

Risk Factors Relating to the Need for Mechanical Ventilation in Isolated Cervical Spinal Cord Injury Patients

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Background: Cervical spinal cord injuries (SCI) are a major public health problem. Respiratory complications are among the most important causes of morbidity and mortality in patients with cervical SCI, especially respiratory failure. Based on our evaluation of the existing English language literature, few previous studies appear to have reported on risk factors associated with the need for mechanical ventilation in isolated cervical SCI patients who had no concomitant injuries or diseases at the time of admission.

Objective: The purpose of this study was to determine incidence and risk factors relating to the need for mechanical ventilation in isolated cervical spinal cord injury (SCI) patients who had no concomitant injuries.

Material and Method: This retrospective study was conducted by reviewing and analyzing the patient data of 66 isolated cervical-SCI patients who were admitted in our hospital between January 1995 and December 2009. Patient medical records were reviewed for demographic data, neurological injuries, need for mechanical ventilation, definitive treatment, complications, and outcomes. Univariate and multivariate analysis were used to identify predisposing risk factors relating to patient dependency on mechanical ventilation.

Results: Of the 66 patients, 30.3% (20/66) required mechanical ventilation and 22.7% (15/66) were identified as complete cord injury, of which seven sustained injury above C5. Of the patients with complete SCI, 66.7% (10/15) were dependent on mechanical ventilation, as were 85% (6/7) with SCI above C5. All five of the patients with complete-SCI above C5 who received operative treatment were dependent upon mechanical ventilation, postoperatively. Only 19.6% (10/51) of the incomplete injury group required mechanical ventilation.

Univariate analysis indicated the following factors as significantly increasing the risk of ventilator dependence: complete SCI ($p = 0.001$), SCI above C5 level ($p = 0.011$) and operative treatment ($p = 0.008$). Multivariate analysis identified the following factors as being predisposing risk factors relating to the need of mechanical ventilation: complete SCI (OR: 12.8; 95% CI 2.4-66.9; $p = 0.003$), SCI above C5 level (OR: 12.0; 95% CI 2.4-60.2; $p = 0.002$), and operative treatment (OR: 14.8; 95% CI 2.1-106.9; $p = 0.008$).

Conclusion: Complete SCI, SCI above C5, and operative treatment were predisposing risk factors relating to the need for mechanical ventilation in isolated cervical SCI patients. The data and findings put forth in this study suggest that these factors may assist in predicting the need for mechanical ventilation as a long-term treatment for isolated cervical SCI patients.

Keywords: Cervical spinal cord injury, Mechanical ventilation, Respiratory failure

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Cervical spinal cord injuries (SCI) are a major public health problem. The worldwide incidence of SCI has been reported to vary from 10.4-83/1 million inhabitants per year⁽¹⁰⁾. More than one half of all SCIs (56.4%) occur at the cervical level⁽¹⁰⁾. Respiratory complications are among the most important causes of

morbidity and mortality in all patients with cervical SCI, due to a loss of normal respiratory muscle function. Of all respiratory complications, atelectasis (36.4%), pneumonia (31.4%), and ventilatory failure (22.6%) were the most common complications⁽⁵⁾.

The development of respiratory complications and respiratory failure directly correlated with the level of injury and the degree of motor deficit. In the literature, it has been reported that complete SCI, high-level SCI (above C5 or C6), significant associated injuries, and pre-existing comorbidities were predisposing risk factors for mechanical ventilation^(1,2,16). A retrospective

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study by Claxton et al found that 36% of their patients needed mechanical ventilation for respiratory failure; 90% of these were within the first three days after injury⁽²⁾.

Based on our evaluation of the existing English language literature, few previous studies appear to have reported on risk factors associated with the need for mechanical ventilation in isolated cervical SCI patients who had no concomitant injuries or diseases at the time of admission. The purpose of the present study was to determine incidence and risk factors relating to the need for mechanical ventilation in isolated cervical SCI patients.

Material and Method

After receiving approval from the Institutional Review Board (IRB) of the Faculty of Medicine Siriraj Hospital, the medical records of cervical SCI patients who were admitted at Siriraj Hospital between January 1995 and December 2009 were retrospectively reviewed. Patients were identified using the International Classification of Disease, 10th revision (ICD-10-TM 2009 Tabular List of Disease), with the following diagnostic codes for cervical spine fracture with spinal cord injury: code S12: fracture of neck; code S13: dislocation, sprain, and strain of joints and ligaments at neck level; and, code S14: injury of nerves and spinal cord at neck level.

Patients who had cervical SCI according to the American Spinal Injury Association impairment scale (ASIA) grades A, B, C and D were included in the present study. The established exclusion criteria were: injury time before admission to Siriraj Hospital of more than 72 hours and patients with significant associated injury, such as head injury, chest trauma, airway injury, and abdominal injury. According to ASIA criteria, the level of neurologic injury is defined as the most caudal segment of the spinal cord with normal sensory and motor function on both sides of the body⁽¹⁾. Patients with an absence of motor and sensory function in the sacral segment level 4-5 were identified as complete SCI (ASIA A). While incomplete SCI patients have motor and/or sensory function at the lowest sacral segment (ASIA B, C and D).

Patient data were retrospectively reviewed for age, gender, mechanism of injury (MOI), underlying disease, injury severity score, Glasgow coma score (GCS), level of neurologic injury, completeness of injury, definitive treatment, surgical options, need for definitive airway, type of airway, indication for airway, need for mechanical ventilation, ventilator days, need for ventilator upon discharge from hospital (MVDC),

complications, and mortality. Respiratory failure was defined as a $PCO_2 > 50$ mmHg and/or $PaO_2 \leq 50$ mmHg on room air. For the purpose of this study, a patient was coded as having needed mechanical ventilation (ventilator dependence) if they received mechanical ventilation after admission and/or the patient required prolonged post-operative intubation for more than 24 hours after surgery.

Quantitative data were analyzed using the Student's t-test (normality) and qualitative data were analyzed using the Chi-square test. The results were expressed as odd ratios (ORs) and 95% confidence interval (CI). SPSS version 13 for Windows was used for statistical analysis. A value of $p < 0.05$ was considered statistically significant. The effect of each predisposing risk factor was investigated using univariate and multivariate analysis.

Results

A database of 190 patients with cervical SCI was identified and 66 of those patients were included in our study. There were 52 males and 14 females. The average age of the patients was 41.61 ± 16 years (age range: 11-80 years). Demographic data and clinical features of the patients are summarized in Table 1.

Thirty percent of the patients were identified as having ventilator dependence and 70% were identified as being part of the ventilator independence group. Half of the patients in the ventilator dependence group had complete SCI; however, only 11% of the complete SCI patients were in the ventilator independence group (Fig. 1). Twenty-two percent (15/66) received tracheostomy and 28% (19/66) developed pneumonia. The patient mortality rate was 3% (2/66). Of the 20 patients who required mechanical ventilation, the average time from injury to receiving mechanical ventilation was 3.15 ± 4 days (range: 0-17 days).

Patients who required mechanical ventilation had a higher frequency of operative treatment ($p = 0.008$), level of injury above C5 ($p = 0.011$), and complete SCI ($p = 0.001$). Average hospital stay of the ventilator dependence group was longer than the ventilator independence group (128 ± 85 days vs. 57 ± 46 days, $p = 0.002$). Respiratory tract infection developed more frequently in the ventilator dependence group, as compared to the ventilator independence group (42.9% vs. 14.4%, $p = 0.014$).

From univariate analysis, complete SCI (odd ratio [OR]: 8.2; 95% confidence interval [CI] 2.3-29.4, $p = 0.001$), SCI above C5 level (OR: 4.8; 95% CI 1.5-15, $p = 0.011$), and operative treatment (OR: 8.3; 95% CI 1.7-

Table 1. Patient demographics

Demographic data	n	%
Gender		
Male	52	78.8
Female	14	21.2
Age* (years)	41.61 (\pm 16.1)	
Mechanism of injury		
Motor vehicle accident	38	59.1
Falling	23	34.8
Body assault	1	1.5
Others	3	4.5
Severity of injury		
Complete SCI	15	22.7
Incomplete SCI	51	77.3
Level of cervical SCI above C5	29	44
Ventilator dependent	20	30
Ventilator day* (days)	34 (\pm 24.2)	
Treatment		
Operative	42	63.6
Non-operative	24	36.4
Length of stay* (days)	78.8 (\pm 69.0)	
Respiratory tract infection	19	28.8
Death	2	3
Tracheostomy	15	22.7
Need ventilator upon discharge	4	6.1

* Mean (\pm SD); SCI = spinal cord injury

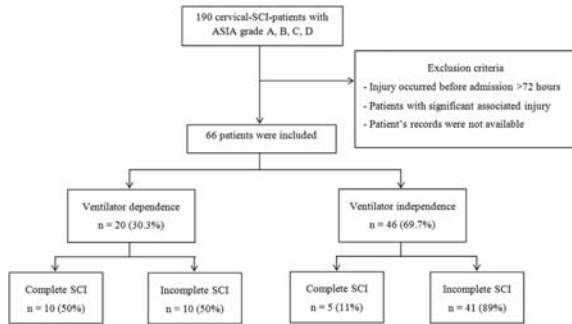


Fig. 1 Patients identified with ventilator dependence and ventilator independence.

39.7, $p = 0.008$) were the factors that significantly increased the risk of ventilator dependence. From multivariate logistic regression, complete SCI (OR: 12.8; 95% CI 2.4-66.9; $p = 0.003$), SCI above C5 level (OR: 12.0; 95% CI 2.4-60.2; $p = 0.002$), and operative treatment (OR: 14.8; 95% CI 2.1-106.9; $p = 0.008$) were identified as predisposing risk factors relating to the need for mechanical ventilation (Table 2).

Of the 42 patients that underwent operations,

30 patients (71%) underwent anterior surgical procedures and 11 patients (26%) underwent posterior surgical procedures. There were no significant differences between anterior and posterior surgical approach with respect to the issue of ventilator dependence ($p = 0.731$). The patients in the ventilator dependence group had longer surgical times, as compared with the ventilator independence group, but the difference was not statistically significant (185 minutes vs. 155 minutes, $p = 0.395$).

Discussion

Cervical spinal cord injury (SCI) is a devastating event that has a profound effect on respiratory function. Respiratory failure is one of the most frequent complications in patients with cervical SCI⁽¹³⁾. Prevention and proper treatment of respiratory complications now appears to be the major challenge to the clinician in order to minimize morbidity and mortality in spinal cord injured persons⁽⁵⁾.

Inspiration involves contraction of the diaphragm and the internal intercostal muscles, which results in the expansion of the chest wall⁽¹⁹⁾. The diaphragm is the most important muscle for inspiration and is innervated by C3-C5. As a result, SCI above this level may result in the need for mechanical ventilation⁽³⁾. The primary expiratory muscles are the rectus abdominus, transversus abdominus, internal and external obliques, and pectoralis major. In cervical SCI patients, forced expiration may also be compromised because of paralysis of the abdominal musculature. This will result in a decreased ability to cough and clear secretions, which may lead to respiratory insufficiency⁽²⁰⁾.

Risk factors relating to the need for mechanical ventilation have been identified in many reports. Claxton et al and Como et al showed that the neurologic levels of C5 and above and complete spinal cord lesion were predictors of the need for mechanical ventilation^(1,2). Velmahos et al identified three independent risk factors for intubation: injury severity score (ISS) >16, SCI above the level of C5, and a complete SCI⁽¹⁶⁾. However, few studies have clarified risk factors concerning the need for mechanical ventilation in isolated cervical SCI patients. Como et al and Velmahos et al found that the respiratory dysfunction seen in most patients in their respective series was likely due to complete cervical SCI, with some contribution from associated injuries^(1,16).

In the present study, patients who were admitted in our hospital more than 72 hours after injury

Table 2. Variables associated with ventilator dependence

	Ventilator dependence n = 20 (%)	Ventilator independence n = 46 (%)	Unadjusted		Adjusted	
			<i>p</i> -value	OR (95% CI)	<i>p</i> -value	OR (95% CI)
Complete SCI	10 (50)	5 (10.9)	0.001	8.2 (2.3- 29.4)	0.003	12.8 (2.4-66.9)
Level of cervical SCI above C5	14 (70)	15 (32.6)	0.011	4.8 (1.5-15)	0.002	12.0 (2.4-60.2)
Operative treatment	18 (90)	24 (52.2)	0.008	8.3 (1.7-39.7)	0.008	14.82 (2.1-106.4)

SCI = spinal cord injury

was sustained were excluded in order to eliminate confounding factors that influence deterioration in respiratory function. Several previous studies emphasized that most of their patients who experienced respiratory distress needed mechanical ventilation within 72 hours after injuries^(1-3,16,17). Patients who are operated upon are usually extubated and taken off ventilator within 24 hours after surgery⁽³⁾. Consequently, the patients, who were operated upon and subsequently required prolonged intubation for more than 24 hours, were identified as being ventilator-dependent.

As noted above, other associated injuries aside from cervical SCI contributed to the need for mechanical ventilation. In our data set, the patients had no significant associated injuries, like airway injuries, head injuries, thoracic injuries, or abdominal injuries. The mean ISS of our patients was 9. No patient had an ISS of more than 16. That means that the respiratory dysfunction experienced by the patients in this study resulted from the spinal cord injury.

The present study shows that complete SCI and neurologic injury at levels above C5 were predisposing risk factors relating to the need of mechanical ventilation. These findings are in agreement with those of previous studies. Claxton et al found that neurologic injury at level C5 and above was identified by univariate analysis as being associated with the need for mechanical ventilation⁽²⁾. They also identified pneumonia as a predictor of the need for mechanical ventilation. However, the treatment of pneumonia was complicated by the use of a mechanical ventilator. Como et al and Velmahos et al also identified complete SCI and neurologic injury at levels above C5 as predictors of the need for mechanical ventilation^(1,16). Patients with cervical SCI lose the function of the intercostal and abdominal muscles. The added impairment of the inspiratory muscles with the loss of diaphragm function in the higher cervical group leads to a higher incidence

of respiratory complications, most notably respiratory failure in patients with lesions between C1-C4, as compared to those with lower cervical injuries.

Interestingly, operative treatment was also found to be a predisposing risk factor relating to the need for mechanical ventilation. The average time from surgery to receiving mechanical ventilation was 3.15 (\pm 4 days). Eleven patients that received mechanical ventilation postoperatively. More specifically, these patients were not able to be extubated within 24 hours after surgery. Another nine patients received mechanical ventilation at other time periods. The average time to receiving mechanical ventilation for these two groups was not statistically different -4 and 3.8 days, respectively. Airway compromise is one of the potential complications from the surgical approach. Sagi et al demonstrated that prolonged procedures (>5 hours) and exposing more than three vertebral levels, including C2, C3 or C4, were significant risk factors relating to airway complication after anterior cervical spine surgery⁽¹⁸⁾. However, a subgroup analysis of the present study failed to show a correlation between surgical approach and ventilator-dependence. It is quite possible that this result was due to a small number of patients in the subgroup analysis. A longer study with a larger sample is required in the future.

The limitations of the present study include: 1) this was a retrospective review with small sample size; 2) this retrospective study spanned 15 years of clinical experience and there have been changes in practice patterns over that period; and 3) there is currently no standard intubation protocol for patients with SCI.

Conclusion

Complete SCI, SCI above C5, and operative treatment were predisposing risk factors of the need for mechanical ventilation in isolated cervical SCI patients. Based on these findings, early establishment

of a definitive airway and mechanical ventilation are recommended in isolated cervical-SCI patients with complete cord injury above C5, especially for patients who have received operative treatment. Patients for whom intubation is deemed not necessary, intensive monitoring of respiratory functions is strongly advised.

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Potential conflicts of interest

None.

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ปัจจัยเสี่ยงของการใช้เครื่องช่วยหายใจในผู้ป่วยที่ได้รับบาดเจ็บที่ไขสันหลังระดับคอ

ธำรง เลิศอุดมผลวนิช, ธเนศ วรรณอภิสิทธิ์, ชลเวช ชวศิริ, อารีศักดิ์ โชติวิจิตร

ภูมิหลัง: ภาวะการได้รับบาดเจ็บที่ไขสันหลังระดับคอเป็นปัญหาทางด้านสาธารณสุขที่สำคัญ ภาวะนี้มักทำให้เกิดภาวะแทรกซ้อนด้านการหายใจ โดยเฉพาะการหายใจล้มเหลว ปัจจุบันยังไม่มีผู้รายงานถึงปัจจัยเสี่ยงของการเกิดภาวะหายใจล้มเหลวและการใช้เครื่องช่วยหายใจในผู้ป่วยที่มีไขสันหลังระดับคอได้รับบาดเจ็บ (ซึ่งปราศจากการได้รับกัญตรายที่อวัยวะอื่น)

วัตถุประสงค์: เพื่อศึกษาอุบัติการณ์และปัจจัยเสี่ยงของการใช้เครื่องช่วยหายใจในผู้ป่วยที่ได้รับบาดเจ็บที่ไขสันหลังระดับคอ (ซึ่งปราศจากการได้รับกัญตรายที่อวัยวะอื่น) ที่เข้ารับการรักษาในโรงพยาบาล

วัสดุและวิธีการ: รูปแบบของการวิจัยเป็นแบบเชิงพรรณนา โดยค้นหาข้อมูลย้อนหลังของผู้ป่วยที่ได้รับการวินิจฉัยว่าได้รับบาดเจ็บที่ไขสันหลังระดับคอ จากอุบัติเหตุจำนวน 66 ราย ที่เข้ารับการรักษาที่ภาควิชาศัลยศาสตร์ออร์โธปิดิกส์และกายภาพบำบัดโรงพยาบาลศิริราชตั้งแต่ปี พ.ศ. 2538-2552 โดยข้อมูลของผู้ป่วยจากเวชระเบียนผู้ป่วยนอกและผู้ป่วยในที่จะถูกบันทึกอันได้แก่ ระบาดวิทยา, การบาดเจ็บที่ไขสันหลัง, การใช้เครื่องช่วยหายใจ, การรักษาที่ผู้ป่วยได้รับ, ภาวะแทรกซ้อนต่างๆ และผลการรักษา โดยข้อมูลต่างๆ ดังกล่าวจะถูกนำมาวิเคราะห์ข้อมูลทางสถิติและสรุปผล

ผลการศึกษา: ผู้ป่วยทั้งหมด 66 ราย ต้องใช้เครื่องช่วยหายใจ 20 ราย (ร้อยละ 30.3) โดยเป็นผู้ป่วยที่มีการบาดเจ็บของไขสันหลังแบบสมบูรณ์ 15 ราย (ร้อยละ 22.7) และในนี้มีผู้ป่วย 7 ราย ที่ได้รับบาดเจ็บที่ไขสันหลังเหนือระดับ C5 ขึ้นไป

ผู้ป่วยที่มีการบาดเจ็บของไขสันหลังแบบสมบูรณ์ ต้องใช้เครื่องช่วยหายใจร้อยละ 66.7 (10/15) ในขณะที่ผู้ป่วยที่มีการบาดเจ็บของไขสันหลังแบบสมบูรณ์เหนือระดับ C5 ขึ้นไปต้องใช้เครื่องช่วยหายใจร้อยละ 85 (6/7)

ผู้ป่วย 5 ราย ที่มีการบาดเจ็บของไขสันหลังแบบสมบูรณ์เหนือระดับ C5 ขึ้นไปและได้รับการรักษาโดยการผ่าตัด ต้องใช้เครื่องช่วยหายใจภายหลังการผ่าตัดทุกราย ในขณะที่กลุ่มซึ่งมีการบาดเจ็บของไขสันหลังแบบไม่สมบูรณ์ต้องใช้เครื่องช่วยหายใจเพียงร้อยละ 19.6 (10/51)

จากการวิเคราะห์ข้อมูลทางสถิติพบว่าภาวะการบาดเจ็บของไขสันหลังแบบสมบูรณ์ ระดับการบาดเจ็บเหนือระดับ C5 และการรักษาโดยการผ่าตัด เป็นปัจจัยเสี่ยงต่อการใช้เครื่องช่วยหายใจในผู้ป่วยที่ได้รับบาดเจ็บที่ไขสันหลังระดับคอ

สรุป: ภาวะการบาดเจ็บของไขสันหลังแบบสมบูรณ์ การได้รับบาดเจ็บในระดับที่เหนือต่อ C5 และการรักษาโดยการผ่าตัด เป็นปัจจัยเสี่ยงต่อการใช้เครื่องช่วยหายใจในผู้ป่วยที่ได้รับบาดเจ็บที่ไขสันหลังระดับคอ โดยปราศจากกัญตรายที่อวัยวะอื่น ๆ ในการรักษาผู้ป่วยที่มีปัจจัยเสี่ยงดังกล่าวจำเป็นต้องมีการดูแลภาวะการหายใจอย่างใกล้ชิดและมีการเตรียมการใช้เครื่องช่วยหายใจอย่างเหมาะสม รวมถึงการวางแผนการรักษาในระยะยาวต่อไป
