Factors predicting outcome after surgeries for cervical spondylotic myelopathy: A prospective study in Egypt

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Abstract
Aim: In this study, we aimed to study factors affecting the outcome after surgeries for cervical spondylotic myelopathy (CSM).

Material and Methods: A prospective study was conducted on 25 patients who had CSM surgeries at our institution. The assessment was done before the operation, at 1, 3, and 12 months after surgery using the Modified Japanese Orthopedic Association score (MJOA).

Results: Patients with age ≥ 65 years had significantly lower MJOA scores than younger patients at 1, 3, and 12 months (P=0.007*), (P=0.007*), and (P=0.035*) respectively. Patients with diabetes had significant lower scores at 3 months (p=0.021*), and 12 months (p=0.017*). The duration of symptoms was significantly correlated with the MJOA score at 3 and 12 months (P=0.035*), (P<0.001*), respectively. There was significant positive correlation between preoperative and postoperative MJOA scores at 1, 3, and 12 months (P=0.001*), (P<0.001*), and (P=0.009*), respectively. The number of operated segments during surgery correlated with the MJOA score at 1 month (p=0.001*), and 3 months (p=0.003*). Hospital admission days after surgery were significantly correlated with MJOAs at 1, 3, and 12 months (P=0.001*), (P=0.004*), and (P=0.004*), respectively. Preoperative somatosensory evoked potential, MRI, and mean arterial pressure at the beginning of surgery had no significant association with outcome.

Discussion: Age, diabetes mellitus, duration of symptoms, severity of myelopathy, number of operated segments and duration of hospital stay after surgery are considered predictors of outcome after CSM surgeries. MRI, somatosensory evoked potentials tests, and mean arterial blood pressure at the start of surgery had no significant association with outcomes.

Keywords
Cervical spondylotic myelopathy; MJOA score; Outcome
Factors predicting outcome of cervical decompression surgery

Introduction
Cervical spondylotic myelopathy (CSM) is the most common cause of spinal cord impairment worldwide [1]. It causes sensory and motor dysfunction of the upper and lower limbs, also it causes gait and sphincter dysfunctions. Surgical decompression is the main treatment, especially in moderate to severe disease, which has been proved to be effective in relieving these symptoms [1,2]. However, the majority of the patients improved after surgery [2]. Some showed variability in the degree of improvement. The Modified Japanese Orthopedic Association score (MJOA), is one of the commonly used outcome measures in patients with CSM that improve after surgery [3]. The aim of our study was to investigate the clinical, radiological, neurophysiological and surgical factors affecting neurological recovery and functional outcome after surgical decompression for patients with cervical spondylotic myelopathy.

Material and Methods
Patients and methods
This prospective study was conducted on 25 patients with CSM who required surgical decompression at our institution. Patients included in the study had symptomatic cervical myelopathy with at least one clinical sign (e.g. gait abnormality, hyperreflexia of upper limbs and/or lower limbs, Hoffman's reflex and Babinski sign), and evidence of cervical spinal cord compression on magnetic resonance imaging (MRI) [4]. Patients with traumatic compression, pathologic fractures, spinal cord tumors, inflammatory disorders of the spinal cord, and infections myelitis were excluded from the study.

Preoperative assessment
All patients underwent history taking, neurological examination, and magnetic response imaging study to assess the cervical spinal cord compression level. The MJOA was performed to evaluate the upper and lower limbs and sphincter functions, as well as the severity of CSM for each patient [3]. The score is an 18-point scale that contains upper limb motor function (5 points) and lower extremity motor function (7 points), sensory function (3 points) and sphincter function (3 points) [3]. A score of 18 reflects no neurological deficits, whereas a lower score indicates a greater degree of disability and functional impairment. Mild myelopathy is a score of ≥15 MJOA indicates mild myelopathy; a score between 12-14 indicates moderate myelopathy, and severe myelopathy is indicated by an MJOA score of <12 [3].

Some patients already had Somatosensory evoked potentials (SSEPs) before surgery to assess tract affection, and we just analyzed the results of SSEPs. Abnormality of SSEP latency or amplitude due to cervical spinal cord lesion was defined as follows: SSEP median nerve abnormality: absent N20, P22 and/or abnormal right-left amplitude ratio of N20 wave. SSEP tibial nerve abnormality: absent P40 wave and/or abnormal N22-P40 inter-peak latency and/or abnormal right-left amplitude ratio of P40 wave [5].

Surgical technique and Anesthesia
All surgeries were performed by an experienced senior spine surgeon using an intraoperative neuro-monitoring modality. The techniques used were either anterior cervical disectomy and fusion (ACDF) or posterior laminectomy with fusion. Total Intravenous anesthesia (TIVA protocol) using propofol and fentanyl was used in all the patients with short-acting muscle relaxants used only during intubation.

Postoperative Outcome
The outcome was assessed using the MJOA score and neurological examination at 1 month, 3 months, and 12 months after surgery.

Statistical analysis
Descriptive data were described as mean ± SD or n (%), and the statistical analyses were performed using IBM SPSS software package version 20.0. (Armonk, NY: IBM Corp). The Mann-Whitney test and the Kruskal-Wallis test were used to test the significant difference between different parameters in the studied group regarding the MJOA score. The correlation was calculated using the Spearman coefficient.

Ethical considerations
Before enrollment in the study, consent was obtained from all recruited patients for the use of their anonymous data and for the surgical process. The Ethical Committee (EC) at Alexandria University Faculty of Medicine approved the study. The EC has had FWA since 2010 and operates according to the ICH GCP guidelines and applicable local and institutional regulations and guidelines.

Results
Twenty-five patients with CSM had cervical decompression surgeries using IONM. These were 19 males and six females with a mean age of 54.24 ± 11.96 years. A detailed description of the preoperative clinical, radiological, SSEP and surgical findings of patients is depicted in Table 1. An example of one case is shown in Figure 1. The association between these findings and outcome (MJOA score) was analyzed as follows:

1. Age and outcome: Patients aged ≥ 65 years had significantly lower MJOA score than patients with age <65 years at 1 month, 3 months, and 12 months follow-up (P = 0.007*), (P = 0.007*), and (P = 0.035*), respectively. (Table 2).
2. Diabetes mellitus comorbidity: It was found that the group of patients with diabetes had significantly lower scores at 3 months (p = 0.021*), and 12 months (p = 0.017*). (Table 2).
3. Duration of symptoms: It was significantly correlated with postoperative MJOA score at 3 and 12 months follow-up (P = 0.035*), (P <0.001*), respectively (Table 3).
4. CSM severity (preoperative MJOA score): There was significant positive correlation between preoperative and postoperative MJOA score at 1 month, 3 months, and 12 months (P < 0.001*), (P = 0.013*), (P = 0.009*), respectively (Table 3).
5. Number of compressed cord segments on MRI: There was no correlation between the number of compressed cord segments and postoperative MJOA score (Table 3).
6. Preoperative SSEP and outcome: Patients who had preoperative normal median nerve SSEP and posterior tibial nerve SSEP had a higher MJOA score than patients with abnormal median nerve SSEP at upper limbs and abnormal posterior tibial nerve SSEP, with no statistically significant difference (Table 2).
7. Other factors related to surgery: The number of operated decompressed segments during surgery correlated with the postoperative MJOA score at 1 month (p 0.001*), and 3 months...
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Table 1. Preoperative clinical, surgical, radiological, electrodiagnostic characteristics of the studied group (n=25)

| Studied group (n = 25) | No. (%) | Mean ± SD (Range) |
|-----------------------|---------|-------------------|
| Sex                   |         |                   |
| Male                  | 19 (76%)|                   |
| Female                | 6 (24%) |                   |
| Age (years)           |         | 54.24 ± 11.96 (33–78) |
| Duration of symptoms (months) | 8.84 ± 5.53 (1–18) |
| Diabetes Mellitus     |         |                   |
| No                    |         |                   |
| Yes                   |         |                   |
| Mean MJOA score (18 points) | 11.84 ± 2.12 (7–16) |
| Severity of myelopathy according to MJOA | | |
| Mild (< 15 points)    | 2 (8%)  |                   |
| Moderate (12–14)      | 11 (44%)|                   |
| Severe (>12)          | 12 (48%)|                   |
| MRI Hyper intense signal T2 | 25 (100) |
| Number of compressed cord segment on MRI | | |
| <3 levels             | 9 (36%) |                   |
| ≥3 levels             | 16 (64%)|                   |

SSEP Median nerve (n = 21)

| Normal | Abnormal |
|--------|----------|
| 5 (23%) | 16 (76.2) |

SSEP posterior tibial nerve (n = 21)

| Normal | Abnormal |
|--------|----------|
| 4 (19%)| 17 (81%) |

Surgical approach

| Anterior cervical discectomy and fusion | 13 (52) |
| Posterior laminectomy with fusion     | 12 (48) |
| Numbers of operated levels            |        |
| <4 levels                            | 8 (32%) |
| ≥4 levels                            | 17 (68%) |
| Baseline mean arterial pressure (mmHg) | 84.56 ± 15.95 (57-125) |
| mean duration of hospital stay (days) | 4.92 ± 2.52 (2-13) |

1 Only 21 patients had SSEPs from the total 25 patients

MJOA: Modified Japanese orthopedic association score; CSM: cervical spondylotic myelopathy; SSEP: somatosensory evoked potential; MAP: mean arterial blood pressure

Table 2. Difference between (mean MJOAOJS score) and characteristic of the studied group

| Age (years) | Mean MJOA score 1 month | Mean MJOA score 3 months | Mean MJOA score 12 months |
|-------------|--------------------------|---------------------------|---------------------------|
| < 65        | 14.40 ± 2.09             | 15.90 ± 1.74              | 16.60 ± 1.47              |
| ≥65         | 11.0 ± 2.0               | 13.20 ± 2.05              | 14.20 ± 2.68              |
| Test of sig. | U=12.50*                  | U=12.0*                   | U=19.0*                   |
| (p value)   | (0.007*)                  | (0.007*)                  | (0.035*)                  |

Diabetes mellitus

| No | Yes |
|----|-----|
| 14.22 ± 2.26 | 12.43 ± 2.64 |
| 16.0 ± 1.64  | 13.71 ± 2.29  |
| 16.78 ± 1.26 | 14.43 ± 2.51  |
| Test of sig. | U=38.0                  | U=25.50*                 | U=24.0*                  |
| (p value)   | (0.141)                 | (0.021*)                 | (0.017*)                 |

SSEP Median nerve

| Abnormal | Normal |
|----------|--------|
| 13.63 ± 2.73 | 14.40 ± 2.41 |
| 15.31 ± 2.56 | 15.60 ± 1.67 |
| 16.06 ± 2.11 | 16.20 ± 2.0 |
| Test of sig. | U=34.0                  | U=39.0                  |
| (p value)   | (0.660)                 | (0.968)                 |

SSEP Tibial nerve

| Abnormal | Normal |
|----------|--------|
| 13.71 ± 2.66 | 14.25 ± 2.75 |
| 15.35 ± 2.29 | 15.50 ± 1.91 |
| 16.12 ± 2.06 | 15.75 ± 2.22 |
| Test of sig. | U=30.0                  | U=30.50                 |
| (p value)   | (0.763)                 | (0.763)                 |

Mean MAP changes

| No drop MAP | MAP drop <70 |
|-------------|---------------|
| 13.84 ± 2.09 | 13.33 ± 3.61 |
| 15.63 ± 1.34 | 14.50 ± 3.62 |
| 16.47 ± 1.31 | 15.00 ± 3.22 |
| Test of sig. | U=54.50                  |
| (p value)   | (0.877)                 |

MJOA: modified Japanese orthopedic association score; SSEP: somatosensory evoked potential; MAP: mean arterial blood pressure

H: H for Kruskal-Wallis test
p: p-value for association between different categories

Figure 1. The 51-year-old man diagnosed as CSM who had C3-C7 posterior cervical decompression surgery, preoperatively had gait instability, severe left brachialgia with very mild weakness left hand

A) Preoperative T2 sagittal MRI cervical spine showed compressive posterior disc herniation at C4-C5, C5-C6 associated with the subtle area of T2 hyper-intense signal of the cord.

B) Right median SSEPs, rate 3 Hz, intensity 5.3 mA, duration 0.3 ms. Latency N20= 24 ms, P22= 21.7, and amplitude 2.63 (abnormal right-left amplitude ratio of N20 wave)

C) Intraoperative field showed fixation of the levels by two rods bilaterally with the application of screws caps

D) Postoperative plain x-ray sagittal showed Posterior laminectomy with fusion (C3-C6).

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2. Diabetes Mellitus and outcome

Diabetes Mellitus is one of the predictors of surgical outcomes, lower MJOA scores at 3 months and 12 months. This indicates that diabetes had significantly poorer outcomes compared with patients without diabetes.

3. Duration of symptoms and outcome

Duration of symptoms was significantly correlated with postoperative MJOA score. This means that the longer duration of symptoms before surgery, the less recovery after surgery. The rationale behind this finding is that patients with longer duration of symptoms may experience irreversible damage of the spinal cord due to chronic compression, which results in severe myelopathy.

4. CSM severity and outcome

There was a significant positive correlation between preoperative and postoperative MJOA scores at 1 month, 3 months, and 12 months. This indicates that the longer duration of myelopathy, the better the recovery after surgery. Similar to our results, many studies have reported a significant association between preoperative myelopathy severity and surgical outcomes [9,10]. This is also explained by the fact that the longer duration of symptoms before surgery, the less recovery after surgery.

5. Preoperative SSEP and outcome

In the present study, patients with abnormal preoperative SSEP had lower postoperative MJOA scores than patients with normal SSEP; however, this was not statistically significant differences. This means that SSEP was not sensitive in detecting myelopathy and was not related to outcome in patients with CSM, similar findings supported by Kellar et al. [19]. That is because CSM with motor dysfunction is usually more frequent than CSM with isolated sensory dysfunction, and SSEP has no role in the diagnosis of motor fibers of corticospinal tracts [19]. On the other hand, Lyu et al [20] reported that SSEP abnormalities commonly reflect severe cord dysfunction and have been correlated with low surgical response.

6. MRI features and outcome

In the present study, all (100%) our patients had increased signal intensities on T2-weighted MRI, thus we tried to find a correlation between numbers of compressed cord segments and the postoperative MJOA score, however, we did not find any correlation between them. This was supported by a systematic review by Tetreault et al. [21], who found low-

Table 3. Correlation between Mean postoperative MJOA score and different parameters

| Table 3. Correlation between Mean postoperative MJOA score and different parameters |
|-----------------------------------------------|
| **1 month** | **3 months** | **12 months** |
| Correlation (rs) | P | Correlation (rs) | P | Correlation (rs) | P |
| Duration of symptoms | -0.256 | 0.177 | -0.424 | 0.035* | -0.673 | <0.001* |
| Mean pre-operative MJOA | 0.090 | 0.418 | 0.180 | 0.618 | 0.003* |
| Number of compressed segments MRI | -0.105 | 0.618 | -0.112 | 0.595 | -0.018 | 0.932 |
| Number of operated segments in surgery | -0.604 | 0.001* | -0.570 | 0.003* | -0.394 | 0.051 |
| MAP | 0.117 | 0.579 | 0.236 | 0.256 | 0.018 | 0.377 |
| Hospital admission days | -0.248 | 0.572 | -0.018 | 0.987 | -0.551 | 0.004* |

**rs**: Spearman coefficient; ***: Statistically significant at p < 0.05
level evidence that MRI factors related to cord properties are predictors of outcome. It was concluded that MRI features of the spinal cord before CSM surgery cannot accurately predict functional outcome after surgery and, hence further studies and alternative imaging approaches may be required.

7. Surgical factors and outcome
With regard to blood pressure during surgery, we use MAP <70 mmHg as the threshold below which blood pressure is needed to be increased [22] because cord hypoperfusion due to hypotension increases the risk of neurologic deficits in spinal surgeries, and unfortunately, is common in patients with spinal cord injury [23]. In the present study, patients with MAP drop <70 mmHg during surgery had less MOJA scores at 1, 3, 12 months follow-up than in the group without MAP drop, however, the difference was not statistically significant. Also, it has been found that baseline MAP at the beginning of surgery was not significantly correlated with the outcome score. This may be due to the optimal ranges of MAP monitored during surgery remain unknown or controversial, also in the present study, blood pressure was immediately therapeutically raised above 70 mmHg, and it has been found that not only the average of MAP, but also the duration of hypotension be more important in spinal cord injury recovery [22].

The number of surgically decompressed segments was significantly correlated with the MJOA score, which means that multilevel decompression surgery had less recovery after surgery. This was explained by the fact that the number of operated segments represents more compressed cord, more severe myelopathy, more complex surgery, and more postoperative complication like dysphagia, wound infection rates, neck pain, postoperative narcotic usage [24]. Also, multilevel decompression surgery had increased soft tissue dissection and retraction needed for exposure, as well as the increased time and manipulation, which may be a direct causes of increased morbidity [24].

The number of days of hospital stay after surgery correlated significantly with the postoperative MJOA scale and recovery rate at 1, 3, and 12 months follow-up. This means that the longer hospital stay after surgery, the lesser improvement in outcome, as it is a reflection of the extra time needed to control postoperative pain or infection [25].

Conclusion
Age, diabetes mellitus, duration of symptoms, severity of myelopathy, number of operated segments and duration of hospital stay after surgery are considered predictors of functional outcome and have a significant association with outcome. With respect to the number of compressed cord segments on MRI, somatosensory evoked potentials tests, we have failed to identify a significant association with outcomes. Finally, patients with MAP <70 mmHg during surgery had less functional improvements than patients without, however, that was not statistically significant.

Scientific Responsibility Statement
The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement
All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. No animal or human studies were carried out by the authors for this article.

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Conflict of interest
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