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

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(Special to the Forum)

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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.

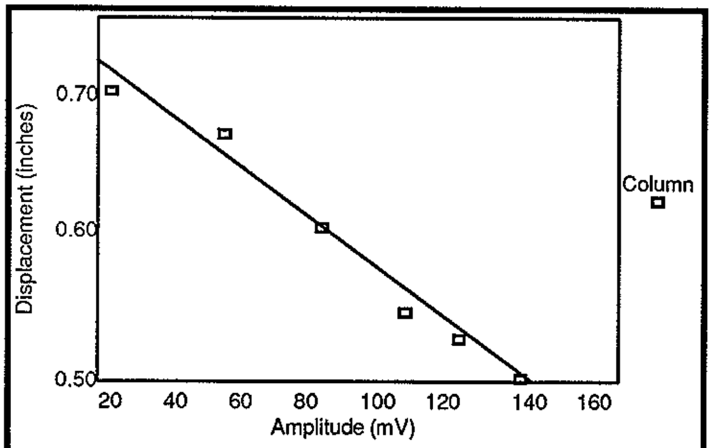

FIGURE I
Calibration curve of the instrument used for the study.
The following equations apply:
$Y = 0.7509 - 0.0018 X$
Y: inches of elongation
X: amplitude (mV)
or
$S = 19.073 - 0.0457 X$
S: magnitude of elongation in mm

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

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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

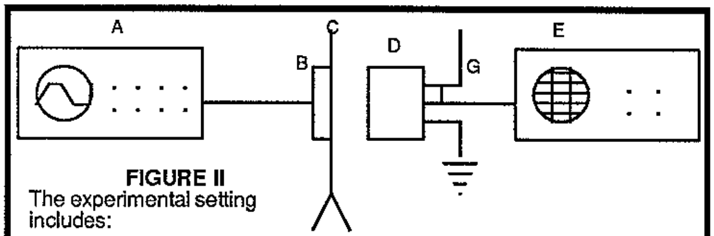

FIGURE II
The experimental setting includes:
A: Oscillator
B: Piezoelectric element
C: Falx Cerebri
D: Microphone
E. Oscilloscope

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

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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

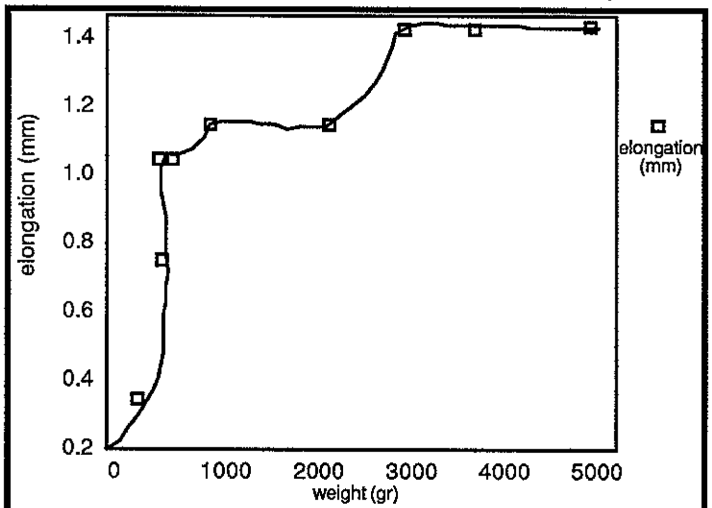

FIGURE III
Correlation curve between relative elongation (mm) of the falx cerebri and force (gr.) applied on the frontal bone of an embalmed cadaver.

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-

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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
242	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.

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