APPRAISAL OF TWO REPORTS ON MATHEMATICAL ANALYSES OF HEAD INJURY

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OF HEAD INJURY

Two papers concerned with mathematical modeling of head injury dynamics have been submitted for biomedical appraisal. [1,2] Both reports define mathematical models of pressure-acceleration dynamics inside the skull during impact events by assuming that:

      (1) The skull is a thin, isotropic, homogenous, elastic, spherical shell.

      (2) The brain is an ideal compressible fluid.

      (3) All impact loading is axisymmetric.

Reference 1 considers the cavitation hypothesis of brain damage for head impact, and assumes a specific impacting load in addition to appropriate constants to define the primary assumptions noted above. The evolved model uses extensional shell theory and coupled differential equations solved by finite difference techniques to define the time-variable pressure field inside the shell. The authors feel that their model supports the cavitation hypothesis because the model indicates transient zones of negative pressure at the impact pole and the opposite (contrecoup) pole at different times after the start of impact. The authors acknowledge that their work does not verify the cavitation hypothesis and does not rule out other mechanisms of brain damage from non-penetrating impact.

Reference 2 considers the pressure effects of various impacting force waveforms in relation to the previously proposed General Motors' Severity Index. [2,3] The Severity Index is an nth power of impact acceleration, or force, integrated with respect to time for the duration of impact. Brief positive pulses of impact force in square, triangular, half sine and eccentric waveforms were defined so as to have identical Severity Index values, indicating that all the pulses had roughly similar products of average amplitude times duration.

The four pulses were used as inputs to the mathematic model described above, and the model showed that the pressure dynamics of the physical system would be "nearly the same" for all pulses tested. From this finding, the authors conclude, "These results indicate that the General Motors' Severity Index is a useful means of determining the severity of vastly different pulses applied to linear systems." The authors go on to caution, however, that "these results do not necessarily indicate that the Severity Index is a valid means of predicting the hazard or injury potential of different pulses. An evaluation such as that must be accomplished by further experimentation and clinical investigations . . . ."

Comments

1. The two papers appear to be ingenious examples of analytical modeling technique applied to the complex dynamics of fluid filled spherical shells subjected to impact.

2. Reference 1 shows that, under the assumed conditions, transient negative pressures will occur at both the impact and contre-coup poles of the impacted shell.

3. Reference 2 shows that, under the assumed conditions, similar impact forces (differing mainly in waveform) selected to have identical General Motors' Severity Indices will cause similar dynamic pressure patterns.

4. It is unfortunate that neither report mentions the detailed results of Lindgren who measured the dynamic pressure patterns of fluid filled spheres and human cadaver heads subjected to impact. [4] Lindgren recorded negative pressures at both the contrecoup and impact poles, as well as similar pressure patterns arising from similar impact forces.

5. With regard to the concussion threshold problem, it would be extremely interesting to see the powerful analytic techniques of Reference 1 and 2 used in a retrospective search for a useful common denominator in a large number of the published investigations on experimental concussion.

REFERENCES

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4. Lindgren, S.O., "Experimental Studies of Mechanical Effects in Head Injury," _Acta Chirurgica Scandinavica_, Supplement 360, 1966, pp 1-100. (UNCL)