Cervical spinal stenosis and risk of pulmonary dysfunction

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ABSTRACT

Background: Cervical spinal stenosis (CSS) is defined as an abnormal narrowing of the cervical spinal canal. The essential clinical challenges with CSS are altered cervical spinal cord function and cervical radiculopathy. Phrenic nerve palsy leading to hemidiaphragmatic paresis may be a temporary or persistent phenomenon after cervical cord injury and CSS.

Objective: The objective of the study is to elucidate the potential effect of CSS on the pulmonary functions.

Methods: This is a case–control study which included 40 patients divided into two groups 30 females and 10 males patients with CSS (C5 and above) and 60 healthy volunteers with body mass index (BMI) <30 Kg/m². Pulmonary function tests have been done for all the patients.

Results: The present study showed that VC in expiration (VC EX%), forced expiratory volume (FEV%), forced vital capacity % (FVC%), PEF%, and mean voluntary ventilation % (MVV%), were low in patients CSS compared with the control groups; $P < 0.001$, $P < 0.001$, $P = 0.042$, and $P = 0.037$, respectively. As well, VC EX%, FEV1%, and FVC% were low in male patients in comparison to the controls $P < 0.05$. Besides, there were no significant differences regarding age, BMI, VC in inspiration (VC IN%), PEF%, FEV1/FVC%, and MVV%. Moreover, VC EX%, FEV1%, and FVC% were low in female patients compared to the controls, $P < 0.001$. Whereas, there were no significant differences that had been identified between female patients and female controls regarding age, BMI, VC IN%, PEF%, FEV1/FVC%, and MVV%. On the other hand, weight, height, and MVV% were low in female patients compared to male patients, $P < 0.001$.

Conclusion: Chronic CSS leads to subclinical pulmonary dysfunction due to the involvement of the phrenic nerve. FEV% is the most sensitive parameter in the detection these disorders.

Key Words: Cervical spinal stenosis, pulmonary function tests, spirometry

INTRODUCTION

Cervical spinal stenosis (CSS) is defined as an abnormal narrowing of the cervical spinal canal.[1] The essential clinical challenges with CSS are altered cervical spinal cord function and cervical radiculopathy. Narrowing of the cervical spinal canal may be unassociated with a separate pathologic process affecting the spinal cord or other portions of the nervous system.[2] CSS can result from any process that narrows the canal. It can be congenital and usually produces no clinical disease in childhood. When degenerative conditions of the spine are superimposed on congenital stenosis, the adults may...
begin to show symptoms or signs of degenerative spine disease prematurely in the age of 30–40 years.\[3\] The abnormal cord signal should be juxtaposed to the stenotic segment and not at a different cervical spine level in order to be postulated as related to the spinal stenosis. The prognosis of CSS depends on the function of the patient at the time of diagnosis and the underlying etiology.\[4,5\]

Usually, pulmonary function and respiratory muscles movement are under control of phrenic nerve (C3-C5), intercostal nerves (T2-T10), and sympathetic neurons (T1-L3). The diaphragm is the most important inspiratory muscle, accounting for 75% of the increase in lung volume during quiet inspiration; intercostal, scalene, and sternocleidomastoid muscles contribute the remaining 25%.\[6\] There is little crossover innervation of the right and left hemidiaphragms, and each can contract independently of the other in the event of unilateral phrenic nerve palsy. In the presence of diaphragmatic paresis, inspiration is achieved largely by contraction of intercostal and accessory muscles and expansion of the rib cage.\[7\]

Phrenic nerve palsy leading to hemidiaphragmatic paresis may be a temporary or persistent phenomenon after cervical cord injury and CSS. Transient phrenic nerve palsy appears to have little clinical significance in terms of both objective (respiratory support) and subjective (dyspnea) features. Persistent phrenic nerve palsy is common after acute cervical cord injury which may lead to acute pulmonary dysfunction.\[8\]

Electrophysiologic studies have been conducted on patients with cervical cord stenosis, specifically addressing the phrenic nerve. Muscle action potentials (MAPs) from the diaphragm as an indirect assessment of spinal cord dysfunction. The phrenic nucleus resides in the ventral gray horn from C3 to C5 of the spinal cord. CMAP is elicited from transcranial electrical stimulation of the motor cortex in patients with high cervical myelopathy.\[9\]

Therefore, the aim of the present study was to elucidate the potential effect of CSS on the pulmonary functions.

**METHODS**

This is case–control, randomized, single-center study involved forty patients (30 females + 10 males) with cervical spine stenosis compared with sixty healthy individuals. The patients were recruited from the Consultant Unite of Department of Neurosurgery in cooperation with Department of Orthopedic of AL-Imamian AL-Kadhymiyian Medical City during the period from November 2018 to May 2019, Baghdad Iraq. The recruited patients were aged 25–70 years, body mass index (BMI) <30 Kg/m² with duration of their disease ranged 1–24 months. The study was approved by the Institutional Review Board of the College of Medicine, Al-Nahrain University, and informed consent was obtained from all the participants.

All patients were clinically examined and diagnosed by magnetic resonance imaging and other radiological diagnostic tools such as computing tomography scanning and X-ray of the cervical spine to determine the level of cervical cord compression. The diagnosis was supported by transcranial magnetic stimulation technique.

**Inclusion criteria**

Any patients with cervical canal stenosis with duration of 1–24 months with or without pulmonary dysfunctions were included in the study.

**Exclusion criteria**

Obesity, chronic smoking, obstructive airway diseases, restrictive airway diseases, malignancy, congenital spinal stenosis, peripheral neuropathy, diabetes mellitus, metabolic diseases, psychiatric, and mental disorders were excluded from the study.

**Assessment of pulmonary functions**

Vital capacity (VC%) in inspiration (VC IN), VC in expiration (VC EX), forced expiratory volume (FEV1), forced VC (FVC), forced expiratory flow FVC, Peak expiratory flow rate PEF, and mean voluntary ventilation (MVV), and ratio of FEV1 to FVC (FEV1/FVC) were estimated by spirometry (spy-ROM-uh-tree, USA). All predicted values of the spirometric parameters were based on the patient’s height, age, and sex. The percentage of predicted values were used for comparison of the results (% predicted = measured + predicted)\[10\]

**Statistical analysis**

Data presented as mean ± standard deviation and unpaired Student’s t-test was used to determine the significance of differences. Data analysis was done using SPSS (IBM SPSS Statistics for Windows version 20.0, 2014, IBM, Corp., Armonk, NY, USA). P < 0.05 was considered statistically significant.

**RESULTS**

The present study showed that VC EX%, FEV1%, FVC%, PEF%, and MVV%, were low in patients CSS compared with the control groups P < 0.001, P < 0.001, P < 0.001, P = 0.042, and P = 0.037, respectively. While, there were no significant differences that had been identified between patients and controls regarding age, weight, height, BMI, VC IN%, and FEV1/FVC%, Table 1.

As well, VC EX%, FEV1%, and FVC% were low in male patients in comparison to the controls, P < 0.05. Besides,
Moreover, VC EX%, FEV1%, and FVC% were low in female patients compared to the controls \( P < 0.001 \). Whereas, there were no significant differences that had been identified between female patients and female controls regarding age, BMI, VC IN%, PEF%, FEV1/FVC%, and MVV% [Table 2].

On the other hand, weight, height, and MVV% were low in female patients compared to male patients, \( P < 0.001 \) [Table 4].

**DISCUSSION**

The present study illustrated insignificant differences in the anthropometric variables in patients with CSS compared to the control as revealed by Toyoda et al.\(^{[11]}\). Besides, the findings of the present study showed that VC%, FVC%, PEF%, FEV1%, and MVV% of patients with CSS were low compared to the controls. It has been reported that dysfunctional breathing is the main cause of morbidity and mortality after traumatic injury of the cervical spinal cord and often necessitates assisted ventilation, thus stressing the need to develop strategies to restore breathing. Cervical interneurons that form synapses on phrenic motor neurons, which control the main inspiratory muscle, can modulate phrenic motor output and diaphragmatic function.\(^{[12]}\) Therefore, patients with compressive CSS lead to the impairment of respiratory function.\(^{[13]}\) Indeed, CSS leads to weakness of diaphragm and intercostal muscles due to partial injury to the phrenic nerve and cervical nerves, respectively, as well as noteworthy reduction of sympathetic neurons activity.\(^{[14]}\) The extent of respiratory complications depends on the level of spinal stenosis, and the degree of motor impairment as VC and forced expired volume (FEV1) were normal in patients with low-level paraplegia.\(^{[15]}\) In the present study, there was no significant difference between FEV1/FVC% of patients with CSS which might due to subclinical myelopathy in the affect patients since; Aljuboori and Boakya confirmed that only advanced CSS leads to autonomic and respiratory dysfunctions.\(^{[16]}\) On the other hand, MVV% was significantly low in females in comparison to males’ patients. This is in accordance with the study done by Budhiraja et al.; this can be attributed to the fact that the men have bigger lungs for the same height as compared to females. Another contributing factor could be the greater strength of respiratory muscles in males.\(^{[17]}\)

Furthermore, this study confirmed that FEV1% was high specific and sensitive among other parameters of spirometry in patients with CSS since; the classification of the severity of obstructive and restrictive pulmonary impairments based on the grade of reduction in FEV1.\(^{[18]}\)

Therefore, various recommendations are reported about the management of respiratory complications associated with CSS. They include positioning and postural changes, breathing techniques, spontaneous cough and cough

### Table 1: Comparison of data between all patients and all controls by unpaired \( t \)-test

| Parameter | All patients \( n = 40 \) Mean±SD | All controls \( n = 60 \) Mean±SD | \( P \) |
|-----------|----------------------------------|----------------------------------|------|
| Age (years) | 50.05±12.5 | 49.92±11.04 | 0.955 |
| Weight (kg) | 67.05±8.04 | 70.42±9.36 | 0.086 |
| Height (cm) | 159.93±8.99 | 162.28±9.49 | 0.217 |
| BMI (kg/m\(^2\)) | 26.21±2.29 | 26.71±2.29 | 0.282 |
| VC IN (%) | 90.48±14.35 | 94.33±13.58 | 0.177 |
| VC EX (%) | 79.23±11.24 | 90.86±11.8 | <0.001 |
| FEV1 (%) | 89.16±15.95 | 105.48±14.04 | <0.001 |
| FVC (%) | 77.26±11.2 | 90.12±16.29 | <0.001 |
| PEF (%) | 85.22±14.82 | 93.21±21.32 | 0.042 |
| FEV1/FVC (%) | 95.72±4.08 | 96.56±3.89 | 0.302 |
| MVV (%) | 98.42±16.77 | 106.14±18.55 | 0.037 |

SD: Standard deviation, BMI: Body mass index, VC IN: Vital capacity inspiration, VC EX: Vital capacity in expiration, FEV1: Forced expiratory volume, FVC: Forced vital capacity, PEF: Peak expiratory flow, MVV: Mean voluntary ventilation

### Table 2: Comparison of data between male patients and all controls by unpaired \( t \)-test

| Parameter | Male patients \( n = 30 \) Mean±SD | Male controls \( n = 60 \) Mean±SD | \( P \) |
|-----------|----------------------------------|----------------------------------|------|
| Age (years) | 56.5±12.07 | 52.9±11.38 | 0.541 |
| Weight (kg) | 75.0±6.38 | 73.87±10.46 | 0.749 |
| Height (cm) | 170.5±5.97 | 168.4±7.89 | 0.446 |
| BMI (kg/m\(^2\)) | 25.78±1.44 | 25.94±2.43 | 0.850 |
| VC IN (%) | 84.7±14.11 | 89.94±12.36 | 0.269 |
| VC EX (%) | 74.71±7.51 | 88.32±11.71 | 0.001 |
| FEV1 (%) | 88.18±12.5 | 105.81±16.36 | 0.004 |
| FVC (%) | 73.51±9.75 | 88.9±13.08 | 0.002 |
| PEF (%) | 89.59±14.02 | 92.1±16.41 | 0.667 |
| FEV1/FVC (%) | 95.36±3.11 | 95.9±4.33 | 0.715 |
| MVV (%) | 119.11±16.67 | 119.2±15.24 | 0.987 |

SD: Standard deviation, BMI: Body mass index, VC IN: Vital capacity inspiration, VC EX: Vital capacity in expiration, FEV1: Forced expiratory volume, FVC: Forced vital capacity, PEF: Peak expiratory flow, MVV: Mean voluntary ventilation

### Table 3: Comparison of data between female patients and all controls by unpaired \( t \)-test \( n = 30 \)

| Parameter | Female patients Mean±SD | Female controls Mean±SD | \( P \) |
|-----------|-------------------------|-------------------------|------|
| Age (years) | 48.23±12.3 | 64.93±10.1 | 0.655 |
| Weight (kg) | 64.4±6.73 | 66.97±6.65 | 0.143 |
| Height (cm) | 156.4±6.8 | 156.17±6.59 | 0.893 |
| BMI (kg/m\(^2\)) | 26.35±2.52 | 27.48±1.86 | 0.051 |
| VC IN (%) | 92.4±14.14 | 98.73±13.49 | 0.082 |
| VC EX (%) | 80.74±11.96 | 93.4±11.53 | <0.001 |
| FEV1 (%) | 89.48±16.76 | 105.25±11.54 | <0.001 |
| FVC (%) | 78.5±13.96 | 92.21±12.29 | <0.001 |
| PEF (%) | 83.74±15.02 | 94.32±25.55 | 0.056 |
| FEV1/FVC (%) | 95.84±4.39 | 97.22±3.33 | 0.177 |
| MVV (%) | 91.52±11.79 | 93.08±10.72 | 0.584 |

SD: Standard deviation, BMI: Body mass index, VC IN: Vital capacity inspiration, VC EX: Vital capacity in expiration, FEV1: Forced expiratory volume, FVC: Forced vital capacity, PEF: Peak expiratory flow, MVV: Mean voluntary ventilation
assistance, suctioning, respiratory muscle training, ventilation techniques and education, vaccination agents for influenza and pneumococcal infections, and pharmacological interventions. Furthermore, the modifiable risk factors must be addressed, particularly in patients with acute but not in CSS.[20]

### CONCLUSION

Chronic CSS leads to subclinical pulmonary dysfunction due to the involvement of the phrenic nerve. FEV% is the most sensitive parameter in the detection of these disorders.

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Nil.

### Conflicts of interest

There are no conflicts of interest.

### Ethical conduct of research

This study was approved by the Institutional Review Board / Ethics Committee. The authors followed applicable EQUATOR Network (http://www.equator-network.org/) guidelines during the conduct of this research project.

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