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Brief communication (Original)

Successful weaning of adult patients with respiratory failure from mechanical ventilators using an L-piece

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Background: There are many methods for weaning patients from mechanical ventilation. Using either a T-piece or CPAP are effective for weaning. Weaning using an L-piece is a strategy similar to using a T-piece, but uses less oxygen flow with air and has less dead space than a T-piece.
Objective: To determine whether adult patients with respiratory failure can be successfully weaned from a ventilator using an L-piece, including a study of factors that may affect the success or failure of weaning.
Method: Retrospective review of the medical records of a cohort of patients who had respiratory failure and were admitted to Wetchakarunrasm Hospital between January 1st, 2012 and September 30th, 2015.
Result: We found 143 cases matched the inclusion criteria. There was a 95.1% success in weaning adult patients with respiratory failure from a ventilator by using an L-piece. No vital signs before weaning and during L-piece weaning were significantly different, except for respiratory rate, which was 1.4 times/min (7.7%, $P < 0.001$) higher using the L-piece than before weaning. The success of weaning a group using oxygen flow at 1-3 L/min was 92.2% and a group using oxygen flow at 4-6 L/min was 96.7%. There was no significant difference in the success rate between these groups ($P = 0.25$).
Conclusion: Weaning patients from mechanical ventilators using an L-piece is safe and has a success of 95.1%. This method of weaning can save oxygen use by reducing the flow of oxygen, which may be beneficial in patients with chronic obstructive pulmonary disease.

Keywords: Extubation, failed weaning, L-piece, respiratory failure, successful weaning, ventilator

Weaning from mechanical ventilation is important for patients with respiratory failure. There are many methods for weaning such patients from ventilation. One of the most effective methods is to use spontaneous breathing trials (SBT), which include pressure support and a T-piece. Many researchers consider the most effective way of weaning by SBT is by using continuous positive-airway pressure (CPAP) and a T-piece (T-tube) [1-4]. Both methods are effective for weaning the patients [5-13].

Respiratory physiology for $PaCO_2$ shows that:

$$PaCO_2 \alpha \frac{KVCO2}{VA}; \quad Va = RR \times (Vt–Vd)$$

$$PaCO_2 \alpha \frac{KVCO2}{RR \times (Vt–Vd)},$$

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where:
$PaCO_2$ = The arterial partial pressure of carbon dioxide
K = Constant (0.863)
$V \cdot CO_2$ = CO2 production
VA = Alveolar minute ventilation
RR = Respiratory rate
Vt = Tidal volume
Vd = Dead space volume

The equation shows that $PaCO_2$ is increased when:
1. Respiratory rate has decreased.
2. Tidal volume has decreased.
3. Dead space has increased.

The aim of the present study was to investigate weaning from a mechanical ventilator using an L-piece, which is almost identical to using a T-piece, but has no reservoir tube, as shown in **Figure 1**.

An L-piece should have less dead space than a T-piece. An L-piece can use less oxygen flow than a T-piece, typically 1–2 L/min because of the absence of a reservoir tube. However, a T-piece needs an oxygen flow of 6–10 L/min to washout exhaled carbon

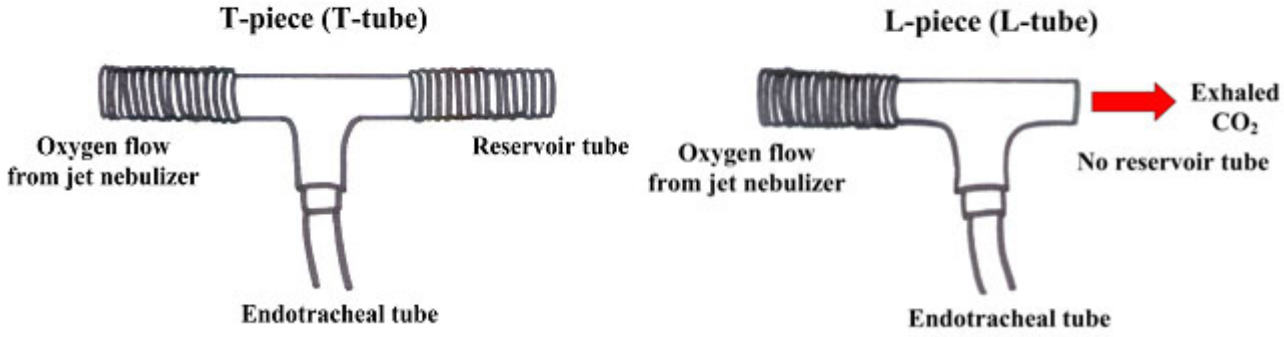

Figure 1. A comparison of the T-piece and an L-piece

dioxide from the reservoir tube. The L-piece also uses less oxygen concentration than patient inspired oxygen from the L-piece because of the mixed air condition. This mixed air condition may benefit patients with chronic obstructive pulmonary disease (COPD) who are prone to carbon dioxide retention from high oxygen concentration.

Many hospitals use jet nebulizers, in which the oxygen concentration (fraction of inspired oxygen, FiO_2) cannot be adjusted, and this may be a problem for patients with COPD and chronic carbon dioxide retention; the T-piece contains a high oxygen concentration (FiO_2 = 100%) from the breathing circuit and oxygen flow cannot be decreased to 1–3 L/min because the reservoir tube needs at least 6–10 L/min to washout expired carbon dioxide [14]. This group of patients are prone to carbon dioxide retention because their hypoxic drive is shut down by the very high oxygen concentration [15, 16]. Wetchakarunrasm hospital has been using an L-piece for weaning patients with respiratory failure from mechanical ventilation since 2007. We sought to determine the rate of successful weaning adult patients with respiratory failure from mechanical ventilation using an L-piece.

Materials and methods

This study approved by the Ethics Committee for Human Research of Bangkok Metropolitan Hospital Administration (Protocol code number S001h/59). The present study is a retrospective study of medical records of patients who had respiratory failure and were admitted to Wetchakarunrasm Hospital between January 1st, 2012 and September 30th, 2015.

Population

The sample size was calculated from:

$$n = \frac{(Z\alpha/2)^2 PQ}{d^2}$$

α = 0.05, $Z\alpha/2$ = 1.96, d = 0.05, P = 0.913

n = 122 cases

Calculated for 10% dropout rate (because of incomplete data) = 136 cases

The inclusion criteria were: patients aged 18–80 years; intubated with mechanical ventilation for at least 2 days, and treated with FiO_2 ≤0.4 before the time of weaning. Exclusion criteria included acute myocardial infarction waiting for primary coronary intervention; patients with respiratory failure awaiting tracheostomy; patients with end stage disease, or patients with end stage cancer receiving palliative or end-of-life care.

Data collection

Data collected included: demographic data, diagnosis, underlying diseases, days on ventilator support, success or failure of weaning and indication for ventilator support, which was divided into 6 groups according to criteria defined by Demoule et al. [17]. Group I, acute or chronic lung disease (i.e., COPD, asthma, obstructive sleep apnea syndrome); Group II, de novo acute renal failure (ARF) (i.e., pneumonia [PNA] and acute lung injury/acute respiratory distress syndrome (ARDS); Group III, chronic pulmonary emphysema (CPE); group IV, ARF associated with neurologic diseases; Group V, cardiopulmonary arrest; and Group VI, others (i.e., postoperative, massive trauma, burns, sepsis, and other cardiac problems).

Interventions

All of the patients in this study had used an L-piece for weaning at least 60 min before extubation. During weaning, their oxygen saturation was monitored by using pulse oximetry and had to be at least 90% before weaning and disconnection from the ventilator. Vital signs, FiO_2 setting, minute ventilation, and rapid

shallow breathing index (RSBI) were monitored during ventilator support and recorded for comparison before and after using an L-piece.

The need for informed consent from participants was specifically waived by the Ethics Committee because this was a retrospective study and there is no need to disclose any information that might identify specific patients. No names or identification number allowing any trace of patient identity was used in this study ensuring their complete anonymity and no harm to any patient was considered to result from this study.

No specific informed consent for weaning patients from mechanical ventilation by any method, such as weaning by CPAP, T-piece, or L-piece, was previously obtained because in our hospital we use the same weaning protocol to monitor vital signs and other parameters to guarantee the safety of the patients to protect them from hypoxemia or from carbon dioxide retention (the L-piece method is similar to the T-piece method, but has less dead space, which is theoretically an advantage in the weaning because less carbon dioxide is retained. The only matter of concern during using an L-piece is a lower oxygen concentration from low oxygen flow, but patient safety can be ensured by keeping their oxygen saturation more than 90% during the weaning).

Primary outcome of the present study was successful weaning using an L-piece. The secondary outcome was identification of factors that may affect the success or failure of weaning. Successful weaning refers to no death or no reintubation within 72 h of extubation. Failed weaning refers to death or reintubation within 72 h of extubation.

Statistical analysis

All the data were analyzed using Stata software (version 13; StataCorp, College Station, TX, USA). Prevalence was calculated as a percentage. Secondary outcomes, such as age group, duration of intubation, were analyzed using a Fisher exact test.

Results

Some 581 patients were intubated between January 1st, 2012 and September 30th, 2015; 148 cases met the inclusion criteria and of these 143 had a completed medical record for analysis (96.6%).

Table 1. Number of adult patients with respiratory failure successful weaned using an L-piece in each year

Year	Ventilator cases	L-piece (n)	Percent using L-piece	Sex		Success	Failure	Success rate
				Male	Female			
2012	152	34	22.4%	16	18	32	2	94.1%
2013	155	43	27.7%	23	20	41	2	95.4%
2014	173	39	22.5%	30	9	38	1	97.4%
2015	101	27	26.7%	19	8	25	2	92.6%
Total	581	143	24.9%	88	55	136	7	95.1%

Table 1 shows the success rate was 95.1% from a total of 143 cases, and success rate in each year was between 92.6% and 97.4%.

Table 2. Comparison of vital signs of the patients during ventilator support and during weaning by using a L-piece

Vital signs	*Success group* (n = 136)			*Failure group* (n = 7)			*Total* (n = 143)		
	Mean	SD	*P*	Mean	SD	*P*	Mean	SD	*P*
Respiratory rate									
On ventilator support	18.2	3.8		19.4	6.0		18.3	3.8	
On L-piece	19.6	3.8	<0.001*	23.7	2.9	0.107ns	19.8	3.9	<0.001*
Mean blood pressure (mmHg)									
On ventilator support	94.0	12.8		93.7	10.8		94.0	12.6	
On L-piece	95.8	12.0	0.044*	88.0	15.6	0.091ns	95.4	12.3	0.099ns
Heart rate (bpm)									
On ventilator support	86.3	15.0		86.7	9.8		86.4	14.8	
On L-piece	87.1	14.8	0.452ns	97.6	23.6	0.173ns	87.6	15.3	0.22ns
Temperature (°C)									
On ventilator support	37.0	0.7		37.1	0.7		37.1	0.7	
On L-piece	36.9	0.5	0.035*	37.2	0.9	0.553ns	37.0	0.5	0.056ns
Oxygen saturation									
On ventilator support	98.5	2.2		99.9	0.4		98.5	2.2	
On L-piece	98.5	2.6	0.93ns	98.7	2.0	0.11ns	98.5	2.5	0.81ns

ns = not significant *$P < 0.01$

Table 2 shows that there was a significant change in respiratory rate between patients on ventilator support and during weaning using an L-piece; using an L-piece produced a higher respiratory rate in both the successfully weaned group (1.5 per minute, 8.2%, $P < 0.001$) and in all patients (1.4 per minute, 7.7%, $P < 0.001$).

Among successfully weaned patients, mean arterial blood pressure was 1.8 mmHg higher in those who were weaned using an L-piece than those on ventilator support.

Body temperature was 0.1 °C lower in patients who were weaned using an L-piece than those on ventilator support ($P = 0.035$). While other vital signs were significantly different between the 3 groups.

Table 3. Relation of factors between success and failure group

Factors (n =143)	Success group (n = 136)		Failure group (n = 7)		Odds ratio	95% CI	*P*
	Cases	Percentage	Cases	Percentage			
A. Age group (years old)							
18–40	9[b]	100.0	0	0.0	–	–	1.0000ns
41–60	50[a]	96.2	2	3.8	1		
61–80	77[a]	93.9	5	6.1	0.6	0.1–4.0	0.5682ns
B. Cigarettes							
Active smoker	29[a]	96.7	1	3.3	1		
Nonsmoker	71[a]	94.7	4	5.3	0.6	0.01–6.6	1.0000ns
Quit	36[a]	94.7	2	5.3	0.6	0.01–12.0	1.0000ns
C. Sex							
Male	86[a]	97.7	2	2.3	1		
Female	50[a]	90.9	5	9.1	0.2	0.02–1.5	0.1070ns
D. Duration of intubation							
2–4 days	69[a]	95.8	3	4.2	1		
5–7 days	38[a]	95.0	2	5	0.8	0.1–10.3	1.0000ns
8–10 days	16[c]	100.0	0	0.0	–	–	1.0000ns
11–14 days	5[a]	71.4	2	28.6	0.1	0.01–1.7	0.06ns
>14 days	8[c]	100.0	0	0.0	–	–	1.0000ns

Table 3. (Con) Relation of factors between success and failure group

Factors (n =143)	Success group (n = 136)		Failure group (n = 7)		Odds ratio	95% CI	*P*
	Cases	Percentage	Cases	Percentage			
E. Reason for ventilator support							
Acute on top of chronic respiratory disease	27[e]	100.0	0	0.0	–	–	1.000[ns]
New respiratory disease	25[a]	92.6	2	7.4	1		
Congestive heart failure	41[a]	97.6	1	2.4	3.3	0.2–198	0.556[ns]
Neuromuscular disease	0	0.0	0	0.0	–	–	–
Cardiopulmonary arrest	13[f]	100.0	0	0.0	–	–	>0.99[ns]
Other	30[a]	88.2	4	11.8	0.6	0.1–4.6	0.685[ns]
F. Oxygen flow during weaning							
1–3 L/min	47[a]	92.2	4	7.8	1		
4–6 L/min	89[a]	96.7	3	3.3	2.5	0.4–17.8	0.248[ns]
G. Rapid shallow breathing index during ventilator support							
<40 years old	64[a]	92.8	5	7.2	1		
41–60 years old	60[a]	98.4	1	1.6	4.7	0.5, 225.3	0.213[ns]
61–80 years old	11[g]	100.0	0	0.0	–	–	1.000[ns]
>80 years old	1[a]	50.0	1	50.0	0.1	0.001, 7.4	0.163[ns]
H. MV during ventilator support							
4.0–6.0 L/min	12	100.0	0	0.0	–	–	1.000[ns]
6.1–8.0 L/min	43[a]	91.5	4	8.5	1		
8.1–10.0 L/min	54[a]	96.4	2	3.6	2.5	0.3, 28.7	0.408[ns]
>10 L/min	27[a]	96.4	1	3.6	2.5	0.2, 128.2	0.645[ns]
I. Oxygen Saturation during weaning							
90–92%	7	100.0	0	0.0	–	–	1.000[ns]
93–95%	12[a]	92.3	1	7.7	1		
96–98%	27[a]	96.4	1	3.6	2.3	0.03, 183.0	0.539[ns]
99–100%	90[a]	94.7	5	5.3	1.5	0.03, 15.1	0.546[ns]

a = Fisher's exact test, ns = not significant.
b = No significant difference between ages 18–40 and 41–60 years, or between ages 18–40 and 61–80 years
c = No significant difference between duration of intubation in 2–4 and 8–10 days, or 2–4 and >14 days.
e = No significant difference between acute on top chronic respiratory disease group and other groups.
f = No significant difference between cardiopulmonary arrest group and other groups.
g = No significant difference between rapid shallow breathing index during ventilator support between the 61–80-year-old age group and other age groups.

Table 3 shows that there was no significant difference in any factor that may affect the success rate of weaning using an L-piece. For example, the reasons for ventilator support, oxygen flow during weaning by using an L-piece also had no apparent effect on the outcome.

Table 4. Data of all failure cases

Case	Sex	Age (y)	Duration of intubation (days)	Reason for intubation	Reintubation time	Reason for reintubation	Final result
1	F	79	2	Others	<24 h	Vocal cord edema	Weaning L-piece; success, discharged
2	M	68	6	Congestive heart failure	<24 h	Pulmonary edema	Weaning L-piece; success, discharged
3	F	45	14	Others	36 h	Secretion obstruction	Weaning L-piece; success, discharged
4	F	74	11	New respiratory disease	<24 h	Secretion obstruction	Tracheostomy, discharged
5	F	55	3	Others	<24 h	Alteration of consciousness	Self extubation, discharged
6	F	62	5	Others	<24 h	Vocal cord edema	Weaning L-piece; success, discharged
7	M	78	2	New respiratory disease	<24 h	Secretion obstruction	Tracheostomy, discharged

Table 4, shows the 7 cases of weaning failure when using an L-piece. The causes of reintubation were vocal cord edema (2 cases), secretion obstruction (3 cases), pulmonary edema (1 case) and alteration of consciousness (1 case). There were 4 of 7 patients for whom an L-piece was used for weaning and had successful extubation; while 2 patients underwent tracheostomy, and 1 patient self-extubated. All 7 patients were discharged from the hospital without any incidence of mortality.

Discussion

The present study shows that using L-piece for weaning patients with respiratory failure has a success rate of about 95.1%, which is higher than that published elsewhere (success rate about 63–71%) [18, 19]. An L-piece has less dead space than a T-piece and patients with COPD may have less carbon dioxide retention under mixed air conditions with an L-piece. Hypoxic drive may also be triggered in patients with COPD causing them to breathe at a higher rate. Wetchakarunrasm Hospital is a secondary level healthcare facility, without a medical school, not a tertiary level hospital. Secondary level hospitals in Thailand receive fewer patients with severe ARDS into their intensive care units.

There was no significant difference in success rate between any group of patients. One of the most important reasons for this was the inclusion criterion that only patients who had $FiO_2 \leq 0.4$ were included. This means that the severity of the condition of these patients may have been less than patients who had an oxygen $FiO_2 > 0.4$, and may have had more a severe lung pathology than this group.

The present study study also shows that we can use a lower oxygen flow with an L-piece than with a T-piece during weaning. Because of the reduced dead space, we can use just 1–2 L/min of oxygen flow in weaning patients using an L-piece without concern that carbon dioxide retention may occur.

The factors studied here, such as sex, age group, duration of intubation, reason for intubation, oxygen flow using an L-piece, RSBI during ventilator support, minute ventilation during ventilator support, oxygen saturation when using an L-piece, do not affect the outcome as long as we maintain oxygen saturation above 90%.

A limitation of this study is its retrospective nature. Therefore, some of the information may not be complete, such as arterial blood gas, end-tidal CO_2 during weaning, minute ventilation during normal breath through endotracheal tube, and RSBI while the patient is breathing through the L-piece.

Further study with a prospective trial to compare other parameters, such as arterial blood gas, pH, or end-tidal CO_2 during weaning using an L-piece and

T-piece is warranted. Patients with COPD who are weaned using an L-piece with low oxygen flow to maintain their oxygen saturation about 90%–92%, may be more successfully weaned than patients using a T-piece with a jet nebulizer. This method cannot change FiO_2 (an L-piece may decrease the risk of shutting down hypoxic drive in patients with COPD). In future, the use of an L-piece may replace the T-piece when weaning patients with COPD from mechanical ventilation.

In conclusion, we consider that weaning patients from mechanical ventilation using an L-piece is safe and has a success rate of 95.1%. There was a slight increase in respiratory rate when using an L-piece for weaning compared with the respiratory rate during ventilation. When using an L-piece we can use less oxygen flow as long as we maintain the patients' oxygen saturation above 90%, This may save 20%–80% oxygen during weaning. If we use a T-piece with oxygen flow at 8 L/min and change to an L-piece at 2 L/min, we can save 6 L/min of oxygen, which is 75% of oxygen throughout the weaning period.

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Conflict of interest statement

The author declares that there is no conflict of interest in this research.

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