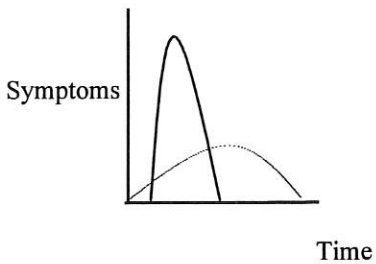
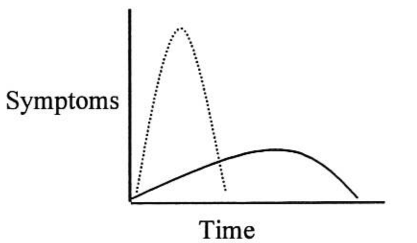
The body 's response should be brisk and the duration of illness short. When treated, the healthy patient should respond as in Fig.3 or Fig.4. This is always a good prognosis as it means their immune system is quite responsive. A poorer prognosis follows with a less responsive immune system.



Dashed is " normal"

Fig. 9 Good response of the body to an acute illness



Dashed is " normal"

Fig. 10 Poor response of the body to an acute illness

Dr. Still stated that we were given all parts of our body for a reason and that these parts work together. He discusses the body's innate intelligence with the understanding that it is greater than that of any practitioner. I interpret this (as do other systems of medicine) as his saying that the body constantly tries to treat itself and, in doing so, expresses its symptoms in the most healthy way possible given any set of circumstances. If we arbitrarily interfere, we can decrease this immune response. Fortunately, osteopathy gives us a way to enhance the body's response by supporting this innate intelligence with appropriate care. ▲

Tensegrity

R. Paul Lee, DO, FAAO

Introduction

Tensegrity is a word that was coined by Buckminster Fuller in 1948 from the contraction of the two words "tensional integrity." "Fuller defined tensegrity as a structural system composed of discontinuous compression elements connected by continuous tension cables, which forms a stable structure that can interact in a dynamic fashion."[1] Studying the geodesic dome, a self-supporting, light-weight, stable structure constructed by one of his students, Fuller elucidated the principles of tensegrity. The geodesic dome can be seen today, applied to many uses, as an example of a very successful architectural design.

Another example of a tensegrity design is a spoked bicycle wheel. As opposed to an ordinary wagon wheel, which bears the weight of the wagon upon each succeeding spoke as the wheel turns, constant tension in the spokes of a bicycle wheel distributes the weight. This tension of the spokes functions to suspend the hub and, therefore, the weight of the bicycle and the rider. Both the forces of gravity (weight) upon the hub and the irregularity of the surface beneath the tire (creating moments of force) are distributed evenly by the tension elements (spokes) to the compression elements (rim). The hub and rim remain stationary, relative to each other, within the dynamic balance of the system. As in the geodesic dome, any forces coming from within the structure or applied to it from without, are translated into only tension and compression forces, thereby eliminating any bending or torsional moments. Triangulation is a key characteristic which distributes these straight-line forces evenly throughout the system..

Tensegrity in the Body

"The human body can be viewed as such a dynamic tensegrity system with the bones acting as discontinuous compression elements and muscles, tendons, and ligaments acting as continuous tension cables that permit the body to change shapes and to be motile through chemomechanical changes in the tension elements."[2]

Biologic systems, like geodesic domes, must be inherently stable and self-contained. The same principle of triangulation of tension and compression elements affords such stability. As in the bicycle wheel, tension and compression elements in the biologic system maintain their respective properties even under a load, and they do so independent of gravity. Astronauts do not implode or explode without the gravitational field of the earth, nor with the extreme forces of blastoff and reentry. The forces holding the body together and those pushing it apart are in balance as an inherent property of biologic systems within or without gravitational fields. Wolf's Law, which states that structure follows function, demands that the organism design its compression elements (bones) and its tension elements (muscles, fascia, ligaments and tendons) to withstand outside compressive forces and internal exploding forces.[3]

The sacrum, as an example of an element of tensegrity, is stationary, like the hub of a wheel, within the constant tension of the system of ligaments which suspend it within the pelvis. The ligaments maintain a constant length, allowing, a dynamic balance, like the spokes of the bicycle wheel. If the sacrum moves, other components, which are related to it through ligaments of constant length, will move with the sacrum in "tension-coupled patterns of motion."[4]

Sutherland and Tensegrity

William G. Sutherland, DO, first proposed in 1939 that the dural membranes within the cerebrospinal compartment of the body behave as a tensegrity structure. He used the term "reciprocal tension" to describe the functional activity of these structures.[5] By applying testing procedures upon his own body, Sutherland obtained knowledge, not just information, that the cranium demonstrates compliance through spontaneous activity consistent with reciprocal tension. He experienced an alternating oscillation of the cranium in three dimensions and a coordinated motion involving the entire spine down to its terminus at the sacrum and coccyx. The meninges, the calvarium and the spinal canal, those structures which house the central nervous system, behave as a single functional unit, controlled by the connective tissues of this region of the body. The bones and dura mater synchronously oscillate. In the model presented by Fuller, the bones of the skull and spine serve as discontinuous compression elements, while the dura mater serves as a continuous tension cable.

Sutherland also referred to the membranes as a "non-extensible link," a term he used to describe inelastic passive coordination of motion across two or more joints. Dr. Sutherland understood that the bones of the skull and spine are discontinuous and the membranes continuous, by design. He reasoned that the membranes are responsible for coordinating the motion of all the bony parts. Tension in the continuous component coordinates the compressive activity across several joints, functioning as a non-extensible link.[6]

As he experimented upon himself and later as he worked with his patients, Sutherland felt the skull swell in the bilateral dimension while concurrently diminishing in both the antero-posterior and the superior-inferior dimensions. Then, he felt these movements reverse themselves with the bilateral dimension narrowing and the other two dimensions lengthening. He named these two phases of the oscillation "flexion" and "extension," respectively. As the bilateral swelling occurs, in flexion, the cranial base elevates, approximating the vertex and drawing the reciprocal tension spinal membranes upward. The spinal dura, from its firm attachment at the foramen magnum tugs on its inferior anchor at the second sacral segment. Because of the conformation of the sacroiliac joints, the sacral base rocks posteriorward as it is drawn cephalad. This is sacral flexion. The reverse motion is sacral extension.

While the midline structures flex and extend, Sutherland recognized that the bilateral structures simultaneously rotate externally and internally, respectively. Thus, as the base of the cranium elevates and the sacrum is drawn cephalad in flexion, the temporal and parietal bones, for example, externally rotate, effectively widening the head. These motions can be viewed as the effects of a non-extensible link effecting a coordination of motion throughout. It can also be described in terms of "tension-coupled motions," referred to earlier in which the length of ligaments are maintained in a dynamic equilibrium. Remember, in the biologic system, tension and compression elements maintain their respective properties even under a load. If the head deforms in one dimension, deformation in another dimension also is required, because of the constant length of the continuous tension element.

Sutherland also recognized that the rest of the body carries this subtle oscillation. We know well, as osteopathic physicians, that the connective tissues are all one functional unit. In the cranial concept, we apply this knowledge readily when it comes to approaching the treatment of the head and the sacrum. We acknowledge that the spinal and cranial dura mater function as a unit. The author wishes to impress upon the reader of this article that the entire organism functions as a unit through the connective tissues, which behave as a tensegrity structure. Tensegrity explains why tension-coupled movements occur throughout the entire organism.

Furthermore, pulmonary respiration creates the same motion in the body as does primary respiration, that which is related to the cranial concept. The long dimension of the body is shortened in deference to the expansion required to inhale. The motion the limbs express with breathing is external rotation with inhalation and internal rotation with exhalation. The inhalation phase of primary respiration exhibits flexion of the cranial mechanism and external rotation of the bilateral structures. These are the motions of respiration, both primary (cranial motion) and secondary (pulmonary motion).

Tissue Tensegrity

Such movements are not only evident on the gross but also on the microscopic level. Cellular tensegrity is just as critical to the healthy functioning of the organism as is gross myofascial tensegrity. Tissue tensegrity has been studied down to the subcellular level. Ingber first recognized in 1975 that the connective tissues of the cells, that is, the microtubules and actin microfilaments of the cytoskeleton behave according to the principles of tensegrity. The microtubules serve as the discontinuous compression elements and the actin microfilaments as the continuous tension elements.[7] The microtubules resist compression applied by the microfilaments. The microtubules float within a sea of tension.

These components integrate the structures of the cell nucleus with that of the cytoplasm. Three-dimensional electron micrographs of the tissue matrix system show the extracellular matrix to be contiguous with the intermediate filaments of the cytoskeleton, which in turn are contiguous with the nuclear matrix.[8] Furthermore, the cell relates, through cell adhesion molecules (CAMS), to the extracellular matrix and neighboring cells. This complex of tensegrity is unitary in function. In the literature, this tensegrity complex, which is composed of the nuclear matrix, the cytoskeleton, and the extracellular matrix, is referred to as the tissue matrix system.

Buckminster Fuller defined a lose-packed lattice an "isotropic vector matrix." This less-organized matrix of units will transform into an economical, highly-packed, stable array of tetrahedra. Tetrahedra are the basic units of structure which build more complex highly-stable matrices. Such an array distributes force equally in all directions, and hence, the sum of all force vectors is zero.[9] Levin states that the most economical form is the icosahedron, composed of 20 equilateral triangles, 30 edges and 12 vertices. The icosahedron can naturally be generated from the tetrahedron. The icosahedron contains the most volume for the surface area, except for the sphere. Pressure at any point on the surface of the icosahedron is transmitted along 30 edges, some under tension, some compression. It is transmitted evenly around the outer shell, as are forces in the bicycle wheel.[10]

The icosahedron, tetrahedron and other geometric forms approximate the living structure of the cells in tissues. The cells reside within the extracellular matrix, which is composed of brush-like macromolecules, the largest found in the body. This macromolecule is constructed of glycoaminoglycans which are attached to proteoglycans which, in turn, are branches off the hyaluronic acid backbone. This macromolecule is crisscrossed with collagen and other fibers. Sulfate moieties on each of the multitude of glycoaminoglycans create a vast field of negative charge. This field attracts water which affords the matrix the quality of a gel. Nutrients from the capillaries must pass through this matrix to reach the parenchymal cells. Waste products from the cells also transit this gel to be properly expelled by the veins and lymphatics. It has been shown that the gel aspect of the extracellular matrix also exhibits a sol phase.[11] Various enzyme systems control the gel/sol equilibrium of the extracellular matrix.[12] The connective tissues therefore have influence over extracellular metabolic activity.

Vitality and Tensegrity

Several investigators have helped us form a living, breathing image of what once was considered to be a relatively inert ground substance, which is now called the extracellular matrix. With more powerful tools which can see finer and finer detail, this ground substance has been discovered to perform vital functions. As osteopathic physicians, we know by palpation how vital the connective tissues are. With the following evidence from the literature, the importance of the connective tissue is further revealed. In the tensegrity model, the microfilaments on the microscopic scale and muscles on the gross scale serve the continuous tension function, while the microtubules and bones serve the discontinuous compressive function.

Pienta and Coffey have applied Fourier analysis to harmonic activities of the matrix. Fourier analysis permits the description of shapes as wave-forms. Complex harmonics of cellular activities can be quantified and analyzed by this means. These investigators measured frequencies of vibrations and information transfers within the tissue matrix. This type of analysis reveals that the tissue matrix system organizes and processes information of both spatial and temporal characteristics and coordinates functions of cells. These information transfers within the tissue matrix system are in the form of particulate, soluble, thermodynamic and harmonic signals.[13]

The tissue matrix system is involved in the organization and function of DNA, protein synthesis and energy production of the cell. The microtubules provide a mechanical channel along which the movement of particles proceed to transfer information. Soluble information activates or deactivates such enzymes as phosphodiesterase and adenylate cyclase.[14]

According to studies by Wang, Butler and Ingber, mechanotransduction is essentially instantaneous throughout the whole cell, and thus more rapid than diffusion. They used magnetic beads with specific ligands attached to them which bind to specific moieties in the extracellular matrix. With these magnetic beads they ingeniously showed, by applying a magnetic force, that integrins within the extracellular matrix link to microfilaments inside the cell through fibronectins, integrin subunits, cadherins and cell surface proteoglycans. Mechanical changes within the extracellular matrix alter the organization of the cytoskeleton and induce biochemical changes in the cells. They showed that such essential biochemical functions as the activities of enzymes and stretch-sensitive ion channels depend upon mechanotransduction. Activities of adenyl cyclase and protein kinase C, which are involved in the production of cyclic AMP, ATP and proteins in the cells are triggered by mechanical changes in the cytoskeleton. There seems to be a linear relationship between the applied stress through the magnetized beads in the extracellular matrix and the stiffening response in the cytoskeleton.[15]

Cellular Oscillators

Vern et al[16] studied cerebral blood flow in cats through windows in their skulls. They measured, by reflectance spectrophotometry, the concentration of hemoglobin to estimate cerebral blood flow and the activity of cytochrome oxidase to estimate the redox state of the blood. They serendipitously discovered, as investigators before them, that these values fluctuate. From the first discovery of this oscillation in 1957, it has been referred to as "oxygen availability waves."[17] These fluctuations are not temporally related to cardiac or respiratory activity. The rate of these waves of biochemical activity are 5-10/min. In Vern's paper, he refers to other studies which indicate that these waves seem to be related to an energy-dependent mechanism and to be secondary to changes in cortical oxidative metabolism.[18, 19] According to Marczynski (1960), these oscillations may be a global cerebral phenomenon.[20] As a possible mechanism to explain this fluctuation of oxidative metabolic activity, Vern refers to the first report of spontaneous contractility of glial cells in tissue culture, by Geiger, in 1963.[21]

Oscillations of oxidative metabolism and other functions in cells have been extensively reported in the literature. As early as 1979, an 80-page review article with up to 200 references appeared in the *Journal of Experimental Biology*, by Berridge and Rapp. This article surveyed the literature about cellular oscillators. At this early date, there was evidence that an external signal may be responsible for the intracellular waves of activity. It was repeatedly found that the concentration of calcium ions oscillates and triggers many other functions due to its role as a secondary messenger. Entrainment of one type of oscillation with another is also common. The oscillation of the activity of glycolysis is in the range of one cycle per every few seconds. Oscillations of pH play a role in contractile mechanisms. Concentrations of cyclic AMP and calcium interact with many positive and negative feedback loops to generate and to modulate the rate of cellular oscillators.

Intracellular calcium ion concentration affects the activity of cell membrane pumps to change the conductance of potassium and other ions across the cell membrane. The potassium conductance is key to many cellular oscillators. It was noted in one report that the cells of the anterior pituitary gland oscillate spontaneously.[22]

Calcium waves have been identified by many investigators. Some have identified extracellular calcium waves to be triggers of intracellular calcium waves, which affect genetic transcription and translation activity.[23] Some have discovered proteins, like albumen, to be triggers calcium waves. Glutamate has also been identified to be a stimulus to the production of calcium waves.[24] Changes in cell volume seem to be associated with cell oscillations and intracellular calcium waves. Volume changes and their relation to calcium waves was studied in fibroblasts and glial cells. It was found that volume regulation is a major function of glial cells and is dependent upon calcium ion concentration inside the cell.[25]

By studying shrinkage-induced activation of the sodium/hydrogen ion exchange system in rat astrocytes, it became apparent that myosin light chain kinase activity was the controlling mechanism. In other words, mechanical change of the cell volume is controlled by fibers of the matrix.[26] In another study, mechanical stimulation, mediated by glutamate, seemed to stimulate calcium waves.[27]

Conclusions

The image that these studies are beginning to elucidate is one of vitality at a cellular level. There is consistent, reproducible evidence of a biochemical/mechanical aspect of cellular respiration. Movements of cells and tissues accompany movements of water, substrates, ions and electrons. Sutherland chose his words carefully as he defined his model of the mechanical motion of the tissues. He wisely chose the word "respiration" as part of the name of this fluid oscillation, the Primary Respiratory Mechanism.

Biochemical, hydraulic and thermodynamic activity is the active component of this mechanism; the tensegrity aspect the restraining, guiding, coordinating and controlling component. Sutherland indicated that the reciprocal tension membranes are the restraining, guiding, coordinating and controlling components of the primary respiratory mechanism on a gross scale. We now can see that the tissue matrix system serves the same function on a biochemical/microscopic scale.

It is on this scale that Sutherland understood the effects of a CV4. He proffered that an exchange of fluids of all compartments of the body occurs with the still point from a CV4.

Sutherland indicated that the active component of the primary respiratory mechanism is the fluctuation of fluid and inherent motion of the central nervous system. The inherent motion described in these latest studies, cited herein, elucidates further the tissue respiration Sutherland referred to in his original works.

Sutherland described the benefits of promoting this tissue respiratory activity by releasing restrictions of motion of the fluid fluctuation. When one releases restrictions of motion in the constraining component, or the component of tensegrity, one promotes the active aspect or the function of tissue respiration. This is the act of returning health to the tissues.

By mechanically changing the body we allow the self-healing capacity or the potency of this inherent activity of the organism to be optimized. This optimization happens with a high velocity maneuver at the lumbosacral junction, by a release of the fascia of the lower extremity or the respiratory diaphragm, by release of a first rib with counterstrain, and by applying skilled promotion of primary respiration.

The further we explore the human, the more evidence we find for the natural principles we call the principles of osteopathy. The body is unified in its function, structure and function are intimately related, and health maintenance depends upon structural maintenance. We are so fortunate to have the opportunity to apply the teachings of A.T. Still and W.G. Sutherland as osteopathic physicians. We honor the osteopathic difference. ▲

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The Dental Corner

Case Study: Classic Dental Trauma Induced Lesion Pattern

James M. Kennedy, DDS

A 39-year-old male came to my office two months post extraction of the upper left third molar. The tooth had been abscessed and he was treated for 48 hours with antibiotics prior to the removal of the roots. It was a difficult procedure requiring osseous surgery to completely remove the tooth. One month after the extraction, the patient began having episodes of pain on the left side of his face which lasted for several minutes. He described this as a stabbing, griping and excruciating pain that had increased in intensity, duration and frequency over the past four weeks, and now involved the entire left side of his head. The pain was occurring hourly by the time he came to my office and lasted up to ten minutes in duration. The only way he could get relief was to drink large amounts of whiskey, which he did each night until he fell asleep. At times, he said he felt like committing suicide.

Dental examination revealed a normal Class I occlusion with all 32 permanent teeth present, except for the recently extracted upper left third molar. The patient felt that his bite had not fit together properly ever since the tooth had been removed. Chewing was difficult and often would initiate the onset of his pain.

Cranial palpation displayed a traumatic left torsion pattern of the SBS with an element of compression also evident. The left temporal bone was lesioned into internal rotation which was opposite to what one would expect to find with a left torsion pattern (*Osteopathy in the Cranial Field* by H.I. Magoun, DO; 1st edition, pg. 40-43; 3rd edition, pg. 60-64). This incongruity creates a separation at the left sphenopetrous suture. The left maxilla was lesioned inferiorly and laterally carrying the palatine bone and the pterygoid process of the sphenoid with it. The left condyle of the mandible followed the temporal bone on that side into internal rotation. If one reviews Dr. Magoun's book for a description of what forces are applied with the extraction of an upper tooth, it is easy to understand how this cranial trauma can occur (1st edition, pg. 129-130; 3rd edition, pg. 297-299). Please note that modern dental chairs do not cup the temporal bones as mentioned in the text, and therefore both temporal bones are not carried into internal rotation in the manner described.

The separation of the left sphenopetrous articulation lesions the tentorium which has a detrimental effect on the cerebrospinal fluid fluctuation and the venous drainage of the skull. Therefore, it is easy to understand that a trauma of this nature has manifestations in the membranes and the fluid as well as the bones of the cranium. Temporal bone disturbances can create dural tension on the Gasserian ganglion or interfere