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ACCURACY AND EFFICIENCY OF FINITE ELEMENT HEAD MODELS: THE ROLE OF FINITE ELEMENT FORMULATION AND MATERIAL LAWS

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1 INTRODUCTION

Traumatic brain injury (TBI) represents a major public health concern due to its high mortality and disability rates. Finite element head models (FEHM) are crucial tools for studying brain mechanics under impact scenarios. This study compares different finite element formulations and material models to optimize both accuracy and computational efficiency in head trauma simulations [1].

2 METHODS

2.1 FINITE ELEMENT MODELING

Two distinct finite element formulations were applied to improve the head model: one using second-order tetrahedral elements, and another employing first-order hexahedral elements. The models were evaluated in terms of computational cost and their ability to replicate experimental data [2].

2.2 BRAIN TISSUE MATERIAL MODELS

Two different material models were implemented in the study: the Rashid et al. model, based on hyper-viscoelastic properties [3], and the more recent Menichetti et al. characterization, using a neo-Hookean viscoelastic assumption [4]. Both models were tested under rotational loading to assess their suitability for traumatic brain injury simulations.

2.3 BRAIN TISSUE MATERIAL MODELS

The FEHM was validated against well-established experimental results from the Nahum et al. (intracranial pressure) [5] and Hardy et al. (brain displacement) [6] experiments. These experiments provided key insights into the performance of the models and helped identify the most efficient and accurate approach. Figure 1 highlights the brain geometry and mesh properties used in the simulations.

3 FIGURES AND TABLES

Figure 1 presents the hexahedral mesh generated for the brain model, which was essential in improving computational performance. As shown in Figure 1 of the original article, the brain mesh highlights critical regions of interest, allowing for more accurate predictions of brain behavior during trauma simulations.

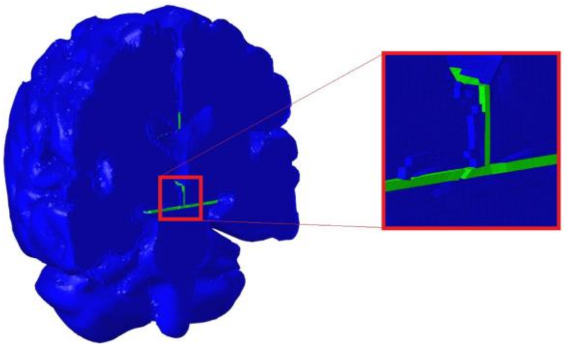

Figure 1 – Highlight on connection areas in the brain to obtain the full brain geometry [7].

Additionally, Table 1 compares the computational efficiency between different element types used in the study. As seen in Table 1 below, first-order hexahedral elements, especially in Model 2 , significantly reduced CPU time compared to tetrahedral elements [2].

Table 1 - Comparison between different models regarding simulation time [7].

Model	Number of elements	Number of Nodes	Cpu Time (s)
Fernandes et al. (C3D10M)	836,328	1,175,577	41,720
Model 1 (C3D8R)	1,367,346	1,462,952	49,479
Model 2 (C3D8R)	720,288	875,358	18,608

This study concludes that first-order hexahedral elements, coupled with advanced integration techniques, provide the best balance between computational efficiency and accuracy for FEHMs.

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