Biomechanics of Neck Injuries Resulting from Rear-End Vehicle Collisions

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KEY POINTS FROM THIS ARTICLE:

1) 85% of the neck injuries caused by car accidents are the result of rear-end collisions.

2) X-rays and/or MRI have a limited ability to diagnose whiplash injuries. Whiplash injuries are "difficult to diagnose using methods such as basic radiography and MRI (Magnetic Resonance Imaging)."

3) "Whiplash injuries," can cause long-term neck pain and limitation of movement.

4) "Whiplash injuries, which can be seen even in low-speed, rear-end collisions, are generally dangerous for the driver and the passenger in the front seat."

5) During the whiplash mechanism, the velocity change is rather small (8-16 km/h [5-10 m/h]), but the *rate* of this *velocity change* is very short (a high value of acceleration). This short *rate of velocity change* increases injury.
["The entire sequence of extension-flexion was completed within 0.5 sec of impact. Therefore, even low-speed rear-end collisions may generate substantial forces and result in significant injuries." Teasell & McCain, in Painful Cervical Trauma, Williams and Wilkins, 1992, p. 293**]**

6) 8 km/h [5 m/h] is the threshold value for whiplash injuries caused by rear-end collisions. Whiplash injuries start with the speed value of 8 km/h [5 m/h], and their severity increases accordingly as the level of speed increases.

7) "The acceleration of the body of the passenger is quite different from the acceleration of the car." The acceleration of the head is about 2-2.5 times greater than the acceleration of the vehicle.
[It has been established for decades that an 8 m/h same size vehicle–vehicle collision causes a 2 g acceleration of the struck vehicle and a 5 g acceleration of the occupant's head: White A and Panjabi M, Clinical Biomechanics of the Spine; Lippincott. 1990, p. 231**]**
[This unique injuring principle is known as "magnification of acceleration"]

8) "According to statistical data, the speed of the impact, the headrest of the seat, the position of the passenger, the material of the seat and the design of the seat all affect the intensity of whiplash injuries."

9) Whiplash injuries are unavoidable in rear-end accidents that generated at least 7 g acceleration.

10) "The position of the passenger is another factor: a passenger in the front seat has a greater risk of whiplash injuries than does a passenger in the back seat."

11) An important injury prevention factor is the seat's headrest. Most head restraints are not adjusted to effectively prevent injury.

12) The distance between the headrest and the head plays a vital role in influencing a whiplash injury:

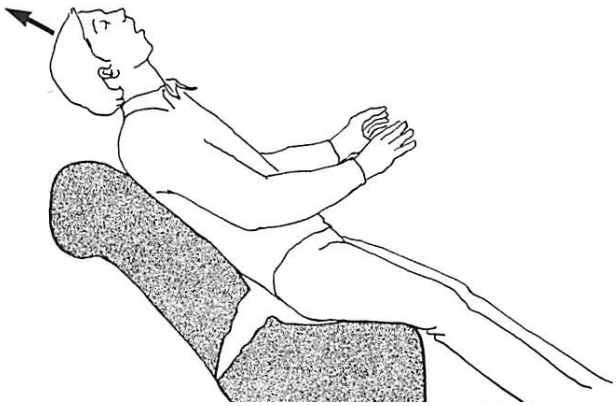
- To reduce the risk of injury, the distance between the headrest and the head must be no greater than 10 cm [less than half an inch], and ideally should be less than 6 cm [a quarter of an inch].

- "Headrests that are not adjusted properly and are too far away from the head cannot prevent whiplash injuries."

13) "The severity of injuries may vary according to not only the acceleration caused by the collision but also the mechanical structure of the car."

14) "Whiplash injuries have increased in number since car seats have been strengthened mechanically."

- Mechanically weaker seats that recline or break backwards during a collision lead to fewer whiplash injuries as the driver/passenger assumes a more recumbent position: **Ian MacNab: <u>The Spine</u>, Rotman and Simeone; Saunders, 1982 p. 649.**



15) During the whiplash mechanism:

- The head moves backwards directly (without rotation) in the first 50 ms.

- Between 50 and 75 ms, the cervical spine takes the shape of an "S." The upper part of the cervical spine flexes while the lower part extends. "During a rear impact, as the thorax is pushed forward, the lower part of the cervical spine experiences extension, whereas the upper part experiences flexion."

- The lower parts of the cervical spine and head extend during the periods of 75 ms and 100 ms.

16) "Whiplash injuries occur when the cervical spine takes the shape of an 'S'." The cervical spine becomes an "S" at about 50 ms after impact.

17) "When the spine has the shape of an "S," the posterior part of the lower cervical spine is exposed to compression, and the anterior part of the lower cervical spine is exposed to tension. When this situation exceeds the limits of the normal spine, it causes soft tissue injury."

18) "Where does whiplash injury occur? Possible injury sites may include the facet joint tissue, the intervertebral disc, the ligaments, the spinal cord, the muscle and the dorsal nerve roots."

19) Experimental evidence has shown that "tension in the facet joint tissue emerges before the head touches the headrest."

20) The primary site of whiplash injury is the facet joints:

- There is compression in the back part of the facet joint.

- The facet joints show an excessive linear gliding backwards movement, which is the "cause of the damage on the facet joint and the whiplash injury."

21) "Neck injury occurs in the first 100 ms of a rear impact and is based on relative acceleration and velocity between the head and upper torso."

22) Biomechanical studies demonstrated that the cervical spine undergoes soft tissue injuries during the rear-end collisions.

23) "Sigmoid deformation occurs just after the impact in the first 50 milliseconds." "In this sigmoid deformation phase, facet joints at the lower cervical [spine] exceed normal physiological limits." The "posterior part of the facet is exposed to compression and the anterior part of the facet is exposed to tension."

COMMENTS FROM DAN MURPHY

The vast majority of whiplash soft tissue injuries occur from rear-end collisions.

Neither x-rays nor MRIs are optimal for diagnosing whiplash soft tissue injuries.

There appears to be consensus agreement that collision speeds of 5 m/h are capable of producing whiplash soft tissue injuries.

Whiplash soft tissue injuries occur during a nonphysiologic "S" curvature of the cervical spine.

Whiplash soft tissue injuries occur very quickly following vehicle contact, classically between 1/20-1/10 of a second (.05-.1 sec.)

Head restraints can mitigate whiplash soft tissue injuries, but ideally they should be less than ¼ inch behind the head, and should not be greater than ½ inch behind the head.