Development and validation of human head finite element model for predicting head injuries.

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Introduction

When the head is impacted, various injuries including bone fractures, intracranial hemorrhage, and cerebral injuries are caused [1]. To investigate causal relationship between head injury and impact on the head mechanically lead to the prediction and elucidation of the mechanisms of head injury, and development of head protector. In the past decades, numerous studies have been conducted to elicidate the intracranial changes caused by impacts on the head, and the finite element (FE) mothod has been used as an effective approach.The purpose of this study is to construct and validate a FE model of the human head for the prediction of head injuries.

Development of human head finite element model

A human head FE model is constructed using T1 weighted MRI data and CT data of a women's head. Each component of the head is extracted by these data based on color intensity. Three-dimensional models are created by superimposing the imaging data, then the surface shape data of bone and brain is obtained. FE models of each components of the brain are constructed using FE modeling software. First, curved surfaces are created inside and outside the surface model, divided into appropriate sizes, and quadrilateral elements were created. Second, hexahedral elements were made between inside and outside corresponding quadrangular elements.

The developped human head FE model consists of skull, meninges, CSF, ventricle, cerebrum, cerebellum, corpus callosum, diencephalon, brain stem (midbrain, pons, medulla oblongata), falx, tentorium, and facial bone(Fig.1). In this model, the meninges, falx and tentorium are constituted of shell elements, and the others are constituted of hexahedron elements. Different material properties are assigned to each component. Elastic properties are assigned to the meninges, falx tentorium and facial bone. Viscoelastic properties are assigned to the CSF, cerebrum, cerebellum, brain stem, corpus callosum and ventricle. Isotropic elastic plastic properties are assigned to the cortical bone and diploe [2].

Validation of human head finite element model

In order to verify the human head FE model, the numerical results of the impact test are compared with those results of the cadaver experiment by Nahum et al. [3]. The outline of the experiment is shown in Fig.2. The time-force history data measured in the experiment is applied to the head model in numerical calculation.Pressure is measured at the frontal region and the posterior fossa. Head acceleration is measured at the center of the brain. In an analysis, tied type is used as the contact condition between each component of the head. In tied type, relative displacement between each component is not allowed. The experimental and numerical time histories of acceleration at the center of gravity are compared in Fig.3.

There is a difference in the peak acceleration at the center of gravity. The peak acceleration in the analysis is 3,084 m/s^2, while the peak acceleration in the Nahum' experiment was 2,047 m/s^2. This difference is attributed to the fact that constructed brain model has a mass of 1.06 kg, which is lighter than the average adult human brain weighing 1.45 kg [4]. The constructed model is 1.37 times lighter than the model in Nahum's experiment, and the acceleration of the constructed model is 1.51 times larger than the experiment. Considering these facts, the head finite element model and the numerical result are confirmed. To evaluate complex head injuries resulting from diverse injury scenarios, it is imperative to assess the validity of models through a greater number of cadaver experiments.

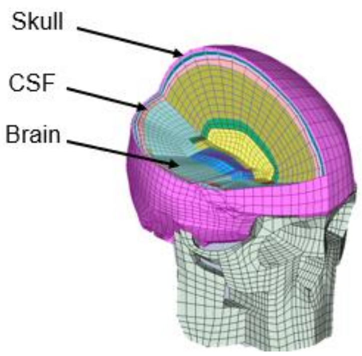

Fig. 1 Head finite element model

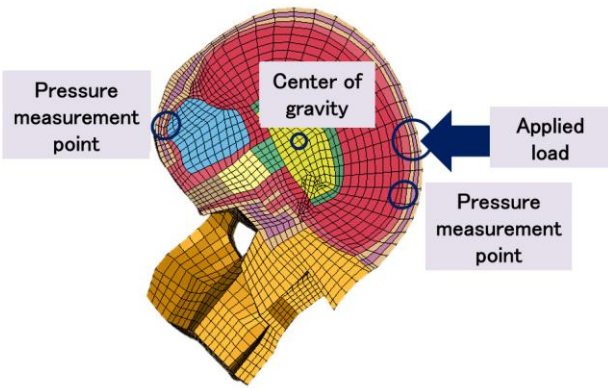

Fig. 2 The experiment by Nahum

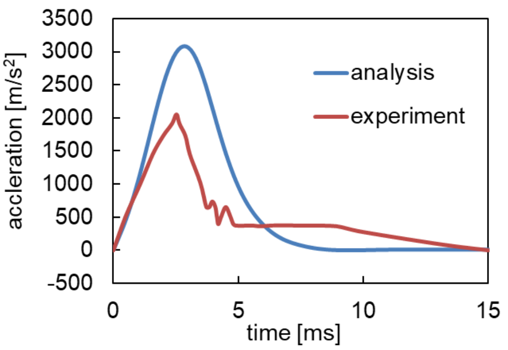

Fig. 3 Time history of acceleration at center of gravity

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