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Ventilatory Strategies in Traumatic Cervical Spinal Cord Injury: Controversies and Current Updates

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Introduction

Trauma remains the leading cause of spinal cord injuries (SCI) worldwide and more than half of these injuries occur at the cervical level [1]. While falls are a major cause of cervical SCI (CSCI) in the elderly, motor vehicle accidents, violence and sports are the common causes in children and the younger adult populations [1,2]. Males are more commonly affected than females and the highest incidence is reported to be among patients aged 15–45 years, with a second peak in those aged 65–80 years [1-3].

CSCI typically presents with significant acute respiratory embarrassment demanding ventilatory support, primarily tracheal intubation, and mechanical ventilation (MV) [4-6]. The ventilatory impairment occur secondary to reduced vital capacity and ventilatory reserve because of disruption of neural pathways to the diaphragm and respiratory muscles of the chest and abdomen. In addition, sympathetic denervation causes bronchospasm, increased mucus secretion and pulmonary edema [7,8]. Depending on the level of CSCI, about 21%–77% of these patients eventually require tracheostomy with the goal of reducing the occurrence of complications (atelectasis, pneumonia, aspiration, acute respiratory distress syndrome, etc.) and mortality [9,10].

In the last 10 years, a lot of studies have been done on the various domains of ventilation in traumatic CSCI. However, the inconsistent results have led to disagreements and sparked debates. We searched electronic citation databases (PubMed, Scopus, the Cochrane Database of Systematic Reviews) for available literature on ventilatory strategies in traumatic cervical SCI published in 2015 and thereafter. This editorial has unraveled the existing controversies and gives readers a thorough update on the subject.

Timing of Tracheal Intubation

An established approach to prevent unexpected respiratory compromise is early routine tracheal intubation in motor-complete CSCI above the C5 level. Due to the risks associated with intubation, the absolute necessity for intubation in patients with CSCI based on initial neurologic assessment is debatable in light of recent developments in multidisciplinary respiratory care.

Yonemitsu et al. [11] conducted a retrospective study to determine the most important predictor of respiratory exacerbation (RE) and emergency tracheal intubation following CSCI (motor-complete injury and/or injury above the level of C5) in non-intubated patients at admission. The authors found that 13 out of 55 patients (22.4%) had RE (mean=3.5 days). Eleven of the 27 patients (40.7%) with motor-complete injury, five of the 22 patients (22.7%) with neurologic injury above C5 and three of the eight pa-

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tients (37.5%) with both risk factors required emergency tracheal intubation. One patient died during hospitalization. Of the various variables studied for multivariate analyses (motor-complete injury, neurologic level above C5, atelectasis, and copious airway secretion), copius airway secretion was an independent predictor for RE. The authors concluded that even in cases with motor-complete injury above C5 without early routine intubation, prompt intubation based on close monitoring and attention to copius airway secretions, especially during the first 3 days of injury may minimize RE and reduce needless invasive airway control [11]. However, the results of this study should be interpreted with caution due to the small sample size and the single center retrospective design of the study. The Emergency Neurological Life Support protocol (2012, 2019) for traumatic spine injury recommends that all patients with acute complete CSCI above C5, as determined by initial neurological examination, should be intubated as soon as possible before admission [12,13]. Further research is needed on this topic to resolve the controversies.

Non-invasive Ventilation versus Invasive Ventilation

Most patients with high-level CSCI require invasive ventilation (endotracheal intubation/tracheostomy) especially those complicated by polytrauma (head injury, chest injury, etc.). These patients eventually become ventilator dependent and suffer ventilator associated complications [14]. However, advances in acute care and rehabilitation of patients with C1–C5 CSCI have shown that cooperative patients and patients without concurrent severe head injury are usually good candidates for non-invasive ventilation (NIV) [15]. In addition, NIV and mechanically assisted coughing (MAC) can also be used to extubate or decannulate "unweanable" patients with CSCI [15,16].

Toki et al. [15] conducted a retrospective study wherein they found that 11 out of 14 tracheostomy ventilator-dependent patients who had sustained high CSCI (above C3) with American Spinal Cord Injury Association Impairment Scale A could be successfully switched to NIV. The success rate of switching to NIV was 100% in patients who had history of tracheostomy ventilation of duration less than 1 year (seven of seven patients) as compared to more than 1 year (four of seven patients, 57%; $p<0.05$). All patients were successfully discharged from the hospital. Later on, two patients died due to unrelated causes while the others did not encounter any major complication. The authors concluded that switching tracheostomy ventilation to NIV in high CSCI is safe and thus recommended its application within 1 year of injury [15].

In another retrospective study, Kim et al. [16] observed that out of 62 patients who were tracheostomized following CSCI, successful decannulation was seen in all the patients after employing NIV and MAC. The mean time since tracheostomy to decannulation was 7.0±14.5 months. Fifteen patients totally weaned off from ventilators after NIV. Two patients who once succeeded in decannulation were re-tracheostomized. For the 31 patients with continuous NIV, mean hours of daily need for ventilatory support had reduced from 15.3±8.0 to 5.7±5.7 hours at final follow-ups [16].

High CSCI can be successfully decannulated through NIV and aggressive use of MAC. Besides, undesirable tracheostomy can be avoided by early initiation of NIV. The primary goal should focus on strengthening of respiratory accessory muscles. Further research is needed to determine how NIV affects long-term respiratory functioning and clinical outcomes, particularly in patients for whom NIV is instituted in the hyperacute phase to avoid endotracheal intubation or tracheostomy.

High Tidal Volume versus Low Tidal Volume

Previous studies have shown that CSCI patients ventilated with high tidal volume (HTV) (≥20 mL/kg predicted body weight [PBW]) have lower incidence of atelectasis and respiratory complications and achieve faster weaning [17,18]. However, few recent studies have shown conflicting results. Hatton et al. [19] found that HTV (mean tidal volume [TV], 10.8 mL/kg PBW; n=22) was associated with increased risk of ventilator associated pneumonia (VAP) (relative risk, 1.96; 95% credible interval, 1.55–2.17) and decreased likelihood of achieving ventilator independence as compared to low tidal volume (LTV) or standard TV (mean TV, 7.6 mL/kg PBW; n=159). Complete injury, high SCI level, low Injury Severity Score (ISS), older age, and blunt injury mechanism were associated with increased VAP development [19]. In another recent study, the odds of pneumonia and adverse pulmonary events were 4.3 times (95% confidence interval [CI], 1.5–12) and 5.4 times (95% CI, 1.8–17) higher respectively in HTV (>15 mL/kg PBW, n=34) group as compared to LTV or medium TV (<15 mL/kg PBW, n=50) in tracheostomized patients following SCI [20]. In contrast, in a prospective randomized study, Sengupta et al. [21] found that the incidence of VAP was significantly higher in CSCI patients ventilated with LTV (6–8 mL/kg PBW, n=28) as compared to HTV (12–15 mL/kg PBW, n=28) (32% versus 11%, p=0.05), though, there was no difference in ventilator free breathing period and mortality. The authors also observed a significant difference in PaO_2:FiO_2 ratio (ratio of partial pressure of oxygen in arterial blood and fraction of inspiratory oxygen concentration) (HTV: 364.0±64; LTV: 321.0±67.0; p=0.01); however, this was not significant clinically [21].

The inconsistency in the results of the above studies has made it difficult to draw definitive conclusions. The reasons of this variability include retrospective nature of majority of the studies, limited sample size and the lack of uniform definition of HTV and LTV. Further research should focus on addressing these important issues so as to derive concrete evidence.

Early versus Late Tracheostomy

In CSCI patients, factors like complete/incomplete SCI, anatomic level of injury, Glasgow Coma Score, ISS, facial fracture, and related thoracic injury have been shown to govern the choice to perform a tracheostomy [22,23]. The need for early tracheostomy versus late tracheostomy in CSCI patients, however, was not clearly established by earlier studies.

In a retrospective study conducted on 5,980 CSCI patients, the authors found that patients in the early tracheostomy group (≤4 days from initial intubation, n=1,010) had lower rates of respiratory complications (30% versus 46%, p=0.01), higher MV-free days (13 days versus 9 days, p=0.02), intensive care unit (ICU)-free days (11 days versus 8 days, p=0.01), and a shorter hospital length of stay (LOS) (22 days versus 29 days, p=0.01) compared with those in the late tracheostomy group (>4 days, n=4,970). On regression analysis, early tracheostomy was associated with lower rates of respiratory complications in patients with both high CSCI (odds ratio, 0.55; 95% CI, 0.41–0.81]) and low CSCI (odds ratio, 0.93; 95% CI, 0.72–0.95). However, no association was found between time to tracheostomy and in-hospital mortality [24]. In another retrospective study, the clinical outcomes of tracheostomies performed on patients with CSCI at various timelines were compared. The authors found that the late group (tracheostomy >10 days from initial intubation, n=40) required significantly more time for MV, longer stay in the ICU, higher rate of ICU mortality and higher pneumonia after tracheostomy as compared to early and medium groups (tracheostomy <4 days [n=46] and 4–10 days [n=38], respectively from initial intubation). The benefits were apparent even at 1-year follow-up, wherein the early and medium groups achieved better improvement of Japanese Orthopedic Association and Neck Disability Index scores than the late group [25]. Again, Khan et al. [26] found that early tracheostomy (≤7 days) in patients with CSCI was associated with significantly lower rates of VAP, shorter duration of MV, and lesser duration of ICU and hospital stay (n=1,139); though, there was no difference in mortality when compared to late tracheostomy (>7 days). On subgroup analysis, early tracheostomy resulted in significantly lower VAP and overall complications in both high CSCI (C1–C4) and low CSCI (C5–C7) as compared to late tracheostomy group [26]. Beom and Seo [27] added that early tracheostomy (≤7 days of intubation) should be taken into consideration if intubation was necessary for longer than 4 days following surgery for CSCI because it was demonstrated in their study to considerably shorten the length of ICU stay as compared to late tracheostomy (>7 days). Similar results were observed in few other studies [28,29]. All of the aforementioned studies had the drawback of being retrospective in nature, with the majority of them having a small sample size.

In a systematic review and meta-analysis of patients (17 studies, n=2,804 patients) with acute cervical or thoracic traumatic SCI, the authors found that early tracheostomy (≤7 days of intubation) decreased the duration of MV, ICU LOS, and hospital LOS in addition to reduced incidence of VAP and tracheostomy-related complications as compared with late tracheostomy (>7 days of intubation). Early tracheostomy did not, however, affect short-term mortality [30]. Similar results were observed in another recent meta-analysis [31]. The limitations of this meta-analyses included the heterogeneity between studies, the inclusion of small single-center studies, mixed cervical and thoracic level SCI populations, and lack of a comparator "no tracheostomy" cohort in the included studies.

Current research, though not conclusive, supports early tracheostomy in CSCI. Randomized controlled trials are needed to determine the effects of tracheostomy timing on the mortality, patient comfort, and quality of life outcomes in CSCI patients.

Conclusions

The lack of innervated muscles after CSCI is insufficient enough to provide ventilation and other activities to complete the respiratory function. In addition to the decline of respiratory capacity, respiratory complications also have a serious impact on the life of patients. The optimal approach to ventilatory management in patients with CSCI remains an area of active research and debate and reflect the complexity of caring for these patients, and the need for individualized approaches that take into account the unique characteristics of each patient's injury, comorbidities, clinical presentation, and overall clinical trajectory.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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