Changes in Blood Flow Associated With Vertebral Artery Stress Tests

Arnold, C.[1], Bourassa, R.[2], Langer, T.[3] & Stoneham, G.[4]

1 Cathy M. Arnold, M.Sc. Assistant Professor, School of Physical Therapy, University of Saskatchewan

2 Richard J. Bourassa, M.Sc., Clinical Professor, School of Physical Therapy, University of Saskatchewan

3 Thomas Langer Ph.D., Lecturer, Dept. of Anatomy and Cell Biology, College of Medicine, University of Saskatchewan

4 Grant Stoneham, MD., Assistant Professor, Dept. of Medical Imaging, College of Medicine, University of Saskatchewan

Introduction

Why should we care?

There is a small, but real risk associated with cervical manipulation. Varying numbers are published, ranging from more than one in a million to approximately one in ten million, for fatalities. It is hard to obtain an accurate estimate in a situation where the risk is so low. While the risk of fatality is apparently low, the risk of neurological complications may be substantially greater. There does not seem to be reliable reporting of minor consequences of cervical manipulation, so we do not know how frequently there are transient or minor neurological complications.

Can injury be prevented?

It is argued by some that we should be able to reduce the frequency of injury by screening tests that detect those at risk of injury. In particular, it is argued that if the vertebral artery is stressed by moving the head and neck into end-range positions, then we should be able to find those individuals that develop neurological signs and symptoms that indicate a reduced oxygenation of the brainstem, and that such individuals are at risk of injury with cervical manipulation. This principle is largely an act of faith, based upon an intuitive extrapolation from the known anatomy and physiology of the region. It has not been shown that such individuals are actually at increased risk or that individuals at risk will test positive with the stress tests. It would probably be unethical to test the first assertion and the second is most apt to be tested *post hoc,* in individuals that have suffered injuries, which is a notoriously unreliable type of study. A study that is not unethical and which need not have a sampling bias is to ask if the stress tests actually stress the vertebral artery. That is the essence of this report.

Rationale for this study

As a first step in evaluating the vertebral artery stress tests, we have examined the blood flow in the vertebral arteries in individuals that do not have positive stress tests. Most of the tested individuals had good range of motion, but some had biomechanical restrictions that might have been candidates for manipulation. It is not clear, *a priori*, whether a reduced mobility is apt to place a person at less risk because of not being able to stretch the artery as much or at more risk, because of adaptive shortening of the artery to accommodate to the reduced range of motion. It is possible that in some instances the reduced ROM is a protective mechanism to prevent undue stress on the artery, to stabilize an unstable joint, or to prevent tearing over an arthritic exostosis.

Motivation for this report

It is assumed that stress upon the vertebral artery will change the rate of blood flow. In fact, flow should be a very sensitive indicator of vertebral artery stress, because laminar flow in a circular pipe is proportional to the fourth power of the pipe's radius. Small changes in the caliber of the artery will produce large changes in the flow rate. It is not known what actually stresses the vertebral artery, but it is suspected that it is stretching the artery between the transverse processes of the first two cervical vertebrae that is critical. It is not known what it is about the relative movements of those vertebrae that is critical or even if it is the stretching in the more caudal and/or more rostral segments of the artery that cause the stress. In this paper, the emphasis is upon determining what positions produce stress and which produce the greatest amount of stress. In other papers, the mechanism of the restriction of blood flow is examined by modeling the anatomy of the region and calculating the consequences of movements in the cranio-vertebral cervical spine.

Methods

The Data Set

Data was collected from 22 test subjects and 2 pilot subjects. The two pilot subjects were re-evaluated as test subjects. The data presented in this paper is based on the responses of the 22 test subjects. The measured parameters were the peak systolic velocity and the end diastolic velocity for a representative trace collected while the subjects head and neck were held in one of the standard vertebral artery stress test positions. Data was collected from each vertebral artery while the head and neck were in each of 13 positions, for a total of 26 samples per subject. Typically, a single test session would last about a half hour.

The Test Positions

Every test session had the same progression of tests. These progressed from what is generally considered the least stressful tests to the most stressful tests. First, the head was rotated to endrange in both directions of **lateral rotation alone**. Then, the head and upper neck was taken to the endrange of **extension** while the lower cervical spine was lordosed. After extension alone, the neck is taken into a combined **lateral rotation and extension** in both directions and, finally, a combination of **lateral rotation, extension, and traction**. These concurrent movements are characterized as being into quadrant positions. Concurrent lateral rotation, extension, and traction is considered a modified De Kleyn's position and it is often used as the definitive vertebral artery stress test. This sequence of positions leading up to the modified De Kleyn's position is the progressive vertebral artery stress test. Some practitioners prefer to use the next position tested, a **full De Kleyn's Position**, as their stress test. It involves full extension of the upper and lower neck by suspension of the shoulders, head, and neck off the end of the table and then lateral rotation, with some traction. Finally, we tested the blood flow when the atlas and axis were rotated into endrange lateral rotation as they would be positioned immediately prior to a rotational manipulation of the atlanto-axial joint. This will be called the **premanipulative hold**. This position involves a sideflexion of the neck and then rotation of the atlas upon the axis. The movement direction is named for the movement of the atlas, therefore, rotation of the anterior arch of the atlas towards the right side of the axis is right rotation

Referencing the Data to Blood Flow in Neutral Position

The data was largely considered as changes from the blood flow in neutral position, expressed as percentages. Since the blood velocities can be quite different for an individual's right and left vertebral arteries, even with their head in neural position, the measured values were normalized to the values for the appropriate artery in neutral position. Therefore, the value of a parameter in a test position was subtracted from the value for that artery in that subject when the head was in neutral position. The difference was divided by the value in neutral position and multiplied by one hundred, to yield a percent change from the value in neutral position.

In all of the subjects, the blood flow in neutral position was assessed at the start of a session and again at the end of the session. There was no overall shift in the values of the peak systolic velocity, end diastolic velocity, or resistive index in neutral position. There was a high degree of intrinsic variability in those measurements, so the estimates of blood flow before and after testing might be substantially different in any particular subject. The values for blood flow for neutral position was usually taken to be the average of the measurements before and after the testing protocol. By doing this we substantially reduce the variability in test results that is due to the normal variation in blood flow.

All the statistical tests were also done using the initial measurements in neutral position, prior to testing, as the reference value. While the values for individual tests differed, the summary statistics were always comparable. None of the reported findings were different with the two ways of determining baseline.

Software Used

The test data was tabulated and manipulated in *Microsoft Excel* and plotted in *CA-Cricket Graph III*. The model of the binomial process was calculated in *Mathematica*. The calculation of the test statistic will be described briefly in the Results.

Results

The Test Sample

The ages of the subjects ranged from 20 to 57 years of age, There were 14 females and 8 males. Eleven of the subjects were in their twenties or thirties, nine were in their forties or fifties. No patient had a medical condition that would place him or her at risk from the testing protocol, however, five had a history of neck injury and eight had histories of neck pain.

A wide spectrum of mobility was obtained in the test sample, ranging from flexibility approaching "double–jointedness" to stiffness that reduced the range of motion to a half or less of normal expectations for the age of the subject. All the subjects were screened to eliminate those that might have vascular or biomechanical abnormalities that might place them at risk of injury due to the testing protocol, but biomechanical restriction, *per se*, was not a reason for elimination. We were interested in how restriction might affect the validity of the testing protocol.

It was found that there was no correlation between the age or mechanical restrictions of the subjects and their responsiveness to the test positions. This came as something of a surprise, because it was thought that a reduced range of motion would not allow the individual's neck to move far enough to take it into the range where there was significant stress upon the vertebral arteries. This observation may be very important, because, if an individual's vertebral artery is already compromised within their normal range of motion, then increasing that range of motion by manipulating the upper cervical spine may well move it into a range where serious injury is possible.

Responses to Test Positions

The responses are considered in groups. For instance, the response of the right artery to left rotation is grouped with the response of the left artery to right rotation, as contralateral rotation alone. There were12 groups, plotted in Figures 1,2, and 3 in the order in which the tests were done. The percent change in peak systolic and end diastolic velocity and resistive index are plotted for each test group. Each dot in Figures 1, 2, and 3 represents a single test in a single individual. The horizontal line through zero is the mean of the flow rates or resistive indices for the tests in neutral prior to testing and after testing. The dashed lines are the 95% confidence limit for that data. It is assumed that the variation in neutral is an index of the variation to be expected in other test positions, if the flow is not reactive to the position. The horizontal displacement within each group is due to a random jitter, added to spread the points, which would otherwise overlap each other.

It is clear that most of the test results in Figure 1, 2, and 3 lie between the outer dashed lines, therefore, most tests, taken individually are consistent with the change from the value in neutral position being due to normal variation. Some individuals have all their test measurements within the 95% confidence limits. Many individuals have one or more test results that lie outside the lines, but we might expect that in a series of 26 tests at least one would lie beyond the 95% confidence limit. On the other hand, there were many individual tests in which there was no doubt that circulation was compromised, because flow ceased for a part or all of the pulse cycle.

However, it is only as we examine the whole population, that we can be sure that there are systematic shifts in the responses to different tests.

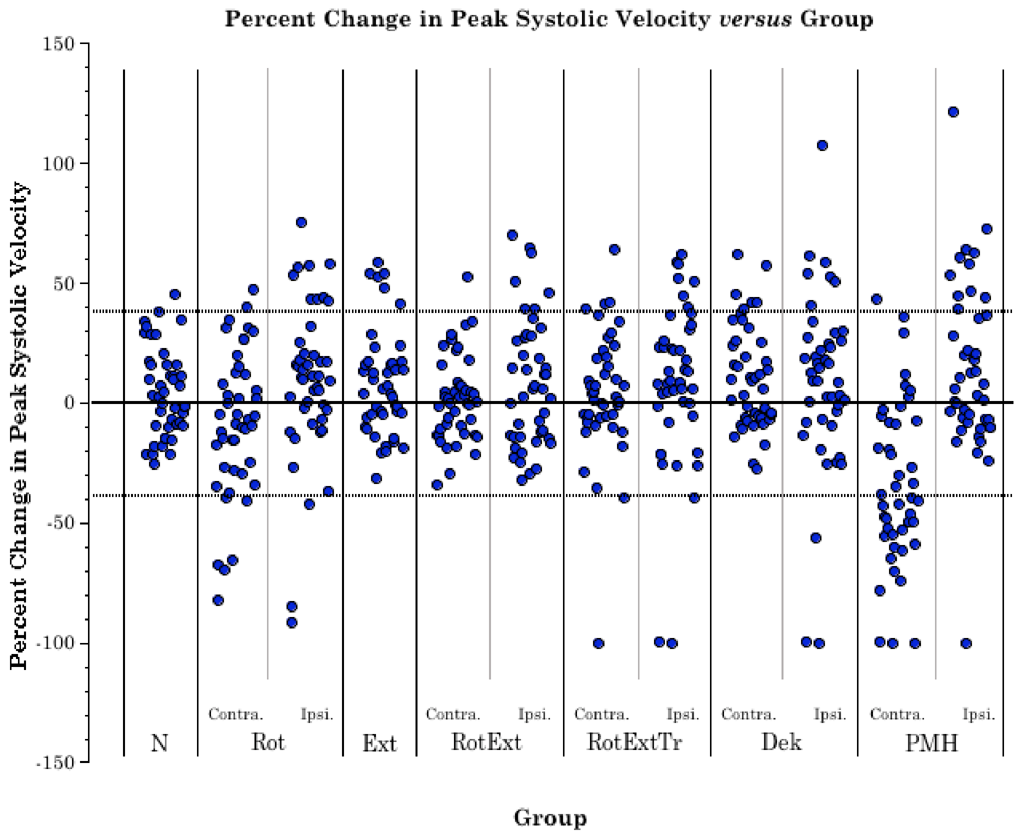

Figure 1. The Percent Change in Peak Systolic Velocity versus Group. The decreases in peak systolic velocity are most prominent for contralateral rotation in the premanipulative hold and contralateral rotation alone. There are several instances of marked decreases of blood flow during systole with contralateral lateral rotation and to a lesser extent in DeKleyn's position with ipsilateral rotation and in rotation with extension and traction. There is a pronounced tendency to increased velocity with ipsilateral rotation in the premanipulative hold and modest tendencies for increased velocity in most of the other tests. Only the distributions of the groups for rotation in PMH and contralateral lateral rotation are significant.

The percent change in peak systolic and end diastolic velocity and resistive index are plotted for each test group. Each dot in Figure 1 represents a single test in a single individual. Lines have been drawn at the no change value (0%) and at 2 standard deviations of the distribution in neutral position, to either side of the no change line. Points between the lines are within the expected normal variation of the data, assuming there is no tendency to increase or decrease blood velocity relative to neutral position. The horizontal displacement within each group is due to a random jitter added to spread the points, which would otherwise overlap each other.

When examined as a population (Figures1, 2, and 3), there are clearly some test positions that have more outliers. Many of these are tests in which the blood ceased to flow during all or a portion of the pulse cycle. For instance, contralateral lateral rotation and contralateral rotation in the premanipulative hold both have several tests in which there were substantial decreases in blood flow. There are other tests where there was clearly a tendency to increase in one or more to the blood flow parameters, including ipsilateral lateral rotation, deKleyn's position, and ipsilateral rotation in the premanipulative hold. Resistive index appears to increase in many of the tests. It decreases only with ipsilateral rotation in the premanipulative hold. Some of these observations are statistically significant and others are not. The remainder of the results consider these points in more detail.

Individual Test Positions

One of the difficulties in analyzing the responses to the stress positions is the large amount of variability in the data, even when there is no stress. While most of the distributions are unimodal and symmetrical, there are clearly some conditions in which the responses are not even approximately normally distributed. Those that violate normality most flagrantly are those of greatest interest. Each of the variables potentially saturates at one end or the other of the distribution and the response distributions that are of greatest interest are those that have multiple responses that are saturated. Consequently, parametric statistics are generally not appropriate for statistical estimates. In any case, the questions that are most interesting are not about means and standard deviations, but about detecting tendencies to reduce or increase blood flow, and about stressing the vertebral arteries to the point of compromising blood flow.

Two similar, but distinct, questions were addressed. First, does blood flow change as the head and neck are placed in the different test positions? Second, are there clinically significant changes?

The first question is effectively whether there is an equal probability of an increase or decrease of blood flow. If blood flow decreases in most individuals when they are placed in contralateral rotation, then it is likely that the position causes a decrease in blood flow. This is a binomial process, therefore the tendency has been quantified by computing the probability that the observed numbers of positive or negative changes, or a greater number, would occur in a binomial distribution with 44 samples and equal probability of positive and negative changes.

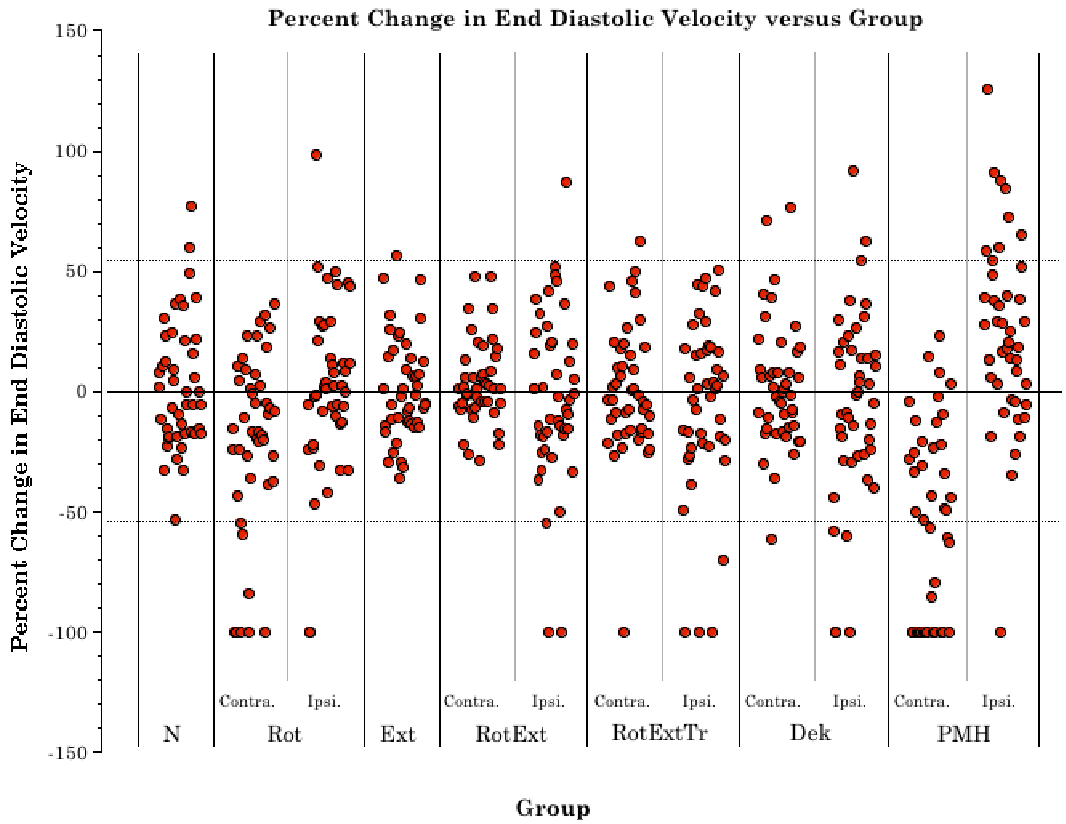

Figure 2. The Percent Change in End Diastolic Velocity versus Group. The changes in end diastolic velocity are most prominent for contralateral rotation in the premanipulative hold. There is a tendency to increased velocity with ipsilateral rotation in the premanipulative hold. There are several instances of cessation of blood flow during diastole with contralateral lateral rotation and to a lesser extent in DeKleyn's position with ipsilateral rotation, ipsilateral rotation with extension, and traction and ipsilateral rotation with extension. Only the distributions for the groups contralateral rotation in PMH and contralateral lateral rotation alone are significant.

The second question is effectively asking how often a test position will cause a marked decrease in blood flow, which would be indicative of possibly dangerous stress upon the vertebral arteries. There is not a unique statistical test for this factor. It depends upon what is considered a clinically relevant risk. One observer might say that cessation of blood flow is necessary, while another may say anything beyond normal variation in neutral position is sufficient. Intuitively, the number of times a test produces a marked decrease in blood flow is the most relevant statistic.

Both cessation of blood flow and reduction of flow beyond two standard deviations of the flow in neutral position are considered below.

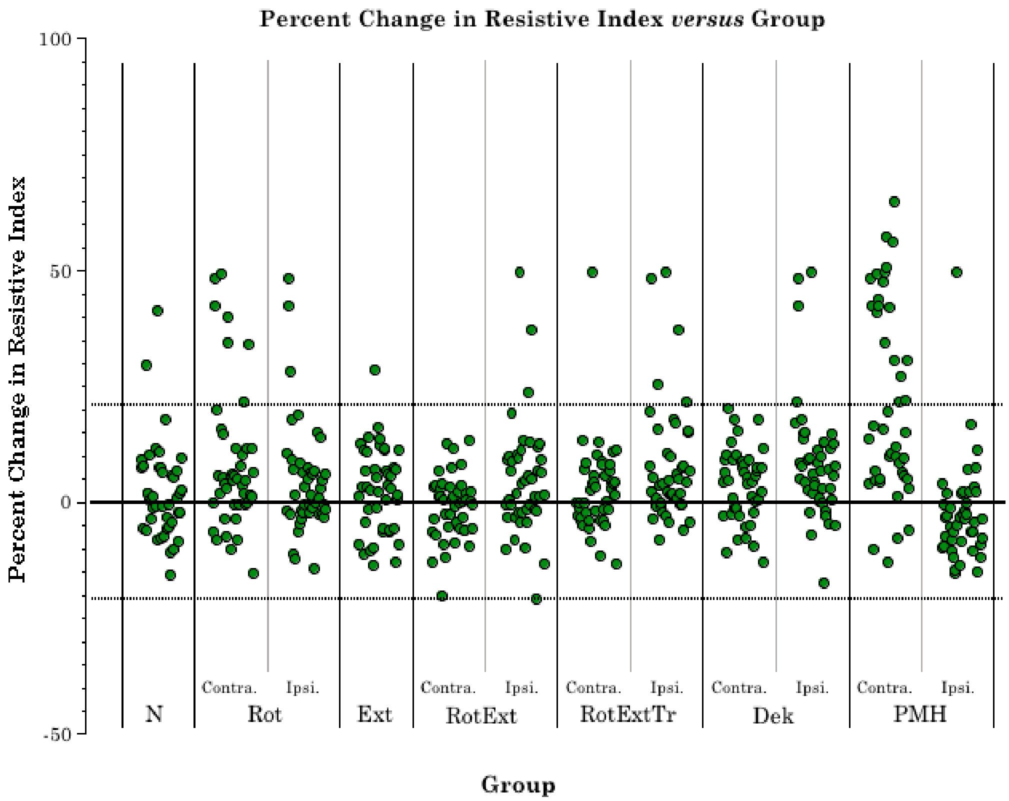

Figure 3. The Percent Change in Resistive Index versus Group. The changes in resistive index are most prominent for contralateral rotation in the premanipulative hold. There is a tendency to decreased resistive index with ipsilateral rotation in the premanipulative hold. There are several instances of increased resistive index with contralateral lateral rotation and to a lesser extent in DeKleyn's position, ipsilateral rotation with extension, and traction and ipsilateral rotation with extension. All of these distributions for the groups are significantly asymmetrical.

We now consider the distributions of responses for each test position. The significance levels are given in Table 1.

Lateral rotation: It was found that the contralateral rotation reduced the diastolic velocity ($p = 0.023$) and increased the resistive index ($p = 0.0095$) and ipsilateral rotation increased the systolic velocity ($p = 0.023$). Note that there were a number of tests in which there was cessation of blood flow during the diastolic phase of the pulse cycle (5, from 4 individuals, in contralateral rotation and 2, from the same individuals, in ipsilateral rotation) and 7 of the 44 tests in contralateral rotation were more than two standard deviations below the no change line.

Extension: Extension alone has no significant effect on any of the measured parameters.

Probabilities of Observed Positive and Negative Changes in %S, %D, and %R

	Number			Percent in Tail		
Test Group	**% S**	**%D**	**%R**	**% S**	**%D**	**%R**
N	20	22	20	65.150	100.000	65.150
ContraR	18	**14**	**13**	29.110	**2.250**	**2.250**
IpsiR	**14**	21	20	**2.250**	88.030	88.030
E	19	20	15	45.130	65.150	65.150
ContraRE	20	19	21	65.150	45.130	88.030
IpsiRE	19	19	17	45.130	45.130	17.410
ContraRET	19	20	17	45.130	65.150	17.410
IpsiRET	**12**	21	**12**	**0.355**	88.030	**0.115**
ContraDek	18	22	**13**	29.110	100.000	**0.945**
IpsiDek	**14**	21	**8**	**2.250**	88.030	**0.002**
ContraPMH	**6**	**4**	**3**	**8.025E-05**	**1.543E-06**	**1.506E-07**
IpsiPMH	18	**11**	**12**	29.110	**0.115**	**0.355**

Table 1. The Probability of the Ratio of Negative to Positive Changes Being Equal To or Exceeding the Observed Values. For each group of test positions the numbers of tests that produced increased or decreased values relative to their value in neutral position were counted for peak systolic velocity, end diastolic velocity, and resistive index. The probability of obtaining that number or a more eccentric ratio was determined by computing the cumulative probabilities for a binomial distribution with 44 sample points and equal probability of positive or negative changes. Test groups in which the results were significantly different from null change have been highlighted by writing them in bold. See the text for descriptions of the findings.

Rotation, Extension, and Traction: The only significant change is an increase in systolic velocity in ipsilateral rotation with extension and traction ($p = 0.0036$). This leads to a concurrent increase in resistive index ($p = 0.0012$). Although the changes in blood velocity did not reach significance, the trend was for increased systolic velocity and decreased diastolic velocity, which is the combination most apt to increase the resistive index.

It is not possible to completely discount these tests, because there were a couple tests, in one individual, in which there was a cessation of blood flow during the entire pulse cycle and a few more in which the blood ceased to flow during the diastolic phase (Figure 1). Two of the three individuals involved also had cessation of blood flow with contralateral rotation alone and with contralateral rotation in premanipulative hold. The third had cessation only in ipsilateral rotation with extension.

deKleyn's Position: There is no preference for either increase or decrease in diastolic velocity, but there is a trend towards increased systolic velocity ($p = 0.023$) with ipsilateral rotation in full deKleyn's position. There is an increase in resistive index for rotations in both directions ($p = 0.0095$ for contralateral rotation and $p = 2*10^{-5}$ for ipsilateral rotation).

A couple individuals had cessation of blood flow in ipsilateral deKleyn's position. These were the same individuals that had cessation in the combinations of rotation, extension, and traction, in contralateral rotation and rotation and in contralateral rotation in premanipulative hold. In the case of one of these individuals the right artery was about half the diameter of the left artery; in the other both arteries were the same size in the mid-cervical neck, but the flow rates were much less in the right artery.

Premanipulative Hold: The changes in blood flow were most impressive for the premanipulative hold when the atlas was rotated contralaterally upon the axis. With contralateral rotation, there is a highly significant decrease in both systolic ($p = 8.02*10^{-7}$) and diastolic ($p = 1.54*10^{-8}$) velocity and a highly significant increase in resistive index ($p = 1.5*10^{-9}$). With ipsilateral rotation of the atlas, there was a highly significant increase in diastolic velocity ($p = 0.0012$) and a significant decrease in resistive index ($p = 0.0036$). Ipsilateral rotation in the premanipulative hold is the only test position where there was a clear decrease in resistive index. Note, however, that none of the points is below the 95% confidence limit.

The tendency towards reduced blood flow with contralateral rotation in the premanipulative hold is obvious in the plot of test results (Figure1, 2). Twenty-four of the 44 tests were below the 95% confidence limit for blood flow in neutral 22, 16 had a complete cessation of blood flow during diastole.

The breadth of the effects

There are test positions that have brisk responses in an occasional individual, test positions that provoke a brisk response in moderate numbers, and test positions that provoke a brisk response in many individuals. The combined movement tests into quadrant positions or deKleyn's position provoked cessation of blood flow in three individuals. Cessation of blood flow with ipsilateral rotation occurred in one of those individuals. Five individuals had cessation of blood flow with contralateral rotation and one more had marked reduction of blood flow. Two of the individuals with cessation on one side had marked reduction on the other side. So, six of the 22 subjects reacted to contralateral rotation alone. Sixteen of the 22 subjects had compromised blood flow with contralateral rotation in the premanipulative hold.

These findings suggest that there are individuals that are much more easily affected by head position than others. Those that respond to the less commonly effective tests, generally response to the more effective tests. This would suggest that there is an anatomical difference in their upper cervical spine that predisposes them to vertebral artery compromise.

Does a decreased blood flow on the right tend to be associated with an increased blood flow on the left? Especially for the premanipulative hold.

It has been suggested that, when one artery is compromised, the contralateral artery might compensate, by increasing blood flow. While, on average, there is an inverse relationship between the directions of change for contralateral versus ipsilateral rotation in the premanipulative hold and, to a substantially lesser extent for lateral rotation, it is not necessarily the case for individuals. It is possible to find individual sessions where velocity dropped in both arteries or increased in both arteries with a particular rotation.

If we plot the change in end diastolic velocity for ipsilateral rotation versus contralateral rotation when the neck is in the premanipulative hold, then the plot in Figure 4 shows that there is a very weak negative correlation ($r^2 = 0.013$) between the velocities in the two vertebral arteries. This indicates that there is not a quantitative reciprocal relationship of any consequence between the flows in the two arteries. However, the plot of the data also indicates that the two changes in diastolic velocity are generally of opposite sign. Only 14 of the 48 sample points have the same sign ($p = 05.29 \times 10^{-3}$ of 14 or less pairs with same sign in 48 sample pairs, given equal probability of same or opposite signs). Most of the pairs have an increase in end diastolic velocity with contralateral rotation and a decrease with ipsilateral rotation. The situation is similar for resistive index ($r^2 = 0.093$) and peak systolic velocity ($r^2 = 0.014$). The tendency towards opposite signs is slightly less strong (15 and 18, respectively, with the same sign). In summary, for premanipulative holds, there is a reciprocity in the directions of change in resistive index, but the magnitudes of the changes are not proportional.

Discussion

Outliers are most apparent for lateral rotation, deKleyn's position and premanipulative hold.

The cessation of flow, either for a portion of the pulse cycle or for the entire cycle, was comparatively rare and undetectable by clinical assessment, but it is probably clinically relevant. That it is rare is one of the principal observations of this Doppler ultrasound study. That it is generally undetectable is based upon the observation that in situations where we demonstrated a complete cessation of blood flow in a vertebral artery and held the position for a minute or more, there were no symptoms other than the discomfort of having one's neck forced into an endrange position.

One subject experienced some dizziness with deKleyn's position and premanipulative hold, but since this lasted into the early evening, it may have been more related to the mechanical strain in her neck, rather than to the cessation of blood flow. She did not have a significant reduction of blood flow in those tests that provoked the dizziness.

Cessation of flow is generally not a risk to the brain, because there are other pathways that will allow circulation to the brainstem, cerebellum, and posterior cerebrum. It is almost never a lethal risk in normal life activities, because if a movement seriously impedes circulation, then it will produce symptoms that will cause the individual to quickly move out of the problematic position. In itself, it is not a risk for manipulation, because there are usually the other routes for blood supply and a manipulation takes only a fraction of a second.

Flow cessation is relevant, however, because it indicates that there is a substantial amount of stress upon the artery. If there is a pre-existing weakness or predisposition to embolize, then a position that causes cessation of flow is a position that stresses the arterial wall. Therefore, it is a position most likely to tear the artery or slough a thrombus or atherosclerotic plaque.

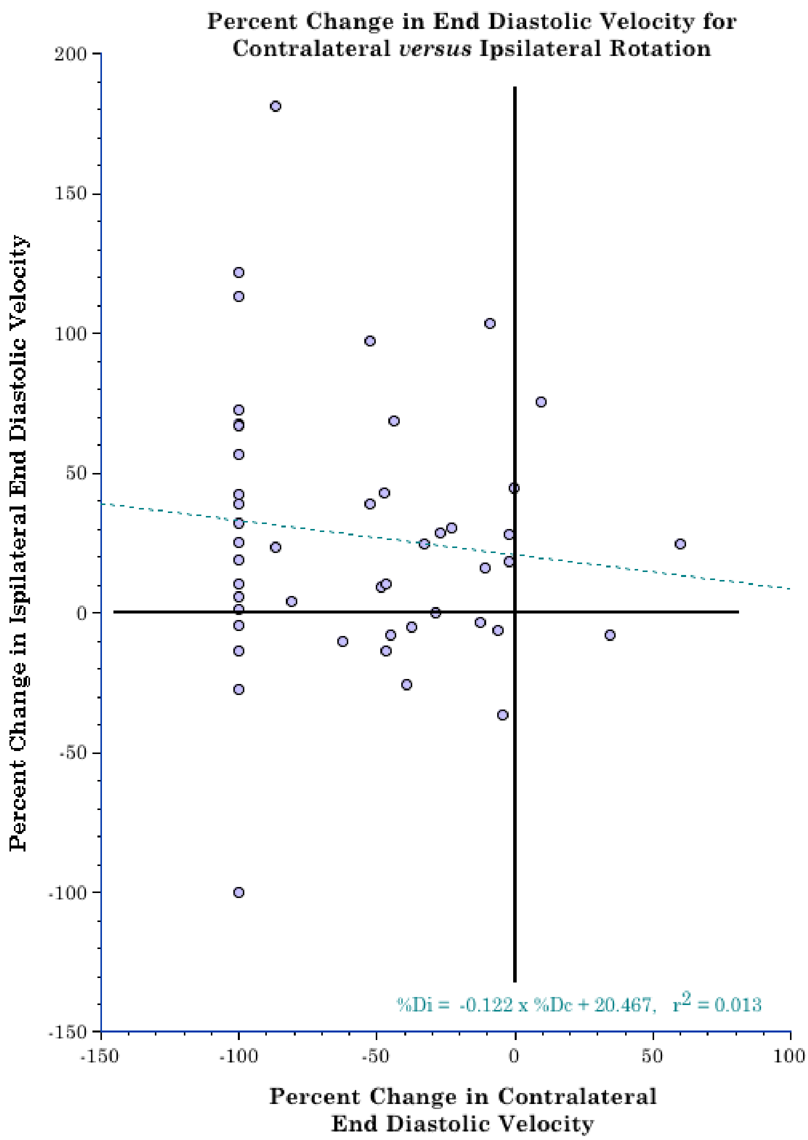

Figure 4. Percent Change in End Diastolic Velocity for Contralateral versus Ipsilateral Rotation. For each subject the end diastolic velocity in each artery is plotted against the end diastolic velocity in the contralateral artery when the atlas is taken to it's endrange of lateral rotation while the head and neck are being held in the premanipulative hold. For the artery contralateral to the direction of rotation the flow rate tends to decrease and for the artery ipsilateral to the rotation it tends to increase. There is no correlation between the flow in one artery and the flow in the other artery (r^2 = 0.13). Still, there is a strong trend for the change in flow to be in opposite directions in the two arteries, Fourteen of the 48 sample points have the same sign for both changes in flow.

Because there are seldom symptoms with the unilateral cessation of blood flow in the vertebral arteries, placing an individual in the position that produces considerable stress will generally not evoke warning signs or symptoms. Consequently, one needs to know what positions are most threatening and what will render them more dangerous.

In this study, it is observed that the positions most likely to cause cessation of blood flow are lateral rotation and the premanipulative hold for atlanto-axial manipulation. There were a few individuals in which there is cessation of blood flow with compound movements involving lateral rotation with extension or extension and traction, but these individuals almost always also had cessation of blood flow when in the pre-manipulative hold. One individual has cessation with ipsilateral compound movements, but not complete cessation with the contralateral rotation in the premanipulative hold.

There was never even approximate cessation of flow with extension alone. Therefore, it is unlikely that extension alone places notable stress upon the C1/C2 segment of the vertebral artery.

Since there was almost always cessation of flow in the premanipulative hold, if there was cessation in any other position, it appears that the premanipulative hold is both the most stressful position and the most sensitive to potential problems.

The Magnitudes of the Changes

It turns out that the sensitivity of flow rate to the vessel's dynamics is a substantial impediment to detecting small changes in the stress in the system. Even in the absence of stress, in neutral position, there are substantial fluctuations in the flow rate from sample to sample. In retrospect, this should not have surprised us, since a 20% change in caliber will reduce the flow by 50% or double it.

However, even against this noisy background, we were able to detect real changes with head and neck position. Perhaps as important, we were able to show that most of the stress tests generally do not in fact stress the vertebral artery to any relevant extent. Many individuals showed no indication of significant stress of the vertebral artery in any of the standard stress tests. A few individuals would respond to one or another test, but not as frequently to those tests that nominally stressed the neck more. It turned out that the most stressful test was the one generally considered least stressful, full lateral rotation.

There was only one test, which we used that seemed to generally stress the vertebral artery, contralateral rotation in the premanipulative hold for atlanto-axial manipulation. In general, if the artery were going to respond to postural stress, it would respond to the premanipulative hold. We had one individual who had cessation of blood flow with rotation, but not as much reduction in the premanipulative hold, otherwise, if the arterial flow ceased in any of the stress tests, then it ceased in the premanipulative hold.

Should the stress tests be done, and, if so, which ones?

Given the findings presented here, one might ask whether anything is gained by doing the standard stress tests? It would appear that, if the purpose for doing the stress test is in preparation for a cervical manipulation, then the most effective test of the possible risk is to actually place the head and neck in the premanipulative position and hold the position for about 15 seconds. That strategy will maximally stress the vertebral artery short of the additional stress produced by the increased range of motion that is supposedly gained by the manipulation. If that extra few degrees is the “straw that breaks the camel’s back”, then the manipulation may still do injury, even with testing. If the injury is tearing or liberation of an embolic fragment, then it may be the forceful thrust that is critical to the injury. Probably there is no test that will predict the injury in such a situation. It is hoped though that if there is undue stress with the manipulation, then it will already be significant prior to the manipulation and the therapist will detect symptoms while waiting in the premanipulative position.

It has been noted that it is not the loss of circulation that is the cause of concern with cervical manipulation. The manipulation itself takes a fraction of a second. Rather, it is the stress upon the artery that is of concern and the loss of circulation is taken as an indicator that such a stress is present. Unfortunately, in almost every individual that looses circulation in a vertebral artery because of cervical spine distortion, there will be no symptoms. Symptoms are not a reliable indicator of stress. In our subjects it was generally possible to hold a position that completely stopped circulation in one artery, for a minute or more, with no signs or symptoms of circulatory insufficiency.

More generally, prior to mobilizing or manipulating the upper cervical spine it is prudent to take the individual to end range and hold their neck in that position for several seconds, It would appear that the stress tests are not sufficient to predict which individuals are going to experience excessive stress with a C1/C2 manipulation. They probably are not even sufficient to detect the individual that is going to experience excessive stress in any position other that the one being tested.