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Magnetic Resonance Image-Based Modeling for Neurosurgical Interventions

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Abstract: Surgeries such as implantation of deep brain stimulation devices require accurate placement of devices within the brain. Because placement affects performance, image guidance and robotic assistance techniques have been widely adopted. These methods require accurate prediction of brain deformation during and following implantation. In this study, a magnetic resonance (MR) image-based finite element (FE) model was proposed by using a coupled Eulerian-Lagrangian method. Anatomical accuracy was achieved by mapping image voxels directly to the volumetric mesh space. The potential utility was demonstrated by evaluating the effect of different surgical approaches on the deformation of the corpus callosum (CC) region. The results showed that the maximum displacement of the corpus callosum increase with an increase of interventional angle with respect to the midline. The maximum displacement of the corpus callosum for different interventional locations was predicted, which is related to the brain curvature and the distance between the interventional area and corpus callosum (CC). The estimated displacement magnitude of the CC region followed those obtained from clinical observations. The proposed method provided an automatic pipeline for generating realistic computational models for interventional surgery. Results also demonstrated the potential of constructing patient-specific models for image-guided, robotic neurological surgery.

Keywords: Brain biomechanics; finite element model; intervention; magnetic resonance image (MRI)