JOURNAL OF NEUROTRAUMA
Volume 22, Number 4, 2005

Pp. 000–000

Whiplash-Associated Disorders Impairment Rating: Neck Disability Index Score According to Severity of MRI Findings of Ligaments and Membranes in the Upper Cervical Spine

BERTEL RUNE KAALE,[1,4] JOSTEIN KRAKENES,[3] GRETHE ALBREKTSEN,[2] and KNUT WESTER[4]

ABSTRACT

The aim of this study was to explore whether reported pain and functional disability in whiplash-associated disorders (WAD) patients is associated with lesions to specific soft tissue structures in the upper cervical spine, as assessed by MRI. Pre-selected structures for MRI assessment included the alar ligaments, the transverse ligament, the tectorial and the posterior atlanto-occipital membranes. The questionnaire employed was a modification of the Oswestry Low Back Pain Index. It was comprised of ten single items related to pain and activity of daily living. Ninety-two whiplash patients and 30 control persons, randomly drawn, were included. WAD patients reported significantly more pain and functional disability than the controls, both for total score and each of the ten single items. In the WAD patients, MRI lesions to the alar ligaments showed the most consistent association to the reported pain and disability. Lesions to other structures often occurred in combination with lesions to the alar ligaments. Lesions to the transverse ligament and to the posterior atlanto-occipital membrane also appeared to be related to the NDI score, although the association was weaker than for the alar ligament. The disability score increased with increasing number of abnormal (grade 2–3) structures. These results indicate that symptoms and complaints among WAD patients can be linked with structural abnormalities in ligaments and membranes in the upper cervical spine, in particular the alar ligaments.

Key words: alar ligaments; MRI; NDI; whiplash

INTRODUCTION

THE DIAGNOSIS of whiplash-associated disorders (WAD) has to date been based primarily on self-reported symptoms and complaints after a motor vehicle accident. It has not been easy to demonstrate physical signs of injury in these patients, or verify that the patients' problems are consequences of the whiplash trauma. The symptoms have often been thought to have a psychosocial rather than a physical explanation. Some patients have been assumed to exaggerate their symptoms in order to achieve financial benefits.

[1]Firda Medical Center, Sandane, [2]Section for Epidemiology and Medical Statistics, Department of Public Health and Primary Health Care, University of Bergen, [3]Section for Radiology, Department of Surgical Sciences, University of Bergen, and Department of Radiology, Haukeland University Hospital, [4] Section for Neurosurgery, Department of Surgical Sciences, University of Bergen, and Department of Neurosurgery, Haukeland University Hospital, Bergen, Norway.

Of the few previous studies that have examined potential associations between symptoms and MRI findings after acute whiplash trauma (Bonuccelli et al., 1999; Borchgrevink et al., 1997; Karlsborg et al., 1997; Pettersson et al., 1994; Voyvodic et al., 1997), most have failed to show any correlation. The MRI abnormalities reported were related primarily to spondylosis or disc pathology. The lack of association with symptoms may be related to small sample size, definition of symptoms, difficulties with lesion visualization, as well as the choice of neck structures for focused evaluation. The Quebeck Task Force (Spitzer et al., 1995) suggested that a whiplash trauma, grade 2, should include neck sprain and bleeding around soft-tissue, such as the articular capsules, ligaments, tendons, and muscles. Post-traumatic changes of the alar ligaments have been proposed to be the cause of chronic pain in patients after whiplash (Muhle et al., 2002). Both the alar and the transverse ligaments have previously been suggested to be particularly exposed in a wiplash trauma (Dvorak et al., 1988; Fielding et al., 1974; Saldinger et al., 1990). Some other studies (Muhle et al., 2002; Volle et al., 2000; Wilmink et al., 2001) have succeeded in visualizing changes that are believed to be associated with alar ligament lesions by means of MRI in whiplash patients. Our recent publications have shown that the alar and the transverse ligaments, and also membranes in the upper cervical spine, as well as lesions of these structures, can be visualized by high resolution MRI (Krakenes et al., 2001, 2002, 2003a,b). Thus, it now seems possible to demonstrate physical evidence of a neck injury in WAD patients.

The aim of the present study is to examine possible associations between self-reported symptoms, as represented by a Neck Disability Index (NDI) score, and severity of lesions to specific ligaments and membranes in the upper cervical spine, as judged by high resolution MRI. Five different neck structures were considered; the left and right alar ligaments, the transverse ligament, the tectorial membrane and the posterior atlanto-occipital membrane.

MATERIALS AND METHODS

The study included information on self-reported symptoms for 92 persons with a diagnosis of whiplash-associated disorder, grade 2 (Quebec Classification of Whiplash-Associated Disorders) (Spitzer et al., 1995) and 30 control persons. The WAD persons were identified through a register comprising 342 persons diagnosed by physicians in seven communities. The diagnosis was based on symptoms and signs after a motor vehicle accident. A final diagnosis was made after 12–16 weeks, ensuring that only patients with chronic symptoms were recorded. Plain x-rays of the neck were normal, and no patient had neurological deficits. Of the initial 342 eligible persons, a total of 45 were excluded owing to missing information, a previous neck injury, or they had been sitting in the back seat. A total of 100 WAD patients were invited to participate, randomly drawn from the remaining 297 eligible persons. Of these, 93 patients gave their informed consent to participate, whereas seven rejected or did not answer. Due to claustrophobia while attempting to perform an MRI examination, one patient was later excluded, leaving 92 WAD patients eligible for analyses (mean age 39.1 years, 64.1% women).

A total of 100 control persons living in the same geographical area, randomly drawn from a list of 300 names generated by the Norwegian Bureau of Statistics, received a preliminary request about participation. Of the 75 persons that were willing to participate, five were excluded because of a previous neck injury. Of the 50 persons that received a final invitation, 38 agreed to participate, whereas 12 gave a negative answer. Eight patients (seven males and one female) did not show up on the examination day. The control persons ($n = 30$) were slightly older than the WAD patients (mean age 45.3 vs. 39.1 years, $p = 0.005$), but had a similar gender distribution (63.3% women vs. 64.1% women in the WAD group, $p = 0.94$).

MRI Classification

The 122 participants (whiplash patients and control persons) were assigned a time and date for a clinical examination, as well as an MRI examination. The mean time from the collision to the MRI examination was 6 years (range, 2.0–9.0 years). The MRI examinations were performed with a 1.5-T system (Magnetom Vision; Siemens Medical System, Erlangen, Germany). A standard head coil was used, and all images were obtained with the head and neck in a neutral position. Previous studies have shown that proton density–weighted fast SE was the superior sequence in discriminating ligaments and membranes from surrounding soft tissue (Krakenes et al., 2001; Wilmink et al., 2001). This sequence was therefore selected for the present study.

Each ligament and membrane was classified in one out of four possible predefined categories, referred to as MRI grade 0–3. The MRI evaluation was done blinded for study group and clinical symptoms. The following classification system was applied: grade 0 reflected a normal structure, with homogenous low signal intensity throughout the cross-sectional area. The alar and transverse ligaments were classified as grade 1 when less than one third of the cross-sectional area showed increased signal in-

tensity, as grade 2 when more than one third, but less than two thirds, showed increased signal intensity, and as grade 3 when more than two thirds of the cross-sectional area showed increased signal intensity. The posterior atlanto-occipital membrane was evaluated indirectly by changes in the adjacent dura mater. An irregularity or thinning of the dura was classified as grade 1, discontinuity as grade 2, and discontinuity with a dural flap as grade 3. Grade 1–3 classification of the tectorial membrane was diagnosed when less than one third, between one third and two thirds, and more than two thirds of the membrane was absent, and only the dura mater was remaining. More detailed information on the MRI protocol, visualizations, as well as reliability of the classification criteria for each soft-tissue structure, is given elsewhere (Krakenes et al., 2001, 2002, 2003a,b). Typical examples of MRI findings and grading are shown in Figures 1–4. None of the control persons had the most pronounced MRI changes (grade 3) in any of the five investigated structures. Moderate MRI changes (grade 2) were observed for a few structures (9 out of a total of $5 \times 30 = 150$ evaluated structures) in the control persons.

F1-4
AU1

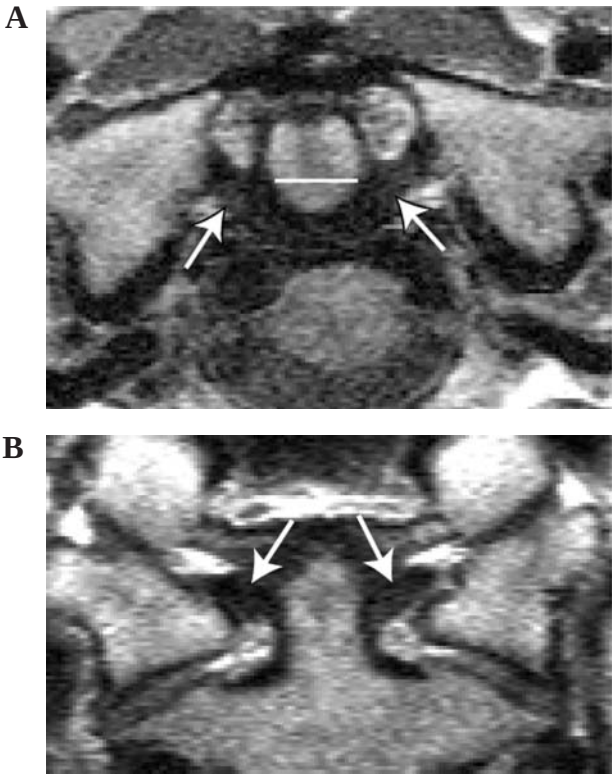

FIG. 1. Proton-weighted images (TR/TE 2200/15) of a normal transverse ligament. (**A**) Axial image shows low signal intensity indicating a normal ligament appearing dark (arrows). (**B**) Coronal view (along the line in A) verifies that the ligament is normal (dark, arrows).

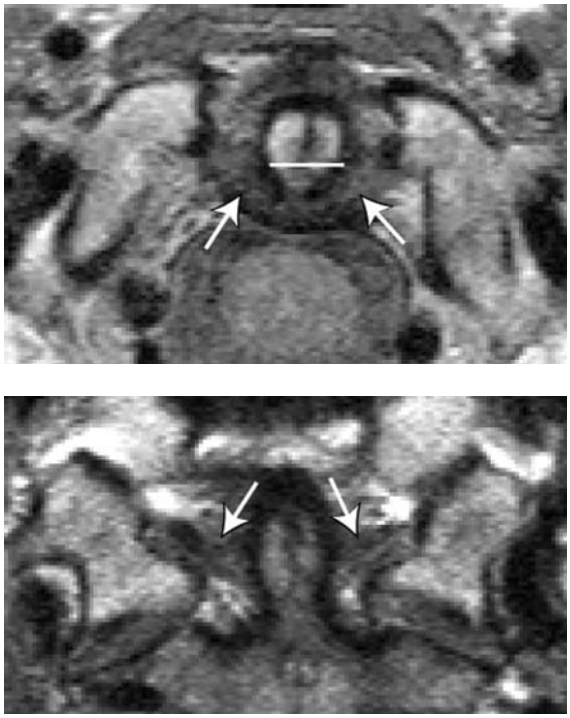

FIG. 2. Transverse ligament grade 3 lesion (similar imaging planes and parameters as in Figure 1). (**A**) The ligament is ill defined and shows generally increased signal intensity (arrows), appearing gray. (**B**) The increased signal intensity is verified in coronal imaging plane (arrows).

Neck Disability Index Score

The participants completed and returned the neck disability questionnaire at the time of the clinical examination, which took place 4–6 days before the MRI assessment. The NDI questionnaire applied was a modification of the Oswestry Low Back Pain Index translated into Norwegian, comprising 10 single items related to activity of daily living. Each item had six predefined response categories, coded as 0–5 on an ordinal scale. The scores reflected either degree of neck pain or degree of difficulties with performing certain actions due to neck pain. The lowest score (0) represented no problem or pain, whereas the highest score represented maximum problems or pain. The participants were instructed to respond according to their experiences during the last 3 days. An NDI percent score, defined on basis of responses to all 10 questions, was calculated as percent of maximum score (50 points). The final NDI percent score thus ranged from 0% to 100%, reflecting increasing degree of pain or disability (Vernon et al., 2001).

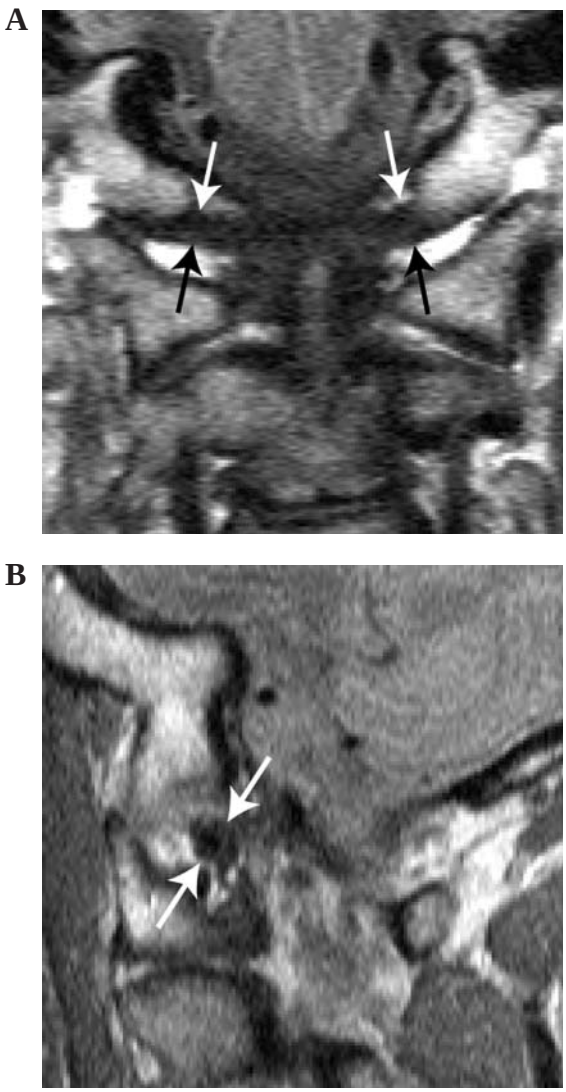

FIG. 3. Normal alar ligaments. (**A**) The ligaments are well defined, appearing dark, and can be followed from the posterior part of the dens axis to the occipital condyles (arrows). (**B**) Sagittal image near the insertion (at the right arrow in A) shows low signal intensity in the cross-sectional area (arrows).

Statistical Analyses

Chi-square tests were applied to compare WAD patients and control persons with respect to responses on the single items in the NDI score. Differences in mean NDI percent score were assessed by analyses of variance (ANOVA). To examine whether the difference in NDI score between WAD patients and control persons differed by gender or age, interaction terms were included in the ANOVA model, one at a time.

To examine whether the degree of disability was related to the MRI findings among the WAD patients, the mean NDI percent score was compared between MRI categories (grade 0–3) of each single structure in an ANOVA model. Additional estimation and tests for linear trends (constant increase or decrease) through the ordered MRI categories were made in analyses of covariance (ANCOVA), with gender and age as grouping factors (adjusted analyses). Effect modification (interaction) by gender and age was also examined. Additional analyses with mutual adjustment for MRI findings of the different structures considered, represented by indicator variables for abnormality (grade 2–3), as well as linear trends through ordered categories, were also performed. Furthermore, we examined associations between disability score and the number of abnormal structures (MRI grade 2–3).

F5

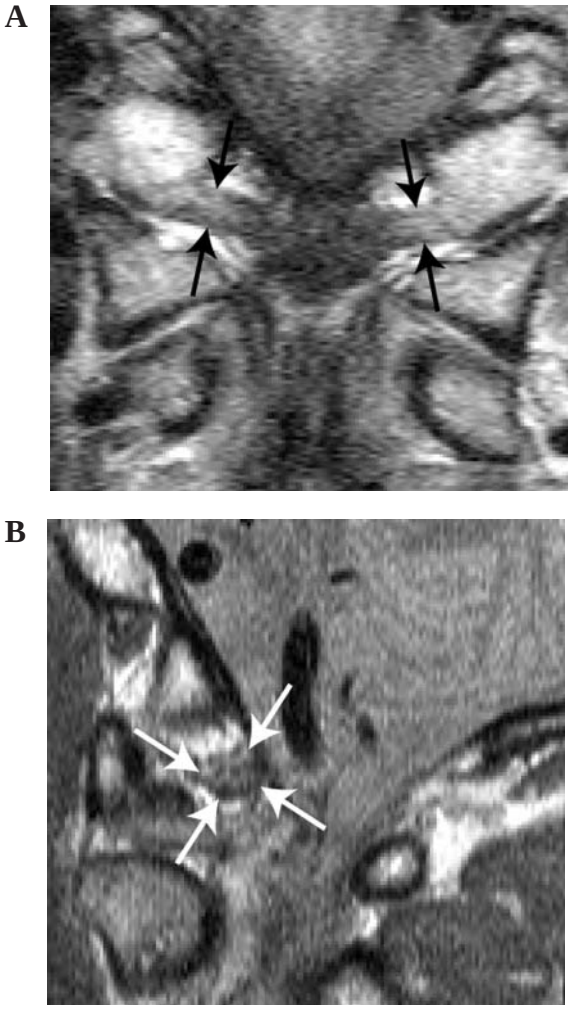

FIG. 4. Alar ligaments grade 3 lesions. (**A**) The ligaments show high signal intensity, appearing light-gray, on both sides, most prominent in the lateral parts (arrows). (**B**) The high signal is reflected in a sagittal image near the right insertion. The entire cross-sectional area (arrows) shows high signal intensity.

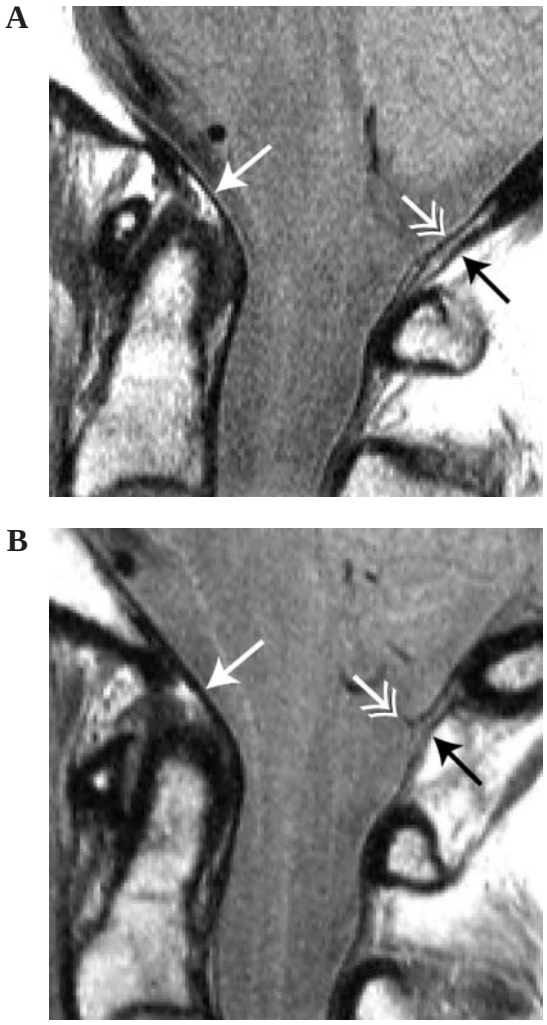

FIG. 5. Mid-sagittal view of the tectorial and the posterior atlanto-occipital membranes. (**A**) Thinning of the tectorial membrane from the dens level upward (white arrow), classified as a grade 3 lesion. Only the dura mater is remaining. The posterior atlanto-occipital membrane (black arrow) and the dura mater (double arrow), which is separated from the membrane in this particular case, is normal. (**B**) Normal tectorial membrane (white arrow). The posterior atlanto-occipital membrane is gray and ill-defined (black arrow). The dura mater shows an anterior flap (double arrow) indicating a transverse rupture, classified as grade 3.

RESULTS

WAD patients scored significantly higher on the 10 single items in the neck disability index (NDI) score than the control persons did (Table 1). The difference was particularly pronounced for problems with neck pain, reading, headache, concentration, car driving, and overall activity level. Mean values of the total score were 42.6 (range 0–78) and 20.3 (range 0–48) for the WAD patients and the control persons, respectively (Table 2). This difference was consistently observed across gender and age groups, despite more variation in disability score by gender and age in the control group than in the WAD group (Table 2).

Disability Score in Relation to Severity of MRI Findings

Among the WAD patients, the NDI score increased significantly with increasing severity of MRI abnormalities of the alar ligaments (Table 3). The association

TABLE 1. RESPONSES ON THE 10 SINGLE ITEMS IN NECK DISABILITY INDEX (NDI) SCALE[a] AMONG 30 CONTROL PERSONS AND 92 WAD PATIENTS

	Control group, n *(%)*	*Whiplash group,* n *(%)*	p-*value*[b]
Current neck pain			<0.001
0–1	18 (60.0)	17 (18.5)	
2–5	12 (40.0)	75 (81.5)	
Personal hygiene			0.011
0–1	28 (93.3)	61 (66.3)	
2–5	2 (6.7)	31 (33.7)	
Lifting from floor			0.001
0–1	28 (93.3)	50 (54.3)	
2–5	2 (6.7)	42 (45.7)	
Reading			<0.001
0–1	20 (66.7)	20 (21.8)	
2–5	10 (33.3)	72 (78.2)	
Headache			<0.001
0–1	15 (50.0)	11 (12.0)	
2–5	15 (50.0)	81 (88.0)	
Concentration			<0.001
0–1	21 (70.0)	15 (16.3)	
2–5	9 (30.0)	77 (83.7)	
Housework			0.001
0–1	20 (66.6)	22 (23.9)	
2–5	10 (33.4)	70 (76.1)	
Car driving			0.001
0–1	18 (60.0)	27 (29.3)	
2–5	12 (40.0)	65 (70.7)	
Sleeping problems			0.014
0–1	20 (66.6)	35 (38.1)	
2–5	10 (33.4)	57 (61.9)	
Overall activity			<0.001
0–1	20 (66.6)	24 (26.1)	
2–5	10 (33.4)	68 (73.9)	

[a]Response options on each item ranged from 0 (no disability) to 5 (maximum disability).

[b]Chi-square test for difference in proportions between the groups, using five categories for each item (0, 1, 2, 3, and 4–5).

WAD, whiplash-associated disorders.

Table 2. Mean Values and Standard Deviation (SD) of the Neck Disability Index (NDI) Score[a] among 30 Control Persons and 92 WAD-2 Patients, Together with Diffrence Between the Groups (with 95% Confidence Interval), Total Sample, and by Gender and Age

	Control group		*WAD group*		*Difference in NDI score*	
	No.	*Mean (SD)*	*No.*	*Mean (SD)*	*Mean (95% CI)*	p-*value*[b]
Total	30	20.3 (15.6)	92	42.6 (18.0)	21.6 (14.3–28.8)	<0.001
By gender						
Males	11	12.5 (12.4)	33	42.2 (18.3)	28.9 (17.1–40.7)	
Females	19	24.7 (15.7)	59	42.8 (17.9)	17.3 (8.3–26.3)	
p, test for interaction[c]						0.12
By age at survey						
<35 years	4	26.5 (17.8)	26	45.8 (19.1)	18.7 (0.25–37.2)	
35–44 years	13	24.5 (14.5)	33	42.8 (18.4)	18.6 (7.4–29.8)	
≥45 years	13	14.2 (14.9)	33	39.9 (16.7)	25.6 (14.3–36.8)	
p, test for interaction[d]						0.65

[a]Calculated as sum of responses on the 10 single items, in percent of maximum score; increasing score represents increasing disability.

[b]*F*-test for difference in mean values in NDI score between groups in an ANOVA model adjusted for gender and age.

[c]*F*-test for effect modification by gender in age-adjusted ANOVA analyses.

[d]*F*-test for effect modification by age in a gender-adjusted ANOVA analyses.

seemed to be stronger for males than for females, but the test for difference in linear trend did not reach statistical significance ($p = 0.41$). No significant age difference was seen ($p = 0.14$), although the linear association tended to be strongest in the youngest age group.

For the transverse ligament, no significant overall difference in mean NDI score between the four MRI grades (0–3) was seen, but the disability score tended to increase with increasing MRI grade (Table 3). The linear trend did not differ significantly between gender or age groups ($p = 0.99$ and $p = 0.36$, respectively).

No consistent pattern was seen for the posterior atlanto-occipital or the tectorial membranes (Table 3). A lack of adjustment for lesions to other structures may have affected these findings, however.

Disability Score in Relation to Multiple MRI Lesions

The distribution of multiple lesions together with observed mean values of the NDI score are shown in Table 4. Lesions only to the alar ligaments were associated with more severe symtoms than lesions to the transverse ligament (mean NDI score of 45.1 and 36.0, respectively). Lesions only to the atlanto-occipital membrane were associated with a similar score as those classified with an abnormal alar ligament (44.0%). However, the number of patients within this group was low ($n = 4$), as membrane injuries rarely occurred without co-existing ligament damage. The few individuals with high-grade lesions confined to the tectorial membrane alone had the lowest NDI score of all (mean 17.0%), even slightly lower than the mean value in the control group (20.3%). WAD patients with several abnormal (grade 2–3) structures had higher disability score than those with few or no abnormal structures. None of the WAD patients were graded 2 or higher on all the five structures studied.

A higher proportion of males than females had ligament lesions only, either of the alar ligament alone, or in combination with lesion of the transverse ligament (Table 4, 63.6% vs. 39.0%). On the other hand, a considerably higher proportion of the women were classified with lesions both to ligaments and membranes (Table 4, 39.0% vs. 15.2%). The main location of high-grade MRI changes (four combined categories defined by indicator variables for ligament and membrane injuries, respectively) differed significantly between men and women ($p = 0.05$). For high-grade lesion only to the alar ligaments, the mean NDI score was higher for males than females (49.3% vs. 41.6%). A similar gender difference was seen also for lesions to both ligaments and membranes (54.0% vs. 45.0%). Among patients with high-grade lesions to the alar and transverse ligaments, women reported the highest degree of disability (50.9% vs. 42.4%). In the other combined categories, the severity of symptoms was quite similar among men and women (results not shown), and approximately equal to those seen in the total sample (Table 4).

Table 3. Mean Values and Standard Deviation (SD) of NDI Score,[a] and Estimated Linear Trends (with 95% Confidence Interval), by Severity of MRI Findings in the Upper Cervical Spine Among 92 WAD Patients

	Neck Disability Index (NDI) score[a] by severity of MRI findings in WAD patients							
	Alar ligaments[b]		*Transverse ligament*		*Tectorial membrane*		*Post. atlanto-occ. membrane*	
	No.	*Mean (SD)*	*No.*	*Mean (SD)*	*No.*	*Mean (SD)*	*No.*	*Mean (SD)*
MRI grading								
Grade 0 (normal)	16	32.6 (20.2)	33	40.4 (17.2)	54	42.0 (17.5)	51	39.5 (19.6)
Grade 1 (possible lesion)	15	35.1 (19.5)	22	40.5 (19.5)	22	47.1 (17.2)	19	46.2 (16.7)
Grade 2 (probable lesion)	30	47.0 (16.7)	19	42.1 (15.6)	11	36.0 (18.9)	11	51.8 (15.3)
Grade 3 (definite lesion)	31	47.2 (14.3)	18	49.8 (19.3)	5	44.0 (24.5)	11	41.6 (10.9)
p test for heterogeneity[c]		0.008		0.30		0.40		0.16
Linear trend (95% CI)[d]		5.3 (2.0–8.6)		3.2 (−0.13 to 6.5)		−1.1 (−5.5 to 3.3)		3.1 (−0.8 to 6.9)
p test for linear trend[e]		0.002		0.059		0.63		0.12

[a]Calculated as sum of responses on the 10 single items, in percent of maximum score; increasing score represents increasing disability.
[b]Highest MRI grade assigned if different for left and right alar ligaments.
[c]*F*-test for heterogeneity in mean values between MRI categories in ANOVA analyses.
[d]Estimated average increase in NDI score per MRI grade, in ANCOVA analyses adjusted for gender and age.
[e]*F*-test for linear trend in gender- and age-adjusted ANCOVA analyses.

Table 4. Distribution of Multiple Lesions (Number and Percent) with Mean Values (Standard Deviation) of NDI Score[a] Among 92 WAD Patients

	Total			
	No. (%)	*Mean NDI (SD)*	*Women, no. (%)*	*Men, no. (%)*
Location of grade 2–3 lesions (combined, any types)				
No MRI finding (all grade 0–1)	11 (12.0)	33.3 (23.6)	6 (10.2)	5 (15.2)
Alar ligaments only	20 (21.7)	45.1 (16.2)	11 (18.6)	9 (27.3)
Transverse ligament only	6 (6.5)	36.0 (17.3)	3 (5.1)	3 (9.1)
Tectorial membrane only	4 (4.3)	17.0 (14.3)	2 (3.4)	2 (6.1)
Atlanto-occ. membrane only	4 (4.3)	44.0 (17.0)	4 (6.8)	0 (0.0)
Both ligaments	18 (19.6)	46.7 (16.7)	9 (15.3)	9 (27.3)
Both membranes	1 (1.1)	48.0 (—)	1 (1.7)	0 (0.0)
Ligament and membrane	28 (30.4)	46.6 (15.3)	23 (39.0)	5 (15.2)
Number of grade 2–3 lesions				
0	11 (12.0)	33.3 (23.6)	6 (10.2)	5 (15.2)
1	34 (37.0)	40.1 (18.1)	20 (33.9)	14 (42.4)
2	39 (42.4)	44.3 (14.8)	28 (47.5)	11 (33.3)
≥3	8 (8.7)	58.3 (14.2)	5 (8.5)	3 (9.1)

[a]Calculated as sum of responses on the 10 single items, in percent of maximum score; increasing score represents increasing disability.

Results from ANOVA and ANCOVA analyses with mutual adjustment for all the four neck structures (using indicator variables for abnormality; i.e., grade 2–3 lesion) showed that abnormal alar ligaments were the strongest predictors for severity of symptoms, with an overall difference in mean NDI score of 12.0 (95% CI = 4.4-19.6, $p = 0.002$) between those with and without severe MRI findings. The associations with the transverse ligament and the posterior atlanto-occipital membrane were weaker (overall difference in NDI score of 6.6 and 5.8, respectively), almost significant for the transverse ligament ($p = 0.081$), but not for the posterior atlanto-occipital membrane ($p = 0.21$). No association was found with the tectorial membrane (overall difference in NDI score of -3.7, $p = 0.47$). Results from the analyses of linear trends were in general rather similar to those obtained in analyses without considering the joint effects of several structures, as presented in Table 3. For the posterior atlanto-occipital membrane, however, the linear association was strengthened (the trend estimate changed from 3.1 to 4.0) and reached statistical significance ($p = 0.035$). Thus, MRI abnormalities of this structure also seem to have an independent effect on the degree of disability.

Finally, the increase in NDI score with increasing number of structures with high-grade MRI changes (Table 4) was highly significant (average increase in NDI score of 6.9 per additional abnormal structure, 95% CI = 2.4–11.3, $p = 0.003$).

DISCUSSION

This study shows that persons with abnormal MRI findings (grade 2 or 3) report more difficulties in daily living, as reflected through increasing neck and head pain as well as functional disability, compared with the control group or WAD patients with no or low-grade MRI abnormalities (grade 0 and 1). The increase in disability score with increasing number of structures that appeared abnormal on MRI gives support to the conclusion that the subjective symptoms and complaints can be consequences of injuries to ligaments and membranes in the cranio-vertebral junction.

Consistent with the hypothesis forwarded by Dvorak et al. (1988), the alar ligaments appeared to be the most important structure in a whiplash trauma, as it was the structure with the most frequent high-grade MRI abnormalities. The severity of lesions to these ligaments also showed the most consistent association with disability score and appeared to play a major role in more complex combinations of lesions. This finding indicates that lesions of the alar ligaments can be a common denominator in explaining the pain and functional disability in the neck after a WAD trauma. Nevertheless, our study also showed that lesions to the tranverse ligament, as well as the posterior atlanto-occipital membrane, may play a role on their own. Lesions to the tectorial membrane were rare, and when present, they were seen primarily in combination with lesions to other structures. The few persons

with lesions only to the tectorial membrane had the lowest NDI score, even lower than the average for the control group. This observation renders it unlikely that this structure is the primary source of pain. One previous study (Bonuccelli et al., 1999) has identified spondylosis and some other MRI abnormalities as potential source of pain in whiplash patients, whereas others (Borchgrevink et al., 1997; Karlsborg et al., 1997; Pettersson et al., 1994; Voyvodic et al., 1997) have failed to show any association between symptoms and such MRI abnormalities.

In our study, female WAD patients had more often lesions to multiple structures compared with male patients. This may be explained by the fact that the neck muscles are weaker in females, thus making their neck structures more vulnerable when under the influence of abrupt external forces. Another recent study (Stemper et al., 2004) also concluded that females are more likely to be injuried under whiplash loading, although focusing of structures in the lower rather than upper cervical spine. In subgroups with the same type of injuries, we found that men and women in general scored similarly on the disability scale. However, males with lesions both to ligaments and membranes experienced more pain and functional disability than the women did. One possible explanation is that males who suffer from multiple lesions may have been involved in more severe accidents, thus leading to more complex injuries.

The NDI questionnaire applied in our study was a modification of the Oswestry low back pain index (Vernon et al., 1991). It has been shown to have a high degree of reliability and internal consistency (Vernon et al., 1991). The 10 single items are not unlike those included in questionnaires for general activity of daily life (ADL), but they were chosen specifically to reflect either the degree of neck pain or the degree of difficulties with performing certain actions believed to be affected by neck pain and discomfort. The NDI scale accesses subjective experiences. It would be of interest to perform similar analyses and comparisons between MRI findings and disability with other, more objective, measures of functional disability.

In summary, the present study shows that increasing severity of MRI findings of soft tissue structures in the upper cervical spine is related to increasing levels of neck pain and functional disability, as experienced by persons with a diagnosis of WAD, grade 2. Lesions to the alar ligaments showed the most pronounced association with severity of subjective complaints. Lesions to the other neck structures without alar ligament abnormalities were rather uncommon. The marked difference in NDI score between WAD patients and control persons, as well as the dose-response relationship among the WAD patients, is indicative of a causal relationship.

REFERENCES

BONUCCELLI, U., PAVESE, N., LUCETTI, C., RENNA, M.R., GAMBACCINI, G., and BERNARDINI, S. (1999). Late whiplash syndrome: a clinical and magnetic resonance imaging study. Funct. Neurol. **14,** 219–225.

BORCHGREVINK, G., SMEVIK, O., HAAVE, I., HARALDSETH, O., NORDBY, A., and LEREIM, I. (1997). MRI of cerebrum and cervical columna within two days after whiplash neck sprain injury. Injury **28,** 331–335.

DVORAK, J., SCHNEIDER, E., SALDINGER, P., and RAHN, B. (1988). Biomechanics of the craniocervical region: the alar and transverse ligaments. J. Orthop. Res. **6,** 452–461.

FIELDING, J.W., COCHRAN, G.B., LAWSING, J.F., and HOHL, M. (1974). Tears of the transverse ligament of the atlas. A clinical and biomechanical study. J. Bone Joint Surg. Am. **56,** 1683–1691.

KARLSBORG, M., SMED, A., JESPERSEN, H., et al. (1997). A prospective study of 39 patients with whiplash injury. Acta Neurol. Scand. **2,** 65–72.

KRAKENES, J., KAALE, B.R., RORVIK, J., and GILHUS, N.E. (2001). MRI assessment of normal ligamentous structures in the craniovertebral junction. Neuroradiology **43,** 1089–1097.

KRAKENES, J., KAALE, B.R., MOEN, G., NORDLI, H., GILHUS, N.E., and RORVIK, J. (2002). MRI assessment of the alar ligaments in the late stage of whiplash injury—a study of structural abnormalities and observer agreement. Neuroradiology **44,** 617–624.

KRAKENES, J., KAALE, B.R., MOEN, G., NORDLI, H., GILHUS, N.E., and RORVIK, J. (2003a). MRI of the tectorial and posterior atlanto-occipital membranes in the late stage of whiplash injury. Neuroradiology **45,** 585–591.

KRAKENES, J., KAALE, B.R., NORDLI, H., MOEN, G., RORVIK, J., and GILHUS, N.E. (2003b). MRI analysis of the transverse ligament in the late stage of whiplash injury. Acta Radiol. **44,** 637–644.

MUHLE, C., BROSSMANN, J., BIEDERER, J., JAHNKE, T., GRIMM, J., and HELLER, M. (2002). Alar ligaments: radiological aspects in the diagnosis of patients with whiplash injuries. Rofo. Fortschr. Geb. Rontgenstr. Neuen. Bildgeb. Verfahr. **174,** 416–422.

PETTERSSON, K., HILDINGSSON, C., TOOLANEN, G., FAGERLUND, M., and BJORNEBRINK, J. (1994). MRI and neurology in acute whiplash trauma. No correlation in prospective examination of 39 cases. Acta Orthop. Scand. **65,** 525–528.

SALDINGER, P., DVORAK, J., RAHN, B.A., and PERREN, S.M. (1990). Histology of the alar and transverse ligaments. Spine **15,** 257–261.

SPITZER, W.O., SKOVRON, M.L., SALMI, L.R., CASSIDY, J.D., DURANCEAU, J., and SUISSA, S. (1995). Scientific

monograph of the Quebec Task Force on Whiplash-Associated Disorders: redefining "whiplash" and its management. Spine **20,** 1S–73S.

STEMPER, B.D., YOGANANDAN, N., and PINTAR, F.A. (2004). Gender- and region-dependent local facet joint kinematics in rear-end impact: implications in whiplash injury. Spine **16,** 1764–1771.

VERNON, H., and MIOR, S. (1991). The Neck Disability Index: a study of reliability and validity. J. Manipulative Physiol. Ther. **14,** 409–415.

VOLLE, E. (2000). Functional magnetic resonance imageing—video diagnosis of soft tissue trauma to craniocervical joints and ligaments. Int. Tinnitus **2,** 134–139.

VOYVODIC, F., DOLINIS, J., MOORE, V.M., et al. (1997). MR of car occupants with whiplash injury. Neuroradiology **1,** 35.40.

WILMINK, J.T., and PATIJN, J. (2001). MR imaging of alar ligament in whiplash-associated disorders: an observer study. Neuroradiology **43,** 859–863.

Address reprint requests to:
Bertel Rune Kaale, M.T.
Firda Medical Center
P.O. Box 194
N-6821 Sandane, Norway

E-mail: kaale@c2i.net

KAALE

AU1
Please cite Fig. 5 in text.