Predicting the need for tracheostomy in patients with cervical spinal cord injury

Pittavat Leelapattana, MD, Jennifer C. Fleming, PhD, Kevin R. Gurr, MD, Stewart I. Bailey, MD,
Neil Parry, MD, and Christopher S. Bailey, MD, MSc, CSC
Ontario, Canada

BACKGROUND: Approximately 75% of hospitalized patients with a cervical spinal cord injury (CSCI) will require intubation and mechanical ventilation (MV) because of compromised respiratory function. It is difficult to predict those CSCI patients who will require prolonged ventilation and therefore will most benefit from early tracheostomy, particularly early, and to identify predictors of prolonged MV after CSCI.

METHODS: A retrospective review of patients aged 16 years and older with acute CSCI admitted to London Health Science Center from 1991 to 2010 was performed. Demographic data and clinical parameters were extracted from medical records and the trauma registry. Regression analysis was used to identify predictors of prolonged MV.

RESULTS: There were 66 eligible patients of which 42 (62%) had a tracheostomy performed. Five patients (7.6%) remained ventilator dependent and seven (10.6%) died more than 7 days after injury secondary to sepsis. After adjusting for the number of ventilator days after injury, patients who had a tracheostomy had fewer pulmonary complications than those who did not have a tracheostomy ($p = 0.001$). Early tracheostomy resulted in fewer days on the ventilator and a shorter hospital stay. Clinical parameters that predicted MV to be required longer than 7 days were Injury Severity Score $\geq 32$, complete SCI, and a $\text{PaO}_2/\text{FiO}_2$ ratio $< 300$ 3 days after MV was initiated.

CONCLUSION: We recommend early tracheostomy if the Injury Severity Score is $> 32$, the patient has a complete SCI, and the $\text{PaO}_2/\text{FiO}_2$ ratio is $< 300$ 3 days after MV was initiated. (J Trauma Acute Care Surg. 2012;73: 880–884. Copyright © 2012 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Prognostic study, level III.
KEY WORDS: Cervical spine; spinal cord injury; tracheostomy.

Traumatic cervical spinal cord injury (CSCI) is a devastating and potentially life-threatening injury. The majority of early deaths following acute traumatic tetraplegia are due to pulmonary complications resulting from variable inspiratory and/or expiratory muscles paralysis as well as excessive tenacious bronchial mucous production. A high level injury, which includes C1–C3, results in complete respiratory failure necessitating immediate ventilator support for survival. Lower CSCI only partially affects the respiratory muscles; therefore, the need for long-term ventilation is variable and difficult to predict.

Complications of prolonged intubation include laryngeal injury and stenosis, nosocomial pneumonia (including ventilator-associated pneumonia), and difficulty weaning from the ventilator. Early tracheostomy provides many advantages over prolonged endotracheal intubation including the potential avoidance of these complications. However, the greatest advantage is that a tracheostomy facilitates weaning from the ventilator and thereby decreases the overall hospital and intensive care unit (ICU) length of stay (LOS).

Apart from a complete CSCI occurring at a high level, it is difficult to predict those CSCI patients who will require prolonged ventilation and therefore will most benefit from early tracheostomy. A review of the National Trauma Database of the American College of Surgeons found the following variables to be predictors of tracheostomy: complete SCI, Injury Severity Score (ISS) $> 16$, facial fracture, thoracic injury, and intubation at the scene of injury or in the emergency room. Although these factors identify patients who are likely to require tracheostomy, it does not necessarily imply the need for prolonged ventilation. Most studies that attempt to identify such a cohort have not concentrated specifically on spinal cord injured patients.

The purpose of this study was to determine whether there is a benefit in a cohort of ventilated acute traumatic CSCI (1) to tracheostomy when compared with patients not undergoing tracheostomy, (2) to early tracheostomy compared with delayed tracheostomy, and (3) to demonstrate the predictors of prolonged mechanical ventilation (MV) as defined by more than 7 days.
PATIENTS AND METHODS

A retrospective cohort study of all adult patients with acute CSCI admitted to London Health Science Center (LHSC) from April 1991 to February 2010 was performed using the LHSC trauma registry and spinal cord registry. These registries contain prospectively collected data on all trauma patients admitted to LHSC, a Level 1 tertiary care trauma hospital responsible for all major injuries.

The following inclusion criteria were used: age 16 years or older; cervical SCI at the level between C4 and C7; admission to LHSC within 24 hours after the injury; and MV for greater than 24 hours. Patients were excluded if death occurred within 7 days after injury or postoperative MV was a direct result of surgery and had duration of less than 24 hours postoperatively. The indication for intubation or tracheostomy was not standardized and was dependent on the experience and judgment of the attending ICU consultant, trauma attending, and spine surgeon caring for the patient.

The following data were extracted from the trauma and spinal cord registries: basic demographics, mechanism of injury, associated injuries, comorbidities, LOS in hospital, LOS in ICU, Abbreviated Injury Scale, ISS, Glasgow Coma Scale score, level of SCI at the day of admission, motor score at the day of admission and discharge, date of tracheostomy, number of tracheostomy days, total MV days, and number of pulmonary complications. For patients requiring reintubation after failure of a trial of extubation, the longest period of continuous support was used in analysis. The attending orthopedic surgeon or neurosurgeon defined the level of SCI and motor score at admission according to American Spinal Injury Association classification. The following ventilatory data were collected on days 2 to 5 after the initiation of MV: alveolar-arterial oxygen gradient (P(A-a) gradient), positive end expiratory pressure, FiO\textsubscript{2}, P\textsubscript{A}O\textsubscript{2}, P\textsubscript{C}O\textsubscript{2}, tidal volume (VT), minute ventilation (VE), P\textsubscript{A}O\textsubscript{2}/FiO\textsubscript{2} (PF) ratio, and amount of secretion. The degree of pulmonary secretions was subjectively classified by the respiratory therapist caring for the patient into grades 0, 1, 2, and 3 which corresponded to none, mild, moderate, and copious, respectively.

Statistical Analysis

The data analysis was performed using PASW Statistics version 18 (SPSS, Chicago, IL). Student's t test was used for continuous parametric variables, and Mann-Whitney U test was used for nonparametric continuous variables. Comparisons for categorical variables were made using the χ² test or Fisher's exact test. Analysis of covariance was used to compare the number of pulmonary complications in patients with or without a tracheostomy adjusting for the number of ventilation days. Pearson's correlation coefficient was used to assess the magnitude and direction of association between the time from injury to tracheostomy and the number of ventilation days after injury (i.e., time to extubation), as well as the time from injury to tracheostomy and the hospital LOS.

Multiple linear regression analysis was used to determine the relationship between time to tracheostomy and outcomes adjusting for ISS, age, and complete SCI. To identify independent predictors for MV more than 7 days, factors that on univariate analysis were significant were entered into a binary logistic regression (stepwise). All p values were considered significant if <0.05.

This study was reviewed and approved by the human subject research ethics board of the University of Western Ontario.

RESULTS

During the study period, a total of 66 patients were identified for analysis. The mean patient age was 37.6 years ± 17.6 years (mean ± standard deviation [SD]) and ranged from 16 years to 87 years. The majority of patients were males (76%) and most of the injuries were as a result of motor vehicle collisions (72%). Most patients sustained the SCI at either C4 or C5 (69%) and most sustained an incomplete injury (68%). The demographic data are further highlighted in Table 1.

The average length of ventilation was 29.2 days ± 38 days. Five patients were ventilator dependent in that they required MV from the time of admission until the time of discharge. Three patients had to be reintubated at days 2, 4, and 5 after extubation, and all underwent subsequent tracheostomy. Mortality rate more than 7 days after their admission was 10.6% and all were secondary to severe sepsis. Only one of the patients who died had a tracheostomy.

Tracheostomy Versus No Tracheostomy

Demographic and clinical data are shown in Table 1. Of the 66 patients with CSCI, 41 (62%) had a tracheostomy performed during the acute hospitalization. The average time from injury to tracheostomy was 12.0 days ± 10.1 days. Tracheostomy placement occurred more frequently in patients with a C4 level SCI (51.2%, p = 0.006). Patients who had a tracheostomy were similar in all respects except that they had a significantly lower motor score at discharge (p = 0.04), a longer hospital stay (p < 0.001), a longer ICU stay (p = 0.002), and required more ventilation days after injury (p = 0.001) compared with those who did not have a tracheostomy (Table 1).

After adjusting for the number of ventilator days after injury, patients who had a tracheostomy had fewer pulmonary complications than those who did not have a tracheostomy (p = 0.001; Table 2). Furthermore, mortality was significantly lower in patients who had a tracheostomy after adjusting for age and ISS (2.4% vs. 24%, p = 0.025; Table 2).

Early Tracheostomy Versus Delayed Tracheostomy

There was a moderate positive correlation between the time from injury to tracheostomy and the number of ventilation days after injury (r = 0.346, p = 0.038) (Fig. 1). Time to tracheostomy also positively correlated with hospital LOS (r = 0.465, p = 0.004) (Fig. 1). Multiple linear regression of the relationship between time to tracheostomy and hospital LOS, adjusting for age, ISS, and complete SCI, showed that the number of days in hospital increased by 2.3 days for every
TABLE 1. Demographic data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Total (n = 66), Mean ± SD</th>
<th>Tracheostomy (n = 41), Mean ± SD</th>
<th>No Tracheostomy (n = 25), Mean ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yr)</td>
<td>37.6 ± 17.6</td>
<td>34.7 ± 16.0</td>
<td>40.6 ± 19.4</td>
</tr>
<tr>
<td>ISS</td>
<td>34.5 ± 12.4</td>
<td>35.4 ± 9.7</td>
<td>32.8 ± 16.1</td>
</tr>
<tr>
<td>First GCS</td>
<td>10.6 ± 4.6</td>
<td>10.2 ± 4.6</td>
<td>11.1 ± 4.7</td>
</tr>
<tr>
<td>Motor score at admission</td>
<td>26.1 ± 22.0</td>
<td>22.5 ± 20.1</td>
<td>32.9 ± 24.3</td>
</tr>
<tr>
<td>Hospital LOS (d)*</td>
<td>46.2 ± 42.4</td>
<td>62.3 ± 46.5</td>
<td>19.8 ± 9.1</td>
</tr>
<tr>
<td>ICU LOS (d)*</td>
<td>30.8 ± 38.6</td>
<td>43.0 ± 44.5</td>
<td>10.8 ± 8.0</td>
</tr>
<tr>
<td>Ventilation (d)*</td>
<td>29.2 ± 38.0</td>
<td>41.6 ± 43.6</td>
<td>8.9 ± 7.3</td>
</tr>
</tbody>
</table>

Gender
- Male                    | 51 (77.3)                 | 32 (78.1)                        | 19 (76.0)                          |
- Female                   | 15 (22.7)                 | 9 (21.9)                         | 6 (24.0)                           |

Mechanism of injury
- MVC                     | 48 (72.2)                 | 32 (78.1)                        | 16 (64.0)                          |
- Fall                     | 13 (19.7)                 | 7 (17.1)                         | 6 (24.0)                           |
- Other                    | 5 (7.6)                   | 2 (4.9)                          | 3 (12.0)                           |

Level of SCI*
- C4                      | 27 (40.9)                 | 21 (51.2)                        | 6 (24.0)                           |
- C5                      | 18 (27.3)                 | 9 (22.0)                         | 9 (36.0)                           |
- C6                      | 14 (21.2)                 | 10 (24.4)                        | 4 (16.0)                           |
- C7                      | 7 (10.6)                  | 1 (2.4)                          | 6 (24.0)                           |

Comorbidity of Respiratory system
- None                     | 61 (92.4)                 | 38 (92.7)                        | 23 (9.0)                           |
- COPD                     | 1 (1.5)                   | 0                                | 1 (0.1)                            |
- Asthma                   | 1 (1.5)                   | 1 (2.4)                          | 0                                  |
- ARDS                     | 0                        | 0                                | 0                                  |
- Pneumonia                | 3 (4.5)                   | 2 (4.9)                          | 1 (0.1)                            |

Infection
- Yes                      | 36 (54.5)                 | 25 (61.0)                        | 11 (44.0)                          |
- No                       | 30 (45.5)                 | 16 (39.0)                        | 14 (56.0)                          |

Associated injury
- Brain                    | 28 (42.4)                 | 16 (39.0)                        | 12 (48.0)                          |
- Abdomen                  | 12 (18.2)                 | 10 (24.4)                        | 2 (8.0)                            |
- Face                     | 6 (9.1)                   | 3 (7.3)                          | 3 (12.0)                           |

Severity of SCI
- Complete                 | 18 (27.3)                 | 20 (48.8)                        | 9 (36.0)                           |
- Incomplete               | 45 (68.2)                 | 20 (48.8)                        | 14 (56.0)                          |
- Unknown                  | 3 (4.5)                   | 1 (1.5)                          | 2 (8.0)                            |

MVC, motor vehicle collision; COPD, chronic obstructive pulmonary disease; ARDS, acute respiratory distress syndrome.
* p value < 0.05 when compared between tracheostomy and no tracheostomy.

additional day from injury to tracheostomy (adjusted \( r^2 = 0.420, p < 0.001 \)).

Predictors of Prolonged Ventilation

On the third day after MV, patients who required MV for greater than 7 days had similar P(A-a) gradient, positive end expiratory pressure value, and degree of secretions as those requiring MV for less than 7 days (Table 3). However, the PF ratio was significantly reduced on the third day in patients who required MV for longer than 7 days. Those patients with an acute lung injury defined as having a PF ratio of less than 300 was an independent predictor of MV greater than 7 days.

A stepwise logistical regression identified ISS > 32, complete SCI, and acute lung injury (PF ratio < 300) on day 3 as predictors for MV greater than 7 days (Table 4). ISS >32 was chosen because a SCI automatically assigns a score of 16. In this CSCI cohort, a patient with one, two, or three of these factors demonstrated approximately a 60%, 88%, and 97% probability of requiring an MV period longer than 7 days, respectively (Table 5).

**DISCUSSION**

This study focused on the use of tracheostomy to facilitate weaning from the ventilator which is most relevant for the subpopulation of patients requiring prolonged MV. Interestingly, we found that the length of time on the ventilator as well as other recognized benefits of tracheostomy, including decreased ICU and hospital LOS, were paradoxically increased compared with the patients who did not have a tracheostomy. This is similar to the findings of Branco et al., who also demonstrated that CSCI patients receiving tracheostomy had more ventilation days, longer ICU, and hospital LOSs. We think this reflects not the effect of the tracheostomy but rather the indications for tracheostomy. It is important to remember that the indication for tracheostomy was not standardized and was at the discretion of the attending ICU consultant, trauma attending, and spine surgeon caring for the patient. Such potential bias may have implications to the results. As both studies were retrospective, the patients may have had a tracheostomy because they were failing more poorly and had required a prolonged course of ventilation. In our study, these patients had a more severe neurologic injury as demonstrated by a lower motor score, and in the Branco study they had a greater ISS and neurologic injury. However, after adjusting for the number of ventilator days, age, and ISS, having a tracheostomy was shown to decrease pulmonary complications and mortality.

Similar improvements in pulmonary complications and mortality rates have been demonstrated for the CSCI population in other studies. This benefit of tracheostomy is further magnified when performed early. We found a moderate correlation between time to tracheostomy and length of ventilation and hospital stay. The hospital LOS was increased by 2.3 days for every additional day from MV to tracheostomy when age, ISS, and severity of the SCI were controlled. The physiologic explanation for the improved capacity to wean from the ventilator after tracheostomy is well accepted to include reduced airway length, airway resistance and improved breathing efficiency, improved respiratory toilet, and decreased pulmonary complications such as infection, atelectasis, and acute respiratory distress syndrome. Therefore, early tracheostomy in the CSCI patient has the potential to better facilitate weaning so as to decrease overall hospital stay as well as avoid the complications associated with prolonged endotracheal intubation such as tracheal stenosis and improve
patient comfort and emotional state. However, although tracheostomy provided great advantages, it is an invasive surgical procedure and these advantages have to be weighed against potential morbidities.

In the CSCI population, it has been suggested that early tracheostomy be performed in patients who are likely to require prolonged MV. Prolonged MV has been defined to range between 7 days and 14 days in the blunt trauma and surgical critical care literature. We chose 7 days to be consistent with previous spine literature addressing this topic. To our knowledge, factors that predict patients at risk of prolonged ventilation have not been ascertained in the CSCI population. In the blunt trauma patient, age, Glasgow Coma Scale score, and P(A-a) gradient assist in the early identification of patients requiring prolonged mechanical ventilatory support and early conversion from endotracheal intubation to tracheostomy.

Specific to a CSCI cohort, we have demonstrated that the ISS, complete SCI, and PF ratio on day 3 should be used in predicting patients who will require MV longer than 7 days. The likelihood of a patient requiring prolonged ventilation ranges between 60% and 97% depending on how many of these factors are positive (Table 4). Therefore, for CSCI patients who have been ventilated for longer than 24 hours, consideration to tracheostomy should be seriously considered if two or more of these factors are present.

### Table 2. Tracheostomy is Beneficial in Reducing Complications and Mortality

<table>
<thead>
<tr>
<th></th>
<th>Tracheostomy</th>
<th>No Tracheostomy</th>
<th>Adjusted Mean Difference (95% CI)</th>
<th>Adjusted p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulmonary complications, mean ± SD</td>
<td>1.5 ± 0.2</td>
<td>2.7 ± 0.4</td>
<td>1.2 ± 0.5 (0.3–2.1)</td>
<td>0.001*</td>
</tr>
<tr>
<td>Mortality</td>
<td>2.4% (1/41)</td>
<td>24% (6/25)</td>
<td>0.08 (0.009–0.725)</td>
<td>0.025†</td>
</tr>
</tbody>
</table>

OR, odds ratio; CI, confidence interval

* The p value was derived from analysis of covariance for number of pulmonary complication after adjustment for number of ventilation days.
† The p value was derived from binary logistic regression for mortality. The p value was obtained after adjustment for age and ISS.

### Table 3. Comparison of Ventilation Parameters in Patients Requiring Prolonged Ventilation

<table>
<thead>
<tr>
<th>Ventilation Parameter</th>
<th>&gt;7 D of Mechanical Ventilation (n = 50), Mean ± SD</th>
<th>&lt;7 D of Mechanical Ventilation (n = 13), Mean ± SD</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>P(A-a) gradient</td>
<td>203.6 ±128.6</td>
<td>139.1 ± 81.3</td>
<td>0.090</td>
</tr>
<tr>
<td>PF-ratio*</td>
<td>225.6 ± 97.7</td>
<td>302.0 ± 78.6</td>
<td>0.010</td>
</tr>
<tr>
<td>PEEP</td>
<td>6.8 ± 2.5</td>
<td>5.6 ± 1.6</td>
<td>0.113</td>
</tr>
<tr>
<td>Secretion</td>
<td></td>
<td></td>
<td>0.288</td>
</tr>
<tr>
<td>None</td>
<td>12 (24.0)</td>
<td>6 (46.1)</td>
<td></td>
</tr>
<tr>
<td>Mild</td>
<td>21 (42.0)</td>
<td>4 (30.1)</td>
<td></td>
</tr>
<tr>
<td>Moderate</td>
<td>14 (28.0)</td>
<td>3 (23.0)</td>
<td></td>
</tr>
<tr>
<td>Copious</td>
<td>3 (6.0)</td>
<td>0 (0)</td>
<td></td>
</tr>
</tbody>
</table>

* p value <0.05 when compared between mechanical ventilation for >7 d and mechanical ventilation >7 d. The p value was derived using Student’s t test or χ² test.

### Table 4. Predictors for Prolonged Mechanical Ventilation

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Adjusted OR (95% CI)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ISS &gt;32</td>
<td>4.3 (1.0–18.6)</td>
<td>0.047</td>
</tr>
<tr>
<td>2</td>
<td>Complete SCI</td>
<td>5.0 (1.0–22.5)</td>
<td>0.048</td>
</tr>
<tr>
<td>3</td>
<td>P(O2/FiO2) on day 3 &lt;300</td>
<td>5.0 (1.1–20.7)</td>
<td>0.036</td>
</tr>
</tbody>
</table>

OR, odds ratio; CI, confidence interval.

p value < 0.05 is a statistical significance.

Variables entered in the regression: complete SCI, ISS >32, P(O2/FiO2) <300 on day 3, P(O2/FiO2) <300 on day 2.
TABLE 5. Degrees of Probability to Predict Prolonged MV More Than 7 d by Combining Predictors

<table>
<thead>
<tr>
<th>ISS &gt;32</th>
<th>Complete SCI</th>
<th>PF Ratio &lt; 300</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>0.97</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>0.89</td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>0.88</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>0.88</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>0.64</td>
</tr>
<tr>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>0.64</td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>0.61</td>
</tr>
<tr>
<td>No</td>
<td>No</td>
<td>No</td>
<td>0.27</td>
</tr>
</tbody>
</table>

CONCLUSION

This study verified that in CSCI patients tracheostomy decreased mortality rate and pulmonary complications compared with endotracheal intubation longer than 7 days. We have demonstrated that early tracheostomy facilitates quicker extubation and shorter hospital stays. We recommend early tracheostomy if at least two of the following three factors are present: the ISS > 32, the patient has a complete SCI, or PF ratio < 300 3 days after MV was initiated.

AUTHORSHIP

S.I.B. designed the study; P.L. and C.S.B. conducted the literature search and collected data. P.L., J.C.F., and C.S.B. analyzed and interpreted the data. All authors participated in writing the manuscript.

DISCLOSURE

The authors declare no conflicts of interest.

REFERENCES