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NUMERICAL METHODS FOR ACCIDENT RECONSTRUCTION AND BRAIN INJURY EVALUATION: INSIGHTS INTO NEUROENDOCRINE DYSFUNCTIONS

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1 Introduction

Traumatic Brain Injury (TBI) is a critical global health issue, accounting for a significant portion of deaths and disabilities. Annually, an estimated 69 million new cases occur worldwide [1]. TBI results from external physical forces leading to brain dysfunction, typically categorized into primary injuries (immediate mechanical damage) and secondary injuries (biomolecular and physiological changes post-impact) [3]. Symptoms range from headaches and sensory disturbances to long-term cognitive and emotional issues [4]. The Glasgow Coma Scale (GCS) is commonly used to classify TBI severity [7]. Despite its prevalence, most TBI research has focused on male subjects, leaving gaps in understanding female-specific injury mechanisms and subsequent neuroendocrine dysfunctions [11, 22]

2 Methods used in the analysis

The multi-body method models mechanical systems using kinematic chains of rigid bodies, allowing precise motion descriptions [41]. In this project, V-SIM software was used to simulate the dynamics of the accidents, focusing on collisions involving the head [31]. FEM was employed to determine nodal solutions for brain injury scenarios. A detailed Finite Element Head Model (FeFEHM) was used, representing a female subject's head to predict damage to brain structures during impact accurately [44]. HIC and BrIC were utilized to quantify the risk of head injuries. HIC focuses on linear acceleration, while BrIC accounts for rotational acceleration, providing a comprehensive evaluation of injury risks [35, 39].

3 Case Study 1 - Electric Scooter Crash at Crosswalk

This case involved an accident where an electric scooter collided with a car. Using multibody simulation in V-SIM, the accident was reconstructed, focusing on a female subject [45]. The simulation showed that the subject experienced significant linear and rotational accelerations. HIC values suggested minor injuries [36], whereas BrIC values indicated a higher risk of moderate to severe brain injury [39]. FEM analysis showed that the subject did not sustain severe TBI [44], aligning with the HIC findings but suggesting potential neuroendocrine dysfunction due to pituitary gland sensitivity [24].

4 Case Study 2 - Fatal Blunt Impact of Construction Prop:

The second case study involved a workplace accident where a construction worker was struck by a falling metal prop. Multibody simulation estimated the prop's velocity at impact [31]. FEM results revealed high intracranial pressure and von Mises stress, exceeding thresholds for brain contusion, oedema, and hematoma [44, 33]. The findings were consistent with the clinical outcome, indicating severe TBI and highlighting the vulnerability of the pituitary gland to mechanical forces [24, 47].

5 Discussion

The simulations from both case studies underscore the importance of using comprehensive criteria, like HIC and BrIC, to assess TBI. While HIC provided insights into linear head accelerations [35], BrIC indicated the severity of rotational forces, which are critical in understanding TBI outcomes [39]. The FEM analysis further emphasized the role of the pituitary gland in TBI, suggesting potential neuroendocrine dysfunctions post-injury [24]. These findings advocate for a holistic approach in TBI research, incorporating sex-specific models to develop more effective treatment strategies [11, 44].

6 Conclusion

This project demonstrates the utility of numerical methods in accident reconstruction and brain injury evaluation, highlighting the significance of sex-specific research in TBI [44, 28]. The findings advocate for early detection and management of neuroendocrine dysfunctions post-TBI [24, 47]. Future research should aim to refine numerical models, expand impact scenarios, and integrate long-term clinical data to enhance the understanding of TBI mechanisms and improve patient care [27, 31].

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