Effect of premanipulative tests on vertebral artery and internal carotid artery blood flow: a pilot study

ABSTRACT

Background: Neck manipulation occasionally causes stroke after trauma to the vertebral or internal carotid artery. Premanipulative tests involving cervical spine rotation or extension have been recommended to detect patients at risk of neurovascular ischemia. However, the effect of these procedures on extracranial blood flow is not well established, and their validity is thus controversial.

Objective: To determine the effect of premanipulative tests involving cervical spine rotation or extension on vertebral artery and internal carotid artery blood flow parameters.

Design: Two-group experimental study.
Subjects: Twenty subjects consisting of 16 patients treated with physiotherapy and four volunteers.

Methods: Subjects were tested with a recommended premanipulative protocol by both an independent physiotherapist and an investigator. One group consisted of 10 subjects with signs or symptoms indicative of neurovascular ischemia on premanipulative testing, with 10 subjects with no signs or symptoms indicative of neurovascular ischemia on premanipulative testing comprising the second group. Hemodynamic measurements for both vertebral and both internal carotid arteries were taken by use of duplex Doppler ultrasonography with color-flow imaging with the subjects in the following positions: neutral, end-range extension, 45 degrees contralateral rotation, end-range contralateral rotation, and combined end-range contralateral rotation/extension.

Results: The reliability of premanipulative testing was supported. Significant changes in flow velocity of the vertebral artery (and to a lesser extent of the internal carotid artery) were shown in end-range positions involving rotation and extension. No meaningful significant differences were found between the two groups.

Conclusions: Screening procedures that use rotation and extension may be useful tests of the adequacy of collateral circulation. A larger study is needed to determine whether subjects testing positive significantly differ from those testing negative. (J Manipulative Physiol Ther 1999;22:368-75)

Key Indexing Terms: Chiropractic Manipulation; Head Movements; Vertebral Artery; Internal Carotid Artery; Doppler Ultrasonography; Blood Flow Velocity

INTRODUCTION

It is widely recognized that passive therapeutic maneuvers applied to the cervical spine are associated with a small risk of iatrogenic stroke. The most frequent cause is trauma of the vertebral artery (VA), although the internal carotid artery (ICA) is occasionally involved. Manipulative or high-velocity thrust procedures involving the upper cervical spine have been implicated in particular.\(^1\) Although the precise incidence rate of these events is unknown, they seem to be very uncommon, if not rare, occurrences. Surveys of the chiropractic, physical therapy, and medical professions provide estimates that range from less than one stroke in 75,500 cervical spine manipulations to one in 1.3 million.\(^1-4\) In spite of the infrequency of neurovascular complications in relation to other conservative interventions,\(^5\) their potentially serious nature has led to some manipulative practitioners recommending premanipulative tests designed to detect "at risk" patients.\(^6-8\)

The Protocol for Pre-manipulative Testing of the Cervical Spine adopted by the Australian Physiotherapy Association (APA)\(^9\) was one of the first, if not the first, formalized protocol endorsed by a professional manipulative therapy body with the aim of preventing manipulative...
strokes. This protocol has also been recommended by other national physiotherapy bodies, such as the New Zealand Society of Physiotherapists. Its effectiveness, however, is largely contingent on the recommended physical tests used for screening for individuals with vertebrobasilar insufficiency (VBI) that are intended to help the clinician decide whether it is safe to manipulate. These precautionary tests therefore have a predictive role in the clinical setting, which makes it crucial that they possess clinically acceptable sensitivity and specificity.

The primary tests recommended in the APA protocol involve end-range cervical spine extension, rotation, and combined rotation/extension, sustained for a minimum of 10 seconds, with the patient sitting or lying supine as appropriate. The latter combined movement test is essentially the same as the Wallenberg test, also known as de Kleyn's test. More recently several studies have used in vivo Doppler ultrasonography to develop a more complete understanding of extracranial arterial blood flow and to determine the validity of premanipulative tests.

Investigations with control subjects have provided conflicting findings with respect to the relationship between blood flow changes and cervical spine position. Using duplex scanning (Doppler spectral analysis with two-dimensional imaging of the target vessel) on 20 healthy subjects, Refshauge demonstrated a significant trend for decreased blood velocity in full contralateral rotation on investigation of the VA and ICA flow. In contrast, Weingart and Bischoff found no significant change in the blood flow rate of the VA at the level of the arch of the atlas in 30 control subjects with various positions of rotation, and in combination with extension, lateral flexion, and traction. However, in this study continuous-wave ultrasonography was used for Doppler sampling so that the target vessel was not actually visualized, raising the possibility of inaccurate sampling, particularly if the tortuosity and common anomalies of the artery in this region are considered.

Stevens, on the other hand, reported that in 62% of subjects with an identified abnormal flow velocity pattern, the VA flow velocity profile reduced on contralateral rotation, with 18% exhibiting decreased flow velocity on cervical extension. Again, vessel identification was a limitation of this study, with only seven of the 250 subjects undergoing duplex investigation. Haynes also found blood flow changes after contralateral rotation in 5% of 280 VAs investigated as part of a premanipulative screening procedure demonstrating cessation of Doppler signals, whereas none were reported for contralateral lateral flexion. Unfortunately no quantification of blood flow was undertaken, and the insonation was conducted with a continuous-wave Doppler velocimeter without imaging capabilities.

Therefore, with the exception of the study by Weingart and Bischoff, there is mounting evidence suggesting that some cervical spine positions, most notably rotation, may influence extracranial blood flow in control
Further support is provided by a recent investigation with triplex ultrasonography (duplex scanning combined with simultaneous color-flow Doppler imaging) to determine the effect of both contralateral and ipsilateral rotation on VA flow velocity in 20 healthy university students. (18) A significant decrease was shown with contralateral rotation (and interestingly a significant increase with ipsilateral rotation), consistent with most previous research. However, measurements were taken very near the origin of the artery, well removed from the more vulnerable and relevant upper cervical region of the vessel, thus limiting the usefulness of the results.

Considering the association between certain cervical spine positions and extracranial blood flow, it is therefore surprising that only two reports have attempted to ascertain the validity of premanipulative testing by use of subjects exhibiting signs or symptoms on testing. Thiel et al(11) investigated blood flow velocity with duplex Doppler ultrasonography during sustained extension, rotation, and combined extension/rotation (Wallenberg test). No subjects demonstrated abnormal flow patterns during testing, and no meaningful significant differences in mean velocity ratios were found between the control group and another group displaying clinical signs and symptoms of VBI. The investigators contended that the results failed to support the validity of the Wallenberg test in screening for VBI. Similar conclusions were drawn by Côté et al,(19) who evaluated the validity of the Wallenberg test as a premanipulative screening procedure by measuring the vascular impedance to blood flow of the VA. They reported the sensitivity for increased impedance to flow and positive predictive value as 0% and concluded that the extension/rotation test is of questionable value for screening patients at risk of stroke with cervical spine manipulation (CSM). It should be noted that both these reports used data from the same study, and, hence, the agreement of the conclusions is not unexpected.

Thus the validity of the premanipulative tests is controversial, and consequently their clinical value is debatable. The aims of this study were therefore to (1) ascertain whether the clinical tests are repeatable; (2) determine whether changes in position will lead to changes in blood flow; and (3) pilot the method for investigating whether changes in position will have a greater effect on blood flow in people who are positive on premanipulative testing than in those who are negative. In addition to the VAs, the ICAs were also examined in an attempt to develop greater understanding of the relationship between cervical spine positions and overall extracranial blood flow to the brain. Furthermore, the ICA has been implicated in a small but significant percentage of strokes resulting from CSM,(20) and therefore the hemodynamic effects of premanipulative testing on these arteries warrants further study.

METHODS

Subject Selection

Twenty subjects volunteered to participate in the study, of whom 16 were referred by local physiotherapists and 4 responded to...
advertisement. All referred subjects had, in the normal course of treatment, undergone premanipulative testing by the referring practitioner according to the Protocol for Pre-manipulative Testing of the Cervical Spine endorsed by the New Zealand Society of Physiotherapists. (9) The other four volunteers were examined according to the same protocol by independent manipulative physiotherapists on the teaching staff of the School of Physiotherapy at the University of Otago. Potential participants were excluded if they reported a history of disorders or medications that may have put them at risk of injury were they to participate and would normally constitute contraindications to CSM,(21, 22) such as severe osteoporosis and anticoagulant medication. Exclusion criteria also included current inner ear conditions and marked postural hypotension. The age criteria for entry was set from 18 to 70 years. Written informed consent was obtained from all subjects after they were provided with an information sheet and their questions were answered.

After admission to the study, all subjects underwent clinical testing by one of the investigators (D. R.) following the above protocol. Subjects were then allocated on the basis of the investigator's examination to either a "positive" (to testing) group or a matched (for age and sex) "negative" group. A positive response was defined as the provocation of signs or symptoms indicative of neurovascular ischemia(23) during or immediately after one of the following tests:

- Sustained (up to 60 seconds) cervical spine positions of end-range extension, end-range rotation each way, combined end-range rotation/extension each way

- Rapid active full-range cervical spine rotation each way

- Sustained (up to 60 seconds) simulated premanipulation (atlanto-axial rotation(24)) position

- Any other nominated provocative cervical position or movement

Initially, testing was conducted with the subject sitting (except for the simulated premanipulation position), but if this produced a negative response, then testing was repeated with the patient lying supine. Tests for differentiation of dizziness arising from the vestibular apparatus of the inner ear from that caused by neck posture or movement were performed in standing position when necessary. All tests were applied in that part of the range of motion that was pain-free. A 60-second rest period separated each test procedure to allow for manifestation of latent responses. On elicitation of possible ischemic signs or symptoms, testing was discontinued, and the response was classified as positive. All positive positional tests were timed with an electronic digital stop-watch with respect to the onset of potential symptoms or signs of neurovascular insufficiency.

The ranges of extension and rotation were measured by use of a cervical range-of-motion (CROM) instrument (Performance Attainment Associates, St. Paul, Minn). This device has been demonstrated to be a highly reliable measure of cervical range of motion.(25, 26) The subject's blood
pressure (BP) and pulse rate (PR) were also recorded with a digital blood pressure monitor, model DS-145 (ALPK2, Japan). This device is accurate to within ±3 mm Hg for BP and ±5% for the PR.

The positive group consisted of 10 subjects (8 women, 2 men) with a mean age of 37.9 years (SD = 13.0, range 24 to 65). The negative group consisted of 10 subjects (8 women, 2 men) with a mean age of 32.7 years (SD = 10.3, range 20 to 47).

Ultrasonic Investigation

An ultrasonographic investigation of the VAs and ICAs was conducted in a radiologic clinic as soon as practical after the clinical examination. A 2D Gateway Series duplex Doppler ultrasound apparatus with B-mode real-time imaging and color flow mapping capability (Diasonics Ultrasound, Santa Clara, Calif) and 5-MHz linear probe was used to measure the hemodynamic parameters. The experimental protocol followed was an extension of that previously described by Refshauge (14) and determined to be reliable. To further enhance reliability, all scanning was undertaken by a qualified ultrasonographer with extensive experience in the examination of the extracranial arterial system. Several practice sessions were conducted before the commencement of the study to confirm the ultrasonographer's familiarity with the experimental protocol.

The procedure began with a 10-minute rest period to help facilitate hemodynamic stability. The subject's BP and PR were monitored at the end of this period by use of the digital blood pressure monitor. Initial hemodynamic measurements of the VAs and ICAs were taken with the subject in a neutral cervical spine position. The common carotid arteries were also insonated with the patient in this position to assist in the determination of the normality of the overall extracranial vasculature. The measures included peak systolic (PS) and end-diastolic (ED) blood flow velocities, as well as an index of vascular impedance (Pourcelot or resistance index [RI] (27)). Transverse diameter measurements (including both the lumen and arterial wall of the blood vessels) were also obtained with the subject in the neutral position. Blood flow measurements were then obtained while the cervical spine was placed in the following positions: end-range extension, 45 degrees contralateral rotation (left and right), end-range contralateral rotation (left and right), and combined end-range contralateral rotation/extension (left and right). Readings taken at 45 degrees of rotation were included to ascertain the effect of restricted range of motion on blood flow and to develop a more complete understanding of the hemodynamic influences of rotation through range. The angle of insonation was set at 60 degrees or less to the arteries to avoid inaccuracies of measuring blood flow velocity related to beam-to-vessel angle (28). Doppler sampling and diameter measurements of the VAs and ICAs were conducted in the region of the arteries between the second and third cervical vertebrae. Only the contralateral artery was investigated for test positions involving rotation because the ipsilateral artery was not practically accessible. On obtaining any flow changes with testing, the contact pressure of the transducer probe was varied to ensure that local pressure was not responsible.
End-range positions were maintained just short of the onset in range of motion of any reported pain or marked discomfort. All positions were sustained for 60 seconds unless there was prior provocation of possible ischemic symptoms or commencement of pain, at which time measurements were immediately taken. A 60-second pause separated each test position, during which the cervical spine was returned to the neutral position to wait for the onset of any latent symptoms and to facilitate the return of blood flow parameters to baseline measures. The subject's BP and PR were again monitored at the end of the investigation. All scans were performed with the subject in the supine position. The achieved ranges of extension and rotation were measured by use of a modified CROM. The modifications involved reversing the compass with the lateral plane inclinometer and reorienting the sagittal plane inclinometer to permit use with the patient lying supine. The various positions were maintained by an investigator (D.R.) monitoring the readings from the CROM instrument and by the application of gentle manual pressure to the subject's head.

All ultrasound scans were reviewed by a radiologist for structural abnormalities of the extracranial vasculature and for cardiovascular pathology. Ethical approval for the study was granted by the Southern Regional Health Authority Ethics Committee (Otago).

Data Analysis

The interrater reliability of the premanipulative testing between the independent physiotherapist and the investigator was calculated with the kappa statistic. Differences between the two groups tot age, BP and PR, range of motion for extension and rotation, and for VA and ICA diameter were examined by use of paired two-tailed t tests. Changes in blood flow (from neutral) in the different positions for each blood vessel were evaluated for each group with a linear mixed effects model. This model was also used to compare the changes in blood flow in the positive and negative groups. Hemodynamic stability was evaluated by comparing PR, systolic BP, and diastolic BP measurements taken immediately before and after ultrasonography, with paired two-tailed t tests and 95% confidence intervals used for the differences. The significance level was set at à = .05 for all tests.

RESULTS

The agreement between the independent or referring physiotherapist and the investigator for premanipulative testing of subjects (classification as positive or negative) was found to be very good,(29) with K = 0.90 with a 95% confidence interval of 0.69 to 1.00. The positive and negative subjects were similar in terms of a number of physical characteristics; however, the positive group had lesser average range of cervical spine motion and higher average systolic BP than the negative group (Table 1). The differences were not statistically significant, but the numbers are small.

For both groups the VA PS blood flow velocity tended to decrease with progressive degrees of rotation and to increase in end-range extension
(compared with the neutral position). Typical patterns of change in blood flow are depicted for the right VA for subjects in both the negative and positive groups in Figs 1 and 2.

Changes in blood flow (from neutral) in the different positions for each blood vessel were analyzed separately for the negative group and the positive group. There was a significant reduction in the PS blood flow velocity for both VAs, particularly involving end-range rotation and combined end-range rotation/extension (Table 2). The ED blood flow velocity in the right VA also varied with changes in position, with the largest decrease being in end-range rotation for the subjects in the negative group and rotation/extension for the subjects in the positive group. In the left VA the changes were not as pronounced. The patterns of change for the RI were less clear. The negative group showed significant decreases in end-range rotation and rotation/extension for the right VA, but similar changes in the left VA were not significant because of greater variability. There were no significant changes in the RI in the positive group. The raw data indicated that the changes were due to a proportionally greater decrease in PS blood flow velocity than ED blood flow velocity. The changes for the ICAs were similar but less marked (Table 3).

Because the end-range rotation varied among subjects, further analyses were carried out examining the trend in decreasing VA blood flow with increasing rotation by use of the measured (at the time of Doppler sampling) end-range rotation for each subject (Table 4). The results of these analyses were consistent with previous results, showing a significant trend of decreasing PS blood flow velocity with increasing rotation and mixed results for ED flow and RI.

There were no significant differences between the positive and negative groups in terms of changes in blood flow velocity for neither VA nor for the right ICA in any position. For the left ICA there was a significant difference in the change in ED blood flow velocity, but this may have been a chance finding resulting from the large number of statistical tests.

In the case of four subjects Doppler sampling was unable to be completed in all five positions for all four arteries because of the provocation of neck pain or possible ischemic symptoms. To determine the effect of these missing data on the findings, the model was again applied, but the subjects with missing data were excluded (ie, a full-case analysis). The results were essentially the same as previously, indicating
that the missing data did not bias the results. In addition, systolic BP ($P = .96$, CI -6.3, 6.0), diastolic BP ($P = .72$, CI -3.5, 2.5), and PR ($P = .06$. CI -0.4, 12.1) readings taken just before the ultrasound were not found to be significantly different from those obtained immediately afterward. No abnormalities were reported by the radiologist reviewing the ultrasound scans.

**DISCUSSION**

The results of this investigation have demonstrated that the blood flow of the extracranial arteries is significantly affected by cervical spine positions involving end-range contralateral rotation or extension. Variations in BP and PR are unlikely to account for the changes observed because these measures did not significantly differ from before to after the ultrasound examination, indicating stability of these parameters.

For the VAs there seems to be a trend of decreasing blood flow velocity (as measured with Doppler sampling in the region between the second and third cervical vertebrae) with increasing degrees of rotation. End-range contralateral rotation significantly reduced PS blood flow velocity for both VAs, consistent with the findings of Refshauge.(14) Refshauge(14) hypothesized that, at end-range rotation, narrowing of the vessel diameter may reach a critical level whereby blood viscosity becomes a factor leading to slowing of the blood flow. The combination of a relatively small vessel orifice (because of positional narrowing) and red blood cell viscosity may result in a decelerating effect known as viscous friction.(30) Alternatively, the decrease in flow velocity observed in the rotatory positions may reflect the fact that the site of sampling is upstream of the likely site of vessel narrowing, the atlanto-axial region. Thus the blood flow approaching this region may tend to slow, whereas the flow velocity at the actual site of narrowing will tend to increase to maintain a constant flow volume.(30)

The RI also decreased in end-range rotation and the combined end-range rotation/extension, suggesting that the resistance encountered by the blood flow is actually reduced. This finding seems to be inconsistent with the expectation of vessel narrowing and associated increased resistance to flow. The RI is based on the premise that diastolic velocity is likely to be reduced to a greater extent by higher resistance than is systolic velocity, leading to a rise in the index. However, the raw data indicate that both the PS and the ED velocities are reduced in these positions, albeit the PS to a proportionally greater degree.

The effect of cervical spine extension on extracranial blood flow has received comparatively little scrutiny in Doppler investigations.(11,16) It is thus notable that flow velocity in this position generally increased for the VA and the ICA. This change in flow velocity with extension may be indicative of narrowing of the vessel at or proximal to the site of sampling. To the best of our knowledge, changes in ICA flow with cervical extension have not been previously investigated in spite of the fact that the ICA has been implicated in a small percentage of manipulative strokes.(20,31) It may thus be of clinical note that neck maneuvers involving extension can result in blood flow changes,
particularly considering that this artery is often already stenotic because of vascular disease. Refshauge(14) demonstrated that rotation may affect ICA peak velocity. The results of this study are not inconsistent with her results, but the trend was not always statistically significant, perhaps because of the small sample size in each group.

The two groups did not significantly differ in any meaningful measure, suggesting that the magnitude of any hemodynamic difference is probably small and of doubtful clinical significance. However, this study was not intended to answer the question of whether changes in position will have a greater effect on blood flow in people with positive clinical testing results than in those with negative results. This is currently being investigated in a further study with a larger sample size. It is possible that subjects with false-positive results were included in the positive group, such as those whose response to premanipulative testing may have been due to stressing of the upper cervical spine musculature or joints, resulting in cervical or reflex vertigo.(23) However, the generalizability of the findings to the clinical situation is supported because all subjects in the positive group were referred from physiotherapy practices and because of the excellent test response agreement between the independent physiotherapists and the investigator.

The negative group reported no signs or symptoms of neurovascular insufficiency during the ultrasound examination, and yet there was demonstrable change in their extracranial blood flow. In fact, one subject experienced total occlusion of the left VA in end-range rotation and also combined end-range rotation/extension on repeated testing. This case is described in detail elsewhere(32); however, it serves to illustrate that the VA may be markedly stressed and effectively ligated and yet the clinical test result is negative. It can be argued that this situation represents a case of false negativity because the vessel is clearly subjected to external forces related to the test position and is therefore at risk of trauma. What the test does indicate is the adequacy of the collateral circulation in preventing an ischemic event if the blood flow of one VA were critically reduced. On the other hand, it is likely that the negative test response does not indicate the real risk of the patient having a stroke. If vessel damage ensued from neck manipulation, then the state of the collateral circulation is of questionable value if an embolus were to dislodge from the site of trauma and enter the intracranial circulation. This risk may be present to a varying extent in lesser degrees of rotation as evidenced by the changes in blood flow at 45 degrees rotation in this investigation and in Refshauge's study.(14)

Thus, from a clinical perspective, a negative result to premanipulative testing does not guarantee that the proposed manipulative procedure is entirely free of risk. Such a response could only be construed as indicating the likelihood of the patient experiencing a stroke in the event of local pathology of an extracranial vessel (for example vasospasm or intimal dissection) and provided the pathology does not project cranially. It can therefore be argued that the patient at risk of manipulative stroke is often undetectable in spite of the use of premanipulative tests. There is further evidence to support this suggestion because two such incidents
occurred even though premanipulative testing was performed according to the APA protocol.\(^{(33)}\) It is therefore desirable to avoid manipulative maneuvers that use rotation or extension, especially those involving end-range positions, There is some evidence that lateral flexion may have minimal effect on the VA\(^{(15-17)}\) and that the risks associated with neck manipulation may be reduced by use of procedures principally involving this movement.

This preliminary study has highlighted the need for further investigation with a larger sample to determine more conclusively whether there are differences in changes in blood flow in the testing positions between subjects in the negative and positive groups. As such, the absence of meaningful differences found in this study must be regarded with caution. It would also be desirable to sample at the atlanto-axial region of the VA if this were consistently feasible and involved an acceptable margin of error, because this is the region most vulnerable to the stresses associated with cervical spine rotation. It would also be more relevant to the interpretation of the hemodynamic findings to solely measure the vessel lumen rather than including the vessel wall.\(^{(11, 14)}\)

**CONCLUSION**

The results of this pilot study provide preliminary evidence that changes in neck position influence blood flow in the extracranial arteries. In particular, the vertebral artery is subjected to forces in positions involving end-range contralateral rotation that are sufficient to significantly reduce blood flow velocity. This finding supports the contention that the premanipulative tests may be of value in assessing the adequacy of the collateral circulation. That no meaningful differences were found between subjects testing positive and those testing negative probably indicates that a larger trial is needed before conclusions can be drawn about the validity of the tests. The reliability of the premanipulative protocol in categorizing subjects as positive or negative was supported.

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By Darren A. Rivett and Peter D. Milburn