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Concerning the article by Magram G et al. Pediatr Neurosurg 1997;26:236-246

The CSF Accumulator: Its Role in the Central Nervous System and Implications for Advancing Hydrocephalus Shunt Technology

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Dear Sir,

This letter is in response to a legitimate question raised by one of the reviewers regarding the definition of an accumulator and its relationship to energy, pressure and volume. The paper addresses these terms in a general qualitative fashion, and to someone mathematically inclined these definitions might lack the desired rigor. The definition of an accumulator as a device for storing and releasing energy I believe is generally accepted, as well as the use of the term capacitance as a measure of the ability to accumulate energy in an storage cell (an electrical model) and the use of term compliance as a measure of the ability to store energy in a fluid model (in a mechanical model the reciprocal of the spring constant is analogous to compliance) [1]. From a qualitative standpoint energy can be expressed as force times distance and pressure can be expressed as force divided by area. Alternatively, a force can be expressed as the pressure times the area. Substituting this latter expression in the one for energy gives the expression that energy is related to the pressure times the area times the distance. Since area times distance expresses a volume the energy in a device used to store fluid can be thought of as being related to the pressure times the volume. Similarly, compliance can be expressed as volume divided by pressure, so to see how compliance is related to the ability to accumulate or store energy then one can substitute the term pressure in the compliance relationship for pressure’s expression in terms of energy (energy divided by volume since energy is related to pressure times volume) and this yields the statement that the ability to store energy in a fluid model (compliance) is related to the volume squared divided by the energy. Expressing volume as energy divided by pressure yields the statement that the ability to store energy (compliance) is related to the energy divided by the pressure squared.

Within a biological system such as the central nervous system the compliance changes as fluid energy is stored and therefore measuring or determining the stored energy with a change in the pressure or the volume is much more complicated and was not addressed in the paper. If compliance is related to the volume squared divided by the energy, then a change in energy can be thought of as the integral of the volume squared divided by the compliance or if the relationship is linear then one half the

volume squared divided by the compliance. So from a more quantitative standpoint a constant compliance is related to one half the volume squared divided by the change in energy, or one half of the change in energy divided by the pressure squared. This is analogous to an electrical model in which the capacitance is related to one half the charge squared divided by the change in stored energy or one half the stored energy divided by the voltage squared. For a variable compliance the energy stored will be related to the integral of the function that describes the change in compliance with respect to pressure times the change in pressure (the area under the compliance curve for a specified pressure interval).

In the central nervous system a change in stored fluid energy (a change in either the pressure or the volume of a fluid) can be distributed between a variety of fluid containers, or can result in a stress-strain relationship on one of the solids or can be converted into kinetic energy and result in the movement or circulation of fluid. How the various containers are arranged (in parallel or series) will influence the total compliance (the combination of the various compliances). The resistance to the circulation of the fluid will determine the energy drop across this resistance. The larger the resistance, the greater the energy drop so the greater the pressure or volume change across this resistance. The degree to which the pressure or the volume will change will depend upon the compliance of the fluid containers on either side of this resistance. While it may be quite complex to mathematically express the relationships that describe the clinically observed pressure and volume changes associated with a change in either the compliance of a container or the resistance of a fluid circulation, the paper attempted to qualitatively describe some of these relationships. In addition the paper suggests that in order to attempt to return the fluid volume distributions towards normal in a patient with hydrocephalus (a patient with an increased resistance within the cerebrospinal fluid circulation) it might be helpful to design a shunt that will restore the compliance of the central nervous systems towards normal as well as lower the resistance to the absorption of cerebrospinal fluid. Such a shunt might have to incorporate an accumulator in addition to a valve.

Reference

1 Karnopp D, Rosenberg R: System Dynamics: A Unified Approach. New York, Wiley, 1975.

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