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Magnetic Resonance Imaging Assessment of the Alar Ligaments in Whiplash Injuries

A Case-Control Study

Rigmor Myran, MD,* Kjell Arne Kvistad, MD, PhD,*‡ Oystein Petter Nygaard, MD, PhD,‡
Hege Andresen, RN,† Mari Folvik, MD,*§¶ and John-Anker Zwart, MD, PhD§

Study Design. Case-control study.

Objective. To use high-resolution magnetic resonance imaging (MRI) in assessing signal intensity areas in the alar ligaments.

Summary of Background Data. Conflicting evidence exists whether areas of high signal intensity in the alar ligament on MRI are more frequent in whiplash patients than in noninjured control subjects.

Methods. A case-control designed study of 173 subjects included one group with persistent whiplash associated disorder Grade I–II after a car accident (n = 59), one with chronic nontraumatic neck pain (n = 57) and one group without neck pain or previous neck trauma (n = 57). High-resolution proton-weighted MRI in 3 planes was used. The images were independently evaluated by two experienced neuroradiologists who were blinded to patient history and group allocation. The alar ligaments were evaluated according to a 4-point grading scale; 0 = low signal intensity throughout the entire cross section area, 1 = high signal intensity in one third or less, 2 = high signal intensity in one-third to two thirds, and 3 = high signal intensity in two thirds or more of the cross section area.

Results. Alar ligament changes Grade 0 to 3 were seen in all 3 diagnostic groups. Areas of high signal intensity (Grade 2–3) were found in at least one alar ligament in 49% of the patients in the whiplash associated disorder Grade I–II group, in 33% of the chronic neck pain group and in 40% of the control group (χ^2, $P = 0.22$).

Conclusion. The previously reported assumption that these changes are due to a trauma itself is not supported by this study. The diagnostic value and the clinical relevance of magnetic resonance detectable areas of high intensity in the alar ligaments are questionable.

Key words: alar ligament, magnetic resonance imaging, whiplash injury, cervical spine. **Spine 2008;33:2012–2016**

In previous magnetic resonance studies of patients with whiplash associated disorder (WAD) Grade I and II (Table 1)[1] attention has been directed toward neck posture, longitudinal ligaments, facet joints, vertebral endplates, discs, spinal cord, and muscles[2–5] without detectable findings different from asymptomatic subjects.

In recent years more detailed magnetic resonance imaging (MRI) techniques have been used to assess morphologic changes in the stabilizing structures of the craniocervical junction, one of which are the alar ligaments. The alar ligaments connect the dens axis to the occipital condyles. The main function of the alar ligaments is to limit the axial rotation of the head. The rotation to the right is limited by the left alar ligament and *vice versa*. Experimental studies indicate that injury to these ligaments may cause rotational instability in the craniocervical junction.[6,7]

The association between the signal intensity in these ligaments and WAD Grade I–II have been investigated, but the results are not conclusive. One study introduced a 4-point grading scale for the alar ligament findings, and reported high signal intensity only in whiplash patients and not in asymptomatic controls.[8] They concluded that high signal intensity in the ligaments was caused by an injury.[8,9] Others, however, have reported high signal intensity also in asymptomatic subjects.[10–12]

The main purpose of the present study was a blinded MRI assessment of the signal intensity changes in the alar ligaments among patients with WAD Grade I–II compared to chronic neck pain patients and subjects without neck pain or previous neck trauma.

Materials and Methods

A case-control study of 173 patients and controls were consecutively recruited at the National Centre of Spinal disorders, St. Olav's University Hospital, Trondheim during the period from January 2004 to October 2006. All subjects gave their written informed consent and the study was approved by the Regional Ethics Committee in Trondheim, Norway. The study was conducted in accordance with the Helsinki Declaration. This study consisted of persons with persistent WAD Grade I–II for more than 6 months (n = 59), a group of chronic neck pain patients (n = 57) and a control group (n = 57). The demographic data are shown in Table 2.

WAD Grade I–II Group

Subjects classified as Québec Task Force WAD Grade I–II were included in this group. They all suffered from neck pain and/or headache after a car collision where they had either been the driver or a passenger of a motor vehicle. A postinjury symptom duration of at least 6 months, but not more than 10 years was required (mean duration 4.3 years). An onset of symptoms within 48 hours after the accident was required.[13] Subjects

From the *Department of Neuroscience, Faculty of Medicine, Norwegian University of Science and Technology, Trondheim, Norway; †Department of Neuroradiology, St. Olavs Hospital, Trondheim, Norway; ‡Department of Neurosurgery, St. Olavs Hospital, Trondheim, Norway; §Department of Neurology, Ullevaal University Hospital, Oslo, Norway; ¶Faculty of Medicine, University of Oslo, Norway.
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Address correspondence and reprint requests to Rigmor Myran, MD, Department of Neuroscience, Faculty of Medicine, Norwegian University of Science and Technology, N-7006 Trondheim, Norway; E-mail: rigmor.myran@ntnu.no

Table 1. The Quebec Classification of Whiplash-Associated Disorders

Grade	Clinical Presentation
0	No complaints about the neck No physical sign(s)
1	Neck complaint of pain, stiffness or tenderness only No physical sign(s)
2	Neck complaint and musculoskeletal sign(s)*
3	Neck complaint and neurological sign(s)†
4	Neck complaint and fracture of dislocation

*Musculoskeletal signs include decreased range of motion and point tenderness.
†Neurological signs include decreased or absent deep tendon reflex, weakness and sensory deficits.

were excluded if they had WAD Grade III–IV, severe head injury or previous cervical spine surgery. They were also excluded if they had a history of similar symptoms previous to the accident or any known systemic disease that could explain their symptoms.

Chronic Neck Pain Group

Subjects with chronic neck pain were included in this group. They were recruited from local physiotherapists and primary care physicians. Pain duration of at least 6 months and not more than 10 years was required for inclusion. Alternatively the subjects could have repeated episodes of pain at least 1 week duration per 3 months during the last 2 years. Mean duration of pain was not measurable due to the insidious onset and the chronicity of the symptoms. Subjects were excluded if they had any history of neck trauma or any known systemic disease that could explain their symptoms.

Control Group

The control group consisted of subjects without neck pain or previous neck trauma.

They were recruited from different workplaces and educational institutions in order to secure a wide range of educational and occupational backgrounds.

Common for all 3 groups was that if there were contraindications to MRI examination (*e.g.*, pregnancy, cardiac pacemaker, magnetic aneurysm clips, *etc.*); they were excluded from the study.

MRI Protocol

MRI was performed at 1.5 T (T) using a Siemens Symphony magnetic resonance system (Siemens Medical, Erlangen, Germany). The patients and controls were scanned in the supine position using both the neck coil and the attachable anterior element from the head coil. The scan protocol of the craniocervical junction consisted of proton-weighted fast spin-echo sequences in 3 planes. In the sagittal plane 16 interleaved, contiguous slices with 2 mm slice thickness were obtained with TR/TE/ETL/NEX/FoV/band width/acquisition time 3290 milliseconds/13 ms/13/4/20 cm/130 Hz/pixel/7.05 minutes and a matrix of 291 × 512 giving a pixel size of 0.6 × 0.4 mm. The sagittal slices covered the area between the occipital condyles including the insertions of the alar ligaments. In the axial plane 17 interleaved contiguous slices with 2 mm slice thickness were obtained with TR/TE/ETL/NEX/FoV/band width/acquisition time 3520 milliseconds/14 milliseconds/13/4/20 cm/130 Hz/pixel/5.43 minutes and a matrix of 291 × 512 giving a pixel size of 0.6 × 0.4 mm. The axial images covered the area from the base of the dens axis to the foramen magnum. In the coronal plane 19 interleaved contiguous slices with 1.5-mm slice thickness were obtained with TR/TE/ETL/NEX/FoV/band width/acquisition time 3090 milliseconds/15 milliseconds/9/5/20 cm/136 Hz/pixel/7.02 minutes and a matrix of 227 × 384 giving a pixel size of 0.7 × 0.5 mm. The coronal images covered the area from the anterior arch of the atlas to the middle part of the spinal canal and the images were angulated parallel to the anterior border of dens axis. Total examination time for all 3 imaging sequences including localizer scans was approximately 25 minutes.

Table 2. Demographic Data

	WAD Grade I–II	Chronic Neck Pain	Controls
N	59	57	57
Women (n)	35	38	28
Men (n)	24	19	29
Age, mean (SD)	37.7 (10.6)	43.4 (12.5)	38.1 (11.0)
Age, range (yr)	20–61	20–65	21–61

Image Evaluation

In all study subjects the alar ligaments on both sides were visualized. Based on a visual assessment of signal-to-noise, image contrast and the presence of image artifacts the image quality was rated as good in 157(88.7%) subjects, slightly reduced in 16 (9%) subjects and poor in 0. Two individuals did not manage the MRI investigation due to claustrophobia and were excluded. All MRI examinations were independently evaluated on a radiologic work-station by two experienced neuroradiologists (interpreter 1 and interpreter 2). The images from patients and controls where presented in random order and the interpreters were blinded to original evaluation, patient data, history and group allocation. One of the interpreters (interpreter 1) re-evaluated the MRI from 50 patients and controls after 6 months and was blinded to the results from the first evaluation. In case of disagreement between the interpreters, those images were re-evaluated and a consensus was reached for the respective study participants (n = 88). The alar ligaments were evaluated according to a 4-point grading scale proposed by Krakenes *et al.*[8] In this grading system on proton density weighted images, low signal throughout the entire cross-section area of the alar ligament was graded 0 (see Figure 1), high signal in less than 1/3 of the cross-section was graded 1, high signal in 1/3–2/3 of the cross-section was graded 2 and high signal in more than 2/3 of the cross-section was graded 3 (see Figure 2). In some examinations the alar ligaments were overall gray. These ligaments were graded as 2. In the evaluation of the alar ligaments the images in the sagittal plane were most useful because the cross section could easily be evaluated. In the lateral part of the ligament care was taken to avoid misinterpretation of partial volume effects from the fatty bone marrow in the occipital condyle as high signal intensity in the ligaments. Before the final grading the findings in the sagittal images were compared with the coronal images and particularly in the areas close to the dens axis and the occipital condyles, as this comparison was useful.

Statistics

Nonparametric analyses were used to assess between group differences.

κ-coefficients were used to evaluate pair-wise interobserver agreement and intraobserver agreement. Linear weighted kappa were calculated on basis of all 4 MRI gradings, and

Figure 1. Proton density weightened MR images of the alar ligaments (arrows) in the coronal plane. Both ligaments have a uniformal low signal corresponding to Grade 0.

when the groups were dichotomized (Grade 0–1 and Grade 2–3), ordinary kappa coefficients were calculated in terms of Cohens kappa.

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 14.0 (SPSS, Chicago, IL).

Results

The distribution of signal intensity changes found in the right and left alar ligaments in all study subjects are displayed in Table 3. There were no significant differences between the groups.

As shown in Table 4, high signal intensity (Grade 2–3) changes were found in 49% of the WAD Grade I–II patients, in 33% of the chronic neck pain group and in 40% of the subjects in the control group (χ^2, $P = 0.22$). Based on the interobserver results the dichotomized grading was used for the between group analyses.

The interobserver agreement in terms of kappa was 0.42 [95% confidence interval (CI): 0.32–0.52] for the right and 0.48 (95% CI: 0.38–0.58) for the left side, indicating fair to moderate agreement. A linear weighted kappa was calculated indicating better agreements for both the right side 0.57 (95% CI: 0.47–0.66) and the left side 0.62 (95% CI: 0.53–0.71). In order to obtain better agreement, the groups were dichotomized into two groups. If an individual had Grade 0 or 1 on one or the other side they were classified as 0, and in case of Grade 2 or 3 on one or the other side they were classified as 1. The kappa values increased when the groups were dichotomised, for both the right 0.60 (95% CI: 0.47–0.73) and the left side 0.66 (95% CI: 0.53–0.79), indicating good agreement.

The intraobserver agreement was performed on 50 subjects randomly selected among the 3 different diagnostic groups evaluated on two occasions 6 months apart. The intraobserver agreement with respect to grading 0–3, was 0.75 (95% CI: 0.60–0.89) on the right, 0.61 (95% CI: 0.43–0.79) on the left. When dichotomized 0.71 (95% CI: 0.52–0.91) for the right and 0.47 (95% CI:0.23–0.72) for the left side.

Discussion

In the present study there was no significant difference in alar ligament signal intensity changes on MRI between whiplash patients, chronic neck pain patients and subjects without neck pain or previous neck trauma. There are a few reports on the association between signal changes in the alar ligaments on magnetic resonance images and WAD Grade I–II.[8,11,14] One of these studies introduced a 4-point grading scale based on the signal

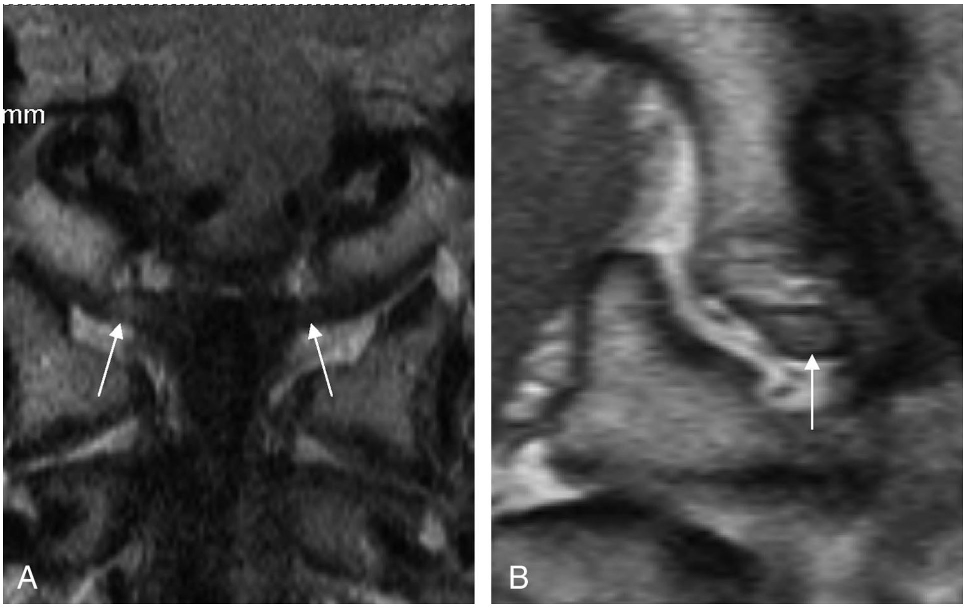

Figure 2. Proton density weightened MR images of both alar ligaments (arrows) in the coronal plane **(A)** and the right alar ligament in the sagittal plane **(B)**. The right alar ligament (arrow) has high signal intensity in more than 2/3 of the cross section corresponding to Grade 3. The left alar ligament has Grade 0. This patient belongs to the whiplash group.

Table 3. Distribution of Alar Ligament Signal Intensities Within Subjects on the Right and the Left Side for the Respective Diagnostic Groups

MRI Grading Groups	0–0	0–1	0–2	0–3	1–1	1–2	1–3	2–2	2–3	3–3
WAD grade I–II	17	8	3	4	5	6	2	4	5	5
Chronic neck pain	22	11	3	0	5	6	1	5	2	2
Controls	17	8	2	0	9	8	3	5	2	3

intensity of the alar ligaments.[8] Low-signal intensity was defined as normal ligaments (Grade 0) and they reported high signal intensity changes (Grade 2 or 3) only among whiplash patients.

Increased signal intensity (Grade 1–3) was regarded as a sign of injury. The present study, using the same MRI protocol and alar ligament grading scale, does not support this assumption because areas of high signal intensity (Grade 2–3) were seen in all 3 groups and there were no significant differences between the groups. There are also previous reports of high signal intensity changes among asymptomatic individuals,[10,12] but in these studies different MRI protocols and different grading scales have been used.

There are important methodologic aspects to consider when interpreting and comparing results from different studies. The magnetic field strength may influence the image quality and thus the ability to detect small structural changes in the ligaments. In some studies low field magnetic strength (0.2 T–0.5 T) have been used[10–12,14,15] whereas other studies have been performed on high field magnetic strength (1.5 T).[8,16] In the present study a magnetic field strength of 1.5 T was used. Another variable that probably influences the wide range of imaging results is the choice of MRI parameters. In some studies both T1 and T2 images have been performed.[8,10,12,14,16] One study investigated various MRI parameters, and concluded that detailed structural information of the ligaments and membranes in the craniocervical region were best obtained with high-resolution proton density weighted images in three planes.[17] This type of imaging sequence was also applied in the present study.

Partial volume effects appear when tissues of different signal intensity are present in the same image element. Reduction in slice thickness lessens partial volume effect.[8] In some studies relatively thick slices of 3 to 5 mm have been used.[10–12,14] This will increase the partial volume effect from high signal intensity tissues like bone marrow and fatty tissues and thus probably contribute to the high signal intensity areas seen in the ligaments. In the present study thin slices (1.5–2 mm) in 3 different imaging planes were used and care was taken to avoid misinterpretation of partial volume effects from the surrounding tissues. The interpretation of signal intensity changes in a structure with a length of 10–13 mm and an elliptical cross sectional diameter of 3×6 mm is difficult even with thin slices and high in-plane resolution. Furthermore, the interindividual variation[6,7] in the orientation and shape of the alar ligaments, makes the interpretation of ligament appearance difficult. Possible anatomic variances in the connective fiber density may also influence on the imaging appearance of these structures. If the ligament has high fiber density it will appear hypointense on MRI, whereas a ligament with loose fiber density and interspersed fatty tissue will appear with high signal intensity. The reported inter-rater agreement rates in the present and previous studies indicate that using a 4 point grading scale is highly questionable in clinical practice. Even the dichotomized inter- and intrarater kappa values did not reach acceptable agreement for this rating scale to be clinically useful.

To assume that these changes are caused by a trauma has important medicolegal aspects.[18] Based on the present results it is not warranted to conclude that these changes are caused by a trauma. The clinical relevance of these findings is unknown and causation should be evaluated in prospective designed studies.

Table 4. Signal Intensity Changes Dichotomised by Grade as Rated by the Two Interpreters

	WAD Grade I–II (n = 59)	Chronic Neck Pain (n = 57)	Controls (n = 57)	χ^2
Interpreter 1				
Grade 0–1	30 (50.8%)	37 (64.9%)	39 (68.4%)	$P = 0.12$
Grade 2–3	29 (49.2%)	20 (35.1%)	18 (31.6%)	
Interpreter 2				
Grade 0–1	25 (42.4%)	41 (71.9%)	38 (66.7%)	$P = 0.26$
Grade 2–3	34 (57.6%)	16 (28.1%)	19 (33.3%)	
Consensus				
Grade 0–1	30 (50.8%)	38 (66.7%)	34 (59.6%)	$P = 0.22$
Grade 2–3	29 (49.2%)	19 (33.3%)	23 (40.4%)	

■ Key Points

- High-signal intensity changes in the alar ligaments are seen with similar frequency among whiplash patients, patients with chronic neck pain and in controls.
- High signal intensity changes were seen in 40% of the control group.
- The diagnostic value of high-resolution MRI to assess signal intensity in the alar ligaments after whiplash is questionable.

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