Original article

A study of risk factors for tracheostomy in patients with a cervical spinal cord injury.

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Study design:

A retrospective, consecutive case series.

Objective: To determine the risk factors for a tracheostomy in patients with a cervical spinal cord injury.

Summary and Background Date:

Respiratory status cannot be stabilized in patients with a cervical spinal cord injury (CSCI) for various reasons, so a number of these patients require long-term respiratory care and a tracheostomy. Various studies have described risk factors for a tracheostomy, but none have indicated a relationship between imaging assessment and the need for a tracheostomy. The current study used imaging assessment and other approaches to assess and examine the risk factors for a tracheostomy in patients with a CSCI.

Methods:

Subjects were 199 patients who were treated at the Spinal Injuries Center within 72 hours of a CSCI over 8-year period. Risk factors for a tracheostomy were retrospectively studied. Patients were assessed in terms of 10 items: (1) age, (2) sex, (3) the presence of a vertebral fracture or dislocation, (4) ASIA Impairment Scale (AIS), (5) the neurological level of injury (NLI), (6)

PaO_2, (7) $PaCO_2$, (8) the level of injury on MRI, (9) the presence of hematoma-like changes (a hypointense core surrounded by a hyperintense rim in T2-weighted images) on MRI, and (10) the Injury Severity Score (ISS).

Items were analyzed multivariate logistic regression, and $p<0.05$ was considered to indicate a significant difference.

Results:

Twenty-three of the 199 patients required a tracheostomy, accounting for 11.6% of patients with a CSCI. Univariate analyses of the risk factors for tracheostomy revealed significant differences for 6 items: age, ISS, presence of fracture or dislocation, AIS A, NLI≥C4, and MRI scans revealing hematoma-like changes. Multivariate logistic regression analyses revealed significant differences in terms of 2 items: NLI≥C4 and MRI scans revealing hematoma-like changes.

Thirty patients had both an NLI≥C4 and MRI scans revealing hematoma-like changes. Of these, 17 (56.7%) required a tracheostomy.

Conclusions:

Patients with an NLI≥C4 and MRI scans revealing hematoma-like changes were likely to require a tracheostomy. An early tracheostomy should be considered for patients with both of

these characteristics.

Background:

Respiratory status cannot be stabilized in patients with a cervical spinal cord injury (CSCI) for various reasons, so a number of these patients require long-term respiratory care and a tracheostomy. Numerous studies have reported that respiratory dysfunction is closely associated with morbidity and mortality in CSCI[1-3], and respiratory dysfunction leads to massive financial expenses[3]. The cause of death for patients with a CSCI is often a urinary complication or a respiratory complication[4,5]. A recent study from abroad has reported that respiratory complications represent the leading cause of death in patients with a CSCI[5], and the same is true in Japan[4].

In the acute phase of CSCI, spinal shock can have an effect and the patient's respiratory status may be unstable, so temporary ventilator management is often required [6-16]. If the patient's respiratory status fails to improve with temporary ventilator management and long-term intubation is required, a tracheostomy is often performed. Performing a tracheostomy early on is known to be useful in reducing respiratory complications, as various studies have reported[6,9,16-18]. However, unnecessary intubation and unnecessary tracheostomies are known to increase the risk of complications in both the short and long term[9]. Exaggerating the usefulness of an early tracheostomy can result in unnecessary tracheal intubation or an unnecessary tracheostomy. Thus, predicting true risk factors for intubation or a tracheostomy in patients with a CSCI is important.

Various studies have described risk factors for a tracheostomy in patients with a CSCI. These include advanced age[7,12], complete paralysis [1,6-8,14,17,19-22,24], a high level of neurological paralysis [6,12,14,21], the patient's general condition prior to the injury and a prior history of lung disease[1,8,12], a high Injury Severity Score (ISS) [8,17], a history of smoking [19], and a low forced vital capacity upon admission [7,9].

However, no previous studies have indicated a relationship between imaging assessment (X-rays, Computed Tomography(CT) or Magnetic Resonance Imaging(MRI)) and the need for a tracheostomy. The current study used imaging assessment and other approaches to assess and examine the risk factors for a tracheostomy in patients with a CSCI.

Methods:

Subjects were 199 patients who were treated by the Department of Orthopedic Surgery of the Spinal Injuries Center within 72 hours of a CSCI over eight year period from January 1, 2005 to December 31, 2012. Patients consisted of 165 males and 34 females ranging in age from 14 to 91 years with a mean age of 61.9 years.

All patients were examined by 2 or more physicians and a physical therapist upon admission, and patients were assessed neurologically. In addition, the presence or absence of a vertebral fracture or dislocation was assessed using X-ray films or CT scans and the presence or absence of cord damage was assessed using MRI scans in all patients upon admission. Surgery (anterior spine fusion (ASF), posterior spine fusion (PSF), or ASF&PSF) was performed on patients with apparent spinal instability. Arterial blood gases were measured in all patients upon admission. If patients had apnea or ventilatory failure prior to initial admission and they needed assistance breathing, a tracheostomy was performed on the day of admission. If, however, a patient's respiratory status gradually worsened after admission, intubation was performed at the discretion of the patient's primary physician in accordance with the patient's respiratory status. When long-term ventilator management was considered necessary, a tracheostomy was performed. This Center has not formulated definite standards for intubation and tracheostomy, though blood gas results of $PaO_2 \leq 70$ mmHg and $PaCO_2 \geq 50$ mmHg serve as somewhat of a guide, regardless of whether O_2 is administered.

Medical records, the patient's discharge summary, and imaging findings upon admission and discharge were retrospectively studied.

The following items were studied retrospectively: (1) age, (2) sex, (3) the presence or absence of a vertebral fracture or dislocation at the level of injury, (4) the American Spinal Association (ASIA) Impairment Scale (AIS), (5) the neurological level of injury (NLI), (6) PaO_2 according to a blood gas analysis, (7) $PaCO_2$ according to a blood gas analysis, (8) the level of injury on MRI, (9) hematoma-like changes on MRI (presence or absence of a hypointense core surrounded by a hyperintense rim in T2-weighted images), and (10) the Injury Severity Score(ISS).

Statistical analyses were done using the Jump11 statistical software package from SAS Institute, Inc.

In instances where there was no avulsion fracture of the anterior aspect of the vertebral body or a spinous process fracture in conjunction with a hyperextension injury, no bone injury on MRI scans, and no need for surgery due to the lack of spinal instability, bone injury or dislocation was deemed to be absent. In addition, the NLI was the most caudal segment where normal motor and sensory function were intact. If hematoma-like changes were present, the level of those changes served as the level of injury on MRI. If those changes were absent, the segment where the center of a wider-ranging hyperintensity was located on T2-weighted images served as the level of injury on MRI (figure 1).

Age, PaO_2, $PaCO_2$, and the ISS were assessed as continuous variables. In order to increase statistic power, the AIS, the NLI, and the level of injury on MRI were dichotomized as an AIS A or not, an NLI ≥C4 or not, and a level of injury on MRI ≥C3/4 or not.

Results:

One hundred and ninety-nine patients with a cervical spinal cord injury were treated at this center over 8-year period. Patients consisted of 165 males and 34 females ranging in age from 14 to 91 years with a mean age of 61.9 years. All of the patients had suffered blunt trauma. Sixty patients (30.1%) had a vertebral fracture or dislocation.

The extent of paralysis upon admission was AIS A in 66 patients (33.2%), AIS B in 38 (19.1%), AIS C in 51 (25.6%), and AIS D in 44(22.1%). The NLI upon admission was C2 in 1 patient (0.5%), C3 in 10 (5.0%), C4 in 90 (45.2%), C5 in 62 (31.2%), C6 in 19 (9.6%), C7 in 6 (3.0%), C8 in 1 (0.5%), and T1 in 10 (5.0%) (Table 1).

All of the patients underwent an MRI upon admission, and hyper-intensity changes on T2-weighted images were noted in all of the patients. The level of injury on MRI was C2/3 in 5 patients (2.5%), C3 in 2 (1.0%), C3/4 in 70 (35.2%), C4 in 4 (2.0%), C4/5 in 49 (24.6%), C5 in 10 (5.0%), C5/6 in 29 (14.6%), C6 in 4 (2.0%), C6/7 in 24 (12.1%), C7 in 1 (0.5%), and C7/T1 in 1 (0.5%). Hematoma-like changes were noted in 46 patients (23.1%) and such changes were not noted in 153 (76.9%) (Table 2).

Twenty-three of the 199 patients required a tracheostomy, accounting for 11.6% of patients with a cervical spinal cord injury. The average time from injury until a tracheostomy was performed was 4.69 days (day of injury–13 days later). Details on the 23 patients who underwent a tracheostomy are indicated below (Table 3).

Eleven patients had a vertebral fracture or dislocation; a bone injury was not noted in 12 patients. Seventeen patients had an AIS A, 4 had AIS B, and 2 had AIS C. The NLI was C2 in 1 patient, C3 in 5, C4 in 15, C5 in 1 and T1 in 1. The level of injury on MRI scans was at C2/3 in 1 patient, at C3/4 in 9, at C4/5 in 7, at C5/6 in 5, and at C6/7 in 1. Hematoma-like changes were noted on MRI images of 17 patients.

The final outcome (state at final follow-up) was death for 1 patient and permanent ventilator management for 7. The respiratory status of 15 patients stabilized, and they were weaned from the ventilator.

Univariate analyses of the risk factors for tracheostomy revealed significant differences for six items: age ($P=0.0422$, Odds Ratio(OR)=1.035), ISS ($P=0.0002$, OR=1.065), presence of fracture or dislocation ($P=0.0209$, OR=2.827), AIS A ($P<0.0001$, OR=7.344), NLI≥C4 ($P=0.0008$, OR=12.599), and MRI scans revealing hematoma-like changes ($P<0.0001$, OR=9.504) (Table 4).

The aforementioned items with significant differences in the univariate analyses were further analyzed using multivariate logistic regression. The results revealed significant differences for 2 items: NLI≥C4 (P=0.0058, OR=9.681) and MRI scans revealing hematoma-like changes (P=0.0212, OR=3.941) (Table 5).

In addition, 17 out of 30 patients (56.7%) who had both an NLI≥C4 and MRI scans revealing hematoma-like changes required a tracheostomy, while 15 out of 40 patients (37.5%) who had both an NLI≥C4 and AIS A on admission required a tracheostomy.

Discussion:

Various complications can occur after a CSCI, though the most frequent are respiratory complications[1-5]. Typical complications include atelectasis, pneumonia, and ventilatory failure. These complications often occur in the acute phase within 5 days of injury[13].

The diaphragm is innervated by nerves originating from C3-C5 (primarily from C4), and damage to the spinal cord at a higher level will immediately necessitate ventilator management. Sputum is expelled and coughing is accomplished primarily with the intercostal muscles and abdominal muscles. Even if the injury occurred at a lower level and the diaphragm still functioned, paralysis of these muscles causes sputum to pool, thereby facilitating atelectasis and pneumonia[10,16]. In the acute phase of injury, the sympathetic nerves are interrupted and the vagus nerve predominates. Furthermore, tracheobronchial secretions increase and the airway constricts. The amount of sputum increases and the sputum cannot be readily expelled. This phenomenon is one reason for why respiratory complications are so frequent.

In the first week after injury, a patient's vital capacity will decrease by 30% or more. About 5 weeks after injury, vital capacity will begin to recover, and 3 months after injury the vital capacity will double[11,16]. If the period of an unstable respiratory status in the acute-subacute phase of injury can be weathered, then the respiratory status will subsequently stabilize for the most part. Thus, predicting risk factors for intubation or tracheostomy in patients with a CSCI is important.

Studies cite widely differing figures for the percentage of patients requiring a tracheostomy after CSCI. These figures range from 15.2–81%, and recent studies have noted that a relatively high percentage of those patients require a tracheostomy[6-9,12,17,19,21,23]. Numerous studies have reported that performing a tracheostomy early on is useful in reducing respiratory complications [6,9,16-18]. This may be the reason for the substantial difference in the percentage of patients with a tracheostomy. That said, one possibility is that intubation or tracheostomy is performed unnecessarily, and such situations should be avoided.

The current study found that 11.6% of patients with a CSCI require a tracheostomy, and this is lower than the percentages described in other studies. This Center is a dedicated facility with a Department of Orthopedic Surgery and in principle this facility does not accept patients in the acute phase of multiple trauma. This Center sees a small proportion of patients with complications such as a brain contusion, multiple rib fractures, a hemopneumothorax, or injuries to the abdominal viscera, which may explain why so few of the current patients required a tracheostomy. The aforementioned reasons are also presumably the reason why tracheal intubation or a tracheostomy is so often indicated for a simple CSCI seen at this

Center. In this study, univariate analyses and multivariate analyses yielded significant differences in terms of 2 items: (1) an NLI≥C4 and (2) MRI scans revealing hematoma-like changes. The aforementioned reasons are presumably why these 2 items were predictors for a tracheostomy, in a true sense, in patients with a CSCI.

Numerous studies have reported that complete paralysis is a risk factor for intubation or a tracheostomy[1,6-8,14,17,19-22,24]. In the current study, univariate analyses indicated that AIS A was a risk factor for tracheostomy, while multivariate analyses revealed no significant differences in AIS A.

This may be because complete paralysis means that the intercostal muscles and abdominal muscles are paralyzed, regardless of the level of the CSCI. However, Yugue et al. [7] reported that 18.8% of patients who were AIS A upon admission had an improved level of paralysis (a grade other than A) at final follow-up. Similarly, 66 patients in the current study were AIS A upon admission, though 8 (12.1%) had improvement at final follow-up. The period of spinal shock may have been included in the 72 hours after injury. Given this possibility, improvement in the level of paralysis needs to be assessed.

The ISS was similarly found to be a risk factor for tracheostomy according to univariate analyses. ISS is a score for the severity of multiple trauma. Several studies have reported that a high ISS is a predictor for tracheostomy in patients with a CSCI[8,21]. However, Velomahos et al. [21] stated that assessment of the ISS is difficult in the acute phase of trauma, and they recommended that the ISS not be used as a predictor of tracheostomy.

No studies have indicated the relationship between imaging assessment and the need for a tracheostomy. The current study is the first to do so. In the acute phase of injury, blurred hyperintensity on T2-weighted MRI indicates spinal cord contusion or edema[25-27]. This imaging finding suggests injury to the spinal cord. If cord damage is severe and hematomyelia is present, hypointensities will be found inside hyperintensities in T2-weighted images. This finding mostly suggests severe spinal cord injury[28,29], and we described those change as "hematoma-like changes" . Bozzo et al.[29] reported that 93% of patients with MRI scans revealing a hypointense core surrounded by a hyperintense rim in T2-weighted images (hematoma-like changes) were AIS A upon admission. Of these, 95% were AIS A at final follow-up. In the current study, 82.6% of patients who were found to have hematoma-like changes were AIS A upon admission. All of the patients were AIS A at final follow-up, and this grade may be correlated with severe paralysis.

In the current study, univariate analyses and multivariate analyses revealed significant differences in MRI scans revealing hematoma-like changes. The AIS grade may change over time because of its relationship to spinal shock. Consequently, the ISS may change as well. Thus, these indicators change. In contrast, MRI images revealing hematoma-like changes do not change with spinal shock, making these MRI findings an independent indicator.

Of course, MRI was performed within a few hours after the injury. Therefore, there was a possibility that hematoma-like changes (hypointense core surrounded by a hyperintense rim) did not appear on T2-weighted images, even if a hematomyelia occurred, reflecting the intracellular oxyhemoglobin[(30)]. However, if hypointensity changes were revealed on T2 weighted image within 72 hours after the injury, they reflected deoxyhemoglobin, suggesting that a hemorrhage had occurred in the spinal cord and that the damage was severe.

In addition, significant differences in the level of injury on MRI scans were not noted, though an NLI≥C4 was a risk factor for tracheostomy.

The level of injury on MRI and the NLI did not necessarily coincide. Results suggested that the NLI is important because of its greater clinical significance.

Several studies have reported that an NLI at a high level is a predictor for tracheotomy[6,12,14,21]. Nerves innervating the diaphragm originate at levels C3–5. The diaphragm is involved in about 65% of breathing. The current study yielded significant differences at C4 or above. Paralysis due to an injury at C4 or above causes motor paralysis of the diaphragm, which is likely to result in the patient's respiratory status worsening.

Several studies have reported that the risk of tracheostomy is related to age [7,12]. However, multivariate analyses revealed no significant differences in patient age. In addition, this study found no significant differences in patient sex.

Studies have reported that the forced vital capacity upon admission is correlated with the risk of tracheostomy[7,9], though this characteristic may present problems for facilities that do not have a simple spirometer on hand. Blood gas analysis is simple and convenient, and the results might serve as an indicator in place of forced vital capacity. In actuality, however, significant differences in blood gas results were not evident.

An extensive search yielded no studies indicating a relationship between bone injury or dislocation and the risk of tracheostomy. The current study noted no significant differences in terms of the presence or absence of a vertebral fracture or dislocation in multivariate analyses. This is probably because the damage to the spinal cord is a more important factor than the presence or absence of a vertebral fracture or dislocation.

In the current study, multivariate analyses revealed significant differences in terms of 2 items: an NLI≥C4 and MRI scans revealing hematoma-like changes.

Multivariate-analyses revealed significant differences in terms of 2 items in 30 patients. Of these patients, 17 (57%) required a tracheostomy, suggesting that patients with both of the aforementioned characteristics are likely to require a tracheostomy.

In addition, we examined the risk factors for a tracheostomy in a total of 101 CSCI patients who had NLI≥C4 on admission. As a result, hematoma-like changes on MRI only showed a significant difference in the multivariate logistic regression model (P=0.0049, OR=6.101) (Table 6). This finding raises the possibility that hematoma-like changes on MRI are an optimal indictor of the risk for tracheostomy in patients with a CSCI.

The current study had several limitations. One is that this study was a retrospective study that studied a relatively small sample over a 8-year period. In addition, this study was conducted at a single special facility, i.e. the Spinal Injuries Center, and not at other facilities. In addition, definite eligibility criteria for a tracheostomy have yet to be formulated at this facility, and the final decision is left to the discretion of the patient's primary physician. Additionally, there is a possibility that hematoma-like changes did not appear on T2-weighted images, when MRI was performed within a few hours after the injury. Moreover, this study did not examine aspects such as patient history, original respiratory status, or whether or not the patient smoked.

Despite these limitations, however, the current study identified significant differences in terms of the 2 items: an NLI≥C4 and MRI scans revealing hematoma-like changes. These 2 items are statistically independent risk factors. If patients have both of these characteristics, they are extremely likely to have respiratory failure even if they had a satisfactory respiratory status upon admission. These characteristics can serve as important indices with which to study early tracheal intubation and early tracheostomy.

Author's contributions:

JT constructed conception and design of this study, corrected data, did statistical analysis and drafted the manuscript. IY did statistical analysis, data interpretation and critical revision. AM did second revision. KS and MN approved the final content of the manuscript. All authors read and approved the final manuscript.

Key Points:

1. The current study used imaging assessment and other approaches to assess and examine the risk factors for a tracheostomy in patients with a CSCI.

2. Univariate analyses of the risk factors for tracheostomy revealed significant differences for six items: age, ISS, presence of fracture or dislocation, AIS A, NLI≥C4, and MRI scans revealing hematoma-like changes.

3. Multivariate logistic regression analyses of the risk factors for tracheostomy revealed significant differences in terms of two items: NLI≥C4 and MRI images revealing hematoma-like changes.

4. Spinal shock has an effect in the acute phase of injury, hampering assessment of the AIS. In contrast, MRI scans revealing hematoma-like changes do not change with spinal shock, making these MRI findings an independent indicator.

5. Patients with an NLI≥C4 and MRI scans revealing hematoma-like changes were likely to require a tracheostomy.

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Figure legends.

Figure 1. “Hematoma-like changes” and the level of injury on MRI

Fig1-a; MRI findings of a hypointense core surrounded by a hyperintense rim in a T2-weighted image. We described these changes as “hematoma-like changes”. When these changes were present, the level of the changes served as the level of injury on MRI. This patient’s level of injury on MRI was “C3/4”.

Fig 1-b; When hematoma-like changes were absent, the segment containing the center of a wider-ranging hyperintensity area served as the level of injury on MRI. This patient’s level of injury on MRI was “C5/6”.

Fig 1-a

Fig 1-b

TABLE 1. Patients demographic data

mean±SD	Overall (n=199)	tracheostomy (n=23)	no tracheostomy (n=176)
Age (years)	61.9±17.7	69.1±15.8	60.9±17.8
Sex			
Male	165 (82.9%)	17 (73.9%)	148 (84.1%)
Female	34 (17.1%)	6 (26.1%)	28 (15.9%)
Fracture or dislocation			
+	60 (30.1%)	11 (43.5%)	49 (27.8%)
−	139 (69.9%)	12 (56.5%)	127 (72.2%)
Initial ASIA impairment scale			
A	66 (33.2%)	17 (73.9%)	49 (27.8%)
B	38 (19.1%)	4 (17.4%)	34 (19.4%)
C	51 (25.6%)	2 (8.7%)	49 (27.8%)
D	44 (22.1%)	0	44 (25.0%)
Initial neurological level of injury			
C2	1 (0.5%)	1 (4.4%)	0
C3	10 (5.0%)	5 (21.7%)	5 (2.8%)
C4	90 (45.2%)	15 (65.3%)	75 (42.6%)
C5	62 (31.2%)	1 (4.4%)	61 (34.7%)
C6	19 (9.6%)	0	19 (10.9%)
C7	6 (3.0%)	0	6 (3.4%)
C8	1 (0.5%)	0	1 (0.5%)
T1	10 (5.0%)	1 (4.4%)	9 (5.1%)
ABG			
PO_2 (mmHg)	91.9 ± 40.7	104.1 ± 71.2	90.3 ± 34.9
PCO_2(mmHg)	38.3 ± 5.1	39.9 ± 5.4	38.1 ± 5.0
ISS	21.4 ± 10.6	31.7 ± 18.9	20.1 ± 8.2

TABLE 2. Level of spinal cord injury and hematoma-like changes on MRI

mean±SD	Overall (n=199)	Tracheostomy (n=23)	No tracheostomy (n=176)
Level of spinal cord injury on MRI			
C2/3	5 (2.5%)	1 (4.4%)	4 (2.3%)
C3	2 (1.0%)	0	2 (1.1%)
C3/4	70 (35.2%)	9 (39.1%)	61 (34.7%)
C4	4 (2.0%)	0	4 (2.3%)
C4/5	49 (24.6%)	7 (30.4%)	42 (23.9%)
C5	10 (5.0%)	0	10 (5.7%)
C5/6	29 (14.6%)	5 (21.7%)	24 (13.6%)
C6	4 (2.0%)	0	4 (2.3%)
C6/7	24 (12.1%)	1 (4.4%)	23 (13.1%)
C7	1 (0.5%)	0	1 (0.5%)
C7/T1	1 (0.5%)	0	1 (0.5%)
Hematoma-like changes on MRI			
+	46 (23.1%)	17 (73.9%)	29 (16.5%)
-	153 (76.9%)	6 (26.1%)	147 (83.5%)

TABLE 3. Demographic data of tracheostomy patients

case No	Age	Gender	Type of fracture	AIS	NLI	T2high level	T2 low in high on MRI	PO_2 on admission (mmHg)	PCO_2 on admission (mmHg)	final form
1	80	F	C6 fracture dislocation	A	C4	C6/7	+	74.73	45.2	Trach collar
2	47	M	C3 tear drop fracture T4 fracture dislocation	A	T1	C3/4	−	80.9	36	closed
3	49	M	C5 burst fracture	A	C4	C5/6	+	66.7	41.8	closed
4	64	M	C4 fracture dislocation	A	C4	C4/5	+	72.1	36.5	Trach collar
5	82	F	C3 fracture dislocation	C	C4	C3/4	+	145.7	45.1	closed
6	84	M	C4 fracture dislocation	A	C3	C4/5	+	74.5	34.4	Mechanical ventilation
7	75	M	C5 fracture (post ASF)	C	C3	C4/5	−	45.8	46.6	closed
8	61	F	C5 fracture dislocation	A	C4	C5/6	+	116.9	37.4	closed
9	80	F	C3 burst fracture	B	C4	C3/4	+	59.0	40.0	closed
10	76	M	C5 fracture dislocation	A	C4	C5/6	+	161.0	33.0	Trach collar
11	70	M	C3 fracture dislocation	A	C3	C3/4	+	166.0	46.7	Mechanical ventilation
12	51	M	No fracture	A	C3	C5/6	−	97.0	49.0	Mechanical ventilation
13	77	M	No fracture	A	C4	C4/5	+	48.6	47.6	Mechanical ventilation
14	22	M	No fracture	A	C3	C2/3	+	392 (intubated)	40.7（intubated）	closed
15	63	M	No fracture	B	C4	C3/4	−	63.4	33.8	closed
16	89	M	No fracture	A	C4	C4/5	+	93.6	34.8	died
17	72	M	No fracture	B	C4	C3/4	−	86.5	33.4	closed
18	69	F	No fracture	A	C4	C3/4	+	123	43.9	closed
19	61	M	No fracture	B	C2	C3/4	+	127	35.7	Mechanical ventilation
20	85	F	No fracture	A	C4	C4/5	+	69.5	43.1	closed
21	83	M	No fracture	A	C5	C5/6	−	72.5	37.2	closed
22	66	M	No fracture	A	C4	C4/5	+	72.7	31.6	Mechanical ventilation
23	84	M	No fracture	A	C4	C3/4	+	86.2	43.9	Mechanical ventilation

TABLE 4. Results of the Simple Logistic Regression Model

	P	Odds Ratio	95% Confidence interval	
Age	0.0422	1.035	1.004 - 1.074	＊
ISS	0.0002	1.065	1.032 - 1.106	＊
PO_2 on admission	0.1445	1.006	0.997 - 1.014	
PCO_2 on admission	0.1055	1.076	0.986 - 1.183	
Sex	0.2284	1.866	0.629 - 4.939	
Fracture or dislocation (+)	0.0209	2.827	1.166 - 6.931	＊
AIS A	< 0.0001	7.344	2.870 - 21.353	＊
NLI≥C4	0.0008	12.599	3.550 - 80.260	＊
Injury level on MRI ≥C3/4	0.6169	1.251	0.508 - 3.004	
Hematoma-like changes on MRI	< 0.0001	9.504	3.780 - 25.604	＊

＊P＜0.05

Age, ISS, PO_2 and PCO_2 were calculated by the continuous variable function unit odds ratio.

TABLE 5. Results of the Multiple Logistic Regression Model

	P	Odds Ratio	95% Confidence interval	
Age	0.0782	1.031	0.999 - 1.071	
ISS	0.2784	1.025	0.983 - 1.077	
Fracture or Dislocation (+)	0.2477	2.049	0.597 - 6.970	
AIS A	0.2180	2.329	0.600 - 9.154	
NLI ≥C4	0.0058	9.681	2.362 - 66.748	＊
Hematoma-like changes on MRI	0.0212	3.941	1.243 - 13.131	＊

＊ P＜0.05

Age and ISS were calculated by the continuous variable function unit odds ratio.

TABLE 6. Results of the Multiple Logistic Regression Model in CSCI patients who had NLI≥

C4 on admission

	P	Odds Ratio	95% Confidence interval	
Age	0.1383	1.031	0.993 - 1.078	
ISS	0.4848	1.016	0.974 - 1.066	
Fracture or dislocation (+)	0.1476	2.617	0.101 - 1.411	
AIS A	0.2180	1.705	0.386 - 7.369	
Hematoma-like changes on MRI	0.0049	6.101	1.779 - 22.842	＊

＊ $P<0.05$

Age and ISS were calculated by the continuous variable function unit odds ratio.