Mechanical response of the human stomach wall to radial compression and associated microstructural changes

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Abstract

During gastric tumor resection or bariatric surgery, the stomach wall is often compressed by clamps, sutures, or staple lines (1,2). These imposed short- and long-term deformations can impair the functionality of the stomach and make it difficult for the tissue to remodel/heal in the desired manner. This can lead to severe intra- and postoperative complications, e.g., leak formation along the staple line. Therefore, this study investigated the tissue response to radial compressive loading of the stomach wall and the associated microstructural changes. For this purpose, human stomach resectates from sleeve gastrectomies were acquired at a local hospital. All samples were frozen at –20∘C within 1.5 hours after explantation, thawed, and tested in cardioplegic solution to ensure passivity of smooth muscle cells. Region-specific stress-relaxation tests were performed in radial compression mode at three different stretches (λrad = 0.8, 0.6, and 0.4). The samples were then fixed with 4% formaldehyde solution under compression in the testing setup. In addition, adjacent samples were fixed in the undeformed state. All samples were investigated using complementary imaging techniques. On the one hand, the histochemical analysis of the main constituents was achieved by combining the histological stainings Elastica van Gieson and Alcian blue (3). On the other hand, two-photon and second-harmonic generation microscopy revealed the region- and stretch-specific elastin and collagen fiber characteristics, namely orientation, thickness, and waviness (4).

During the stress-relaxation tests, significant regional differences in the peak stresses were found for all compression levels. The histological study highlighted the heterogeneity of the stomach wall and its influence on the mechanical behavior. Furthermore, it implied that the stomach layers deform sequentially and not homogeneously from the undeformed configuration to the highest compression level. The microscopy scans showed that the radial compression of the stomach wall leads to a straightening of the naturally wavy elastin and collagen fibers and their reorientation towards the circumferential-longitudinal plane.

This study shows that radial compression of the stomach wall leads to significant alterations in the characteristics of multiple tissue components within each stomach layer. Besides, the

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remarkable interplay between mechanical tissue response and the microstructural composition in each of the three stomach regions was highlighted, which must be taken into account when developing and improving surgical devices.

References

(1) Barski et al., Wideochir Inne Tech Maloinwazyjne, 13, 2018.
(2) Johnson & Johnson MedTech, ECHELON reloads with gripping surface technology, 2023.
(3) Holzer et al., Acta Biomater, 173:167-183, 2024.
(4) Polzer et al., Microsc Microanal, 29:2108-2126, 2023.

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