ORIGINAL RESEARCH **PERIOPERATIVE MEDICINE**

The outcomes and predictors associated with prolonged weaning of postoperative patients requiring mechanical ventilation in general wards

Asamaporn Puetpaiboon, Sunisa Chatmongkolchart ✉, Maliwan Oofuvong ✉

Author affiliation:

Department of Anesthesiology, Faculty of Medicine, Prince of Songkla University, Hat Yai, Songkhla, 90110, Thailand.

Correspondence: Asamaporn Puetpaiboon, MD; E-mail :asmaporn.p@psu.ac.th; tuptim_jung@hotmail.com

Abstract

Background & Objective: Many of the postoperative patients may require ventilatory management. In a resource-limited country, not all of them may find a place in intensive care units (ICUs), and may need to be ventilated in general wards till they are weaned off or shifted to ICU. Our primary objective was to describe weaning outcomes of such patients in the general wards, and the secondary objective was to assess predictors associated with prolonged weaning in these patients.

Methodology: This retrospective study was conducted in a tertiary care hospital in Thailand. From January 2014 to December 2019, we identified 553 patients who received postoperative mechanical ventilation in general wards after non-cardiac surgeries. The weaning characteristics and the factors associated with prolonged ventilation and weaning were recorded.

Results: Incidence of short (≤ 24 h), difficult (> 1, but ≤ 7 days), prolonged (> 7 days) and no weaning were 53.0%, 28.6%, 15.0% and 3.4%, respectively. The predictors of prolonged weaning were postoperative Glasgow Coma Scale ≤ 8 [adjusted odds ratio (OR) 11.34, 95% confidence interval (CI) 5.05-25.47], repeated surgeries (OR 7.38, 95% CI 3.67-14.83), totally dependent functional status (OR 3.22, 95% CI 1.35-7.72), and age more than 65 y (OR 2.35 95% CI 1.29-4.25). Reintubation rate was 5.1%. Accidental extubation rate was 2.3%. Incidence of ventilator associated pneumonia was 11.6%. The 30-day mortality rate was 6%.

Conclusion: Weaning processes in general wards were mostly terminated within 24 h; however, 15% of patients experienced prolonged weaning. Postoperative Glasgow Coma Scale ≤ 8, repeated surgeries, totally dependent functional status, and age more than 65 y were the predictors of prolonged weaning.

Key words: Mechanical ventilators, ventilator weaning, postoperative care, surgical ward

Abbreviations: ICU - Intensive care units; MV - Mechanical ventilation; PEEP - Positive end-expiratory pressure

Citation: Puetpaiboon A, Chatmongkolchart S, Oofuvong M. The outcomes and predictors associated with prolonged weaning of postoperative patients requiring mechanical ventilation in general wards. Anaesth. pain intensive care 2022;26(2):161-167; **DOI:** 10.35975/apic.v26i2.1832

Received: October 24, 2020, **Reviewed:** January 19, 2022, **Accepted:** January 29, 2022,

1. Introduction

The improvements of anesthetic care and surgical techniques such as minimally invasive surgeries and endovascular stents have reduced the rate of postoperative mechanical ventilation (MV).[1] However, certain types of patients and surgeries frequently require ventilatory support in the immediate postoperative period.

The Society of Critical Care Medicine recommended admitting mechanically ventilated patients to the intensive care unit (ICU).[2] However, in Thailand, the number of patients that require intensive care treatment exceeds the number of ICU beds. Therefore, some immediate postoperative patients unavoidably receive

MV in general wards. Some patients are discharged from the ICU while the weaning processes have not been successful. Dealing with this situation, our respiratory care team has made an effort to expand our service from the surgical ICU to surgical-based general wards. Hospital guidelines for weaning and extubation have also been used in general ward settings.

Mechanically ventilated postoperative patients uncommonly required complex ventilatory management. Most of these patients received ventilatory support only one day.[3,4] However, 8-11% of planned surgical patients who underwent postoperative MV in the ICU encountered the prolonged weaning problem and the incidence was doubled to 14-22% for emergency surgeries.[3,4]

The 28-day or 30-day mortality rate of surgical patients admitted to the ICU ranged from 12-14%.[5,6] Compared to directly admitted patients, the mortality rate of surgical patients who were transferred from general wards to ICUs was significantly increased to 21%.[6]

We found few studies investigating outcomes of medical patients who received MV outside the ICU; the incidences of MV in medical general wards were 51-66%.[7,8] However, weaning outcomes of surgical patients who were ventilated outside the ICU have not been reported.

Our primary objective was to report weaning outcome of postoperative patients who were ventilated in general wards, which was categorized into: short, difficult, prolonged, and no weaning. The secondary objective was to assess predictors associated with prolonged weaning.

2. Methodology

A retrospective study, approved by the institutional ethics committee, was conducted in the 855-bed tertiary care teaching hospital in Thailand. It has a 12-bed surgical ICU and an 8-bed surgical respiratory care unit. There are ten surgical-based general wards: surgical, neurosurgical, trauma, orthopedic, obstetrics, gynecology, and otorhinolaryngology wards.

The data was collected from the hospital information system and respiratory care records between January, 2014 and December, 2019. We included adult patients (aged over 15 years) who required postoperative invasive MV (via endotracheal tube or tracheostomy tube), after non-cardiac surgery or radiological intervention under general anesthesia, and directly admitted to the general wards. The duration from the surgery to the first weaning attempt was not limited. We excluded mechanically ventilated patients who were transferred from the ICU, and who were admitted to the burn unit. For patients with multiple episodes of postoperative MV during admission, we used only the first episode.

Weaning outcomes were classified into 4 groups by the duration from the first separation attempt to a termination of the weaning process (by success or by death); within 24 h, more than 1 day, but less than 1 week, and more than 7 days were categorized into; short, difficult and prolonged weaning, respectively. Patients, who never showed any improvement were classified as ‘no weaning group’. Weaning success was defined as: extubation not requiring reinstitution of ventilator support (reintubation or non-invasive ventilation) within 48 h.[9] Accidental extubation included self-extubation and any cause of unplanned extubation.

After 48 h of MV, diagnosis of ventilator associated pneumonia was established if the patient had new or progressive radiographic pulmonary infiltration along with at least two of three clinical features (body temperature > 38°C, purulent sputum and white blood cell count ≥ 12,000 or < 4,000 /mm^3) and positive tracheal aspirate culture.[10]

Ventilator dependence was defined as ‘the need for more than 21 consecutive days of MV, for more than 6 h per day’.[11]

Premorbid functional status was classified as ‘independent’, if they did not require assistance from another person for any activities of daily living, and ‘partially dependent’ or ‘totally dependent’, if they required some or total assistance.[12] Postoperative Glasgow Coma Scale scores (verbal score = 1) was the highest score during a postoperative 24 h period. Postoperative shock was the need for a vasopressor or an inotrope (norepinephrine, dopamine or adrenaline), to maintain a mean arterial pressure of greater than 60 mm Hg within 48 h, postoperatively.

Box 1: Readiness for weaning criteria for non-cardiac surgical patients

1. Include all of the following;

- □ Improvement of the condition that led to MV initiation
- □ No neuromuscular blocking agent
- □ Systolic blood pressure 90-180 mmHg without vasopressor or with dopamine or dobutamine < 5 µg/kg/min
- □ Respiratory rate < 35 breath/min
- □ Minute ventilation 5 - 15 L/min
- □ $SpO_2 \geq 93\%$ or $PaO_2/FiO_2 \geq 150$, using $FiO_2 \leq 0.5$ and PEEP ≤ 8 cmH_2O
- □ Glasgow Coma Scale scores ≥ 8

2. Require at least two of the following;

- □ Body temperature ≤ 38.5° C
- □ No or light sedation
- □ Serum potassium ≥ 3.5 mmol/L
- □ Hemoglobin level ≥ 7 gm/dL

Care of mechanically ventilated patients in general wards is managed by the respiratory care team including intensive care physicians (residents and a supervisor), respiratory care nurses, and physiotherapists.

Hospital guidelines for weaning and extubation in postoperative patients were implemented. Daily assessment of readiness for weaning was conducted by the respiratory care nurses, following the hospital guideline for non-cardiac surgical patients (Box 1). Patients who fulfilled the criteria, underwent the weaning process as early as possible. The weaning modalities included; T-piece, pressure support ventilation, synchronized intermittent mandatory ventilation (SIMV) and a tracheostomy mask for tracheostomy patients.

The weaning process was discontinued if the patients had any sign of weaning failure for at least 5 min, including decreasing level of consciousness, increasing respiratory effort, paradoxical breathing, diaphoresis, > 20% changes of heart rate or blood pressure from the baseline, cardiac arrhythmia, respiratory rate > 35 breath/min and SpO_2 < 93%.

Successfully weaned patients were evaluated according to the readiness for extubation criteria, which included effective cough, no frequent tracheal suction (less than every 2 h), no plan for surgery within 24 h, and negative cuff leak test. The doctor made the final decision to extubate.

Table 1: Baseline characteristics of the study subjects

	Characteristics	Number (%)
Age (years)		59 (44, 57)
Gender :male		324 (58.6)
ASA Classification	I	1 (0.2)
	II	83 (15.0)
	III	425 (76.9)
	IV	44 (8.0)
Comorbidity*	Chronic obstructive pulmonary disease	23 (4.2)
	Asthma	16 (2.9)
	Pneumonia	10 (1.8)
	Coronary artery disease	14 (2.5)
	Chronic atrial fibrillation	18 (3.3)
	Congestive heart failure	11 (2)
	Renal failure (GFR < 15 ml/min/1.73 m^2)	19 (3.4)
	Advance stage cancer	39 (7.1)
	Mechanically ventilated before surgery	135 (24.4)
	Tracheostomy status	24 (4.3)
	Traumatic injury	146 (26.4)
	Surgical emergency	351 (63.5)
Site of operation	Brain	151 (27.3)
	Abdomen: laparotomy	95 (17.2)
	Abdomen: laparoscopy	21 (3.8)
	Thorax	59 (10.7)
	Extremities	101 (18.3)
	Spine	29 (5.2)
	Interventional neuroradiology	57 (10.3)
	Others	40 (7.2)
Multiple surgeries in the same episode of MV		66 (11.8)

Data are presented as n (%) or median (interquartile range)
**Data was non-mutually exclusive*
ASA = American Society of Anesthesiologists, GFR = glomerular filtration rate, ml = milliliter, m = meter

Data was analyzed by RStudio version 1.2.5003. Denominator of weaning success rate, postextubation non-invasive ventilation, reintubation, accidental extubation and tracheostomy during hospitalization was the number of patients ventilated via endotracheal tubes (n = 529). Denominator of incidence of ventilator associated pneumonia was the number of patients using ventilator support for more than 48 h (n = 207). Denominator of other variables was the number of total patients (n = 553). Excluding tracheostomy and no weaned patients (n = 511), factors related to prolonged weaning (prolonged vs. short and difficult weaning) were identified by univariate analysis. If the P < 0.2, the factors were included in the multivariate logistic regression analysis, using backward elimination approach. The criterion for statistical significance was a P < 0.05. Data were presented as mean and standard deviation, median and interquartile ranges, or number and percentage; as appropriate. Results of multivariate logistic regression analysis were reported as adjusted odds ratio (OR) and 95% confidence intervals (CI). The sample size was calculated based on the previously reported proportion of prolonged weaning among surgical patients admitted to the ICU, this being 0.12.[4] Using the estimation of an infinite population proportion formula at 95% CI and 3% margin of error; minimum 451 patients were required.

3. Results

In the course of five years, 553 patients qualified for the study. Baseline patient characteristics are presented in Table 1. Median age was 59 years. Most of the patients

Table 2: Outcomes of postoperative MV in general wards (n = 553)

Outcomes	Number (%)
Ventilator day (days)	2 (1, 5)
Weaning attempt started	
On postoperative day 0	53 (9.6)
On postoperative day 1	317 (57.3)
On postoperative day 2 or later	164 (29.7)
Never	19 (3.4)
Weaning outcome	
Short (<1 day)	293 (53.0)
Difficult (1-7 days)	158 (28.6)
Prolonged (>7 days)	83 (15.0)
No weaning	19 (3.4)
Weaning success*	423 (80.0)
Post-extubation non-invasive ventilation*	41 (7.8)
Reintubation*	27 (5.1)
Accidental extubation*	12 (2.3)
Ventilator-associated pneumonia†	24 (11.6)
Tracheostomy*	36 (6.8)
Ventilator dependence	28 (5.1)
Transfer to ICU or respiratory care unit while using MV	64 (11.6)
30-day mortality	33 (6.0)
Cause of death	
Intracranial lesion	10 (1.8)
Respiratory-related	9 (1.6)
Septic shock	4 (0.7)
Hemorrhagic shock	3 (0.5)
Others	7 (1.3)
Hospital discharge status	
Breath spontaneously	488 (88.2)
Hospital transfer with MV	9 (1.6)
Discharge against medical advice while receiving MV	11 (2.0)
Death	45 (8.1)
Hospital stay (days)	20 (12, 35)

Data are presented as number (%) or median (interquartile range)

** Denominator was the number of patients ventilated via endotracheal tube*

†Denominator was the number of patients required ventilator support for more than 48 h

(76.9%) were categorized as American Society of Anesthesiologists Physical Status Classification 3. Of

these patients, 135 (24.4%) received MV before their operations, and twenty-two (4.3%) were ventilated via tracheostomy. Sixty-four percent of surgical procedures were emergency operations. The sites of surgeries were brain 27.3%, extremities 18.3%, abdomen (laparotomy) 17.2%, thorax 10.7%, interventional neuroradiology 10.3%, spine 5.2%, laparoscopic abdomen 3.8% and others at 7.2%. Sixty-six patients (11.8%) underwent multiple surgeries during the same episode of MV.

Table 2 presents outcomes of postoperative MV in general wards. Median ventilator days were two days. Incidences of short, difficult, prolonged and no weaning were 53.0%, 28.6%, 15.0% and 3.4%, respectively. From the 529 patients, who were ventilated via endotracheal tube, the rate of successful weaning was 80.0%. Rate of tracheostomy was 6.8%. Incidence of reintubation, accidental extubation and ventilator-associated pneumonia were 5.1%, 2.3% and 11.6%, respectively. Ventilator dependence occurred in 5.1% of patients. After general ward admission, 11.6% were subsequently transferred to the ICU, or the respiratory care unit while receiving MV.

Overall 30-day mortality was 6.0%. Among the 33 deaths, nine (27.3%) were respiratory-related deaths including ventilator associated pneumonia, hypoxia, and upper airway obstruction. In-hospital mortality was 8.1%, whilst 2.0% were discharged against medical advice while receiving MV.

Subgroup analysis of 64 patients, who were initially admitted to general wards, and subsequently transferred to the ICU while using MV, found that the incidence of prolonged weaning increased from 15.0% to 42.2%. Weaning success decreased from 80.0% to 47.5%. The 30-day mortality rate was increased from 6.0% to 14.1%. Median hospital stay prolonged to 29 days.

We performed univariate analysis (Table 3) as well as multivariate logistic regression analysis (Table 4) to identify predictors of prolonged weaning. There were four significant variables associated with prolonged weaning, including postoperative Glasgow Coma Scale scores ≤8 (OR 11.34, 95% CI 5.05-25.47, $P < 0.001$), repeated surgery (OR 7.38, 95%CI 3.67-14.83, $P < 0.001$), totally dependent functional status (OR 3.22, 95% CI 1.35-7.72, P 0.02) and being elderly (> 65 years) (OR 2.35, 95%CI 1.29-4.25, P 0.01).

Table 3: Univariate analysis of factors associated with prolonged weaning (n = 511)

Factors	Short and difficult weaning N (%)	Prolonged weaning N (%)	P value
Age (y)			
15-65	288 (88.6)	37 (11.4)	0.01
> 65	147 (79.0)	39 (21.0)	
Functional status			
Independent	336 (88.2)	45 (11.8)	0.01
Partially dependent	64 (83.1)	13 (16.9)	
Totally dependent	28 (71.8)	11 (28.2)	
Traumatic patient	119 (86.9)	18 (13.1)	0.60
Type of operation			
Elective	163 (88.1)	22 (11.9)	0.20
Emergency	272 (83.4)	54 (16.6)	
Site of operation			
Brain	114 (83.2)	23 (16.8)	0.90
Abdomen :laparotomy	77 (83.7)	15 (16.3)	
Abdomen :laparoscopy	18 (94.7)	1 (5.3)	
Thoracic	47 (82.5)	10 (17.5)	
Extremities	48 (88.9)	6 (11.1)	
Spine	23 (82.1)	5 (17.9)	
Interventional neuroradiology	41 (83.7)	8 (16.3)	
Others	28 (84.8)	5 (15.2)	
Repeated surgeries in the same episode of MV			
Yes	36 (60)	24 (40)	< 0.001
No	399 (88.5)	52 (11.5)	
Postoperative GCS scores			
≤ 8	15 (38.5)	24 (61.5)	< 0.001
> 8	420 (89.0)	52 (11.0)	
Postoperative shock			
Yes	27 (71.1)	11 (28.9)	0.02
No	408 (86.3)	65 (13.7)	

4. Discussion

In our study, 53% of postoperative weaning processes in the general wards were simple and terminated within 24 h. The overall incidence of prolonged weaning was 15%. The incidences of prolonged weaning for elective and emergency surgeries were 11.9% and 16.6%, respectively. Although statistically insignificant, emergency surgery tended to increase prolonged weaning when compared to elective surgery. These numbers of prolonged weaning were close to previous reports in postoperative patients ventilated in the ICU, ranging from 8-11% for elective and 14-22% for emergency operations.[3,4]

We analyzed the predictors associated with prolonged weaning in these patients. Among sites of surgeries, there were no surgical sites that significantly increased the risk of prolonged weaning. However, the incidence of prolonged weaning in laparoscopic surgery was obviously low; e.g., 5.1%.

Totally dependent functional status was shown to predict prolonged weaning (OR 3.22, 95% CI 1.35-7.72). This was also shown for not only weaning difficulty, as Scarborough et al. reported that functionally dependent patients, who underwent major surgeries, had higher postoperative death and major morbidity than functionally independent patients.[12]

Repeated surgeries in the same episode of MV were associated with prolonged weaning (OR 7.38, 95% CI 3.67-4.83). This might be related to our hospital guideline which suggested to postpone extubation if there was a plan for surgery within the next 24 h. Another factor that should be further explored is the impact of cumulative positive fluid balance from multiple surgeries on the weaning outcome.

Patients with neurological impairment, who had the highest Glasgow Coma Scale scores ≤ 8 in 24 h postoperatively, were the strong candidates for prolonged weaning (OR 11.34, 95% CI 5.05-25.47). These patients remain intubated, as in a coma they loose the ability to maintain airway patency.[13] Early tracheostomy might be considered in neurologically injured patients especially who had potential for neurologic recovery in order to reduce mortality and the length of stay.[14]

Our results show that adverse events, related to MV care in general wards, were higher than previously reported in case of surgical ICUs. The incidence of accidental extubation was 2.3%. This was almost double compared to a report from multicenter surgical ICUs in Thailand, which was 1.2%.[5] Reintubation rate in our study was

Table 4: Multivariate logistic regression analysis of factors associated with prolonged weaning

Parameter	Crude odds ratio (95% CI)	Adjusted odds ratio (95% CI)	P value (LR test)
Age > 65 y	2.07 (1.24,3.46)	2.35 (1.29,4.25)	0.01
Functional status			
Partially dependent	1.52 (0.77,2.97)	2 (0.93,4.27)	0.02
Totally dependent	2.93 (1.37,6.3)	3.22 (1.35,7.72)	
Repeated surgeries	5.99 (3.27,10.96)	7.38 (3.67,14.83)	< 0.001
Postoperative GCS scores ≤ 8	11.24 (5.4,23.37)	11.34 (5.05,25.47)	< 0.001

GCS: Glasgow Coma Scale, CI: confidence interval, LR: likelihood-ratio

5.3%, within 48 h. It was also higher, compared to 3.0% in Thai surgical ICUs.[5] The incidence of ventilator associated pneumonia was 11.3% compared to 9.2% for a single surgical ICU in Thailand.[15] Lower adverse events in the ICU may be related to the higher nursing-to-patients ratio, trained nurses and thus better ICU care.

The 30-day mortality rate of this study was 6%. It was lower than previously reported 28-day mortality of surgical ICUs in Thailand, which was 13.8%.[5] It may be correlated with the severity of the patients condition.

All postoperative mechanically-ventilated patients should preferably receive care in the ICU; however, in a resource-limited country, we always struggle with inadequate ICU beds. Considering that prolonged weaning was associated with increased risk of death in mixed medical and surgical patients,[4,16] patients who had the potential to survive, but carried the risk of prolonged weaning, should be given priority for ICU admission.

Our result was consistent with the previous study which found that postoperative patients who were admitted to ICUs after initial care in wards had higher perioperative mortality when compared with patients who were directly admitted from operating rooms to ICUs.[6] To improve the weaning success in general wards, other than the respiratory care, we should pay attention to multiple aspects including pain control, respiratory rehabilitation, nutrition, and professional competence level of the ward nursing staff.

5. Limitations

There were several limitations to our study. First, our study design was retrospective. As such, weaning techniques and decisions on extubation were based on the physicians, which might affect weaning outcomes. Second, the primary physicians decided to allocate mechanically ventilated patients to the ICU or general wards according to patients' severity and prognosis. Therefore, selection bias was inevitable. Third, several factors such as quality of pain control, presence of postoperative delirium, and weaning methods, which might affect weaning outcomes, were not included in our study. A future study should include the explicit criteria for admission to ICU or general wards, weaning protocol, guideline for postoperative pain control, and recognition of postoperative delirium.

6. Conclusion

In a resource-limited country, some mechanically ventilated postoperative patients have to receive care in the general wards. Our study shows that weaning process in majority of these patients was completed within 24 h; however, 15% of these patients experienced prolonged weaning. Predictors of prolonged weaning were postoperative Glasgow Coma Scale ≤ 8, repeated surgeries, totally dependent functional status, and age more than 65 years. Patients with the risks of prolonged weaning in general wards might be prioritized to the higher level of care.

7. Acknowledgements

We would like to thank Andrew Tait, from the International Affairs Department, for his kind assistance in proofreading of the manuscript.

8. Conflicts of Interest

There are no potential conflicts of interest to declare.

9. Author contribution

AP: Study design, literature review, data collection, statistical analysis, manuscript writing

SC: Concept, manuscript editing

MO: Study design, manuscript editing

10. References

1. Zisk-Rony RY, Weissman C, Weiss YG. Mechanical ventilation patterns and trends over 20 years in an Israeli hospital system:

policy ramifications. Isr J Health Policy Res. 2019;8:20. [PubMed] DOI: 10.1186/s13584-019-0291-y

2. Nates JL, Nunnally M, Kleinpell R, Blosser S, Goldner J, Birriel B, et al. ICU admission, discharge, and triage guidelines: a framework to enhance clinical operations, development of institutional policies, and further research. Crit Care Med. 2016;44:1553-602. [PubMed] DOI: 10.1097/CCM.0000000000001856

3. Beduneau G, Pham T, Schortgen F, Piquilloud L, Zogheib E, Jonas M, et al. Epidemiology of weaning outcome according to a new definition. The WIND study. Am J RespirCrit Care Med 2017;195:772-83. [PubMed] DOI: 10.1164/rccm.201602-0320OC

4. Funk GC, Anders S, Breyer MK, Burghuber OC, Edelmann G, Heindl W, et al. Incidence and outcome of weaning from mechanical ventilation according to new categories. Eur Respir J. 2010;35:88-94. [PubMed] DOI: 10.1183/09031936.00056909

5. Kongsayreepong S, Chittawatanarat K, Thawitsri T, Chatmongkolchart S, Morakul S, Wacharasint P, et al. A multi-center Thai university-based surgical intensive care units study (THAI-SICU study): outcome of ICU care and adverse events. J Med Assoc Thai. 2016;99Suppl 6:S1-14. [PubMed]

6. Gillies MA, Harrison EM, Pearse RM, Garrioch S, Haddow C, Smyth L, et al. Intensive care utilization and outcomes after high-risk surgery in Scotland: a population-based cohort study. Br J Anaesth. 2017;118:123-31. [PubMed] DOI: 10.1093/bja/aew396

7. Hersch M, Sonnenblick M, Karlic A, Einav S, Sprung CL, Izbicki G. Mechanical ventilation of patients hospitalized in medical wards vs the intensive care unit--an observational, comparative study. J Critical Care. 2007;22:13-7. [PubMed] DOI: 10.1016/j.jcrc.2006.06.004

8. Lieberman D, Nachshon L, Miloslavsky O, Dvorkin V, Shimoni A, Zelinger J, et al. Elderly patients undergoing mechanical ventilation in and out of intensive care units: a comparative, prospective study of 579 ventilations. Crit Care. 2010;14:R48. [PubMed] DOI: 10.1186/cc8935

9. Boles JM, Bion J, Connors A, Herridge M, Marsh B, Melot C, et al. Weaning from mechanical ventilation. Eur Respir J. 2007;29:1033-56. [PubMed] DOI: 10.1183/09031936.00010206

10. Kalanuria AA, Zai W, Mirski M. Ventilator-associated pneumonia in the ICU. Crit Care. 2014;18:209. [PubMed] DOI: 10.1186/cc13775

11. Chang YC, Huang KT, Chen YM, Wang CC, Wang YH, Tseng CC, et al. Ventilator dependence risk score for the prediction of prolonged mechanical ventilation in patients who survive sepsis/septic shock with respiratory failure. Sci Rep. 2018;8:5650. [PubMed] DOI: 10.1038/s41598-018-24028-4

12. Scarborough JE, Bennett KM, Englum BR, Pappas TN, Lagoo-Deenadayalan SA. The impact of functional dependency on outcomes after complex general and vascular surgery. Ann Surg. 2015;261:432-7. [PubMed] DOI: 10.1097/SLA.0000000000000767

13. Souter MJ, Manno EM. Ventilatory management and extubation criteria of the neurological/neurosurgical patient. Neurohospitalist. 2013;3:39-45. [PubMed] DOI: 10.1177/1941874412463944

14. Bice T, Nelson JE, Carson SS. To trach or not to trach: uncertainty in the care of the chronically critically ill. Semin Respir Crit Care Med. 2015;36:851-8. [PubMed] DOI: 10.1055/s-0035-1564872

15. Nakaviroj S, Cherdrungsi R, Chaiwat O. Incidence and risk factors for ventilator-associated pneumonia in the surgical intensive care unit, Siriraj Hospital. J Med Assoc Thai. 2014;97Suppl 1:S61-8. [PubMed]

16. Penuelas O, Frutos-Vivar F, Fernandez C, Anzueto A, Epstein SK, Apezteguia C, et al. Characteristics and outcomes of ventilated patients according to time to liberation from mechanical ventilation. Am J RespirCrit Care Med. 2011;184:430-7. [PubMed] DOI: 10.1164/rccm.201011-1887OC

