Cell Biochem Biophys (2014) 70:455–459
DOI 10.1007/s12013-014-9940-5

ORIGINAL PAPER

Respiratory Nursing Interventions Following Tracheostomy in Acute Traumatic Cervical Spinal Cord Injury

Chunmei Luo · Hongli Yang · Yu Chen · Zhengfeng Zhang · Zili Gong

Published online: 13 April 2014

Abstract Tracheostomy is frequently performed in severe cervical spinal cord injury (SCI) patients with the pulmonary dysfunction. A series of respiratory nursing interventions are required to plan tracheostomy removal. Tracheostomy was performed in 29 patients after acute traumatic cervical SCI. A series of respiratory nursing interventions were introduced in these patients after closed tracheostomy and decannulation, including closed tracheostomy tube training, manually assisted cough. Chacheostomy was successfully removed in 21 patients after the respiratory nursing interventions. In contrast, eight patients died from associated injuries. The average time from tracheostomy to decannulation was 40 days (14–104 days), the average time from closed tracheostomy to decannulation was 18.80 $\pm$ 13.50 days. Second tracheostomy was performed in one patient after 29 days' removal due to pulmonary infection. One patient presented with delayed incision healing for 29 days. Closed tracheostomy tube training and manually assisted cough are key factors for tracheostomy removal, although intensive nursing are also needed. The time from tracheostomy to decannulation and from closed tracheostomy to decannulation is increased in case of "late" (>24 h) tracheostomy and longer mechanical ventilation.

C. Luo · H. Yang · Y. Chen · Z. Zhang
Department of Orthopedics, Xinqiao Hospital, Third Military Medical University, 183 Xinqiao Street, Shapingba District, Chongqing 400037, China

Z. Gong (✉)
Department of Neuropsychiatry, Xinqiao Hospital, Third Military Medical University, 183 Xinqiao Street, Shapingba District, Chongqing 400037, China
e-mail: drziligong@163.com

Keywords Cervical spine · Spinal cord injuries · Nursing · Tracheostomy · Decannulation

Introduction

Acute traumatic cervical spinal cord injury (SCI) not only seriously compromises sensory and motor function and sympathetic activity but also produces the weakness or paralysis of respiratory muscles and respiratory function impairment [1]. It is estimated that 40–70 % patients with cervical lesions complicates with respiratory infections (tracheobronchitis and pneumonia) and atelectasis, which will require prolonged mechanical ventilation [2]. Tracheostomy is commonly performed in these patients to improve outcomes of artificial ventilation support, to avoid complications of prolonged orotracheal intubation, to facilitate bronchial clearance, to support phonation and swallowing, and to reduce the length of sedation to prevent related complications [3].

Prolonged tracheostomy tube significantly increases the risk of early complications (misplacement, subcutaneous emphysema, wound infection, and bleeding) or late complications (tracheal stenosis, especially subglottic, stoma infection, swallowing problems, tracheoesophageal fistula, and mediastinitis) [4]. Therefore, removal of tracheostomy is a necessary step to lower the mortality rate and rehabilitation time of SCI patients who suffered from respiratory muscle paralysis and respiratory function impairment. Clinical evidence has shown that the majority of critically ill tracheostomized patients who survive to ICU discharge can eventually be successfully decannulated [5]. However, few studies have been conducted to investigate the application of respiratory nursing interventions from tracheostomy to decannulation in SCI patients. In this study, a retrospective study is conducted to evaluate the clinical benefits of respiratory nursing interventions following tracheostomy in acute traumatic cervical SCI.

Patients and Methods

Patients

Between July 2004 and December 2012, tracheostomy was performed in a total of 43 patients with acute traumatic cervical SCI. Among these patients, 8 patients died and 14 patients transferred to other hospitals or departments because of medical or social reasons. These patients were excluded from the study. The clinical characteristics of 21 patients who reached successful tracheostomy removal were summarized in Table 1. In these 21 patients (17 males and 4 females), the distribution of cervical level was from C2 to C7; the causes of trauma included motor vehicle accidents, bruise the neck and fell. Tracheostomy was performed in all these patients to improve artificial ventilation to correct respiratory function impairment. The neurological statuses and the score were evaluated using the American Spinal Injury Association (ASIA) impairment classification. The average time from tracheostomy to decannulation [D, $M(X_{\min} - X_{\max})$] and from closed tracheostomy to decannulation (D, $\bar{x} \pm s$) was recorded to evaluate the nursing interventions.

Nursing Interventions

Criteria to Closed Tracheostomy

Following intensive care such as humidification and warming of inspired gases, effective suctioning and communications was performed to minimize the dependence of patients on ventilation support for swallowing and speech assessment. Closed tracheostomy was performed according to a set of objectively determined criteria.

Closed Tracheostomy Tube Training

Before closed tracheostomy to be achieved, half closed and intermittent closed trainings were necessary to avoid respiratory failure due to airway obstruction and sputum retention. After releasing the airbag of tube, a rubber plug with two holes was filled with tube. The warmed and humidified air/oxygen was inspired through the holes. The rubber plug was removed if suctioning was necessary. Consciousness, heart rate, breath, and blood oxygen saturation were monitored.

Down-sizing (Use of Decreasing Size of Tracheostomy Tubes)

Tracheal tube occupied almost half of tracheal diameter which was associated with airway obstruction and sputum retention. The tracheostomy tubes should be gradually replaced with decreasing size tubes.

Deep Breathing Exercises

Abdominal and pursed lip deep breathing exercises were encouraged for an increase in tidal volumes (TVs) and functional residual capacity. Deep breathing exercises were undertaken 10 min for three–four times every day as possible. Breath training device was also used to assist patients generating a large sustained inspired breath, with 10–15 min for two times every day according patients' Physical tolerance.

Chest Physiotherapy (Percussion and Vibration)

Percussion was achieved through manually aiding the clearance of secretions by clapping the chest above the affected lung area for 5 min every 4–6 h. Vibration was applied using a shaking motion to the patients' chest for 15–30 min twice every day. Chest percussion and vibration also were used with postural drainage to help dislodge secretions for severe pulmonary infection according to auscultation situation and X-rays.

Manually Assisted Cough

Manually assisted coughing was applied in the care of coughing problematic patients especially for respiratory muscles paralysis due to SCI. The technique of manually assisted coughing involved the application of pressure to chest and abdominal wall to coordinate with the patients' passive expiration to promote an increase in the velocity of exhaled air and help the movement of secretions into the major airways. Usually, another staff would be used to brace the shoulders of patients with cervical injuries to prevent any unnecessary movement of the spine. If assisted coughing techniques are proved ineffective in some patients, then the insertion of a tracheostomy to aid suctioning would be required.

Criteria for Decannulation

Removal of tracheostomy was performed by a competent doctor with additional airway support when a set of objective criteria is met.

Table 1 Patient characteristics and clinical data for study cohort

	Numbers	From tracheostomy to decannulation [D, $M(X_{\min} - X_{\max})$]*	T	p	From closed tracheostomy to decannulation (D, $\bar{x} \pm s$)	T	p
Sex							
Male	$n = 17$, 81 %						
Female	$n = 4$, 19 %						
Age							
Mean and range	44.57; 12–68 years						
Median	47 years						
Spine injury cause							
Traffic trauma	$n = 9$, 42.8 %						
Bruise the neck	$n = 6$, 28.6 %						
Fall injuries	$n = 5$, 23.8 %						
Assault	$n = 1$, 4.8 %						
Associated injury							
Thoracic injury	$n = 8$, 38.1 %						
Brain injury	$n = 7$, 33.3 %						
Other region injury	$n = 6$, 28.6 %						
Spine injury level							
C2–C4	7, 33.3 %	43.0 (30–86)	0.507	0.618	21.57 ± 16.65	0.870	0.395
C5–C7	14, 66.7 %	36.5 (14–104)			17.42 ± 12.08		
Spine injury grade							
ASIA A	$n = 16$, 76.2 %	40.5 (14–104)	1.318	0.203	20.25 ± 14.47	0.654	0.572
ASIA B\C\D	$n = 5$, 23.8 %	30.0 (22–43)			14.20 ± 9.52		
Artificial ventilatory							
>10 days	9	43.0 (30–104)	−2.876	0.028	24.33 ± 16.17	−1.699	0.106
<10 days	12	34.0 (14–57)**			14.67 ± 9.87		
From injury to tracheostomy							
<24 h	10	42.0 (23–104)	2.045	0.066	26.70 ± 14.60**	3.033	0.011
>24 h	11	35.0 (14–46)			11.63 ± 7.31		
Total	21, 100 %	40.0 (14–104)			18.80 ± 13.50		

* $p < 0.05$, ** $p < 0.01$

Statistical Analysis

Comparisons were performed using Student's t tests and linear regression analysis. A p value of <0.05 was regarded the criterion for a significant difference. The odds ratio was reported with 95 % confidence intervals.

Results

Clinical data are summarized in Table 1. The average time from tracheostomy to decannulation [D, $M(X_{\min} - X_{\max})$] was 40.0 (14–104) days, the average time from closed tracheostomy to decannulation (D, $\bar{x} \pm s$) was 18.80 ± 13.50 days. Spine injury level C2–C4 may produce paralysis of diaphragmatic muscles, leading to respiratory failure. However, the M and D value showed no significant difference from C5 to C7 levels ($p > 0.05$). Spine injury grade ASIA A did not contribute the M and D value compared with ASIA B\C\D. For artificial ventilation, M value was significantly decreased in group of ventilation for less than 10 days compared with group of ventilation for more than 10 days. If the time interval from injury to tracheostomy was less than 24 h, the D value was greater compared with interval of more than 24 h ($p < 0.05$), which indicates that "late" (>24 h) tracheostomy is associated with less time for intensive care need and mechanical ventilation.

Thirteen patients presented with expectoration difficulty soon after closed tracheostomy. These conditions were improved by changing the silver catheter. Second tracheostomy was performed in one patient 29 days after due to severe pulmonary infection. One patient presented with delayed wound healing for 29 days after removal of tracheostomies. One patient experienced wound infection (*Escherichia coli*) 24 days after tracheostomies.

Discussion

A multitude of nursing interventions are critical for removing a tracheostomy, which is an essential step for rehabilitation of cervical SCI patients with lower mortality rate. O'Connor HH argued that the presence of a tracheostomy tube in the trachea can cause complications, including tracheal stenosis, bleeding, infection, aspiration pneumonia, and fistula formation from the trachea to either the esophagus or the innominate artery. Final removal of the tracheostomy tube is an important step in the recovery from chronic critical illness and can usually be done once the indication for the tube placement has resolved [6]. Generally, removal tracheostomy can be performed when the patients met the criteria for decannulation. However, the cervical SCI patients are difficult to reach these criteria because of paralysis of respiratory muscles and respiratory function impairment [1, 7–9], which presented as restrictive ventilatory functional disturbance [10, 11]. The long-time intensive care of stay and mechanical ventilation would be required by cervical SCI patients. In this study, all patients presented lowering pulmonary ventilation and sputum ability. Therefore, they need a longer time for *D* value by the way of closed tracheostomy tube training, deep breathing exercises, and manually assisted cough.

The closed tracheostomy tube training is the first fundamental step to interrupt pulmonary infection chain for cervical SCI patients. The presence of a tracheostomy tube in the trachea for cervical SCI patients can cause pulmonary infection and increase the secretions. Paralysis of respiratory muscles significantly compromises the movement of secretions into the major airways, resulting in more serious of pulmonary infection. We performed closed tracheostomy tube training in patients who did not have severe pulmonary infection soon after they become less dependent on ventilation support even in case of problematic coughing. This early training in our study helps patients adapt to breathing and avoid air exposure of lower respiratory tract, which is very beneficial for interruption of pulmonary infection chain. In the meantime, humidification, oxygen, and suctioning were necessary.

Use of smaller size of tracheostomy tubes helps effective dislodge of secretions. Valentini et al. [12] indicated that the decrease of the tracheotomy tube size in tracheotomized difficult to wean patients was associated with an increased of diaphragm pressure time product per min (PTP_{di}), breathing frequency and TV (*f*/VT), and Tension–Time Index of the diaphragm (TT_{di}) that were otherwise normal, using an higher diameter. The in vitro study showed that the resistances increased similarly for tracheotomy tube and endotracheal tubes decreasing the diameter and increasing the flows [12]. Core material of tracheotomy tube also has a great impact on the secretion retention. Silverware tracheotomy tube is recommended according to our experience.

Assisted coughing is a core subject in multitude of nursing interventions for decannulation in cervical SCI patients. Choate et al. [13] indicated that the primary reason for decannulation failure was sputum retention. In 52.5 % of cases ($n = 21$), decannulation failure followed an inability to expectorate secretions independently. A related maneuver known as a "quad cough" is proved effective [14].

The therapist enhances the cough effort by vigorous pressure applied to the abdomen, in the rhythm of a cough, and the process is continued to low lung volume. The application of pressure to the abdomen greatly enhances expiratory flow and mobilization of secretions. Contraindications to performing quad coughs are the presence of an inferior vena cava filter or abdominal aortic aneurysm or prosthesis. Although various assisted coughing techniques have been reported including electrically stimulated cough [15], we modified the techniques for the cervical SCI patients. An additional person braces the shoulders in patients with cervical injuries to prevent any unnecessary movement of the spine. The application of pressure is involved not only to chest but also to abdominal wall. Suctioning is always required for effective assisted coughing at the initial stage. Our results showed that this procedure is effective for assisted coughing for cervical SCI patients.

The whole process and each detail in multitude of nursing interventions are important from closed tracheostomy tube to decannulation in cervical SCI patients. Marchese et al. [16] evaluated 427 tracheostomies for decannulation: 96 (22.5 %) were closed; 175 patients (41 %) were discharged with home mechanical ventilation; 114 patients (26.5 %) maintained the tracheostomy despite weaning from mechanical ventilation and 42 patients (10 %) died or lost. In our series, 21 patients were decannulated (36.8 % in 43 patients), with the 40.0 (14–104) for *M* value and 8.80 ± 13.50 for *D* value. Spine injury level and SCI grade did not contribute the *M* and *D* value significant difference. Theoretically, spine injury level C2–C4 and SCI grade produce paralysis of diaphragmatic muscles and respiratory failure which may contribute bigger *M* and *D* value. Our negative results maybe because of the small size of the sample. The "late" (>24 h) tracheostomy and less than 10 days artificial ventilator reduced the *M* and *D* value. The reason, we supposed, is associated primary injury which produce respiratory function impairment.

Conclusion

The management of tracheostomy removal in SCI presents a unique challenge to health care professionals. An understanding of multitude of nursing interventions involved in spinal injury is essential to develop comprehensive assessment for decannulation. Closed tracheostomy tube training and manually assisted cough are even more important for tracheostomy removal compared other interventions. Late tracheostomy and longer mechanical ventilation influence the time from tracheostomy to decannulation and from closed tracheostomy to decannulation. Limitation of small size of the sample in our series maybe contributes the result of no significant diffidence from the SCI level and grade in present paper.

Conflict of interest The authors declare no conflict of interest.

References

1. Winslow, C., et al. (2002). Impact of respiratory complications on length of stay and hospital costs in acute cervical spine injury. *Chest, 121*(5), 1548–1554.
2. Determann, R. M., et al. (2010). Ventilation with lower tidal volumes as compared with conventional tidal volumes for patients without acute lung injury: A preventive randomized controlled trial. *Critical Care, 14*(1), R1.
3. Lemons, V. R., & Wagner, F. C., Jr. (1994). Respiratory complications after cervical spinal cord injury. *Spine (Phila Pa 1976), 19*(20), 2315–2320.
4. Bellamy, R., Pitts, F. W., & Stauffer, E. S. (1973). Respiratory complications in traumatic quadriplegia. Analysis of 20 years' experience. *Journal of Neurosurgery, 39*(5), 596–600.
5. Kiwerski, J. (1992). Respiratory problems in patients with high lesion quadriplegia. *International Journal of Rehabilitation Research, 15*(1), 49–52.
6. O'Connor, H. H., & White, A. C. (2010). Tracheostomy decannulation. *Respiratory Care, 55*(8), 1076–1081.
7. McMichan, J. C., Michel, L., & Westbrook, P. R. (1980). Pulmonary dysfunction following traumatic quadriplegia. Recognition, prevention, and treatment. *JAMA, 243*(6), 528–531.
8. Urdaneta, F., & Layon, A. J. (2003). Respiratory complications in patients with traumatic cervical spine injuries: Case report and review of the literature. *Journal of Clinical Anesthesia, 15*(5), 398–405.
9. DeVivo, M. J., Black, K. J., & Stover, S. L. (1993). Causes of death during the first 12 years after spinal cord injury. *Archives of Physical Medicine and Rehabilitation, 74*(3), 248–254.
10. Estenne, M., & De Troyer, A. (1986). The effects of tetraplegia on chest wall statics. *American Review of Respiratory Disease, 134*(1), 121–124.
11. Baydur, A., Adkins, R. H., & Milic-Emili, J. (2001). Lung mechanics in individuals with spinal cord injury: Effects of injury level and posture. *Journal of Applied Physiology, 90*(2), 405–411.
12. Valentini, I., et al. (2012). Different tracheotomy tube diameters influence diaphragmatic effort and indices of weanability in difficult to wean patients. *Respiratory Care, 57*(12), 2012–2018.
13. Choate, K., Barbetti, J., & Currey, J. (2009). Tracheostomy decannulation failure rate following critical illness: A prospective descriptive study. *Australian Critical Care, 22*(1), 8–15.
14. Brown, R., et al. (2006). Respiratory dysfunction and management in spinal cord injury. *Respiratory Care, 51*(8), 853–868; discussion 869–870.
15. Jaeger, R. J., et al. (1993). Cough in spinal cord injured patients: Comparison of three methods to produce cough. *Archives of Physical Medicine and Rehabilitation, 74*(12), 1358–1361.
16. Marchese, S., et al. (2010). Tracheostomy in patients with long-term mechanical ventilation: A survey. *Respiratory Medicine, 104*(5), 749–753.