Ultrasound analysis of the vertebral artery during non-thrust cervical translatoric spinal manipulation

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Objective: Cervical translatoric spinal manipulation (TSM) techniques have been suggested as a safer alternative to cervical thrust rotatory techniques. The objective of this study was to determine the effect of three C5–C6 non-thrust TSM techniques on vertebral artery (VA) lumen diameter (LD) and two blood flow velocity parameters. The two-tailed research hypothesis was that the TSM techniques would result in a significant change (increase or decrease) in blood flow velocity and arterial LD at the C5–C6 intertransverse portion of the VA.
Methods: In a sample of 30 subjects representative of a clinical population, color-coded duplex Doppler diagnostic ultrasound imaging was used to collect data on LD, peak systolic velocity (PSV), and end diastolic velocity with the cervical spine positioned in neutral and in three different manipulation positions. Pair-wise mean differences between measurements at baseline (neutral position) and in all three manipulation positions were analyzed using two-tailed paired *t*-tests with alpha set at 0.05.
Results: Of the 18 paired comparisons, there were four statistically significant differences between measurements in the neutral position and a manipulation position, three concerning LD and one PSV.
Discussion: The three significant differences in LD ranged from 4.6 to 3.2% and were not associated with changes in blood flow velocity. The one significant change in PSV was only 6.6 cm/s. A value that still greatly exceeded the end diastolic velocity. No subject experienced symptoms associated with VA compromise. This study has provided evidence for the safety of the three lower cervical non-thrust TSM techniques on the current population studied. Further study is required on thrust versus non-thrust TSM techniques and on levels other than C5–C6.

Keywords: Translatoric spinal manipulation, Cervical spine, Color-coded duplex Doppler diagnostic ultrasound imaging, Blood flow velocity, Lumen diameter

Manual therapy has been a prominent part of the physical therapy scope of practice ever since the first therapists were educated at the Royal Central Institute of Gymnastics in Stockholm as early as 1813.[1,2] Currently, instruction in joint manipulation is a standardized component of both entry-level and postgraduate physical therapy programs.[3,4] Specific to thrust and non-thrust manipulation of the cervical spine, there is a growing body of research evidence supporting its use as a sole intervention or as part of a multimodal management approach for patients with mechanical neck pain, cervical radiculopathy, cervicogenic dizziness, cervicogenic and migraine headache, temporomandibular disorders, subacromial impingement, and lateral epicondylalgia.[5] However, the literature also reports an association between the use of cervical manipulation and various minor and major adverse events, among the latter most notably vertebral artery (VA) ischemia, dissection, and stroke. Minor events were reported in as few as 35%, and as many as 61% of patients who received their first cervical manipulation. Minor events occurred at a rate of one incident for every 476 to 1573 manipulations, compared to serious adverse events which occurred at a rate of one incident per 20 000 to 3 000 000 manipulations.[6–12]

DiFabio[7] reported that in those cases where the technique was identified rotatory manipulations were most often associated with adverse events. Kaltenborn *et al.*[13] strongly advised against the use of rotatory manipulation techniques and noted a high risk of adverse events with such techniques. Kaltenborn *et al.*[13,14] and Krauss *et al.*[15] have suggested and described translatoric spinal manipulation (TSM) techniques as a safer alternative to rotatory techniques. TSM is defined as a system of

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small-amplitude manipulative techniques using straight-line impulses delivered in a parallel or perpendicular direction to an individual vertebral joint or motion segment.[15] In recent years, there has been an increasing body and also progressively higher level of evidence supporting the clinical effectiveness of TSM in the management of patients with cervical impairments.[16–19]

In addition to being effective, TSM techniques also appear to be safe. Maher *et al.*[19] reported no adverse events including significant changes in pain or perceived stiffness in 32 postgraduate students receiving TSM to the cervical spine from peers over a 6-month period. In a case report, Kondratek and colleagues[17] analyzed VA blood flow during application of translatoric non-thrust techniques at C1–C2 and C5–C6 and found no significant differences as compared to baseline values in the neutral spine position. Considering the potentially serious nature of adverse events there is, however, a need to further study the safety of TSM. With mechanical compromise of the VA during cervical manipulation proposed as one possible mechanism for manipulation-associated adverse events, the objective of this study was to determine by way of color-coded duplex Doppler diagnostic ultrasound (US) imaging the effect of three lower cervical non-thrust TSM techniques on VA lumen diameter (LD) and two blood flow velocity parameters. Specifically, our two-tailed research hypothesis was that the TSM techniques would result in a significant change, i.e. an increase or decrease, in blood flow velocity and arterial LD at the C5–C6 intertransverse portion of the VA.

Methods

Subjects

Study subjects were recruited from among orthopedic manual physical therapy residents and patients in the primary author's clinical practice and also from personnel at the diagnostic ultrasound clinic. Each subject completed a survey that included questions regarding demographic information, medical history, and history of cervical spine pain and stiffness. Exclusion criteria included a current episode of acute-onset cervical pain and conditions associated with a sensation of dizziness during cervical movement, such as vestibular involvement or visual disturbances.[17,20] After reading the informed consent forms, subjects were given the opportunity to discuss the procedures with the researchers prior to giving written consent. This study and the informed consent were approved by the Institutional Review Board of Oakland University in Rochester, Michigan.

Thirty subjects (21 females; 36.6±9.9 years old; range 21–57 years) participated in this study. Of these, seven reported a history of cervical arthritis with radiographic confirmation of arthritic changes. Four of those seven subjects indicated that they were currently experiencing their typical symptoms. Ten subjects noted a history of intermittent cervical pain but were not currently experiencing symptoms and nine participants noted that their cervical region was currently asymptomatic but they felt stiffness/movement limitation. We feel that this sample was representative of the patient population on which the TSM techniques studied might be used clinically.

Measurement

In this study, we used color-coded duplex Doppler US imaging to measure arterial LD in millimeters (mm) and blood flow velocity in centimeters per second (cm/s). Blood flow velocity was measured at initial ventricular contraction yielding the peak systolic velocity (PSV) and at the end of ventricular contraction yielding the end diastolic velocity (EDV). These measurements quantify maximum (PSV) and minimum flow velocity (EDV). All testing was performed in a vascular laboratory by a single qualified ultrasonographer with over 10 years of experience in the examination of extracranial vessels using the same duplex Doppler US machine with color flow imaging (Philips HDI 5000; Philips Medical Systems, Best, The Netherland) and a 7.4 mHz linear array transducer. All measurements of VA blood flow velocity and LD were performed at the V2 segment of the VA, specifically on the intertransverse portion of the artery at the C5–C6 level.

Buckenham and Wright[21] noted that in 95% of all cases, the V2 segment can be visualized with color-coded duplex Doppler US. Johnson *et al.*[22] established an intra-class correlation coefficient of 0.81 for single measurements of blood flow rate at the intertransverse portion of the VA at the C5–C6 segment. Compared to the gold standard of angiography, color-coded duplex Doppler US has demonstrated 90% sensitivity, 100% specificity, 100% positive predictive value, and 95% negative predictive value for detection of disease at any point in the vertebrobasilar circulation.[23] Adding color coding has advanced the field of diagnostic US in that the blood flow can be visualized to confirm the location of the target vessel. Normative values for blood flow velocities and LD, as measured using color-coded duplex Doppler US, have been described in several studies and are summarized and compared to values found in the current study in Table 1.[24–26]

Manual therapy techniques

Three non-thrust TSM techniques were chosen that incorporate all of the basic passive arthrokinematic facet motions most commonly used to achieve

Figure 1 C/5/C6 ventral/cranial facet joint gliding manipulation.

Figure 2 C5/C6 dorsal/caudal facet joint gliding manipulation.

capsular stretching.[15] All techniques were performed bilaterally with the patient seated, a position commonly used for TSM techniques.[15] For the C5–C6 ventral/cranial facet joint gliding manipulation shown on the right side in Fig. 1, the C0–C5 segments were passively pre-positioned in flexion, side bending, and rotation away from the treatment (US evaluation side). The therapist then manually stabilized the C6 vertebra with a bilateral laminar contact while the right inferior facet of C5 was mobilized in a ventral and cranial direction on the right superior facet of C6 (to improve left rotation). For the C5–C6 dorsal/caudal facet joint gliding manipulation shown on the right side in Fig. 2, the C0–C5 segments were passively pre-positioned in extension, side bending, and rotation toward the treatment (US evaluation side). The C6 vertebra was manually stabilized while the right inferior facet of the C5 was mobilized in a dorsal and caudal direction on the right superior facet of C6 (to improve right rotation). For the C5–C6 facet joint distraction (separation) manipulation shown on the right side in Fig. 3, all cervical segments including C5 were passively pre-positioned with a combination of flexion and side bending away from the treatment (US evaluation) side and rotation toward the treatment (US evaluation) side. Facet joint distraction was achieved by passively mobilizing the right superior facet of C6 in a direction perpendicular to the right inferior facet joint of C5. For each US evaluation, the end range position for the joint/segment was determined by the therapist prior to performing the grade III technique.[14,15] One therapist with 25 years of clinical experience and over 15 years of entry-level and post-professional teaching experience using these manipulative techniques performed all TSM techniques.

Procedure

To promote hemodynamic stability, each subject rested in a seated position for 5 minutes prior to taking baseline measurements.[27] While in the seated position, the ultrasonographer positioned the transducer such that the VA was visualized as it coursed cranially between the C6 and C5 transverse foramina.[23] A single, baseline measurement of PSV, EDV, and arterial LD was taken of the left and right VA with the subject's head and cervical spine in a neutral position. After the segments were pre-positioned, the US transducer was placed on the anterior aspect of the neck and the VA was identified on the duplex Doppler screen as it entered the C6 transverse foramen. At that point, a grade III non-thrust manipulation force was applied as described above. The PSV, EDV, and arterial LD measurements were then again measured during the performance of the three different non-thrust TSM techniques on the left and the right sides. Each non-thrust TSM was held for 30–45 seconds while the ultrasonographer completed all measurements of the VA. In clinical practice, these techniques are often held for a similar time frame when applied to patients with cervical motion impairments characterized by segmental stiffness. After each non-thrust manipulation, the

Table 1 Normative values for vertebral artery blood flow velocities and lumen diameter established in previous and the current study

Study	*n*	Mean age (years)	Age range (years)	Left LD (mm)	Right LD (mm)	Left PSV (cm/s)	Right PSV (cm/s)	Left EDV (cm/s)	Right EDV (cm/s)
Bartels *et al.*[24]	54	46	22–75	3.88 (0.78)	3.81 (0.46)	43.0 (8.9)	43.3 (9.6)	…	…
Lovrencic-Huzjan *et al.*[26]	59	53	…	3.55 (0.6)	3.37 (0.6)	48.9 (13.9)	48.3 (14.1)	…	…
Kuhl *et al.*[25]	50	54	27–84	…	…	57.9 (10.3)	60.3 (14.3)	16.9 (5.1)	16.4 (5.3)
Current study	30	37	27–57	4.33 (0.1)	4.11 (0.1)	62.3 (2.6)	60.5 (3.1)	16.2 (0.8)	15.1 (0.8)

Note: LD=lumen diameter; PSV=peak systolic velocity; EDV=end diastolic velocity.

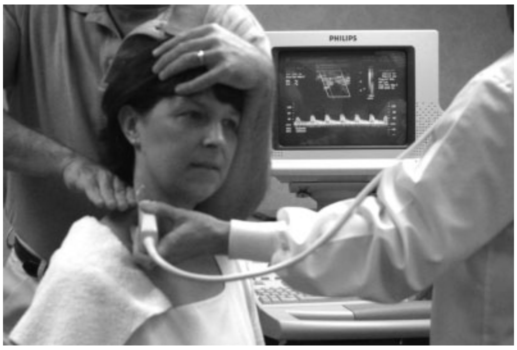

Figure 3 C5/C6 facet joint distraction (separation) manipulation.

subject was given a 1- to 3-minute rest period while data were recorded. Subjects were instructed to inform the researchers of any cervical discomfort, dizziness, or abnormal sensation experienced during the measurement process at which point the application of the technique would be terminated. No subject reported any such sensations.

Data analysis

Descriptive statistics calculated included mean, standard deviation, standard error, and 95% confidence intervals for the 18 pair-wise mean differences between baseline and all three manipulation positions left and right for PSV, EDV, and LD (Table 2). These pair-wise differences were analyzed for statistical significance with alpha set at 0.05 using paired *t*-tests (Table 2). All statistical tests were completed using SPSS 17.01 for Windows (SPSS Inc., Chicago, IL, USA).

Results

Upon reviewing Table 2, we note that there are four statistically significant differences between measurements in the neutral spine and a manipulation position. These statistically significant differences also correspond with the four 95% confidence intervals that do not include the value of zero. With regard to blood flow velocity measures, there was a significant decrease ($P<0.01$) in PSV with left C5–C6 dorsal/caudal facet joint gliding manipulation (pair-wise comparison 1, Table 2). There were statistically significant decreases in LD from baseline during right C5–C6 ventral/cranial facet joint gliding ($P=0.013$) and right C5–C6 facet joint distraction ($P=0.024$) (pair-wise comparisons 17 and 18, Table 2), whereas there was a significant increase ($P=0.037$) in LD from baseline during left C5–C6 facet joint distraction (pair-wise comparison 15, Table 2).

Discussion

Of the four statistically significant changes (Table 2), only one concerned blood flow velocity. With left C5–C6 dorsal/caudal facet joint gliding manipulation, PSV decreased by 6.6 cm/s or 10.6% from left PSV baseline value (Table 1). Because this value still greatly exceeded the left baseline EDV value (in fact it was 3.4 times greater than baseline EDV), we have to question clinical relevance of this change. The three remaining significant changes were in LD. During right C5–C6 ventral/cranial facet joint gliding and right C5–C6 facet joint distraction, there were decreases in right LD of 4.6 and 3.5%, respectively, compared to baseline LD values. In contrast, with left C5–C6 facet joint distraction, there was an increase of 3.2% in LD as compared to baseline (Table 1). It is very important to note that these percent differences are very small and none of these changes in LD were associated with significant changes in blood flow velocity parameters. Further, these subjects did not report any symptoms associated with VA compromise. These paradoxical findings with regard to effect on LD seem to mirror the findings by Wuest *et al.*[28] Measuring the strain in the VA during various cervical manipulative procedures, these researchers reported complex and non-intuitive strain patterns of the VA within the transverse foramina and suggested a possible role in explaining that these strain patterns were anatomical variations in fascial connections within the transverse foramina and/or coupled segmental movement behavior. With Wuest *et al.*[28] studying a single older cadaver and this study using 30 living subjects, in our opinion such intra- and interindividual variations are even more likely to play a role.

Next, we would like to discuss two choices we made with regard to statistical analysis. First, we chose to do a two-tailed analysis consistent with our two-tailed research hypothesis. One could argue that a two-tailed as compared to a one-tailed analysis cut chances of finding a statistically significant difference in half. One could also argue that the clinically relevant direction of change would have been a decrease in LD and a resultant increase in both blood flow velocity parameters (PSV and EDV), as the same volume makes it way through a now smaller lumen. Indeed, Mitchell[29] noted how the Bernoulli principle explains an increase in blood flow velocity at and/or immediately beyond the point of constriction of a vessel indicating stretching or compression of the vessel. However, with blood flow proportional to the fourth power of the radius of the vessel as described in Poiseuille's law, there is a spurting or turbulence of blood immediately downstream from the area of vessel constriction which causes a decrease in blood flow velocity parameters.[29] So the location where data were collected was crucial and small changes in location that may have been possible during US measurements in the three manipulative positions would likely lead to contradictory findings with regard to changes in blood flow velocity parameters

Table 2 Summary of paired *t*-tests

Paired comparisons	Paired differences							
				95% confidence interval of the difference				
	Mean	Standard deviation	Standard error	Lower	Upper	*t*	d.f.	Significance (two-tailed) or *P* value
1. PSV base L versus PSV C5 DC L	−6.600	11.825	2.159	−11.016	−2.184	−3.057	29	0.005
2. PSV base L versus PSV C5 VC L	−3.567	12.681	2.315	−8.302	1.168	−1.541	29	0.134
3. PSV base L versus PSV C5 facet distrac L	−1.533	11.608	2.119	−5.868	2.801	−0.724	29	0.475
4. PSV base R versus PSV C5 DC R	−2.857	14.613	2.762	−8.523	2.809	−1.035	27	0.310
5. PSV base R versus PS C5 VC R	−3.107	14.307	2.704	−8.655	2.441	−1.149	27	0.261
6. PSV base R v ersus PSV C5 facet distrac R	−1.821	10.566	1.997	−5.918	2.276	−0.912	27	0.370
7. EDV base L versus EDV C5 DC L	−0.400	4.461	0.815	−2.066	1.266	−0.491	29	0.627
8. EDV base L versus EDV C5 VC L	−1.133	3.989	0.728	−2.623	0.356	−1.556	29	0.131
9. EDV base L versus EDV C5 facet distrac L	−0.100	4.213	0.769	−1.673	1.473	−0.130	29	0.897
10. EDV base R versus EDV C5 DC R	0.393	5.087	0.961	−1.580	2.365	0.409	27	0.686
11. EDV base R versus EDV C5 VC R	0.250	4.518	0.854	−1.502	2.002	0.293	27	0.772
12. EDV base R – ED C5 facet distrac R	−0.500	3.677	0.695	−1.926	0.926	−0.720	27	0.478
13. LD base L versus LD C5 DC L	−0.0267	0.3759	0.0686	−0.1670	0.1137	−0.389	29	0.700
14. LD base L versus LD C5 VC L	0.0600	0.5130	0.0937	−0.1316	0.2516	0.641	29	0.527
15. LD base L versus LD C5 facet distrac L	0.1400	0.3500	0.0639	0.0093	0.2707	2.191	29	0.037
16. LD base R versus LD C5 DC R	−0.1071	0.4136	0.0782	−0.2675	0.0532	−1.371	27	0.182
17. LD base R versus LD C5 VC R	−0.1893	0.3775	0.0713	−0.3356	−0.0429	−2.654	27	0.013
18. LD base R versus LD C5 facet distrac R	−0.1429	0.3167	0.0599	−0.2657	−0.0200	−2.387	27	0.024

Note: PSV=peak systolic velocity; EDV=end diastolic velocity; LD=lumen diameter; base=baseline or cervical neutral position measurement; VC=ventral/cranial glide manipulation (Fig. 1); DC=dorsal/caudal glide manipulation (Fig. 2); facet distrac=facet joint distraction manipulation (Fig. 3); L=left; R=right.

leading us to the decision to test for non-directional rather than directional change. In addition, we would like to note that there were no significant findings in Table 2 other than the four pair-wise comparisons discussed under results even at double the current significance level.

Second, since our hypothesis is a composite, one could argue that Bonferroni adjustment should have been used to control for family-wise type I error rate. For a significance level of alpha=0.05 and 18 pair-wise comparisons, the Bonferroni procedure declares that an individual test is significant if its *P* value is smaller than 0.05/18=0.003.[30] There were certainly no statistically significant changes in PSV, EDV, and LD readings at this significance level. However, a Bonferroni adjustment although justified would decrease the chance of noting any statistically significant differences. The clinical relevance of such differences due to the serious nature of possible manipulation-associated adverse events is such that we chose to not adjust the *P* value but rather to see if there were changes at the higher *P* value, which if present we then would analyze for clinical significance.

Lastly we would like to acknowledge the limitations of the present study. There is a clear challenge in terms of study reproducibility given the clinical nature and training required for consistent and correct manipulative technique application. Also, while Table 1 demonstrates that the present study findings closely mirror previously collected normal values for PSV, EDV, and LD, there exists still, a potential for technical error in the measurement of LD and placement of the US transducer head directly over the C5–C6 transverse foramen.

Conclusion

In a sample of both asymptomatic and symptomatic subjects, the latter in our opinion representative of the patient population on which these techniques might be used, and using what may be considered an overly cautious approach to data analysis, the three cervical TSM techniques studied led to one statistically significant effect on blood flow velocity and three significant effects on LD. However, changes in LD were small and paradoxically in opposite directions for the same technique. Changes in blood flow velocity only occurred in PSV in one of the paired comparisons and led to values that still greatly exceed baseline lower (EDV) limits for blood flow velocity. No patient reported symptoms associated with VA compromise. In summary, analysis of the paired comparisons showed that the non-thrust TSM techniques studied on this particular population of 30 subjects had no clinically relevant mechanical effect of the VA. We acknowledge that further study is required on thrust TSM techniques. Levels other than C5–C6 must be examined with the same imaging techniques before far-reaching statements on the safety of cervical TSM techniques can be made. In particular, additional duplex Doppler US studies need to investigate the effect of other TSM techniques on the VA at the C1–C2 level with varying degrees of upper cervical rotation. The results of this study provide evidence for the safety of the three lower cervical non-thrust TSM techniques studied.

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