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PRESSURE RESPONSE ANALYSIS IN HEAD INJURY

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ABSTRACT

A new approach to generating physical and numerical models of the human head is presented and we aim to investigate whether it is possible to predict the response of the head for a particular impact scenario using these modelling techniques. Finite element (FE) and rapid prototyped (RP) models were generated from the conversion of 3D image data. Both the numerical and physical models were used to validate an approximate analytical model based on full 3D elasticity equations as developed by one of the authors. Good agreement was observed between the three modelling techniques and large transient pressure amplification at the site of impact was observed for impacts of low duration. In this paper, analytical, numerical and experimental models were used in parallel to explore the pressure response of the human head as a result of low velocity impact.

High resolution T1-weighted whole head MRI scans of normal volunteer young males were obtained in vivo (see Figure 1c). Three-dimensional patient specific finite element models were generated automatically from the 3D data sets using ScanIP and +ScanFE software [1]. The models were generated using a technique adapted from the marching cubes approach which automates the generation of meshes based on 3D scan data and allows for a number of different structures (e.g. skull, scalp, brain) to be meshed simultaneously.

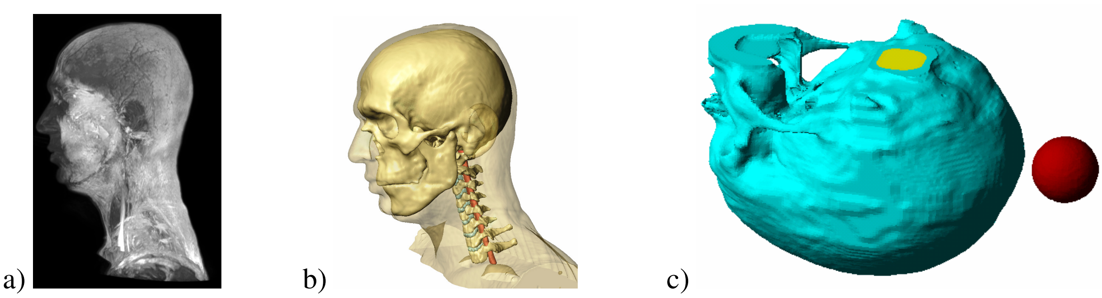

Figure 1: a) MRI scan, b) Rendered model of whole head, c) final LS-DYNA finite element model of fluid filled skull and impacting projectile.

The resulting models are geometrically very accurate (see Figure 1b and c) and were used to explore the intra-cranial response to impact. A rapid prototyped model of the finite element mesh was also generated in parallel using +ScanFE to provide experimental corroboration for some of the finite element results obtained. Previously developed approximate closed form analytical expressions were also used to provide additional comparison results.

The finite element models generated were solved using LS Dyna [2]. Low velocity (2 ms^{-1}) impacts to the back of the head (occipital region) with spherical balls of 4 cm radius were simulated. The mass of the ball was varied between 0.01 kg and 100 kg by varying its density and the Young's modulus of the ball was kept constant E = 13.8 GPa (for skull bone). The skull was modelled filled with inviscid fluid with properties of water (Bulk modulus B = 2.18 GPa and density 1000 kg/m^3). As the mass of the impactor decreases below a threshold value a dynamic/transient response is observed with a resultant pressure distribution which is qualitatively different and which varies throughout the impact. At early stages after contact a high pressure transient is observed under the site of impact which is followed by a negative pressure transient and then a high positive pressure transient as shown in Figure 2.

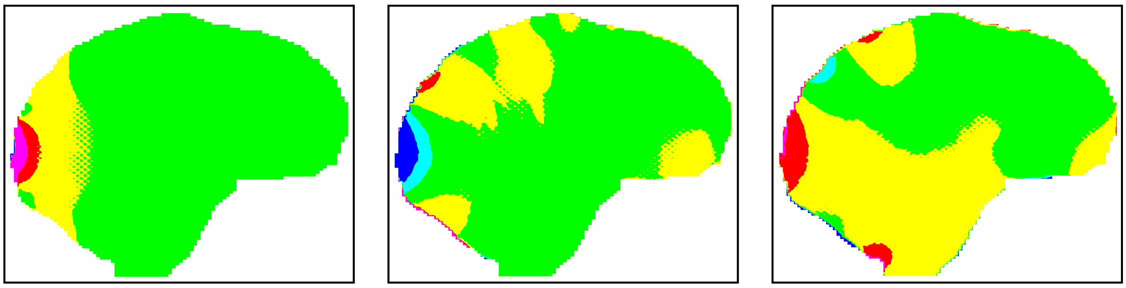

Figure 2: Intra-cranial pressure response (red positive pressure, blue negative pressure) during impact.

Although the study was based on simplified models, the three-way validation provides confidence in results which might be obtained from models with increased bio-fidelity. Beyond its significance in the area of head impact biomechanics, the study has demonstrated that numerical models generated from 3D medical data in parallel with exact physical replica models can be used effectively to simulate physical processes. This is particularly useful when considering the risks, difficulties and ethical issues involved when using cadavers.

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