The Effect of an Alternative Medical Procedure Upon Low-Frequency Oscillations in Cutaneous Blood Flow Velocity

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Abstract

Objective: Compression of the fourth ventricle (CV-4) is a manual, noninvasive procedure that reportedly affects the cranial rhythmic impulse, a phenomenon recognized by practitioners of cranial manipulation, that is concomitant with low-frequency Traube-Hering (TH) oscillations in blood flow velocity. This study examines the CV-4 and its effect upon blood flow velocity.

Methods: Human subjects were paired with 28 individual physicians for application of the CV-4, and the duration of the application was recorded. Flowmetry records tracking the course of the procedure were obtained, 20 of which were useable for intergroup comparisons. Segments of these records (control, treatment, response) were Fourier-transformed; the Fourier-transformed spectra were subtracted from one another and the resultant difference-spectra compared.

Results: The mean CV-4 procedure length was 4.43 ± 2.22 minutes. The mean frequency of the TH waveform visible in the blood flowmetry record was 7.10 ± 2.07 cpm. The CV-4 procedure specifically affected the low-frequency oscillations in blood flow velocity. After application, the amplitude of the TH, 0.10 Hz, frequency wave increased (relative area units: control minus treatment [0.08010 units) compared with control minus response [−0.03358 units]; $P = .011$).

Conclusions: This study showed that CV-4 has an effect on the TH frequency component of blood flow velocity. The practitioners of cranial manipulation who participated in this study affected their subjects in a quantifiable manner with the application of the CV-4 procedure. (J Manipulative Physiol Ther 2006;29:626-636)

Key Indexing Terms: *Skull; Manipulation, Osteopathic; Flowmeters; Blood Circulation; Baroreflex*

Cranial manipulation is a treatment modality that is classified as a form of alternative (manual) medicine. Its clinical indication is the treatment of somatic dysfunction (balanced membranous tension) of the head, and of the remainder of the body, through the use of gentle manually applied forces. It is thought to affect the patient, in part, through modulation of the proposed primary respiratory mechanism (PRM).[1-3] One manifestation of this mechanism is a palpable oscillation with a reported frequency from 4 to 14 cycles per minute, called the cranial rhythmic impulse (CRI).[4-13] The PRM/CRI is a subtle phenomenon that reportedly is readily palpable only by experienced individuals, thus making its very existence subject to debate.[14,15] Therefore, it is appropriate to attempt to elucidate the PRM/CRI in the context of established physiologic phenomena.

Within human physiology, there are documented low-frequency oscillations that occur at rates approximating those reported for the PRM/CRI. One such phenomenon, a complex waveform demonstrable in blood pressure and blood flow velocity, is the Traube-Hering-Mayer (THM) oscillation (Fig 1). This complex phenomenon has been subdivided into 3 contributing components of independent frequencies. Of particular interest to this study, because multiple authors have commented upon the similarity between the Traube-Hering (TH) wave and the CRI,[16-19] is the TH oscillatory component that has a frequency reported here (Table 1) of 5 to 9 cycles per minute (0.09-0.15 Hz). The TH waveform was first described as an independent phenomenon when, in 1865, Traube[20] reported measurement of a pulse pressure fluctuation at the frequency of respiration that persisted, however, after respiration had been arrested. Fourier-transform analysis of blood physiologic parameters shows the 3 principle

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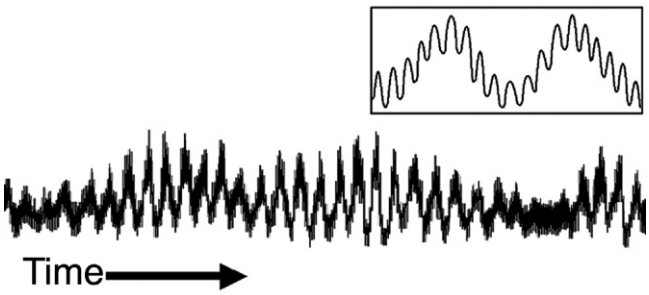

Fig 1. *The THM oscillation, a complex waveform visibly demonstrable in blood pressure and blood flow velocity. This figure is a compressed flowmetry representing approximately 5 minutes of recording time. The inset illustrates an expanded portion of the record showing 2 TH waves with the heart rate clearly visible.*

spectral signals that constitute the THM fluctuation. Identified, according to increasing frequency, they are the thermal or Mayer wave (0.02-0.09 Hz; 1.2-5.4 cpm), the baro or TH wave (0.09-0.15 Hz; 5.4-9.0 cycles per minute), and the respiratory wave, which shifts in frequency with changes in the respiratory rate.[21] A fourth heretofore unrecognized minor spectral component at 0.08 Hz is identified in this article.

By comparing blood flow velocities, as measured by laser-Doppler flowmetry, with cranial palpation, we have shown previously that the palpable CRI is congruous with the TH component of the THM oscillation.[22] We have further shown that a patient-individualized cranial manipulation, as compared with a sham intervention consisting of palpation only, specifically affects the TH component of the THM oscillation,[23] and that the effect can be elicited intermittently, on demand, according to a previously-agreed-upon off/on timed protocol.[24] In this study, again using laser-Doppler flowmetry, we have elected to evaluate a recognized specific cranial manipulative procedure, the compression of the fourth ventricle (CV-4).[2,3,25] The CV-4 procedure is commonly used to stimulate the circulatory mechanisms of the PRM in a fashion similar to the cranial procedures previously studied. It however involves the induction of a still point, the reduction of the CRI to 0 amplitude, as its therapeutic end point. Thus, it is of particular interest to compare the process, the therapeutic intervention, with its end point, the still point, and with its therapeutic effect, stimulation of the PRM. The use of flowmetry permits the acquisition of a greater precision of measurement that not only provides insight into the physiologic effect of the CV-4, but also allows the computation of the amount of time necessary to accomplish a therapeutic effect, a measurement of practical value in the clinical setting.

There are therefore several questions to be evaluated in this study. (1) How long does it take an experienced practitioner to accomplish the intended therapeutic goal using the CV-4 procedure? (2) What is the effect of the CV-4 procedure upon blood flow velocity? (3) Is the effect of the CV-4 procedure quantifiable through Fourier-transformation analysis of flowmetry data? (4) And, if it is quantifiable, is the effect reproducible from practitioner to practitioner? The underlying hypothesis is that, the CV-4 procedure results in, first, a suppression of the TH wave to a still point, at what the practitioner perceives as the therapeutic end point, followed by a rebound response increasing the TH wave.

Methods

Setting/Protocol

Experiments were conducted during the annual American Academy of Osteopathy Convocation, Colorado Springs, Colo, March 18 to 19, 2004, within a designated treatment booth in the Osteopathic Diagnosis and Treatment Service area. Interested, trained (minimum of 5 years) physicians were asked if they could perform the CV-4 procedure. Individuals who indicated that they were comfortable performing the procedure were given a written description of the CV-4 and asked whether that description of the procedure was consistent with the way they used it. Those responding in the affirmative were then asked to complete a physician's demographic form and were assigned a unique statistical identifier. A cooperative subject was recruited at random from among participants in the Osteopathic Diagnosis and Treatment Service, given an informed consent form to read, then given time to ask questions and sign the form if still interested in participating. The Midwestern University institutional review board approved this study.

Subjects/Physician Demographics

Subjects (n = 26) were adults (>18 years) of both sexes (no pregnant females), in reasonably good health, and taking no medications. Although 28 records were taken and all used to compute the mean duration of a CV-4 procedure, 8 of these (29%) were not suitable for quantification and for intergroup comparisons because of the presence of high-frequency noise or insufficient length that rendered the flowmetry records unusable for subsequent data reductions and statistical analyses. There were 20 useable records for intergroup comparisons (n = 20). Of these, 13 subjects were male and 7 female, with a mean age ± SD of 39.6 ± 15.0 years (range, 24-75 years). The combination of 1 physician plus 1 subject at 1 CV-4 application constituted 1 statistical case.

Physicians (n = 28; mean clinical experience ± SD, 23.2 ± 10.2 years [range, 5-51 years], with a mean age ± SD of 53.2 ± 10.4 years [range, 33-75 years]). On average, they saw 48 patients per week, during which osteopathic manipulative treatment was used in 91.8% of visits and cranial manipulation in 79.6% of visits.

Table 1. *Descriptive statistics for the duration of the low-frequency, TH oscillation in blood flow velocities obtained from 3062 discrete measurements (28 subjects) from flowmetry time-course data*

TH wave in cycles per minute	n	Range	Minimum	Maximum	Mean	SD	Variance
	3062	19.95	1.40	21.35	7.0969	2.0733	4.299

Blood Flow Velocity

Blood flow velocity was measured using a laser transcutaneous blood flowmeter (Transonic Laser-Doppler Monitors, BLF21 Series, Transonic Systems, Inc, Ithaca, NY). This perfusion monitor determines the Doppler velocity change of the erythrocyte (hemoglobin) in blood in the subcutaneous capillaries. That information is digitized for subsequent data reduction. The device uses a fiber-optic probe that rests upon the skin surface and causes no discomfort to the subject. The type R probe has 2 optic fibers, one that sends laser light into the tissue, whereas the other transfers the reflected light from those tissues to a photo detector for electronic processing (WinDaq Data Acquisition and Playback Software, Transonic Systems, Inc).

The physicians were seated at the head of a standard manual treatment table. The subjects laid supine upon the treatment table, with the laser-Doppler probe affixed to the midline of their foreheads using double-sided tape, and with the lead directed caudally so as not to interfere with the physicians' actions. This lead placement was determined by experimental trials and represents utility in that the probe could be placed on any cutaneous surface of the body and obtain analogous results. Subjects were allowed to lie quietly upon the table for a 3-minute equilibration period before the initiation of recording. A baseline blood flow velocity record of 5 to 7 minutes, the control segment (Fig 2, "control"), was then obtained. During this control segment period, the subjects' heads rested upon the physicians' hands, which were held in the appropriate positions for diagnosis and treatment; however, no treatment was administered. At the end of this control segment, the physicians were instructed to begin implementation of the CV-4 cranial manipulation, and upon the treating physicians' indication that they had begun treatment, an event mark was entered into the electronic record by the technician (Fig 2).

The treatment phase lasted from 1.42 to 10.07 minutes (Table 2) until the physicians indicated that they had obtained their therapeutic goal, at which point a second event mark was entered into the flowmetry record, indicating the end of the treatment segment, (Fig 2, "treatment"). The physicians then removed their hands from contact with the subjects' heads, and the response to treatments was followed for an additional 5 to 7 minutes (Fig 2, "response"). Twenty-eight physicians and 26 volunteer subjects participated in this study. Both treating physicians and subjects were blinded to operations at the computer console.

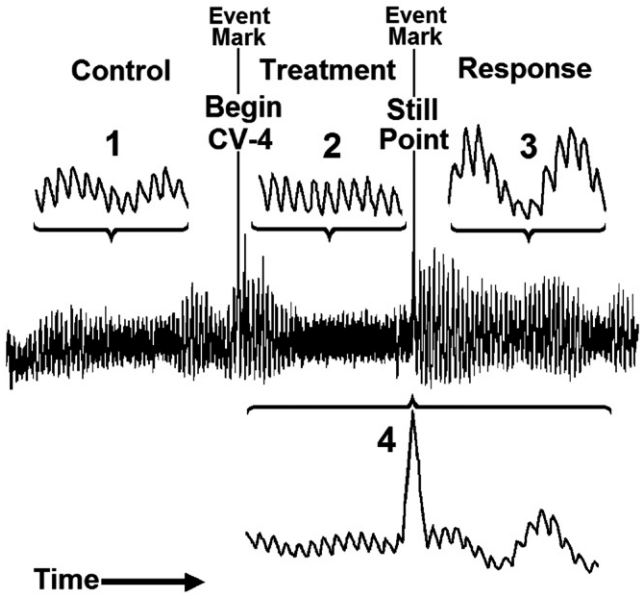

Fig 2. *A complete flowmetry time-course record of 1 experimental session demonstrating inserted event marks delineating the beginning and termination of the CV-4 procedure. Numbered inserts represent expanded portions of the record at the following points: 1, control segment before the initiation of treatment; 2, the CV-4 procedure, treatment segment; 3, response-to-treatment segment; 4, the record including the event mark at the termination of treatment, the still point immediately prior (left), and the rebound response immediately posttreatment (right).*

The CV-4 Procedure

The CV-4 is a cranial treatment procedure that has been used by practitioners of cranial manipulation for more than 60 years.[2,3,25] A general description of the CV-4, as used in this study, follows. It must be noted here that the procedure may be performed with minor variations by individual practitioners, and in this protocol, for the sake of maximizing the number of participants, individual practitioners were allowed to use their own personal variations. In spite of these variations, the points when the physician was to give verbal indication to the technician, who then entered an event mark into the flowmetry record, remain the same and are identified, in the procedural description below.

For the procedure, the patient lies supine upon the treatment table, and the physician is seated at the end of the table, at the patient's head. The physician's hands are placed, palms up, beneath the patient's head, with one hand resting in

Table 2. *Duration of the application of the CV-4 procedure necessary to achieve a therapeutic end point*

Procedure Duration (min)	n	Range	Minimum	Maximum	Mean	SD	Variance
	28	8.65	1.42	10.07	4.426	2.223	4.942

Descriptive statistics of the time required for a CV-4 procedure by the participating physicians of this study, beginning as directed by the treating physician and ending when the physician indicated that the treatment was completed. Case values were derived by computing the lapsed time between event marks entered into the flowmetry console.

the palm of the other, in such a fashion that the thenar eminences are parallel, contacting the lateral angles of the patient's occiput. It is stressed that the physician's thenar eminences must contact the patient's head on the squamous portion of the occiput, medial to the occipitomastoid suture. The weight of the patient's head is allowed to rest upon the physician's thenar eminences, resulting in medially directed pressure upon the lateral angles of the occiput. The physician can then palpate the occiput, and the biphasic flexion/extension of the CRI. As the occiput moves into flexion, the physician perceives a swelling sensation accompanied by the perception of lateral and caudal (relative to the patient) displacement of their thenar eminences, and as the occiput moves into extension, a sense of medial and cephalad displacement is appreciated. The physician can thus passively monitor the rate, rhythm, and amplitude of the CRI.

The treatment phase of the procedure begins (first event mark entered) by the physician actively following the occiput into the extension phase of the CRI and gently increasing the medially directed pressure of their thenar eminences upon the lateral angles of the occiput. When the occiput reaches full extension, it is poised to reverse direction and enter the flexion phase of the cycle. At this point, the physician gently resists and holds the occiput in extension. The process is repeated with each progressive cycle of the CRI, with the physician tracking the amplitude of the palpable CRI as it becomes progressively lower until a still point is reached, the still point being the moment when the CRI seems to palpably stop[3] (Fig 2, immediately left of the second event mark). After the still point, the physician waits for the motion of the CRI to return and then follows it into the ensuing flexion and extension. At this point the physician indicated that the procedure was complete, and the second event mark was entered.

Low-Frequency Blood Flow Oscillation

The mean frequency of the dominant low-frequency oscillation in blood flow velocity was measured by identifying the peak-to-peak intervals within control segments of the flowmetry records from all 28 subjects (Fig 3). Detected signals corresponded to oscillations having a computed signal-to-noise ratio of more than 0.16 (signal amplitude/peak-to-peak noise). This minimum signal amplitude corresponds to the nominal minimum amplitude palpable by a trained examiner.

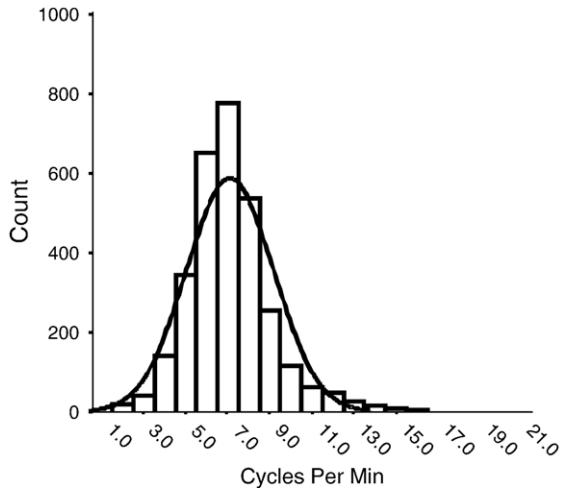

Fig 3. *Distribution of the mean frequency of the visibly dominant low-frequency oscillation (TH wave) in blood flow velocity from 28 subjects (n = 3062; mean, 7.10 ± 2.07; range 5.02-9.17). The solid line identifies the computed statistical distribution.*

Data Reduction and Statistical Analysis

From the 28 available records, experimental records of low noise and appropriate segment length, suitable for quantification and for intergroup comparisons (n = 20), ranged from 15- to 24-minute duration. These records consisted of 3 continuously linked segments delineated by the event marks entered into the record by the technician on command of the treating physician. The 3 segments are identified consecutively (Fig 2) as follows: control, the pretreatment resting period; treatment, the CV-4 treatment period; and response, the immediate response period (total waveform segments = 60). Within each of these segments, a portion of the record from at least 4 to 6 minutes of duration, the minimum block providing acceptable Fourier-transform spectra for statistical analyses, was identified. Typically, these portions were located immediately before therapeutic intervention for the control segment, immediately upon the treatment culmination, often in association with a still point, for the treatment segment, and a response segment approximately 45 seconds after the indicated cessation of the procedure and removal of the treating physician's hands from the subject's head. Minor adjustments were sometimes needed to allow sufficient time for each subject's response, or to avoid noise in the record or atypical sections.

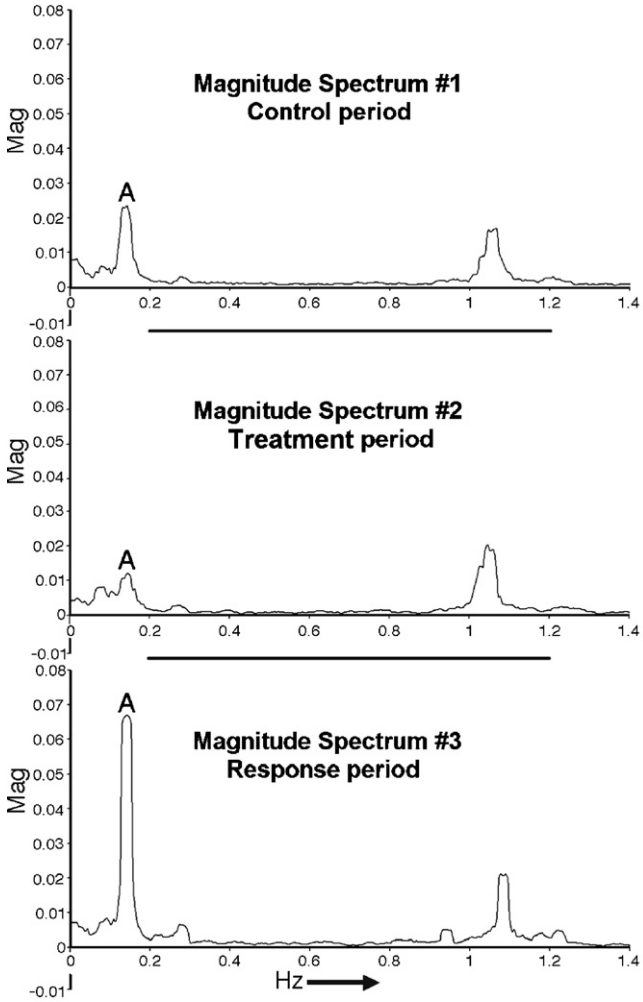

Fig 4. *Frequency-domain spectra obtained through Fourier transformation of the 3 time-course segments of Fig 2: 1, control; 2, treatment period; 3, response to treatment period. The signal designated as "A" occurs at 0.1 Hz; it is this signal that changes magnitude significantly with the CV-4 procedure.*

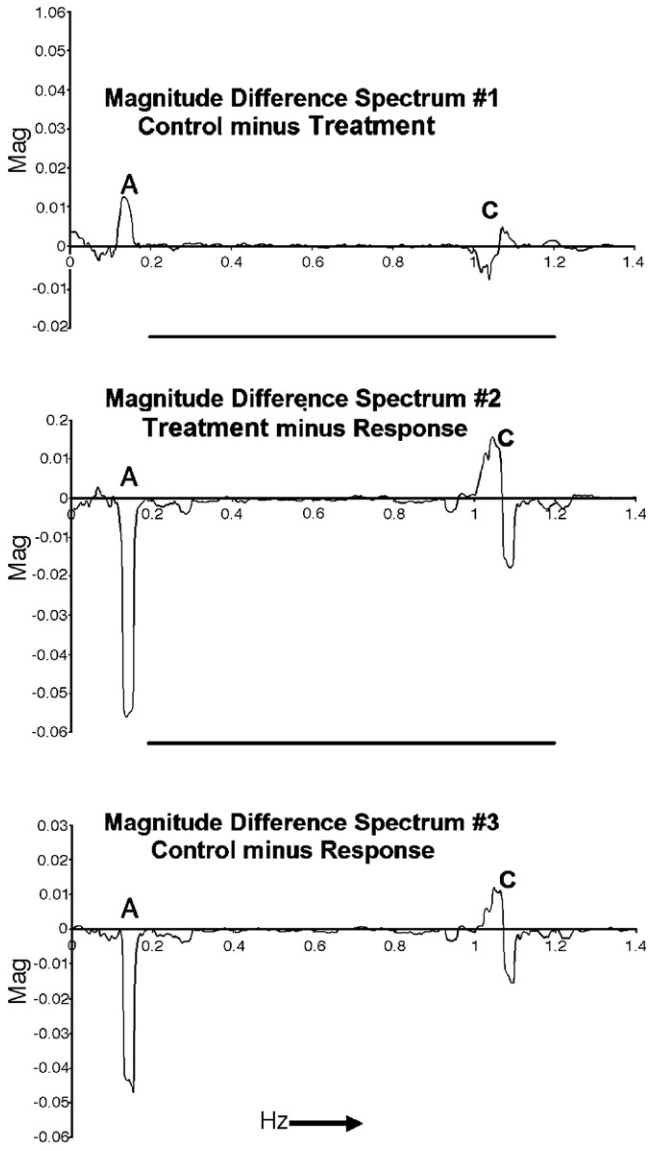

Fig 5. *Difference spectra obtained through point-by-point magnitude subtraction along the frequency axis (abscissa) of the 3 spectra in Fig 4: 1, C − T; 2, T − R; 3; C − R. In these spectra, the (residual) signals correspond to those components that change magnitude (either positive or negative) between the subtracted pairs.*

For each discrete subject record, the shortest of the 3 identified segments, control, treatment, and response, was selected, and its duration noted to the nearest 0.01 second. Then, portions of that flowmetry recording from the remaining 2 segments, each of precisely identical duration to that of the shortest segment, were extracted for Fourier transformation into frequency-domain spectra (energy, as power or magnitude, as a function of frequency in hertz).

A transformed spectrum was then computed for each of these waveform segments to generate 60 frequency-domain spectra, each with identical frequency-matched abscissa, and each corresponding to 1 of the respective 60 identified waveform segments (Fig 4). These discrete Fourier-transforms (DFT) were performed by the WinDaq Waveform Browser (DI-151RS, Dataq Instruments, Akron, Ohio) flowmetry data processing program, using an average power of 5 (number of data points averaged using a moving-average filter) and a compression of 30 (number of data points evaluated for a minimum/maximum value), and output as an ASCII file for subsequent processing in the spreadsheet program Microsoft Excel (Microsoft, Inc, Redmond, Wash). After translation of the output files into Excel, these were plotted and compared with the discrete Fourier-transformed spectra generated by WinDaq.

A coherent point-by-point subtraction was then carried out in Excel to generate the following difference spectra: control minus treatment ($C - T$), treatment minus response ($T - R$),

Table 3. *Descriptive statistics for the 1-way ANOVA comparing signal areas and frequencies from difference spectra: C − T, C − R, and T − R*

Variable	Difference spectrum	n	Mean	SD	SE	95% Confidence interval for mean		Minimum	Maximum
						Lower bound	Upper bound		
0.02-Hz area	$C - T$	20	0.03557	0.11082	0.02478	−0.01628	0.08744	−0.13316	0.33390
	$C - R$	20	0.00921	0.10491	0.02345	−0.03988	0.05832	−0.21342	0.22589
	$T - R$	20	−0.02540	0.06916	0.01546	−0.05777	0.00696	−0.16746	0.07687
	Total	60	0.00646	0.09835	0.01269	−0.01894	0.03187	−0.21342	0.33390
0.08-Hz area	$C - T$	20	0.01027	0.03131	0.00700	−0.00438	0.02492	−0.04052	0.07236
	$C - R$	20	−0.01330	0.04557	0.01019	−0.03463	0.00802	−0.16415	0.04293
	$T - R$	20	−0.01556	0.02408	0.00538	−0.02683	−0.00429	−0.07367	0.02639
	Total	60	−0.00619	0.03619	0.00467	−0.01555	0.00315	−0.16415	0.07236
0.10-Hz area	$C - T$	20	0.08010	0.13239	0.02960	0.01813	0.14206	−0.08777	0.53175
	$C - R$	20	−0.03358	0.10473	0.02341	−0.08260	0.01543	−0.24212	0.27762
	$T - R$	20	−0.11156	0.10441	0.02334	−0.16042	−0.06269	−0.34498	0.07134
	Total	60	−0.02168	0.13779	0.01778	−0.05727	0.01391	−0.34498	0.53175
Lower cardiac frequency	$C - T$	20	1.1163	0.17807	0.03981	1.0329	1.1996	0.827	1.481
	$C - R$	20	1.1113	0.18694	0.04180	1.0237	1.1987	0.737	1.486
	$T - R$	20	1.1166	0.17663	0.03949	1.0339	1.1992	0.827	1.471
	Total	60	1.1147	0.17753	0.02292	1.0688	1.1605	0.737	1.486
Lower cardiac area	$C - T$	20	−0.00452	0.08751	0.01956	−0.04548	0.03643	−0.15880	0.14283
	$C - R$	20	−0.00834	0.08485	0.01897	−0.04806	0.03136	−0.15615	0.15041
	$T - R$	20	−0.02085	0.10726	0.02398	−0.07105	0.02934	−0.32067	0.13869
	Total	60	−0.01124	0.09241	0.01193	−0.03511	0.01262	−0.32067	0.15041
Upper cardiac frequency	$C - T$	20	1.1883	0.18370	0.04107	1.1023	1.2742	0.898	1.592
	$C - R$	20	1.1916	0.17750	0.03969	1.1085	1.2747	0.921	1.567
	$T - R$	20	1.1868	0.17623	0.03940	1.1043	1.2693	0.890	1.559
	Total	60	1.1889	0.17612	0.02273	1.1434	1.2344	0.890	1.592
Upper cardiac area	$C - T$	20	0.04231	0.17292	0.03866	−0.03861	0.12324	−0.16004	0.51880
	$C - R$	20	0.02343	0.09891	0.02211	−0.02285	0.06972	−0.15618	0.28395
	$T - R$	20	−0.01656	0.10117	0.02262	−0.06391	0.03078	−0.29504	0.13484
	Total	60	0.01639	0.12918	0.01667	−0.01697	0.04976	−0.29504	0.51880

and control minus response ($C - R$) (Fig 5). These difference spectra, which represented only that which was different between the subtracted spectral pair, were also plotted and subsequently integrated to obtain spectral signal areas.

From these difference spectra, signal areas were computed from 3 signals in the low-frequency region centered at 0.02, 0.08, and 0.10 Hz. The 0.02-Hz signal represents physiologic activity in the range of the Mayer wave, and the 0.10-Hz signal represents activity consistent with the TH wave. The signal at 0.08 Hz is a minor signal that is resolved in flowmetry data, but not reported in earlier work with lower reported frequency and signal-to-noise resolution. Sufficient data have now been accumulated verifying the existence of this minor resonance in the subject flowmetry records.

In addition, areas were computed from both the low- and high-frequency halves of the cardiac signal (centered approximately at 1.1 Hz depending upon the subject). Because heart rates changed with treatment, these signals in the difference spectra are no longer necessarily in register. The representation of the cardiac signal in all 3 difference spectra in Fig 5 contains both positive and negative components, resulting in the sinusoidal trace displayed for this signal. The minimum and maximum frequency components of the cardiac signal also were recorded. The procedural details of this data reduction, including analysis of DFT difference spectra and computed indexes, have been published previously.[26]

The analysis of variance (ANOVA) was used to determine significance among the 3 groups ($C - T$, $T - R$, $C - R$) for each signal-area and frequency value, 7 scalar variables in total consisting of the areas of the signals centered at 0.02, 0.08, and 0.10 Hz; areas of the lower-frequency cardiac bands; areas of the higher-frequency cardiac bands; and the frequencies at the maximum amplitude (either positive or negative) of both cardiac bands. Pairwise comparisons between group pairs also were evaluated using Scheffé, Bonferroni, Tukey, and least significant difference range tests (respectively, from most conservative), with an α of .05 accepted as significant.

Results

Frequency of the TH Waveform

The range of the dominant low-frequency oscillation (TH) visibly present in the flowmetry record (Fig 1) was determined by counting the peak-to-peak intervals within the control segment of the records from 28 subjects (a total

Table 4. *One-way ANOVA for each spectral signal (variable) among the 3 segment-difference groups of the experimental time course (n = 20)*

Variable		Sum of squares	*df*	Mean square	F	*P*
0.02-Hz area	Between groups	0.037	2	0.019	1.999	.145
	Within groups	0.533	57	0.009		
	Total	0.571	59			
0.08-Hz area	Between groups	0.008	2	0.004	3.377	.041[a]
	Within groups	0.069	57	0.001		
	Total	0.077	59			
0.10-Hz area	Between groups	0.372	2	0.186	14.147	.000[a]
	Within groups	0.749	57	0.013		
	Total	1.120	59			
Lower cardiac frequency	Between groups	0.000	2	0.000	0.006	.995
	Within groups	1.859	57	0.033		
	Total	1.860	59			
Lower cardiac area	Between groups	0.003	2	0.001	0.166	.847
	Within groups	0.501	57	0.009		
	Total	0.504	59			
Upper cardiac frequency	Between groups	0.000	2	0.000	0.004	.996
	Within groups	1.830	57	0.032		
	Total	1.830	59			
Upper cardiac area	Between groups	0.036	2	0.018	1.086	.344
	Within groups	0.949	57	0.017		
	Total	0.985	59			

The groups compared are as follows: $C - T$ with $C - R$, $C - T$ with $T - R$, and $C - R$ with $T - R$.
[a] Significant at the .05 level.

of 3062 determinations). A mean rate of 7.10 cycles per minute (Table 1 and Fig 3) was obtained, with a range within 1 SD (2.073) of 5.02 to 9.17.

The Duration of the CV-4 Procedure

The duration of treatment with the CV-4 procedure was computed from 28 individual records of different subjects, each being treated by a different physician (Table 2). The treatment interval was determined by measuring the elapsed time on the flowmetry record between the event mark entered into the record when the physician indicated that they had commenced the active CV-4 procedure and the event mark entered into the record when they indicated that they had attained their therapeutic goal. The mean duration of treatment calculated for the CV-4 procedure was 4.43 minutes, with a range of 8.65 minutes (minimum, 1.42 minutes; maximum, 10.07 minutes), an SD of ±2.22 minutes, and a variance of 4.94.

Statistical Comparisons of the Frequency Components Derived from Fourier-Transform Difference Spectra

The difference spectra comparing $C - R$, $C - T$, and $T - R$ segments of the flowmetry record contain the same set of characteristic signals. These signals occur at the lower frequencies of 0.02, 0.08, and 0.10 Hz. In addition, because of the change in the heart rate during the protocol, the high-frequency cardiac signal also found in these spectra was divided into a low-frequency band and a high-frequency band (these separated by a characteristic transition point). Both halves of the cardiac signal were integrated as separate signals, and further, the characteristic frequency of each band (the frequencies at the maximum amplitude, either positive or negative, of both cardiac bands) was tabulated and compared statistically.

Analysis of Variance

The Fourier-transform difference spectra were tested for significance among the 3 difference-spectral groups, $C - R$, $C - T$, and $T - R$, for 7 signal-area and frequency variables using the ANOVA. Descriptive statistics are presented in Table 3, the 1-way ANOVA in Table 4, and pairwise comparisons in Table 5. Significant differences among the 3 groups were determined for 2 signal-area variables, the minor signal at 0.08 Hz ($P = .041$), and the baro, or TH, signal at 0.10 Hz ($P = .000$). No significant differences were determined for the low-frequency, thermo (Mayer) signal at 0.02 Hz or for any of the 4 cardiac signal variables.

Pairwise Comparisons

In the pairwise analysis using the Scheffé range test (Table 5), significant differences were found only for the 0.10-Hz area variable at the .05 α level; however, the 0.08-Hz signal did exhibit parallel differences at the .072 level. Using the Bonferroni, Tukey, and least significant difference range tests, which are all less conservative than the Scheffé, the 0.08-Hz α computed, respectively, to .067, .057, and .022. It is considered probable, therefore, that both signals are affected together, and in the same sense, by the

Table 5. *Pairwise comparison of control, treatment, and response spectral segment differences using the Scheffé comparison procedure applied to the mean signal areas of the 0.02-, 0.08-, and 0.10-Hz signal difference-spectra*

Dependent variable	Means, difference pairs: $C - T$, $C - R$, $T - R$	(I) DCTR	(J) DCTR	Mean difference ($I - J$)	SE	P	95% Confidence interval	
							Lower bound	Upper bound
0.02-Hz area	0.03558	$C - T$	$C - R$	0.02636	0.03059	.692	−0.05052	0.10324
		$T - R$	0.06098	0.03059		.146	−0.01590	0.13787
	0.00922	$C - R$	$C - T$	−0.02636	0.03059	.692	−0.10324	0.05052
		$T - R$	0.03462	0.03059		.531	−0.04226	0.11151
	−0.02540	$T - R$	$C - T$	−0.06098	0.03059	.146	−0.13787	0.01590
		$C - R$	−0.03462	0.03059		.531	−0.11151	0.04226
0.08-Hz area	0.01027	$C - T$	$C - R$	0.02357	0.01101	.110	−0.00410	0.05125
		$T - R$	0.02583	0.01101		.072	−0.00184	0.05351
	−0.01330	$C - R$	$C - T$	−0.02357	0.01101	.110	−0.05125	0.00410
		$T - R$	0.00226	0.01101		.979	−0.02541	0.02993
	−0.01557	$T - R$	$C - T$	−0.02583	0.01106	.072	−0.05351	0.00184
		$C - R$	−0.00226	0.01101		.979	−0.02993	0.02541
0.10-Hz area	0.08010	$C - T$	$C - R$	0.11368[a]	0.03624	.011	0.02259	0.20477
		$T - R$	0.19166[a]	0.03624		.000	0.10057	0.28275
	−0.03358	$C - R$	$C - T$	−0.11368[a]	0.03622	.011	−0.20477	−0.02259
		$T - R$	0.07797	0.03622		.108	−0.01311	0.16906
	−0.11156	$T - R$	$C - T$	−0.19166[a]	0.03624	.000	−0.28275	−0.10050
		$C - R$	−0.07797	0.03624		.108	−0.16906	0.01311

Mean differences are derived from the means of signal areas computed by integration of the magnitude Fourier-transform spectra.
DCTR, paired differences among data groups C, T, and R.
[a] The mean difference for segment pairs is significant at the .05 level.

experimental manipulation, and that the differences in significance between the 2 variables reflect the much lower signal-to-noise ratio of the minor 0.08-Hz signal rather than fundamental differences in the behavior of each signal band with CV-4 manipulation.

The variable that shows the largest mean difference in response to CV-4 manipulation is the area of the 0.10-Hz signal, and all 3 combinations, $C - R$, $C - T$, and $T - R$, are significantly different from each other.

Discussion

This study looks at the duration of application, and the effect, of an established alternative medicine manipulative procedure. The CV-4 is one of the first procedures to be used by practitioners using cranial manipulation.[2,25] It shows that the procedure, CV-4, may be monitored by flowmetry in such a way that all parts of the procedure can be observed by multiple individuals in real time, if this is appropriate, as in a teaching venue.

The CV-4 is said to increase the amplitude of the CRI, enhancing fluid motion within the PRM.[2] This is what appears to have occurred in this study. The instrumentation used in this protocol measures blood flow velocity, and the amplitude of the TH wave in the flowmetry record was markedly increased (Fig 2) indicating increased fluid, in this case blood, motion at the 0.09- to 0.15-Hz frequency. The TH wave has been shown to correspond with the palpable phenomenon of the CRI.[22] The increased amplitude of the TH wave (Table 3, Figs 4 and 5) in this instance, therefore, appears to confirm the observations of clinicians that, after a CV-4 procedure, the CRI is amplified. The flowmetry analysis, because it is capable of dissecting the complex TH waveform into its component parts, allows for precise identification of the affected physiologic phenomena, leading to greater precision in theoretical interpretation and the development of more focused studies.

The identities of the low-frequency hemodynamic components are established, having been shown by means of spectral analysis and correlated with physiology.[21] These low-frequency oscillations have been identified as manifestations of the sympathetic nervous system regulation upon peripheral vasculature[27] and both sympathetic and parasympathetic regulation of heart rate.[28] The flowmetry waveforms used for purposes of data analysis in this protocol are complex phenomena, generated by the interplay between the established low-frequency components within blood flow velocity. Because the application of the CV-4 procedure is based upon the palpatory perception of the CRI, which we have interpreted as being equivalent to the dominant oscillation in the flowmetry record, it was deemed appropriate to visually extract the rate of the dominant low-frequency waveform directly from the flowmetry time-domain trace (Table 1 and Fig 3) to establish its correspondence with the frequencies of the data obtained by means of Fourier transformation. The peak-to-peak visual assessment for the rate of the TH corresponds precisely to the frequency range obtained through Fourier transformation. This is because the 0.1-Hz frequency ("A" in

Fig 4) is the dominant signal contributing to TH waves (Figs 1 and 2).

The $C - T$, $C - R$, and $T - R$ spectra are difference spectra obtained from a coherent subtraction of the frequency-domain spectrum of one segment of the CV-4 protocol from that of another segment. They are spectra only of that which is different between the experimental segments. To examine the effect the CV-4 procedure on the 0.10-Hz baroreflex signal, it is necessary to compare the mean values of signal magnitude from each difference pair (Table 5, 0.10-Hz area; Fig 5, frequency spikes indicated as "A"). Considering the $C - T$ spectral pair, the difference signal is positive (0.08). This indicates that the 0.1-Hz signal magnitude is diminished during treatment relative to control. In contrast, the difference signal of the $T - R$ spectral pair is negative (-0.11) because the response rebound of the 0.1-Hz signal is greater than during the treatment segment. Relative to control, the net response to treatment ($C - R$) is also negative (-0.03), indicating a net increased magnitude of the 0.10-Hz signal in the response segment. Moreover, the amplitude difference is nearly 4 times greater for the $T - R$ spectral pair than for the $C - R$ spectral pair, indicating a substantial magnitude amplification after treatment. Thus, the net effect of manipulation upon the 0.10-Hz signal is to increase signal strength.

The duration of the CV-4 treatment intervention required to obtain what the individual practitioners perceived to be a therapeutic end point, in this instance, was 4.43 ± 2.22 minutes (mean $\pm$ SD). This is a duration that is consistent with the published report of 3 to 7 minutes for CV-4 application.[29] It must, however, be acknowledged here that the subjects being treated, in this instance, were individuals of relatively good health, without significant somatic dysfunction, and that patients with significant organic pathology may require as much as 45 minutes for a successful application of the CV-4.[29]

The clinicians who participated in this study were all established practitioners who used cranial manipulation on a regular basis with, in many cases, decades of experience with the CV-4 procedure. It should be recognized that, because cranial manipulation is an advanced psychomotor skill, individual practitioners develop their own variations of manipulative procedures such as the CV-4. In this protocol, the positions of the subjects and the physicians, including hand placement, were always the same. The greatest variability was in what the individual physician used as their personal indication of treatment end point. There is some debate among practitioners as to what the most effective end point for treatment should be, although the literature defines the end point as immediately after the induction of a still point.[2,3,25] In this instance it was elected to allow experienced individuals who, by training and clinical experience, understood the desired therapeutic end point of the CV-4, to use their own personal modifications of the procedure, as long as it conformed generally to the procedure write-up given to the physician at the outset of each encounter. This allowed us to acquire as many participants for the protocol as possible.

There was nothing extraordinary about the subjects who participated in this study, with the exception that, given the venue, they were almost exclusively physicians interested in the subject of cranial manipulation. For this reason it might be suggested that they could have brought bias as to the outcome of the procedure. Although both the physician performing the procedure and the subject were blinded to the flowmetry record, the subject was aware of the sequence of the protocol because of the verbal commands given by the treating physician to the technician, indicating initiation and cessation of the procedure. This could be construed to invalidate the results of this study based upon the probable expectations of the subjects that the intervention would have an effect. Taken in the context of this study alone, this issue may well be a valid criticism. We have, however, already showed that cranial manipulation (equilibration of the global cranial motion pattern and the craniocervical junction) specifically affected the TH component of blood flow velocity, whereas a sham intervention, touch with similar hand placement to that of treatment but without the application of therapeutic forces, had no such effect.[23] In that earlier study, the demonstrated effect upon the TH wave, amplification, was the same as shown in this present study. Therefore, we can safely state that the CV-4 impacts the patient in similar fashion to the previously studied cranial manipulation, and that it does so in the area of physiology that has been associated with the palpable CRI.

Of additional interest is the fact that during the application of CV-4, a procedure intended to hold the CRI in the extension phase of the oscillation and to decrease its amplitude, the effect upon blood flow velocity was to dampen the TH oscillation and to essentially eliminate it when the still point was obtained (Fig 2 and Table 5, 0.10-Hz area, $C - T$ is positive). In another study, the use of bilateral temporal rocking, an incitant procedure applied to amplify the CRI, resulted in significant amplification of the TH wave during application.[24] Thus, during the application of the CV-4 procedure, it has been demonstrated that blood flow velocity is affected in a manner consistent with what should be expected from descriptions of the effect of the CV-4 upon the CRI, and in a manner opposite to that shown during the application of incitant temporal rocking.

In 2 instances now we have demonstrated that cranial manipulation affects blood flow velocity in a manner that is consistent with the description of the effect of those procedures by cranial practitioners.

Conclusions

From the above data, we have drawn 5 conclusions. First, that the duration of the CV-4 treatment intervention

required to obtain a therapeutic end point in this instance was 4.43 ± 2.22 minutes (mean ± SD), consistent with the previously published report of 3 to 7 minutes.[29] Second, the application of the CV-4 procedure has an effect upon the low-frequency oscillations observed in blood flow velocity. After its application, the amplitude of the TH wave, the component of blood flow velocity that has been linked to the palpable phenomenon of the CRI, increases.[22] Third, cranial manipulation may affect the autonomic nervous system because TH frequency phenomena have been shown to be mediated through parasympathetic and sympathetic activity.[21,27,28] Fourth, there is a quantifiable difference between palpation alone, the control section above, and cranial treatment using the CV-4 procedure. It is suggested that palpation alone may be used as a sham treatment in future research in the field of cranial manipulation. This protocol used the skills of 28 experienced clinicians, performing the procedure in the fashion that they generally use during the course of their respective clinical practices; therefore, the results are reproducible among these individuals skilled in cranial manipulation. Practitioners of cranial manipulation who participated in this study may affect their patients in a quantifiable manner when they perform the CV-4 procedure.

Practical Applications

- The cranial rhythmic impulse appears to be related to low-frequency oscillations in blood flow velocity.
- Application of the CV-4 in this study resulted in amplification of the 0.1-Hz frequency, baroreflex-mediated, oscillation in blood flow velocity.
- Fourier transformation of flowmetry records showed that human physiology may be affected by cranial manipulation.

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