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Head Impact Biomechanics Simulations: A Forensic Tool for Reconstructing Head Injury?

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Establishing the cause of death in forensic investigations can be facilitated by in-depth knowledge of the mechanics of skull fracture and associated lesions to intracranial tissue. Deformation of the skull arising from mechanical impact can lead directly to various soft tissue brain injuries. Advanced simulation techniques, as used in aerospace design and automotive safety, can usefully serve to quantify levels of force associated with skull fracture and with levels of strain or stress associated with brain trauma. Such simulations require physical material failure data so as to ensure predictions are accurate both in relative terms and in absolute quantitative terms. Computer simulations based on multibody dynamics and the finite element method can be used to reconstruct the mechanics of head injury in order to establish the causes of occurrences of skull fracture and TBI.

Introduction

Methods

Multibody dynamics simulations provide envelopes of velocity, acceleration and force as experienced by a victim’s heads during an impact event. These predicted velocity-time profiles are, in turn, used as prescribed input conditions for three-dimensional finite element models of the human head to predict levels of metrics including stress, strain, strain rate, and energy throughout the brain and skull. These various mechanical measurements are then compared against documented levels associated with particular lesions to infer which sequence of events would most plausibly lead to the occurrence of any observed injuries.

Conclusions

In order for such tools to benefit legal medicine practitioners, it is important to realise the limitations of such simulations tools. These include the level of anatomical detail associated with such models, and uncertainty in hypothesising initial conditions such as orientation and velocity of a body prior to head impact. Nevertheless, it is proposed that this engineering approach could assist in reconstructing forensic investigations.

Forensic information can give indications of possible likely situations which led to injury

Eg. Height of fall, direction of fall, object used to inflict injury etc.

Fig. 1. An example of a Madymo simulation reconstructing a boy’s fall at a water fountain


Fig. 2. An example of the linear acceleration of the head during a boy’s fall at a water fountain (sensitivity analysis of the initial conditions)


Fig. 3. The UCD finite element head model (i) the cranial vault (ii) the whole head


Fig. 4. Prediction of site of skull fracture via computer simulation.

Fig. 4. Prediction of site of skull fracture via computer simulation.