CHANGES IN ELONGATION OF FALX CEREBRI DURING CRANIOSACRAL THERAPY TECHNIQUES APPLIED ON THE SKULL OF AN EMBALMED CADAVER

Dimitrios C. Kostopoulos, MA, PT, George Keramidas, MS

0886-9634/92/1001-0000$03.00/0, THE JOURNAL OF CRANIOMANDIBULAR PRACTICE,

Manuscript received May 3, 1991; revised manuscript received June 13, 1991; accepted August 22, 1991

Address for reprint requests:
Dimitrios C. Kostopoulos
32-44 31 Street
Apartment 1E
Astoria, New York 11106

ABSTRACT: Craniosacral therapy supports that light forces applied to the skull may be transmitted to the dura membrane having a therapeutic effect to the cranial system. This study examines the changes in elongation of falx cerebri during the application of some of the craniosacral therapy techniques to the skull of an embalmed cadaver. The study demonstrates that the relative elongation of the falx cerebri changes as follows: for the frontal lift, 1.44 mm; for the parietal lift, 1.08 mm; for the sphenobasilar compression, −0.33 mm; for the sphenobasilar decompression, 0.28 mm; and for the ear pull, inconclusive results. The present study offers validation for the scientific basis of craniosacral therapy and the contention for cranial suture mobility.

Mr. Dimitrios C. Kostopoulos *is a registered physical therapist practicing in New York City, New York. He earned his undergraduate degree in physical therapy from the University of Athens, Greece, and his master's degree in physical therapy from New York University. He is currently a doctorate candidate at New York University concentrating in pathokinesiology. Mr. Kostopoulos specializes in craniosacral therapy, myofascial release, acupressure therapy, trigger point therapy, and other manual techniques, treating both adult and pediatric populations. He is also researching projects involving craniosacral therapy and myofascial release.*

Mr. George Keramidas *is a physicist involved in research and development in electro-optics and quantum electronics. He has two master's degrees; one in physics and the other in electrical engineering. He was elected a member of Sigma Pi Honor Society. He is a research assistant at Polytechnic University studying "Conducted energy transfer and fluorescence spectroscopy on a single electrodynamically levitated micro-particle."*

Craniosacral therapy is a relatively new therapeutic approach that derives primarily from the field of cranial osteopathy. Twenty-five to 30 years ago some osteopaths expressed the belief that they could produce therapeutic changes using slow and slight "manipulations" of the cranial bones.

In the mid-1970s a research team at Michigan State University began extensive research on craniosacral therapy and the questions behind it. They claimed that the craniosacral system with the production and absorption of the cerebrospinal fluid (CSF) has all the characteristics of a semiclosed hydraulic system.[1] The production and absorption of the CSF produces a rhythm of six to 12 cycles per minute, which is called "cranial rhythm." One of the key researchers of that team was Dr. John E. Upledger.

Upledger[2] developed a "Ten Step Protocol" for the most effective application of craniosacral therapy. According to the hydraulic model, Upledger suggested that light forces applied on specific points of the skull have a therapeutic effect on the craniosacral system and on the entire body. The "Ten Step Protocol" describes certain hand positions as well as manipulations for the evaluation and treatment of the craniosacral system. These techniques are the following: still point (or CV-4), diaphragm releases, frontal lift (for the vertical cranial membrane system), parietal lift (for the vertical cranial membrane system), sphenobasilar compression and decompression (for the horizontal cranial membrane system and also the vertical), temporal decompression (ear pull), dural tube evaluation, temporomandibular joint (TMJ) compression and decompression and still point (repeat).

This study examines five of the above techniques: frontal lift, parietal lift, sphenobasilar compression, sphenobasilar decompression, and ear pull. The work discussed below offers validation to the scientific basis of craniosacral therapy.

Background

Cranial suture mobility is one of the key theoretical points of craniosacral therapy. The claim for cranial suture mobility still remains controversial. However, the previously mentioned research team of Michigan State University studied fresh cranial bone specimens and showed that there is potential for cranial suture mobility.[3,4] In addition, they found little evidence of sutural ossification that might prevent movement between two adjacent cranial bones.[5,6] Cranial suture mobility has been documented by researchers in studies on squirrel monkeys.[7] However, traditional anatomists claim that the cranial sutures allow some degree of movement only in young infants and are solidly fused in adulthood.[8]

The boundaries of the craniosacral system are formed by the meningeal membranes (dura membrane, arachnoid membrane, and pia mater). The dura membrane is a thick, tough membrane that consists of elastocollagenous fibers. Its elastocollagenous bundles are interlaced and appear disorganized.[1] When the dura membrane is subjected to abnormal tension over an extended period of time, its fibers tend to align themselves in the direction of tension.[1] Dura membrane has three divisions or septa, which are: (1) falx cerebri, (2) falx cerebelli, and (3) tentorium cerebelli.[9]

The dura membrane with all of its anatomical divisions is in indirect contact with many different areas of the brain and at the same time is in direct contact with the inner surface of the cranial bones. Therefore, if we assume that there is cranial suture mobility, then an external force applied to the cranial bones will affect the elastocollagenous dura membrane and, consequently, the brain itself.

Rowe,[10] in her studies on fresh cadavers, palpated the cranial membranes and felt the tension and stretch created during the application of craniosacral therapy techniques.

In a nonpublished study Rowe et al. measured the relative elongation of falx cerebri in an unembalmed cadaver using a technique of multiple photography. They recorded a 1 mm displacement of the falx cerebri when they applied 48.2 grams of external force on the frontal bone.[11]

Kostopoulos and Keramidas[12] in another study measured the relative elongation of the falx cerebri during the application of external forces on the frontal bone of an embalmed cadaver and found a positive correlation between the applied force and the degree of relative elongation of falx cerebri. However, they did not apply forces on the other cranial bones.

No systematic, published study is available at this point to examine the magnitude of the tension and the elongation created on the falx cerebri during the application of the craniosacral therapy techniques.

Purpose and Methodology

The purpose of this study was to determine the degree of relative elongation of the falx cerebri of an embalmed cadaver during the application of some of the craniosacral therapy techniques as they are described in the "Ten Step Protocol" by Upledger. Relative elongation is the length that describes the amount of elastic vertical displacement of a solid system as a response to an external cause.[13] In the study the authors defined relative elongation as the elastic deformation in length of falx cerebri in response to the external forces applied to the cranial bones. The techniques that were used were:

1. Frontal lift—involves application of force to the frontal bone in the anterior direction.
2. Parietal lift—involves application of force to the parietal bones in the cephalad direction.
3. Sphenobasilar compression—involves application of force to the great wings of the sphenoid bone in a posterior direction and sphenobasilar decompression—same position but force in an anterior direction.
4. Ear pull—involves application of force to the temporal bones (through the external pinna of each ear) in a posterolateral direction.

These techniques were applied manually by a physical therapist who specializes in craniosacral therapy.

For the study the researchers used a six-month embalmed male cadaver. The cadaver was positioned in supine position and the researchers made two window cuts in the cranium, one on each side. The brain tissue was carefully removed while the three divisions of the dura membrane were left intact (**Figure 1**).

The authors' equipment consisted of an oscillator that could produce audio frequencies between 0 and 20 kHz, a piezoelectric element with resonant frequency 2.8 kHz $\pm$500 Hz, an electric capacitative

Figure 1
Falx cerebri exposed after anatomical dissection.

microphone, and an oscilloscope. The oscillator was used to provide a sine wave of approximately 18 kHz.[14]

The microphone was placed opposite to the piezoelectric element, which was attached to the falx cerebri so an average initial displacement of 30 to 40 mV could be obtained. By applying the above-mentioned craniosacral therapy techniques on the skull of the cadaver, the authors were able to shift the relative position between the microphone and the piezoelectric element and to produce a change in the observed amplitude of the oscillation of the oscilloscope (**Figure 2**).

One of the researchers, a physical therapist, applied each technique four times and the second researcher, a physicist, collected the data. The researcher who applied the techniques was unable to see the changes on the screen of the oscilloscope. In order to evaluate the actual displacement of falx cerebri, the authors calibrated the apparatus. From the calibration an average percentage change of 46.11% per millimeter was found when the microphone was shifted relatively to the piezoelectric element (**Tables 1** and **2**).

Results

From calculations it was discovered that the displacement of the falx cerebri was: (1) frontal lift, 1.44 mm; (2) parietal lift, 1.08 mm; (3) sphenobasilar compression, −0.33 mm; sphenobasilar decompression, +0.28 mm; and (4) ear pull, relatively inconclusive (**Tables 3–5**).

Discussion

The results of the study offer scientific evidence that the forces applied to the skull during the application of craniosacral therapy techniques produce an elongation of the falx cerebri. For the study the authors used an embalmed cadaver in which the cranial membranes had become tougher and more resistant to movement. In a fresh cadaver it may be possible to observe higher amounts of displacement.

A very important aspect of this study is that the sphenoid compression and sphenoid decompression produced almost equal but opposite results in the falx

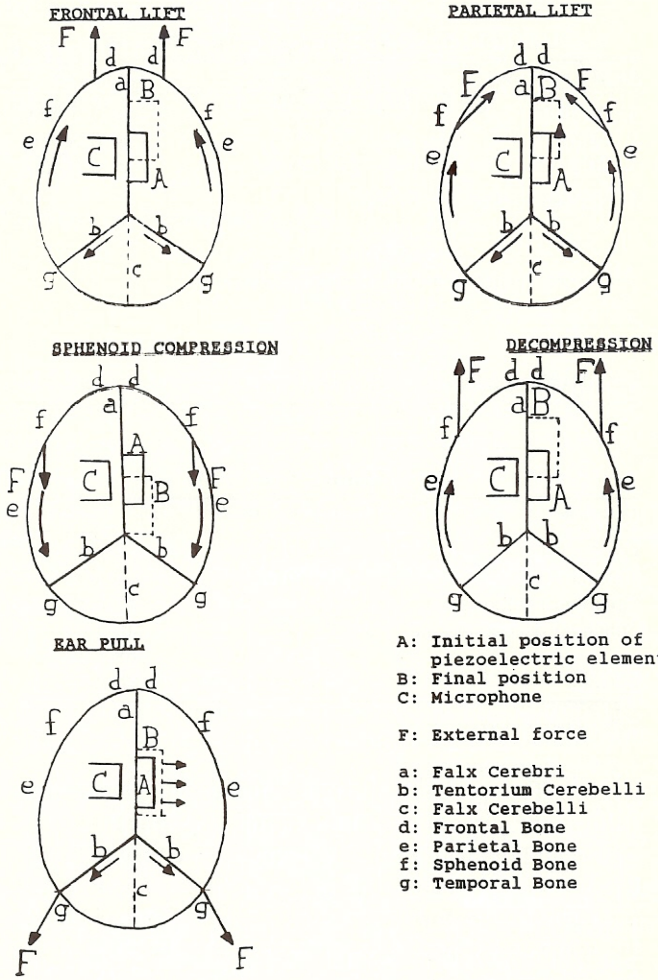

Figure 2
Demonstrating the displacement of the piezoelectric element that is attached to the falx cerebri, relative to the microphone.

Table 1
Oscillation Frequency

3 wavelengths	$= 8.2 \times 20$ msec $= 1.64 \times 10^{-4}$ sec
1 wavelength	$= 5.46 \times 10^{-5}$ sec $=$ T
$f = 1/T$	$= 18.2927$ kHz $= 18$ kHz

Table 2
Calibration of the Piezoelectric Element

Initial Amplitude	Final Amplitude	Displacement
1. 20 mV	52 mV	3 ± 0.5 mm
2. 20 mV	50 mV	4 ± 0.5 mm
3. 20 mV	58 mV	4 ± 0.5 mm

Percentage change: 1: 160%
2: 150%
3: 190%

Percentage change per mm (% change/distance):
1: 53.33%
2: 37.50%
3: 47.50%

Average percentage change per mm: 46.11%

Table 3

Technique	Initial Amplitude	Final Amplitude
Frontal lift	30 mV	50 mV
Parietal lift	40 mV	60 mV
Sphenoid compression	45 mV, 50 mV	40 mV
Sphenoid decompression	36; 44; 46; 42 mV	42; 50; 50; 48 mV
Ear pull	44; 50; 50; inc*	54; 12; 30; inc*

*inc, Inconclusive.

cerebri. This probably indicates that the displacement follows the direction of the externally applied force.

The authors had relatively inconclusive results from the ear pull, because the ear pull technique affects primarily the tentorium cerebelli, which is attached to the temporal bones. The microphone, placed 2 to 3 mm from the falx cerebri, was translating into the membrane relative to the piezoelectric element (falx cerebri).

Further research on the effect of craniosacral therapy techniques on the other two cranial membranes (falx cerebelli and tentorium cerebelli) needs to be done in future studies on fresh cadavers. The authors

Table 4
Amplitude Percentage Change in Each Technique

$$f - f_i/f_i \times 100$$

f_i = initial amplitude
f = final amplitude

1. Frontal lift: 66.66%
2. Parietal lift: 50.0%
3. Sphenoid compression: −15.55%
4. Sphenoid decompression: +13.31%
5. Ear pull: inconclusive

Table 5
Displacement of the Falx Cerebri*

1) Frontal lift: 66.66%/46.11% = 1.44
2) Parietal lift: 50.00%/46.11% = 1.08
3) Sphenoid compression: −15.55%/46.11% = −0.33
4) Sphenoid decompression: 13.31%/46.11% = +0.28
5) Ear pull: inconclusive

*In millimeters.

believe the results of this study answer some of the questions in the field of craniosacral therapy and increase the confidence of physical therapists, doctors of dentistry, and other health professionals who use craniosacral therapy.

Acknowledgments

The researchers are indebted to the Anatomy Laboratory of New York University School of Dentistry and to Dr. Ormond G. Mitchell for giving permission to use the cadavers and to hold the experiment in the laboratory. We are very grateful to Dr. Leni Yarmus and to the physics department of New York University for lending us several instruments. We thank Dr. J. Upledger and Professor C. Rowe for their suggestions and encouragement. We thank K. Rizopoulos and S. Boletsis for their help. Finally, we thank our parents for their substantial support and encouragement.

References

1. Upledger JE, Vredevoogd JD: *CranioSacral Therapy*. Seattle: Eastland Press, 1988
2. Upledger JE: *The Upledger Institute Manual*. Florida
3. Norman P, Roppel R, Retzlaff E: The detection of relative movements of cranial bones. *J Am Osteopath Assoc* 1976; 76:286–289
4. Retzlaff EW, Michael DM, Roppel R: Cranial bone mobility. *J Am Osteopath Assoc* 1975; 74:869–872
5. Pritchard JJ, Scott JH, Girgis FG: The structure and development of cranial and fascial sutures. *J Anat* 1956; 90:70–76
6. Retzlaff EW, Michael D, Roppel R, Mitchell F: The structures of cranial bone sutures. *J Am Osteopath Assoc* 1976; 75:607–608
7. Michael DK, Retzlaff EW: A preliminary study of cranial bone movement in the squirrel monkey. *J Am Osteopath Assoc* 1975; 74:866–868
8. Moore KL: *Clinical Oriented Anatomy*. Baltimore: Williams & Wilkins, 1984
9. Anderson JE: *Grant's Atlas of Anatomy*. Baltimore: Williams & Wilkins, 1983
10. Rowe CS: Cranial dissections. *Upledger Institute Newsletter*, 1989
11. Rowe CS, Upledger JE, Palmer LM, et al.: Cranial Dissections and CranioSacral Therapy. Nonpublished study. Commentary in *Phys Ther Forum* 1991; X(18):6
12. Kostopoulos DC, Keramidas G: Changes in Magnitude of Relative Elongation of Falx Cerebri during the Application of External Forces on the Frontal Bone of an Embalmed Cadaver. *Phys Ther Forum* 1991; X(10):10–13
13. Landau LD, Lifshitz: *Theory of Elasticity*. Oxford: Pergamon Press, 1986
14. Halliday D, Resnick R: *Fundamentals of Physics*. New York: John Wiley & Sons, Inc., 1981

Changes in Magnitude of Relative Cerebri During the Application of External Forces on the Frontal Bone of an Embalmed Cadaver

Dimitrios Kostopoulos, MA, RPT
and George Keramidas, MS
(Special to the Forum)

(Ed. Note: This is a peer-reviewed article. Reviewers are acknowledged at the end of the article. Reader response is encouraged.)

The following article offers validation to the scientific basis of Craniosacral Therapy. The study suggests that when a controlled external force is applied on the frontal bone of an embalmed cadaver, this force may be transmitted to the falx cerebri causing a relative elongation of it. There is a positive correlation between the applied force and the relative elongation of the falx cerebri.

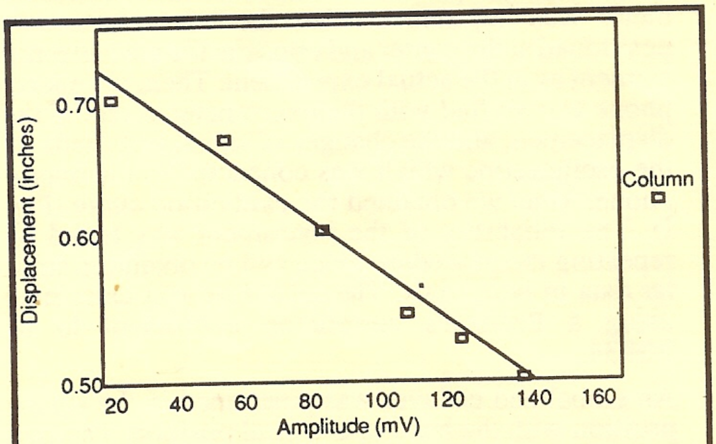

FIGURE I
Calibration curve of the instrument used for the study.
The following equations apply:
$Y = 0.7509 - 0.0018X$
Y: inches of elongation
X: amplitude (mV)
or
$S = 19.073 - 0.0457X$
S: magnitude of elongation in mm

Abstract

Craniosacral Therapy—a relatively new therapeutic approach—supports that light forces applied on the cranial vault may affect the dura mater therapeutically. This study seems to offer evidence that external forces applied on the frontal bone of a cadaver are transmitted into the falx cerebri. A positive correlation between the applied force and the relative elongation of the falx cerebri is demonstrated. The results of this study support the contention that cranial sutures are mobile even after death.

Craniosacral therapy, developed within the last two decades, supports that through light forces applied on the cranial bones, a therapist may affect the dura mater and provide therapeutic results. This therapeutic approach is surrounded by significant controversy related to both the claimed therapeutic results and its scientific basis. The work discussed below offers validation to the scientific basis of Craniosacral Therapy.

Cranial suture mobility is essential in the model used to develop the theories which underlie Craniosacral Therapy. The possibility of cranial suture mobility remains controversial. Many of the traditional anatomists believe that the cranial sutures are movable only in young infants and are solidly fused in adulthood. Moore considers that " . . . the cranium of a mature adult is essentially a single complex bone."[1] Other anatomists have a different opinion. A research team at the Michigan State University studied fresh cranial bone specimens and showed the potential for cranial suture movement.[2-6] They showed that within the cranial sutures there is an abundance of blood vessels, nerve fibers, collagen and elastic fibers. In these fresh specimens they found little evidence of sutural ossification which might prevent movement between two adjacent cranial bones. These structures, blood vessels, nerve fibers, collagen and elastic fibers, penetrate the sutural bone margins and transverse from the diploe into the suture and vice versa. Researchers recorded cranial suture movements in their study on squirrel monkeys.[4,5,7,8] Rowe, in her studies on cadavers, palpated the cranial membranes and felt the tension and stretch created during the application of external forces on the cranial vault. She was able to feel the transmission of the external forces she applied into the membranes.[9] In our study we measured the magnitude of elongation of the falx cerebri during the application of external forces on the frontal bone, the parietal bones and the sphenoid bone. We did not however control and measure the external force which was applied. The results of that study showed that when an unmeasured normal force was applied to the frontal cone there was an elongation of 2.33 mm of the falx cerebri. When the force was applied to the parietal bones, the elongation of the falx cerebri was 1.94 mm, and when the force was applied to the sphenoid bone the elongation was 0.677 mm.[10] No other systematic study is available at this point to examine the magnitude of the elongation of the falx cerebri during the application of controlled external forces to the frontal bone. On the other hand there is no published study to oppose the fact that there is a degree of elongation of the falx cerebri as it has been described in this study. This

(Cont'd on next page)

Changes in Magnitude of Relative Cerebri During the Application of External Forces on the Frontal Bone of an Embalmed Cadaver

(Cont'd from preceding page)

study attempts to take a further step and give some possible answers to this problem.

The purpose of the present study is to measure the magnitude of relative elongation of falx cerebri during the application of controlled external forces on the frontal bone of an embalmed cadaver and to examine the correlation between the magnitude of relative elongation of falx cerebri and the magnitude of the applied external forces.

The dura mater with all of its anatomical divisions is in indirect contact with several different areas of the brain. One of these anatomical dural divisions is the falx cerebri. The dura mater is in direct contact with the inner surface of the cranial bones. If it is assumed that cranial suture mobility does exist, a force which is applied in an anterior direction to the frontal

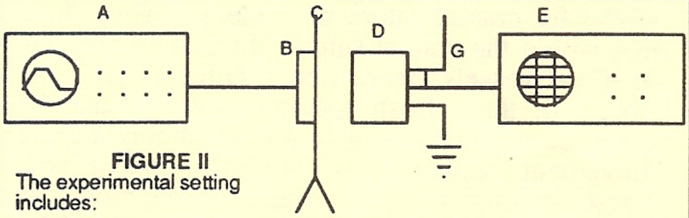

FIGURE II
The experimental setting includes:
A: Oscillator
B: Piezoelectric element
C: Falx Cerebri
D: Microphone
E. Oscilloscope

bone will cause the frontal bone to move slightly away from its initial position. This force should then be transmitted to the falx cerebri which is attached to the internal aspect of this frontal bone. The result would be a measurable elongation of the elasto-collagenous falx cerebri. This elongation of falx cerebri was measured by instrumentation that was developed specifically for this study.

Magnitude of relative elongation is the length that describes the amount of elastic vertical displacement of a solid system as a response to an external cause.[11,12] Operationally, the magnitude of relative elongation is defined as the elastic deformation in length of the falx cerebri in response to the external force applied to the frontal bone. The magnitude of relative elongation excludes cases of any other kind of displacement such as "absolute displacement" due to arbitrary motion or any oscillatory displacement. Force is the cause that changes the motion of a body.[12] Physically this is defined as: F=m.a In this study the external force was represented by weights applied on the frontal bone through a system of pulleys. Force was calculated by: F=m.g

For this study the researchers used a 6 to 9 months embalmed male cadaver. There was no optical evidence of any severe injury or malformation to the cadaver's cranial area. The instrument set-up consisted of an oscillator that could produce audio frequencies between 0 and 20,000 Hz, a piezoelectric element with resonant frequency 2.8 KHZ +or- 500 Hz, an electric capacitive microphone and an oscilloscope. The validity of the instrument was tested by a thorough calibration of the apparatus. From the calibration, the equation of the relative elongation was determined:

$$S = 19.073 - 0.0475*X$$

S : Magnitude of elongation in mm.
X : Amplitude (mV).

The calibration procedure was as follows. A micrometer was adjusted so that the microphone was positioned at the center and opposite the piezoelectric element as in the actual experiment. Then, the microphone was shifted with the micrometer to record the displacement and the changes of signal amplitude on the oscilloscope which was connected to the microphone. Thus we obtained the calibration curve (Fig. I). The reliability of the instrument was tested by repeating the procedure twice and by obtaining similar data in both trials. The reliability was calculated using a Pearson's correlation coefficient to be 0.9934.

An embalmed cadaver was positioned in the supine position with the head in a neutral position. The skin which covers frontal and parietal bones was removed and the coronal and part of the sagittal suture were exposed. We did two window cuts in the cranium, one in each side. Each window cut occupied an area of 55 cm^2 (11 cm x 5 cm). Two 3 cm long nails were placed on the frontal bone, each of them 4 1/2 cm away from the midline and 2 1/2 cm above the supra-orbital margin. The bone in the window cuts as well as the brain tissue were carefully removed, while the falx cerebri, falx cerebelli and tentorium cerebelli were left intact. The oscillator was connected with the piezoelectric element which we attached to the falx cerebri using some vacuum silicon gel, which allowed attachment to the membrane without changing the mechanical properties of the membrane. The oscillator was used to provide a sine wave of approximately 3,000 Hz. The oscilloscope was connected with a microphone which was stabilized with pins and clips in the opposite side of the falx cerebri. The position of the microphone was 1 cm. away from the falx cerebri and in exactly the

(Cont'd on next page)

Changes in Magnitude of Relative Cerebri During the Application of External Forces on the Frontal Bone of an Embalmed Cadaver

(Cont'd from preceding page)

opposite direction of the piezoelectric element (Fig. II). The position of the piezoelectric element in relation to the position of the microphone was changed until the maximum amplitude of signal was established on the screen of the oscilloscope. The initial amplitude was recorded. A stable metallic bar was placed 75 cm. above the frontal bone in a parallel direction with the axis between the two nails. Two, 2 cm. diameter pulleys were stabilized on the metallic bar. Two threads of fishing line—1 m. each—were tied to the nails, passed through the pulleys and tied with their other ends to two balance trays. The angle between the axis of the body was 90°. Each of the balance trays weighted 71 grams (142 grams both trays). We added a total weight of

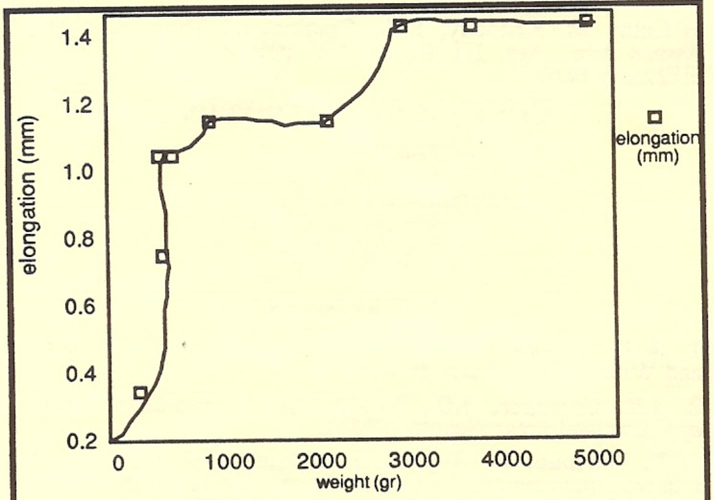

FIGURE III
Correlation curve between relative elongation (mm) of the falx cerebri and force (gr.) applied on the frontal bone of an embalmed cadaver.

242, 392, 442, 542, 642, 974, 1806, 2850, 3752, and 4654 grams respectively. Each of these weights was applied on the balance trays. A shift between the relative positions of the microphone and the piezoelectric element occurred. This shift produced changes in the observed amplitude of oscillation on the oscilloscope. These changes were recorded by an assistant data recorder. The researcher added equal amounts of weight on each tray each time.

The initial amplitude of oscillation that was recorded in the oscilloscope, using 0 gr. of weight was: 5.6 * 10 mV. After applying additional weights, the researcher recorded the relative changes in the amplitude on the oscilloscope. The relative change was calculated from the following equation:

Relative Change (mV) = Initial Amplitude - Amplitude

Initial Amplitude : 5.6 * 10 mV

After obtaining the relative changes in amplitude, the numbers were applied in the following equation to transform the changes in amplitude (mV) to changes in relative elongation (mm).

Relative elongation = 0.0457 * Relative change

The accompanying table presents the results from the application of the equation in all the different numbers of relative change (Table I). Based on the magnitude of relative elongation obtained, the correlational curve was drawn in Figure III. The data was further tested using linear correlation coefficient. For the curve, the Pearson's correlation coefficient is +0.083. This number shows that there is a small positive correlation (+0.083 or 8.3%) between an external force applied on the frontal bone of an embalmed cadaver and the relative elongation of the galx cerebri which is caused by the transmission of this force to the falx cerebri. The hypothesis of sutural mobility is supported by these results. The researcher found that 642 grams was the critical weight. After that point there is minimal change of the magnitude of elongation even if more weight was applied. If we calculate the correlation between weight and relative elongation up to the critical point, the Pearson's correlation coefficient is +0.97 or 97%. This means that up to a certain point there is an elastic deformation of the membrane which takes place due to the elastic component of the falx cerebri. At the region of elastic deformation the correlation between the weight and the magnitude of relative elongation was very high. After this critical point, which was 642 gr. in this experiment, a plastic deformation takes place. At the region of plastic deformation the correlation becomes minimal.

Considering the assumption that there is cranial suture mobility,[2-6] when the weight was applied on the frontal bone it caused the frontal bone to move slightly away from its initial position. The applied force was transmitted from the frontal bone to the attached falx cerebri causing an elongation/deformation. falx cerebri consists of elasto-collagenous fibers. At the region of elastic deformation, elastic fibers are primarily stretched out producing the relative elongation of the falx cerebri. For the plastic deformation of falx cerebri, collagenous fibers are primarily responsible. The elastic deformation is mostly a temporary deformation with temporary or permanent effects in the cranium. The plastic deformation is a permanent deformation with permanent effects in the cranium. The results of this study are in agreement with our study concerning the elon-

(Cont'd on next page)

Changes in Magnitude of Relative Cerebri During the Application of External Forces on the Frontal Bone of an Embalmed Cadaver

(Cont'd from preceding page)

gation of the falx cerebri during the application of external forces on the frontal bone. However, this study went a step further by examining the correlation of these two variables. The results of this study present evidence in opposition to the belief of Moore and other traditional anatomists,[1,7] that cranial sutures are solidly fused and immobile in adulthood. If the cranial sutures were fused, we would not be able to record changes in the magnitude of relative elongation of the falx cerebri. The results of the studies by Retzlaff et al.[3,4,6,7] are similar to the results of this study concerning cranial suture mobility. This study is based on the same basic principles as the study by Rowe.[9] However, Rowe's study was an empirical study which did not include any statistical

Weight (gr.)	Amplitude (MV)	Change (MV)	Magn. of Rel. Elong (mm)
0	5.6 x 10	0	0.300
2424	4.8 x 10	0.8 x 10	0.366
392	4.0 x 10	1.6 x 10	0.731
442	3.4 x 10	2.2 x 10	1.005
542	3.4 x 10	2.2 x 10	1.005
642	3.2 x 10	2.4 x 10	1.097
974	3.2 x 10	2.4 x 10	1.097
1806	3.2 x 10	2.4 x 10	1.097
2850	2.6 x 10	3.0 x 10	1.371
2752	2.6 x 10	3.0 x 10	1.371
4654	2.6 x 10	3.0 x 10	1.371

Table I
Changes in the magnitude of relative elongation (mm) of the falx cerebri when weights (gr.) were applied on the frontal bone of an embalmed cadaver.

analysis. This study includes measurements and statistical calculations to support the hypothesis.

The researchers acknowledge the fact that the instrument used for this study may not be sensitive enough to record changes in the magnitude of relative elongation with less weight. Researchers can use more sensitive instruments and fresh cadavers for future studies. Further research on elongation of the falx cerebri with external forces on the parietal and/or sphenoid bones and on elongation of the falx cerebelli and/or tentorium cerebelli needs to be done.

In conclusion this study demonstrated that when an external force is applied on the frontal bone of an embalmed cadaver, this force may be transmitted to the falx cerebri causing a relative elongation of it. According to this study a relative elongation of 0.366 mm was recorded when weight of 242 gr. was applied. The maximum relative elongation was 1.371 mm. A relative elongation of 1.097 mm, which was the outcome of the application of 642 gr., constituted the critical point where the elastic deformation of the membranes stops and a plastic deformation begins. There is a positive but low correlation between an external force applied on the frontal bone and the relative elongation of the falx cerebri which is caused by the transmission of this force to the falx cerebri.

REVIEWERS

1) John E. Upledger, D.O., F.A.A.O., 11211 Prosperity Farms Rd., Palm Beach Gardens, FL 33410; (407) 622-4334.

2) Dr. Wen Ling, Physical Therapy Dept., New York University, 433 First Ave., N.Y., NY 10010; (212) 998-9407.

3) Melissa Lieberman, M.S., R.P.T., 2678 Ocean Ave., Apt. 5L, Brooklyn, NY 11229; (718) 332-3769; (212) 995-1410.

4) Ioannis Psarobas, M.S., Physicist, Polytechnic Univ., Dept. of Physics, 333 Jay St., Brooklyn, NY 11201; (718) 260-3613.

5) Cathy M. Kennedy, P.T., Craniosacral Therapist, 2922 Barnes Ave., Apt. 1-J, Bronx, NY 10467; (212) 653-2074; (212) 995-1410.

COLLEAGUE REVIEWERS

Reuben Ingber, M.D.
Dr. A. Nelson
Konstantine Rizopoulos, M.A., P.T.
Claudia Garcia, P.T.A.
Sylvia Ferst, R.P.T.
Elein Becker, R.P.T.

REFERENCES

1. **K.L. Moore**, *Clinically Oriented Anatomy*, Williams and Wilkins, Baltimore, (1984).

2. **J.E. Upledger, J.D., Vredevoogd**, *CranioSacral Therapy*, Eastland Press, Seattle, (1988).

3. **P. Norman, R. Roppel, E. Retzlaff,** The detection of relative movements of cranial bones, Proceedings of the twentieth national osteopathic research conference part II, *JAOA*, 76, pp. 286-289, (1976).

4. **E.W. Retzlaff, D.M. Michael, R. Roppel,** *Cranial bone mobility*, Papers and abstracts from the eighteenth national osteopathic research conference, 74, pp. 869-872, (1975).

5. **J.J. Pritchard, J.H. Scott, F.G. Girgis**, The structure and development of cranial and facial sutures, *Journal of Anatomy*, 90, pp. 70-76, (1956).

6. **E.W. Retzlaff, D. Michael, R. Roppel, F. Mitchell**, The structures of cranial bone sutures, *JAOA*, 75, pp. 607-608, (1976).

7. **J.E. Anderson**, *Grant's Atlas of Anatomy*, Williams and Wilkins, Baltimore, (1983).

8. **D.K. Michael, E.W. Retzlaff,** A preliminary study of cranial bone movement in the squirrel monkey, Papers and abstracts from the eighteenth national osteopathic research conference, *JAOA*, 74, pp. 866-868, (1975).

9. **C.S. Rowe**, Cranial dissections, *Upledger Institute Newsletter*, March 1989.

10. **D.C. Kostopoulos and G. Keramidas**, *Changes in tension of the cranial membranes during craniosacral therapy techniques*, Unpublished study, July 1989.

11. **L.D. Landau and E.M. Lifshitz**, *Theory of Elasticity*, Pergamon Press, Oxford, (1986).

12. **D. Halliday, R. Resnick**, *Fundamentals of Physics*, John Wiley and Sons, Inc., New York, (1981).