The Inherent Rhythmic Motion of the Cranial Bones

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The most controversial phenomenon of the PRM from a scientific perspective is the concept of palpable cranial bone motion. Misgivings have been expressed based primarily on the assumed anatomic impossibility of such motion.[1,2] The basis of the traditional anatomic position of cranial bone immobility is derived primarily from forensic anthropology research done to estimate the age of skeletal remains. However, there is a growing body of literature that brings into question this long held anatomically based dogma. The challenge to the position that cranial bones are incapable of motion is based on examination of basis for this conclusion in the first place and empirical evidence of cranial bone motion in the second place.

To appreciate the conceptual change implied by the concept of cranial bone motion, it is important to know that respected scientists, anatomists, and anthropologists posited the fusion and inherent immobility of cranial bones. Most often cited are the works of Bolk,[3] Melsen,[4] Perizonius,[5] Cohen,[6] and Sahni et al.,[7] all of whom are reported to have held the view that cranial sutures were fused and immobile. Based on thorough examination of this debate, it may turn out that this view has been an anatomic version of "the world is flat" debate of the last millennium.

With the exception of Bolk,[3] all of the aforementioned anthropologists and anatomists cite as precedent for their work, that of Todd and Lyon as central to the idea that cranial bones fuse and therefore are immobile.[8,9] There is reason to question Todd and Lyon's conclusions based on a close reading of their lengthy manuscripts. Paul Dart, MD states,[10] "In interpreting this data, it must be noted that Todd and Lyon were attempting to establish 'modal' norms for sutural closure, and they discounted data that was clearly out of the modal pattern before creating their summary. 11.7% of their 307 white male specimens and 25.8% of their 120 negro male specimens were excluded from the data due to prolonged sutural patency."

Further reason to doubt the concept of universal sutural fusion was given by Singer.[11] He found a high percentage of specimens with much less closure than Todd and Lyon's norms, including a 64 year old specimen with no closure at sagittal, lambdoid, or left coronal sutures and 3 specimens ages early 40's with virtually no sutural closure in the coronal, lambdoid, or sagittal sutures. Also in the 1950s, Pritchard et al.[12] commented to the effect that obliteration of sutures and synostosis of adjoining bones, *if it happens at all*, occurs usually after all growth has ceased. In great apes synostosis of all sutures occurs immediately after growth has ceased, but in man and most laboratory animals sutures may never completely close.

A recent article by Sabini and Elkowitz[13] gives pictorial and systematic review of 36 human cadaver skulls ranging in age from 56 to 101 years, all well above the age when bone growth is complete. Twenty-six of the skulls showed less than 100% obliteration of the coronal suture, 31 of the skulls had unobliterated lamboidal sutures, and 24 of the skulls had unobliterated sagittal sutures. The lamboidal suture was the least fused on a majority and the attachment of musculature on the occipital bone cited as the probable cause of maintaining sutural patency. The authors speculate that the chewing motion contributes to muscular tension on the bones, maintaining some degree of sutural patency. The endocranial (inner) surface of the skull was not evaluated so that some estimate of through and through fusion of each suture could not be made. However, the finding of a significant amount of sutural patency (non-fusion) certainly brings in to question that all cranial sutures are fused and therefore can not move.

Prior to the Sabini and Elkowitz publication, the work of Retzlaff and associates dealt directly with the nature of cranial suture morphology and cranial bone motion. Retzlaff et al. state, "Gross and microscopic examination of the parieto-parietal and parieto-temporal cranial sutures obtained by autopsy from 17 human cadavers with age range of 7 to 78 years shows that these sutures remain as clearly identifiable structures even in the oldest samples."[14, p.663] Retzlaff et al. identified sutural elements contradicting ossification and demonstrated the presence of vascular and neural structures in the sutures.[15] These studies also showed the presence of nerve and vascular tissue substantial enough to supply the needs of connective tissue activated beyond mere bony sutural adhesions and ossification. Additionally, Retzlaff et al. traced nerve endings from the sagittal sinus through the falx cerebri and third ventricle to the superior cervical ganglion in primates and mammals.[16] That such structures were found in cranial sutures brings further doubt to the idea that these sutures fuse and are immobile.

Empirically demonstrated cranial bone motion in animals is well documented. Michael and Retzlaff demonstrated cranial bone (parietal) mobility in the squirrel monkey.[17] In cats, parietal bone motion in the range of 200-300 microns was induced by laboratory controlled changes in the CSF volume.[18-20] Jaslow[21] demonstrated in goat skulls (*Capra hircus*), that patent cranial sutures in adult animals may play a role in shock absorption and re-distribution of forces directed against the skull (e.g. ballistic forces directed against the goat's skull) and during chewing movements. Thus a compliant skull is a stronger skull in that it is capable of absorbing and re-distributing forces directed against it.

Research involving assessment of human cranial bone motion has been done by neurologists, space physiologists, and osteopathic medical profession physicians and basic scientists. In work later cited by NASA scientists, Frymann[22] developed a non-invasive apparatus for mechanically measuring the changes in cranial diameter. Cranial motion was recorded simultaneously with thoracic respiration. On the basis of her extensive recordings, she was able to conclude that a rhythmic pattern of cranial bone mobility exists and moves at a rate that is different than that of thoracic respiration.

In a 1981 neurology study, by Heifetz and Weiss,[23] using a stain gauge device, they were able to demonstrate cranial vault expansion associated with a rise in intracranial pressure (ICP) in two comatose patients. Utilizing a head holding device similar to Gardner-Wells tongs, accompanied by a strain gauge meter, the skull device was inserted into the calvaria above the external auditory canal. The strain gauge device was part of what is called a "Wheatstone Bridge," which was designed to detect any expansion of the skull of about 0.0003 mm or greater, which when it occurred, would produce a voltage change of 1uV. They performed 19 trials and each time ICP was artificially elevated, there was a voltage change. This voltage change indicated that the skull tong pins were being spread apart. This could only occur with expansion of the cranial vault.

A promising approach to assessing cranial bone motion after cranial manipulation was carried out utilizing x-rays (Dental Orthogonal Radiographic Analysis) on 12 subjects.[24] The before to after changes in cranial bone position measured in degrees ranged from 0^{o} to 8^{o} for atlas, mastoid, malar, sphenoid, and temporal bone position. The percentage of subjects with identifiable changes ranged 66.6% with the mastoid to 91.6 % for the atlas, sphenoid and temporal bones. There are plans to expand this research utilizing a larger number of subjects.

Russian and United States Space Research

One of the strongest areas of research which involved assessment of cranial bone motion has been that carried out by the Russian and United States astronaut programs. The concerns that led to this research had to do with the nature of human response to prolonged weightlessness in space. Without gravity would the human circulatory and central nervous systems function normally? In the process of assessing intracranial fluid dynamics, various types of radiographic and ultrasound equipment have been used to measure intracranial volume as well as cranial bone dimensions, and changes in these dimensions have been observed.

Yuri Moskalenko, PhD first published research on cats in space that described "third order waves" similar to that described above in glial cells.[25,26] After being introduced to OCF, Moskalenko and associates carried out several studies which showed cranial bone motion. One utilizing NMR tomograms, showed cranial bone motion between 380 microns to 1 mm, and cranial cavity volume increases by 12-15 mL, with a rhythmicity of 6-14 cycles per minute.[27] This work was followed by a study utilizing bioimpedence measures and transcranial ultrasound Doppler echography showing slow oscillations of the cranial bones at 0.08-0.2 Hz.[28] Moskalenko demonstrated that these oscillations, "…were of intracranial origin and were related to the mechanisms of regulation of the blood supply to and oxygen consumption by cerebral tissue, as well as with the dynamics of CSF circulation.[28, p.171] Moskalenko and Frymann have carried this work into a formulation of a theory that explains the physiology of the PRM.[29]

In the mid-1990s NASA was also concerned about intracranial fluid volume changes in astronauts in space. NASA carried out research and developed an ultrasound device, pulse-phase locked loop (PPLL) with sensitivity to 0.1 μm to more precisely assess intracranial anatomy and physiogy.[30] This NASA team at the Ames Research Center carried out a series of studies.[31-34]

On two fresh cadavera (less than 24 hours post-mortem), female 83 and male 93, ICP pulsations were generated manually by infusing saline into the intracranial ventricular system at a rate of 1 cycle/second (1 hertz).[31] In this study an increase in ICP of 15 mL Hg caused a skull expansion of 0.029mm, and this was interpreted by the authors as similar to that found by Heisey and Adams,[18] Hiefetz and Weiss,[23] and Frymann.[22]

In another study, 7 healthy volunteers fitted with the PPLL device were placed in $60,^{o}$ 30^{o} head-up tilt, supine, and 10^{o} head-down tilt positions. The average path length from forehead to occipital bone increased 1.038 ± 0.207 mm at 10^{o} head down tilt relative to 90^{o} upright. "In other words, when intracranial pressure increases, arterial pulsation produces a higher amplitude ICP pulsation. Increased amplitude of ICP pulsations will be manifested by larger fluctuations in distance across the skull."[32, p.3]

Summarizing their work to a certain point, the NASA research team stated, "Although the skull is often assumed to be a rigid container with a constant volume, many researchers have demonstrated that the skull moves on the order of a few μm in association with changes in intracranial pressure."[33,p.66] In their last publication in this series they state, "…analysis of covariance reveled that there was a significant effect of tilt angle on amplitude of cranial diameter pulsation ($p < 0.001$)….As a result, amplitudes of cranial distance pulsation increased as the angle of tilt decreased. The observed changes in cranial diameter pulsation are considered to be statistically significant."[34,p.883]

Recent Osteopathic Research on Cranial Bone Motion

Research comparing palpatory assessment of cranial bone motion with simultaneous assessment by laser Doppler flowmetry technology has been done. Striking correlations have been found between cranial palpation reports and the technologically measured physiologic motion phenomena identified by the laser Doppler flowmetry. Nelson, Sergueef and Glonek posit that it is the Traube-Hering and Meyer oscillations that they have now empirically can assess.[35-38] They describe oscillations which occur about 4 to 6 cycles per minute and in their studies have been shown to occur at the same time the osteopathic cranial practitioner reports a certain phase of the cranial bone motion. To have instrumented recordings of physiologic activity correspond to the palpatory experience is strong support for the PRM and the concept of cranial bone motion. This line of research is continuing.

[The Cranial Academy and Sutherland Cranial Teaching Foundation sponsored a "PRM Research Symposium" which was held in October 2003. Pictured was a panel featuring several of the most outstanding cranial osteopathic researchers. From left to right: Viola M. Frymann, DO, Yuri Moskalenko, PhD, Kenneth Nelson, DO, Tom Glonek, PhD and Toshiaki Ueno, MD, PhD.] Can the picture be placed about here – perhaps Mark has a better picture of the panel?

The Inherent Motion of the Cranial Bones – References

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