An Investigation of the Effect of Impact Locations on Strain within the Brain

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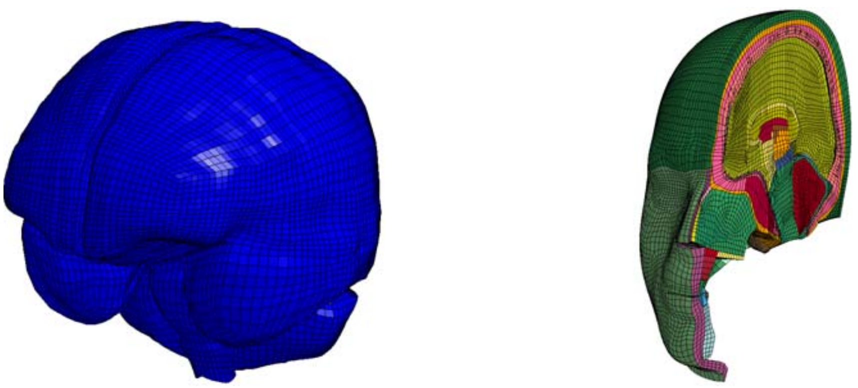
I. INTRODUCTION

Considerable research into mild traumatic brain injury (mTBI) has focused on the investigation of injury criteria that predict when an individual may have sustained a concussion (a form of mTBI). The linear and rotational acceleration that an individual sustains during an impact are commonly used criteria for measuring the risk of concussion [1].The ability to measure the head accelerations sustained during impact has improved with advances in technology, the availability of wearable devices [2-5] and video analysis software [6-7]. This has allowed researchers to develop a number of criteria based on linear and rotational kinematics, this data has also been used as the boundary conditions for computational models. Principal strain has been proposed as one of the causes of diffuse axonal injury [8], strain threshold values have been developed from computer simulation studies of known concussive impacts [6-7][9]. Studies using these models have also assessed the magnitude, shape [10] and duration [11] of the acceleration pulses but there has been little analysis, to date, on how the location and direction of the impact affects different regions of the brain. This study will investigate the relationship between impact, magnitude and direction, and the subsequent variation of strain levels in the central core of the brain. In particular the strain in the Corpus Callosum, Midbrain, Thalamus, and Brain Stem are examined as these regions have been identified as *hot spots* during concussive impacts [6].

II. METHODS

Methodology

A range of linear and rotational accelerations were developed from a series of drop tests using an anthropomorphic head, instrumented with triaxial accelerometer (Kistler 8688A) and a three axis gyroscope (DTS ARS 12k). The headform was dropped from a range of heights and orientations so impacts were sustained to the front, rear and side of the headform. Sinusoidal waveforms based on the maximum amplitudes were calculated using Matlab. The magnitudes ranged from 130g and 6000 rads/s^2 to 30g and 2000 rads/s^2 these are similar to the ranges published in Rugby and American Football studies [5-6]. A finite element model based on a 50th percentile male (GHBMC Model) was used with the explicit solver LS-Dyna. The skull and brain is constructed of 33 parts consisting of 156,093 elements.



(a) (b)

Fig. 1. (a) Brain parts including Cerebellum, Cerebrum, and Brain Stem. (b) Section of the GHBMC Model.

The acceleration profiles where applied to the skull of the model in the coronal and sagittal plane. These planes were selected to create impacts to the front, side and rear of the head.

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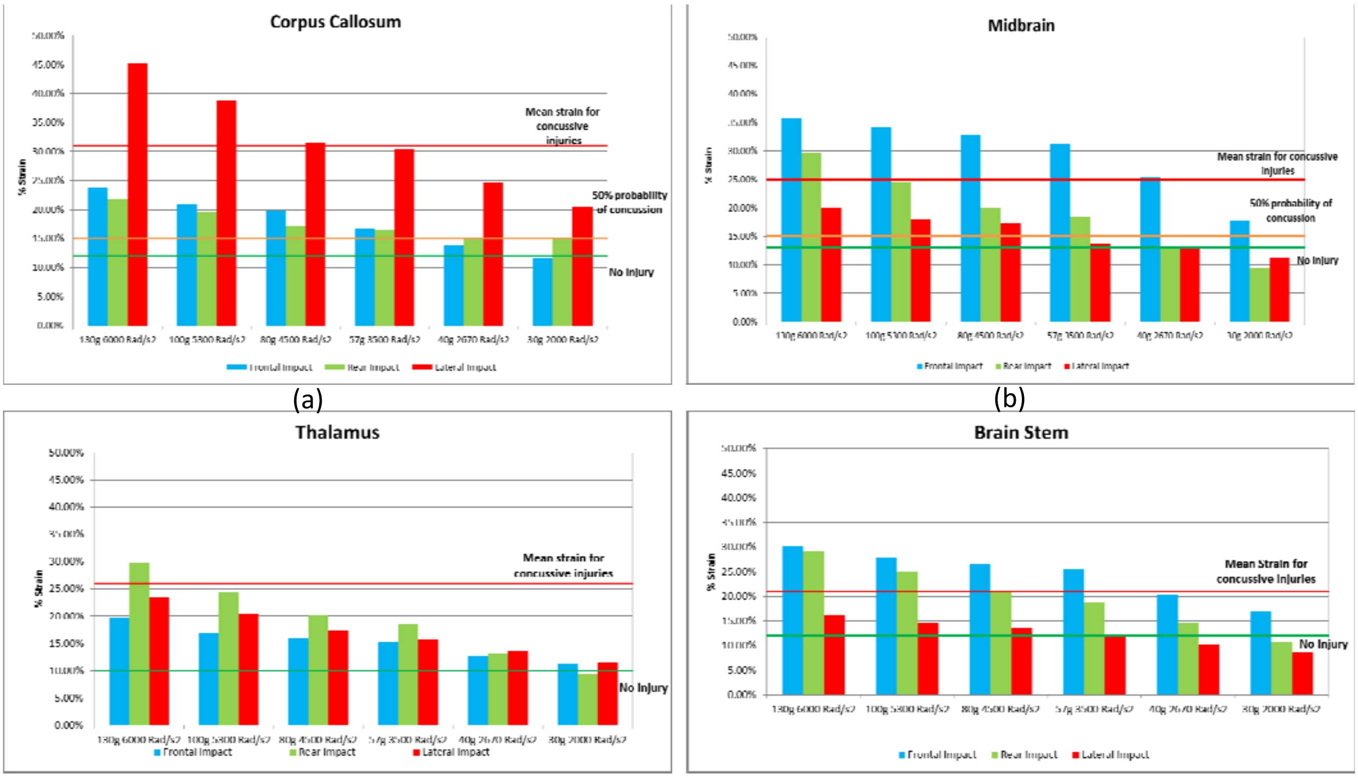
III. RESULTS



(c) (d)

Fig 2. Comparison of strain response versus impact location,(a) Corpus Callosum (b) Midbrain,(c) Thalamus, (d) Brain Stem.

IV. DISCUSSION

The simulation results showed distinct differences in strain depending on the impact location. Principal strain in the Corpus Callosum was significantly higher when the head was impacted from the side causing the head to move in the coronal plane. On average the strain was 43% higher for side impacts when compared to other impact locations. Strain in the Corpus Callosum has been previously shown to relate to changes in the fractional anisotropy and mean diffusivity during concussive injuries [12]. Angular acceleration in the coronal plane has also been shown to have a strong correlation with concussive injuries in un-helmeted sport, this is possibly due to damage to the Corpus Callosum [7]. Impacts to the front of the head caused the Midbrain to undergo more severe strains when compared to other locations. This is significant as studies analysing head impacts in American Football determined that the highest numbers of impacts are sustained to the front of the head[3]. Published threshold values from the reconstruction and simulation of concussive injuries in rugby and Australian rules football indicate that 25% strain in the Midbrain and 31% in the Corpus Callosum would result in a concussion [9]. These concussive strain values compare with previous accident recreation studies in American Football [6] but the published non-injurious strain thresholds vary widely. The Midbrain strain indicates that impacts to the frontal region would have resulted in four concussive injuries, if the same impacts were to the rear of the head only one injury would have occurred, and if to the side there would have been no injury. The Corpus Callosum threshold indicates that three side impacts would result in an injury, whereas if these impacts were to the front or side of the head there would not have been an injury. This study shows that the direction of an impact is very significant in determining the location and the magnitude of the resulting strain and therefore if an injury may have occurred.

I. REFERENCES

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