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Examination of Porcine Gastric Biomechanics in the Antrum Region

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Abstract : Gastric biomechanics governs a large range of scientific and engineering fields, from gastric health issues to interaction mechanisms between external devices and the tissue. Determination of mechanical properties of the stomach is, thus, crucial, both for understanding gastric pathologies as well as for the development of medical concepts and device designs. Although the field of gastric biomechanics is emerging, advances within medical devices interacting with the gastric tissue could greatly benefit from an increased understanding of tissue anisotropy and heterogeneity. Thus, in this study, uniaxial tensile tests of gastric tissue were executed in order to study biomechanical properties within the same individual as well as across individuals. With biomechanical tests in the strain domain, tissue from the antrum region of six porcine stomachs was tested using eight samples from each stomach (n = 48). The samples were cut so that they followed dominant fiber orientations. Accordingly, from each stomach, four samples were longitudinally oriented, and four samples were circumferentially oriented. A step-wise stress relaxation test with five incremental steps up to 25 % strain with 200 s rest periods for each step was performed, followed by a 25 % strain ramp test with three different strain rates. Theoretical analysis of the data provided stress-strain/time curves as well as 20 material parameters (e.g., stiffness coefficients, dissipative energy densities, and relaxation time coefficients) used for statistical comparisons between samples from the same stomach as well as in between stomachs. Results showed that, for the 20 material parameters, heterogeneity across individuals, when extracting samples from the same area, was in the same order of variation as the samples within the same stomach. For samples from the same stomach, the mean deviation percentage for all 20 parameters was 21 % and 18 % for longitudinal and circumferential orientations, compared to 25 % and 19 %, respectively, for samples across individuals. This observation was also supported by a nonparametric one-way ANOVA analysis, where results showed that the 20 material parameters from each of the six stomachs came from the same distribution with a level of statistical significance of $P > 0.05$. Direction-dependency was also examined, and it was found that the maximum stress for longitudinal samples was significantly higher than for circumferential samples. However, there were no significant differences in the 20 material parameters, with the exception of the equilibrium stiffness coefficient ($P = 0.0039$) and two other stiffness coefficients found from the relaxation tests ($P = 0.0065, 0.0374$). Nor did the stomach tissue show any significant differences between the three strain-rates used in the ramp test. Heterogeneity within the same region has not been examined earlier, yet, the importance of the sampling area has been demonstrated in this study. All material parameters found are essential to understand the passive mechanics of the stomach and may be used for mathematical and computational modeling. Additionally, an extension of the protocol used may be relevant for compiling a comparative study between the human stomach and the pig stomach.

Keywords : antrum region, gastric biomechanics, loading-unloading, stress relaxation, uniaxial tensile testing
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