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ANALYSIS OF BRAIN TRAUMA IN SIDE CRASH BASED ON FEM MODEL

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Abstract— Head trauma is one of the most common causes of deaths in car accidents, sports Activities, war and etc. Based on complicated modelling problems, in this study, a finite element model of the human head has been developed in order to evaluate different types of brain damage. First 233 sections MRI images of the head of a 42 years old man were prepared. The geometric models of Skull, Meninges and brain were extracted. Using 3-Matic software, Multi-Stage editing operation, surface smoothing, and removing the border interaction was conducted. Mechanical properties related to any of the tissues of the skull, meninges and brain membrane are applied. The brain pressure was validated against intracranial pressure data reported by Nahum et al. After ensuring the validity of the model, data acceleration in the head recording from side impact test was applied to the model. Data from the simulation were compared with the injury criteria. Developing a new computational model for these injuries evaluation including side crash case, have not been considered in previous studies. So, considering this problem in addition to developing an accurate and efficient FEM head model could be supposing the considerable innovation of this study.

Keywords- Brain Injury Biomechanics, Side Crash, FEM Head Model, SDH, DAI

I. INTRODUCTION

Direct impact and sudden acceleration are major sources of death and disability as the result of transportation collisions, falls, assaults, military and sport accidents. On the other hand human brain is the most important organ in severe damage due to rupture of blood vessels and damage to brain tissue, causing long-term unconsciousness and even death. Today, traffic accidents are statistically ranked first among the events. In the US, there are about 1.4 million people who sustained TBI each year and estimated one-fifth of the hospitalized persons cannot return to work [1]. The major causes of deaths in accidents are due to brain damage. Simulating and analyzing the dynamic response under impact and sudden acceleration is the only way to predict the severity of the Brain injury. Traumatic Brain Injury Biomechanics connects physical processes associated with traumatic brain injury to physiological pathology of brain tissue.

II. MATERIALS AND MODELS

A. Image processing and extracting initial geometric modeling

Geometric modeling to include the skull, brain and meningeal membrane, is a phased and orderly process. These steps include preparing the MRI images, Build initial parts using image processing method in MIMICS17 software, surface editing in 3Matic software and preparing CAD models, and finally Assembly process. The first step to build head geometric model is preparing CT or MRI medical images of the head. High resolution of the medical Images makes it possible to detect boundaries between tissues and. Also, number of images affects the accuracy of measurements.

At this point prepared medical images were imported to the MIMICS17 medical image processing software in DCM format. Figure 1 shows MRI images in three orthogonal views in workspace of MIMICS17. After identifying MRI images by MIMICS17 software, the initial CAD models of skull bone and brain tissue were extracted.

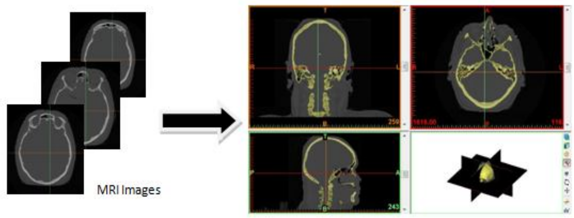

Figure 1: MRI images in three orthogonal views

The CAD model of the skull and brain has many holes and unevenness on their inner and outer surfaces. In order to smoothing the surface roughness, 3Matic software was used. After final editing operation in 3Matic software, each model of skull and brain was saved using STEP format. The final model of skull, meningeal membrane, and brain was shown in Figure 2. Assembly operation is the final step of geometric modeling.

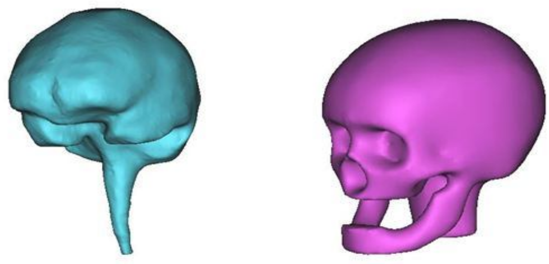

Figure 2: Final model of skull, meningeal membrane, and brain

B. Model Preparing for Dynamic Analysis

The final geometrical model of human head was imported to ABAQUS6.14 finite element solver software in order to dynamic analysis. The mechanical properties of living tissues of the body specially the brain tissue are always a challenging research subject in the field of biomechanics. Mechanical properties used in this study are assumed elastic for skull and hyperelastic for brain tissues. Because of the very short time of impact, the effects of the cervical spine and muscles could be ignored and free boundary condition could be used. The conditions have been considered for contact between the skull, meningeal membrane and brain tissue as inseparable connection. In this stage, mesh generation operation was performed and the quality of generated elements was controlled. The mesh of skull and meningeal membrane were shown in Figure 3.

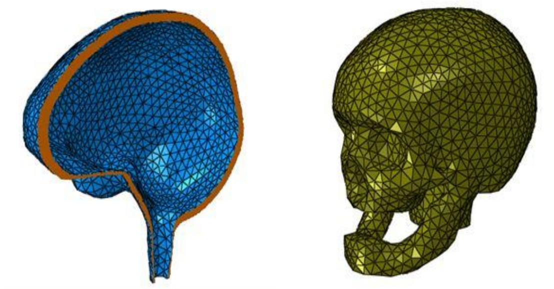

Figure 3: Skull and meningeal membrane mesh

C. Validation

For verifying the finite element model, the numerical results were compared with results of cadaver experiment by Nahum et. al. [2]. The Impact direction was along the specimen's mid-sagittal plane. The measured pressure on the back of brain in numerical simulation and experimental test are in good accordance as it could be clearly seen in Figure 4.

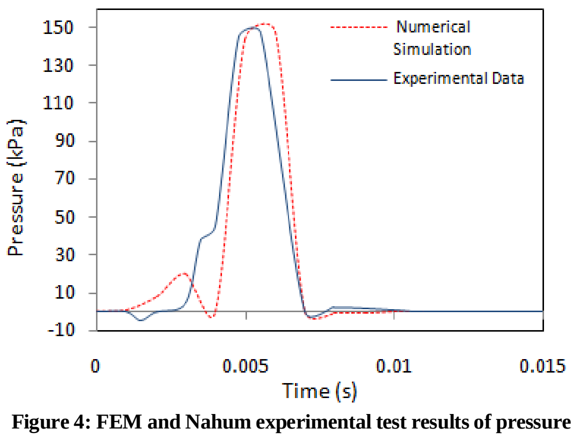

Figure 4: FEM and Nahum experimental test results of pressure on brain

III. RESULTS AND DISCUSSION

In order to obtaining rotational and translational acceleration experienced by human head in side crash, a FEM simulation on LS-Dyna human body dummy has been done as it shown in Figure 5.

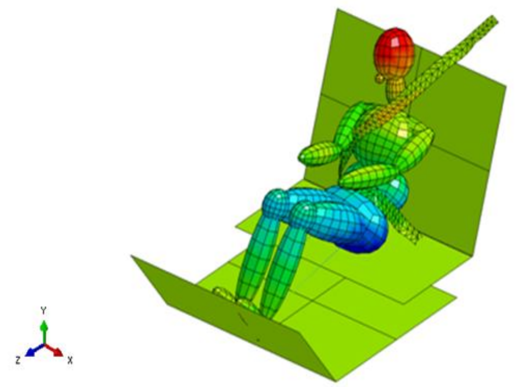

Figure 5: FEM human bod model for side crash simulation

Obtained results for maximum von Mises stress as well as maximum pressure in brain related to Rotational, translational and combined loading could be seen in Figures 6 and 7.

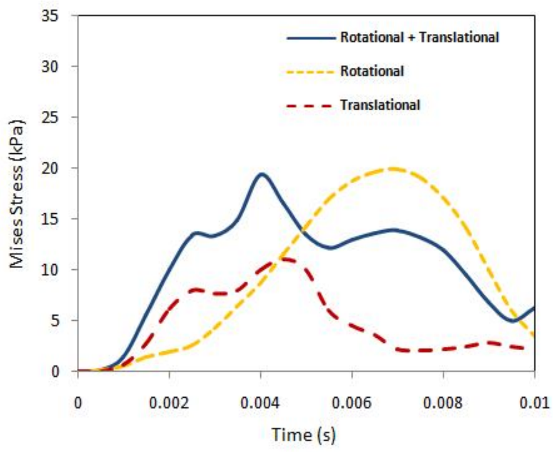

Figure 6: Maximum von Mises stress in brain during crash time

The simulation results showed that the rotational acceleration, due to high strain rate in the brain and increased pressure in meninges, is responsible for rupturing arteries and veins. However, linear acceleration alone does not lead to severe damages in the brain.

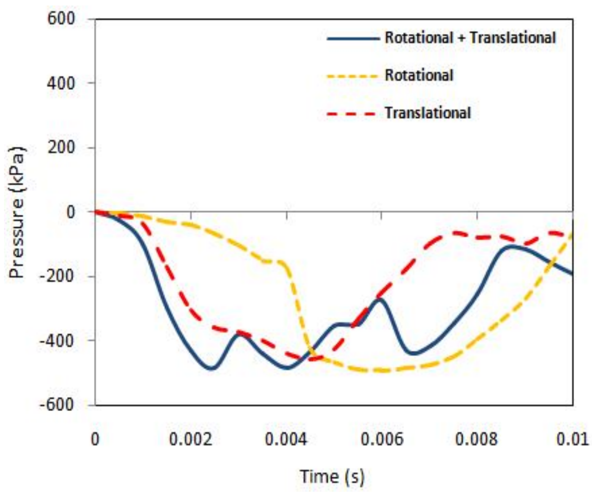

Figure 7. Maximum pressure in brain during crash time

CONCLUSIONS

The brain pressure was validated against intracranial pressure data reported by Nahum et al. Obtained results from simulation correlated well with experimental results. The Acceleration of driver head in side and frontal impact, obtained from accident tests, were applied to the finite element model. Brain injuries caused by both of side and frontal impact was investigated. Focus was aimed on getting brain strain and stress responses and minimum pressure of meningeal membrane to study SDH and DAI Injuries. Computational results indicate that the intensity of SDH and DAI Injuries caused by frontal impact 3.7 and 1.5 times more than side impact respectively.

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