

## Whiplash injuries can be visible by functional magnetic resonance imaging

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Whiplash trauma can result in injuries that are difficult to diagnose. Diagnosis is particularly difficult in injuries to the upper segments of the cervical spine (craniocervical joint [CCJ] complex). Studies indicate that injuries in that region may be responsible for the cervicoencephalic syndrome, as evidenced by headache, balance problems, vertigo, dizziness, eye problems, tinnitus, poor concentration, sensitivity to light and pronounced fatigue. Consequently, diagnosis of lesions in the CCJ region is important. Functional magnetic resonance imaging is a radiological technique that can visualize injuries of the ligaments and the joint capsules, and accompanying pathological movement patterns.

Three severely injured patients that had been extensively examined without any findings of structural lesions were diagnosed by functional magnetic resonance imaging to have injuries in the CCJ region. These injuries were confirmed at surgery, and after surgical stabilization the medical condition was highly improved.

It is important to draw attention to the urgent need to diagnose lesions and dysfunction in the CCJ complex and also improve diagnostic methods.

**Key Words:** *Alar ligament; Craniocervical joint complex; Diagnosis, Functional magnetic resonance imaging; Instability; Whiplash*

Injuries from whiplash trauma are difficult to identify objectively. X-ray examination cannot typically reveal minor injuries. Consequently, reports of pathoanatomical injuries are underestimated (1). The problem is compounded by the paradox that major injury can result in minor symptoms whereas minor trauma can result in severe, disabling symptoms. Consequently, the need to render injuries visible is important.

During the late 1980s, Dvorak et al (2) focused on injuries in the upper segments of the cervical spine (skull base, atlas, axis and upper joint segment of C3), ie, the region designated the craniocervical joint (CCJ) complex. They showed that the alar ligaments stabilized the complex and injuries to those ligaments led to considerable hypermobility of the segments.

In 1992, Radanov et al (3) described two different groups of syndromes after whiplash injuries to the cervical spine. One syndrome was called 'cervicoencephalic syndrome' and was characterized by headaches, balance problems, disturbed accommodation, poor concentration, sensitivity to light and pronounced fatigue. The other syndrome was called 'lower cervical syndrome' and was characterized by cervical and

## Les coups de fouet cervicaux peuvent être visibles grâce à l'imagerie par résonance magnétique fonctionnelle

Les traumatismes par coup de fouet cervical peuvent causer des blessures difficiles à diagnostiquer. Le diagnostic est particulièrement difficile dans le cas de blessures des segments supérieurs de la colonne cervicale (complexe crâniocervical [CCC]). D'après les études, les blessures dans cette région peuvent être responsables du syndrome cervico-encéphalique qui se manifeste par des maux de tête, des troubles d'équilibre, des vertiges, des étourdissements, des troubles oculaires, des acouphènes, un manque de concentration, une sensibilité à la lumière et une fatigue prononcée. Par conséquent, il est important de diagnostiquer les lésions dans la région CCC. L'imagerie par résonance magnétique fonctionnelle est une technique radiologique qui permet de visualiser les blessures des ligaments et des capsules articulaires ainsi que les tracés des mouvements pathologiques connexes.

Grâce à l'imagerie par résonance magnétique fonctionnelle, trois patients gravement blessés qui avaient fait l'objet d'examen approfondis sans qu'on puisse repérer de lésions structurelles ont reçu un diagnostic de lésions dans la région CCC. Ces lésions ont été confirmées à l'opération, et après une stabilisation chirurgicale, leur état s'est grandement amélioré. Il est important de souligner l'urgent besoin de diagnostiquer les lésions et le dysfonctionnement du complexe CCC ainsi que d'améliorer les méthodes diagnostiques.

cervicobrachial pain. A combination of both syndromes was possible. In 1993, Taylor et al (4) and Schonstrom et al (5) described injuries to the upper cervical joints observed post-mortem, which they hypothesized could be responsible for the cervicoencephalic syndrome.

The division of whiplash-associated disorders into upper and lower syndromes has not generally been recognized in clinical practice. A consequence of this division is that clinicians do not inquire about changes of the CCJ complex when they refer a patient for radiological examination of the upper spine. Accordingly, radiologists do not pay special attention to this region. Appropriate techniques to examine this area have not been developed.

In 1996, Volle et al (6) described a method to assess the alar ligaments by functional magnetic resonance imaging (fMRI). The following year, they published a paper (7) that showed a strong correlation between injuries of the CCJ complex and symptoms such as headaches, concentration disturbances, vertigo, dizziness, visual problems, tinnitus and balance disturbances.

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An fMRI examination is performed by positioning the cervical spine in approximately 40 different positions such that the pathological movement patterns and injuries to the ligaments and the joint capsules can be detected. These injuries cannot be demonstrated without systematically assuming the different positions. The method has been developed and recently published in a German textbook for neurosurgeons (8).

In the present paper, three patients are described who experienced whiplash trauma and subsequently developed chronic symptoms. Examinations in Sweden failed to find any structural lesions. The patients underwent an fMRI examination, and later, surgical fixation (C0 to C3 as per the Magerl method [9]). During the operation, serious injuries to joint capsules were observed that were previously undetected.

## CASE PRESENTATIONS

### Patient 1

While driving, a 27-year-old woman was hit by another car from the right side. She did not lose consciousness but developed pain in her neck, and numbness and decreased strength in her right arm. A computed tomography scan did not show skeletal injury, luxation or herniation. Soon after the accident, she developed headaches and sensitivity to light and noise that increased over time. She had problems reading, primarily in the ability to follow text lines. She also developed increasing tinnitus and intermittent numbness in her tongue. She occasionally fainted. Physiotherapy increased her symptoms. A few years after the accident, both arms began to shake and she had problems moving her left leg, which felt numb. She was carefully examined at a university neurological department. An MRI showed some disc changes but no changes that neurological disturbances could be attributed to. She was finally diagnosed as suffering from functional disturbances, ie, psychogenic symptoms.

In 2004, the patient underwent an fMRI examination and a pronounced cervical myelopathy was diagnosed. Around the odontoid process, scar tissue was evident, which, on rotation of her head, came in contact with the upper part of the spinal cord. There were also widespread injuries with scar tissue on the C1/C2 joint capsules and a pronounced instability pattern at that level as well as at C0/C1. Both alar ligaments showed signs of injury and granulation changes.

As a result of these findings, the patient underwent cervical stabilization surgery (C0 to C3) as per the Magerl method of fixation (9). At surgery, the atlas moved in a paradoxical way when her head was bent laterally. The C1/C2 joint capsules were clearly torn on both sides, and the capsules were thickened with scar tissue. The injuries were so widespread that the surgeon could look into the joint from the dorsal aspect. During surgery, C0/C1 instability was noted during extension of her neck.

After the operation, her headaches decreased, the shaking of her arms ceased, her reading ability normalized and her sensitivity to light disappeared, although her sensitivity to noise remained. Her balance became normal and her vertigo disappeared. She felt that her concentration had improved, and she could take part in discussions. The tinnitus remained but was not as annoying. She was also able to sleep better.

### Patient 2

In 1989, a 38-year-old man was driving his car at a speed of 90 km/h and hit a road railing. The patient's head was tossed

toward his chest with great force and he immediately felt pain in his neck and head. He was not able to work due to headaches, sickness and eye problems (he could not read text), and his concentration was reduced. He also experienced intermittent dizziness, balance problems, pain behind his left eye, chewing problems, varying degrees of tinnitus and numbness on the right side of his tongue. The problems were aggravated when bending forward and he felt better when wearing a stiff collar. He was examined extensively at a central regional hospital and a rehabilitation clinic. A number of radiological examinations gave no explanation of his symptoms. Following the examinations, the National Assurance Board declared him fit although he not was able to earn his living. In 2003, he was awarded sickness benefits by the court.

In 2004, he had an fMRI examination that showed functional cervical myelopathy of the upper cervical spine. There was a displacement of structures by scar tissue related to the dens. Rotation of his head brought the scar tissue into contact with the spinal cord. The dens-related capsules showed serious injuries as well as lesions in the capsules of the lateral atlantoaxial joints, with scar tissue and signs of chronic instability. The alar ligaments showed signs of injuries and scar tissue.

The patient underwent surgical fixation from C0 to C3 (Magerl's method [9]). During surgery, instability of the C0/C1 joint was noted when the head was extended. The capsule of the right lateral atlantoaxial joint was completely torn, leaving the joint cavity wide open.

After surgery, the headaches and vertigo vanished immediately. His balance became normal, and he felt mentally alert again. He summarized his recovery by saying that he got his life back.

### Patient 3

A 32-year-old female driver was rear-ended by another car at high speed. At the moment of impact, the patient's head twisted maximally to the right. Her car was extensively damaged.

The patient immediately experienced pain in her head, and on the right side of her neck radiating into her right arm and hand. Initially, she could not move her right arm. She developed bursting headaches, nausea and severe dizziness. After three days, she developed eye disturbances with blurred vision and difficulty following text when reading. She also had balance problems and decreased ability to move her left leg. After several months, her right arm started trembling and she experienced occasional spasms and unconsciousness. She was examined many times at the university hospital where they diagnosed a psychosomatic disorder.

Two years after the accident, she had an fMRI examination. Functional cervical myelopathy with thickened structure following scar tissue was diagnosed. Upon rotation of her head, the dens pressed on the spinal cord. Severe injuries of the alar ligaments as well as injuries with scar changes of the joint capsules of C0/C1 and C1/C2 were noticed. There were also signs of instability of the C1/C2 segment.

During the subsequent operation with fixation from C0 to C3, it was noted that the ligaments connecting C0 to C1 were partly torn, leading to an unusually large distance between C0/C1 upon neck extension. There was also abnormal mobility associated with lesions on the alar ligaments. The capsule of

the left lateral atlantoaxial joint was torn and scarred, and the right capsule sagged.

Immediately after the operation her headaches vanished, the vision problems improved and she had no cramps or periods of unconsciousness.

### DISCUSSION

The kind of surgery that these patients underwent allows only joint capsules of the lateral atlantoaxial joints to be inspected directly. The lesions observed are known only to arise from trauma and are, therefore, clearly pathological changes. The alar ligaments and lesions around dens axis can not be seen in the operation field but the abnormal mobility, described by the surgeon, was consistent with injury to the alar ligaments and impairment of their stabilizing function.

These three cases show that severe injuries can exist in the upper cervical region without being diagnosed in the Swedish medical system. It seems reasonable to assume that the situation in Sweden is representative of other developed countries.

Under these conditions, severely injured patients can be deemed to be mentally disturbed, denied compensation and offended. Missed diagnosis can also lead to inadequate or improper treatments, which appears to be quite a common occurrence.

The aim of the present article is not to discuss the treatment of injuries to the craniocervical joints, but to draw attention to

the urgent need to improve diagnostic methods. An fMRI is an appropriate diagnostic tool. This examination is comprehensive and takes approximately 4 h.

Another examination method that is restricted to detecting lesions on ligaments is described by Krakenes et al (10). This method, however, does not address functional disturbances and, consequently, has considerable limitations.

An fMRI is not indicated for every patient with a whiplash-associated disorder. These three patients shared certain clinical features that can serve as prima facie indications for an fMRI investigation, including headache, difficulty reading, numbness of the tongue and the development of neurological features in the upper and lower limbs. All are consistent with injury and instability of the C1/C2 segment.

Pain from the lateral atlantoaxial and atlanto-occipital joints can be referred to various regions of the head (11-13). Following text during reading requires cervical pursuit movements, which require a structurally and physiologically intact C1/C2 segment. Numbness of the tongue is caused by subluxation of the lateral atlantoaxial joint (14,15). Neurological disturbances in the upper and lower limbs imply spinal cord compromise.

In the presence of such features, physicians should be alert to the strong possibility of injury to the craniocervical joints. If injuries are not apparent on conventional imaging, they could be rendered evident by fMRI.

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