THE ANALYSIS OF PRESSURE RESPONSE IN HEAD INJURY: A VALIDATION STUDY

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INTRODUCTION

The study of head injuries is of obvious importance with approximately 1 million head injury cases reported in the UK each year. 60% of all such injuries are caused by motor vehicle accidents but even a simple fall or blow to the head can result in serious damage. In the present study a new approach to generating physical and numerical models of the human head is presented. We aim to investigate whether it is possible to predict the response of the head for a particular impact scenario using these modelling techniques. Firstly, by predicting the global response characteristics of the head such as the duration of impact (T_p) and secondly, by studying the pressure response of the intra-cranial tissues. An approximate analytical model based on full 3D elasticity equations was developed by one of the authors and implicit analytical expressions proposed to predict the response to blunt impact [1]. The model is based on significant geometric and material simplifications and so in order to test the validity of the assumptions on which the analytical model is based, experimental and numerical models were developed for comparison. The predictions from this model were validated using finite element (FE) and rapid prototyped (RP) models generated from MRI scans obtained *in vivo*. Both the numerical and physical models were generated from the conversion of 3D image data using an in-house software package, Scan FE/IP™.

METHODS

The analytical model, presents a blunt direct impact with a solid, elastic spherical shell of isotropic homogeneous linear elastic material properties and filled with an inviscid compressible fluid. Even for this simplified case the response is dependent on a number of material and geometric parameters including the shell thickness (h), radius of curvature (R), Young's Modulus (E) and Poisson's Ratio (ν).

MRI scan data of an adult male was obtained and an STL file was created using an in-house software package, Scan IP™ [2]. The STL file was used to manufacture a 3D, patient specific, rapid prototyped (RP) model of the human skull using Duraform™ Polyamide, a material used typically for strong, functional applications. A 3D FE mesh of the skull and intra-cranial contents was also generated from the same MRI dataset, using the in-house software package ScanFE™. The FE model consisted of over 200,000 hexahedral and tetrahedral elements and a sliding contact surface was assumed at the brain-skull interface. The material properties for the RP material and a steel impactor were incorporated into the model and LS-DYNA3D was used to perform the numerical solutions.

RESULTS AND DISCUSSION

The authors have previously reported [3] on the excellent agreement between the three modelling modalities for the measurement of global response characteristics such as impact duration, acceleration and peak force. The emphasis of this current paper is, therefore, on the pressure response of the intracranial fluid. Impacts of low duration, for example, have often been associated with increasingly large pressure transients as illustrated in Figure 1 and carry significant implications for the occurrence of brain tissue damage.

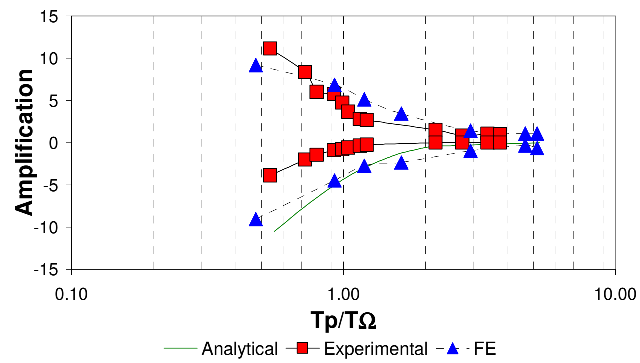

Figure 1. Peak positive and negative pressure values as obtained using the three modelling methods

The remarkable conformity between the three modelling techniques is clear and corroborates the prediction of increasing pressure amplification at the site of impact, for impacts of low duration.

CONCLUSIONS

In addition to the obvious significance in the area of head injury biomechanics, the study demonstrates how numerical and biofidelic physical models, can be generated from 3D medical imaging modalities and used effectively to simulate physical processes.

REFERENCES

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