

## Effect of Sub-axial Cervical Lateral Mass Screw Fixation on Functional Outcome in Patients with Cervical Spondylotic Myelopathy

### Abstract

**Background:** The role of laminectomy alone as an etiology of postoperative cervical instability is well known. Cervical sagittal malalignment of the spine has been linked to unfavorable functional outcome, so the effect of restoration of sagittal spinal alignment on functional outcomes and treatment effectiveness has recently gained attention. **Objective:** This is a prospective observational study aims to observe the possible relation between cervical sagittal alignment and functional outcomes following sub-axial cervical lateral mass screw fixation in patients with cervical spondylotic myelopathy. **Patients and Methods:** Thirty patients were included in this study all suffering from cervical spondylotic myelopathy (CSM) who underwent cervical laminectomy and screw-rod fixation and followed up over 6 months. Functional outcome accessed using Nurick myelopathy score and neck disability index (NDI). We also used the Cobb angle method ( $C_2-C_7$ ) as a parameter for radiographic assessment of the cervical sagittal alignment which was measured preoperatively and postoperatively on lateral neutral views of cervical X-ray. **Results:** All the patients underwent cervical laminectomy and fixation in a range of 3–5 levels. Two intraoperative facet fractures and four facet joint violations were observed. All the patients were followed-up for at least 6 months. There were significant improvements of the motor power (88.5%), Nurick score (90%), and NDI (90%) postoperatively. The mean preoperative Cobb angle for all patients was  $-8.51^\circ \pm 14.07^\circ$  standard deviation (SD) which changed to  $-10.29 \pm 12.43$  SD at the end of follow-up. **Conclusion:** Combing posterior decompression with lateral mass screw–rod in patients with CSM was effective in improving or at least maintaining cervical alignment with the good functional outcome.

**Keywords:** Cervical sagittal alignment, functional outcomes, sub-axial lateral mass fixation

### Introduction

As the cervical spine is considered the most mobile part of the spinal column, a wide range of normal alignment has been described.<sup>[1]</sup> Cervical sagittal malalignment has received increased attention in the literature as it has found to be linked to clinical symptoms, degenerative diseases progression as well as clinical outcomes.<sup>[2]</sup> Patients suffering from cervical spondylotic myelopathy (CSM) treated by posterior cervical decompression alone without fixation are considered among the most common causes of cervical malalignment (iatrogenic cervical kyphosis), so posterior cervical fixation became an ideal procedure in the surgical management of the unstable spondylotic cervical spine.<sup>[3]</sup>

Posterior fixation using lateral mass screw fixation has been widely accepted as a simple, safe, and effective method with a high rate of fusion. Due to its ease of use, as well as its

good intrarater and interrater reliability, Cobb angle method remains the clinical mainstay for the measurement of cervical lordosis.<sup>[4]</sup>

The aim of this study is to access the effect of the sub-axial cervical lateral mass screw fixation on cervical sagittal alignment, and its impact on the functional outcome in patients with CSM.

### Patients and Methods

This is a prospective observational study of pre- and post-operative clinical and radiological data of 30 patients admitted to our hospital suffering from CSM with instability and/or kyphosis, all patients were operated on for posterior lateral mass fixation with fusion and laminectomy (long-segment fixation  $\geq 3$  segments).

Patients that clearly documented physical examination findings consistent with progressive myelopathy or myeloradiculopathy who failed nonoperative

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measures and radiographic (magnetic resonance image [MRI]) confirmation of cord compression at three or more cervical levels with kyphotic curve or lordotic curve with evidence of instability were included in this study.

Any patient underwent surgery for CSM was included, but it is not the aim of our study to discuss these criteria, our study aims to access the relation between the changes in the sub-axial sagittal alignment represented by Cobb angle and the functional outcome represented in the motor power, Nurick myelopathy scale, and neck disability index (NDI).

Patients with inability to give informed consent, stenotic single level, or patients whose presenting complaint was axial neck pain alone, traumatic fractures, tumor, metabolic disorders, and patients who had concurrent anterior cervical spine procedures were excluded from this study.

### Functional evaluation

Complete general and neurological examinations were performed. Evaluation of the patient function was done using Modified Medical Research Council for motor power evaluation, Nurick score for evaluation of the myelopathy, and the functional disability was evaluated using NDI [Table 1].

### Radiographic evaluation

Preoperatively, sub-axial Cervical sagittal alignment was assessed using C2–C7 Cobb's angle, measured by formal Cobb methods in standard lateral standing radiographs and/or CT with sagittal reconstruction, signs of instability were detected using dynamic X-ray films [Figure 1a]. MRI was done for all patients for detection of radiological signs of spondylotic myelopathy [Figure 1b]. Postoperatively, the follow-up radiographs were obtained (1–2 days), and at least 6 months after surgery, the cervical sagittal alignment was evaluated.

## Results

### Demographic data

Thirty patients who underwent posterior cervical laminectomy with lateral mass screw-rod fixation were analyzed. There were 21 male and 9 female patients [Table 2]. The mean age was 57.7 years  $\pm$  6.20, ranges from 45 to 72 years [Table 3]. A total of 226 screws were placed. All the thirty patients showed neither intraoperative vascular injury nor neural injury or dural tears. There were 2 lateral masses of 2 separate patients were skipped because of lateral mass fracture, a C4 lateral mass in one patient and a C5 lateral mass of the other one. One screw violated the foramen transversarium was revealed on the follow-up, but without penetration of the vertebral artery, the patient was clinically free, and there was no need for further investigations or redirection otherwise there were no vertebral artery injuries. For the specific placement of pedicle screws at the C7 level, a total of 10 screws ( $n = 5$  patients) were placed in the C7 pedicles. Patients were followed up for at least 6 months; all patients had standard lateral and anteroposterior

**Table 1: Functional evaluation**

Score	Function
mMRC	For motor power evaluation
Nurick score	For evaluation of the myelopathy
NDI	For evaluation of the functional disability

mMRC – Modified Medical Research Council; NDI – Neck disability index

**Table 2: Sex distribution**

Sex	n (%)	P
Male	21 (70)	0.002*
Female	9 (30)	
Total	30 (100)	

\* significant

**Table 3: Age distribution**

Age (years)	Count (%)	P
40-49	2 (6.66)	0.002*
50-59	16 (53.33)	
60-69	11 (36.66)	
$\geq 70$	1 (3.33)	

\* significant

plain X-ray radiographs at the end of the follow-up. No neurological deterioration or instances of instrumentation failure occurred, and no lucencies observed surrounding the screws and successful fusion was documented in all patients. The great majority of change in sagittal alignment in this study occurred between the preoperative and the immediate postoperative imaging with little changes in the Cobb angle observed on late follow-up imaging compared with the immediate postoperative imaging.

### Functional outcome

#### Motor power

Motor weakness was present in 26 patients of which 23 patients (88.5%) improved and 3 patients (11.5%) remained same, with no case of worsening. Weakness was absent in 4 patients (13.3%) of 30 patients whose power remained the same after surgery. Statistical analysis proved that there is significant improvement of the motor power postoperatively [Table 4].

#### Nurick's score scale

Twenty-seven patients (90%) showed improvement at least one grade up, while three patients (10%) remained the same with no cases of worsening in their Nurick score. Statistical analysis proved that there was significant improvement of the Nurick score postoperatively [Table 5].

#### Neck disability index scale

According to the NDI outcome score, 27 (90%) patients showed improvement at least one grade up. Preoperatively, there was one (3%) patient with complete

disability, eight (27.7%) patients with severe disability, 16 (53.3%) patients with moderate disability, and five (16.7%) patients mild disability [Table 6].

Changed postoperatively to be as follow, 9 patients (30%) had no disability, 13 patients (43.3%) had mild disability, 6 patients (20%) with moderate disability, 8 patients (27.7%) and 2 patients (6.7%) had severe disability. Statistical analysis proved that there was significant improvement of the NDI postoperatively [Table 7].

### Radiographic outcome

There were no incidences of instrumentation lucencies or hardware failures, with good fusion seen in all patients during follow-up radiographs.

**Table 4: Comparison between pre- and post-operative motor power**

Motor	Preoperative, n (%)	Postoperative, n (%)
3	1 (3.3)	0
4	6 (20.0)	2 (6.7)
4+	19 (63.3)	6 (20.0)
5	4 (13.3)	22 (73.3)
Total	30 (100)	30 (100)
$\chi^2$		19.704
P		0.001*

\* significant

**Table 5: Pre- and post-operative Nurick score**

Nurick	Preoperative	Postoperative
Range	1-5	0-4
Mean±SD	2.97±0.93	1.37±1.38
t-test		27.863
P		0.001*

\* significant. SD – Standard deviation

**Table 6: Mean for pre- and post-operative neck disability index-score**

NDI	Preoperative	Postoperative
Range	7-37	0-27
Mean±SD	20.93±7.76	11.23±7.99
t-test		22.718
P		0.001*

\* significant. NDI – Neck disability index; SD – Standard deviation

**Table 7: Pre- and post-operative neck disability index-score**

Raw score	Relative disability	Preoperative, n (%)	Postoperative n (%)
0-4	No disability	0	9 (30)
5-14	Mild	5 (16.66)	13 (43.33)
15-24	Moderate	16 (53.33)	6 (20)
25-34	Sever	8 (26.66)	2 (6.66)
35-50	Complete	1 (3.33)	0

### Cervical alignment

We chose negative angulation as indicative of lordosis and positive angulation to represent kyphosis. For all patients, the mean preoperative Cobb angle (inferior border of C2 to the inferior border of C7) was  $-8.51^\circ \pm 14.07^\circ$ , ranged from  $-30^\circ$  to  $+17^\circ$  while the mean immediate postoperative Cobb angle was  $-10.49 \pm 10.53$  (ranging from  $-30$  to  $+15$ ) and the mean Cobb angle at the end of our follow-up was  $-10.29 \pm 12.43$ . There was no significant difference between the preoperative and the postoperative mean Cobb angles for all patients [Table 8].

Patients were divided into 2 study groups according to their cervical sagittal alignment as follows: the first group (Group 1) included patients that showed lordotic sagittal alignment preoperatively the mean Cobb angle for this group was  $-16.55^\circ \pm 7.81^\circ$  (ranged from  $-30^\circ$  to  $-5^\circ$ ). All 21 patients (100%) retained lordotic curve postoperatively with the mean Cobb angle equals  $-15.89 \pm 6.02$  immediately postoperative and  $-15.61 \pm 5.32$  at the end of our follow-up. There were no significant difference between the preoperative, the immediate postoperative and the late follow-up of this group.

The second group (Group 2) included nine (20%) patients that showed loss of the lordotic sagittal alignment (kyphotic or straight curve) preoperatively with the mean Cobb angle equals  $9.89^\circ \pm 4.59^\circ$  (ranged from  $-25$  to  $-5$ ). The mean postoperative curve of this group was  $2.67 \pm 8.08$  at the immediate postoperative and remained unchanged till the end of the follow-up. There was a significant difference in the mean Cobb angle for this group between preoperative and immediate postoperative and between the preoperative and at the end of the follow-up. There was significant shift of this group toward lordosis.

Postoperatively, 2 subgroups were reported: First, subgroup (subgroup A) included 5 patients (13.66%) who had a preoperative kyphotic curve who remained kyphotic postoperatively and retained kyphotic to the end of our follow-up. The mean preoperative Cobb angle was  $12.20 \pm 3.96$  changed to  $9.22 \pm 7.33$  at the immediate postoperative and  $9.0 \pm 4.06$  at the end of the follow-up. There was no significant difference in the mean Cobb angle for this group between preoperative and immediate postoperative and between the preoperative and at the end of the follow-up. This group showed a slight improvement in the kyphosis or at least no deterioration of the cervical curve postlaminectomy.

The second subgroup (subgroup B) includes 4 patients (13.33%) who had a preoperative kyphotic curve, and they shifted to have a lordotic curve postoperatively. The preoperative mean Cobb angle for them was  $7.0 \pm 3.92$ , changed to  $-5.25 \pm 1.25$  at the immediate postoperative and remained unchanged at the end of the follow-up. There was a significant difference in the mean Cobb angle for this group between preoperative and immediate postoperative and

**Table 8: Mean Cobb angle for 30 patients, preoperative, immediate postoperative, and follow-up**

	<i>n</i>	Preoperative	Postoperative	Follow-up	<i>P</i> <sub>1</sub>	<i>P</i> <sub>2</sub>	<i>P</i> <sub>3</sub>
All over	30	-8.51°±14.07°	-10.49±10.53	-10.29±12.43	0.540	0.606	0.947
Group 1	21	-16.54±7.49	-15.89±6.02	-15.61±5.32	0.761	0.689	0.890
Group 2	9	9.89±4.59	2.67±8.08	2.67±8.08	0.007*	0.007*	0.998
Subgroup A	5	12.20±3.96	9.22±7.33	9.0±4.06	0.495	0.628	0.989
Subgroup B	4	7.0±3.92	-5.25±1.25	-5.25±1.25	0.001*	0.001*	1.0

\* significant. *P*<sub>1</sub>: Preoperative and immediate postoperative; *P*<sub>2</sub>: Preoperative and at the end of follow-up; *P*<sub>3</sub>: Immediate postoperative and at the end of follow-up

between the preoperative and at the end of the follow-up. There was significant shift of this group toward lordosis. The total number of patients with lordotic group postoperatively was 25 patients (86.66%) with lordotic sagittal alignment; the mean Cobb angle for this group was  $-14.23^\circ \pm 6.02^\circ$  in the immediate postoperative period and  $-13.91 \pm 7.46$  in the end of our follow-up. The aim of our study was not to assess the amount of correction of the kyphotic deformity, but it aimed for the assessment of the change in the Cobb angle pre- and post-operatively. Group A (lordotic) indicating negative angle while the kyphotic group represent the positive angle, and we studied the impact of the changes in the Cobb angle and the functional outcome.

#### The relation between the preoperative duration of symptoms and the functional outcome

The duration of symptoms ranged from 4 to 30 months with a mean duration of 14.6 months. To study the relation between the preoperative duration of symptoms and the functional outcome, we divided the patients into 5 groups with a 6-month interval between each group and the next one. We found that there was a significant correlation between the preoperative duration of symptoms and the postoperative motor power improvement, Nurick score, and the NDI score [Tables 9-11].

#### Relation between age and functional outcome

We divided the patients according to their ages into younger group <60 and older group ≥60 years, and we found that there was no correlation between the patient age and their functional outcome [Table 12].

#### The relation between the change in the cervical alignment and the functional outcome

Overall, we found that patients with preoperative cervical lordosis have a better functional outcome than those who have kyphotic one [Table 13].

In patients with maintained cervical lordosis (Group 1), there was significant improvement in the functional outcome. In patients with preoperative kyphotic curve who remained kyphotic postoperatively (Subgroup A), there was no significant difference between the pre- and post-operative functional condition.

In patients with preoperative kyphotic curve who shifted toward lordosis postoperatively, Subgroup B showed significant improvement in the functional outcome [Table 14].

**Table 9: The relation between the duration of symptoms and the motor power**

Duration	Motor improvement	
	Improved	The same
0-6	3	0
7-12	13	0
13-18	5	0
19-24	0	1
24-30	0	2
Total	23	3
$\chi^2$		14.8231
<i>P</i>		0.005*

\* significant

**Table 10: The relation between the duration of symptoms and the neck disability index (NDI)**

Duration	NDI scale		
	Preoperative	Improved	Same
0-6	4	4	0
7-12	16	16	0
13-18	5	5	0
19-24	3	1	2
24-30	2	1	1
Total	<i>n</i>	27	3
$\chi^2$		24.231	
<i>P</i>		0.005*	

\* significant. NDI – Neck disability index

**Table 11: The Relation between the duration of symptoms and the Nurick score**

Duration	Nurick score		
	Preoperative	Improved	Same
0-6	4	4	0
7-12	16	16	0
13-18	5	5	0
19-24	3	1	2
24-30	2	0	2
Total	<i>n</i>	26	4
$\chi^2$		24.231	
<i>P</i>		0.005*	

\* significant

## Discussion

In our series, all patients presented with CSM were operated on for posterior cervical laminectomy and lateral mass screw fixation and fusion [Figure 1 c,d]. We combined the lateral mass

**Table 12 :Relation between age and functional outcome**

Age	Nurick mean			NDI mean		
	Preoperative	Postoperative	P	Preoperative	Postoperative	P
≥60	3.67±0.65	2.58±1.08	0.007*	27.75±4.81	19.17±5.25	0.001*
<60	2.50±0.79	0.56±0.86	0.001*	16.39±5.76	5.94±4.15	0.001*

\* significant. NDI – Neck disability index

**Table 13: The relation between the change in the cervical alignment and the functional outcome for Group 1 and Group 2**

	Group 1	Group 12	t-test	P
Cobb				
Range	-30--5	3-17	95.397	0.001*
Mean±SD	-16.55°±7.81°	9.89°±4.59°		
NDI				
Range	7-25	20-37	27.111	0.001*
Mean±SD	17.43±5.91	29.11±4.86		
Nurick				
Range	1-4	3-5	14.347	0.001*
Mean±SD	2.62±0.80	3.78±0.67		

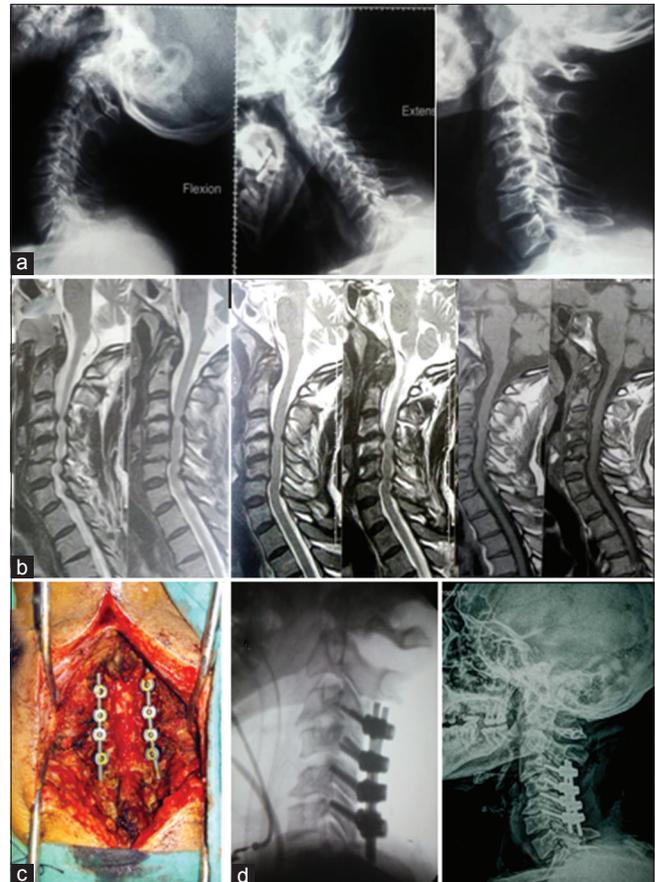
\* significant. NDI – Neck disability index; SD – Standard deviation

fixation to the laminectomy to improve outcome by prevention of postlaminectomy kyphotic deformity. In a study conducted by Suk *et al.*<sup>[5]</sup> on 85 patients underwent laminoplasty and they found a significant loss of cervical lordosis with 10% of previously lordotic patients converting to kyphosis.

However, in a recent study by Nurboja *et al.*,<sup>[6]</sup> 268 patients undergoing cervical laminectomy and laminoplasty were followed up for an average of 6.7 years, and no significant change in sagittal alignment was noted.

Determination of the presence and extent of instability depends on meticulous assessment of not only static and dynamic radiological imaging but also on the detection of clinical signs of instability as Olson and Joder,<sup>[7]</sup> considered the presence of paraspinal muscle spasm, decreased cervical lordosis, and pain with sustained posture are signs of instability.

McAllister *et al.*<sup>[8]</sup> concluded that posterior cervical fusion usually appropriate if patients showed one or more of the following: the presence of preoperative instability, significant axial neck pain, younger age, minimal lordosis or straightening of the cervical spine, or if the patient will need a postoperative radiation. Epstein<sup>[9]</sup> demonstrated on his study that cervical instability was evaluated before surgery using dynamic films and all patients with even loss of cervical lordosis operated for posterior decompression and fixation as these patients had a great risk for postlaminectomy kyphosis. As regard to complications, two lateral mass fractures occurred intraoperatively in two cases in our series, none of them were at the extremity of the fixation construct, and the fractured lateral masses were bypassed without screw insertion as shown in figure 2.



**Figure 1:** Male patient aged 59 years with cervical spondylotic myelopathy. (a) preoperative plain lateral view neutral and dynamic X-rays (b) preoperative magnetic resonance imaging had abnormal T2-weighted signal in the spinal cord at level of C3–C4 disc. (c) intraoperative view showing laminectomy and fixation. (d) intraoperative fluoroscopic view and postoperative upright lateral X-ray view

Inoue *et al.*<sup>[10]</sup> reported 18 intraoperative lateral mass fractures of the 471 lateral masses; they reinserted the screw with a different trajectory angle, it succeeded in four lateral masses but reinsertion was impossible in the remaining cases, and the levels.

In our series, there were four facet violations. Heller *et al.*<sup>[11]</sup> reported that the risk of FV was higher in Roy–Camille technique (22.5%) than Magerl technique (2.4%). While Barrey *et al.*<sup>[12]</sup> reported that facet violation occurred in 4 of 80 lateral mass screws (5.0%) with the use of Magerl technique.

We did not observe any manifestations of nerve root injury or other neural injury related to screws insertion. Postoperatively, there was no clinical evidence of vertebral

artery injury as all patients were observed for local neck hematomas, vertebrobasilar stroke, and for any further neurological deterioration.

Al-Barbarawi *et al.*<sup>[13]</sup> reported that there was no active bleeding occurred neither intraoperative as a result of vertebral artery injury nor postoperatively. Only one case had CSF leak from the wound that treated successfully with reinforcement sutures and lumbar drain for 3 days.

One screw showed violation of the cortex of the vertebral artery foramen opposite C5 lateral mass without penetration of the vertebral artery [Figure 3]. Kim *et al.*<sup>[14]</sup> reported in a prospective study on the evaluation of 1256 lateral mass screws positioned in 178 consecutive patients at their institution. One screw revealed in the follow-up CT violating the foramen transversarium without penetrating the vertebral artery required no further intervention.

In our study, all patients were thought to be stable, based on the absence of motion on postoperative radiographs and the absence of hardware breakage or migration, coupled with the maintenance of alignment at the end of the follow-up.

We agreed with Al-Barbarawi *et al.*,<sup>[13]</sup> based on the postoperative radiograph, no pseudoarthrosis was noted.

There was almost no increased morbidity due to added instrumentation. That was agreed with the study conducted by McAllister *et al.*<sup>[8]</sup> they advocated combining cervical laminectomy with fusion, as laminectomy alone can result in postoperative kyphosis and late deterioration. They

found that cervical fusions are associated with relatively low complication rates and as they say “the morbidity of lateral mass screw/plate fixation is low.”

As regard to the functional outcome, we found that there is no ideal metric method to judge the functional outcomes; with different minimum magnitude of clinical differences can be detected for varying CSM severity categories.

In our study, we found significant improvement between the preoperative and the postoperative Nurick score, with no correlation between the preoperative and the postoperative Nurick score, in which 23 (88.5%) patients of 26 (with preoperative weakness) showed at least one grade up while only 3 patients (11.5%) of 26 remained the same with significant improvement.

Our opinion was supported by the study of Rajshekhar and Kumar,<sup>[15]</sup> who found clinical improvement in 100% of patients at follow-up of 17 patients with Nurick scores of 5.

While Macdonald *et al.*<sup>[16]</sup> studied eight cases of CSM with Nurick scores of 5 undergoing surgery and found 50% clinical improvement (improvement of at least 1° in the Nurick scale), also Matsunaga *et al.*<sup>[17]</sup> considered 31 patients with Nurick scores of 5 and reported improvement in only 16.2%.

On the other side, Holly *et al.*<sup>[18]</sup> found that there was a correlation between the preoperative and the postoperative Nurick score, and had shown that patients with preoperative lower Nurick’s grade had a better outcome.

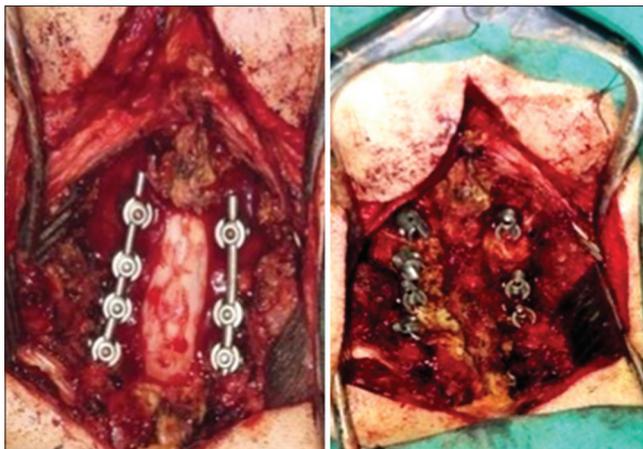


Figure 2: Intraoperative views of laminectomy and lateral mass fixation showing fracture of the left lateral mass of the 4<sup>th</sup> cervical vertebra and that level was skipped on the left side

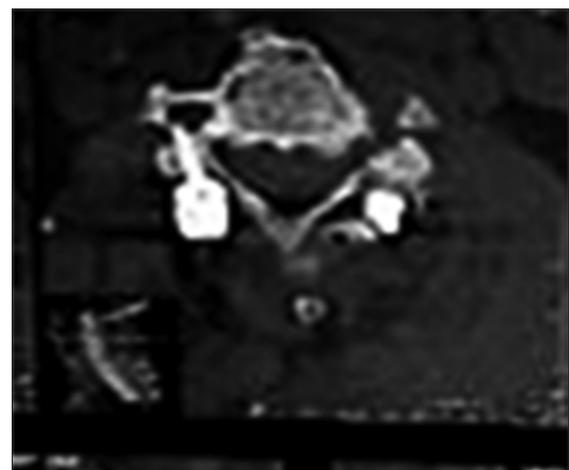


Figure 3: Showing violation of the foramen transversarium without penetration of the vertebral artery

**Table 14: The relation between the change in the cervical alignment and the functional outcome for subgroup A and subgroup B**

	Mean Nurick			Mean NDI			Cobb		
	Preoperative	Postoperative	P	Preoperative	Postoperative	P	Preoperative	Postoperative	P
Subgroup A	3.40±0.55	3.40±0.55	1.0	27.40±5.18	21.20±6.53	0.135	12.20±3.96	9.0±4.06	0.243
Subgroup B	4.25±0.50	2.25±1.50	0.045*	31.25±4.03	19.25±4.43	0.007*	7.0±3.92	-5.25±1.25	0.001*

\* significant. NDI – Neck disability index

We found that functional outcome is better in younger patients than older one. We think that may be due to the presence of several comorbidities such as atherosclerosis, hypertension, and diabetes mellitus in older ages. Our results agree with the study conducted by Naderi *et al.*<sup>[19]</sup> concluded that there was no relation between surgical outcome and age of the patient.

On the other side Nakashima *et al.*<sup>[20]</sup> concluded that “surgical decompression results in superior functional status in younger patients compared with elderly patients and confirms that the elderly are less effective at translating neurological recovery into functional improvements.”

The duration of symptoms in our cases ranged from 4 to 30 months with the mean duration of 12.9 months. In our study, we found that there was significant correlation between the duration and the functional outcome. Our results agreed with Ebersold *et al.*<sup>[21]</sup> who studied 100 patients with CSM, they underwent surgical decompression and found that poor neurological outcome was related to increased duration of preoperative symptoms. On the other side, a study published by Fehlings *et al.*<sup>[22]</sup> who concluded that there’s no correlation between duration of symptoms and the surgical outcome.

Suri *et al.*<sup>[23]</sup> prospectively evaluated 146 consecutive patients with CSM over a 2-year period. Assessed patients clinically and with the Nurick grading system preoperatively, and at 3 and 6 months’ postoperatively, he found that patients with symptoms >2-year duration of showed significantly less improvement in their postoperative Nurick score.

In the literature, We did not find standard values for “normal” curvature, several arguments about the value of the normal cervical lordosis measurements including the study conducted by Guo *et al.*,<sup>[24]</sup> who calculated normal cervical sagittal alignment, obtained by measuring the C2–C7 Cobb angle, on cervical lateral radiographs in the neutral position to be  $-12.7 \pm 6.6$  in female patients and  $-16.3 \pm 7.3$  in male patients in 414 asymptomatic volunteers.

Benzel,<sup>[25]</sup> defined an effective cervical lordosis “as the configuration where no dorsal component of C3 to C7 crosses a line from the posterior caudal corner of C2 to an identical point on C7.” Hamanishi and Tanaka,<sup>[26]</sup> considered a minimum lordosis of  $10^\circ$  required for adequate dorsal migration of the spinal cord.

Yamazaki *et al.*<sup>[27]</sup> noted in a study conducted in patients presented with ossification of the posterior longitudinal ligament that ventral compression after posterior decompression continued when the lordosis was  $>10^\circ$  and if the extent of ventral canal encroachment exceeded 7 mm. On the same topic, McAviney *et al.*<sup>[28]</sup> published a study, in which almost 300 cervical X-rays were examined after dividing the patients into groups with and without cervical

pain. The authors conclude that they found a statistically significant association between cervical pain and lordosis  $<20^\circ$  and a “clinically normal” range for cervical lordosis of  $31^\circ$ – $40^\circ$ .

Kuntz *et al.*<sup>[29]</sup> accumulated data from multiple studies and in a total of 464 patients, found the pooled mean and variance of cervical lordosis to be  $-17 \pm 14$  standard deviation.

Overall, we found that patients with preoperative cervical lordosis have a better functional outcome than those who have kyphotic one. That was agreed with a study conducted by Shamji *et al.*<sup>[30]</sup> as they studied the association between cervical spine alignments with neurologic recovery and concluded that the majority of patients with CSM showed postoperative neurologic improvement. However, patients with preoperative lordotic alignment exhibited greater improvement than those with preoperative kyphotic alignment. In our study, we found that patients with maintained cervical lordosis (Group 1) showed significant improvement in the functional outcome with nonsignificant change in cervical lordosis indicating that there is no correlation between the change in the cervical lordosis and the functional outcome in patients with maintained lordotic curve, however, in patients with a preoperative kyphotic curve who shifted toward lordosis postoperatively (Subgroup B) showed significant improvement in the functional outcome than the patients who remained kyphotic postoperatively (subgroup A). Our results agreed with Sielatycki *et al.*<sup>[31]</sup> in a study of patients with maintained cervical lordosis who underwent posterior decompression and lateral mass fixation, they found no correlations between cervical sagittal alignment and postoperative outcomes. Neither baseline nor postoperative myelopathy severity was associated with either the amount of SVA or degree of lordosis. Also a study conducted by Roguski *et al.*,<sup>[32]</sup> they found that when baseline kyphosis is present, any increase in the sagittal vertical axis and degree of kyphosis is associated with worse myelopathy and poor outcomes.

There was no neurological deterioration detected of the functional grading at the end of our follow-up, this proves the importance of cervical fixation using lateral mass fixation in resolving the dynamic compressive factors, whose role as the main etiology for the progressive neurological deterioration in long-term follow-up of patients with CSM.

## Conclusion

Combining posterior decompression with lateral mass screw rod in patients with CSM was effective in improving or at least maintaining cervical alignment with good functional outcome.

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## Conflicts of interest

There are no conflicts of interest.

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