Weaning of Long-Term Mechanically-Ventilated Patients Following Video Bronchoscopy-Guided Percutaneous Dilatational Tracheostomy

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Background: This is a prospective study of peri-procedure and post-procedure complications and successful weaning of long-term mechanically-ventilated patients following video bronchoscopy-guided percutaneous dilatational tracheostomy (PDT).

Methods: Video bronchoscopy guided PDT was performed for long-term mechanically-ventilated patients in a medical intensive care unit (ICU). Peri-procedure and post-procedure complications were prospectively observed and evaluated. The success of weaning and the factors affecting the outcomes of these patients after PDT were also investigated.

Results: A total of 107 patients with mechanical ventilation were enrolled. The average duration of trans-laryngeal intubation was 27.8 $\pm$ 18.4 days which was longer than reported in previous studies. There were 70 men and 37 women, all of whom underwent bedside PDT at a medical ICU. The complication rates during and post-procedure were 8.4% and 14%, respectively. The most common complications were desaturation during the procedure and bleeding during the follow-up period. Only one death was procedure related (0.9%). After PDT, 50 patients (46.7%) were successfully weaned from mechanical ventilation. The rate of successful weaning (p = 0.02) increased while the days to achievement ($p < 0.001$) decreased with decreasing duration of trans-laryngeal intubation. Gender, age, body weight, Acute Physiology and Chronic Health Evaluation II (APACHE II) score, duration of procedure, endotracheal tube diameter and position, and history of self-extubation were not related to successful weaning.

Conclusions: PDT is a bedside procedure with relatively low complication and mortality rates when performed for patients on long-term mechanical ventilation in a medical ICU. The previous duration of trans-laryngeal intubation was an important determinant for successful weaning after PDT.

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Key words: percutaneous dilatational tracheostomy, long-term mechanical ventilation, successful weaning.

When critically ill patients develop acute respiratory failure, trans-laryngeal intubation is a necessary and life-saving procedure to connect the patient to the ventilator. Compared with trans-laryn-

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geal intubation,[1] tracheostomy offers several benefits, including a shorter length of the tracheostomy tube which has been associated with less airway resistance and improved patient comfort, more effective airway suctioning, enhanced patient mobility, increased opportunities for articulated speech, the ability to eat orally, a more secure airway, and most importantly, accelerated weaning from mechanical ventilation.[2,3] As such, tracheostomy has become the most commonly performed surgical procedure in critically ill patients requiring mechanical ventilation.[4,5]

Percutaneous dilatational tracheostomy (PDT) and surgical tracheostomy (ST) are the two major methods of tracheostomy. However, the preferred technique remains controversial. When comparing PDT with surgical tracheostomy, some researchers suggested the potential advantages of PDT, including ease of performance, lower incidence of peri-stromal bleeding and post-operative infection, convenience, and lower costs.[6,7] In addition, logistical problems of transporting critically ill patients to the operating room and searching for operating room availability are reduced.[8]

Modern PDT was first described by Ciaglia in 1985. An additional safety element that was added by Marelli *et al.* in 1990 was the use of fiberoptic bronchoscopy to visualize the tracheal puncture and cannulation.[9] Video bronchoscopic guidance may offer several advantages over blind PDT including enhanced safety and reduced risk of para-tracheal insertion or posterior tracheal wall tears.[10-12]

We conducted a prospective study to evaluate the peri-procedure and post-procedure complications of video bronchoscopy-guided PDT, which was performed in long-term mechanically-ventilated patients. The success of weaning and the factors affecting the outcomes of these patients after PDT were also investigated.

METHODS

Study population

This study was conducted in the 32-bed medical intensive care unit (ICU) of the Chang Gung Memorial Hospital, a university-affiliated teaching hospital in Kaohsiung, Taiwan. During a 14-month period (November 2003 through December 2004), 107 consecutive patients receiving PDT were enrolled. Patients with any of the following contraindications were excluded from the procedure: active infections over the proposed entry site, uncontrollable bleeding disorder, previous major surgery or gross anatomical distortion, or unstable cervical vertebrae. All of the patients had acute respiratory failure due to various medical causes and the emergency trans-laryngeal intubations were performed orally by residents either in the emergency room or the ward.

Soft, high-volume, low-pressure cuffed endotracheal tubes (ETT) (7-7.5 mm in internal diameter; Curity, TYCO Healthcare Group, Mansfield, Mass, USA) were used. The ventilators were either Evita 2 or 4 (Drager, Lubeck, Germany) or Puritan-Bennett 7200 (Carlsbad, Calif, USA). Elective PDT was considered for all of the patients who had difficulty being weaned from the ventilation and were expected to be on long-term mechanical ventilation.

Percutaneous dilatational tracheostomy

Using the Ciaglia technique,[13,14] video bronchoscopy-guided PDT utilizing a percutaneous tracheostomy introducer set (C-PTIS-100-HC, BLUE RHINO, COOK, USA) was performed by a team of three specialists. One physician was responsible for airway management, one performed the video bronchoscopy, and the other performed the actual tracheostomy. All of the patients were ventilated with 100% oxygen throughout the procedure and received adequate analog-sedation with a combination of midazolam (0.15-0.25 mg/kg) and fentanyl (2 μg/kg). To avoid the cough reflex, neuromuscular relaxation was facilitated with rocuronium (0.6 mg/kg).

A flexible video bronchoscopy unit (P260F, Olympus, Tokyo, Japan) equipped with a high definition monitor (OEV181H, Olympus, Tokyo, Japan) was used. Under direct bronchoscopic video imaging, the tip of the ETT was retracted just below the vocal cords. The proposed tracheostomy site was infiltrated with 2% lidocaine hydrochloride to provide additional analgesia. A 1.5 to 2.0 cm transverse midline incision was made between the first and second, or second and third, tracheal rings. After percutaneous needle puncture and one-time dilatation using the BLUE RHINO dilator, an 8-mm tracheostomy tube (Shiley, TYCO Healthcare Group, Pleasanton, Calif, USA) was placed over a 24 French lubricated dilator for tracheal insertion. At the end of

the procedure, video bronchoscopy was inserted through the tracheostomy tube to confirm tracheal placement prior to ventilation.

Data collection

On admission to the ICU and/or prior to tracheostomy, the following parameters were recorded: age, gender, body weight, indication for mechanical ventilation, duration of trans-laryngeal intubation, ETT diameter and position, Acute Physiology and Chronic Health Evaluation System II (APACHE II) score, mode of ventilation, fraction of inspired oxygen (FiO_2), and history of self-extubation. Subsequently, the procedure time (from skin incision to tracheostomy tube placement) and peri-procedural and late complications were evaluated. Post-procedural complications were observed until hospital discharge or death. The definition of significant bleeding is bleeding that required blood transfusion and the desaturation is saturation of oxygen (SaO_2) $<$ 90% according to the pulse oximeter. Tracheostomy wound infection was defined as erythematous skin combined with foul-smelling discharge without pneumonic lesion on chest radiography.

Weaning protocol

After the procedure, indications to start weaning included the reversal or improvement of the indications for ventilation, $SaO_2 \geqq 90\%$, $FiO_2 \leqq 35\%$ and positive end-expiratory pressure $\leqq 5$ cmH_2O, intact ventilatory drive, stable hemodynamic status, normal vital signs, and electrolytes within reference ranges. The weaning process was begun with synchronized intermittent mandatory ventilation, pressure supports with continuous positive airway pressure and a T-piece only, without mechanical ventilator. We defined successful weaning as weaning from mechanical ventilator for more than 72 hours.

Statistical analysis

Results were expressed as numerical values and percentages for categorical variables and as mean $\pm$ SD for continuous variables. Continuous variables were compared using an independent *t*-test. Categorical variables were compared using the Fisher exact test and the χ^2 test. Pearson bivariate correlation test analyzed the correlation between the intubation period and the weaning time. Stepwise multiple logistic regression was used to evaluate the relationship between the recorded data and weaning of successful groups adjusting for potential confounding factors. All of the statistical tests were two-tailed, and a $p < 0.05$ was considered significant.

RESULTS

A total of 107 mechanically-ventilated patients received elective tracheostomy in the 32-bed medical intensive care unit. The mean duration of trans-laryngeal intubation was 27.8 $\pm$ 18.4 days (range: 3-97 days). The mean of intubation period was longer than that reported in a previous study. There were 70 men and 37 women with a mean age of 71 $\pm$ 13.5 years (range: 19-95 years). The mean body weight was 55.9 $\pm$ 12.4 kg. Indications for mechanical ventilation were classified into pneumonia in 52 patients (48.6%), chronic obstructive pulmonary disease in 11 (10.3%), malignancy in 11 (10.3%), cardiogenic pulmonary edema in 10 (9.3%), neurologic causes in 10 (9.3%), cardio-respiratory arrest in six (5.6%), sepsis in three (2.8%), upper airway obstruction in three (2.8%), and intoxication in one (0.9%).

The patient's average APACHE II scores were 23.6 $\pm$ 6.7 (range: 7-45). We used 7.5 mm ETT in 90 patients (85.1%). The position of the trans-laryngeal intubation was on average 21.5 $\pm$ 1.3 cm (range: 18-25 cm) from the incisors. Previously established average FiO_2 before PDT was 35.3 $\pm$ 6.3% (range: 25-60%). A total of 71 patients (66.4%) used the assist-control mode of ventilation. There were 13 patients (12.1%) with a history of self-extubation. The demographics of these patients are summarized in Table 1.

The average duration of the PDT was 5.4 $\pm$ 4.0 min (range: 1-22 min). Complications developed in nine patients during the procedure and in 15 patients during the follow-up period (34.4 $\pm$ 23.3 days). The overall complication rates were 8.4% and 14% for during and post-operation, respectively. Desaturation was the most common complication during the procedure, occurring in four patients (3.7%), while bleeding was the most common post-procedural complication, occurring in nine patients (8.4%). Only one death (0.9%) was considered to be related to this procedure during the follow-up period (Tables 2 and 3).

After PDT, 50 patients (46.7%) achieved successful weaning. The average duration for the attain-

Table 1. Patient Demographics

Characteristic		Total (n = 107)	Weaning successful	Weaning failure	Univariate analysis *p*	Multivariate analysis *p*	Odds Ratio (95% CI)
Gender	Male	70 (65.4%)	31	39	0.49	0.98	0.984
	Female	37 (34.6%)	19	18			(0.338-2.863)
Age (years)		71.4 ± 13.5	69.7 ± 13.2	73.0 ± 13.7	0.20	0.40	1.014
							(0.982-1.047)
Body weight (kg)		55.9 ± 12.4	55.9 ± 12.4	55.9 ± 12.4	0.99	0.86	1.003
							(0.967-1.041)
APACH II score		23.6 ± 6.7	23.0 ± 5.9	24.0 ± 7.4	0.45	0.35	1.033
							(0.965-1.107)
Intubation period		27.8 ± 18.4	23.0 ± 15.6	31.2 ± 19.8	0.02	0.03	1.032
							(1.002-1.062)
ETT ID	6.50	1 (0.9%)	1	0	0.24	0.14	2.557
	7.00	16 (45.0%)	5	11			(0.742-8.809)
	7.50	90 (84.1%)	44	46			
ETT position		21.5 ± 1.3	21.4	21.6	0.54	0.77	1.062
							(0.715-1.578)
Self-extubation	Yes	13 (12.1%)	3	10	0.07	0.10	3.803
	No	94 (87.9%)	47	47			(0.789-18.319)
FiO_2 %		35.3 ± 6.3	34.2 ± 5.6	36.3 ± 6.7	0.08	0.17	1.052
							(0.979-1.130)
Ventilator mode	A/C	71 (66.4%)	30	41	0.19	0.10	2.332
	Non-A/C	36 (13.6%)	20	16			(0.860-6.322)
Underlying disease	Pneumonia	52 (48.6%)	21	31	0.20	0.43	0.700
							(0.288-1.703)
	Non pneumonia	55 (51.4%)	29	26			
Complication*	Complication	23 (21.5%)	11	12	0.91	0.94	0.960
	No complication	84 (78.5%)	39	45			(0.309-2.983)

Abbreviations: A/C: assist-control; APACHE: Acute Physiology and Chronic Health; CI: confidence interval; Evaluation; ETT: endotracheal tube; FiO_2: fraction of inspired oxygen; ID: internal diameter.
* Procedure-related complication.

Table 2. Complications of Percutaneous Dilatation Tracheostomy during the Procedure

	N	%
No complications	98	91.6%
Significant bleeding	2	1.9%
Desaturation	4	3.7%
Shock	1	0.9%
Significant bleeding and desaturation	1	0.9%
Desaturation and shock	1	0.9%

Table 3. Complications of Percutaneous Dilatation Tracheostomy after the Procedure

	N	%
No complications	92	86.0%
Significant bleeding	9	8.4%
Subcutaneous emphysema	2	1.9%
Pneumothorax	1	0.9%
Infection	1	0.9%
Subcutaneous emphysema and Pneumothorax	1	0.9%
Death related to procedure	1	0.9%

ment of successful weaning was 9.0 ± 8.7 days (range: 0-35 days). There were 38 patients (35.5%) that needed ventilatory support and 36 patients that did not, at the time of discharge. The remaining 33 patients (30.8%) had died during hospitalization.

Successful weaning rates increased with decreased duration of trans-laryngeal intubation (23.0 versus 31.2 days $p = 0.02$) (Fig. 1). In addition, a positive correlation existed between the duration of trans-laryngeal intubation and the time needed for successful weaning (r = 0.49; 95% confidence interval, 0.25-0.68; $p < 0.001$) (Fig. 2). Neither univariate

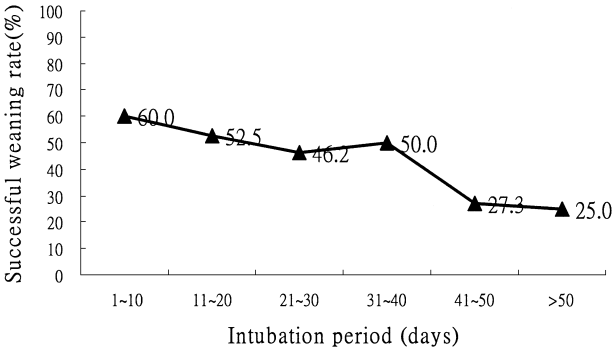

Fig. 1 Relationship of successful weaning rates and duration of intubation.

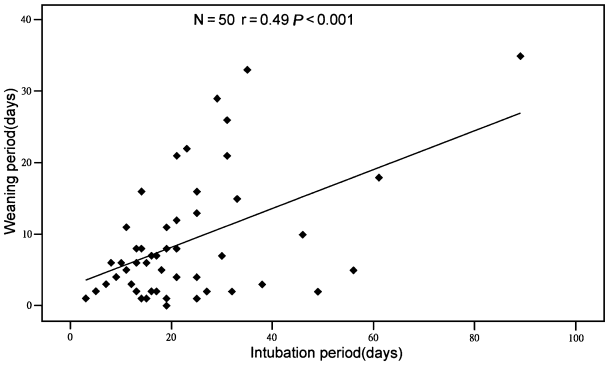

Fig. 2 Correlation of the intubation period and the weaning period.

analysis nor multivariate analysis, gender, age, body weight, APACHE II score, duration of procedure, ETT diameter and position, FiO_2, history of self-extubation, procedure-related complications, and underlying disease were related to successful weaning. The *p* values of multivariate analysis are showed on Table 1.

DISCUSSION

As use of PDT increased, several complications were reported, including barotrauma (pneumothorax, mediastinal emphysema, and subcutaneous emphysema), tracheo-esophageal fistula, and para-tracheal insertion, which were not common in ST.[15-17] Other researchers reported major complications after PDT, including difficulty of dilatation, excessive bleeding, false passage of the tracheal cannula, and death.[18] Compared with ST, the incidence of peri-operative complications of PDT was higher.[17] However, Hazard *et al.* reported the results of a study that randomly selected 46 mechanically-ventilated patients with respiratory failure who underwent either conventional ST or PDT.[19] Hemorrhage, infection, and pneumothorax were the most common early adverse events in both groups. These complications were significantly more common among patients who underwent STs (45.8%), as opposed to patients who underwent PDT (12.5%). Khalili *et al.* compared data on the safety and complications in 94 patients who underwent PDT and 252 patients who underwent ST.[20] PDT and ST had similar complication rates: 2.1% for PDT versus 2.8% for ST. Post-operative bleeding was the most frequent complication.

The mean intubation period of our patients was 27.8 days which is longer than that reported in a previous study. In this long-term mechanical ventilation group, nine patients (8.4%) had peri-procedural complications. The most common complication was desaturation, followed by bleeding. All conditions of desaturation were resolved after pulling out the video bronchoscope from the ETT. We thought that introducing the bronchoscope intermittently (only during certain critical stages of the procedure), by using a small-diameter bronchoscope, and by avoiding continuous suction through the bronchoscope, would decrease all of the reversible complications.

The post-procedure complication rate during the follow-up period (34.4 ± 23.3 days) was 14%. Significant bleeding requiring blood transfusion was the most frequent (8.4%) complication. Other complications were subcutaneous emphysema (1.9%) and pneumothorax (0.9%). One patient (0.9%) had both complications. Speculating on the two patients who suffered from subcutaneous emphysema, tracheal lacerations were excluded according to the follow-up bronchoscopy. After changing to a tracheostomy tube with a smaller diameter (6 mm), the symptoms resolved immediately. We suspected that this complication was due to an outer skin wound that was tighter than the inner tracheal wound, resulting in air from the ventilator to pass through the subcutaneous tissue. Slight over-dilatation using the BLUE RHINO dilator improved this condition.

In an overview of the peri-procedure and post-procedure complications, bleeding was still the most frequent adverse complication when the reversible desaturation was excluded. This result is same as

most of those reported previously. Only one patient (0.9%) died due to uncontrolled massive bleeding from the tracheostomy wound during the follow-up period. Erosion of the innominate artery was the most likely cause. In general, these complications were not related to weaning. Long-term complications after hospital discharge, such as subglottic/tracheal stenosis after decannulation, need follow-up using video bronchoscopy in the future.

The ideal time of tracheostomy remains unanswered. Most physicians perform tracheostomy at about 10 to 14 days. Recent studies found that an intubation period of more than 21 days was associated with prolonged weaning period, weaning failure, and prolonged ICU stay.[21] The results of another study showed that early tracheotomy (≦ 10 days) in critically ill medical patients may have significant benefits over delayed tracheotomy (≥ 14 days).[22,23] These include reduction in mortality rate, lower hospital costs, and decreased duration of mechanical ventilation and ICU stay. However, the mean intubation period of the above studies was not longer than 20 days (10.3 to 18.5 days).

Due to the medical policy, as well as a general fear of undergoing surgery, which exists in Taiwanese society, the period of trans-laryngeal intubation in our patients was longer (27.8 ± 18.4 days). In our study patients on long-term mechanical ventilation, decreasing the duration of trans-laryngeal intubation correlated with an increased rate of successful weaning. Performing PDT earlier shorten the time needed to achieve successful weaning. Gender, age, APACHE II score, and underlying disease were not related to weaning success. Our results were the same as those reported in a recent study.[21] We also found that body weight, duration of procedure, ETT diameter and position, FiO_2 and history of self-extubation or procedure-related complications were not related.

Performing PDT for prolonged trans-laryngeal intubated patients in the medical ICU was preferred because of lower complication and mortality rates. In patients on long-term mechanical ventilation, the shorter duration of trans-laryngeal intubation played an important role in determining the success of weaning. Hence, relatively early tracheostomy is recommended in patients on long-term mechanical ventilation.

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長期使用呼吸器的病人接受支氣管鏡導引經皮擴張氣切術後成功脫離呼吸器

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背 景： 觀察並探討長期使用呼吸器的病人於接受經皮擴張氣切術後的結果。

方 法： 內科加護病房中長期使用呼吸器的病人，在接受以支氣管鏡導引的經皮擴張氣切術後，對於術中及術後併發症和影響脫離呼吸器的因子做前瞻性的觀察與探討。

結 果： 14 個月的期間，共 107 個使用和呼吸器的病人，平均爲 27.8 ± 18.4 天。這樣長時間的使用氣管內管是比以往的文獻的平均天數都要來的長。經皮擴張氣切術所造成的併發症機率很低，而且這些併發症都可以適當的來預防和處理。影響脫離呼吸器及所用的時間主要和氣管內管的使用時間有關。年齡，體重，性別和其它因子則和脫離呼吸器無關。

結 論： 經皮擴張氣切術在長期使用氣管內管和呼吸器的病人是安全的。面對長期使用呼吸器的病人，較早施行氣切術仍有助於早一點脫離呼吸器。

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關鍵字： 經皮擴張氣切術，長期使用呼吸器，成功脫離呼吸器。

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