Patient-specific stomach modelling before and after laparoscopic sleeve gastrectomy

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Aim

The **aim** of the research activities consists in the development of patient-specific **stomach** models starting from MRI data, **before and after Laparoscopic Sleeve Gastrectomy (LSG)** to provide **computational clinical tool** able to improve bariatric surgery success' rate in treating people with severe obesity.

Materials and Methods

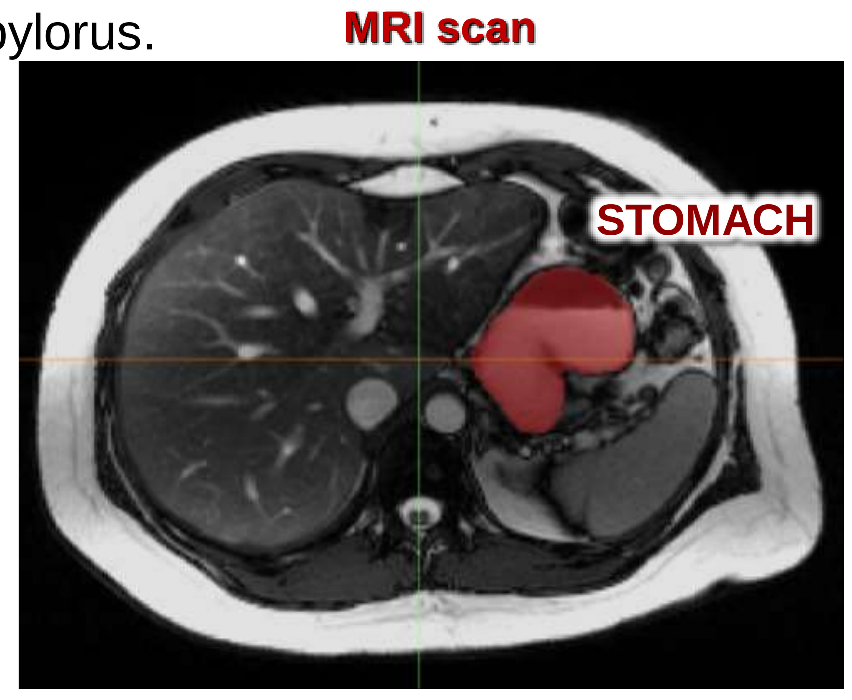
A. Data

- 46 pre- and post-surgical models of 23 patients with morbid obesity were generated starting from MRI scans before and after LSG [1].

B. Volume extraction from MRI.

- Segmentation of empty stomachs performed by Synopsys Simpleware ScanIP on the transversal plane from cardia to pylorus.

MRI scan



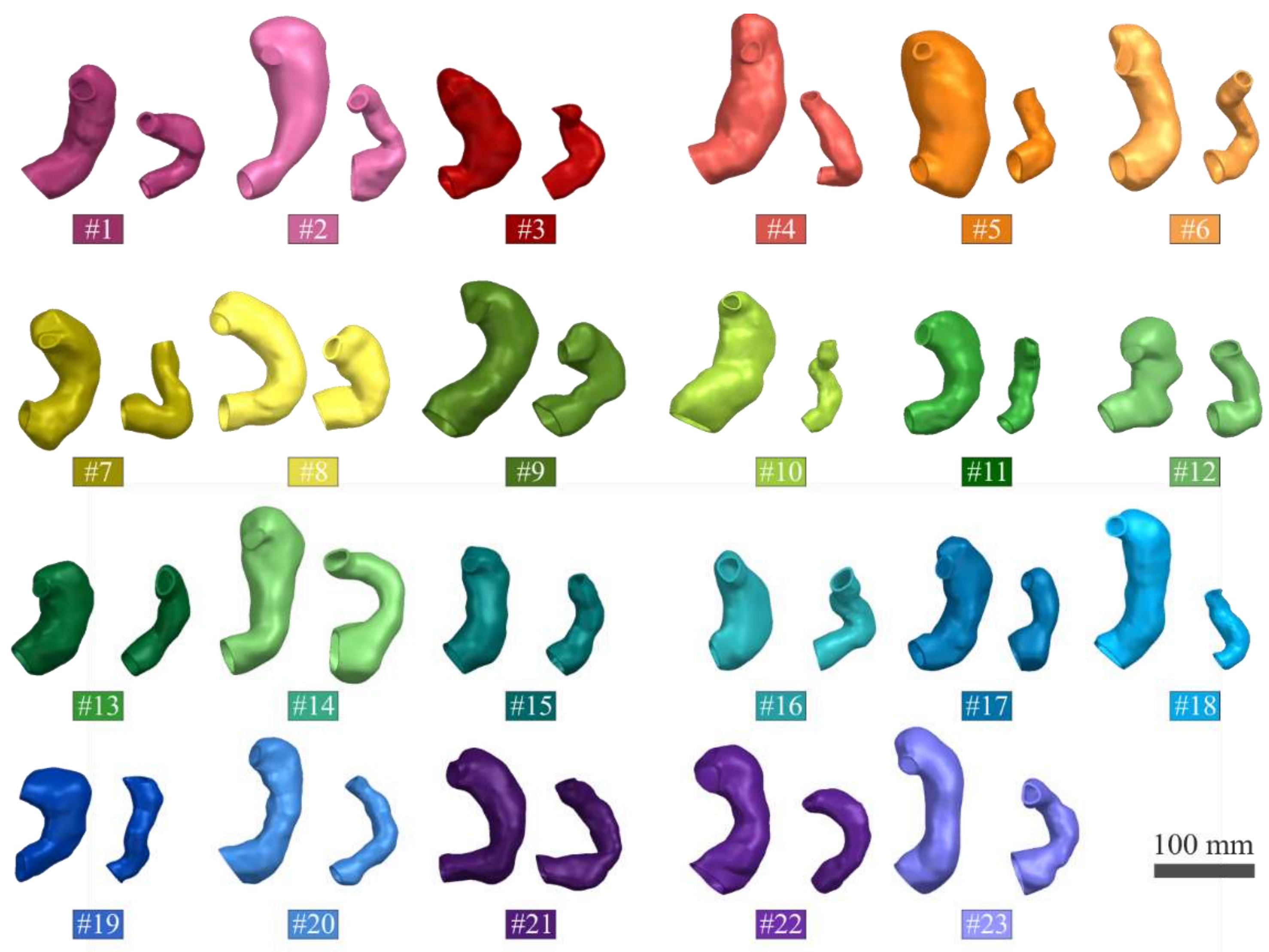


Fig.1: Patient-specific models obtained from the MRI of the 23 considered patients, before and after LSG.

C. Virtual model realization

- Double-layered geometry (submucosa-mucosa layer and muscularis stratum) from subsequent different offsets of the external stomach surface by means of Solidworks Dassault Systemes, 2018 (Fig. 1).

D. Material principal direction assignment.

- Fibre-reinforced hyperelastic constitutive formulation: tissue anisotropy and non-linear elasticity [2].
- Principal directions defined by a user-defined Matlab code.
- Assignation of principal directions to mesh elements performed by *ad hoc* UMAT subroutine.

E. Simulation details

- Abaqus CAE 2018.
- Linear hexahedral elements of 1-mm edge size.
- At least 5 nodes for each layer (Fig. 2)
- Inflation process: pressure ramp and fluid cavity interaction.

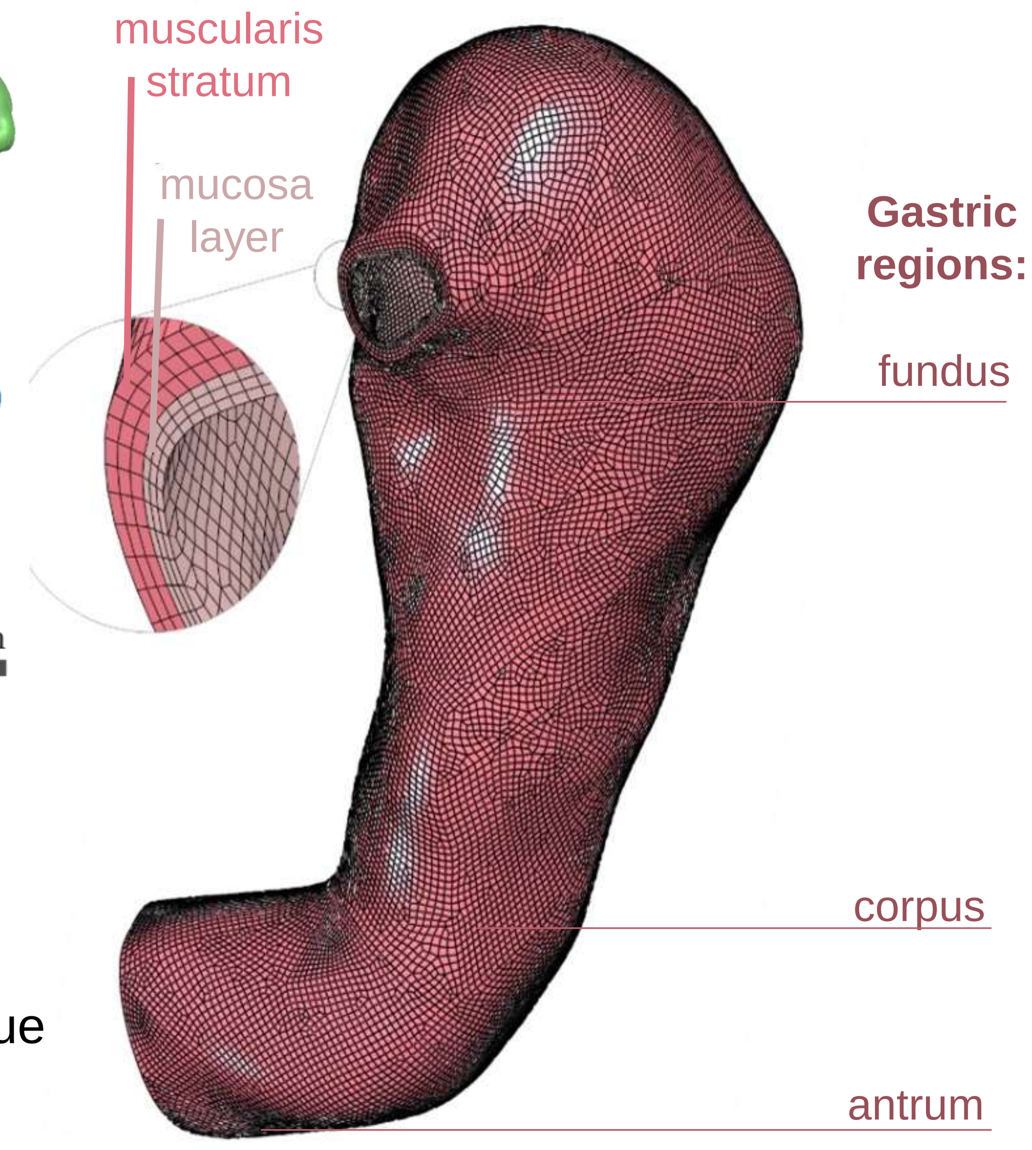


Fig.2: Finite element discretization of a patient-specific pre-surgical model

Results

- ❑ Inter-patients' variability affected the biomechanical response of the stomach.
- ❑ Post-surgical statistical band of pressure-volume behavior narrower than pre-surgical band (Fig. 3a)
- ❑ Statistical minor values of elongation strain in post-surgical models than pre-surgical ones at the same intragastric pressure (Fig. 3b-c).

Stomach computational biomechanics during inflation tests

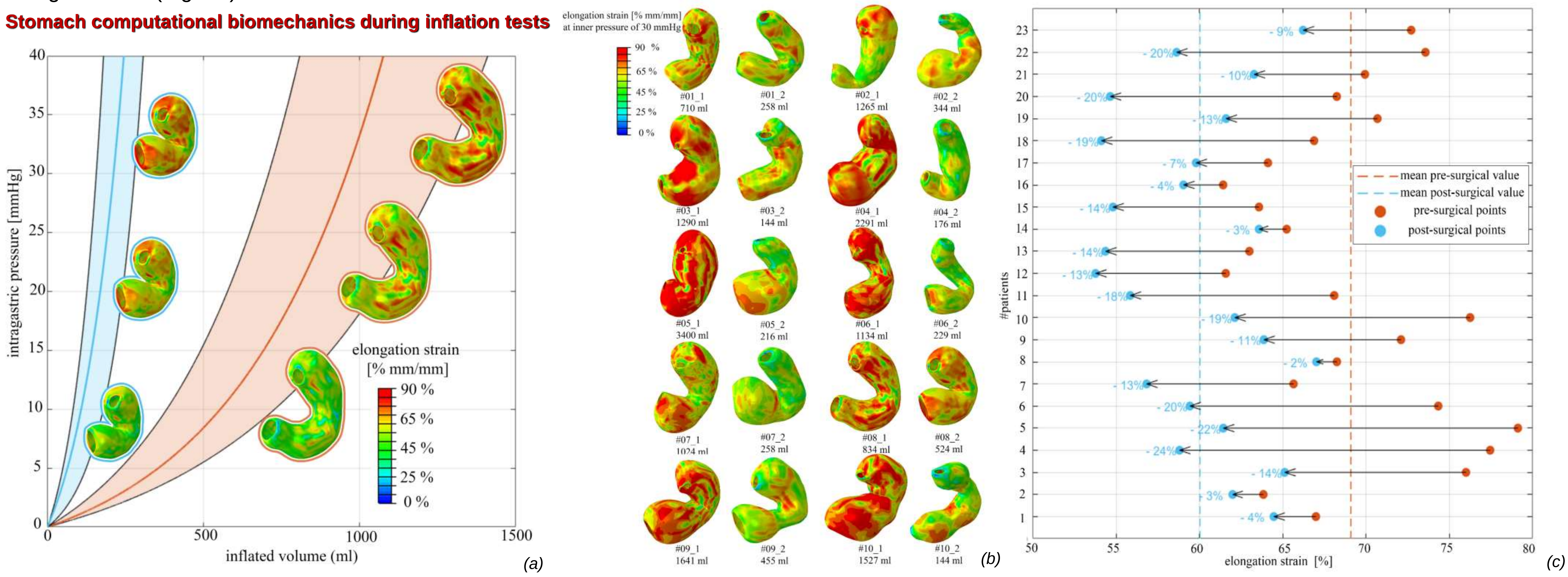


Fig.3: (a) The statistical bands (C.I. 75%) and the corresponding median curves of pre- and post-surgical stomachs. (b) Patients from #01 to #10: colormaps of the distribution of elongation strain for pre- and post-surgical stomachs at a pressure of 30 mmHg. (c) Red dashed line states for the mean elongation strain value of pre-surgical models at 30 mmHg, blue dashed line represent the mean strain value of the post-surgical models, at the same applied pressure.

Discussion

Post-surgical band of pressure-volume behavior presented a less variability due to the standardization introduced by LSG in stomach geometry. The band was in the leftish part of the chart because of the strong reduction introduced by LSG in volumetric stomach capacity (Fig. 3a). Post-surgical stomachs showed smaller elongation strain values respect to pre-surgical ones, suggesting that LSG influences the global stomach stiffness. The non-homogeneous elongation strain distribution is due to patient-specific geometrical shape and different gastric region (Fig. 3b). Computational patient-specific models may contribute to improve the current knowledge about anatomical and physiological changes induced by LSG, aiming at reducing post-operative complications and improving operative outcomes in weight loss and quality of life in the long run [3].

Reference

[1] Quero et al, «The Causes of Gastroesophageal Reflux after Laparoscopic Sleeve Gastrectomy: Quantitative Assessment of the Structure and Function of the Esophagogastric Junction by Magnetic Resonance Imaging and High-Resolution Manometry», *Obesity Surgery* (2020)
[2] Toniolo et al., «Biomechanical Investigation of the Stomach Following Different Bariatric Surgery Approaches», *Bioengineering* (2020)
[3] Toniolo et al., «Computational evaluation of laparoscopic sleeve gastrectomy», *Updates in Surgery* (2021)

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