

Efficacy and Safety of Early Tracheotomy in Acute Cervical Spinal Cord Injury

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ABSTRACT

Objective: To evaluate the clinical efficacy and safety of early tracheotomy *versus* delayed tracheotomy for patients with cervical spinal cord injury.

Study Design: A descriptive study.

Place and Duration of Study: Department of Orthopedic Surgery, The 80th Army Hospital of PLA, Weifang, Shandong, China, from January 2012 to June 2019.

Methodology: Data of 45 patients with cervical spinal cord injury, who underwent tracheotomy and cervical spine internal fixation at the study place, were retrospectively analysed. Twenty-five patients underwent tracheotomy immediately after cervical spine internal fixation (early tracheotomy group) and 20 patients underwent tracheotomy 3-12 days after cervical spine internal fixation (delayed tracheotomy group). Clinical outcomes and tracheotomy complications were compared between the two groups.

Results: Compared with the delayed tracheotomy, the early tracheotomy significantly reduced the total duration of mechanical ventilation ($p < 0.01$), duration of mechanical ventilation after tracheotomy ($p < 0.05$), duration of indwelling tracheal tube ($p < 0.05$), and hospital stay ($p < 0.01$). There were no significant differences in pneumonia, mortality, and complications related to tracheotomy between the groups. No incision infection for tracheotomy and cervical spine internal fixation were found in all patients.

Conclusion: Compared with delayed tracheotomy, early tracheotomy can significantly reduce the duration of mechanical ventilation, duration of indwelling tracheal tube, and hospital stay. Early tracheotomy did not increase the risk of infection of the cervical spine internal fixation. Therefore, early tracheotomy was beneficial and safe for patients.

Key Words: Spinal cord injuries, Tracheotomy, Complications.

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INTRODUCTION

Cervical spinal cord injury (CSCI) is common in clinical practice and is associated with high morbidity, high mortality, high complication rate, and poor prognosis.¹ Due to central nervous system damage, cervical spinal cord injury can lead to multiple system dysfunctions.² Among them, respiratory dysfunction has become the most important factor for patient death.^{3,4}

Various airway managements including tracheal intubation, tracheotomy, and mechanical ventilation are essential for patients with CSCI.⁵ Tracheotomy should be performed on patients with recurrent respiratory failure, prolonged mechanical ventilation, or intolerance to tracheal intubation. For patients with CSCI, tracheotomy can improve ventilation, reduce complications of tracheal intubation, increase patient's ventilation tolerance, and facilitate airway care and pulmonary secretion clearance.⁶⁻¹⁰ However, tracheotomy is an invasive operation, the timing of tracheotomy for patients with CSCI remains controversial.¹¹⁻¹³ There are no strict objective criteria for the timing of tracheotomy at present.^{11,13}

The aim of this study was to evaluate the clinical efficacy and safety of early tracheotomy (immediately after spine fixation) *versus* delayed tracheotomy (3-12 days after fixation).

METHODOLOGY

This study was approved by the Ethical Committee of the 80th Army Hospital of PLA. Clinical data of 45 patients with acute

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CSCI, who underwent tracheotomy and cervical spine internal fixation in this hospital from January 2012 to June 2019, were retrospectively analysed. Clinical records with respiratory diseases, such as chronic bronchitis, chronic obstructive pulmonary disease and asthma, other injuries such as intracranial haemorrhage, brain contusion and lung injury, and patients who gave up treatment or were transferred, were excluded. Finally, the clinical data of 45 patients with CSCI, who underwent tracheotomy and cervical spine internal fixation at the hospital, was compared for the prognosis between early tracheotomy (tracheotomy performed immediately after cervical spine internal fixation) and delayed tracheotomy (tracheotomy performed 3-12 days after cervical spine internal fixation) for patients with CSCI. The decision of tracheotomy to a patient was made by either the physicians in this primary unit or in consultation with the physicians in the ICU, based on the patient's age, previous diseases, degree of injury, injury levels, respiratory strength, cough strength, blood gas analysis results, and mechanical ventilation evaluation.^{5,14} It was especially considered for those with high complete cervical spinal cord injury; oxygen saturation is continuously less than 90%; considerable sputum secretions and weak cough strength needed an artificial airway for sputum excretion; those expected to require prolonged mechanical ventilation, and those who underwent orotracheal intubation, and failed to wean from the ventilator after repeated attempts. Tracheotomy performed immediately after cervical spine internal fixation in the operating room was early tracheotomy. While tracheotomy performed 3-12 days after cervical spine internal fixation was defined as delayed tracheotomy.

The degree of CSCI was assessed by ASIA standards. The level of CSCI was based on the highest injury segment of the cervical spinal cord indicated by MRI. The following clinical parameters were recorded: total duration of mechanical ventilation, duration of mechanical ventilation after tracheotomy, duration of indwelling tracheal tube, hospital stay, pneumonia, mortality, incision infection of anterior cervical spine internal fixation, and tracheotomy complications. The diagnosis of pneumonia required two or more serial chest radiographs of new or progressive and persistent infiltrate and at least two of the following criteria: (1) temperature $>38^{\circ}\text{C}$ or $<35.5^{\circ}\text{C}$; (2) leukocytosis (>12000 WBC/ mm^3) or leukopenia (<4000 WBC/ mm^3); (3) new onset of purulent bronchial secretions or change in its character.¹⁵ The complications of tracheotomy referred to postoperative haemorrhage, subcutaneous emphysema, tracheal stenosis, incision infection, tracheomalacia, and tracheoesophageal fistula. Tracheal stenosis referred to airway stenosis caused by granulomatosis or concentric stenosis; and was diagnosed by an otolaryngologist based on clinical symptoms (wheezing and dyspnoea) and confirmed by laryngoscopy or bronchoscopy. Patients were followed up 3, 6, and 12 months after surgery, and once a year thereafter.

Continuous variables were expressed as mean \pm standard deviation (SD) and median (inter-quartile range, IQR). Categorical variables were expressed as numbers and percentages. The 1-Sample Kolmogorov-Smirnov test was used to test the distribution of continuous variables. The two groups were compared with the Student's t-test or Mann-Whitney U-test for continuous variables, and the Chi-square test or Fisher's exact test for categorical variables. Statistical analysis was performed with SPSS 21 software. The value of $p \leq 0.05$ was considered to be statistically significant.

RESULTS

Clinical records of 45 patients were included, including 32 (71.1%) males and 13 (28.9%) females, and the mean age was 50.02 years (ranging from 26 to 69 years). The mean follow-up duration was 15.07 months with a range of 3 to 36 months. The time from cervical spine internal fixation to tracheotomy was 7.1 ± 2.25 days in delayed tracheotomy group. There were no significant differences in age, gender, cause of injury, ASIA classification, injury level, surgical approach, and follow-up duration between the two groups ($p > 0.05$). Table I shows the demographic data in early tracheotomy group and delayed tracheotomy group.

Table II shows the clinical outcomes of patients in early tracheotomy group and delayed tracheotomy group. Compared with the delayed tracheotomy, the early tracheotomy significantly reduced the total duration of mechanical ventilation ($p=0.001$), duration of mechanical ventilation after tracheotomy ($p=0.011$), duration of indwelling tracheal tube ($p=0.011$), and hospital stay ($p=0.001$). There were no significant differences in pneumonia rate ($p=0.161$) and mortality rate ($p=0.192$). No incision infection of anterior cervical spine internal fixation was found in either group.

Table III shows the complications related to tracheotomy in early tracheotomy group and delayed tracheotomy group. There were no significant differences in postoperative haemorrhage ($p=0.577$), subcutaneous emphysema ($p=0.577$), and tracheal stenosis ($p=0.080$) between the two groups. No incision infection, tracheomalacia, and tracheoesophageal fistula were found in either group.

DISCUSSION

Patients with cervical spinal cord injury often have respiratory dysfunction or even respiratory failure due to respiratory muscle paralysis. About 21-77% of patients require tracheotomy and rely on mechanical ventilation to varying degrees.¹⁶ Compared with tracheal intubation, tracheotomy can reduce dead cavity ventilation and work of breathing, benefit to airway care and pulmonary secretion clearance, and it can reduce laryngeal injury, sedation time, and increase patient comfort.⁶⁻¹⁰ However, there are no strict standards for tracheotomy indications, and no clear criteria for tracheotomy timing.¹¹⁻¹³

Table I: Comparison of demographic data between early tracheotomy group and delayed tracheotomy group.

Characteristics	Tracheotomy		p-value
	Early	Delayed	
Patients (n)	25	20	
Mean age (years)	51.04 ±8.71	48.75±10.42	0.426
Gender (n)			0.745
Male	17 (68%)	15 (75%)	
Female	8 (68%)	5 (25%)	
Cause of injury (n)			0.915
Traffic accidents	13 (52%)	12 (60%)	
Fall injuries	8 (32%)	6 (30%)	
Blunt traumas	4 (16%)	2 (10%)	
ASIA classification (n)			0.626
Grade A	15 (60%)	9 (45%)	
Grade B	6 (24%)	7 (35%)	
Grade C	4 (16%)	3 (15%)	
Grade D	0 (0%)	1 (5%)	
Injury level (n)			0.872
C1-2	3 (12%)	2 (10%)	
C3-5	20 (80%)	15 (75%)	
C6-7	2 (8%)	3 (15%)	
Surgical approach (n)			0.787
Anterior	14 (56%)	12 (60%)	
Anterior-posterior	11 (44%)	8 (40%)	
Follow-up	12 (6-12)	12 (12-24)	0.163

Table II: Comparison of clinical outcomes between early tracheotomy group and delayed tracheotomy group.

Variable	Tracheotomy		p-value
	Early	Delayed	
Total duration of mechanical ventilation (days)	15.68±6.82	22.50±5.69	0.001
Duration of mechanical ventilation after tracheotomy (days)	14.36±6.22	18.70±4.28	0.011
Duration of indwelling tracheal tube (d)	18.04±5.05	21.85±4.43	0.011
Hospital stay (days)	32.36±6.76	41.00±8.93	0.001
Pneumonia (n, %)	11 (44%)	13 (65%)	0.161
Mortality (n, %)	0 (0%)	2 (10%)	0.192
Incision infection of anterior cervical spine internal fixation (n, %)	0 (0%)	0 (0%)	-

According to several authors, early tracheotomy is beneficial to patients. Flanagan *et al.*¹¹ found that early tracheotomy (within 7 days of orotracheal intubation) can significantly reduce the duration of mechanical ventilation, duration of indwelling tracheal tube, and ICU stay compared with late tracheotomy (after 7 days of orotracheal intubation).¹¹ They pointed out that regardless of the severity and level of CSCI, early tracheotomy can improve respiratory outcomes of patients without

increasing the incidence of complications.¹¹ Romero *et al.*¹⁷ also found that early tracheotomy (within 7 days of orotracheal intubation) can reduce the duration of mechanical ventilation, ICU stay, and complications of long-term intubation.¹⁷ They recommend early tracheotomy for patients with CSCI who were likely to require prolonged mechanical ventilation.¹⁷ Guirgis *et al.*¹⁸ pointed out that early tracheotomy (within 7 days after injury) can reduce the duration of mechanical ventilation, and it can reduce the mortality of patients with high CSCI.¹⁸

Table III: Comparison of tracheotomy complications between early tracheotomy group and delayed tracheotomy group.

Variable	Tracheotomy		p-value
	Early	Delayed	
Total complications (n, %)	2 (8%)	7 (35%)	0.057
Postoperative haemorrhage (n)	1(4%)	2(10%)	0.577
Subcutaneous emphysema (n)	1(4%)	2(10%)	0.577
Tracheal stenosis (n)	0(0%)	3(15%)	0.080
Incision infection (n)	0(0%)	0(0%)	-
Tracheomalacia (n)	0(0%)	0(0%)	-
Tracheoesophageal fistula (n)	0(0%)	0(0%)	-

Different from their division of tracheotomy, it is found here that early tracheotomy can significantly reduce the duration of mechanical ventilation, duration of indwelling tracheal tube, and hospital stay compared with delayed tracheotomy. However, there were no significant differences in pneumonia, mortality, and tracheotomy complications between the two groups. Moscovici *et al.*¹⁹ found it was the changes of respiratory mechanics by which that tracheotomy promoted weaning from the ventilator.

The incidence of pneumonia was high in both groups, reaching 44% and 65%, respectively. Ventilator-associated pneumonia (VAP) is one of the common and serious complications during mechanical ventilation.²⁰ Although early tracheotomy significantly reduced duration of mechanical ventilation, it didn't significantly reduce pneumonia compared with delayed tracheotomy. For these patients, infection was actively fought and patient were given nutritional support. All patients were successfully weaned from the ventilator and the pneumonia were cured or improved when discharged. Two deaths during follow-up were recorded in the delayed tracheotomy group; of which, one death was due to pneumonia and respiratory failure, and another death due to pressure ulcers caused by improper nursing. Moreover, no death was reported in the early tracheotomy group. However, the difference was not statistically significant. Considering the small sample size, a study with a larger sample size is needed to investigate whether early tracheotomy can reduce the mortality.

When planning surgery, a common concern is whether tracheotomy will affect cervical surgery because the incision for tracheotomy is close to; or even the same as the incision for anterior cervical spine internal fixation. The former is a clean-contaminated wound while the latter is a clean wound. Cervical internal fixation surgery requires the placement of internal fixation devices. Once infected, it is difficult to control and may

cause serious central nervous system infections. For this reason, some scholars accepted orotracheal intubation during perioperative period. But orotracheal intubation cannot be retained for a longer time. Orotracheal intubation for 8 days can result in a high rate of laryngeal injury (83%).²¹ Lozano *et al.*²² performed early tracheotomy within 4 days after anterior cervical fusion. They did not find anterior cervical surgical wound or deep tissue infections. For patients who have undergone tracheotomy before anterior cervical surgery, Northrup *et al.*²³ also did not find evidences of cervical soft tissue or bony infection after surgery. Even Galeiras *et al.*²⁴ suggested that the performance of tracheotomy before or immediately after anterior cervical spine fixation was associated with a low risk of infection of the anterior cervical surgical wound. In the present study, no one encountered anterior cervical surgical wound or deep tissue infections.

Therefore, it is believed that tracheotomy does not increase the risk of infection of the anterior cervical spine internal fixation as long as the two incisions and the skin between the two incisions are well-designed and carefully prepared.

No incision infection, tracheomalacia and tracheoesophageal fistula related to tracheotomy were found among the included 45 patients. Three patients with tracheotomy presented with postoperative bleeding oozing from the vein. Two of these patients were treated with a pressure dressing for homeostasis, and the third patient was treated with wound suture and pressure dressing for homeostasis. It is believed that careful intraoperative hemostasis can effectively reduce postoperative haemorrhage. Subcutaneous emphysema occurred in three patients. One exhibited spontaneous resorption. In the other two patients, emphysema subsided after air evacuation *via* thick needles. Tracheal stenosis is a common late complication of tracheotomy. The frictional stimulation of the tracheal tube, abnormal wound healing with excess granulation tissue formation, wound sepsis, and excessive cartilage damage are important causes of tracheal stenosis after tracheotomy.²⁵

In summary, the authors retrospectively analysed the clinical data of patients with CSCI, who underwent tracheotomy in the past 7 years, and compared the clinical efficacy and security between early tracheotomy and delayed tracheotomy for patients with CSCI. Early tracheotomy has many advantages. This study provides new ideas for the airway management for patients with CSCI. However, this study is a retrospective single-centre study. Limitations such as small sample size and bias are unavoidable. Multicentre, large-sample-size randomised controlled trials should be conducted in the future.

CONCLUSION

Compared with delayed tracheotomy, early tracheotomy can significantly reduce the duration of mechanical ventilation, duration of indwelling tracheal tube, and hospital stay. Early tracheotomy did not increase the risk of infection of the cervical spine internal fixation surgery. Early tracheotomy is a safe and effective choice for patients with cervical spinal cord injury, who need tracheotomy.

ETHICAL APPROVAL:

This study was approved by the Ethical Committee of The 80th Army Hospital of PLA.

PATIENTS' CONSENT:

Not applicable as it is a retrospective study for clinical records. Moreover, patient identifiers were removed before data analysis for confidentiality.

CONFLICT OF INTEREST:

Authors declared no conflict of interest.

AUTHORS' CONTRIBUTION:

YW: Literature search, manuscript writing, result interpretation and discussion.

HL, HT: Data collection and analysis and manuscript drafting.

GC, DF: Research design and conception, supervised study and revalidated data.

ML: Revised critically for important content, final manuscript preparation, proofreading, final approval, and overall coordination.

YW, HL, HT: Contributed equally to this study.

All authors approved final version of the manuscript.

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