Effect of rotated head posture on dynamic vertebral artery elongation during simulated rear impact

Clinical Biomechanics
March 2006, Volume 21, Issue 3, Pages 213-220

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FROM ABSTRACT

Background
Elongation-induced vertebral artery injury has been hypothesized to occur during non-physiological coupled axial rotation and extension of head.

No studies have quantified dynamic vertebral artery elongation during head-turned rear impacts. Therefore, we evaluated effect of rotated head posture vs. forward head posture at the time of impact on dynamic vertebral artery elongation during simulated rear impacts.

Findings
Average (SD) peak dynamic vertebral artery elongation of up to 30.5 mm during head-turned rear-impact significantly exceeded the physiological limits beginning at 5 g.

Highest peak elongation of 5.8 mm during head-forward rear impact did not exceed physiological limit.

Head-turned rear impact caused earlier occurrence of average peak vertebral artery elongation, 84.5 ms [for head-turned rear impact] vs. 161.0 ms [for head-forward rear impact], and higher average peak vertebral artery elongation rate, 1336.7 mm/s [for head-turned rear impact] vs. 211.5 mm/s [for head-forward rear impact], as compared to head-forward rear impact.

Interpretation
Elongation-induced vertebral artery injury is more likely to occur in those with rotated head posture at the time of rear impact, as compared to head-forward.

THESE AUTHORS ALSO NOTE:

“Chronic symptoms of headaches, blurred vision, tinnitus, dizziness, and vertigo have been documented in whiplash patients” but their exact etiology is poorly understood.

“Clinical studies have associated these symptoms with altered blood flow rates due to spasm and/or narrowing of vertebral arteries (VAs) in victims of high velocity automobile collisions with or without blunt head impact.”
“VA injuries resulting in vascular compromise have been documented clinically due to a variety of trauma scenarios from whiplash to blunt-force head injury, and also due to activities of daily living such as fitness exercises, painting and coughing.”

“Coupled cervical spine extension and axial rotation beyond physiological limits may cause elongation-induced VA injury and vascular compromise, particularly at the upper cervical spine.”

“VA injury, often a partial tear in the vessel’s intimal layer, and resulting vascular compromise, may cause symptoms of vertebrobasilar insufficiency in whiplash victims.”

Previous biomechanical studies have noted “statistically significant increases in dynamic VA elongation above physiological limits” from experimental whiplash perturbations.

The goal of the present study was to evaluate the relative effect of rotated head posture at the time of impact on dynamic VA elongation during simulated rear impacts.

This study used 12 fresh-frozen human osteoligamentous whole cervical spine specimens.

Apart from typical age-related degenerative changes, the donors did not suffer from any disease or trauma that could have affected the osteoligamentous structures.

RESULTS

With head-forward, “head extension occurred causing minimal VA elongation.”

“In sharp contrast, rotated head posture at the time of rear impact caused dramatic effects on VA elongation peaks and timing.” [Important]

Significant increases in dynamic vertebral artery elongation above physiological limits were observed due to head-turned rear impact beginning at 5 g, while no significant increases due to head-forward rear impact were observed.

The average times of peak dynamic vertebral artery elongation due to “head-turned rear impact occurred significantly earlier than corresponding times during head-forward rear impact for all impact accelerations.”

DISCUSSION

Chronic symptoms in whiplash patients include headaches, blurred vision, tinnitus, dizziness, and vertigo.
“Dynamic VA elongation of up to 30.5 mm due to head-turned rear impact significantly exceeded physiological values beginning at 5 g, while VA elongation during head-forward rear impact remained within physiological limits.”

“Peak VA elongation occurred as early as 84.5 ms following head-turned rear impact.” Cervical muscle activity can be achieved no earlier than 192 ms following head-turned rear impact. [Very Important] Thus, VA injury during head-turned rear impact occurs prior to neuromuscular protective mechanisms achieved via peak muscle tension. “In contrast, peak VA elongation during head-forward rear impact occurred significantly later.”

In this study, “peak VA elongation rates were greater and occurred earlier with head-turned as compared to head-forward rear impact.”

“Elongation-induced VA injury is more likely to occur in those with rotated head posture at the time of rear impact, as compared to head forward.”

The cadavers used in this study were between 70 – 80 years old so their spinal mechanical properties are stiffer than those of a younger population, which would reduce the stress on the vertebral artery. Therefore, the “peak dynamic VA elongation data of the present study are conservative, as compared to the younger population.”

The VA elongation observed in this study would be similar to that of an unwarned [caught by surprise] real-life subject.

“Researchers have hypothesized that non-physiological coupled extension and axial rotation of the head may cause VA injury, particularly at the upper cervical spine due to its high mobility.”

“Coupled cervical spine rotations observed during head-turned rear impact of the present study caused dynamic hyper-elongation of the left and right VAs.”

“VA elongation causes a decrease in its diameter due to Poisson’s effect and may lead to transient vascular compromise.”

While being elongated, the VA may be pinched and injured, potentially tearing the intimal layer, primarily at C1–C2.

“Severe VA injury results in acute vascular compromise caused by arterial dissection with possible rupture or thrombosis leading to stroke.”

In the present study, head-turned rear impact caused highest peak elongation rate in the left VA, significantly greater (more than 6 times greater) than the corresponding head-forward peak rate.

The high elongation rate observed due to head-turned rear impact may accentuate elongation-induced injury of the VA. [Important]
CONCLUSIONS

In conclusion, the present study, using a whole cervical spine model with muscle force replication in simulated head-forward and head-turned rear impacts, has demonstrated “elongation-induced VA injury due to head-turned rear impact.”

“In contrast, VA injury during head-forward rear impact is unlikely.”

Vertebral artery injury during head-turned rear impact occurs prior to peak muscle tension, indicating that the neuromuscular control system is not be able to protect the vertebral arteries from injury. [Very Important]

“Present results cumulatively demonstrate that elongation-induced VA injury is more likely to occur during head-turned rear impact, as compared to forward facing.”

KEY POINTS FROM DAN MURPHY

1) “Chronic symptoms of headaches, blurred vision, tinnitus, dizziness, and vertigo have been documented in whiplash patients” and they may be caused by vertebral artery injury.

2) Whiplash vertebral artery injury may be due to spasm and narrowing of vertebral arteries, from dynamic hyper-elongation of the vertebral arteries which decreases its diameter, or from tearing the intimal layer (primarily at C1–C2), resulting in arterial dissection with possible thrombosis leading to stroke.

3) “Rotated head posture at the time of rear impact caused dramatic effects on VA elongation peaks and timing.” [Important]

4) Vertebral artery injury during head-turned rear impact occurs very quickly, before neuromuscular protective muscle reflexes can offer any protection.

5) “Elongation-induced vertebral artery injury is more likely to occur in those with rotated head posture at the time of rear impact, as compared to head forward.”

6) Younger patients are more flexible, which puts their vertebral artery at even greater risk of injury when subjected to head-turned rear impacts.

7) “Vertebral artery injury during head-forward rear impact is unlikely.”

8) Even if the subject is aware of collision, the protective forces offered by the neuromuscular reflexes “may not be able to protect the vertebral arteries from injury.”

9) “Present results cumulatively demonstrate that elongation-induced VA injury is more likely to occur during head-turned rear impact, as compared to forward facing.”