechanical behavior. The constitutive formulation was chosen taking into account the anisotropic fiber-reinforced behavior and the stratification of the gastric tissue in two main layers, the mucosa-submucosa layer and the muscular layer [6]. Four-nodes tetrahedral hybrid elements were adopted to mesh the stomach wall.

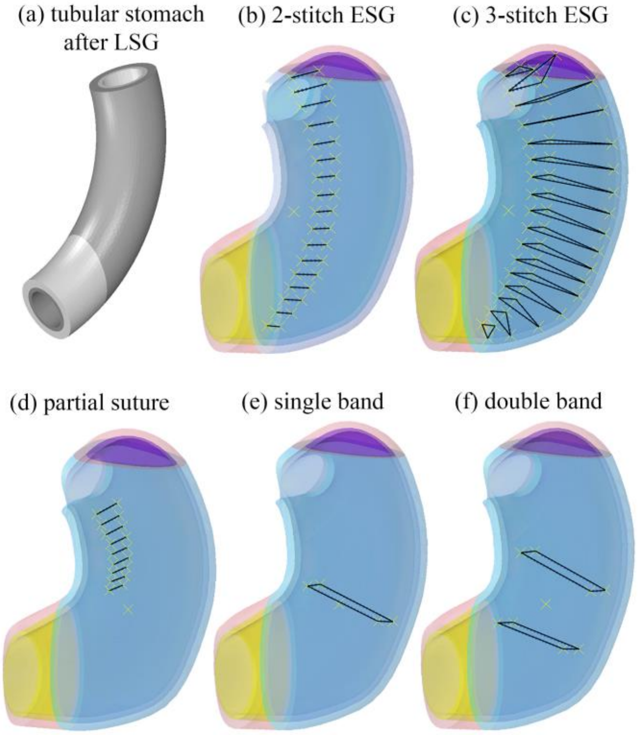

Figure 1: undeformed representations of the tested stomach configurations. The endoscopic schematizations (b)-(f) have the gastric walls in transparency with different colors according to layer and position.

The final model consisted of about 370,000 elements and 74,000 nodes. The validation of the model took place by comparing the numerical pressure-volume relationship with the experimental one obtained during the insufflation tests on pig stomachs [5].

Computational investigations were carried out by the general-purpose finite element software Abaqus 2018 (Dassault Systèmes, Simulia Corp., Providence, RI).

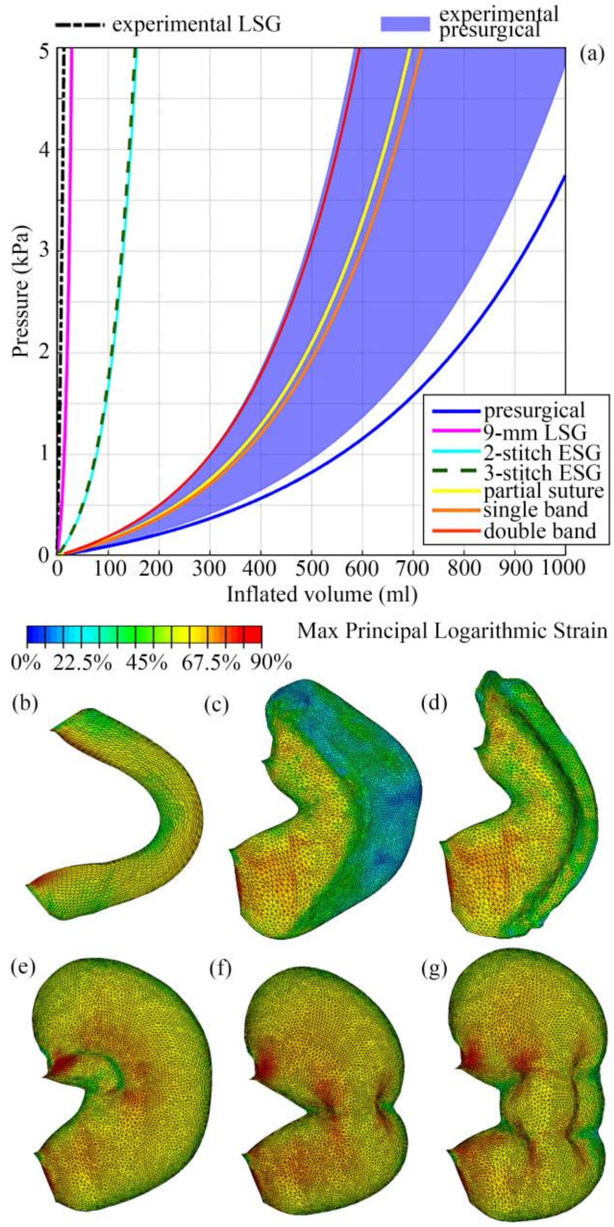

Figure 3: pressure-volume data of experimental tests were compared to numerical curves with respect to the inflated volume(a). Results of computational simulations were analyzed. All models were subjected to controlled insufflation. The strain field distributions have been reported with respect to an internal pressure of 5 kPa. Here contours have been reported: L SG (a), 2-stitch ESG (b), 3-stitch ESG (c), partial suture (d), single band (e) and double band (f).

B. Numerical simulations

Computational methods were exploited to analyze the influence of bariatric interventions on stomach functionality.

In the case of laparoscopic SG, the resulting tubular stomach was simulated by a circular tube with a diameter of 9 mm comprising antral and body tissues, as in Figure 1(a). The wall thickness and the material properties of the tissue layers were preserved as in the complete model.

Other approaches with wall anchoring points in different setups have been explored. Two ESG versions have been numerically tested, by considering or not the stitch on the greater curvature of the stomach, as in Figure 1(b)-(c). Another configuration in Figure 1(d) took into account a partial suture of the proximal stomach. Moreover, endoscopic bandages mimicked with wires fixed at a total of 4 anchoring points were simulated. The bands were positioned in two ways, as in Figure 1(e)-(f). The wires shortening was imposed up to 50% of the initial length of each segment.

The numerical pressure-volume relationships were then compared with the experimental statistical band relating to pig stomach inflations in an unmodified physiological condition and to the mean pressure-volume curve corresponding to the post-SG tubular pig stomach inflation.

III. Results

The analysis of numerical pressure-volume data characterizing the pre-surgical conformation, the LSG and EGS techniques and the innovative surgical approaches, reported in Figure 2(a), reveals an alteration of the structural stiffness of the stomach when subjected to bariatric surgery. The numerical simulations provided pressure-volume trends consistent with experimental data. They also allow the analysis of stress-strain field distributions, which proved to be technical-specific.

IV. Conclusion

The computational approach has enabled the extraction of information that could not be provided by the experimental methods. The distribution of the stress-strain states gives an indication of the tissue locations subject to greater stresses during the gastric filling phase and therefore crucial in the communication of the sense of satiety through the gastric mechanoreceptors. With regard to the analyzed configurations, numerical simulations have provided a prediction of the distribution of the characteristic strain field and an insight into possible endoscopic approaches, showing the full potential of computational methods in the study of bariatric surgery.

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