

Injury Mechanisms of the Cervical Intervertebral Disc During Simulated Whiplash

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Panjabi, Manohar M. PhD; Ito, Shigeki MD; Pearson, Adam M. BA; Ivancic, Paul C.

FROM ABSTRACT

Study Design.

A kinematic analysis of cervical intervertebral disc deformation during simulated whiplash using the whole cervical spine with muscle force replication model was performed.

Objectives.

To quantify anulus fibrosus fiber strain, disc shear strain, and axial disc deformation in the cervical spine during simulated whiplash.

Summary of Background Data.

Clinical studies have documented acute intervertebral disc injury and accelerated disc degeneration in whiplash patients, although there has been no biomechanical investigation of the disc injury mechanisms.

Methods.

A bench-top sled was used to simulate whiplash at 3.5, 5, 6.5, and 8 g using six specimens.

The 30° and 150° fiber strains, disc shear strains, and axial disc deformations during whiplash were compared with the sagittal physiologic levels.

Results.

Increases over sagittal physiologic levels were first observed during the 3.5 g simulation.

Peak fiber strain was greatest in the posterior 150° fibers (running posterosuperiorly), reaching a maximum of 51.4% at C5-C6 during the 8 g simulation.

Peak disc shear strain was also greatest at the posterior region of C5-C6, reaching a maximum of 1.0 radian due to posterior translation during the 8 g simulation.

Axial deformation at the anterior disc region exceeded physiologic levels at 3.5 g and above, while axial deformation at the posterior region exceeded physiologic limits only at C5-C6 at 6.5 g and 8 g.

Conclusions.

The cervical intervertebral discs may be at risk for injury during whiplash because of excessive 150° fiber strain, disc shear strain, and anterior axial deformation.

THESE AUTHORS ALSO NOTE:

"Approximately 50% of whiplash patients reported chronic neck pain 15 years after the trauma." **[IMPORTANT]**

Following rear collision impact, the lower cervical spine experiences complex loading consisting of an extension moment and posterior shearing and compressive forces, which the authors hypothesize may injure the intervertebral disc.

"Cervical disc injury is the only lesion that has been consistently documented in radiographic studies of whiplash patients."

The authors reference 3 studies that conclude whiplash can injure and herniate the cervical discs. "The most common site of disc injury was C5-C6." In a prospective study, the incidence was that "25% of whiplash patients had herniated cervical discs."

[1) Pettersson K, Hildingsson C, Toolanen G, et al. Disc pathology after whiplash injury: a prospective magnetic resonance imaging and clinical investigation. *Spine*. 1997;22:283-287.

2) Jonsson H Jr, Cesarini K, Sahlstedt B, et al. Findings and outcome in whiplash-type neck distortions. *Spine*. 1994;19:2733-2743.

3) Davis SJ, Teresi LM, Bradley WG Jr, et al. Cervical spine hyperextension injuries: MR findings. *Radiology*. 1991;180:245-251.]

The authors reference 3 studies that "suggests that whiplash patients are at an increased risk of premature disc degeneration." One study "demonstrated that 39% of whiplash patients without initial radiographic signs of disc degeneration had developed degenerative changes within 5 to 10 years." Another study found that the incidence required cervical fusion surgery in whiplash patients was twice that of control patients, and the whiplash patients required fusion 8 years earlier than the controls.

[1) Hohl M. Soft-tissue injuries of the neck in automobile accidents: factors influencing prognosis. *J Bone Joint Surg Am*. 1974;56:1675-1682.

2) Hamer AJ, Gargan MF, Bannister GC, et al. Whiplash injury and surgically treated cervical disc disease. *Injury*. 1993;24:549-550.

3) Watkinson A, Gargan MF, Bannister GC. Prognostic factors in soft tissue injuries of the cervical spine. *Injury*. 1991;22:307-309.]

"Clinical studies have thoroughly documented the occurrence of cervical disc injury in whiplash patients." This study is a biomechanical studies investigating the injury mechanisms of the intervertebral disc during whiplash.

"The annulus fibrosus is a laminated structure in which fibers run in the same direction within each layer but in opposite directions in adjacent layers, forming either 30° or 150° angles to the z-axis."

"Peak disc shear strain resulting from posterior translation exceeded sagittal physiologic levels throughout the C5-C6 disc beginning at the 3.5 g simulation and at C4-C5 and C6-C7 at 5 g."

"In general, the disc shear strain increased with increasing impact acceleration."

"The greatest disc shear strain resulting from posterior translation occurred at the posterior region of the disc, reaching 1.0 radian at C5-C6 during the 8 g simulation."

DISCUSSION

"Clinical evidence suggests that disc injury and accelerated degeneration are common in whiplash patients."

"Based on the current data, whiplash trauma could potentially injure the cervical discs posteriorly, *via* excessive 150° fiber strain and disc shear strain, or anteriorly, due to axial elongation."

"If it is assumed that the failure strains of cervical and lumbar disc material are similar, then the results of the present study suggest that the 150° fibers at C4-C5 and C5-C6 are at risk for failure at low impact accelerations (approximately 25%-35% strain at 3.5 g), while those at C3-C4 and C6-C7 are at risk at higher accelerations only." **[IMPORTANT]**

"Sufficient clinical evidence exists to support our conclusion that the cervical discs are at risk for acute injury during whiplash."

"Multiple MRI studies have demonstrated posterior and posterolateral disc herniations in whiplash patients immediately following trauma, implying that the annulus fibrosus failed during the impact."

"The vast majority of the disc injuries reported in the previous studies occurred at C5-C6, which is consistent with our findings that the 150° fiber and disc shear strains were greatest at the posterior region of the C5-C6 disc."

“While acute injury to the cervical disc appears to cause immediate herniation in a minority of whiplash patients, a greater number of patients are vulnerable to accelerated disc degeneration over 5 to 10 years following the whiplash trauma.”
[VERY IMPORTANT]

“The mechanism of degeneration in these patients is unknown; however, animal studies have demonstrated that small tears in the annulus fibrosus can initiate the disc degeneration process. It seems likely that a similar mechanism may underlie disc degeneration in whiplash patients: the trauma may produce a small tear in the annulus that triggers the biochemical cascade leading to degeneration.”

“The presence of nerve endings in the outer annulus fibrosus makes disc injury a plausible etiology of neck pain.”

Electrical stimulation of the disc can trigger a reflex arc leading to multifidus contraction. “Thus, the mechanism of muscle spasm observed in some whiplash patients may be related to subfailure injuries of the disc.”

“Clinical studies have implicated the facet joint as the source of chronic pain in approximately 50% of whiplash patients.”

“Annulus fibrosus injury can lead to disc degeneration and facet joint osteoarthritis.”

A decrease in disc height results in increased loading to the facet joints.

Radiographic studies demonstrate that lumbar facet joint osteoarthritis rarely occurred without prior disc degeneration.

“Annulus fibrosus injuries sustained during whiplash could potentially lead to disc degeneration accompanied by increased loading, pain, and osteoarthritis of the cervical facet joints.” **[VERY IMPORTANT]**

“The current study demonstrated that excessive 150° fiber and disc shear strain occurred during simulated whiplash. These strains were greatest at the posterior region of the C5-C6 disc, and clinical data suggest that this is the most common location for disc herniation in whiplash patients. While disc injury may be the cause of acute pain and muscle spasm following the trauma, it could also lead to disc degeneration, facet osteoarthritis, and chronic neck pain.” **[VERY IMPORTANT]**

COMMENT FROM DAN

Most recent article on whiplash emphasize injury to the facet joints and facet joint capsules. This article documents injury to the disc.

KEY POINTS FROM DAN MURPHY

- 1) 50% of whiplash patients reported chronic neck pain 15 years after the trauma.
- 2) Even low impact rear-end collisions can injure and herniate the cervical discs.
- 3) The most common site of whiplash disc injury is C5-C6.
- 4) Whiplash trauma can accelerate disc degeneration, especially in the following 5 to 10 years following the trauma.
- 5) Small tears in the anulus fibrosus can initiate the disc degeneration process.
- 6) The anulus of the disc has pain nerve fibers which makes disc injury a plausible etiology of neck pain.
- 7) Subfailure injuries to the disc can trigger a reflex arc leading to multifidus contraction and muscle spasm.
- 8) The facet joint is the source of chronic whiplash pain in about 50% of whiplash patients.
- 9) Anulus fibrosus injury can lead to disc degeneration, increased loading to the facet joints, and facet joint osteoarthritis.
- 10) Whiplash disc injury can cause acute neck pain and muscle spas, and lead to disc degeneration, facet osteoarthritis, and chronic neck pain.