

INFLUENCE OF COMPLICATED HEAD SHAPE ON INTRACRANIAL PRESSURE DISTRIBUTION AT COUP AND CONTECOUP SITES

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Introduction

It has not been clarified the reason why Brain contusion tends to occur mostly at frontal part of a brain in each case that the impact is subjected at frontal or occipital part of the head[1]. Therefore, the purpose of this study is to discuss a mechanism of cerebral contusion occurring at the impact site, called 'coup', and the site opposite the impact called 'contrecoup', from results of both experiments and simulations. Especially, both a high-shape fidelity physical model of a human head and the Finite Element (FE) model were constructed from same medical images of a subject's head. Both high impact simulations in case of possible brain injury and low impact experiments were carried out to investigate intracranial pressure responses.

Construction of a FE and Physical Model

Process for construction of a physical model or FE model of a human head of a specific individual is shown in Fig.1. Firstly, CT and MRI images for a subject were taken at Tsukuba University with its approval from ethical committee. Next, skull and brain part were extracted and laminated three dimensionally to create the 3D polygon models by using Zedview (Lexi Inc.). Finally, the polygon model was converted to IGES surface to construct a FE model by using Hypermesh(Altair.co.,Ltd.), or were exported as STL file format for stereo-lithography system (SOUP II 600GS: CMET Inc.) to construct a 3D head physical model. Head FE model consists of the three layered-skull, face, mandible, CSF (Cerebral Spinal Fluid), meninges, cerebrum, cerebellum, and brainstem. The material characteristics of the model were based on Zhang et al[2]. The physical model consists of the parts of a skull, brain and CSF. The skull model, formed the complicated skull base and asymmetric skull shape accurately, was made of epoxy resin(HS-680: CMET Inc.). The brain part of the physical model including left and right cerebrum and cerebellum made of a silicone gel(KE-1052: Shin-Etsu Chemical Co.,). Water was filled between the skull and brain model to simulate cerebrospinal fluid affecting pressure wave propagation in intracranial space.

Simulation and Experimental Conditions

To investigate possible brain injury cases, high impact simulations in case of frontal or occipital impact were carried out. Acceleration pulse defined as half sinus with amplitude of 1394m/s^2 and duration of 10ms was applied to the skull part, which corresponds to HIC value of 1000. Both the physical model and an 3kg steel impactor with rubber foam embeded on the impact surface were hanged on aluminum frames with wires. The impactor collided with 2m/s at frontal or occipital sites on the skull. Pressure responses in the frontal and occipital region were measured with pressure transducers ((PDB-PA200KPAS: Tokyo Sokki Kenkyujo Co., Ltd.).

Results and Discussion

Figure 2 shows simulation results according to pressure responses obtained at frontal and occipital sites in case of

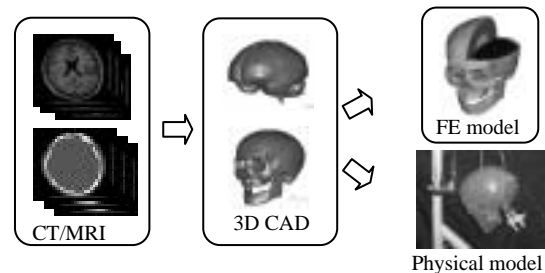


Figure 1 schematic procedure for construction of a head FE and physical model.

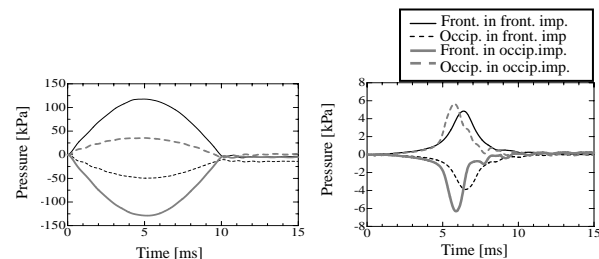


Figure 2 Pressure responses observed in the simulations

Figure 3 Pressure responses observed in the experiments

frontal or occipital impact. In each case of impact direction, positive pressure responses were observed at the site impacted, and negative ones were observed at the opposite side. Moreover, absolute value of pressure responses in frontal part resulted higher than those in occipital one. This phenomenon was observed in not only simulations but also experiments, as shown in Figure 3. And, these phenomenon corresponds with a clinical evidence that coup contusion mainly occurs in frontal impact, whereas contrecoup contusion occurs in occipital impact[1]. This is thought to be caused by dynamic pressure concentration at frontal region of the intracranial space, having a larger curvature than the occipital one.

Conclusion

Both high impact simulations and low impact experiments were carried out to investigate intracranial pressure distribution by using a FE model of a human head with high-shape fidelity or the physical model. The results showed that pressure concentrates at the frontal region with higher curvature more than the occipital region, which corresponds with clinical data.

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References

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