The System Approach

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In engineering, the systems approach, the coordination of all components and effort, is employed to bring a project to completion with all the components functioning in a timely manner. The systems approach was first developed in medicine and biology where many systems interact to control and manage growth, health, pregnancy, illness and injury. Later, it was taken up by engineering and project management.

Prior to the Medicare Act of 1965, the use of the case method, the systems approach and evaluation of the end result of case management was the rule in medicine and was most evident at clinical pathological conferences which were attended by the medical staff of all specialties. Subsequent to Medicare, the focus was on specialties and sub-specialties, so that the organization of medicine became very fragmented and conferences became more departmental and exclusive.

Our concern is blood flow to the brain and what effects that flow and how alterations in blood delivery effects the brain. Therefore, the system approach of which we speak is concerned with blood flow to the brain, system and brain hemodynamics and cell function. It begins with the return of blood to the heart through veins, the oxygenation of the blood in the lung, the pumping of blood to the four arteries to the head, the Circle of Willis, the end arteries to the brain distal to the Circle of Willis, the perfusion of the capillaries by blood and the metabolism and function of brain cells, especially the most active metabolic cells.

The most active metabolic cells? Absolutely because they are most vulnerable to injury. Since the development of molecular medicine and cell marker technology, the phenomenon of *apoptosis* has become well recognized and accepted.

In 1984, Aaberg, using neuronal markers in the cerebral spinal fluid brain following cardiopulmonary bypass demonstrated neuronal apoptosis in man. But the clinical recognition of marked loss of memory and cognitive function was observed long before such sophisticated means of detection and quantitation were available. Cell death was demonstrated as early as 1914 by Crile as a result of surgical shock. Today, infants and children, subjected to deep hypothermic circulatory arrest for congenital heart repair, experience choreathetosis and mental deficiency in an alarming frequency.

There are three common activities what can markedly affect blood flow to the brain: standing up, turning the head and occluding the carotid +/or vertebral artery, either by manual compression, by balloon or at surgery. Yet examination of patients under the stress of these activities is rarely done. In fact, practically every technique of studying the brain is done lying down and in neutral head position. A form of stress testing what results in vasodilation of the cerebral vessels (diamox) is often used, but how it related to the normal physical stresses is unknown. The high incidence of stroke following carotid resection with a negative balloon occlusion test is because hypotension does not occur in the supine position and but occurs when the patient is upright and can be catastrophic. The upright position, normally reduces cardiac output by 15-20% and also reduces the arterial pressure in the head. Following surgery, the fall in blood pressure and cardiac output may be more profound, especially if the normal circulation blood volume and blood elements are not replenished.

The head and skull sit upon the atlas and axis, a compound joint, that permits the widest range of motion of any joint in the body. Under various head positions, one or more of the four arteries crossing from the neck into the head become compressed and may be occluded by head positions. No symptoms occur, if the remaining patent vessels increase their flow to the normal reserve capacity and maintain blood flow to the brain. For that to occur, there must be an adequate Circle of Willis and adequate blood flow to it. Brain hemodynamics addresses the multitude of factors including head and body position, circulating blood volume which alter brain perfusion..

Since 1981, there have been many advances in technology which must be noted. In 1981, the measurement of cerebral perfusion was done with great difficulty, but perfusion of the brain stem and cerebellum was not studied. The recent advances of magnetic resonance imaging techniques permit the measurement of regional brain perfusion, regional end artery flow, and diffusion and perfusion imaging with greater ease. During brain surgery, it is now possible to measure oxygen and carbon dioxide levels in brain tissue. But as we focus on perfusion and metabolism at the microcirculation level, we must be careful not to miss the gross changes in cardiac output.

During non-cardiac anesthesia and surgery, catastrophic brain damage can occur due to head position, shock, blood loss, inadequate volume replacement, low perfusion pressure or blood composition which does not support or protect the brain. During cardiopulmonary bypass, the problem is compounded by the hemodilution, by non-pulsative, low perfusion pressure, and by the resistance of cardiovascular anesthesia to monitor brain function during these procedures. Intravenous fluids used in massive amounts tend to be devoid of albumin, which reduces oncotic pressure and promotes brain edema.

The system approach addresses blood flow to the brain and attempts to estimate the contributing factors of the heart as a pump, the blood (volume and composition), the arteries to the brain and the brain substance itself. The system addressed is the hemodynamic system, the brain blood flow system.

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