CASE REPORT

Spinal cord metabolism and muscle water diffusion in whiplash

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Study design: Case series.

Objectives: To quantify spinal cord metabolites and neck muscle fast and slow water diffusion in a small sample of patients with chronic whiplash and healthy controls.

Setting: Brisbane, Queensland, Australia.

Methods: In five subjects with chronic whiplash and seven controls, we performed magnetic resonance spectroscopy (MRS) of the cervical spinal cord and diffusion-weighted imaging (DWI) of the cervical multifidus muscle.

Results: Significant reductions in *N*-acetylaspartate/creatine ratios were found in subjects with chronic whiplash when compared with healthy controls ($P = 0.02$). Significantly higher fast apparent diffusion coefficients (ADCs) were found in chronic whiplash when compared with the healthy controls ($P = 0.01$). There was no difference in slow ADCs between the two groups ($P = 0.3$).

Conclusion: The potential value of MRS and DWI to quantify the presence of neuromuscular degeneration as a potential mechanism underlying chronic whiplash is recognized. Larger-scaled prospective studies are warranted and required.

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Keywords: whiplash; MR spectroscopy; diffusion-weighted imaging; pain

Introduction

Radiological evidence for pathology following whiplash is scant.¹ Degenerated muscle (for example, fatty infiltrates) has been observed, but the mechanisms are unclear.² Advanced imaging (for example, magnetic resonance spectroscopy (MRS) and diffusion-weighted imaging (DWI)) may assist in determining the mechanisms. Altered cord biochemistry has been observed in neurological disorders³ and cervical myelopathy⁴ using MRS, and increased water diffusion of denervated muscles is detailed with DWI.⁵ We compared cord biochemistry and neck muscle water diffusion in subjects with chronic whiplash and controls.

Materials and methods

Five patients with chronic whiplash (>6 months post-injury) and 7 controls were recruited. The patients' mean

age was 36 years (range 28–44). Mean duration of symptoms was 42 months (range 6–132). Mean Neck Disability Index score was 48/100 (range 34–62/100). Mean age for controls was 28 years (range 24–44). MRI data were collected on a 3-Tesla, TRIO system (Siemens, Germany).

MRS of the cervical cord

Participants underwent MRS of the cervical cord to assay magnetic resonance-visible metabolites (*N*-acetylaspartate (NAA), creatine (Cr) and choline (Cho)). A single voxel ($1 \times 1 \times 2 \text{ cm}^3$) was placed in the cord, spanning the C1 and C2 levels and superior portion of C3 (Figure 1). A short echo time point-resolved spectroscopy sequence (TR:TE (3000:30)) was obtained. An automated shim produced consistent peaks. Acquisition time was 7 min and 20 s (7.2 min). The peak values of NAA, Cr and Cho were measured on the screen and ratios were calculated.

DWI of neck muscle

DWI was performed using a volumetric head coil with the following: a spin-echo single-shot echo planar image; TR: 4000 ms; TE: 92 ms; 128×128 matrix; FOV $220 \times 220 \text{ mm}^2$;

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Figure 1 MRS of the cervical spinal cord in a subject with chronic whiplash with corresponding peaks for NAA, Cho and Cr.

slice thickness 5 mm, with five b values (0, 50, 100, 200, 300 $\text{mm}^2 \text{s}^{-1}$); TA: 4.2 min.

In addition, axial T2-weighted turbo-spin echo images (TR:TE (4500:68), matrix 320×320 , FOV 160×160 mm, slice thickness 3 mm) were obtained for anatomical reference. The DWI and turbo-spin echo scans covered the inferior portion of C4 to the superior portion of C6. A region of interest (mm^2) was drawn in the axial plane for the right multifidus at C5. Previous work has established normative data with the same b -value ranges.⁶

We certify that all applicable institutional regulations concerning the ethical use of human volunteers were followed during the course of this research.

Statistical analysis

We hypothesized that a reduction in metabolite ratios and altered apparent diffusion coefficients (ADCs) would be present in whiplash. Paired uni-directional one-tailed t -tests were used to assess this and the significance was set at $P < 0.05$.

Results

MRS data were obtained in all subjects. Participants with chronic whiplash revealed significantly lower NAA/Cr ratios (mean (s.d.): 1.3 (0.5)) than healthy controls (2.0 (0.7)) ($P = 0.02$), but not Cho/Cr ratios (whiplash: 1.03 (0.4) and controls: 1.27 (0.5)) ($P = 0.19$).

Fast-diffusion ADC between b -values of 0 and 50 $\text{mm}^2 \text{s}^{-1}$ and slow-diffusion ADC between b -values of 50 and 300 $\text{mm}^2 \text{s}^{-1}$ were measured for both groups. Mean whiplash fast ADC (ADC_{fast}) and slow ADC (ADC_{slow}) were 3.2×10^{-3} and $3.8 \times 10^{-4} \text{mm}^2 \text{s}^{-1}$, respectively, for the right multifidus at C5. Data for ADC_{fast} and ADC_{slow} for controls were 2.2×10^{-3} and $4.7 \times 10^{-4} \text{mm}^2 \text{s}^{-1}$, respectively. Participants with chronic whiplash demonstrated significantly faster ADC_{fast} when compared with healthy controls ($P = 0.01$), but there were no significant between-group alterations for ADC_{slow} ($P = 0.3$).

Discussion

We demonstrate changes in cord biochemistry in tandem with altered water diffusion in the cervical multifidus in chronic whiplash.

NAA is a marker for neuronal integrity and reduced NAA/Cr on MRS has been associated with damaged axons in various disorders.^{3,4} We report a similar reduction of NAA/Cr in patients with chronic whiplash as observed in cervical myelopathy.⁴ This suggests neuronal loss in the cord and may point to an initial mild cord injury and/or persistent abnormal afferent input following injury to peripheral structures.

The study supports the observation of fast and slow ADCs for the multifidus. The fast-component ADCs are similar to ADCs for healthy lumbar paraspinals.⁷ However, the fast ADC for chronic whiplash ($3.2 \times 10^{-3} \text{mm}^2 \text{s}^{-1}$) was faster than established data,⁷ suggesting a passive enlargement of the extra-myocellular space secondary to denervation atrophy.⁵

The observed biochemical alterations and muscle water diffusion provide preliminary evidence to suggest involvement of the spinal cord with subsequent denervation atrophy⁵ in a small sample of patients with chronic whiplash.

These findings provide the foundation for prospectively probing the biochemical environment of the cord and physical structure of neck muscles following whiplash. This is well underway.

Conflict of interest

The authors declare no conflict of interest.

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Disclaimer

We certify that no party having a direct interest in the results of the research supporting this article has or will confer a

benefit on us or on any organization with which we are associated, and, if applicable, we certify that all financial and material support for this research (for example, NIH or NHS grants) and work are clearly identified in the title page of the paper.

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