Pre-manipulative testing: where do we go from here?

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ABSTRACT
The currently advocated pre-manipulative risk assessment protocols include the use of provocative positional tests to challenge the integrity of the vascular supply to the brain. This paper examines the validity of these pre-manipulative provocative tests in light of recent studies involving ultrasound scanning of the vertebral arteries in subjects who also had provocative tests performed. These studies indicate that the provocative positional tests may produce both false positive and false negative findings. Recent research concerning the use of a continuous wave Doppler velocimeter suggests this device may provide a more objective assessment of vertebral artery blood flow than the present provocative tests. However, the sensitivity and specificity of the use of the velocimeter in identifying altered or abnormal vascular flow in the vertebral arteries, and therefore its clinical utility, remain to be fully established. Rivett DA, Thomas L, Bolton P (2005). Pre-manipulative testing: where do we go from here? New Zealand Journal of Physiotherapy 33(3) 78-84.

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INTRODUCTION
Cervical spine manipulation is a procedure commonly used by a number of health care professions including physiotherapists, osteopaths, chiropractors and medical practitioners, primarily for the treatment of neck pain and headache. It is important to recognise that cervical spine manipulation may result in adverse events and complications (Di Fabio 1999; Senstad et al. 1997). These side effects may be minor and transient, ranging from localised discomfort and stiffness to dizziness and nausea. However more serious events such as transient ischaemic attack, stroke and even death have been reported subsequent to neck manipulation (Kleynhans 1980; Klougart et al. 1996; Leboeuf-Yde et al. 1996). The Australian Physiotherapy Association (APA) and the Chartered Society of Physiotherapy have developed and recommended guidelines to assist the clinician in identifying patients in whom cervical spine manipulation may be contraindicated (APA 2000; Barker et al. 2000; Grant 1988). The medical, osteopathic and chiropractic professions have similar guidelines in place (George et al. 1981; International Federation of Manual Medicine 1979; Kleynhans 1980). The New Zealand Society of Physiotherapists has recently adopted the APA clinical guidelines for pre-manipulative procedures for the cervical spine.

Side effects or adverse events following spinal manipulation occur in up to 55% of patients (Senstad et al. 1997). Most of these events are self-limiting. The more serious complications of transient ischaemic attack, stroke and death are considered to be rare. The precise incidence of such post-manipulative neurovascular events is unknown but estimates vary widely, including 1 vertebral artery dissection per 5,000,000 cervical spine manipulations (Haldeman et al. 2001), 1 cerebrovascular accident per 400,000 sessions involving upper cervical spine manipulation (Klougart et al. 1996) and 1 cerebrovascular accident for every 100,000 patients (<45 years of age) within one week of visiting a chiropractor (Rothwell et al. 2001). Rivett and Reid (1998) have estimated the risk for physiotherapists to be 1 stroke per 163,000 manipulations of the cervical spine. Most of these estimates however, have been based on retrospective studies of medico-legal cases or case reports in the published literature. Under-reporting and cases settled out of court are likely to significantly distort the figures (Ernst 2002). Interestingly, others have questioned the cause and effect relationship and raised the possibility that at least some complications attributed to neck manipulation may actually be the result of failure to identify a pre-existing vertebral artery dissection or may simply be coincidental (Haldeman et al. 2002; Leboeuf-Yde et al. 1996; Terrett 2002). Nevertheless, it is clear that, although considered rare, neurovascular events may be associated with cervical spine manipulation.
The more devastating complications of neck manipulation are thought to arise from changes in blood flow or the integrity of vascular structures of the neck (Terrett 1987). It has been shown that cervical spine rotation, common to many manipulative procedures, can alter blood flow in the vertebral arteries (Selecki 1969; Toole & Tucker 1960). It has also been proposed that mechanical insult to one or more of the vertebral arteries (and much less frequently the internal carotid arteries) in the neck during the manipulative procedure may account for some of the neurovascular events (Terrett 1987). However, a review of cases suggests that the incidence of neurovascular complications subsequent to cervical spine manipulation is not limited to procedures involving rotation of the head and neck (Haldeman et al. 1999). On the other hand, a recent biomechanical study reported that a single neck manipulation is unlikely to cause mechanical trauma to a healthy vertebral artery (Symons et al. 2002), although the effect on pathological vessels and from repeated manipulations was not investigated.

In any case, the onus is on the manipulative practitioner to determine that the patient’s presenting condition does not include symptoms or signs likely to be indicative of, or associated with, cerebrovascular ischaemia. Such a clinical presentation should prompt immediate referral for a medical opinion. The practitioner considering the use of cervical spine manipulation as a therapeutic intervention should also seek the presence of risk factors for a neurovascular event subsequent to manipulation. Furthermore, they should take all due care to avoid any actions that may actually induce an adverse event, such as the application of an overly-vigorous or inappropriate manipulative technique.

Pre-manipulative risk assessment protocols

Concerns about serious neurovascular complications following neck manipulation have led physiotherapists using manual therapy to introduce protocols or clinical guidelines to aid in the identification of the patient at risk (APA 2000; Grant 1988). In principle, the protocols aim to determine if the patient is presenting at the time of consultation with a neurovascular event or has any previous or current signs or symptoms that suggest the patient may be at risk of a cerebrovascular event, particularly during a manipulative or other manual procedure. The protocols typically consist of three components. Firstly, a case history is used to determine if any previous or current symptoms exist that suggest the patient is presenting with cerebrovascular compromise or disease (e.g. a history of transient hemianopia). Importantly, it is also used to help determine if the patient’s neck may be vulnerable to vascular injury subsequent to manipulation. Secondly, a physical examination is performed to ascertain if there are any signs of risk factors (e.g. segmental instability) and if the patient is a suitable candidate for manipulative therapy. Finally, specific provocation tests are performed to assess and challenge the vascular supply to the hindbrain by positioning the cervical spine in end-range rotation and/or extension.

The original protocol and more recent guidelines proposed by the Australian Physiotherapy Association (APA 2000; Grant 1988) have been subjected to critical review in recent years, particularly in respect of the validity of the provocative tests (Dunne 2001; Grant 2001; Gross & Kay 2001; Refshauge 2001; Reid & Hing 2001; Rivett 2001). The possibility of false negative provocative test results was first demonstrated in a single case report involving the use of digital subtraction angiography (Bolton et al. 1989). Later studies involving duplex ultrasound measurement of vertebral artery blood flow during the performance of provocative positional tests have further cast doubt on the validity of the tests to determine the patency of the vertebral arteries and raised questions about their ability to detect impedance changes to cerebrovascular blood flow (Cote et al. 1996; Licht et al. 1998; Rivett et al. 2000; Thiel et al. 1994). Both false positive and false negative findings have now been reported (Cote et al. 1996). These recent studies clearly draw into question the adequacy of the provocative tests to detect those patients at risk of complication from manipulative procedures.

The aim of this paper is to critically review current pre-manipulative provocative testing procedures and consider possible improvements to the existing pre-manipulative risk assessment protocols and guidelines.

Pre-manipulative provocative tests

The provocative tests are intended to challenge the vascular supply to the brain by compromising the blood flow in one vertebral artery and examining for the onset of signs and symptoms of cerebrovascular ischaemia (APA 2000; George et al. 1981; International Federation of Manual Medicine 1979; Kleynhans 1980). In general, these tests involve slow passive rotation and/or extension of the patient’s head and neck to the maximal range of motion with the patient in either the upright (seated or standing) or supine lying position. It is known from cadaveric (Selecki 1969; Toole & Tucker 1960), modeling (Haynes et al. 2002) and in vivo studies (Faris et al. 1963; Haynes & Milne 2001) that cervical spine rotation can reduce flow in the vertebral artery contralateral to the direction of rotation. This position also simulates the head and neck posture of many manipulative procedures, although the test procedure cannot mimic the mechanics associated with the thrust itself. If potential signs or symptoms of vertebrobasilar ischaemia arise during this procedure the patient’s neck is then immediately returned to the neutral position and medical attention should be sought. In this instance, the assumption is that the manoeuvre has temporarily ‘provoked’ a neurovascular event,
which is clearly a contraindication for cervical spine manipulation.

It is conceivable that the provocative test may produce cerebrovascular ischaemia because the vertebral artery flow has been compromised by the neck movement and is necessary, in that patient, for adequate perfusion of the brain. Alternatively, the cervical spine movement may have initiated a neurovascular event due to the release of thrombo-embolic material or at least changed the vascular haemodynamics sufficient enough to produce ischaemic symptoms or signs. It is important to be aware that the provocative tests, in and of themselves, cannot identify anatomical anomalies or pathology that may be associated with a cerebrovascular ischaemic event subsequent to neck manipulation. It is also important to recognise that signs and symptoms such as dizziness and nausea occurring during the performance of the provocative tests may arise from non-ischaemic events, for example, vestibular dysfunction.

If signs or symptoms of vertebrobasilar ischaemia are not evident during or immediately subsequent to the provocative test procedure it can be concluded that the manoeuvre does not compromise blood perfusion to the brain sufficient enough to produce such signs and symptoms. This could have resulted from failure of the head and neck positioning to compromise blood flow in the contralateral vertebral artery or because the collateral vascular supply to the brain is sufficient (even if the contralateral vertebral artery is mechanically compromised) to maintain adequate perfusion. Thus, one of the limitations of the provocative tests is that they only indirectly assess blood flow dynamics.

In a contemporary specialty or tertiary medical setting, the gold standard for in vivo diagnosis of vascular pathology or dysfunction is achieved with imaging studies using digital subtraction angiography or magnetic resonance angiography (Zwiebel 2000). Duplex ultrasound, pulsed wave Doppler with real-time imaging, is also used to examine the status of blood flow in vessels in various regions of the body (Zwiebel 2000). More recently, duplex ultrasound has been employed to measure blood flow changes in the vertebral arteries in studies investigating the haemodynamic effects of cervical spine movement (Arnetoli et al. 1989; Haynes 2000; Johnson et al. 2000; Licht et al. 1998; Refshauge 1994; Rivett et al. 2000). Duplex ultrasound studies of the effects of the provocative screening tests on vertebral artery blood flow have raised concerns about the validity and appropriate interpretation of the provocative test findings. False positive provocative test results have been reported in some studies (Licht et al. 1998; Thiel et al. 1994), while others have documented both false positive and false negative findings (Rivett et al. 2000). Notably, in a study of 100 patients with both positive and negative provocative test findings, Rivett et al. found there were no meaningful significant differences in blood flow velocity or flow rate in various positions (including end-range rotation and/or extension) between patients testing positive and those testing negative. However, the use of duplex ultrasound as a pre-manipulative screening tool is not a practical or affordable option for use in the typical clinical practice of manipulative physiotherapists. Instead, Haynes (1995) and Rivett (2001) have proposed that a simpler ultrasound device, the Doppler velocimeter, may be suitable to assess the status of vertebral artery blood flow during pre-manipulative provocative tests.

![Figure 1: An example of a velocimeter (Huntleigh Super Dopplex II, Huntleigh Diagnostics, Perth, Australia) with digital display and transducer probe detached](image)

**Doppler velocimeter**

The Doppler velocimeter is a basic continuous wave Doppler ultrasound device that is commonly used in medical settings to evaluate peripheral blood flow. It has a hand-held transducer probe the size of a pen, which can be applied to the upper cervical and sub-occipital regions to access the vertebral artery. The device produces an audible signal that varies in pitch and amplitude to reflect blood flow changes, such as resistance to flow in the vessel being scanned. An auditory output and digital display provide information concerning blood flow direction (with respect to the probe) and velocity, including specific values for peak systolic and mean velocities in some models. In contrast to the duplex ultrasound scanner, the velocimeter does not have real-time imaging to assist in the accurate location of vessels. Successful scanning of a vertebral artery results in a characteristic audible pulsatile signal which distinguishes it from veins and other arteries in the region.

Haynes (2002) and Rivett (2001) have proposed that the velocimeter could be used to determine the presence of left and right vertebral artery blood flow in the neutral position, and then examine for blood flow (velocity) changes when the cervical spine has
been rotated. Such changes in blood flow should be indicated by a change in pitch or amplitude of the characteristic audible signal. Haynes (2000) has proposed that such a change in signal may reflect the biomechanical forces imparted to the artery by the positioning of the neck during the scan, although this remains to be demonstrated. Arguably the absence of flow or a marked alteration in velocity during rotation would also be an indication of the need for a more comprehensive vascular evaluation of the patient.

**Clinical procedure**

Haynes (1995; 1996; 2000) has described a two part clinical examination of the vertebral artery using the velocimeter. The first part involves insonation of the vessel at the sub-occipital level where the artery runs along the atlantal transverse process. The second part involves interrogating the artery at the level of the axis where the artery exits the transverse foramen and courses supero-laterally before passing posterior to the lateral mass of the atlas. The atlanto-axial portion of the vertebral artery is particularly of interest because this region is usually injured in cases of post-manipulative vertebral artery dissection and because of the large excursion of movement that takes place at this joint during neck rotation (Selecki 1969). Haynes (2002) recommends that primary screening should be at the sub-occipital level as the vertebral artery is readily accessible for insonation at this location. The axial approach is used by Haynes (2000; 2002) to confirm abnormalities or alterations of the blood flow signal found at the higher level or if a rotational manipulative technique is to be applied.

Haynes (1996) recommends that Doppler examination be performed with the patient in the sitting position for ease of application of the velocimeter probe to the patient’s neck and because blood flow changes are more likely to be demonstrable in this position due to the vascular challenge induced by gravity. The absence of vertebral artery signal in the neutral cervical spine position may indicate (i) an absent or hypoplastic artery, or (ii) occlusion or stenosis of the artery, or (iii) a technical artifact, such as due to a very deep artery (Haynes 2002). Loss of signal with contralateral cervical spine rotation suggests either (i) poor insonation, or (ii) that the new position has reduced the blood flow rate to a level no longer able to elicit a Doppler response. A marked increase or decrease in the signal on rotation indicates some compromise of the arterial blood flow by the neck position. It is proposed that abnormal or altered blood flow determined by the velocimeter, until proven otherwise, should be considered a risk factor for an ischaemic event associated with manipulation.

It is important to note that Doppler velocimeter examination of the vertebral artery can be subject to operator error (Haynes 2000). In particular, the vertebral artery is a small vessel with a mean diameter of approximately 4 mm (Zwiebel 2000) and can be difficult to locate. The lack of imaging capability and waveform display of the velocimeter makes accurate location of the artery more difficult than with duplex scanning. Errors may also arise from the ultrasound beam losing contact with the artery, particularly during movement of the neck such as rotation. Use of too much pressure with the probe may compress the artery and if insufficient conducting gel is used there may be poor contact with the skin, potentially causing distortion of the signal (Haynes 2000). Furthermore, there are currently no normative values for peak systolic, mean and end diastolic velocities for the vertebral artery on which to base clinical decisions due to the wide variation of vessel calibre in the general population. Interpretation of velocimeter findings is therefore mainly based on the qualitative information obtained from the auditory signal. However, the human ear is considered to be highly sensitive in its ability to distinguish quite subtle alterations in pitch (Zwiebel 2000).

**Validity and reliability**

A preliminary study by Haynes (2000) evaluated the sensitivity and specificity of the velocimeter in examining vertebral artery flow by comparing findings to that of duplex ultrasound. Twenty patients presenting to a private chiropractic practice were examined with a velocimeter at the sub-occipital and axial levels by a very experienced operator and blood flow signals were categorized as either unchanged, major decrease in flow, or major increase in flow. The patients were then examined with a duplex ultrasound scanner at the C3-C4 and atlanto-axial levels and peak systolic flow values
an inexperienced operator. A naive operator was trained in a two hour session in the technique of insonating the vertebral artery at both the sub-occipital and axial levels in neutral and during contralateral rotation. Twenty patients were first examined by the experienced operator and then by the inexperienced operator who was blind to the findings of the initial examiner. The study showed good inter-examiner reliability ($k = 0.78$ at $p = 0.05$) for the identification of major changes in blood flow which suggests that the device could be successfully used by a novice following a short training workshop. However, it remains to be determined if the velocimeter can be used to reliably detect abnormal blood flow in the vertebral artery consequent to existing dysfunction or pathology.

Haynes (1996) examined the vertebral arteries of 140 patients using Doppler velocimetry and found complete cessation of the Doppler signal on contralateral passive neck rotation in 5% of patients, suggesting no blood flow in those arteries. Of particular interest was that there were no symptoms of vertebrobasilar ischaemia elicited during pre-manipulative provocative testing of these same persons. Although only one patient’s results were verified by follow-up duplex scanning, this study suggests that use of the velocimeter may allow identification of altered vascular status in the vertebral artery that is not detectable by the provocative tests currently used in the pre-manipulative risk assessment protocols (APA 2000; George et al. 1981; Grant 1988; Kleynhans 1980). However there is a need for further research to first confirm the preliminary but promising results of Haynes and colleagues as to the sensitivity, specificity and reliability of velocimeter examination of the vertebral artery. It is also important to recognise that the velocimeter, like the currently used provocative tests, will not predict cerebrovascular events due to inappropriate or poor performance of neck manipulation, nor provide detailed diagnostic findings. Nevertheless, it may provide more objective pre-manipulative clinical information than is currently available to the practitioner.

**CONCLUSION**

In the light of recent studies casting doubts on the validity of provocative positional testing, it would seem prudent to seek more objective means of evaluating vertebral artery blood flow during pre-manipulative screening. Doppler ultrasound in the form of a hand-held velocimeter may offer a more objective screening tool for manipulative physiotherapists. If the velocimeter is established as a valid and reliable measure of vertebral artery blood flow it would give manual therapy practitioners greater ability to identify patients presenting with a putative risk factor for a vertebrobasilar complication following cervical spine manipulation.

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**Figure 3: Velocimeter insonation of the right vertebral artery using the sub-occipital approach in neutral (A) and in contralateral rotation (B)**

measured. The study found perfect concordance between the velocimeter and duplex findings, and it was concluded that the velocimeter was a valid tool in the hands of an experienced operator. However, a particular limitation of the study was that the patients were pre-selected by velocimeter examination. The sensitivity and specificity of the use of the velocimeter to detect individuals who have abnormal or altered blood flow first identified on duplex scanning or another type of imaging, remains to be established.

Haynes et al. (2000) compared the results of velocimeter examinations by an experienced and
Key Points

- Vertebral artery injury with consequent neurological insult can occasionally complicate cervical spine manipulation, particularly that involving atlanto-axial rotation.
- Current pre-manipulative risk assessment protocols, including provocative positional tests designed to challenge vascular supply to the brain, can produce both false negative and false positive findings.
- The vertebral artery can be accessed at the sub-occipital level and at the level of the axis by continuous wave Doppler velocimetry which provides ultrasound information regarding blood flow velocity.
- Preliminary research suggests that the Doppler velocimeter has potential to be a valid and reliable tool for detecting marked vertebral artery blood flow changes during rotation, although further research is needed to establish its clinical utility.

REFERENCES


**ADDRESS FOR CORRESPONDENCE**

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