FINITE ELEMENT HEAD MODEL FOR ASSESSING HEAD IMPACTS AND CONCUSSION IN RUGBY

K. McGill, M. Rutledge, A. Callanan, F. Teixeira-Dias

School of Engineering, University of Edinburgh, United Kingdom

Introduction

Concussion is the most commonly reported injury in Rugby Union, accounting for 20% of all injuries and costing players an average of 19 days off play when sustained [1]. Finite Element Head Models (FEHM) can be a valuable tool in investigating concussion and a number of models are already available [2]. However, these have been developed for a range of applications and it has been shown that both model properties and impact severity strongly affect the FEHM response [3]. This work develops an FEHM specifically targeted at impacts found within rugby, investigating how model properties influence behaviour and suitability.

Methods

A simple finite element model of the human head is developed representing the skull/facial structure, the CSF/meninges system and a homogeneous brain, as seen in Figure 1a. A separate layer is also added in variants of the model between the CSF and skull meshes to represent the Dura matter. Four different viscoelastic material models, based on the following constitutive relation

$$G(t) = G_\infty + (G_0 - G_\infty)^{\beta t} \qquad (1)$$

are applied to the brain creating a parametric test across two sets of shear moduli (G_0 and G_∞) and two decay constants (β), while the remaining FEHM properties remain unchanged. The models are used to simulate two cadaver impacts, reported by Hardy et al. [4], with kinematics similar to typical measurements found in rugby monitoring studies [5]. The simulation results are analysed to consider the effect material changes have on model behaviour and the suitability of the FEHM for research into rugby head impacts. The influence of brain geometry was similarly considered using the model variations seen in Figure 1 to replicate the impact scenarios described above.

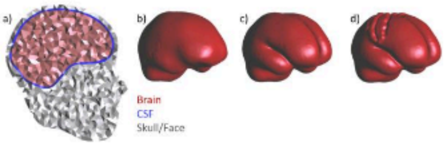

Figure 1: (a) Basic model structure, solid tetrahedral mesh, lateral view cut through mid-sagittal plane. (b) Basic model brain surface geometry. (c) Surface geometry including longitudinal and lateral fissures (d) Surface geometry with fissures and major sulci *included.*

Results and Discussion

Simulation results show both the shear moduli and decay behaviour influence the response of the FEHM to impact. Although reducing the shear moduli by 50% only changes the average peak displacement magnitudes by 5%, the decay constant still significantly affects the impact response. As illustrated in Figure 2, reducing β has minimal effect on the initial motion of the brain compared to the skull, but increases the rate and extent of the rebound/return response. Subsequent motions are therefore better represented which is thought to be particularly significant for rugby-type impacts where collisions can involve multiple strikers and complex motions.

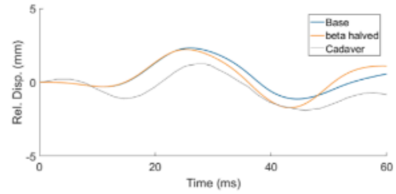

Figure 2: Displacement response of a sample point in the brain against time for the base model and the reduced decay constant material, compared to the original cadaver data [4].

Initial results show that geometric features also affect model behaviour, creating focal points for stresses and strains. Further investigations into this are ongoing. The basic brain model with material properties of G_0 = 10 kPa, G_∞ = 2 kPa and β = 40 s^{-1} leads to an average peak displacement response within 10% of the cadaver data for an impact with peak accelerations of 22g and 1896 rad/s^2 [4], and a similar shaped response, indicating a valid representation. The proposed FEHM is highly computationally cost-effective, providing a useful tool for investigations into the intra-cranial mechanics of rugby head impacts.

References

1. England Professional Rugby Injury Surveillance Project, 2017-2018 Season Report, 2019.
2. Tse et al., Am J Eng, Tech & Soc, 1(5):28-52, 2015.
3. Zhao et al., J Mech Behaviour Bio Mats, 80:222-234, 2018.
4. Hardy et al., Stapp Car Crash J, 45:337-368, 2001.
5. King et al., Am J Sports Med, 43:614-624, 2014.

Acknowledgements

This work was supported by the Engineering and Physical Sciences Research Council (EPSRC) [grant number EP/N509644/1].