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Subclinical respiratory dysfunction in chronic cervical cord compression: a pulmonary function test correlation

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OBJECTIVE Respiratory abnormalities are well documented in acute spinal cord injury; however, the literature available for respiratory dysfunction in chronic compressive myelopathy (CCM) is limited. Respiratory dysfunction in CCM is often subtle and subclinical. The authors studied the pattern of respiratory dysfunction in patients with chronic cord compression by using spirometry, and the clinical and surgical implications of this dysfunction. In this study they also attempted to address the postoperative respiratory function in these patients.

METHODS A prospective study was done in 30 patients in whom cervical CCM due to either cervical spondylosis or ossification of the posterior longitudinal ligament (OPLL) was diagnosed. Thirty age-matched healthy volunteers were recruited as controls. None of the patients included in the study had any symptoms or signs of respiratory dysfunction. After clinical and radiological diagnosis, all patients underwent pulmonary function tests (PFTs) performed using a standardized Spirometry Kit Micro before and after surgery. The data were analyzed using Statistical Software SPSS version 13.0. Comparison between the 2 groups was done using the Student t-test. The Pearson correlation coefficient was used for PFT results and Nurick classification scores. A p value < 0.05 was considered significant.

RESULTS Cervical spondylotic myelopathy (prolapsed intervertebral disc) was the predominant cause of compression (n = 21, 70%) followed by OPLL (n = 9, 30%). The average patient age was 45.06 years. Degenerative cervical spine disease has a relatively younger onset in the Indian population. The majority of the patients (n = 28, 93.3%) had compression at or above the C-5 level. Ten patients (33.3%) underwent an anterior approach and discectomy, 11 patients (36.7%) underwent decompressive laminectomy, and the remaining 9 underwent either corpectomy with fusion or laminoplasty.

The mean preoperative forced vital capacity (FVC) (65%) of the patients was significantly lower than that of the controls (88%) ($p < 0.001$). The mean postoperative FVC (73.7%) in the patients showed significant improvement compared with the preoperative values ($p = 0.003$). The mean postoperative FVC was still significantly lower than the control value ($p = 0.002$). The mean preoperative forced expiratory volume in 1 second (FEV_1) (72%) of the patients was significantly lower than that of the controls (96%) ($p < 0.001$). The mean postoperative FEV_1 (75.3%) in the cases showed no significant improvement compared with the preoperative values ($p = 0.212$). The mean postoperative FEV_1 was still significantly lower than the control value ($p < 0.001$). The mean postoperative FEV_1/FVC was not significantly different from the control value ($p = 0.204$). The mean postoperative peak expiratory flow rate was significantly lower than the control value ($p = 0.01$). The mean postoperative maximal voluntary ventilation was still significantly lower than the control value ($p < 0.001$). On correlating the FVC and Nurick scores using the Pearson correlation coefficient, a negative correlation was found.

CONCLUSIONS There is subclinical respiratory dysfunction and significant impairment of various lung capacities in patients with CCM. The FVC showed significant improvement postoperatively. Respiratory function needs to be evaluated and monitored to avoid potential respiratory complications.

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KEY WORDS spirometry; chronic compressive myelopathy; cord compression; pulmonary function test; subclinical respiratory depression; cervical spondylotic myelopathy

ABBREVIATIONS CCM = chronic compressive myelopathy; CSM = cervical spondylotic myelopathy; FEV_1 = forced expiratory volume in 1 second; FEV_1/FVC = ratio of FEV_1 to FVC; FVC = forced vital capacity; MVV = maximal voluntary ventilation; OPLL = ossification of the posterior longitudinal ligament; PEFR = peak expiratory flow rate; PFT = pulmonary function test; VC = vital capacity.

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Respiratory dysfunction is one of the leading causes of morbidity and mortality after cervical spine injury.[1,4,5,7,10–12,14,16,19] Respiratory abnormalities and complications are well documented after acute spinal cord injury; however, the literature for respiratory abnormalities in patients with chronic cord compression is limited. The aim of this study was to look for potential respiratory dysfunction and for surgical outcomes in patients with cervical chronic compressive myelopathy (CCM).

Review of the Literature

Often the respiratory changes in patients with chronic cord compression are subtle and subclinical.[13,17] The studies considered in this review suggest that the abnormality is subclinical, can involve inspiratory or expiratory flow differently, and can be complete or incomplete.

Patients with chronic cervical cord compression often do not have overt signs and symptoms of respiratory dysfunction—hence, respiratory function is often ignored in these patients.[13,17] It is important to evaluate these patients for subclinical respiratory dysfunction because of their high risk of intraoperative and postoperative respiratory complications.[17]

Methods

Approval was obtained from the Institute's ethics committee for this study in humans. A prospective study was done in 30 patients in whom cervical CCM due to either cervical spondylosis or ossification of the posterior longitudinal ligament (OPLL) was diagnosed. Thirty age- and sex-matched, healthy volunteers were recruited as controls. None of the patients included in the study had any symptoms or signs of respiratory dysfunction. Patients with traumatic injury to the cervical spine and patients undergoing repeat surgery were not included in this study.

All patients were clinically examined and evaluated with MRI with or without CT scanning of the cervical spine to determine the level of compression. Nurick classification was used to assess the neurological status before and after surgery. All patients underwent pulmonary function tests (PFTs) using a standardized Spirometry Kit Micro (COSMED) before and after surgery. If a cervical collar was being used, it was removed during the procedure. The PFT was conducted in the neurophysiology laboratory by a qualified physiologist with special interest in neurophysiology and respiratory physiology. For those patients who could not be moved to the laboratory, bedside PFT was conducted by one of the medical doctors from the neurophysiology laboratory. The laboratory had normative data for age- and sex-matched subjects. The controls were healthy volunteers—hence, reading and reporting of the results were always done by neurophysiologists.

As per our standard policy, PFT is done as part of the preoperative planning in these patients, and the neurophysiologist was not aware of the extent of the disease. Hence, no specific blinding was performed. The spirometric parameters measured were forced vital capacity (FVC), forced expiratory volume in 1 second (FEV_1), ratio of FEV_1 to FVC (FEV_1/FVC), peak expiratory flow rate (PEFR), and maximal voluntary ventilation (MVV). The predicted values of the spirometric parameters were based on the patient's height, age, and sex. The percentage of predicted values was used for comparison. The data were analyzed using Statistical Software SPSS version 13.0. All values were expressed as the mean ± SD. Comparison between the 2 groups was done using the Student t-test. The relationship between PFT and Nurick scores was studied using the Pearson correlation coefficient. A p value < 0.05 was considered significant. Postoperatively PFT was done at an average of 17 weeks after the surgery (range 5–44 weeks). The pre- and postoperative spirometric values were obtained and compared with those of the control group.

Results

Thirty patients were included in the study. The spirometric values (percentage of predicted value) were compared with 30 healthy controls.

Table 1 shows the age distribution of the sample. The average age of the patients was 45.06 years (range 30–67 years) and the average age of the controls was 42.8 years (range 27–62 years). Nineteen (63.3%) patients were in the 30- to 50-year age group. There was no significant difference between the mean age of the patients and the controls (Pearson correlation coefficient = 0.928). The average body mass index of the patient and control groups was 23.36 and 24.12, respectively, with no significant difference between the 2 groups (p = 0.243). The majority of the patients were male.

Table 2 shows the various causes of cord compression. The predominant cause of compression was cervical spondylotic myelopathy (CSM; prolapsed intervertebral disc) (n = 21, 70%), followed by OPLL (n = 9, 30%). All patients had presented clinically with signs and symptoms of myelopathy.

Table 3 shows the levels of compression. The majority of the patients (93.3%) had compression at or above the C-5 level. The average duration of signs and symptoms was 20.36 months (range 1–204 months).

Treatment and Outcomes

All patients underwent surgery. The various surgical procedures that were performed are detailed in Table 4. The neurological grade of the patients pre- and postoperatively are as shown in Table 5. The majority of the patients improved neurologically, as is evident from this table. Preoperatively only 2 patients were categorized in the good neurological grade (Grades 0–2). Postoperatively the number increased to 15. Postoperatively PFTs were done at an

TABLE 1. Age distribution in adult patients with cervical CCM

Age Group (yrs)	No. of Pts	%	No. of Controls	%
21–30	1	3.3	1	3.3
31–40	10	33.3	13	43.3
41–50	8	26.7	5	16.7
51–60	6	20.0	6	20.0
61–70	5	16.7	5	16.7
Total	30	100	30	100

Pts = patients.

TABLE 2. Causes of cord compression in patients with cervical CCM

Etiology	No. of Pts	%
CSM	21	70.0
OPLL	9	30.0
Total	30	100

average of 17 weeks after the surgery (range 5–44 weeks). The preoperative and postoperative spirometric values obtained and their comparison with those of the control group is as follows.

Pulmonary Function Test Findings

Forced Vital Capacity

As shown in Fig. 1, the mean preoperative FVC (65%) of the patients was significantly lower than that of the controls (88%) ($p < 0.001$). The mean postoperative FVC (73.7%) in the patients showed significant improvement compared with the preoperative values ($p = 0.003$). The mean postoperative FVC was still significantly lower than the control value ($p = 0.002$).

Forced Expiratory Volume in 1 Second

As shown in Fig. 2, the mean preoperative FEV_1 (72%) of the patients was significantly lower than that of the controls (96%) ($p < 0.001$). The mean postoperative FEV_1 (75.3%) in the cases showed no significant improvement compared with the preoperative values ($p = 0.212$). The mean postoperative FEV_1 was still significantly lower than the control value ($p < 0.001$).

Ratio of FEV_1 to FVC

As shown in Fig. 3, the mean preoperative FEV_1/FVC (114.5%) of the patients was almost equal to that of the controls (114.6%) ($p = 0.983$). The mean postoperative FEV_1/FVC (109%) was also similar compared with the preoperative values ($p = 0.453$). The mean postoperative FEV_1/FVC was not significantly different from the control value ($p = 0.204$).

Peak Expiratory Flow Rate

As shown in Fig. 4, the mean preoperative PEFR (56.6%) of the patients was significantly lower than that of the controls (68.3%) ($p = 0.032$). The mean postoperative PEFR (55.1%) in the cases showed no significant improvement compared with the preoperative values ($p = 0.64$). The mean postoperative PEFR was significantly lower than the control value ($p = 0.01$).

Maximal Voluntary Ventilation

As shown in Fig. 5, the mean preoperative MVV (67%) of the patients was significantly lower than that of the controls (97%) ($p < 0.001$). The mean postoperative MVV (68.8%) in the cases showed significant improvement compared with the preoperative values ($p = 0.64$). The mean postoperative MVV was still significantly lower than the control value ($p < 0.001$).

TABLE 3. Level of compression in patients with cervical CCM

Level of Compression	No. of Pts	%
At/above C-5	28	93.3
Below C-5	2	6.7
Total	30	100

TABLE 4. Treatment in patients with cervical CCM

Surgical Procedure	No. of Pts	%
Anterior approach & discectomy	10	33.3
Corpectomy w/ fusion	5	16.7
Decompressive laminectomy	11	36.7
Laminoplasty	4	13.3
Total	30	100

Relationship Between FVC and Nurick Scores

As shown in Fig. 6, on correlating the FVC and Nurick scores using the Pearson correlation coefficient, a negative correlation was found—i.e., higher FVC levels were associated with lower Nurick scores (good grades). There were no intraoperative or postoperative respiratory complications.

Discussion

In the present study the patients were much younger than the Western population, and the level of compression in the majority was at C-5 and above. None of the patients had any comorbidities or premorbid respiratory dysfunction. The pulmonary function testing was done by a physiologist with specific interest in pulmonary physiology. Pulmonary function testing was done for all patients admitted with cervical spine pathology. The present study showed that there is subclinical respiratory dysfunction in the form of impairment of FVC, FEV_1, FEV_1/FVC, PEFR, and MVV in patients with cervical CCM. The impairment of these lung capacities was significant in comparison with healthy controls. Postoperatively the FVC showed significant improvement, possibly due to improvement in function of the diaphragm. However, the other parameters did not show any significant change. The study also showed that although there was a significant improvement in the FVC values, the improvement did not equal the control values. The results were commensurate to the earlier studies by Toyoda et al.[17] and Ishibe and Takahashi,[9] in which they reported lower values for % vital capacity (%VC), %FVC, PEFR, and increased respiratory rate and expiratory velocities at 50% and 25% of vital capacity. Yanaka et al.[18] re-

TABLE 5. Neurological grade pre- and postoperatively in patients with cervical CCM

Nurick Grade	Preop	Postop
0	0	1
1	1	4
2	1	10
3	12	12
4	14	2
5	2	1

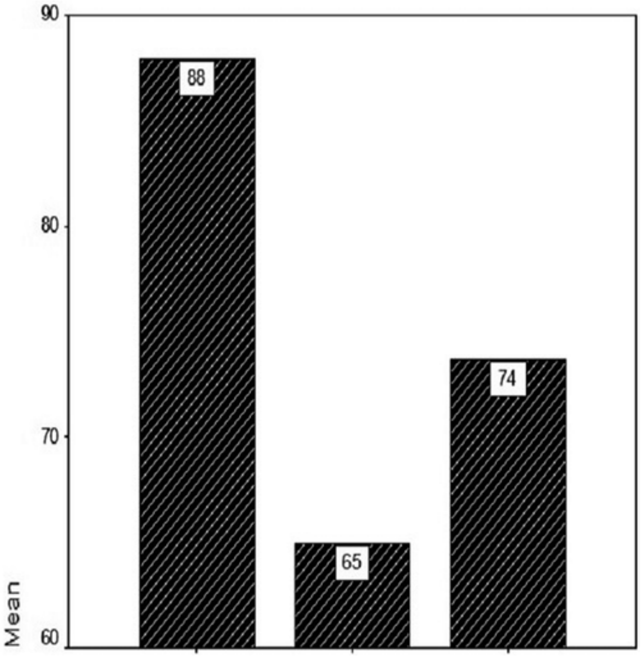

FIG. 1. Graph showing the mean FVC in the control population (*left*) and in the patient population pre- (*center*) and postoperatively (*right*).

ported low tidal volumes that showed significant improvement after surgery. Our study also shows that FVC tends to be lower in patients with worse neurological grades.

Toyoda et al.[17] have speculated that respiratory dysfunction associated with cervical CCM may be due either to less severe damage to the respiratory tracts due to resistance to the chronic compressive stress, or to the potential compensatory reactions of the cervical spinal cord to preserve the respiratory system. In terms of the mechanism of respiratory dysfunction in patients with cervical CCM, several authors have reported impairment of anterior C5–T1 nerve roots that supply motor, sensory, and autonomic fibers to the upper thorax, shoulder, and arms; however, the exact mechanism of the impaired but preserved respiratory function in CCM awaits elucidation.[17]

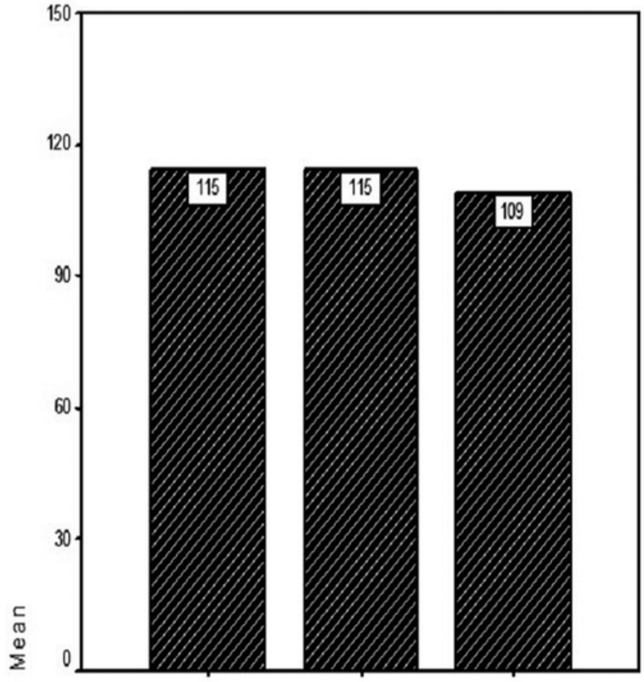

FIG. 3. Graph showing the mean FEV_1/FVC in the control population (*left*) and in the patient population pre- (*center*) and postoperatively (*right*).

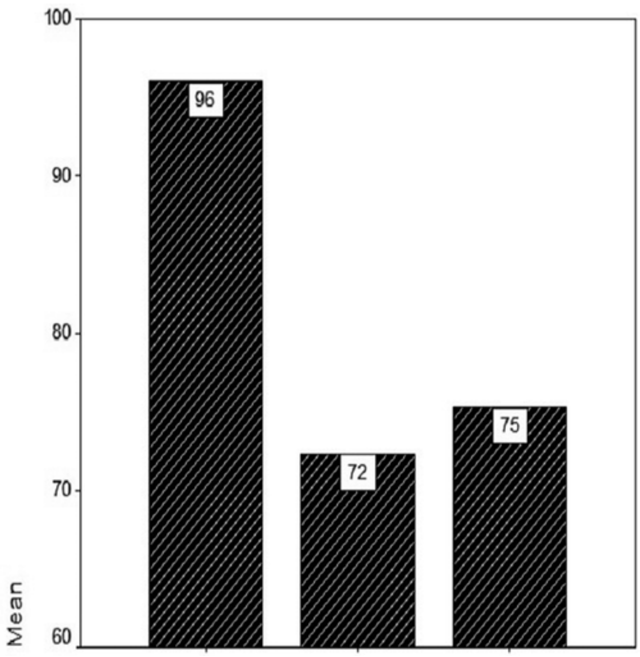

FIG. 2. Graph showing the mean FEV_1 in the control population (*left*) and in the patient population pre- (*center*) and postoperatively (*right*).

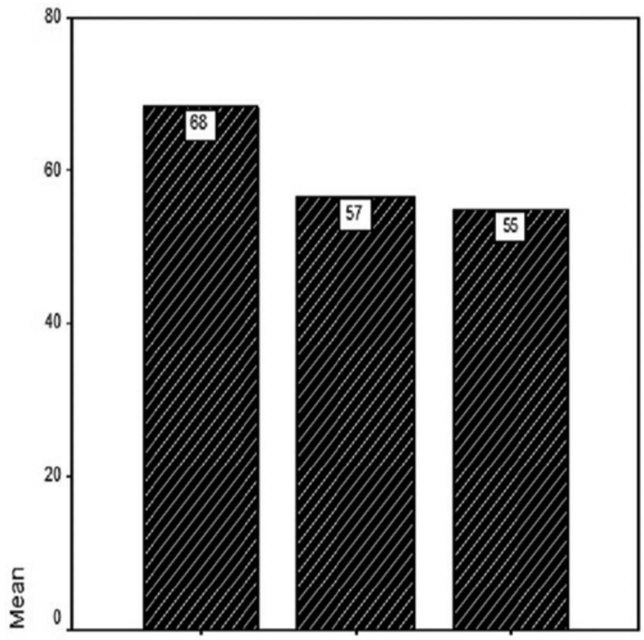

FIG. 4. Graph showing the mean PEFR in the control population (*left*) and in the patient population pre- (*center*) and postoperatively (*right*).

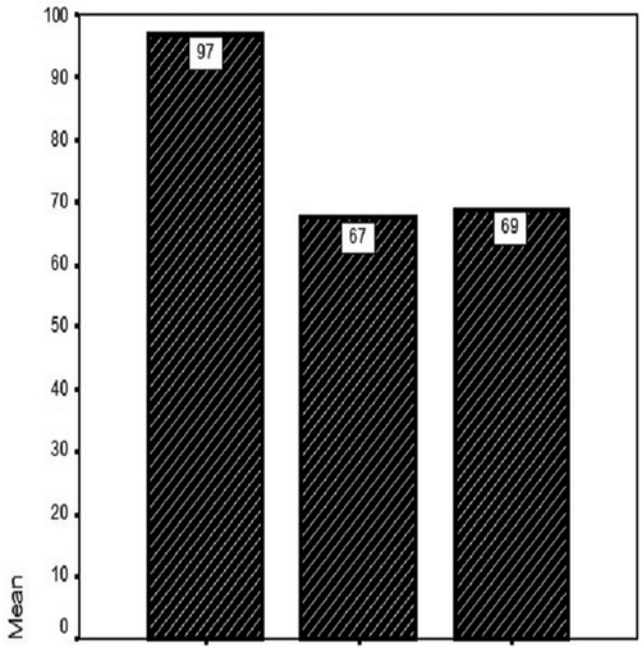

FIG. 5. Graph showing the mean MVV in the control population (*left*) and in the patient population pre- (*center*) and postoperatively (*right*).

Ishibe and Takahashi[9] quote a study in which it is reported that %VC significantly decreased in patients with low neurological scores compared with those with moderate to high scores, and that respiratory and psychological complications were higher in the former group of patients.[8] Respiratory insufficiency has been cited as a major postoperative complication associated with cervical spine surgery, especially performed via an anterior cervical approach,[2,15] which was partly because the surgery compromised airway function. Additionally, in cases requiring posterior cervical surgery, placing a patient prone may compromise respiratory function. Preoperative subclinical respiratory dysfunction can also lead to intraoperative or postoperative respiratory insufficiency. In summary, there is a possibility of a subclinical disorder in respiratory function in patients with cervical CCM. Although the outcome associated with the disorder would be mild, without significant symptoms, its subclinical pathological background should be considered in postoperative management to avoid the potential respiratory complications in such patients.[3,9]

Ishibe and Takahashi[9] also reported that the higher the level of lesion and with multiple levels of compression, the more impairment there is of %VC. The %VC also correlated with the preoperative neurological score. Respiratory dysfunction is a well-known serious complication after cervical spine injury, causing significant morbidity and mortality. However, respiratory function in cervical CCM has not been studied extensively. It is known that vital capacity is affected both by compliance of the lungs and chest wall and by the strength of the respiratory muscles, of which the diaphragm is the main inspiratory muscle, aided by the intercostal muscles. The diaphragm is innervated by the phrenic nerve, which originates from C-3 to C-5 nerve roots, whereas the intercostals are supplied by

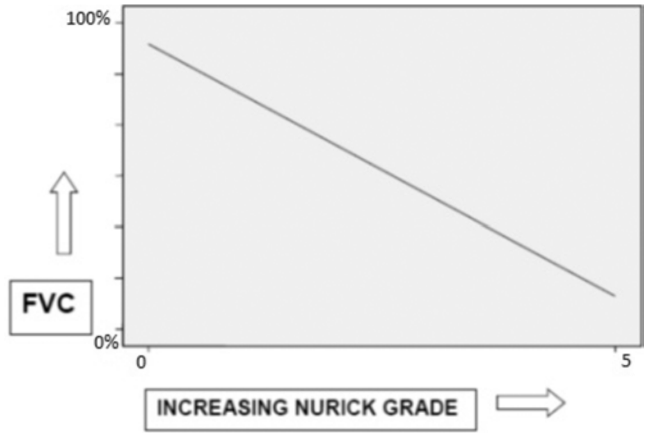

FIG. 6. Graph showing a negative correlation of FVC and Nurick scores.

the intercostal nerves originating from the thoracic segments. Impulses from the higher respiratory centers to the respiratory motor neurons are carried by the reticulospinal tracts located in the anterior part of the spinal cord. It has been shown that damage to these tracts during cervical cordotomies can impair spontaneous respiratory activity. Injury to the cervical cord at or above C-5 causes reduction in the FVC as well as other lung capacities. However, because the diaphragm is the main inspiratory muscle, reduction in FVC is most marked.

Yanaka et al.[18] state that the scales routinely used for measuring the neurological status take into account the motor, sensory, and urinary disturbances. The tracts subserving these functions (the corticospinal, the lateral spinothalamic, and the posterior column tracts) are located in the posterior two-thirds of the spinal cord in the axial plane. Hence, these scores may not be indicative of the degree of respiratory impairment caused by the damage to the descending respiratory tracts, which are located in the most anterior part of the spinal cord. So Yanaka et al. suggest that measurement of lung volumes can be a method of evaluating the function of the spinal cord.

The pathophysiological cause of respiratory dysfunction may be damage to the segments from which the phrenic nerves originate, loss of motor input to the intercostals from the higher centers, loss of muscle tone, and loss of sympathetic input. However, the exact pathophysiology is not known. The reason for subclinical respiratory dysfunction may be either a milder stress as a result of the chronic nature of the compression, predominant compression of the posterior two-thirds of the cord, or plasticity of the respiratory pathways. Although the respiratory dysfunction was subclinical, it assumes importance in view of the potential intraoperative or postoperative respiratory complications like atelectasis and pneumonia. Respiratory complications in anterior cervical spine surgery are known to be mainly due to airway problems, which can be aggravated by the subclinical respiratory dysfunction or vice versa. Fujibayashi et al.[6] reported bilateral phrenic nerve palsy as a complication of anterior decompression and fusion for cervical OPLL. They opined that the complication may be due to either bilateral C-4 nerve root stretching, iatrogenic injury of the gray matter in the ven-

tral horn, alteration of blood circulation related to spinal edema, or reimpingement on the spinal cord at the cranial part of the decompression site. Also, positioning a patient prone for posterior cervical surgery may accentuate the respiratory dysfunction.[9]

We suggest that spirometry is not a one-time test and that repeated evaluation at longer follow-up may show more improvement and can be useful in predicting the beneficial effect of the decompression.

Conclusions

There is subclinical respiratory dysfunction in patients with CCM, and there is significant impairment of the various lung capacities. In this study the FVC showed significant improvement postoperatively. Repeat spirometric evaluation at later periods may show further improvement. Respiratory function needs to be evaluated and monitored to avoid potential respiratory complications, both intraoperatively and postoperatively. Pulmonary function tests may also be used as a tool for evaluation and monitoring of the cervical spinal cord.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Bhagavatula, Bhat. Acquisition of data: Maste, Vilanilam, Sathyaprabha. Analysis and interpretation of data: Bhagavatula, Bhat, Sasidharan, Maste, Vilanilam, Sathyaprabha. Drafting the article: Bhagavatula, Mishra. Critically revising the article: Bhagavatula, Bhat, Mishra. Reviewed submitted version of manuscript: Bhagavatula, Mishra, Sathyaprabha. Approved the final version of the manuscript on behalf of all authors: Bhagavatula. Statistical analysis: Sasidharan, Mishra, Maste, Vilanilam. Administrative/technical/material support: Bhagavatula, Bhat, Sasidharan, Sathyaprabha. Study supervision: Bhagavatula.

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