Characterizing the Need for Mechanical Ventilation Following Cervical Spinal Cord Injury with Neurologic Deficit

John J. Como, MD, Erica R. H. Sutton, MD, Maureen McCunn, MD, Richard P. Dutton, MD, Steven B. Johnson, MD, Bizhan Aarabi, MD, and Thomas M. Scalea, MD

Background: Patients who sustain cervical spinal cord injury (C-SCI) with neurologic deficit may require a definitive airway and/or prolonged mechanical ventilation. The purpose of this study was to characterize factors associated with a high risk for respiratory failure and/or the need for mechanical ventilation in C-SCI patients.

Methods: Patients with C-SCI and neurologic deficit admitted to a Level I Trauma Center between July 1, 2000 and June 30, 2002 were retrospectively reviewed for demographics, level and completeness of neurologic deficit, need for definitive airway, need for tracheostomy, need for mechanical ventilation at hospital discharge (MVDC), and outcomes. The level and completeness of injury were defined by American Spinal Injury Association standards.

Results: One hundred nineteen patients with C-SCI and neurologic deficit were identified over this period. Of these, 45 were identified as complete C-SCI: 12 (27%) patients had levels of C1 to C4; 19 (42%) had a level of C5; and 14 (31%) had levels of C6 and below. There were 37 males and 8 females. There were 36 blunt and 9 penetrating injuries. The average age of these patients was 40+/-21, and the average ISS was 45+/-22. Eight of the patients with complete C-SCI died, for a mortality of 18%. Of the 37 survivors, 92% received a definitive airway, 81% received tracheostomy, and 51% required MVDC. All patients with complete injuries at the C5 level and above required a definitive airway and tracheostomy, and 71% of survivors required MVDC. Of the patients with complete injuries of C6 and below, 79% received a definitive airway, 50% required tracheostomy, and 15% of survivors required MVDC. Only 35% of incomplete injuries required a definitive airway, and only 7% required tracheostomy.

Conclusions: The need for definitive airway control, tracheostomy, and ventilator dependence is significant, especially for patients with high complete C-SCI. Based on these results we recommend consideration of early intubation and tracheostomy for patients with complete C-SCI, especially for those with levels of C5 and above.

Key Words: Airway, Cervical spine, Cricothyroidotomy, Intubation, Neurologic deficit, Tracheostomy.

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Traumatic injuries to the spinal cord result in paralysis of the muscles that are innervated by segments caudal to the involved spinal cord segment. In particular, if the cervical spinal cord is involved, paralysis of the diaphragm and accessory muscles of respiration may occur. The cord injury may also ascend one or two levels because of bleeding or swelling in the area of the trauma, paralyzing muscles not originally involved.[1] In addition, patients with traumatic quadriplegia are at risk for subsequent respiratory complications, such as atelectasis and pneumonia.[2] All of these situations may lead to the need for mechanical ventilation. In general, it is best to proceed with intubation and to initiate mechanical ventilation under controlled circumstances rather than as an emergency. There is a paucity of data in the literature regarding the need for a definitive airway in the patient with cervical spinal cord injury (C-SCI). The objective of this study was to characterize factors that are associated with respiratory failure and the need for mechanical ventilation in C-SCI patients.

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From the Case Western Reserve University School of Medicine, MetroHealth Medical Center, Department of Surgery, Division of Trauma, Critical Care, Burns, and Metro Life Flight, Cleveland, Ohio (J.C.J) and the Department of Surgery (E.R.H.S.), Section of Trauma Anesthesiology (M.M., R.P.D.), Program in Trauma and Surgical Critical Care (S.B.J., T.M.S.), R. Adams Cowley Shock Trauma Center, and the Department of Neurosurgery (B.A.), University of Maryland School of Medicine, Baltimore, Maryland.

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Address for correspondence: John Como, MD, FACS, Assistant Professor of Surgery, MetroHealth Medical Center, 2500 MetroHealth Drive, Cleveland, OH, 44109; email: jjc0965@aol.com.

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PATIENTS AND METHODS

A retrospective review of all patients with cervical spine injury and neurologic deficit admitted to the R Adams Cowley Shock Trauma Center from July 1, 2000 through June 30, 2002 was performed. The trauma center database was used to identify these patients. The demographic data were extracted through a query of the database and a chart review. The data extracted included: age, gender, length of stay (LOS), intensive care unit (ICU) days, survival, Injury Severity Score (ISS), Abbreviated Injury Scale (AIS) score, mechanism of injury (MOI), admission vitals, Glascow Coma Score (GCS), level of deficit, complete versus incomplete injury, admission lactate, fluid and blood products given over the first 48 hospital hours, need for a definitive airway, type of airway, timing of airway, indication for airway, need for tracheostomy, tracheostomy day, ventilator days, and need for ventilator upon discharge from the hospital.

The level and completeness of injury were defined according to American Spinal Injury Association (ASIA) standards.[3–5] These were then documented in the chart by the attending neurosurgeon on the first admission day. According to ASIA criteria, a spinal cord injury is defined as complete when there is an absence of motor or sensory function at sacral segments S4-5. In comparison, an incomplete injury has motor and/or sensory function at the lowest sacral segment. Neurologic level of injury refers to the most caudal segment of the spinal cord with normal sensory and motor function on both sides of the body. Motor level refers to the most caudal segment of the spinal cord with normal motor function on both sides of the body. Normal motor function in this context means a motor grade of greater than or equal to 3 with all the superior motor levels being grade 5. Per ASIA standards, C5 supplies elbow flexors; C6 supplies wrist extensors; C7 supplies elbow extensors; C8 supplies finger flexors (flexor digitorum profundus) to the middle finger; and T1 supplies small finger abductors (abductor digiti minimi).[4] Sensory level is similarly defined as the most caudal segment with normal sensory function on both sides of the body.

A patient was coded as having received a definitive airway if any of the following were performed: orotracheal intubation, nasotracheal intubation, tracheostomy, or cricothyroidotomy. Patients who were intubated only for the operating room and subsequently extubated within six hours of the operation were not coded as having received a definitive airway for the purposes of this study.

Dichotomous data were analyzed by a two-tailed Fisher's exact test. SPSS version 11.5 for Windows (SPSS, Inc., Chicago, Ill) was used for data analysis. A value of $p < 0.05$ was considered statistically significant.

This study was reviewed by the Institutional Review Board (IRB) at the University of Maryland at Baltimore and determined to be exempt from the IRB approval process.

RESULTS

For the 24-month period of review, 119 patients were identified with C-SCI and neurologic deficit (Figure 1). There were 93 males and 26 females. There were 108 blunt traumas and 11 penetrating traumas. Overall mortality was 10%. Forty-five had complete C-SCI, and 74 were incomplete. The average age of those with complete and incomplete injuries was 40 and 50 years, respectively, while the average ISS was 45 and 20, respectively.

Our patient population with complete C-SCIs (n = 45) consists of predominantly middle-aged males who sustained blunt trauma (Table 1). Of these complete C-SCIs, there were 37 males and 8 females; 36 blunt injuries and 9 penetrating injuries. Eight of these patients died while in the hospital for a mortality of 18%. Twelve patients with complete C-SCI had levels of C4 and above; 19 had a level of C5; and 14 had levels of C6 and below (Table 2). Of the complete C-SCIs, 41

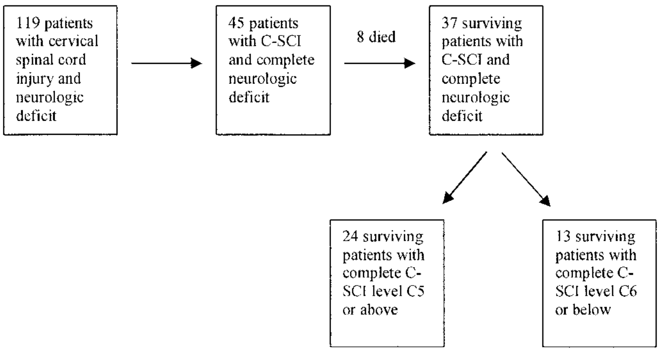

Fig. 1. *Patients identified with C-SCI and neurologic deficit.*

(91%) received a definitive airway, 32 (71%) received tracheostomy, and 19 (42%) required continued mechanical ventilation after hospital discharge (MVDC). Some of the patients in this study died before they could receive an intervention such as a definitive airway or a tracheostomy. Of those who survived long enough to be a candidate for an airway or a tracheostomy, 41/44 (93%) received a definitive airway; 32/39 (82%) had a tracheostomy performed, while 19/37 (51%) required continued MVDC.

There were 31 complete C-SCIs with levels of C5 and above. All these patients were deemed to require a definitive airway. An airway was subsequently placed in all of these patients, except for an 85 year-old C4 complete quadriplegic male who refused intubation and subsequently expired. All remaining patients in this group subsequently also required tracheostomy, except for four additional patients who died early in their hospitalization (two on hospital day seven and one each on hospital days one and nine) after a definitive airway was achieved, but before tracheostomy could be performed. It is likely that had these patients survived, they would have required tracheostomy. Two additional patients also died after tracheostomy was performed, but before hospital discharge, on hospital days 4 and 23. Of note, the former patient was admitted as a complete C5 C-SCI. His level

Table 1 Patient Demographics

Mean (± SD)	Overall (n = 45)	C5 and above (n = 31)	C6 and below (n = 14)
Age (yrs)	40 (±21)	41 (±22)	36 (±18)
Gender			
Male	37 (82%)	24 (77%)	13 (93%)
Female	8 (18%)	7 (23%)	1 (7%)
Mechanism			
Blunt	36 (80%)	24 (77%)	12 (86%)
Penetrating	9 (20%)	7 (23%)	2 (14%)
Admission vital signs			
SBP	114 (±20)	116 (±21)	108 (±19)
HR	76 (±21)	79 (±22)	69 (±16)
RR	16 (±6)	16 (±6)	16 (±6)
GCS	12 (±5)	11 (±5)	15 (±1)
Time to airway (hrs)	6 (±11)	5 (±11)	9 (±9)
LOS (days)	22 (±11)	23 (±11)	22 (±12)
Died	8 (18%)	7 (23%)	1 (7%)

Table 2 Results

	Overall (n=45)	C5 and above (n=31)	C6 and below (n=14)	*p* value
Airway	41 (91%)	30 (97%)	11 (79%)	0.082
Airway or died first	42 (93%)	31 (100%)	11 (79%)	0.026
Airway (survivors)	34/37 (92%)	24/24 (100%)	10/13 (77%)	0.037
Tracheostomy	32 (71%)	26 (84%)	6(43%)	0.011
Tracheostomy or died first	38 (84%)	31 (100%)	7 (50%)	<0.001
Tracheostomy (survivors)	30/37 (81%)	24/24 (100%)	6/13 (46%)	<0.001
MVDC	19 (42%)	17 (55%)	2 (14%)	0.021
MVDC or died first	27 (60%)	24 (77%)	3 (21%)	0.001
MVDC (survivors)	19/37 (51%)	17/24 (71%)	2/13 (15%)	0.002

MVDC, Mechanical ventilation at hospital discharge.

apparently ascended and he had a respiratory arrest. He was hypoxic, but made no respiratory effort. Endotracheal intubation was unsuccessful, and cricothyroidotomy was necessary as a life-saving measure. Care was subsequently withdrawn. Of the remaining 24 patients, 17 (71%) still required mechanical ventilation at the time of hospital discharge, including all 8 surviving patients with levels of C4 and above.

There were 14 patients with levels of C6 and below. A definitive airway was placed in 11 (79%) of these patients. Six of these patients eventually received a tracheostomy, while another patient would have likely required a tracheostomy also had he not expired on hospital day eight. Of the surviving 13 patients, only 2 still required a ventilator at hospital discharge. Therefore, of the 14 original patients who had a level of C6 and below, 7 (50%) would have required tracheostomy had all lived. This is significantly different ($p = 0.001$) from the same data on those with a complete C5 injury, in which all 19 patients either expired or had tracheostomy placed.

Of the patients with complete C-SCIs, 32 eventually received tracheostomy. The range of hospital day of tracheostomy was from day 1 to day 27. The average day of tracheostomy was day 10. Those with higher C-SCIs tended to receive tracheostomy earlier, but this did not reach statistical significance. Of the sixteen patients with levels of C5, the average day of tracheostomy was day 12.

Nineteen of the patients with complete C-SCIs were still ventilator-dependent at discharge from the hospital. The range of day of discharge to the ventilator unit was from day 17 to day 42. The average day of discharge for these patients was day 28.

There were 74 incomplete C-SCIs, of which only 26 (35%) required a definitive airway, only 5(7%) required tracheostomy, and only 1 (1%) required mechanical ventilation at the time of hospital discharge.

DISCUSSION

Spinal cord injury (SCI) is a common problem, occurring with an annual incidence of 15–40 cases per million.[5] Typically, about one in 40 patients admitted to a major trauma center suffers an acute SCI.[6] Approximately 55% of all SCIs occur in the cervical region.[5] Cervical spinal cord injury (C-SCI) is often associated with alterations in respiratory function that may lead to the need for mechanical ventilation. Inspiration involves contraction of the diaphragm and the internal intercostal muscles, which allow the chest wall to expand.[7] The accessory muscles are recruited to aid in this process at high levels of activity. Expiration is mostly passive but can be augmented in this process by the abdominal musculature.

The diaphragm is innervated by C3-C5, and SCI above this level will result in the need for immediate mechanical ventilation. Even if this segment is preserved, any C-SCI will lead to substantial compromise in ventilatory function because of paralysis of the intercostal muscles. This will result in chest wall contraction with inspiration. In addition, forced expiration will also be compromised because of paralysis of the abdominal musculature. This will also result in a decreased ability to cough and to clear secretions, which may later lead to respiratory insufficiency. [8] In the first week after injury, the vital capacity of patients with C-SCI is 30% or less.[9] Occasionally, cord swelling or bleeding in the area of injury may cause the level of the cord injury to ascend, and a patient who originally had intact phrenic nerve function may develop diaphragmatic paralysis due to the higher level of cord involvement.[1] More commonly, however, delayed respiratory insufficiency will be due to retained secretions and patient fatigue. Later, an improvement in respiratory function often occurs as the paralysis of the intercostal muscles becomes spastic, resulting in a rigid chest wall that no longer collapses with inspiration.[7] A significant increase in vital capacity subsequently occurs within five weeks of injury with an approximate doubling of vital capacity three months after injury.[9] Because of this, a patient who is initially dependent on mechanical ventilation might eventually leave the hospital off the ventilator. Factors that adversely affect the ability of a patient to wean from the ventilator include high level of injury, age greater than 50 years, and other associated injuries.[1]

Because of the respiratory difficulties associated with C-SCI, a definitive airway commonly needs to be established. In general, this can be safely accomplished via orotracheal intubation.[10,11] This is ideally performed under controlled circumstances rather than as an emergency.[12,13] Most of the high C-SCI patients in our series were orotracheally intubated either in the field or within the first hour of their admission for respiratory distress of some form. At high levels, especially at C1-C4, the patients are in respiratory distress in the field or on arrival and thus have a definitive airway placed. For patients with a C5 level, however, there is no acute paralysis of the diaphragm, and respiratory distress may not be apparent. These patients had a definitive airway placed anywhere from on arrival to the trauma center to 63 hours after arrival. The average time for a patient with a C5 injury to receive a definitive airway was three hours, if the patient who received an airway at 63 hours is excluded.

Almost all patients in this group required a very early definitive airway. They received this because of their initial injury and not because of subsequent respiratory failure. Other injuries aside from the cervical spinal cord injury may also have contributed to the initial need to establish an airway. Because of our long experience with this disease we recognize that ventilatory dysfunction is likely, and we will semi-electively intubate complete cervical spinal cord-injured patients at the first signs of distress. If one waits until the airway is an emergency, then an emergency intubation is required, which is riskier than identifying the patient early enough to allow for a fiberoptic intubation while awake, under controlled conditions.

As noted above, it is possible that other injuries aside from the C-SCI contributed to the need for ventilatory support. In our data set, a trend was noted for more associated injuries in the group of patients with levels of C5 and above. Review of our data, however, suggests that significant injuries to other portions of the body were not overwhelmingly common. AIS scores were reviewed for all 45 complete C-SCI patients. There were only five patients that had an AIS score for any body region aside from AIS = 1 (head or neck, including cervical spine) of 4 or more. There were only 22 patients that had an AIS score for any body region aside from AIS = 1 of 3 or more. Almost all of these were from the AIS = 3 (chest) body region. Of note only 1 patient had an AIS = 4 (abdominal or pelvic contents) score as high as 3. The respiratory dysfunction seen in most patients in this series was likely due to the complete C-SCI, with some contribution from associated injuries.

All patients with injuries of C5 and above that survived had severe enough respiratory failure that they received tracheostomy. Except for one patient that received a cricothyroidotomy on the first day because of failure to intubate or ventilate, all of these tracheostomies were performed on hospital day six or later. The average day of tracheostomy for C5 complete injuries was day 11. There has not been a policy at our hospital to perform tracheostomy on any patient with a C-SCI at C5; these patients required tracheostomy because of failure to wean from the ventilator as shown by the late average time of tracheostomy for this patient population.

All surviving patients with a C-SCI level of C4 or higher were eventually discharged to a ventilator unit, with an average day of discharge of day 29 (range = 17–36). Of the 16 surviving C5 injuries, 9 were ventilator-dependent upon discharge. Of the 14 patients with levels of C6 and below, only 6 (43%) required tracheostomy, and only 2 (15%) of 13 surviving patients were ventilator-dependent on discharge. The long-term outlook of the respiratory status of patients with complete C-SCI is certainly dependent on the level of injury. All those with injuries above the C5 level needed a ventilator on discharge; almost all those below this level were free from the ventilator on discharge; and about half of the C5 survivors required ventilatory support upon discharge, although all of these patients did require tracheostomy.

We have identified in this study significant differences in ventilatory function between patients with a spinal cord level of C5 and above and those with levels of C6 and below. Other studies have also shown a difference in respiratory function between these two groups of patients. Claxton et al. showed that neurologic level of C5 and above and complete spinal cord lesions were predictors of the need for mechanical ventilation.[14] A recent study by Harrop et al. found that while 79% of their complete spinal cord injuries with a neurologic level of C5 and above received tracheostomy, only 35% of those with levels of C6 and below received this intervention.[15] The trends we have identified in this study have thus also been noted in prior reviews of the subject, although the exact numbers vary somewhat.

The benefits of early tracheostomy have been well-documented, and reports have shown a decrease in the incidence of pulmonary infections, a decrease in the incidence of laryngeal injury, shorter mean hospital and intensive care unit stays and shorter duration of mechanical ventilation, accompanied by lower cost of hospitalization.[16–19] Because a C-SCI level of C5 and above is so highly correlated with the need for tracheostomy, we feel that early tracheostomy should be strongly considered in this patient population.

We have also identified a difference in respiratory management between complete and incomplete injuries. Although incomplete injuries in this study encompassed a wide range of injuries (ASIA grades B, C, and D), it is important to note that very few (35%) required a definitive airway and almost none (7%) required tracheostomy. Thus, the relationships we have identified for complete injuries do not apply to incomplete lesions.

This study is a retrospective study and is thus limited in that it cannot predict outcomes, but can only characterize relationships between variables. The group is a heterogeneous population, including both blunt and penetrating injuries. The study is also limited by the relatively small amount of patients. A subsequent study might examine only complete injuries over a longer period. A prospective study would be difficult since it would be difficult to blind all involved in the respiratory care of the patients, although a prospective observational study might be possible. Even given these limitations, the trends we have identified are significant and have implications on patient management. Patients with high C-SCI, even in the absence of respiratory distress, should be considered at high risk for respiratory failure, and efforts should be made to perform endotracheal intubation on these patients early, before the airway needs to be controlled as an emergency. Tracheostomy should also be performed early, both to decrease the length of stay in the intensive care unit and to facilitate weaning from the ventilator.

CONCLUSION

The need for definitive airway control, tracheostomy, and ventilator dependence is significant, especially for patients with high complete C-SCI. Based on these results we recommend consideration of early intubation and subsequent tracheostomy for patients with complete C-SCI, especially for those with levels of C5 and above. Many of these patients will go on to require mechanical ventilation after hospital discharge.

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EDITORIAL COMMENT

The authors present a retrospective review of patients with cervical spinal cord injury admitted to a single Level I Trauma Center and assess the need for a definitive airway, mechanical ventilation and tracheostomy. The study covers a two-year period, from July 1, 2000 to June 30, 2002 and reviews data on 119 patients admitted with cervical spinal cord injury and neurologic deficit, concluding that patients with complete cervical spinal cord injury above the level of C5 should undergo early intubation and tracheostomy. Although the results may seem intuitive, this study is important in that it brings attention to a topic for which there is little data, and the authors are to be congratulated on their efforts. Limitations of this paper include: its retrospective nature, small sample size, and short follow-up. But despite these limitations, I agree with the author's comment that trends they have identified are significant and have implications for patient care. Early intubation/tracheostomy of patients with complete cervical spinal cord injury above C5 will hopefully improve the care of these patients with serious injury.

Jack Jallo, MD, PhD
Department of Neurosurgery
Temple University