HEAD INJURY NEEDS LIFE SAVING CARE – AN ANALYTICAL STUDY

[1]Saktipada Nanda [2]Biswadip Basu Mallik [3*]Shubho Das [4]Srishti Kumari [5]C.Lisa [5]Pritam Sanyal

[1]Department of ECE, Institute of Engineering & Management, Salt Lake Electronics Complex, Kolkata-700091.

[2]Department of Basic Science & Humanities, Institute of Engineering & Management, Salt Lake Electronics Complex, Kolkata-700091.

[3]Department of CSE, Institute of Engineering & Management, Salt Lake Electronics Complex, Kolkata-700091.

[4]Department of IT, Institute of Engineering & Management, Salt Lake Electronics Complex, Kolkata-700091.

[5]Department of EE, Institute of Engineering & Management, Salt Lake Electronics Complex, Kolkata-700091.

**Corresponding Author: shubhodas2000@gmail.com*

Abstract

The cause, effect and remedial measures of head injury is presented in a capsule form. The position of Brain is in the central location of the cranium and is well protected by nature with some layers surrounding it. Brain is the controlling organ of the human body, so its damage or even injury has gained attention among the scientists and physicians. As nobody will allow his/her head for investigation so modelling is a must for study of brain injury problems. The analytical study may give some idea on the location and degree of brain injury.

Keywords*: Skull, Scalp, Diploë, Cranium, CSF, Brain Injury*

1. INTRODUCTION

A human head is the part of an organism which usually includes organs like the ears, brain, forehead, cheeks, chin, eyes, nose, and mouth, each of which aid in various sensory functions such as sight, hearing, smell and taste respectively. Some very simple animals may not have a head, but many bilaterally symmetric forms do, regardless of size. Heads develop in animals by an evolutionary trend known as cephalization. In bilaterally symmetrical animals, nervous tissues concentrate at the interior region, forming structures responsible for information processing. Through biological evolution, sense organs and feeding structures also concentrate into the anterior region; these collectively form the head.

2. COMPARATIVE IMPORTANCE OF BRAIN TO OTHER ORGANS OF THE HUMAN BODY

Under normal physiological condition, the reactions of the organisms to various stimuli (excitements) are transmitted by the sensory nerve to the brain for analysis and synthesis of that simulation. Then the finest adjustment and integration of the activity of all systems, organs and tissues follows on the basis of that result. As an example, when a mosquito simply sits or bites any point of the body, the information is instantaneously transmitted to the brain through the sensory nerves. The brain analyses the signal and commands the appropriate organ (hand or leg) to take necessary action (strike or kill the mosquito).When a human body is infected with virus or bacteria, the brain commands the temperature control system of the body to increase the temperature of the body so that those parasites may be killed through the natural process. Broadly speaking, *brain* controls all activities of a living human organism.

3. LOCATION OF BRAIN IN THE CRANIAL VAULT (HEAD) AND ITS NATURAL PROTECTION

The basic components of the human head that protects the brain from external hit are: the scalp, the skull, the diploe, the cerebrospinal fluid (CSF) - the brain being at the central location.

(i) *Scalp*: It is the outermost cerebral covering varying in thickness from 6.4 mm to 12.7 mm. It appears to have a leathery consistency and the outer surface is skin with hairy covering. With the use of its elastic property and hairy covering it initially protects the brain from excess heat, humidity and mild external blow.

(ii) *Skull*: It completely encloses the brain except for the spinal cord opening. It is placed on the upper end of the vertebral column and acts as the bony protection of the brain. It is almost spheroidal in shape and has two fold structure- the cranium and the face. The thickness of the skull varies from 9.6 mm to 12.7 mm and moves like a rigid body.

(iii) *Diplo*ë: A highly vesicular layer that separates the outer and the inner tables of eight solid bones forming the skull. It is a porous layer resembling a honeycomb and the fluid substances filling the cavities are almost Newtonian viscous.

(iv) *Cerebrospinal Fluid (CSF)*: The CSF acts as a cushion between the hard cranium and the soft and delicate brain matters. The fluid is pressed out when intracranial pressure tends to rise and more fluid is retained when the pressure tends to fall. Thus mechanical injury to the brain is prevented by evenly distributing the change of pressure, if any. It is clear, colourless, nearly Newtonian fluid with a specific gravity of 1.004 – 1.007 containing protein, glucose and inorganic salts (NaCl, KCl etc.)

(v) Brain: The egg shaped brain is somewhat like a gel, although not as stiff. Its principal components are water (78%), esters (12%), protein (8%) and small amounts of carbohydrates,

inorganic salts & soluble organic substances. It is divided texturally into white and grey matter, the density being slightly more than water. The weight of an adult human brain ranges from 1100 – 1700 gms and the capacity is 1200 cc approximately. The length and transverse diameter are about 165 mm and 140 mm respectively. Experimental works on a variety of brain specimens establishes that brain exhibits viscoelastic behaviour (damping property).

4. BRAIN DAMAGES-ITS CAUSES

It is an established fact that cranio-cerebral trauma accounts for most of the sudden deaths due to vehicular accidents, soccer victims in the football ground and diseases related to ischemic and cardiac problems. So, the problems of brain injury should deserve scientific attention in both diagnosis and treatment of such trauma and in the design and construction of protective environments. Based on theoretical as well as experimental investigations on inter cranial trauma, the following three hypotheses are proposed to explain mechanical brain damage:

(a)*Cavitation Hypothesis*: Following a direct impact or an impulsive load (like a projectile) on the head, an area of low pressure is developed within the brain material leading to extrusion of the tissues or high concentration of shear stress in the brain stem.

(b)*Whiplash Hypothesis*: The fracture or dislocation of the cervical spine may occur when the head is fixed but the body moves forward or backward and that may lead to concussion. It appears probable that such fractures may occur in vehicular accidents when the head is fixed but is subjected to severe hyper extension while the body moves forward.

(c) *Rotation Hypothesis*: High shear strains may develop due to rotational acceleration of the head leading to rupture of the tethering cerebral blood vessels, neo and subcortical tissues. The injury in the brain cannot be detected externally though rotational acceleration dominates translational or linear acceleration in producing maximum shear tress in the brain region leading to concussion.

5. ROLE OF MATHEMATICAL MODELS IN STUDY OF BRAIN INJURY PROBLEMS:

Mathematical models play an important role in the study of Brain Injury Problems due to the following reasons:

(i) It is not possible to conduct experiments (theoretical or experimental) on human head.

(ii) Nobody will allow investigation on his head.

(iii) As human brain is much superior to other animals, the data available for subhuman primates cannot be readily accepted for the human system.

(iv) The properties exhibited by a living brain stops just after the brain death.

(v) The geometry of the cranial vault does not resemble to any standard geometric structure.

(vi) No two persons can be found whose brain geometry are exactly similar.

So, more and more sophisticated mathematical models are being developed or old models are being improved for studies pertaining to the mechanics of human cranial system.

It is an accepted fact that physical models based on experimental investigation can be constructed more realistically than the mathematical models based on theoretical analysis. But the applicability of the physical ones has got limitations due to the difficulties faced while taking necessary measurements and collecting the necessary data. On the other hand, mathematical models based on simple geometry (principally spherical and cylindrical) can be effectively used to explore a variety of cases related to brain injury over a short period of time.

6. STUDY ON BRAIN INJURY DUE TO AN INPUT ROTATIONAL ACCELERATION ON SKULL-BRAIN SYSTEM OF THE HUMAN HEAD

It is now established that lifesaving medicines applied for treatment of many fatal diseases like cancer, diabetes, heart failure damage some other organs /cells of the human body.

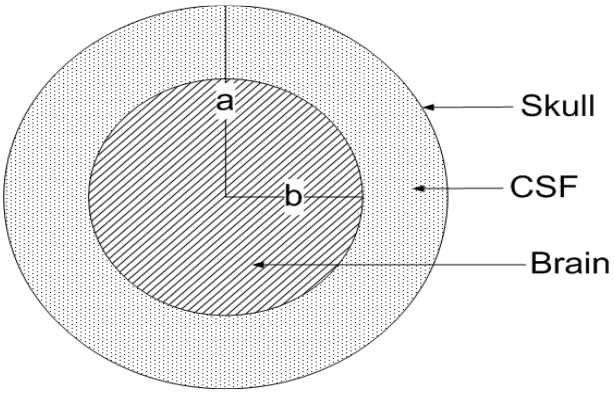

Figure : Simplified model of the composite structure of the Brain, the CSF and the Skull

Fig.1 The motion of the brain matter and the CSF are governed by two partial differential equations

$$\frac{\rho_1}{\mu_1}\frac{\partial^2 w}{\partial t^2} = \frac{1}{r}\left(r\frac{\partial^2 w}{\partial r^2} + 2\frac{\partial w}{\partial r} + \frac{1}{r}\frac{\partial^2 w}{\partial \theta^2} - \frac{w}{r}\frac{1}{\sin^2\theta} + \frac{\cot\theta}{r}\frac{\partial w}{\partial \theta}\right) ----(i)$$

$$\frac{1}{c_2{}^2}\frac{\partial^2 \phi_1}{\partial t^2} = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial \phi_1}{\partial r}\right) + \frac{1}{r^2\sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial \phi_1}{\partial \theta}\right) --------(ii)$$

Let the head is subjected to an input angular acceleration given by

$$\ddot{\phi} = \begin{cases} B\sin\Omega t, & 0 < t < \dfrac{\pi}{\Omega} \\ 0, & t > \dfrac{\pi}{\Omega} \end{cases} \text{---------}(iii)$$

Ω is the angular frequency at r=a (outermost surface).

At r=b (the interface between the brain and the CSF), $\dfrac{\partial w}{\partial t} = \dfrac{1}{r}\dfrac{\partial \phi_1}{\partial \theta}$ ----(iv)

and $\tau_{r\theta}^{\ br} = \tau_{r\theta}^{\ CSF}$ -----(v)

where $\tau_{r\theta}$ denotes the shear stress and the superscripts 'br' and 'CSF' represent respectively the brain and CSF regions. For the computational purpose, the following values of different material constants and other parameters have been used:
$a = 0.0774m \;\; b = 0.0762m \;\; \rho_1 = 0.9774\times10^3 kg/m^3 \;\; \rho_2 = 0.998\times10^3 kg/m^3$

$1/J = \left(0.1379\times10^5 + 0.0345\times10^3\right)N/m^2 \;\; c_2 = 145.03m/s \;\; \mu_2 = 8.98kg/ms$

On the basis of the data, the shear strain in various locations of the brain is computed. It will throw light on the location and degree of the brain damage.

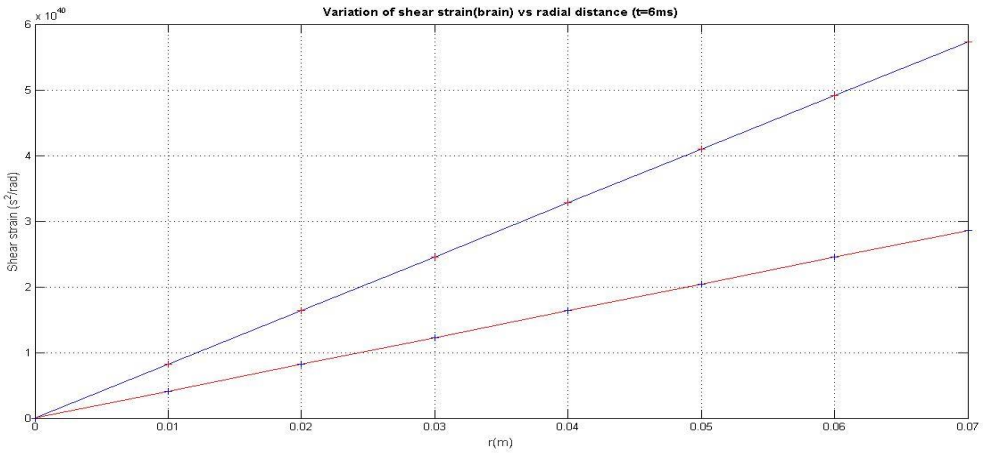

Fig. 2 The strain is found to increase along the radial distance.

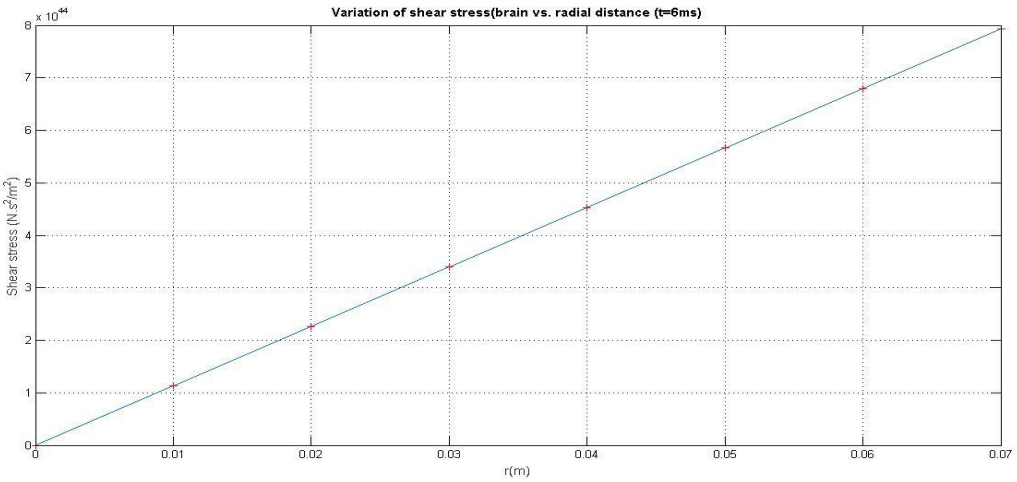

Fig. 3

7. HOW TO REDUCE THE DEGREE OF DAMAGE IN THE BRAIN DUE TO INJURY?

The main focus is to prevent or in extreme case to treat the MTBI (Mild Traumatic Brain Injury) victims which are very regular in vehicular accidents or in football games. The results obtained in the analysis may be used to study the bio mechanical conditions for concussion. Also the methodology may provide a solid foundation in the design and construction of improved model of the protective devices like Helmets, Air cushion bags etc.

8. CONCLUSION:

A number of interesting conclusions can be drawn from the Article:
(i) An analytical model may provide an enhanced understanding of the key parameters that control the system.

(ii) The consideration of the three layered solid structure provides confidence in the analysis.

(ii) More refined result may be obtained due to the consideration of the porosity of the skull.

(iv) The results that may be obtained through this analysis may be used in the design and construction of the protective gears for the human head.

REFERENCES

1. Goldsmith W, (1972) - Biomechanics -its foundation and objectives.

2. S. P. Nanda- A forced vibration analysis for the human cranial system- J. Math. Phy. Sc., , (1989), **23(2)**, pg 171 - 184.

3. S.P. Nanda: Brain Injury due to an input angular acceleration of the head - an analytical study- J. Mathl. Comp.Modelling (1990), **13(1)**, pg 1-6.

4. Sosin D. M. *et. al.* (1995) Trends in death due to traumatic brain injury.

5.Saktipada Nanda, B. Basu Mallik & Paulami Basu Mallik: An analytical study on the dynamic response of a fluid-filled spherical shell subjected to a local radial and axi-symmetric load, American Journal of Electronics & Communication, (2016) **Vol III(1)**, page 8 - 14.

6. Saktipada Nanda *et. al.*: An analytical study on Brain Injury due to an input rotational acceleration on skull-brain system of the Human head. J. of Chemical, Biological and Physical Sciences, Sec C, (2017), 7(1), pg 38-48.