Effect of Cranial Osteopathic Manipulative Medicine on Cerebral Tissue Oxygenation

Xiangrong Shi, PhD; Seth Rehrer, OMS IV; Parna Prajapati, MBBS, MPH; Scott T. Stoll, DO, PhD; Russell G. Gamber, DO, MPH; and H. Fred Downey, PhD

Context: The use of cranial osteopathic manipulative medicine (OMM) to alter cerebral tissue oxygen saturation could play a role in the maintenance of cerebral homeostasis.

Objective: To examine the effects of cranial OMM on cerebral tissue oxygen saturation (S_cT_O_2) and cardiac autonomic function in healthy adults.

Methods: Cranial OMM augmentation and suppression techniques and sham therapy were randomly applied to healthy adults. During cranial OMM and sham therapy, S_cT_O_2 of the prefrontal cortex was determined bilaterally by using near-infrared spectroscopy. Heart rate, blood pressure, and systemic arterial blood oxygen saturation (SaO_2) were also measured. Power spectral analysis was applied to continuous 4-minute R-R intervals. Measurements were made during 2-minute baseline periods, during 4-minute applications of the techniques, and during 5-minute recovery periods.

Results: Twenty-one adults (age range, 23-32 y) participated in the present study. Differences in mean baseline measurements for the augmentation technique, suppression technique, and sham therapy were not statistically significant for heart rate, blood pressure, SaO_2, left S_cT_O_2, or right S_cT_O_2. During the suppression technique, there was a statistically significant decrease in both left (slope [standard deviation] = -0.33 [0.08] %/min, R^2 = 0.85, P = .026) and right (slope [standard deviation] = -0.37 [0.06] %/min, R^2 = 0.94, P = .007) S_cT_O_2 with increased cranial OMM time. However, neither the augmentation technique nor the sham therapy had a statistically significant effect on S_cT_O_2. Decreases in normalized low-frequency power of R-R interval variability and enhancements of its high-frequency power were statistically significant (P = .05) during cranial OMM and sham therapy, indicating a decrease in cardiac sympathetic influence and an enhanced parasympathetic modulation.

Conclusion: The cranial OMM suppression technique effectively and progressively reduced S_cT_O_2 in both prefrontal lobes with the treatment time.

J Am Osteopath Assoc. 2011;111(12):660-666

The efficacy of cranial osteopathic manipulative medicine (OMM) has been reported in the treatment of tension-type headache. To our knowledge, however, the mechanisms of action for cranial OMM have not been explored and are poorly understood. It has been hypothesized that these mechanisms, at least in part, involve improved cerebral homeostasis associated with changes in cerebral blood flow and cerebral tissue oxygenation (S_cT_O_2).

Cranial OMM is an area of study based on the postulation that intracranial structures exhibit interdependent movements during the process of internal respiration, or the primary respiratory mechanism. Brain tissues, including the parenchyma, arteries, and cerebrospinal fluid, show rhythmic motion. Human lambdoid sutures, which join the occipital and parietal bones, maintain the patency that allows small amounts of movement. Although the cranial bones and the dura mater do not generate rhythmic movement, their compliance allows limited movement and they can, thus, respond to cranial OMM.

During flexion movement, the sphenoid and occipital bones rotate about their transverse axes anteriorly; during extension movement, these bones move in reverse. Therefore, we postulated that use of cranial OMM to enhance flexion and extension of the cranial sphenobasilar synchondrosis at the occipital and posterior parietal bones could augment the primary respiratory mechanism (ie, augmentation technique) and that the use of cranial OMM to prohibit flexion and enhance extension of the movement of the cranial base and the petrous portions of the temporal bones could suppress the

From the departments of integrative physiology (Drs Shi and Downey and Mr Prajapati) and osteopathic manipulative medicine (Drs Rehrer, Stoll, and Gamber), the Cardiovascular Research Institute (Drs Shi and Downey), and The Osteopathic Research Center (Drs Shi, Gamber, and Downey) at the University of North Texas Health Science Center in Fort Worth.

Financial Disclosure: This study was supported in part by AOA grant #09-11-594.

Address correspondence to Xiangrong Shi, PhD, 3500 Camp Bowie Blvd, Department of Integrative Physiology, University of North Texas Health Science Center, Fort Worth, TX 76107-2644.

E-mail: xiangrong.shi@unthsc.edu

Submitted December 22, 2010; final revision received July 15, 2011; accepted August 22, 2011.
primary respiratory mechanism (i.e., suppression technique).

The purpose of the present study was to examine whether \( S_{\text{CTO}_2} \) and cardiac autonomic modulation would be responsive to cranial OMM augmentation and suppression techniques. We hypothesized that the use of cranial OMM to alter the primary respiratory mechanism or to cause movement at the occipital and posterior parietal bones could elicit responses or changes in \( S_{\text{CTO}_2} \) and cerebral blood flow or volume. In other words, we believed that the augmentation technique would increase \( S_{\text{CTO}_2} \), and the suppression technique would decrease \( S_{\text{CTO}_2} \). Furthermore, we hypothesized that cranial OMM would help balance the cardiac autonomic nervous function, as reflected by change in heart rate or R-R interval variability.

**Methods**

The present study took place October 12, 2009, through December 10, 2009, at the research laboratory of the Department of Integrative Physiology, University of North Texas Health Science Center in Fort Worth. The study was approved by the institutional review board of the University of North Texas Health Science Center.

**Participants**

Participants were recruited by means of advertisement, personal contact, and e-mail during September 2009 through November 2009. Participants were included in the study if they were 18 to 75 years old, healthy, and normotensive. Exclusion criteria included the use of antihypertensive medication. Volunteers who met the study criteria gave their consent to participate in the study and completed a physical examination within 2 weeks of recruitment. Cranial OMM appointments were scheduled on a rolling basis according to the availability of the participant and the physician.

**Procedure**

After approximately 15 minutes of supine rest after instrumentation (i.e., placing instruments on the participant), the participant underwent 2 cranial OMM techniques and sham therapy (Table 1). The order of the cranial OMM techniques and sham therapy was randomly assigned. The procedures followed a single-blind protocol; participants were blinded to the order of therapy. In a previous study, we found that 5 minutes of recovery time between treatments was sufficient for return to baseline. Each of the steps was completed with either “hands on” or “hands off.” For hands-on steps, the physician’s hands were placed directly behind the back of the participant’s head. For hands-off steps, the physician’s hands were removed from the back of the participant’s head. The cranial OMM techniques and sham therapy comprised 2 minutes of baseline with hands on, 4 minutes of therapy, and 5 minutes of recovery with hands off. All procedures were performed by the same AOA board-certified osteopathic physician (S.T.S.). These cranial OMM techniques were selected based on the findings of a pilot study; they caused no substantial head movement and no interference with continuous measurement of \( S_{\text{CTO}_2} \) from the prefrontal lobes of the cortex.

The cranial OMM used in the procedure comprised an augmentation technique and a suppression technique. The augmentation technique involved enhancing flexion and extension movement of the cranial sphenobasilar synchondrosis at the occipital and posterior parietal bones to augment the primary respiratory mechanism. This technique was performed using the standard vault hold. With the participant lying supine on a table, the operator (S.T.S.) sat 8 to 10 inches away from the head of the table. With forearms resting comfortably on the head of the table, he then lightly contacted the sides of the participant’s head with both hands, using the palmar surface of all his fingers and palms but not the thumbs. The index and middle fingers were placed bilaterally on the greater wings of the sphenoid bones, while the ring and little fingers were placed on the lateral angles of the occiput. The operator encouraged both flexion and extension by enhancing the motion of the sphenoid and occiput bones with his own hands.

The suppression technique involved prohibiting flexion movement and enhancing extension movement of the cranial

---

**Table 1.**

<table>
<thead>
<tr>
<th>Protocol Step</th>
<th>Duration, min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>5</td>
</tr>
<tr>
<td>Augmentation</td>
<td></td>
</tr>
<tr>
<td>Baseline with hands on</td>
<td>2</td>
</tr>
<tr>
<td>Augmentation technique</td>
<td>4</td>
</tr>
<tr>
<td>Recovery with hands off</td>
<td>5</td>
</tr>
<tr>
<td>Suppression</td>
<td></td>
</tr>
<tr>
<td>Baseline with hands on</td>
<td>2</td>
</tr>
<tr>
<td>Suppression technique</td>
<td>4</td>
</tr>
<tr>
<td>Recovery with hands off</td>
<td>5</td>
</tr>
<tr>
<td>Sham Therapy</td>
<td></td>
</tr>
<tr>
<td>Baseline with hands on</td>
<td>2</td>
</tr>
<tr>
<td>Sham therapy</td>
<td>4</td>
</tr>
<tr>
<td>Recovery with hands off</td>
<td>5</td>
</tr>
</tbody>
</table>

* The order of the manipulative techniques and sham therapy was randomized in a single-blind fashion; however, all patients began with baseline. “Hands on” means the physician’s hands were placed directly behind the back of the patient’s head; “hands off” means the physician’s hands were removed from the back of the patient’s head.
base and the petrous portions of the temporal bones to suppress the primary respiratory mechanism. To perform this technique, the operator applied compression of the fourth ventricle (CV-4) technique. With the participant resting in the supine position on the table, the operator placed 1 of his hands in the palm of the other, so that his thenar eminences laid parallel to one another. The operator then slipped his hands under the participant’s head, with the lateral angles of the occiput medial to the occipitomastoid suture resting on the thenar eminences. The operator’s fingers were free and not pressing on the neck. The weight of the head rested on the thenar eminences, which gently compressed the lateral angles.

The operator suppressed the cranial rhythm by enhancing cranial extension and discouraging cranial flexion. During extension, the occiput moved in a superior direction. The operator enhanced this motion by adding superior traction to the occiput during that phase of the cycle. He then discouraged flexion movement by maintaining that superior traction. The sham therapy was uniform for each participant and mimicked the suppression technique (ie, CV-4 technique) by using a random manual maneuver. Neither augmentation nor suppression was performed during the sham therapy.

**Measurements**

During the study, heart rate, blood pressure, \( S_{\text{ct}}O_2 \), and systemic arterial oxygen saturation (\( SaO_2 \)) were continuously monitored. Heart rate was determined using electrocardiography. Systemic arterial blood oxygen saturation was continuously measured using an arterial pulse oximeter (OXY100C; BIOPAC Systems Inc; Goleta, California). Beat-to-beat radial systolic blood pressure and diastolic blood pressure were noninvasively monitored with blood pressure tonometry (Colin CBM-7000, San Antonio, Texas). In a previous study, we validated that radial blood pressure carefully measured with the tonometry method is highly correlated with the blood pressure monitored with an intraradial arterial catheter. In addition, R-R interval variability was assessed as an indication of cardiac autonomic modulation. A strong correlation (slope=0.98, \( R^2=0.96 \)) between changes in \( S_{\text{ct}}O_2 \) and jugular venous blood oxygen saturation has been demonstrated previously.

**Data Analysis**

We converted a section of 4-minute continuous beat-to-beat R-R interval data with minimum variance into power spectral data by using a fast Fourier transform algorithm. Both low-frequency (0.05-0.15 Hz) and high-frequency (0.20-0.30 Hz) power spectra of R-R interval variability were extracted and were normalized by the ratios of low frequency/low frequency + high frequency and high frequency/(low frequency + high frequency), respectively. These low frequency and high frequency ranges include the rhythms for the Mayer wave (approximately 0.1 Hz) and normal breathing frequency (approximately 15 cycles/min), respectively.

Analysis of variance was applied to test the effect of different procedures on the cardiovascular and oxygenation variables. Linear regression was applied to test the changes in these variables with the time of the procedures. \( P \) values less than or equal to .05 were considered to indicate a statistically significant difference. The data were reported as group mean and standard error of the mean (SEM). Statistical Analysis System (SAS, Cary, North Carolina) and DADiSP (DSP Development Corporation, Cambridge, Massachusetts) software programs were applied for statistical analysis and power spectral analysis, respectively.

**Results**

Twenty-one healthy volunteers (8 women, 13 men) aged 23 to 32 years (mean [SEM] body mass index, 24 [3.7]) gave written consent and participated in the present study. No volunteers were excluded from the study. Differences in baseline measurements (group mean [SEM]) for the augmentation technique, suppression technique, and sham therapy were not statistically significant for heart rate (69 [15], 71 [23], 69 [9] beats/min), mean blood pressure (79 [2], 77 [3], 76 [3] mm Hg), \( SaO_2 \) (98 [1], 97 [1], 97 [1]%), left \( S_{\text{ct}}O_2 \) (65 [9], 66 [10], 66 [10]%), or right \( S_{\text{ct}}O_2 \) (66 [11], 67 [10], 67 [10]%) (Table 2).

Heart rate, blood pressure, and \( SaO_2 \) remained constant during the cranial OMM techniques and sham therapy (Figure 1). Neither augmentation (left: 0.10 [0.05]%/min, \( R^2=0.56, P=.144 \); right: 0.06 [0.05]%/min, \( R^2=0.33, P=.314 \)) nor sham therapy (left: -0.06 [0.02]%/min, \( R^2=0.68, P=.084 \); right: -0.10 [0.05]%/min, \( R^2=0.54, P=.156 \)) affected cerebral tissue oxygenation. Cerebral tissue oxygenation was decreased in left (-0.33 [0.08]%/min, \( R^2=0.85, P=0.026 \)) and right (-0.37 [0.06]%/min, \( R^2=0.94, P=.007 \)) prefrontal lobes by the suppression technique (Figure 2).

The group mean (SEM) low-frequency power of R-R interval variability for the baseline condition, augmentation
technique, suppression technique, and sham therapy was 461.7 (90.3), 460.3 (152.2), 396.7 (96.0), and 426.0 (89.0) milliseconds, respectively. The group mean (SEM) high-frequency power of R-R interval variability was 383.6 (248.0), 555.3 (374.7), 395.6 (182.2), and 535.8 (301.2) milliseconds for the baseline condition, augmentation technique, suppression technique, and sham therapy, respectively. The differences of these variables were not statistically significant between baseline and therapies. However, the normalized low-frequency power was statistically significantly lower and the normalized high-frequency power was statistically significantly higher during the augmentation maneuver ($P=0.035$), the suppression maneuver ($P=0.032$), and the sham therapy ($P=0.013$) than during the baseline condition. This finding indicates a diminished sympathetic influence and an enhanced parasympathetic modulation on the heart (Figure 3).

**Comment**

The present study provides 2 novel findings. First, cranial OMM with suppression technique can effectively and progressively elicit cerebral hemodynamic response by decreasing cerebral tissue oxygenation in the left and right prefrontal cortex with the treatment time. Second, cranial OMM and sham therapy to the cranium relax cardiac sympathetic modulation and enhance cardiac vagal modulation as reflected by power spectral analysis of R-R interval variability.

We did not observe a statistically significant increase in $S_{CTO_2}$ during cranial OMM with the augmentation technique, which was contrary to our original hypothesis. This finding suggests that the augmentation technique is ineffective in altering the cerebral hemodynamic response in healthy young participants when there is no cerebral tissue oxygen deficiency (Figure 2). However, the suppression technique, or CV-4 technique, elicited a response in $S_{CTO_2}$ which was progressively decreased in both the left and right sides of the prefrontal lobes with the increasing application time (Figure 2). This response could not be a result of the placebo factor because there was no response to sham therapy. Also, the order of the techniques was random and patients were blinded.

Changes in heart rate, blood pressure, and $SaO_2$ during the augmentation technique, suppression technique, and sham therapy were not statistically significant (Figure 1). Furthermore, neither cranial OMM nor sham therapy seemed to increase the oxygen extraction rate in the cerebral tissue as indicated by $S_{CTO_2}$. On the basis of these findings, we may assume that the participant’s overall systemic and cerebral metabolic rate remained constant during the experiment and that the decrease in $S_{CTO_2}$ we observed during the suppression technique was most likely due to reduced oxygen delivery resulting from depression of cerebral blood flow. This notion is supported by findings from Formes et al, which revealed that decreases in middle cerebral blood flow velocity, determined with transcranial Doppler ultrasonography, closely paralleled decreases in $S_{CTO_2}$ during central hypovolemia or simulated hemorrhage. In another study, Zhang et al observed increases in $S_{CTO_2}$ during CO2 stimulated cerebral vasodilation, which appeared to be independent of oxygen content.

Collectively, findings of the present study suggest that the cranial OMM suppression technique could be effectively applied to alleviate excessive intracranial pressure by reducing cerebral blood flow or volume. Although the mechanism by which the suppression technique was able to elicit $S_{CTO_2}$ responses was not clear, we postulated that suppression of the cranial rhythmic impulses as a result of enhancing cranial extension and discouraging cranial flexion could more effectively create intracranial force to facilitate venous outflow from the dural sinuses into the internal jugular vein and to resist internal carotid arterial blood flow. This impact of the suppression technique may be even greater if the technique is applied on patients with excessive intracranial pressure or volume. In addition, the effect could be further enhanced with repeated therapy bouts or multiple therapy sessions. Thus, these findings support application of cranial OMM for conditions in which cerebral blood flow or pressure is excessive, such as migraine headaches. In any case, findings from the present study suggest that the decrease in $S_{CTO_2}$

### Table 2.

Baseline Characteristics of Healthy Participants Receiving Cranial Osteopathic Manipulative Medicine and Sham Therapy (N=21)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Manipulative Technique, Group Mean (SEM)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Augmentation Technique</td>
</tr>
<tr>
<td>$SaO_2$, %</td>
<td>97.6 (0.18)</td>
</tr>
<tr>
<td>Heart Rate, beats/min</td>
<td>67 (2)</td>
</tr>
<tr>
<td>Blood Pressure, mm Hg</td>
<td></td>
</tr>
<tr>
<td>Systolic</td>
<td>115 (3)</td>
</tr>
<tr>
<td>Diastolic</td>
<td>61 (2)</td>
</tr>
<tr>
<td>$S_{CTO_2}$, %</td>
<td></td>
</tr>
<tr>
<td>Left side</td>
<td>65.3 (1.9)</td>
</tr>
<tr>
<td>Right side</td>
<td>66.8 (2.1)</td>
</tr>
</tbody>
</table>

*No differences were statistically significant.

Abbreviations: $SaO_2$, systemic arterial oxygen saturation; $S_{CTO_2}$, cerebral tissue oxygen saturation; SEM, standard error of the mean.
produced by the suppression technique of cranial OMM is benign in a group of healthy, young adults.

Although heart rate was not statistically significantly affected by cranial OMM or sham therapy, the normalized R-R interval variability was decreased in the low-frequency power spectrum and increased in the high-frequency power spectrum (Figure 3). This outcome is consistent with a study by Henley et al\textsuperscript{18} that determined that both cervical OMM and its sham therapy statistically significantly improved heart rate variability. It is well recognized that low frequency of the R-R interval variability power spectrum is modulated by sympathetic nerve activity, and high frequency is influenced by parasympathetic modulation.\textsuperscript{10} Improved cardiac vagal dominance and reduced sympathetic nervous activity are protective against cardiac attack and arrhythmia.\textsuperscript{10,19,20} In the present study, cardiac autonomic function improved during sham therapy as well as during the cranial OMM augmentation and suppression techniques. Although there was an apparent placebo effect on the normalized R-R interval variability during the cranial OMM, these results demonstrate positive effects of manually touching the patient in accordance with osteopathic principles.\textsuperscript{21} This outcome suggests that the autonomic nervous system could be more readily affected by psychological influence than other physiologic responses (eg, cerebral tissue oxygenation).

A limitation of this study is that the present interventional observation is unable to pinpoint the physiologic mechanism for the responses of \( S_{\text{TOT}}O_2 \) that were correlated with

\textbf{Figure 1.} Group heart rate, mean blood pressure, and arterial oxygen saturation during cranial osteopathic manipulative medicine augmentation technique, suppression technique, and sham therapy. No statistically significant differences from baseline were noted for any variables during any therapy.
...cant reduction in the cerebral blood flow as manifested by \( S_{CTO_2} \) (an index of cerebral blood flow) that correlated with the treatment time. Thus, this technique could be applied to alleviate conditions associated with intracranial hypertension or excessive volume. Future studies should be conducted in patients with these types of chronic clinical conditions to further assess the effect of multiple sessions of cranial OMM with suppression technique on cerebral homeostasis, as well as on autonomic nervous balance. We believe that the physiologic response, or the efficacy of cranial OMM, will be more substantial in patients with intracranial hypertension or excessive volume than in healthy adults.

Acknowledgments
We sincerely thank our volunteer participants for their cheerful cooperation.

References

Figure 2. Cerebral tissue oxygen saturation during cranial osteopathic manipulative medicine augmentation technique, suppression technique, and sham therapy.


**Figure 3.** Normalized low-frequency and high-frequency power of R-R interval variability. Compared to the baseline, the low frequency power was lower and the high frequency power was higher during cranial osteopathic manipulative medicine augmentation technique, suppression technique, and sham therapy (P<0.05). No statistically significant differences were found between therapies.