Optic nerve sheath bleeding driven by rapid cerebrospinal fluid pressure amplification

Peter S. Stewart[1], Oliver E. Jensen[2] and Richard Bonshek[3]

[1] School of Mathematics and Statistics, University of Glasgow.
peter.stewart@glasgow.ac.uk
[2] School of Mathematics, University of Manchester. oliver.jensen@manchester.ac.uk
[3] Manchester Royal Eye Hospital. r.e.bonshek@manchester.ac.uk

Keywords: *retinal haemorrhage, shock dynamics, optic nerve*

One of the indicators of non-accidental head injury in infants is subdural haemorrhage (bleeding) along the optic nerve, especially at the distal end closest to the eye. We propose a new mechanism to explain this observation, which is tested using a mathematical model.

The optic nerve is a dense collection of dendrite fibres which connect the eye to the brain. This nerve is surrounded by a sheath which contains a thin layer of cerebrospinal fluid (CSF) which also surrounds the brain. Hence, the CSF pressure in the optic nerve sheath will be directly influenced by pressure changes in the brain [1].

We examine the flow of CSF along the optic nerve sheath driven by a sudden large pressure in the brain (mimicking a traumatic injury). We predict the temporal and spatial evolution of the CSF flow speed and pressure, as well as the optic nerve sheath thickness, using a spatially one-dimensional model.

The model predicts that the pressure perturbation triggers a propagating pressure wave along the nerve towards the eye, and for sufficiently large perturbations this wave can steepen to form an elastic jump (shock wave). We use a sophisticated numerical method to track the propagation of these shock waves along the vessel. Since the optic nerve sheath is closed-ended where it meets the eye, we show that this pressure wave is then reflected back towards the brain. This wave reflection results in a significant amplification of the CSF pressure localised to region close to the eye, in some cases almost ten times larger than the corresponding CSF pressure at the inlet to the nerve.

We hypothesise that this dramatic increase in CSF pressure, and accompanying rapid expansion of the sheath close to the eye, can lead to rupture of blood vessels spanning across the optic nerve and subsequent subdural bleeding at the distal end [2].

REFERENCES

[1] S. Singh and R. Dass, The central artery of the retina I. Origin and course, *Br. J. Ophthalmol.*, Vol. **44**(4),193, 1960.

[2] R. E. Bonshek *et al.*, Understanding patterns of haemorrhage in the eye, 2014 Mathematics in Medicine Study group, www.nc3rs.org.uk