Morphological changes of deep extensor muscles in relation to the maximum level of Compression and canal compromise in patients with degenerative cervical myelopathy

Neda Naghdi[1], James M. Elliott[2], Michael H. Weber[3], Michael G. Fehlings[4], Maryse Fortin [1,5,6]

[1] Concordia University, Montreal, QC; [2] The University of Sydney, Sydney, Australia, [3]McGill University Health Centre, Montreal, QC, [4] University of Toronto, Toronto, ON, [5] PERFORM Centre, Concordia University, Montreal, QC , [6] Centre de Recherche Interdisciplinaire en Réadaptation (CRIR), Montreal, QC.

Introduction

Degenerative cervical myelopathy (DCM) is a major cause of disability in the adult population. This condition is characterized by a narrowing of the cervical spinal canal, leading to pain and neurological impairments (1).

Deep extensor neck muscles of the cervical spine play an important role in maintaining normal cervical curvature, stability, and activity (2,3).

Recent studies have reported that the deep extensor neck muscles, especially the cervical multifidus (MF) and semispinalis cervicis (Scer), are often impaired in patients with cervical disorders (4,5), and atrophied in patients with whiplash-type injury or chronic neck pain (5,6).

However, few studies have evaluated the deep extensor neck muscles of patients with DCM (7,8). Therefore, the presence and extent of morphologic muscle changes in patients with DCM warrants further attention.

Objectives

This study aimed to examine the relationship between morphological changes of the deep extensor neck muscles in patients with degenerative cervical myelopathy (DCM) and the level of maximum spinal compression and canal compromise.

Materials/Methods

A total of 171 patients from a Prospective DCM-International cohort study database were included in this study.

Total cross-sectional area (CSA), functional CSA (fat free area, FCSA), ratio of FCSA/CSA (fatty infiltration) and asymmetry of the MF+SCer together, and deep extensor muscles as a group (e.g., MF, SCer, semispinalis capitis, splenius capitis) were obtained bilaterally from axial T2-weighted MR images at mid-disc, at the level of maximum cord compression and the level below (fig 1B, C).

The level and degree maximum spinal cord compression (MSCC) and maximum canal compromise (MCC) was determined using the following formulas MSCC= $[1 - di\ (da + db)/2] \times 100$, and MCC = $[1 - Di\ (Da + Db)/2] \times 100$ as defined by Fehlings et al. (9) (fig 1A). The FCSA was measured using a highly reliable thresholding technique described in a previous study (10) (fig 1C), and the relative percent asymmetry in CSA, FCSA and FCSA/CSA was calculated using: $[(L - S)/L] \times 100$, where L is the larger side, and S is the smaller side (11). The relationship between the muscle parameters of interest, MSCC and MCC was assessed using multivariate linear regression models, adjusting for age, BMI and sex. Separate models were used for each muscle group and spinal level.

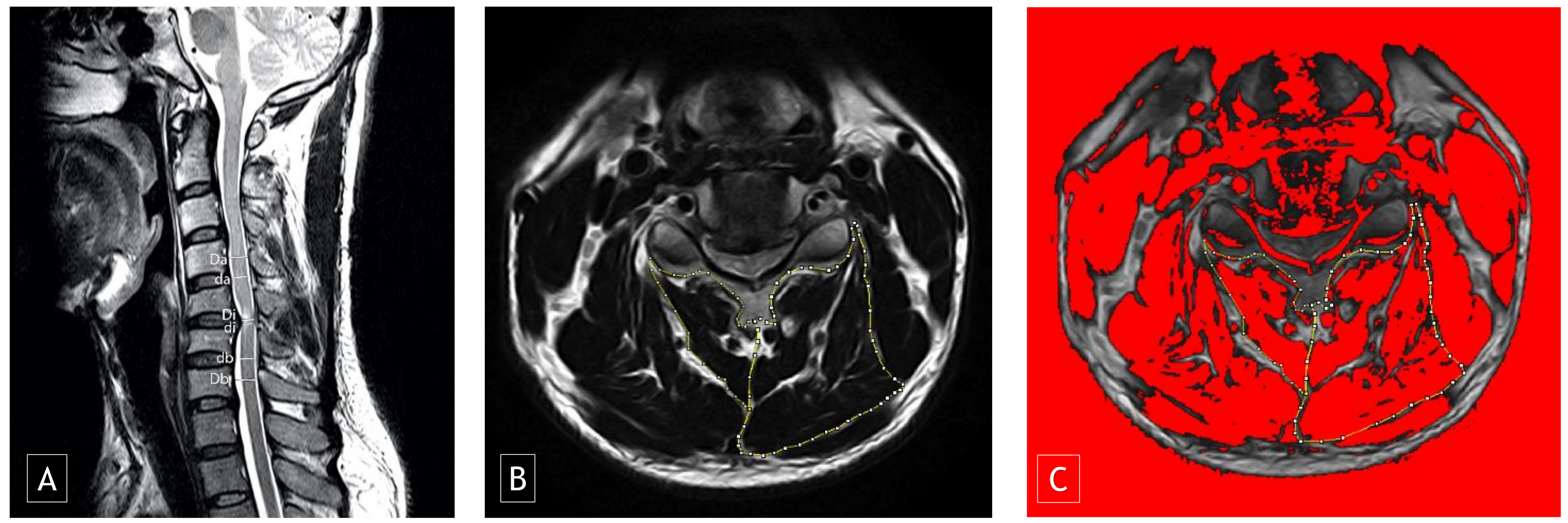

Figure 1. (A) Measurements required for MCC and MSCC calculation. Di, Da, and Db measure the diameter of the spinal canal at the site of compression and at the normal site above and below, respectively; di, da, and db indicate the diameter of the spinal cord at the site of compression and at the normal site above and below respectively. (B) Measurements of the Total CSA of the MF+SCer muscles and extensor muscles group on axial T2-weighted image at the C5-C6 level. (C) The image shows the application of a signal threshold filter (ImageJ) to highlight the fat-free muscle area and obtain the FCSA muscle measurements.

Results

- The average MSCC and MCC was 42.84%(SD=17.7) and 45.38% (SD=14.96), respectively.
- Greater MF+Scer fatty infiltration (e.g., lower FCSA/CSA) was associated with greater MCC (P= 0.032) and MSCC (p=0.049) at the same level. Greater asymmetry in MF+SCer CSA was also associated with greater MCC (p=0.006).
- Similarly, greater asymmetry in FCSA and FCSA/CSA of the entire extensor muscle group was associated with greater MCC (p=0.011, p=0.013).
- There was no significant association between muscle measurements obtained at the level below the level of maximum compression, MCC and MSCC.

Table 1 – Mean (standard deviation) of characteristics of patients and paraspinal muscle measurements at the Max level and level below.

Characteristics of patients	Mean (standard deviation)	
Age	54.92 (11.85)	
BMI	25.77 (5.43)	
Gender	1.64 (0.48)	
MCC	45.38% (14.96)	
MSCC	42.84% (17.7)	
Paraspinal muscle measurements	**Max level**	**Level below**
FCSA/CSAMF+SCer	0.6 (0.16)	0.6 (0.11)
FCSA/CSA group	0.68 (0.09)	0.69 (0.09)
FCSA/CSA asy MF+Scer	11.07 (9.95)	11.09 (9.03)
FCSA/CSA asy group	5.8 (5.06)	6.52 (5.44)
CSA asy MF+SCer	10.48 (8.33)	9 (6.97)
CSA asy group	7.16 (6.36)	6.65 (5.17)
FCSA asy MF+SCer	13.31 (11.37)	13.13 (10.25)
FCSA asy Group	7.6 (7.5)	7.21 (6.34)

- BMI : Body mass index,
- MCC : Maximum canal compromise,
- MSCC : Maximum spinal cord compression,
- CSA: Cross-sectional area, FCSA: Functional cross-sectional area, MF: Multifidus muscle, SCer,: Semispinalis Cervicis, Asy : Asymmetry.

Table2 - Results of multivariable regression analyses and MCC

Paraspinal muscle measurements	Regression coefficient	P-value (95% CI)
Max level		
FCSA/CSA MF+SCer	-0.0018	0.032 * [-0.0034 , -0.0001]
FCSA/CSA group	-0.0006	0.212 [-0.0016 , 0.0003]
CSA asy MF+SCer	0.1161	0.006* [0.0334 , 0.1988]
FCSA asy Group	0.0975	0.011* [0.0228 , 0.1722]
FCSA/CSA asy MF+SCer	0.0159	0.755 [-0.0849 , 0.1169]
FCSA/CSA asy group	0.0643	0.013 * [0.0139 , 0.1147]
Level below		
FCSA/CSA MF+SCer	-0.0006	0.280 [-0.0017 , 0.0005]
FCSA/CSA group	-0.00007	0.880 [-0.0009 , 0.0008]
CSA asy MF+SCer	0.0296	0.408 [-0.0409 , 0.1002]
CSA asy Group	0.0129	0.626 [-0.0394 , 0.0653]
FCSA/CSA asy MF+SCer	0.0478	0.302 [-0.0434 , 0.1391]
FCSA/CSA asy group	-0.0266	0.340 [-0.0817 , 0.0283]

- CI= Confidence interval,
- *=P<0.05

Discussion

This study is the first to demonstrate that the degree of cervical muscle fatty infiltration and asymmetry in patients with DCM is associated with the degree of spinal cord compression and canal compromise at the maximum level of compression.

The paraspinal muscles are innervated by the dorsal branches of the adjacent spinal nerves. Therefore, the structure of the paraspinal muscles may be affected by spinal cord compression or nerve root damage (12) which could explain the phenomenon of more obvious fat infiltration and atrophy of the paraspinal muscles at the spinal cord compression segment.

Conclusion

Greater MCC is associated with increased fatty infiltration and greater asymmetry of the deep extensor cervical muscles in patients with DCM. Our findings also suggest that MCC is a better indicator of cervical muscle morphological changes than MSCC. Whether such markers of muscle degeneration can be modified with pre- or post-operation rehabilitation exercise to impact patient heath related quality-of-life scores and neck function warrant further investigations. Given the importance that patients with DCM place on neck pain, this work has important translational significance.

References

1.Nouri A, Tetreault L, Singh A, Karadimas SK, Fehlings MG. Degenerative cervical myelopathy: epidemiology, genetics, and pathogenesis. Spine 2015;40:E675–93. 0362-2436.

2. Anderson JS, Hsu AW, Vasavada AN. Morphology, architecture, and biomechanics of human cervical multifidus. Spine (Phila Pa 1976). 2005;30:E86-E91.

3. Boyd-Clark LC, Briggs CA, Galea MP. Muscle spindle distribution, morphology, and density in longus colli and multifidus muscles of the cervical spine. Spine (Phila Pa 1976). 2002;27:694-701.

4. Chae SH, Lee SJ, Kim MS, Kim TU, Hyun JK. Cervical multifidus muscle atrophy in patients with unilateral unilateral cervical radiculopathy. J Korean Acad Rehabil Med 2010;34:743-51.

5. Elliott J, Jull G, Noteboom JT, Darnell R, Galloway G,Gibbon WW. Fatty infiltration in the cervical extensor muscles in persistent whiplash-associated disorders: a magnetic resonance imaging analysis. Spine (Phila Pa 1976) 2006;31:E847-55.

6. Rezasoltani A, Ahmadipoor A, Khademi-Kalantari K, Javanshir K. The sign of unilateral neck semispinalis capitis muscle atrophy in patients with chronic non-specific neck pain. J Back Musculoskelet Rehabil. 2012;25:67-72.

7. Fortin M, Dobrescu O, Courtemanche M, et al. Association between paraspinal muscle morphology, clinical symptoms, and functional status in patients with degenerative cervical myelopathy. Spine (Phila Pa 1976). 2017;42:232-239.

8. Cloney M, Smith AC, Coffey T, et al. Fatty infiltration of the cervical multifidus musculature and their clinical correlates in spondylotic myelopathy. J Clin Neurosci. 2018;57:208-213.

9. Fehlings MG , Rao SC , Tator CH , et al. The optimal radiologic method for assessing spinal canal compromise and cord compression in patients with cervical spinal cord injury. Part II: results of a multicenter study. Spine 1999; 24: 605 – 13.

10. Fortin M, Battié MC. Quantitative paraspinal muscle measurements: inter-software reliability and agreement using OsiriX and ImageJ. Phys Ther. 2012;92:853-864.

11. Fortin M, Dobrescu O, Courtemanche M, et al Association between paraspinal muscle morphology, clinical symptoms, and functional status in patients with degenerative cervical myelopathy. Spine (Phila Pa 1976). 2017;42:232-239.

12. Hayashi N, Masumoto T, Abe O, Aoki S, Ohtomo K, Tajiri Y. Accuracy of abnormal paraspinal muscle findings on contrast-enhanced MR images as indirect signs of unilateral cervical rootavulsion injury. Radiology. 2002;223:397-402.

Contact

Neda Naghdi (nd.naghdi@gmail.com)
Department of Health, Kinesiology, and Applied Physiology
Concordia University