THE HYDROMECHANICS OF HYDROCEPHALUS: STEADY-STATE SOLUTIONS FOR CYLINDRICAL GEOMETRY

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Hydrocephalus is a state in which the circulation of cerebrospinal fluid is disturbed. This fluid, produced within the brain at a constant rate, moves through internal cavities in it (ventricles), then exits through passages so that it may be absorbed by the surrounding membranes (meninges). Failure of fluid to move properly through these passages results in the distention of the passages and the ventricles. Ultimately, this distention causes large displacements and distortion of brain tissue as well as an increase of fluid in the extracellular space of the brain (edema). We use a two-phase model of fluid-saturated material to simulate the steady state of the hydrocephalic brain. Analytic solutions for the displacement of brain tissue and the distribution of edema for the annular regions of an idealized cylindrical geometry and small-strain theory are found. The solutions are used for a large-deformation analysis by superposition of the responses obtained for incrementally increasing loading. The effects of structural and hydraulic differences of white and gray brain matter, and the ependymal lining surrounding the ventricles, are examined. The results reproduce the characteristic steady-state distribution of edema seen in hydrocephalus, and are compared with experiment. © 1997 Society for Mathematical Biology
1. Introduction. Obstructive hydrocephalus is a disease caused by conditions that obstruct the outflow of cerebrospinal fluid (CSF) from the brain ventricles. It is characterized by significant changes in the water content and transport in the brain. These changes are always accompanied by brain deformation, often large. The purpose of this work is to develop a mathematical model which reproduces both the hydraulic and mechanical changes that occur in a hydrocephalic brain.

The brain ventricles, marked "V" in Fig. 1, are a series of connected cavities in the brain, filled with CSF. CSF, which is mainly composed of water, is largely produced (about 80%) by the choroid plexus that lines the interior of the ventricular walls (Rekate and Olivero, 1990). From there, the CSF flows through the fourth ventricle into the (subarachnoid) space around the spinal cord and the brain, and is absorbed into the venous blood.

![Figure 1. Schematic of the brain. (a) Normal brain; (b) hydrocephalic brain.](image)