INTERNAL CAROTID ARTERY STRAINS DURING HIGH-SPEED, LOW-AMPLITUDE SPINAL MANIPULATIONS OF THE NECK

Walter Herzog, PhD,[a,b,c] Conrad Tang, DC,[d] and Tim Leonard, PhD[e]

ABSTRACT

Objective: The primary objective of this study was to quantify the strains applied to the internal carotid artery (ICA) during neck spinal manipulative treatments and range of motion (ROM)/diagnostic testing of the head and neck.
Methods: Strains of the ICA (n = 12) were measured in 6 fresh, unembalmed cadaveric specimens using sonomicrometry. Peak and average strains of the ICA obtained during cervical spinal manipulations given by experienced doctors of chiropractic were compared with the corresponding strains obtained during ROM and diagnostic testing of the head and neck.
Results: Peak and average strains of the ICA for cervical spinal manipulative treatments were significantly smaller ($P < .001$) than the corresponding strains obtained for the ROM and diagnostic testing. All strains during ROM and treatment testing were dramatically smaller than the initial failure strains of the ICA.
Conclusions: This study showed that maximal ICA strains imparted by cervical spinal manipulative treatments were well within the normal ROM. Chiropractic manipulation of the neck did not cause strains to the ICA in excess of those experienced during normal everyday movements. Therefore, cervical spinal manipulative therapy as performed by the trained clinicians in this study, did not appear to place undue strain on the ICA and thus does not seem to be a factor in ICA injuries. (J Manipulative Physiol Ther 2015;38:664-671)
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Spinal manipulative therapy (SMT) has become a widely accepted modality to treat back and neck problems including headaches.[1-4] Spinal manipulative therapy has been shown to be effective, specifically when used with high-speed of force application and a low-amplitude of thrust.[5] Although the peak forces exerted during SMT vary dramatically between clinicians[6] and depend strongly on the area of application,[7,8] the thrust times remain consistent within approximately 100 milliseconds across clinicians and techniques (Fig 1).

Although the total forces applied during SMT can be high, in excess of 1000 N (220 lb) in the thoracic and lumbar spine, the local forces applied to the target area (25 mm^2) are known to be a mere fraction of the total force (5-20 N; 1.1-4.4 lb[9]). Nevertheless, it has been argued that there is the possibility of damaging internal structures at the treatment site.[10-14] However, there is little information on the forces transmitted by internal structures during SMTs, with some exceptions, for example, the forces transmitted by the lumbosacral spine[15] and the stresses and strains transmitted by the vertebral artery[16-18] during high-speed, low-amplitude SMTs of the low back and cervical spine, respectively.

One of the major concerns for safety is SMTs of the neck and the risk of stroke.[19-22] Although the estimates of stroke associated with SMT are small—approximately 1 in a million, based on a systematic review of the literature involving a great

[a] Killam Memorial Chair, Human Performance Lab, Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada.
[b] Canada Research Chair (Tier 1) in Molecular and Cellular Biomechanics, Human Performance Lab, Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada.
[c] Professor in Kinesiology, Medicine, Engineering and Veterinary Medicine, Human Performance Lab, Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada.
[d] Chiropractor, Human Performance Lab, Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada.
[e] Research Associate, Human Performance Lab, Faculty of Kinesiology, University of Calgary, Calgary, Alberta, Canada.
Submit requests for reprints to: Walter Herzog, PhD, 2500 University Drive NW, KNB 402, Calgary, AB, T2N 1N4 (e-mail: *walter@kin.ucalgary.ca*).
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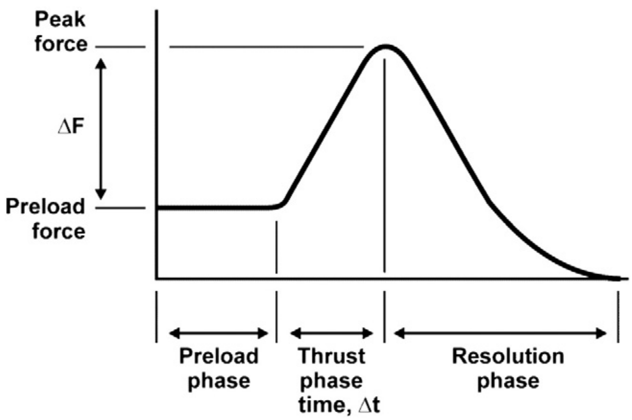

Fig 1. *Definition of selected mechanical variables used to quantify spinal manipulative treatments.*

divergence of values[1]—the severity and irreversible nature of such accidents make this a material risk.[16,17] Most of these accidents involve the vertebrobasilar system, specifically the vertebral artery (VA) between C2/C1 and the cephalad/distal loop as the VA exits the C1 foramen transversarium and travels to the foramen magnum.[23] Because of the specific anatomy of the VA in that region, it has been assumed that the VA experiences considerable stretch during extension and rotation of the neck, which may lead to hemodynamic occlusions and damage to the VA, predisposing the patient to stroke.[16,17] However, recent evidence suggests that such damage appears unlikely.[18,24]

The internal carotid artery (ICA) has also been implicated with stretch-induced damage caused by neck SMTs (eg, Peters et al[25] and Parwar et al[26]), although to a much lesser degree than the vertebral artery. However, there are no data on the mechanics of ICA during neck manipulation that would allow for evaluation of such implications. Therefore, the purpose of this study was to test the hypothesis that stretching of the ICA during cervical SMTs does not cause strains in excess of those experienced during normal everyday movements such as extending the head and neck when looking up at the sky or when rotating the head while backing out a car from the driveway. Because strains cannot be measured directly in live subjects, we measured ICA strains in cadaveric specimens while they were subjected to 10 different neck treatments using high-speed and low-amplitude manipulative techniques and compared the ICA strains of these treatments with the strains observed for eight head/neck range of motion (ROM) tests, as done previously.[16-18,24]

Methods

Subjects

Testing was performed on 8 fresh (< 72 hours after death), unembalmed human cadaveric specimens and 15 ICAs. Specimens were obtained from the donor program of the department of Anatomy at the University of Calgary. The first 2 specimens (and 3 ICAs) were used to refine the strain measurement techniques, and the results of these tests were not included in the analysis, leaving 6 specimens and 12 ICAs for the final results. The characteristics of the cadavers used in this study are shown in Table 1.

ICA Dissection

The ICA was approached by blunt dissection using an anterolateral approach, similar to that described previously for the vertebral artery.[16] Care was taken to leave all structures intact while exposing the ICA. Specifically, no ligaments, muscles, or bones were cut to preserve the in situ mechanical behavior of the ICA.

Range of Motion Testing and Spinal Manipulative Treatments

Range of motion testing was performed in flexion, extension, rotation, and lateral bending (Fig 2). Range of motion was established by moving the head passively from the neutral position (head and neck aligned straight; Fig 2A) to the point where no further movement was possible (Fig 2B, end range of rotational movement). Following that, a Houle's vertebrobasilar insufficiency test[27] was performed by placing the head and neck in a rotated/extended position. All asymmetric tests were performed bilaterally (ie, rotation to the left and right). Following the ROM testing, neck SMTs consisting of a diversified lateral/rotary manipulation with a second metacarpal contact specifically against the articular pillar with the cadaver supine and also a pure lateral manipulation with the force applied in an essentially lateral direction to the neck were performed (Fig 2C). These SMTs were delivered at levels C1/C2, C3/C4, and C6/C7 while measuring strains in the ICAs bilaterally. All ROM testing was repeated 3 times and was performed bilaterally; all SMTs were repeated 3 times, on all levels and both sides of the neck. Therefore, each cadaver was exposed to 60 strain measurements during SMTs (2 arteries × 10 SMTs × 3 repeat measurements) and 48 strain measurements during ROM testing (2 arteries × 8 ROM tests × 3 repeat measurements) per clinician (2-4 clinicians per subject). The corresponding total numbers of strain measurements per cadaver were then multiplied by the number of clinicians to arrive at the number of strain measurements shown in Table 1. In total, we performed 1080 strain measurements during SMTs and 864 during ROM testing resulting from 36 clinician/ICA combinations. Before all testing, the ICAs were injected with ultrasound gel to give the arteries their normal, fluid-filled shape and to enhance ultrasound transmission that was used for the strain measurements.[18]

All ROM and SMT testing was performed by 2, 3, or 4 licensed chiropractors per cadaver (Table 1). A total of 5 different chiropractors, all male, were involved in the study with 3, 3, 14, 22, and 42 years of experience.