Timely Intubation With Early Prediction of Respiratory Exacerbation in Acute Traumatic Cervical Spinal Cord Injury

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Abstract

Background: Early routine intubation in motor-complete cervical spinal cord injury (CSCI) above the C5 level is a conventional protocol to prevent unexpected respiratory exacerbation (RE). However, in context of the recent advances in multidisciplinary respiratory management, the absolute indication for intubation in CSCI patients based on initial neurologic assessment is controversial because of the drawbacks of intubation. This study aimed to redetermine the most important predictor of RE following CSCI after admission without routine intubation among patients admitted with motor-complete injury and/or injury above the C5 level to ensure timely intubation.

Methods: We performed a retrospective review of patients with acute traumatic CSCI admitted to our hospital without an initial routine intubation protocol from January 2013 to December 2017. CSCI patients who developed RE (defined as unexpected emergent intubation for respiratory resuscitation) were compared with those who did not. Baseline characteristics and severity of trauma data were collected. Univariate analyses were performed to compare treatment data and clinical outcomes between the two groups. Further, multivariate logistic regressions were performed with clinically important independent variables: motor-complete injury, neurologic level above C5, atelectasis, and copious airway secretion (CAS).

Results: Among the analyzed 58 patients with CSCI, 35 (60.3%) required post-injury intubation and 1 (1.7%) died during hospitalization. Thirteen (22.4%) had RE in 3.5 days (mean) post-injury; 3 (37.5%) of eight motor-complete CSCI patients above C5 developed RE. Eleven of the 27 (40.7%) patients with motor-complete injury and five of the 22 (22.7%) patients with neurologic injury above C5 required emergency intubation at RE. Three of the eight CSCI patients with both risk factors (motor-complete injury above C5) resulted in emergent RE intubation (37.5%). CAS was an independent predictor for RE (odds ratio 7.19, 95% confidence interval 1.48–42.72, P=0.0144) in multivariate analyses.

Conclusion: Timely intubation post-CSCI based on close attention to CAS during the acute 3-day phase may prevent RE and reduce unnecessary invasive airway control even without immediate routine intubation in motor-complete injury above C5.

1. Background

Patients with acute traumatic cervical spinal cord injury (CSCI) often undergo endotracheal intubation for definitive airway control in cases of acute respiratory exacerbation (refractory desaturation, major dyspnea, and respiratory arrest) induced by pulmonary complications. Prevention of pulmonary complications (copious sputum, atelectasis, pneumonia, and ventilatory disorder) in patients with CSCI by prompt diagnosis and appropriate treatment is necessary to reduce the morbidity and mortality in CSCI cases [1]. Endotracheal intubation for definitive airway control should ideally be performed under controlled conditions rather than as a emergency to avoid deterioration of the neurological status of the patient [2]. Nevertheless, 42% of the patients with CSCI who did not exhibit obvious signs of respiratory impairment in the emergency department (ED) before hospital admission later developed unexpected respiratory exacerbation (RE) and required emergency intubation up to 53 h after admission [3]. Recently, however, there has been remarkable improvement in the nonsurgical care of spinal cord injury, particularly the multidisciplinary care delivered in the pre-hospital, ED, and intensive care unit (ICU) settings [4], thus reducing the need for emergency endotracheal intubation in clinical practice.

Early routine intubation followed by mechanical ventilation and tracheostomy, as determined by a neurological examination before admission, increases the incidence of pneumonia and is a risk factor for mortality. For physicians providing primary care for patients with CSCI, it is challenging to correctly determine the motor level and type of lesion (complete or incomplete) [5]. Nevertheless, the 2017 Emergency Neurological Life Support protocol (version 3.0) for traumatic spine injury recommends that all patients with an acute complete CSCI above C5, as determined by initial neurological examination, should be intubated as soon as possible before admission ("absolute indication of intubation") [6]. Moreover, endotracheal intubation and hypoxia can stimulate an adverse bradycardic response in patients with CSCI [7]. Tracheostomy followed by intubation and mechanical ventilation have been reported as risk factors for early mortality in patients with CSCI because of the additional physiological stress and compromised natural immunological barrier between the lung and outside environment [8]. Atelectasis and pneumonia are the leading causes of respiratory failure among patients with CSCI [1]. In mechanically ventilated patients, the risk of developing pneumonia increases by 1–3% per day of intubation [9]. Copious sputum is an independent predictor to determine the need for mechanical ventilation in patients with CSCI [10]. These respiratory morbidities occur shortly after admission (post-admission RE predictors). Considering that such adverse respiratory events occur after intubation, there are concerns that early routine CSCI intubation based on classical and cumbersome neurological examination rather than respiratory factors may increase unnecessary intubations. It is unclear whether the classic routine CSCI intubation is relevant now with the advancement in respiratory management techniques.

We hypothesized that determining new predictors of RE may provide new indications for the timing of intubation, thereby reducing unnecessary invasive airway control in patients with acute traumatic CSCI. Therefore, this study aimed to redetermine the most important predictor of RE following CSCI after admission without routine intubation among patients admitted with motor-complete injury and/or injury above the C5 level to ensure timely intubation.

2. Methods

2-1. **Study Design**

We conducted a retrospective case-control study including adult patients with acute traumatic CSCI with or without bone injury, consecutively admitted to a single tertiary emergency medical center in Japan from January 2013 to December 2017. This study was approved by the local institutional review board of the study hospital (approval no. 2412).

2-2. Patient Selection

We screened consecutive patients aged 18–89 years with acute traumatic CSCI, who were admitted to the ED of Wakayama Medical University Hospital, and prospectively reviewed their medical records. Patients were diagnosed with CSCI by the physicians and orthopedic surgeons in the ED upon performing neurological examination and magnetic resonance imaging (MRI) after initial emergency, life-saving medical treatment. Patients with acute, traumatic injuries with lack of motor or sensory functions in the sacral segments, S4–S5, were diagnosed with complete CSCI (defined as motor-complete injury if no motor function below the zone of injury was preserved based on the American Spinal Injury Association [ASIA] impairment scale [version 2003] modified from Frankel grade) [11]. During the study period, the ED physician intubated patients with CSCI initially before hospital admission based on the following three indications alone: airway protection, obvious respiratory/circulatory failure, and emergency preoperative procedure. The indication for cervical spine fixation surgery or tracheostomy was dependent on the experience and judgment of the orthopedic surgeon and attending intensivist without standardization.

Patients were excluded from the study as per the following criteria: central cord syndrome, injury severity score (ISS) > 41, uncertain injury level (such as concomitant severe traumatic brain injury), regular outpatient attendance with an orthopedic of our hospital, and transfer within the first 3 days of hospitalization. RE was defined as unexpected, urgent intubation for respiratory resuscitation or re-intubation within 72 h after planned extubation, including after surgery and at the time of rapid respiratory impairment (refractory desaturation, major dyspnea, and respiratory arrest). We included emergent re-intubation in the definition of RE because of the recent tendency toward an increase in early surgical decompression with planned anesthetic intubation less than 24 h post-injury [12]. In the final analysis, we did not include patients who underwent empiric tracheostomy without any extubation attempts following pre-admission intubation since they had a decreased risk of developing RE with continuous definitive airway control during most of their hospitalization period. Finally, the selected patients with CSCI were stratified into those affected by RE (hereafter referred to as RE group) and those who were not (control group).

2-3. Outcome Measures

We prospectively collected data on baseline characteristics and the severity of traumatic injury, including age, sex, body mass index, Charlson comorbidity index [13], age-adjusted Charlson comorbidity index, pulmonary centrilobular emphysema in the apex of the lung on cervical computed tomography (CT), cervical ossification of posterior longitudinal ligament and thoracolumbar diffuse idiopathic skeletal hyperostosis on CT, initial Glasgow Coma Scale score, initial bradycardia (heart rate < 60 beats/min) and initial hypotension (systolic blood pressure < 90 mm Hg) in the ED; mechanism of injury (falls, motor vehicle accident, sports, or hit by an object), ISS, Abbreviated Injury Scale for the chest, concomitant lung injury (lung contusion, lung laceration defined as traumatic pneumatocele on CT, pneumothorax, or hemothorax), bony thorax injury (rib fracture or sternal fracture), and/or thoracic vertebral fracture; and ASIA impairment scale, motor-complete injury, estimated CSCI level, and injury level at and above C5. We defined emphysema in the superior sulcus on the CT scan as a decrease in lung function in heavy smokers [14] because data collected on smoking history were partially lacking. A board-certified radiologist retrospectively confirmed the key findings of all radiographs, CT, and MRIs to confirm the radiological evidence of baseline and injury characteristics. Regarding the patients' treatment and clinical course, we collected the following data: intubation before hospitalization, initial admission to the ICU, incidence of copious airway secretion (CAS), atelectasis, pneumonia, cervical spine surgery, and/or tracheostomy; steroid administration, halo vest immobilization until the surgery, length of stay in the ED and hospital, dysphasia and/or ventilatory assistance at discharge, and in-hospital death. CAS was defined as retained tracheobronchial secretions attributable to a respiratory cause (acute refractory desaturation, major dyspnea, and abnormality on auscultation) and required airway (including nasotracheal) suctioning every 2 h (or more, as needed) on each patient's daily flowsheet as recorded by the nursing staff. Atelectasis was assessed with chest radiography as the loss of lung volume, involving clinical hypoxemia and hypophonesis in the affected lung without symptoms of pulmonary infection, as interpreted by the attending physician. Pneumonia was diagnosed based on radiographic parenchymal inflammatory evidence with clinical acute fever requiring antibiotic administration. Empiric antibiotics were not administered routinely in patients with CSCI, except to prevent surgical site infections. We routinely examined the patients for CAS, atelectasis, and pneumonia during the acute 3-day phase after admission or within 24 h before RE.

The primary outcome was RE after admission in patients with traumatic CSCI. We identified and evaluated the possible risk factors contributing to RE. The secondary outcome were time from injury to onset of RE, incidence of tracheostomy, length of stay (in emergency medical center or hospital), ventilatory assistance at discharge, and in-hospital death.

2-4. **Statistical Analysis**

In the univariate analysis, all continuous variables were expressed as medians (interquartile ranges) and assessed using the Wilcoxon rank-sum test. Categorical variables were expressed as numbers and percentages and assessed using the two-tailed Fisher's exact probability test. P-values < 0.05 were considered statistically significant. A multivariate analysis was performed using a binomial logistic regression to determine the independent predictors of RE by calculating adjusted odds ratios (ORs) and 95% confidence intervals (CIs). In accordance with previous studies, we entered the following four variables based on clinical plausibility and availability into multivariate logistic regression analysis: "motor-complete injury" as a simple predictor based on initial evaluation of sacral sparing, "level of injury above C5" as evaluated by pre-admission neurological examination and MRI, "atelectasis" as a subjective post-admission factor that required radiographic interpretation by the physicians, and "CAS" as an objective post-admission factor mostly assessed by nursing staff at the bedside. However, we excluded ISS from the list of predictive variables for RE because of its difficulty to be clinically calculated promptly prior to admission. We also determined pneumonia in patients with CSCI as an ineligible predictor of RE because of its delayed onset (approximately 7 days) compared with atelectasis [1]. All statistical analyses were conducted using the JMP version 13.0 software program (SAS Institute, Cary, NC, USA).

3. Results

During the 5-year study period, there were 33 899 ED visits at our hospital (19 015 ground ambulance and 1784 air ambulance). Our registry dataset included 1831 hospital admissions of the 8388 trauma victims who were under the primary care of emergency physicians. One thousand and thirty-five trauma victims had ISS > 16. The mean and median ISS were 17 ± 13 and 14 (interquartile range [IQR]: 9–25), respectively. Among the 166 consecutively enrolled patients diagnosed with traumatic CSCI, 66 were enrolled in the study. We finally performed statistical analyses on the data of 58 patients, excluding 8 patients who underwent empiric tracheostomy because of concerns regarding RE (Fig. 1). Of the 58 patients with CSCI, 35 (60.3%) required post-injury intubation (3 pre-/32 post-admission), 8 (13.8%) required tracheostomy, and 1 (1.7%) died. RE was observed in 13 (22.4%) patients on an average of 3.5 days from injury. All RE did not directly lead to death. Of these 13 patients, 6 (46.2%) required unexpected urgent intubation (average of 2.7 days post-injury) and 7 (53.8%) were re-intubated urgently within 72 h after planned extubation (an average of 4.3 days post-injury). Of the total 58 CSCI patients, 27 (46.6%) had motor-complete injury and 22 had injuries above C5 (37.9%). Eleven of the 27 (40.7%) patients with motor-complete injury and five of the 22 (22.7%) patients with neurologic injury above C5 required emergency intubation at RE. Three of the eight CSCI patients with both risk factors (motor-complete injury above C5) required emergent RE intubation (37.5%). Three (23.1%) of the 13 CSCI patients intubated with RE had both motor-complete injury and injury level above C5 as the representative risk factors for intubation before admission.

3-1. **Outline of Airway Management (Including Empiric Tracheostomy)**

Figure 2 shows the clinical trajectories of airway control in the 66 enrolled CSCI patients, including eight who underwent empiric tracheostomy, to summarize the overall invasive airway management in this study. Forty-three (65.2%) of the 66 enrolled CSCI patients were orally intubated of which 13 developed RE. Eleven (25.5%) of the 43 patients were intubated pre-admission for the following causes: unstable airway due to acute traumatic retropharyngeal hematoma (n = 5), hypoxemia or hypercapnia associated with abdominal breathing (n = 4), and circulatory collapse with neurogenic shock (n = 2). The location where patients were intubated were: ED (n = 7), former hospital (n = 3), and field by air ambulance doctor (n = 1). Eight (72.7%) of the 11 patients who underwent pre-admission intubation progressed directly to tracheostomy at an average of 8.6 days post-injury without an attempt at extubation, which excluded them from the final statistical analysis because of the difficulty in the accurate assessment of RE. These 8 patients with empiric tracheostomy were intubated not at RE but as the initial resuscitative or preoperative procedure.

One of the 8 patients undergoing empiric tracheostomy died of respiratory failure on day 37 of hospitalization without any RE. Of the 7 patients who underwent spine surgery following pre-admission intubation, 2 patients developed RE, requiring re-intubation within 72 h after postoperative extubation. Among the 32 patients without pre-admission intubation, 6 (18.7%) underwent unexpected emergent intubation after admission at an average of 2.7 days post-injury with RE, while 26 (81.3%) underwent planned intubation with general anesthesia for elective spine surgery at an average of 5 days post-injury. No apparent worsening of neurological outcomes was observed. Twenty-five (78.1%) patients were successfully extubated, whereas 6 (18.8%) patients who failed ventilatory weaning or extubation required tracheostomy, which provided complete success of ventilator weaning for all six of them. Of the 32 patients with post-admission intubation, one died on day 16 of admission from postoperative septic shock with RE as emergency re-intubation. Cardiopulmonary arrest with good neurological recovery occurred in one of 2 RE patients who were re-intubated after deliberate extubation, and in one of 6 RE patients who required unexpected emergent intubation due to airway secretion obstruction. Every intubation maneuver, including emergent procedures, did not worsen the neurological deficits. Eventually, 41 patients survived to discharge at an average of 47 days post-injury, including 26 natural airways (63.4%) with five RE and 15 tracheostomies (36.6%) with seven RE. Only 3 (20.0%) of the 15 patients who underwent tracheostomy required mechanical ventilation on transfer to another hospital.

3-2. **RE Versus Non-RE**

Table 1 shows the baseline and injury characteristics between the RE group and the control group. This study population did not include neurological C1–C2 (highest cervical) and C7–C8 (lowest cervical) levels of injury. Of the total CSCI patients, mean age was 68.9 years (median: 70, IQR: 65–75); 46 male (79.3%) and 12 female (20.7%) patients were included, and the mean ISS was 18.8 (median: 17, IQR: 16–22). There were no intracranial injuries and hemorrhagic/obstructive shock observed during the initial treatment in this study. Complete injuries (Frankel grade A) were present in nine patients (15.5%), and incomplete injuries (Frankel grade B, C, and D) were found in 49 patients (84.5%). No patients with RE had Frankel grade D injury. In injury-related characteristics, RE patients had a higher severity of overall injury (median: 25 vs. 17, P = 0.0023), whereas the Abbreviated Injury Scale for the chest (1–5) and concomitant chest injury (lung injury, bony thorax injury, thoracic vertebral fracture) observed in the RE group were not significantly greater than those in the control group. None of the patients had a frail chest. The RE group also had a higher frequency of motor-complete injury than the control group (84.6% vs. 35.6%, P = 0.0034). However, there were no significant differences observed in other baseline characteristics and injury-related factors among the groups.

The treatment and clinical outcomes of the 58 patients are shown in Table 2. Of the 13 RE patients, 1 (7.7%) died because of postoperative sepsis. The overall incidences of CAS, atelectasis, and pneumonia during the acute 3-day phase post-admission or within 24 h before RE were 32.7%, 25.9%, and 3.4%, respectively. Surgical stabilization was performed in 31 (53.4%) patients at an average of 5.6 days post-injury, including three urgent and 28 elective surgeries. The relationship between cervical spine surgery and RE was not statistically significant in either group. The following clinical outcomes were significantly higher in the RE group than in the control group: initial ICU admission (2 vs. 1; P = 0.1230), CAS (10 vs. 9; P = 0.0003), atelectasis (8 vs. 7; P = 0.022), tracheostomy (7 vs. 1; P < 0.0001), length of emergency medical center stay (median [days], 36 vs. 18; P = 0.0009), and hospital stay (median [days] 57 vs. 21; P = 0.0004); discharge with dysphasia (7 vs. 4; P = 0.0012), and discharge with ventilatory assistance (1 vs. 0; P = 0.0489).

3-3. **Predictors of RE**

Table 1
Baseline and injury characteristics of the study population

	Overall (n = 58)	RE group (n = 13)	Control group (n = 45)	P-value
Age, median [IQR], y	70 [65–75]	75 [68–80]	70 [64–74]	0.1759
Male sex, n (%)	46 (79.3)	12 (92.3)	34 (75.6)	0.2640
Body mass index, median [IQR]	22 [20–24]	22 [21–25]	21 [20–25]	0.0572
CCI, median [IQR]	0 [0–1]	1 [0–3]	0 [0–1]	0.1020
Age-adjusted CCI, median [IQR]	3 [2–4]	4 [3–7]	3 [2–4]	0.0644
Pulmonary centrilobular emphysema, n (%)	14 (24.1)	3 (23.1)	11 (24.4)	1.0000
Cervical OPLL, n (%)	13 (22.4)	3 (23.1)	10 (22.2)	1.0000
DISH, n (%)	8 (13.8)	2 (15.4)	6 (13.3)	1.0000
Initial GCS, median [IQR]	15 [14–15]	14 [13–15]	15 [14–15]	0.0827
Initial bradycardia, n (%)	18 (31.1)	5 (38.5)	13 (28.9)	0.5156
Initial hypotension, n (%)	14 (24.1)	4 (30.8)	10 (22.2)	0.7138
Mechanism of injury				
Falls, n (%)	36 (62.1)	9 (69.2)	27 (60.0)	0.7475
Motor vehicle accident, n (%)	18 (31.1)	2 (15.4)	16 (35.6)	0.3068
Sports, n (%)	2 (3.4)	1 (7.7)	1 (2.2)	0.4010
Bruised by an object, n (%)	2 (3.4)	1 (7.7)	1 (2.2)	0.4010
ISS, median [IQR]	17 [16–22]	25 [18–26]	17 [16–18]	0.0023*
ISS > 16, n (%)	53 (91.3)	13 (100)	40 (88.9)	0.5773
AIS for chest				
1, n (%)	1 (1.7)	0	1 (2.2)	1.0000
2, n (%)	2 (3.4)	1 (7.7)	1 (2.2)	0.4010
3, n (%)	2 (3.4)	0	2 (4.4)	1.0000

IQR, interquartile range; RE, respiratory exacerbation; CCI, Charlson Comorbidity Index; OPLL, ossification of posterior longitudinal ligament; DISH, diffuse idiopathic skeletal hyperostosis; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale; ASIA, American Spinal Injury Association; CSCI, cervical spinal cord injury

*Statistically significant at P < 0.05

	Overall (n = 58)	RE group (n = 13)	Control group (n = 45)	P-value
4, n (%)	1 (1.7)	0	1 (2.2)	1.0000
5	0	0	0	-
Lung injury, n (%)	2 (3.4)	1 (7.7)	1 (2.2)	0.4010
Bony thorax injury, n (%)	1 (1.7)	0	1 (2.2)	1.0000
Thoracic vertebral fracture, n (%)	4 (7.0)	1 (7.7)	3 (6.7)	1.0000
ASIA impairment scale				
A, n (%)	9 (15.5)	4 (30.8)	5 (11.1)	0.1025
B, n (%)	18 (31.1)	7 (53.9)	11 (24.4)	0.0851
C, n (%)	17 (29.3)	2 (15.4)	15 (33.3)	0.3068
D, n (%)	14 (24.1)	0	14 (31.1)	0.0269*
Motor-complete injury, n (%)	27 (46.6)	11 (84.6)	16 (35.6)	0.0034*
Neurological CSCI level				
C3, n (%)	12 (20.7)	1 (7.7)	11 (24.4)	0.2640
C4, n (%)	10 (17.2)	4 (30.8)	6 (13.3)	0.2083
C5, n (%)	22 (37.9)	7 (53.9)	15 (33.3)	0.2078
C6, n (%)	14 (24.1)	1 (7.7)	13 (28.9)	0.1553
Level of injury above C5, n (%)	22 (37.9)	5 (38.5)	17 (37.8)	1.0000

IQR, interquartile range; RE, respiratory exacerbation; CCI, Charlson Comorbidity Index; OPLL, ossification of posterior longitudinal ligament; DISH, diffuse idiopathic skeletal hyperostosis; GCS, Glasgow Coma Scale; ISS, Injury Severity Score; AIS, Abbreviated Injury Scale; ASIA, American Spinal Injury Association; CSCI, cervical spinal cord injury

*Statistically significant at $P < 0.05$

Table 2
Treatment and clinical outcomes of the 58 analyzed CSCI patients

	Overall (n = 58)	**RE group (n = 13)**	**Control group (n = 45)**	**P-value**
Intubation before admission, n (%)	3 (5.2)	2 (15.4)	1 (2.2)	0.1230
Initial ICU admission, n (%)	3 (5.2)	2 (15.4)	1 (2.2)	0.1230
CAS in acute stage, n (%)	19 (32.7)	10 (76.9)	9 (20.0)	0.0003*
Atelectasis in acute stage, n (%)	15 (25.9)	8 (61.6)	7 (15.6)	0.0022*
Pneumonia in acute stage, n (%)	2 (3.4)	1 (7.7)	1 (2.2)	0.4010
Steroid administration, n (%)	31 (53.4)	8 (61.6)	23 (51.1)	0.5461
Halo-Vest immobilization, n (%)	9 (15.5)	4 (30.8)	5 (11.1)	0.1025
Cervical spine surgery, n (%)	31 (53.4)	9 (69.2)	22 (48.9)	0.2248
Tracheostomy, n (%)	8 (13.8)	7 (53.9)	1 (2.2)	< 0.0001*
Emergency medical center stay, median [IQR], days	21 [15–34]	36 [28–44]	18 [12–28]	0.0009*
Hospital stay, median [IQR], days	24 [15–54]	57 [35–62]	21 [13–36]	0.0004*
Discharged with dysphasia, n (%)	11 (18.9)	7 (53.9)	4 (8.9)	0.0012*
Discharged with ventilatory assistance, n (%)	2 (3.5)	1 (8.3)	0	0.0489*
In-hospital death	1 (1.7)	1 (7.7)	0	0.2241
CSCI, cervical spinal cord injury; ICU, intensive care unit; CAS, copious airway secretion				
*Statistically significant at P < 0.05				

We conducted a multivariate analysis to identify plausible and available predictors for RE in clinical practice (Table 3). Our analysis revealed that CAS was an independent predictor for RE (adjusted OR: 7.19, 95% CI: 1.48–42.72, P = 0.0144).

Table 3
Multiple logistic regression analysis of independent risk factors for RE in patients with traumatic CSCI

	Odds ratio (95% confidence interval)	P-value
Complete motor injury	4.65 (0.73–40.52)	0.1036
Level of injury above C5	2.09 (0.39–12.48)	0.3851
Atelectasis	2.91 (0.53–16.48)	0.2144
Copious airway secretion	7.19 (1.48–42.72)	0.0144*
RE, respiratory exacerbation; CSCI, cervical spinal cord injury		
*Statistically significant at $P < 0.05$		

4. Discussion

Here, we showed that CAS was a simple independent predictor for RE, especially during the acute 3-day phase. We suggest a reconsideration of early routine intubations based on neurological examinations in the ED for patients with CSCI.

Several studies have been conducted for the determination of appropriate indications for endotracheal intubation in patients with CSCI [2, 3, 10, 19]. However, when viewed from the standpoint of current advances in respiratory care in patients with spinal cord injury, these classical studies do not address the question of whether early routine intubation based on pre-admission neurological assessment is truly needed in the present scenario. Additionally, we need to consider the possibility that early routine intubation may be an over-treatment, resulting in unnecessary adverse events. A study in rats reported that mechanical ventilation in spinal cord injury leads to local inflammation in the lung and spinal cord via inflammatory cytotoxic cytokines and critical mediators, without direct tissue injury [15].

However, despite evidence that tracheostomy is associated with major respiratory morbidity (such as ventilator-associated pneumonia, acute lung injury, and acute respiratory distress syndrome) in patients with CSCI [16], 57.2% of patients with CSCI requiring intubation in this study progressed directly to early tracheostomy without any extubation attempts (empiric tracheostomy). In a previous study, the intubation rate for RE was 90.0% in motor-complete injury and 87.5% in injury above C5 [3]. In another study, 97 of the 127 patients (76%) with low CSCI (C5–T1) and motor-complete injury were intubated for RE [17]. In the present study, intubation for RE in motor-complete injury, injury above C5, and motor-complete injury above C5 was performed in 3/15 (20.0%), 5/22 (22.7%), and 3/8 (37.5%) patients, respectively. The need for intubation in case of post-admission emergency RE remarkably decreased during the study period at our ED as compared with that nearly 20 years ago when routine intubation based on the initial neurological assessment was not performed. Ventilator dependence in patients with CSCI at discharge or transfer in the present study was also found to be lower than that in the past 10 years (32.4%) [18]. Fortunately, the development in medical technology and strategies has enabled patients with CSCI to breathe with the assistance of various treatments and/or devices, such as physical therapy, antibiotics, diaphragm-pacemakers, and ventilators [19]. It is likely that the significant advances in multidisciplinary neuroprotective and respiratory strategies over the last several decades have been beneficial for patients with CSCI with both natural and intubated airway control.

Our findings demonstrate that post-admission RE occurs during the 3-day acute phase post-injury. Strategies to prevent, to recognize, and to manage CAS can reduce the need for mechanical ventilation in tetraplegic patients with CSCI [20]. Stand-by intubation based on CAS monitoring during the acute 3-day phase after CSCI may obviate the need for invasive airway management within the premise of multidisciplinary respiratory care. However, our results do not suggest the abandonment of pre-intubation neurological assessment or resuscitative intubation as standard care for cardiopulmonary adverse events in patients with CSCI.

Our study was limited mainly by the small sample size owing to the rarity of this severe trauma and single-center retrospective design. Consequently, the independent variables that could be assessed using the logistic regression model were also limited. Moreover, RE is an infrequent outcome for patients with CSCI in every hospital because of the widespread acceptance of the early routine intubation practice based on the neurological assessment.

5. Conclusion

In conclusion, frequent occurrence of RE is characteristic of the acute 3-day phase of patients with CSCI wherein routine intubation based on neurological assessment (such as motor-complete injury above C5) is not performed before admission. However, such post-admission RE requiring emergency intubation has decreased compared to about 20 years ago. We found that careful monitoring of acute-stage CAS may ensure timely intubation, preventing RE and reducing the need for unnecessary invasive airway control.

Abbreviations

CSCI, Cervical spinal cord injury

ED, Emergency department

RE, Respiratory exacerbation

ICU, Intensive care unit

MRI, Magnetic resonance imaging

ASIA, American spinal injury association

ISS, Injury severity score

CT, Computed tomography

CAS, Copious airway secretion

OR, Odds ratio

CI, Confidence interval

IQR, Interquartile range

Declarations

Ethics approval and consent to participate: This study was approved by the local institutional review board of the study hospital (approval no. 2412). The requirement for informed consent was waived by the institutional review board.

Consent for publication: Not applicable.

Availability of data and material: The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

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Figures

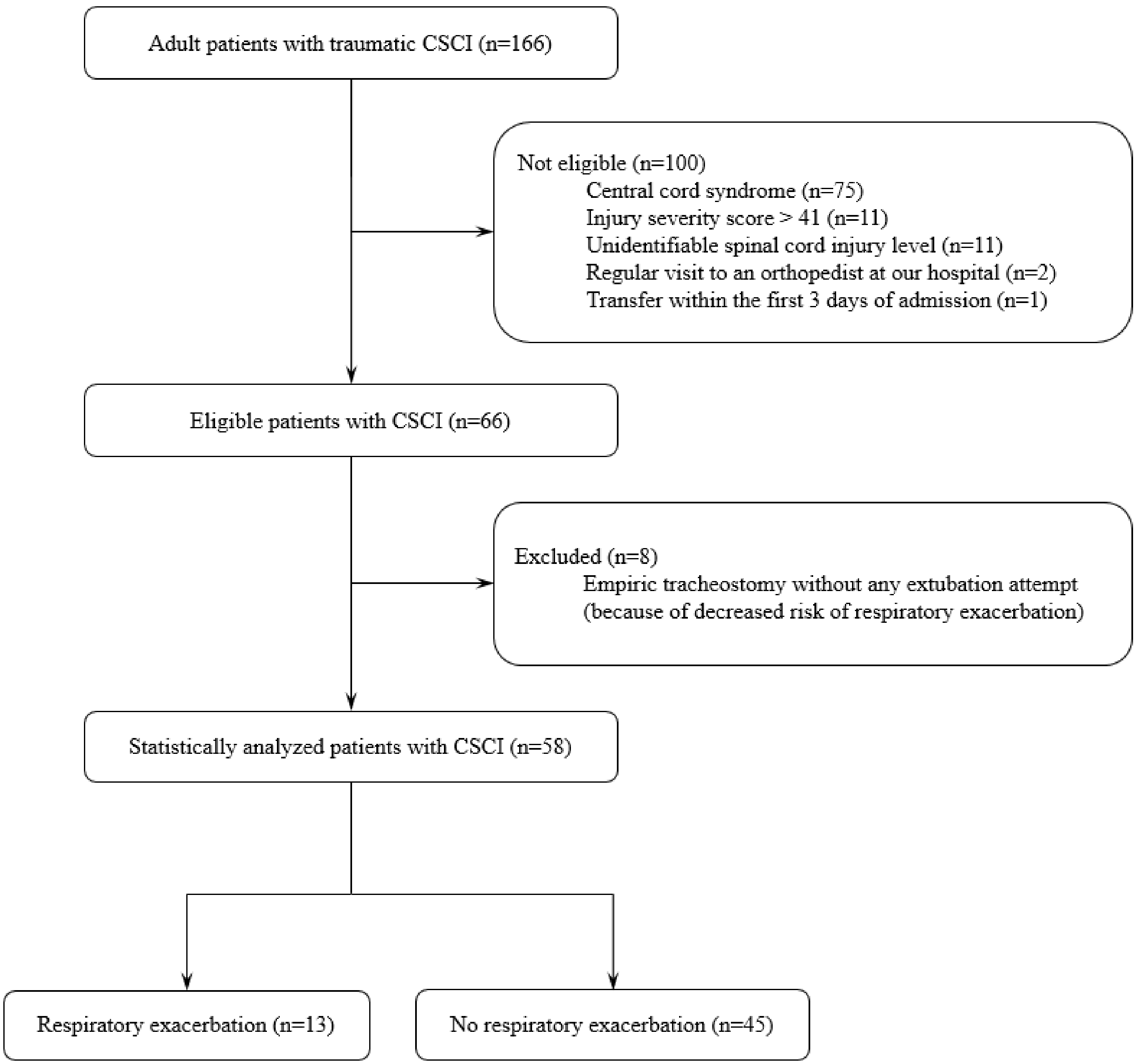

Figure 1

Case inclusion criteria and flow of patients in this analysis. CSCI, cervical spinal cord injury

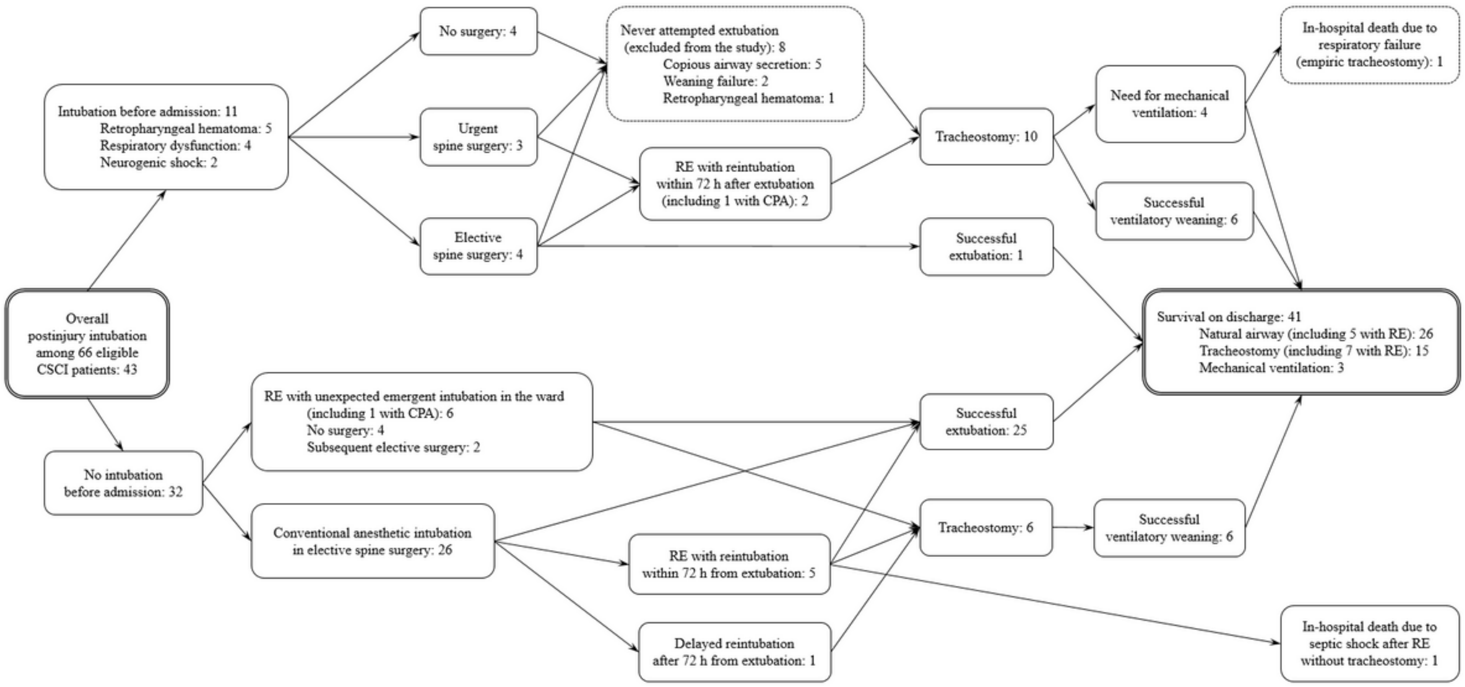

Figure 2

Clinical trajectories of airway management among 66 enrolled CSCI patients including empiric tracheostomy. CSCI, cervical spinal cord injury; RE, respiratory exacerbation; CPA, cardiopulmonary arrest