Two approaches to simulate the abdominal wall: solid and membrane Finite Element models

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Abstract. The paper concerns modelling of the human abdominal wall. Two Finite Element models are considered: (1) membrane model based on external geometry of real abdominal wall and (2) simplified solid model with geometry based on MRI scans. The aim of this preliminary research is to discuss two approaches to model the human abdominal wall.

INTRODUCTION

The background of this study is ventral hernia. Ventral hernia repair is nowadays a very common procedure. Despite many research, the consensus on properties of a surgical mesh and the method of its fixation to the abdominal wall has not been reached yet. Computational models can be used to predict behavior of abdominal wall-implant systems and can be used in the process of optimization of ventral hernia repair parameters. In this preliminary study two approaches to abdominal wall modelling are presented: membrane and solid Finite Element (FE) models.

MATERIALS AND METHODS

The models are created with the commercial FE system MSC. Marc. The material is assumed to be homogenous, linear elastic and isotropic with elastic modulus equal to 27.7 kPa, which is the value identified by Song et al. [1] for living male human abdominal wall. Poisson's ratio is assumed to be equal to 0.49. Displacements in the nodes along all the edges of the abdominal wall are fixed. The abdominal wall is subjected to a pressure of 981 Pa. The value corresponds to intraabdominal pressure of patient undergoing peritoneal dialysis with infused 2 l of dialysis fluid [2]. Geometrically nonlinear static analysis of the model is performed is this study.

The first FE model is composed of quadrilateral four-node isoparametric membrane elements with translational degrees of freedom (Fig. 1a). The geometry was constructed on the basis of measurements of the grid points marked on the skin of living man [3]. The model was proposed in [2] where its behavior was compared with measurements of the living human abdominal wall showing a good accordance with experimental results. The model has a constant thickness (in this paper assumed to be 2 cm), which does not correspond to the real structure of the abdominal wall. Nevertheless, it is a patient-specific model constructed on the basis of relatively simple measurements. Therefore it can be easily used in the studies of identification of abdominal wall mechanics *in vivo* which are based on measurements of external surface of the abdominal wall as proposed by Song et al. [1].

The second model is composed of linear three-dimensional four-node isporametric tetrahedral elements. The proposed model was constructed on the basis of MRI images using Mimics and 3-Matic (Materialise, Belgium) software, which makes is more realistic. However, the construction of patient specific models requires an access to MRI (or CT) images of the studied abdominal wall.

(a) (b)

FIGURE 1. Considered models (a) membrane model, (b) solid model created on the basis of MRI images

RESULTS

The maximum displacement obtained from the simulations was equal to 2.25 cm (while using the membrane model) and to 8.52 cm (while using the solid model). The membrane models gave results closer to the experiment described in [2]. It can be explained by the fact that the used elasticity modulus was identified by measuring deformations only on the surface of the abdominal wall [1]. The modelling of the abdominal wall with a more detailed geometry requires also a more detailed description of the material. Literature reports that some components of the abdominal wall e.g. linea alba are stiffer than identified for the abdominal wall as a whole homogenous structure [4].

CONLUSIONS

Two models of the human abdominal wall have been discussed with a view of their potential use in a further process of optimization of ventral hernia repair parameters. The study is limited by applying a simple material model and boundary conditions.

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