

Magnetic Resonance Imaging Assessment of Craniovertebral Ligaments and Membranes After Whiplash Trauma

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Jostein Krakenes, MD, PhD and Bertel R. Kaale, MT

FROM ABSTRACT

Objectives.

To review the literature on soft tissue lesions of the upper cervical spine in whiplash trauma with focus on imaging.

Summary of Background Data.

Whiplash injury is associated with chronic impairment in a substantial number of patients.

Methods.

Review the literature on the anatomic source of the chronic whiplash syndrome.

Review the literature on imaging of the upper cervical spine, emphasizing on the author's own research.

Results.

MRI shows structural changes in ligaments and membranes after whiplash injury, and such lesions can be assessed with reasonable reliability.

Lesions to specific structures can be linked with specific trauma mechanisms.

There is a correlation between clinical impairment and morphologic findings.

Conclusion.

Whiplash trauma can damage soft tissue structures of the upper cervical spine, particularly the alar ligaments.

THESE AUTHORS ALSO NOTE:

"Most investigators who have studied the natural history of whiplash patients have found long-term symptoms in 24% to 70%, among whom 12% to 16% are severely impaired many years after the accident interfering with their job and everyday activities."

The prevalence of the cervical facet joint as an anatomic source of chronic pain after whiplash trauma is 60%.

Whiplash trauma can cause structural changes predisposing to premature degenerative disc disease. One study found that "10% of patients with normal radiographic findings in the acute stage of whiplash injury developed new degenerative changes at 2- to 3-year follow-up."

[Ovadia D, Steinberg EL, Nissan MN, et al. Whiplash injury: a retrospective study on patients seeking compensation. *Injury* 2002;33:569-73].

Flexion and extension x-rays in chronic whiplash syndrome tend to show "significantly decreased range of motion in chronic whiplash syndrome compared with asymptomatic individuals."

"The alar ligaments are the main restraints to axial rotation and lateral bending in the upper cervical spine."

CT documented increased upper cervical rotation toward one side indicates alar ligament injury with laxity on the opposite side. **[Important]**

33% of patients with chronic neck pain from whiplash have increased rotation of the upper cervical spine.

Rotation of more than 7° at C0-C1 and more than 54° at C1-C2 (on CT rotational scanning) is considered to be a pathologic instability.

Studies document that craniovertebral ligaments are vulnerable to trauma even though there is no dislocation.

To best examine the alar ligaments with MRI, note the following imaging protocol:

- 1) Slice thickness of 3-4 mm is too large for adequate low spatial resolution. [Slice thickness should not exceed 2 mm].
- 2) Both T1- and T2-weighted sequences give insufficient contrast resolution. [Proton-density weighted sequences are the format of choice].
- 3) Magnetic strength is important. A 0.5T [Tesla] MR scanner gives low image quality and therefore the conventional 1.5T [Tesla] scanner should be used.

"High spatial resolution and good contrast between tissues were obtained by using proton-density-weighted sequence with 2-mm-thick sections."

Using High-resolution proton-density-weighted sequence with 2-mm-thick sections with a 1.5 Tesla strength magnet, these authors evaluated the upper cervical spines of 92 chronic whiplash patients and 30 matched control patients. All patients were 2-9 years chronic with normal x-rays.

66.3% of the chronic whiplash group had high-grade (abnormal) changes in their alar ligaments, and 17.4% had similar changes in their tectorial membrane. No high-grade (abnormal) changes were found in the control group. **[Important]**

These authors “found significantly more high-grade alar ligament lesions among those with rotated head position (85.1%) than among those with neutral head position (46.7%,)”.

“A total of 61.7% of those with rotated head position had alar ligament Grade 3 (most abnormal grade), whereas only 4.4% had Grade 3 in the group with neutral head position.” **[Very Important]**

“The association between rotated head position and high-grade lesions was more pronounced after rear-end than after frontal collision (93.8% vs. 31.8%).”

“High-grade changes in the transverse ligament were significantly more common in frontal than in rear-end collision (61.1% vs. 10.5%).”

The 92 whiplash patients and 30 controls completed the Neck Disability Index (NDI) score, a modification of the Oswestry Low Back Pain Index, comprising 10 single items related to activity of daily living. Results showed significantly higher NDI score in the whiplash group than in the control group for all items, particularly for neck pain, head ache, reading abilities, concentration, car driving, and activity level in general.

Importantly, in the whiplash group NDI score increased significantly with increasing MRI grading for the alar ligaments and transverse ligament injuries.

DISCUSSION

The soft tissues of the craniovertebral joints can be imaged by use of high-resolution MR imaging.

“The alar ligaments are particularly vulnerable to neck trauma when the head is rotated at the moment of impact.” **[Very Important]**

“When the head rotates, the alar ligaments twist around the dens. Reaching 90° rotation, these ligaments are maximally tightened and obtain an anteroposterior orientation. Not unexpected, such tightened anteroposteriorly oriented alar ligaments are more vulnerable to hyperextension-hyperflexion trauma than relaxed, transversely oriented ligaments.”

“The transverse ligament and the atlanto-occipital membrane showed significantly more high-grade lesions in frontal than in rear-end collision.”

“The atlanto-occipital and the tectorial membranes restrict hyperflexion in the craniovertebral joint. Both of these membranes showed more lesions in frontal than in rear-end collisions, indicating that hyperflexion is the predominant trauma mechanism. The atlanto-occipital membrane is elastic. When this membrane is stretched beyond its elastic properties, the hyperflexion forces are transmitted to the adjoining dura, which can sprain or even rupture.”

NDI score increased significantly with increasing alar ligament grading, indicating that these ligaments are important as a causative factor of pain and disability in chronic whiplash syndrome.

CONCLUSION

“The number of high-grade changes in whiplash patients compared with noninjured individuals indicates that these lesions are indeed caused by a whiplash trauma.”

There is a strong association between disability score on the NDI and the MRI findings for the alar ligament pathology.

“Our findings add support to the hypothesis that injured soft tissue structures in the upper cervical spine, particularly the alar ligaments, play an important role in the understanding of the chronic whiplash syndrome.”

KEY POINTS FROM AUTHORS:

- 1) “By use of high-resolution MRI, it is possible to assess ligaments and membranes in the craniovertebral junction with reasonable reliability.”
- 2) There are significantly more MRI documented high-grade lesions in a whiplash-injured patient than in a noninjured population.
- 3) There is an association between whiplash injuries to the alar ligaments and clinical impairment.
- 4) There is an association between specific upper cervical injury and the specific mechanism of trauma.

KEY POINTS FROM DAN MURPHY

- 1) Whiplash injury is associated with chronic impairment in a substantial number of patients.
- 2) MRI shows structural changes in ligaments and membranes after whiplash injury, and such lesions can be assessed with reasonable reliability using proton density-weighted MRI.

- 3) 24% to 70% of whiplash patients will suffer from long-term symptoms.
- 4) 12% to 16% of whiplash patients are severely impaired many years after the accident, interfering with their job and everyday activities.
- 5) The cervical facet joints are an anatomic source of chronic pain after whiplash trauma in 60% of patients.
- 6) Whiplash trauma can cause structural changes that lead to premature degenerative disc disease.
- 7) "10% of patients with normal radiographic findings in the acute stage of whiplash injury developed new degenerative changes at 2- to 3-year follow-up."
- 8) Flexion and extension x-rays in chronic whiplash syndrome tend to show "significantly decreased range of motion in chronic whiplash syndrome compared with asymptomatic individuals."
- 9) "The alar ligaments are the main restraints to axial rotation and lateral bending in the upper cervical spine."
- 10) CT documented increased upper cervical rotation toward one side indicates alar ligament injury with laxity on the opposite side. **[Important]**
- 11) 33% of patients with chronic neck pain from whiplash have increased rotation of the upper cervical spine.
- 12) Rotation of more than 7° at C0-C1 and more than 54° at C1-C2 (on CT rotational scanning) is considered to be a pathologic instability.
- 13) The craniovertebral ligaments are vulnerable to trauma even though there is no dislocation.
- 14) To best examine the alar ligaments with MRI, proton-density weighted formatting should be used (not T1- and T2-weighted sequences), the magnet should have a least 1.5 Tesla strength, and the slice thickness should not exceed 2 mm.
- 15) 66.3% of the chronic whiplash patients have abnormal changes in their alar ligaments, and 17.4% have abnormal changes in their tectorial membrane.
- 16) No high-grade abnormal changes were found in the alar ligaments or tectorial membranes of the control group. **[Important: this indicates that high-grade abnormal changes are caused by trauma]**
- 17) "The alar ligaments are particularly vulnerable to neck trauma when the head is rotated at the moment of impact." **[Very Important]**

18) The transverse ligament and the atlanto-occipital membrane are most vulnerable to injury in frontal impacts.

19) "The atlanto-occipital and the tectorial membranes restrict hyperflexion in the craniovertebral joint. Both of these membranes showed more lesions in frontal than in rear-end collision, indicating that hyperflexion is the predominant trauma mechanism. The atlanto-occipital membrane is elastic. When this membrane is stretched beyond its elastic properties, the hyperflexion forces are transmitted to the adjoining dura, which can sprain or even rupture."

20) NDI (Neck Disability Index) score increased significantly with increasing alar ligament grading, indicating that these ligaments are important as a causative factor of pain and disability in chronic whiplash syndrome.

21) The alar ligament, atlanto-occipital and the tectorial membrane injuries documented in this study "are indeed caused by a whiplash trauma."

22) "Injured soft tissue structures in the upper cervical spine, particularly the alar ligaments, play an important role in the understanding of the chronic whiplash syndrome."

23) Whiplash trauma can damage soft tissue structures of the upper cervical spine, particularly the alar ligaments.