Magnetic resonance imaging of cranoovertebral structures: clinical significance in cervicogenic headaches

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Abstract This paper aims to investigate the relevance of morphological changes in the main stabilizing structures of the craniovertebral junction in persons with cervicogenic headache (CEH). A case control study of 46 consecutive persons with CEH, 22 consecutive with headache attributed to whiplash associated headache (WLaH) and 19 consecutive persons with migraine. The criteria of the Cervicogenic Headache International Study Group (CHISG) were used for diagnosing CEH; otherwise the criteria of the International Classification of Headache Disorders (ICHD II) were applied. All participants had a clinical interview, and physical and neurological examination. Proton weighted magnetic resonance imaging (MRI) of the craniovertebral junction, and the alar and transverse ligaments were evaluated and blinded to clinical information. The MRI of the craniovertebral and the cervical junctions, the alar and transverse ligaments disclosed no significant differences between those with CEH, WLaH and or migraine. The site of CEH pain was not correlated with the site of signal intensity changes of the alar and transverse ligaments. In fact, very few had moderate or severe signal intensity changes in their ligaments. MRI shows no specific changes of cervical discs or craniovertebral ligaments in CEH.

Keywords Cervicogenic headache · Alar ligaments · Transverse ligaments · Craniovertebral junction · Cervical junction · MRI

Introduction Cervicogenic headache (CEH) is a symptomatic headache characterized by chronic unilateral headache possibly secondary to dysfunction of the cervical spine [1–3]. CEH is often worsen by neck movement, sustained awkward head position, external pressure of the upper cervical or occipital region on the symptomatic side [1, 2]. Anaesthetic blockades of cervical structures or related nerves can temporarily abolish pain in CEH patients, which may suggest that the pain could be attributed to a neck disorder or structural lesion [1, 2, 4]. Clinical and/or imaging evidence of neck disorder or lesion can be accepted as a valid cause of headache. However, there is an agreement that degenerative changes in the cervical spine do not necessarily correlate with pain [1, 5]. Nevertheless, the research is striven to identify causative changes in the cervical spine, which may be attributed to CEH. The craniovertebral junction is stabilized by joint capsules, tectorial membrane, transverse and alar ligaments. Those anatomic structures are innervated by C2 root [6]. Convergence of the nociceptive afferents of the trigeminal and upper three cervical spinal nerves onto the second-order neurons in the trigemino-cervical nucleus in the upper cervical spinal cord refers the pain from the cervical spine to the head [7, 8].
The pain in CEH may originate from various anatomic structures in the cervical spine. A German study suggests that lower cervical disc prolapse may cause CEH [9]. It is conceivable that injury to the ligamentous structures can trigger CEH. High-resolution proton density-weighted magnetic resonance imaging (MRI) can visualize structural changes of ligaments and membranes in the upper cervical spine, and it is possible to grade the severity of these structural changes [10–12]. The diagnostic value of such changes is still controversial and their relevance in CEH is unknown. The aim of our study was to examine the frequency of structural changes in the alar and transverse ligaments in persons with CEH, whiplash associated headache (WLaH) and migraine.

Materials and methods

Study sample

The case–control study included patients referred to a general neurological outpatient clinic (Dept. of Neurology, Innlandet Hospital, Norway). A total of 118 participants were eligible for the study, but 31 refrained from participation. Of the 87 participants, 46 had CEH, 22 had WLaH, and 19 had migraine. The participants were interviewed and examined by a neurological resident (HK). CEH was classified according to the criteria of the Cervicogenic Headache International Study Group (CHISG) requiring at least three criteria to be fulfilled, not including a Greater Occipital Nerve (GON) blockade, i.e. criteria 1a, 1a1, 1a2, 1b, 1c and/or III (Table 1), [13]. Otherwise, the criteria of the International Classification of Headache Disorders (ICHD II) were applied [1]. WhipLash was defined by an acceleration/deceleration trauma that caused flexion/extension distortion of the neck followed by pain/stiffness. Three persons (two with CEH and one with migraine) refrained from MRI due to claustrophobia and two persons with CEH were excluded due to reduced image quality, ending up with 82 participants.

Magnetic resonance imaging protocol and evaluation

We examined the craniovertebral junction in three orthogonal planes (Siemens Symphony, Erlangen, Germany). The persons were scanned in supine position using both the neck coil and the attachable anterior element from the head coil. Images were obtained using a fast spin-echo (SE) T2 and proton-density-weighted sequences.

| Major criteria | I. Symptoms and signs of neck involvement |
|----------------|------------------------------------------|
|                | Ia. Precipitation of head pain, similar to the usually occurring one |
|                | Ia (1) by neck movement and/or sustained, awkward head positioning, and/or |
|                | Ia (2) by external pressure over the upper cervical or occipital region on the symptomatic side |
|                | Ib. Restriction of the range of motion (ROM) in the neck |
|                | Ic. Ipsilateral neck, shoulder or arm pain of a rather vague, non-radicular nature, or—occasionally—arm pain of a radicular nature |
|                | II. Confirmatory evidence by diagnostic anaesthetic blockades |
|                | III. Unilaterality of the head pain, without side shift |

| Head pain characteristics | IV. Moderate–severe, non-throbbing pain, usually starting in the neck. Episodes of varying duration, or fluctuating, continuous pain |
|---------------------------|----------------------------------------------------------------------------|
| Other characteristics of some importance | V. Only marginal effect or lack of effect of indomethacin. Only marginal effect or lack of effect of ergotamine and sumatriptan. Female sex. Not infrequent occurrence of head or indirect neck trauma by history, usually of more than only medium severity |
| Other features of lesser importance | VI. Various attack-related phenomena, only occasionally present, and/or moderately expressed when present: (a) nausea, (b) phono- and photophobia, (c) dizziness, (d) ipsilateral “blurred vision”, (e) difficulties swallowing, (f) ipsilateral oedema, mostly in the periorbital area |

It is obligatory that one or more of the phenomena Ia–Ic are present.

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The classification of the alar and transverse ligament lesions is based on the ratio between any high-signal part and the total cross-sectional area of the ligament. The alar and the transverse ligaments were graded according to the following criteria: grade 0—ligament with low signal throughout the entire cross-section; grade 1—ligaments with high signal in \( \frac{1}{3} \) or less of cross-section; grade 2—high signal in \( \frac{1}{3} \)–\( \frac{2}{3} \) of cross-section and grade 3—high signal in \( \frac{2}{3} \) or more of cross-section. Both sides of the alar and transverse ligaments were visualized in all participants [10–12, 14].

**MRI evaluation**

All MR images were evaluated by an experienced consultant in Neuroradiology (JK), who was blinded to clinical information.

**Statistical analysis**

The statistical analysis was performed using SPSS Base System for Windows 15.0 for all four MRI gradings and dichotomized groups (Grade 0–1 and Grade 2–3). We used the \( \chi^2 \)-test with 5% level of significance.

**Ethical issues**

The Regional Committees for Medical Research Ethics and the Norwegian Social Science Data Services approved the project. The participants that received GON blockade were informed about the procedure and side effects. All participation was based on informed consent.

**Results**

Table 2 shows demographic data of the participants. Signal intensity changes in the alar and transverse ligaments were found in 43% \( (n = 18) \) of persons with CEH, in 41% \( (n = 9) \) in persons with WLmH and in 50% \( (N = 9) \) of the persons with migraine. The results were dichotomized in two groups between none to mild (grade 0–1) and moderate to severe (grade 2–3) signal intensity changes. Table 3 shows that moderate to severe signal intensity changes in any of the transverse or alar ligaments (graded 2–3) were equally distributed on the right and left side and there were no statistical significant differences between the CEH, WLmH or migraine groups. Only 16% had moderate or severe signal changes. Mild signal intensity changes (grade 1) were found in 21, 32, and 44% of the subjects with CEH, WLmH and migraine, respectively. We disclosed no statistical significant changes regarding side of the change or between the CEH, WLmH and migraine groups dichotomizing the groups into none and mild to severe signal intensity changes (graded 0 and 1–3).

Table 4 shows disc degeneration. Moderate or severe degeneration of the craniovertebral and cervical discs was rare and only found in the C4/5, C5/6 and C6/7. Changes were seen in all three diagnostic groups, although there were no significant differences among the groups.

Signal intensity changes in the transverse and alar ligaments in relation to the location of the CEH are shown in Table 5. The statistical analyses showed no significant correlation between the site of signal intensity change and site of CEH. Dichotomizing the results in none and mild to severe signal intensity changes did not change the outcome of the analyses.

**Discussion**

We found no significant difference in MRI signal intensity changes in the alar and transverse ligaments or any difference in disc degenerative between subjects with CEH, WLmH and migraine. However, the pain in CEH may originate from various other structures in the cervical spine and cervical ligaments not identified with this MRI protocol which focused on certain structures [15]. But still all pathological changes in the cervical spine with sensory connection to the spinal tract of the trigeminal nerve might potentially be the pain generating structures which has to be focused on [7]. The alar ligament system is involved during cervical extension, lateral flexion, and ipsilateral rotation; nevertheless we found no correlation between side
location of pathological signal intensity (higher signal intensity) in the ligaments and the side location of the CEH [16, 17]. The transverse ligaments are strained at various movements of the head, still high-signal intensity (graded 2–3) in those ligaments was rare in all three diagnostic groups. A cross-sectional study applying conventional

| Table 3 | Signal intensity changes in any of the transverse or alar ligaments (details for grading is described in “Materials and methods” section) |
|---|---|---|---|---|
| | CEH | WLaH | Migraine | p value |
| | N = 42% (n) | N = 22% (n) | N = 18% (n) | |
| **Right alar ligament** | | | | |
| Grade 0–1 | 86 (36) | 86 (19) | 89 (16) | n.s. |
| Grade 2–3 | 14 (6) | 14 (3) | 11 (2) | |
| **Left alar ligament** | | | | |
| Grade 0–1 | 86 (36) | 95 (21) | 89 (16) | n.s. |
| Grade 2–3 | 14 (6) | 5 (1) | 11 (2) | |
| **Both sides alar ligament** | | | | |
| Grade 0–1 | 83 (35) | 86 (19) | 89 (16) | n.s. |
| Grade 2–3 | 17 (7) | 14 (3) | 11 (2) | |
| **Right transverse ligament** | | | | |
| Grade 0–1 | 90 (38) | 95 (21) | 100 (18) | n.s. |
| Grade 2–3 | 10 (4) | 5 (1) | 0 (0) | |
| **Left transverse ligament** | | | | |
| Grade 0–1 | 88 (37) | 95 (21) | 89 (16) | n.s. |
| Grade 2–3 | 12 (5) | 5 (1) | 11 (2) | |
| **Both sides transverse ligament** | | | | |
| Grade 0–1 | 88 (37) | 91 (20) | 89 (16) | n.s. |
| Grade 2–3 | 12 (5) | 9 (2) | 11 (2) | |

n.s. denotes non-significant

| Table 4 | Signal intensity changes in the craniovertebral and cervical junction (details for grading is described in “Materials and methods” section) |
|---|---|---|---|---|
| | CEH | WLaH | Migraine | p value |
| | N = 42% (n) | N = 22% (n) | N = 18% (n) | |
| **C2/3** | | | | |
| Grade 0–1 | 100 (42) | 100 (22) | 100 (18) | n.s. |
| Grade 2–3 | 0 (0) | 0 (0) | 0 (0) | |
| **C3/4** | | | | |
| Grade 0–1 | 100 (42) | 100 (22) | 100 (18) | n.s. |
| Grade 2–3 | 0 (0) | 0 (0) | 0 (0) | |
| **C4/5** | | | | |
| Grade 0–1 | 88 (37) | 91 (20) | 89 (16) | n.s. |
| Grade 2–3 | 12 (5) | 9 (2) | 11 (2) | |
| **C5/6** | | | | |
| Grade 0–1 | 69 (29) | 91 (20) | 83 (15) | n.s. |
| Grade 2–3 | 31 (13) | 9 (2) | 17 (3) | |
| **C6/7** | | | | |
| Grade 0–1 | 95 (40) | 100 (22) | 100 (18) | n.s. |
| Grade 2–3 | 5 (2) | 0 (0) | 0 (0) | |
| **C7/TH1** | | | | |
| Grade 0–1 | 100 (42) | 100 (22) | 100 (18) | n.s. |
| Grade 2–3 | 0 (0) | 0 (0) | 0 (0) | |
| **Change any junctions** | | | | |
| Grade 0–1 | 70 (29) | 86 (19) | 84 (15) | n.s. |
| Grade 2–3 | 30 (13) | 14 (3) | 16 (3) | |

n.s. denotes non-significant

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cervical MRI found no significant difference between patients with CEH and control subjects \[18\]. More specifically designed MRI protocols and evaluation grading scales were introduced focusing on the structural assessment of craniovertebral ligaments and craniovertebral junctions in persons with whiplash associated disorders \[12, 14, 19, 20\]. High grade changes were far more frequently observed in cases with a previous whiplash trauma than in a control group using a high-resolution proton density-weighted MRI in three orthogonal planes \[10, 11\].

There are at least four case control studies that used similar MRI methodology as our present study—two of those studies suggests injury of craniovertebral structures, while two recent studies failed to reproduce those findings. A new improved MRI protocol showing the ligaments and membranes in the craniovertebral junction was developed 10 years ago \[14\]. Further, they studied and classified structural changes in the alar ligaments in the late stage of whiplash injuries by the use of a new MRI protocol \[10\]. Almost half of whiplash associated disorder (WAD) subjects had structural changes in the alar ligaments, while no grade 2 or 3 lesion was found in the control group. Authors suggest that whiplash trauma might cause permanent damage to the alar ligaments, shown by high-resolution proton density-weighted MRI in three orthogonal planes \[10, 11\].

| Table 5 | Signal intensity changes in the transverse and alar ligaments in relation to location of the cervicogenic headache (CEH) |
|---------|--------------------------------------------------------------------------------------------------|
|         | Grade of structural changes on MRI                                                              |  \( p \) values  |
|         | 0–1  | 2–3 |
| Right-sided CEH \( n = 19 \) |  Right alar ligament 17 (89)  | 2 (11)  | n.s.  |
|         |  Left alar ligament 17 (89)  | 2 (11)  | n.s.  |
|         |  Right transverse ligament 15 (80)  | 4 (20)  | n.s.  |
|         |  Left transverse ligament 14 (74)  | 5 (26)  | n.s.  |
| Left-sided CEH \( n = 23 \) |  Right alar ligament 19 (83)  | 4 (17)  | n.s.  |
|         |  Left alar ligament 19 (83)  | 4 (17)  | n.s.  |
|         |  Right transverse ligament 23 (100)  | 0  | n.s.  |
|         |  Left transverse ligament 23 (100)  | 0  | n.s.  |

\( n.s. \) denotes non-significant.
Future investigations might have to focus more on the heterogenic origin of CEH and alternative operational tests in addition to the MRI.

**Conclusion**

Morphological MRI changes in craniovertebral ligaments showed similar frequency in patients with CEH compared to those with WLaH and/or migraine. According to our data, such changes have no established value for the diagnosis or work up of CEH.

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**Conflict of interest** None.

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