Weaning from mechanical ventilation

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Crit Care Med 2020; epub

Premature, Opportune, and Delayed Weaning in Mechanically Ventilated Patients: A Call for Implementation of Weaning Protocols in Low- and Middle-Income Countries

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TABLE 2. Unadjusted and Adjusted Clinical and Mortality Outcomes for Premature and Delayed Weaning Groups Compared With Opportune Weaning

	Premature vs Opportune		Delayed vs Opportune	
Outcomes	Unadjusted	Adjusted	Unadjusted	Adjusted
Ventilator-free days, mean difference (p)	−2.47 ($p = 0.003$)	−2.17 ($p = 0.009$)	−3.84 ($p < 0.001$)	−3.54 ($p < 0.001$)
ICU-free days, mean difference (p)	−2.60 ($p < 0.001$)	−2.23 ($p = 0.002$)	−4.14 ($p < 0.001$)	−3.67 ($p < 0.001$)
Hospital-free days, mean difference (p)	−3.46 ($p = 0.014$)	−2.76 ($p = 0.044$)	−5.77 ($p < 0.001$)	−4.41 ($p = 0.006$)
90-d mortality, mean difference (p)	1.17 ($p = 0.37$)	1.06 ($p = 0.76$)	1.27 ($p = 0.22$)	1.12 ($p = 0.58$)

Linear and logistic regression models were adjusted by age, sex, disease severity, and ICU.

These included

3 **cardiovascular** variables:
systolic blood pressure greater than or equal to 90 mm Hg, heart rate less than or equal to 140 beats/minute, and no vasopressor support;

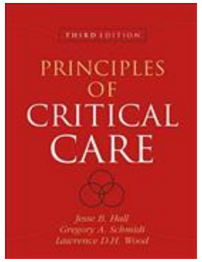
2 **respiratory** variables:
Fio2 less than or equal to 50% and positive endexpiratory pressure (PEEP) less than or equal to 5 cm H2O;

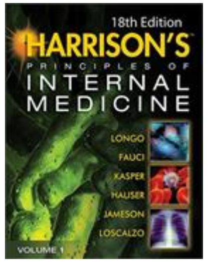
1 **neurologic** variable:
either a Glasgow greater than or equal to 9, Ramsay greater than or equal to 3, or a Richmond Agitation-Sedation Scale score between –2 and 1 in that order of priority.

Table 31 – 3. Mechanistic Approach to Respiratory Failure

	Type I, Acute Hypoxemic	Type II, Ventilatory	Type III, Perioperative	Type IV, Shock
Mechanism	$\dot{Q}_S/\dot{Q}_T$	$\dot{V}_A$	Atelectasis	Hypoperfusion
Etiology	Airspace flooding	1. CNS drive 2. N-M coupling 3. Work/dead-space	1. FRC 2. CV	1. Cardiogenic 2. Hypovolemic 3. Septic
Clinical Description	1. ARDS 2. Cardiogenic pulmonary edema 3. Pneumonia 4. Alveolar hemorrhage	1. Overdose/CNS injury 2. Myasthenia gravis, polyradiculitis/ALS, botulism/curare 3. Asthma/COPD, pulmonary fibrosis, kyphoscoliosis	1. Supine/obese, ascites/peritonitis, upper abdominal incision, anesthesia 2. Age/smoking, fluid overload, bronchospasm, airway secretions	1. Myocardial infarct, pulmonary hypertension 2. Hemorrhage, dehydration, tamponade 3. Endotoxemia, bacteremia

ABBREVIATIONS: ALS, amyotrophic lateral sclerosis; ARDS, acute respiratory distress syndrome; CNS, central nervous system; COPD, chronic obstructive pulmonary disease; CV, cardiovascular; FRC, functional residual capacity; N-M, neuromuscular; $\dot{Q}_S/\dot{Q}_T$, intrapulmonary shunt; $\dot{V}_A$, alveolar ventilation.





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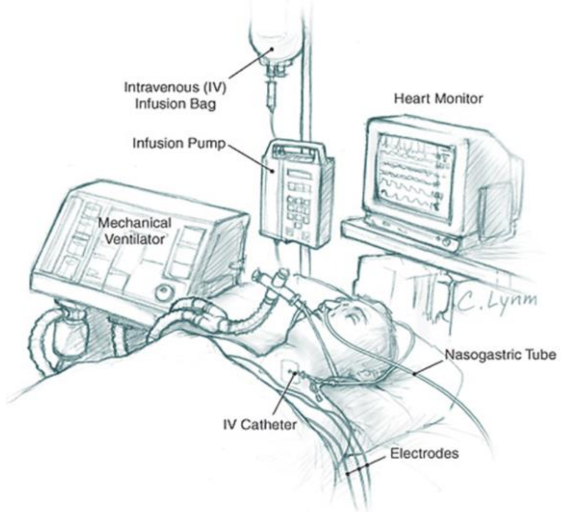
Discontinuation of mechanical ventilation

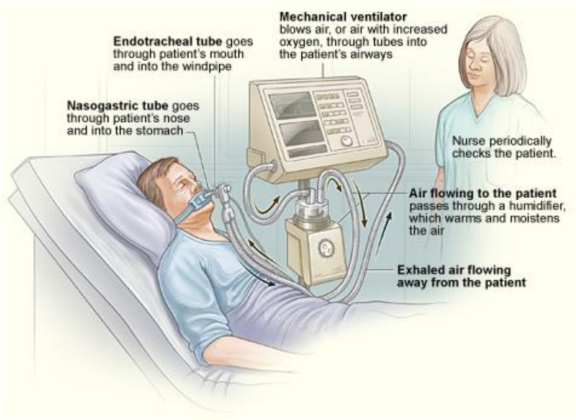


- two-step process :
  - **readiness testing** and **weaning**

- Readiness testing – Readiness testing is the evaluation of objective criteria to determine whether a patient might be able to successfully and safely wean from mechanical ventilation

- Weaning – Weaning is the process of decreasing the amount of support that the patient receives from the mechanical ventilator, so the patient assumes a greater proportion of the ventilatory effort.

Readiness testing



- Readiness testing has 2 major purposes

- The first is to identify patients who are ready to wean from mechanical ventilation.
  - This is important because clinicians tend to underestimate the capacity of patients to breathe independently.
  - Unnecessary mechanical ventilation needlessly increases the risk of complications related to mechanical ventilation
- The second major purpose of readiness testing is to identify patients who are not ready for weaning,
  - thereby protecting them against the risks of premature weaning (eg, cardiovascular dysfunction, respiratory muscle fatigue, psychological distress)

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Clinical criteria used to determine readiness for trials of spontaneous breathing

Required criteria
1. The cause of the respiratory failure has improved
2. PaO_2/FiO_2 ≥150* or SpO_2 ≥90 percent on FiO_2 ≤40 percent and positive end-expiratory pressure (PEEP) ≤5 cmH_2O
3. pH >7.25
4. Hemodynamic stability (no or low dose vasopressor medications)
5. Able to initiate an inspiratory effort
Additional criteria (optional criteria)
1. Hemoglobin ≥7 mg/dL
2. Core temperature ≤38 to 38.5°Centigrade
3. Mental status awake and alert or easily arousable

* A threshold of PaO_2/FiO_2 ≥120 can be used for patients with chronic hypoxemia. Some patients require higher levels of PEEP to avoid atelectasis during mechanical ventilation.

- All of the criteria are objective,
  - since clinicians are poor at predicting readiness to wean on the basis of their subjective impression

- However, even objective criteria are imperfect,
  - since up to 30 percent of patients who never satisfy such criteria can be successfully weaned

Intensive Care Med 1999; 25:581.

Weaning predictors[1]

Measurements of oxygenation and gas exchange
PaO_2/FiO_2
PaO_2/PAO_2
Alveolar-arterial (A-a) oxygen gradient
Dead space (V_D/V_T)
Simple measurements of respiratory system load and respiratory muscle capacity
Negative inspiratory force (NIF) or maximal inspiratory pressure (MIP)*
Respiratory system compliance (dynamic, static)
Respiratory system resistance
Total minute ventilation*
Vital capacity
Respiratory frequency*
Tidal volume*

Integrative indices
Frequency-tidal volume ratio, f/V_T, or rapid shallow breathing index (RSBI)*
CROP index (dynamic **C**ompliance, **R**espiratory rate, **O**xygenation, maximal inspiratory **P**ressure)*
CORE index (**C**ompliance, **O**xygenation, **R**espiration, **E**ffort)
Integrative Weaning Index (IWI)
Inspiratory Effort Quotient (IEQ)
Complex measurements (may require special equipment)
Airway occlusion pressure measured at 100 msec (P0.1)
P0.1/MIP*
Esophageal pressure
Oxygen cost of breathing (O_2COB)
Mechanical work of breathing
Pdi/Pdimax
Tension-time index
Gastric intramucosal pH or P_gCO_2

PaO_2: arterial oxygen tension; PAO_2: alveolar oxygen; FiO_2: fraction of inspired oxygen; Pdi: diaphragmatic pressure; P_gCO_2: gastric carbon dioxide tension.
* Predictors found to be most accurate in a systematic review.[2]

Weaning

- may involve either an immediate shift from full ventilatory support to a period of breathing without assistance from the ventilator
- or a gradual reduction in the amount of ventilator support

- Weaning has also been referred to as the discontinuation of mechanical ventilation or liberation from the mechanical ventilator

Slutsky AS. Mechanical ventilation. American College of Chest Physicians' Consensus Conference. Chest 1993; 104:1833

- The most successful weaning strategies include a daily assessment of the patient's readiness to wean and the careful use of sedatives

Awakening and Breathing Controlled trial. Lancet 2008; 371:126.
N Engl J Med 1996; 335:1864.

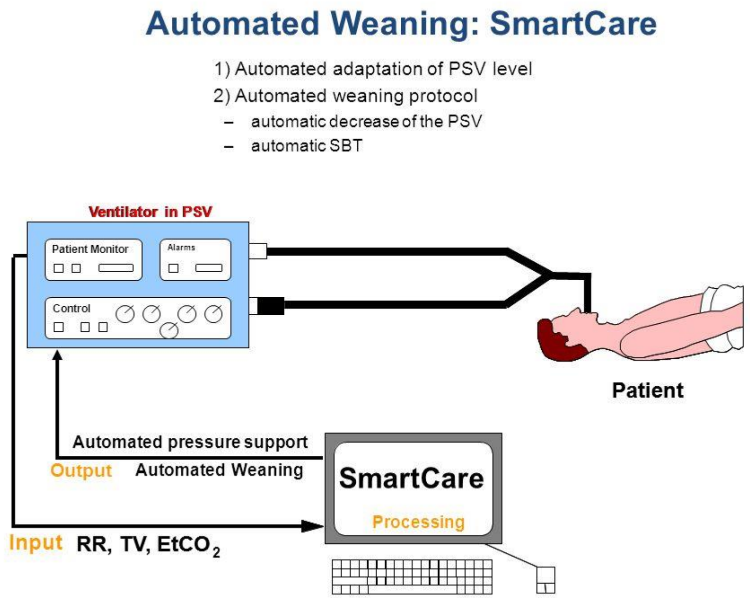
Traditional methods of weaning

- spontaneous breathing trials (SBTs),
- progressive decreases in the level of pressure support during pressure support ventilation (PSV),
- and progressive decreases in the number of ventilator-assisted breaths during intermittent mandatory ventilation (IMV).

Newer weaning methods

- computer-driven automated PSV weaning

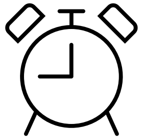
- early extubation with immediate use of post-extubation noninvasive positive pressure ventilation (NPPV).



SBT (spontaneous breathing trials)

- a patient spontaneously breathing through the endotracheal tube (ETT)

- for a set period of time (usually 30 minutes to two hours)



- either without any ventilator support (eg, through a T-piece)
- or with minimal ventilator support.

Methods of minimal ventilator support for an SBT

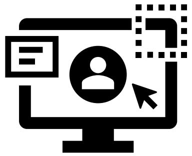
- include a low level of PSV (eg, inspiratory pressure augmentation of 5 to 8 cm H_2O),
- automatic tube compensation (ATC),
- or continuous positive airway pressure (CPAP).

☺

- A successful SBT is one where a patient passes a number of pre-set physiologic criteria
  - (eg, heart rate, respiratory rate, blood pressure, gas exchange)
- at completion of the SBT that potentially indicate candidacy for extubation.

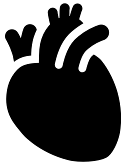
- When a patient successfully passes an SBT and no contraindication to extubation is present, the ETT is typically removed.

- When a patient fails an SBT, then the patient is typically **not extubated and a workup** for weaning failure is performed.

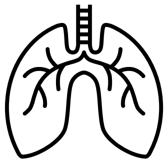
 

- An additional advantage of using PSV, ATC, or CPAP is that they allow the ventilator's monitoring system and alarms to alert the clinician about significant changes in respiratory rate or minute ventilation,

- whereas a T-piece does not provide this information.



- patients at risk for acute cardiogenic pulmonary edema and patients with obstructive lung disease



- may show falsely reassuring SBTs in the presence of CPAP, which improves cardiac output when cardiac filling pressures are elevated and reduces work of breathing

Tobin MJ. Extubation and the myth of "minimal ventilator settings". Am J Respir Crit Care Med 2012; 185:349.

Overcoming endotracheal tube resistance

- — The rationale for performing an SBT with minimal ventilator support (eg, ATC, low level pressure support, or CPAP) rather than without ventilator support (eg, T-piece)
- the additional support may overcome the resistance created by the ETT.

- that the endotracheal tube can contribute to iatrogenic weaning failure

Chest 2009; 136:1006.

Intensive Care Med 2006; 32:165.

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

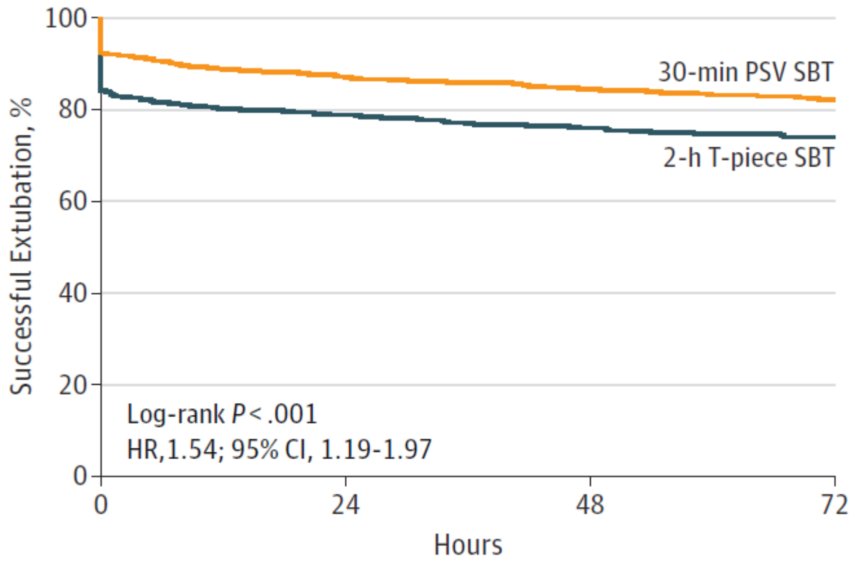
Effect of Pressure Support vs T-Piece Ventilation Strategies During Spontaneous Breathing Trials on Successful Extubation Among Patients Receiving Mechanical Ventilation

A Randomized Clinical Trial

Table 2. Primary, Secondary, Exploratory, and Post Hoc Outcomes of Patients Who Underwent a 2-Hour T-Piece SBT or a 30-Minute PSV SBT[a]

Outcomes	30-min PSV SBT (n = 575)	2-h T-Piece SBT (n = 578)	Difference, PSV SBT Minus T-Piece SBT (95% CI)[b]	*P* Value
Primary Outcome				
Successful extubation, No. (%)[c]	473 (82.3)	428 (74.0)	8.2 (3.4 to 13.0)	.001
Secondary Outcomes				
Extubation after first SBT, No. (%)	532 (92.5)	486 (84.1)	8.4 (4.7 to 12.1)	<.001
Reintubation within 72 h, No. (%)[d]	59 (11.1)	58 (11.9)	−0.8 (−4.8 to 3.1)	.63
ICU length of stay, median (IQR), d	9 (5-17)	10 (5-17)	−0.3 (−1.7 to 1.1)	.69
Hospital length of stay, median (IQR), d	24 (15-40)	24 (15-39)	1.3 (−2.2 to 4.9)	.45
Hospital mortality, No. (%)	60 (10.4)	86 (14.9)	−4.4 (−8.3 to −0.6)	.02
90-Day mortality, No. (%)	76 (13.2)	100 (17.3)	−4.1 (−8.2 to 0.01)	.04
Exploratory Outcome				
Tracheostomy, No. (%)	41 (7.1)	50 (8.7)	−1.5 (−4.6 to 1.6)	.38
Post Hoc Outcome				
ICU mortality, No. (%)	29 (5.0)	38 (6.6)	−1.5 (−4.2 to 1.1)	.26

Figure 2. Probability of Successful Extubation After First SBT in Each Group

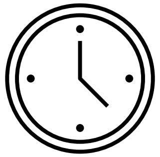


No. at risk	0	24	48	72
30-min PSV SBT	575	501	484	472
2-h T-piece SBT	578	456	438	426

PSV indicates pressure support ventilation; SBT, spontaneous breathing trial. Successful extubation was defined as remaining free of mechanical ventilation for 72 hours after first SBT.

JAMA 2019;321(22):2175-2182

Duration of a weaning trial



- The optimal duration of an SBT is unknown but typically ranges from 30 minutes to two hours.
- In general, an initial SBT of 30 minutes duration is considered sufficient to determine whether mechanical ventilation can be discontinued

- For patients who fail their initial SBT, longer trials of up to two hours may be warranted
- For patients who are mechanically ventilated for more prolonged periods (eg, more than 10 days), → SBTs of longer duration (eg, two hours)

Am J Respir Crit Care Med 2001; 164:225.

Rapid Shallow Breathing Index

$$\text{RSBI} = \frac{\text{Respiratory frequency (f)}}{\text{Tidal volume } (V_T)}$$

Rapid shallow breathing is present when

f/V_T exceeds 100 breaths/min/liter

— e.g., f = 30 breaths/min

V_T = 0.30 liter

o capture the degree of rapid shallow breathing, we used a simple ratio

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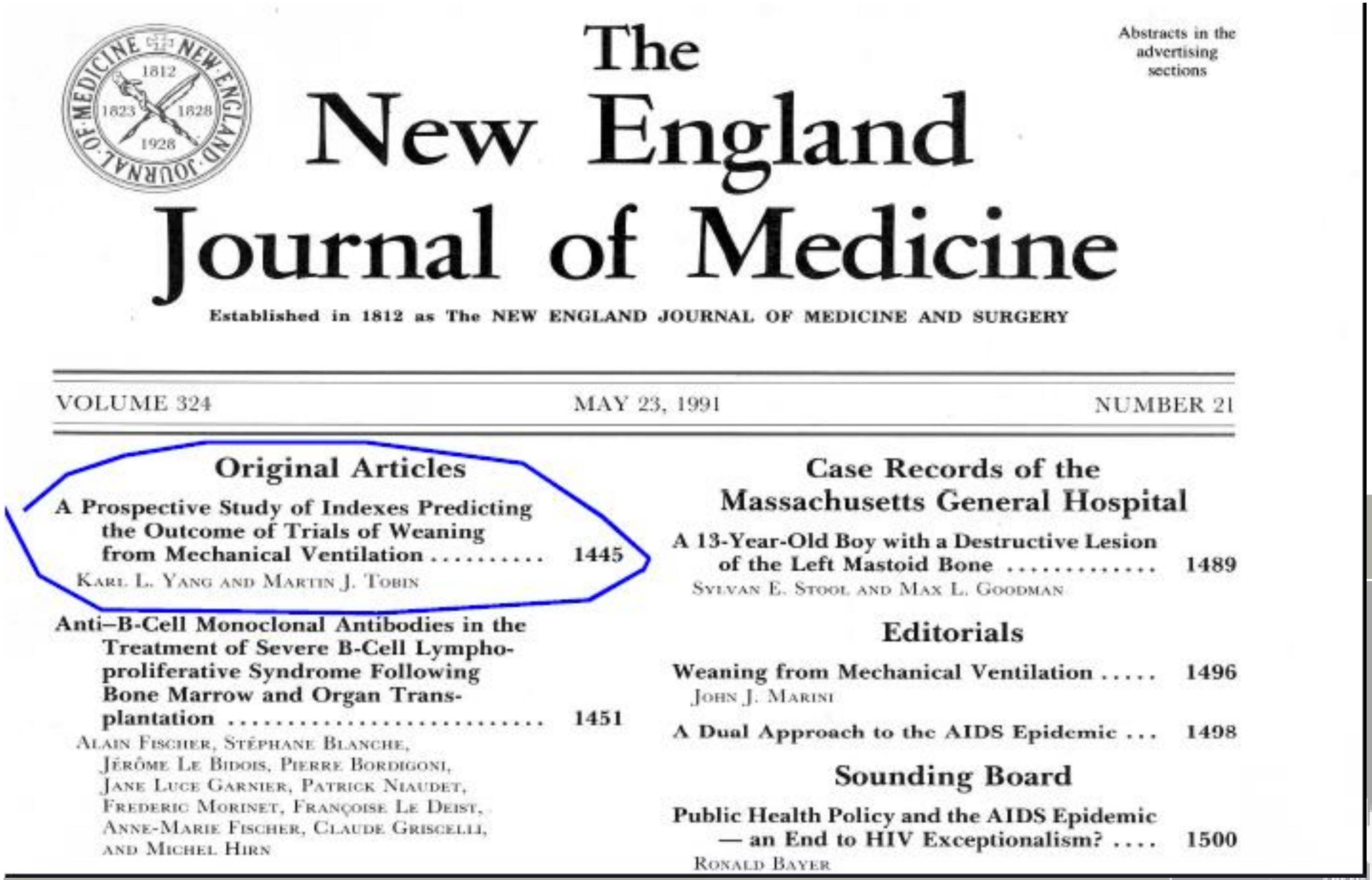

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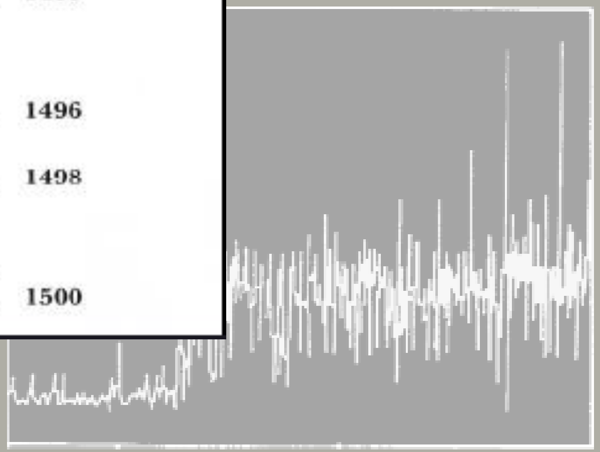

The Frequency-Tidal Volume Index

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I wondered whether these findings might be applied to one of the most frustrating clinical problems of the day -- deciding the right time to wean a patient from the ventilator

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A Prospective Study
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Volume 324 | MAY 23, 1991 | Number 21

A PROSPECTIVE STUDY OF INDEXES PREDICTING THE OUTCOME OF TRIALS OF WEANING FROM MECHANICAL VENTILATION

Karl L. Yang, M.D., and Martin J. Tobin, M.D.

Abstract *Background.* The traditional predictors of the outcome of weaning from mechanical ventilation — minute ventilation ($\dot{V}_E$) and maximal inspiratory pressure ($P_I$max) — are frequently inaccurate. We developed two new indexes: the first quantitates rapid shallow breathing as the ratio of respiratory frequency to tidal volume (f/V_T), and the second is termed CROP, because it integrates thoracic compliance, respiratory rate, arterial oxygenation, and $P_I$max.

Methods. The threshold values for each index that discriminated best between a successful and an unsuccessful outcome of weaning were determined in 36 patients, and the predictive accuracy of these values was then tested prospectively in an additional 64 patients. Sensitivity and specificity were calculated, and the data were also analyzed with receiver-operating-characteristic (ROC) curves, in which the proportions of true positive results and false positive results are plotted against each other for a number of threshold values of an index; the area under the curve reflects the accuracy of the index.

Results. Sensitivity was highest for $P_I$max (1.00), followed closely by the f/V_T ratio (0.97). Specificity was highest for the f/V_T ratio (0.64) and lowest for $P_I$max (0.11). The f/V_T ratio was the best predictor of successful weaning, and $P_I$max and the f/V_T ratio were the best predictors of failure. The area under the ROC curve for the f/V_T ratio (0.89) was larger than that under the curves for the CROP index (0.78, $P<0.05$), $P_I$max (0.61, $P<0.001$), and $\dot{V}_E$ (0.40, $P<0.001$).

Conclusions. Rapid shallow breathing, as reflected by the f/V_T ratio, was the most accurate predictor of failure, and its absence the most accurate predictor of success, in weaning patients from mechanical ventilation. (N Engl J Med 1991; 324:1445-50.)

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Table 2. Accuracy of the Indexes Used to Predict Weaning Outcome.*

Index	Sensitivity	Specificity	Positive Predictive Value	Negative Predictive Value
Minute ventilation	0.78	0.18	0.55	0.38
Respiratory frequency	0.92	0.36	0.65	0.77
Tidal volume	0.97	0.54	0.73	0.94
Tidal volume/patient's weight	0.94	0.39	0.67	0.85
Maximal inspiratory pressure	1.00	0.11	0.59	1.00
Dynamic compliance	0.72	0.50	0.65	0.58
Static compliance	0.75	0.36	0.60	0.53
PaO_2/PAO_2 ratio	0.81	0.29	0.59	0.53
Frequency/tidal volume ratio	0.97	0.64	0.78	0.95
CROP index	0.81	0.57	0.71	0.70

We expressed our results in terms of sensitivity, specificity, positive- and negative-predictive value – this was actually novel for critical care in 1991

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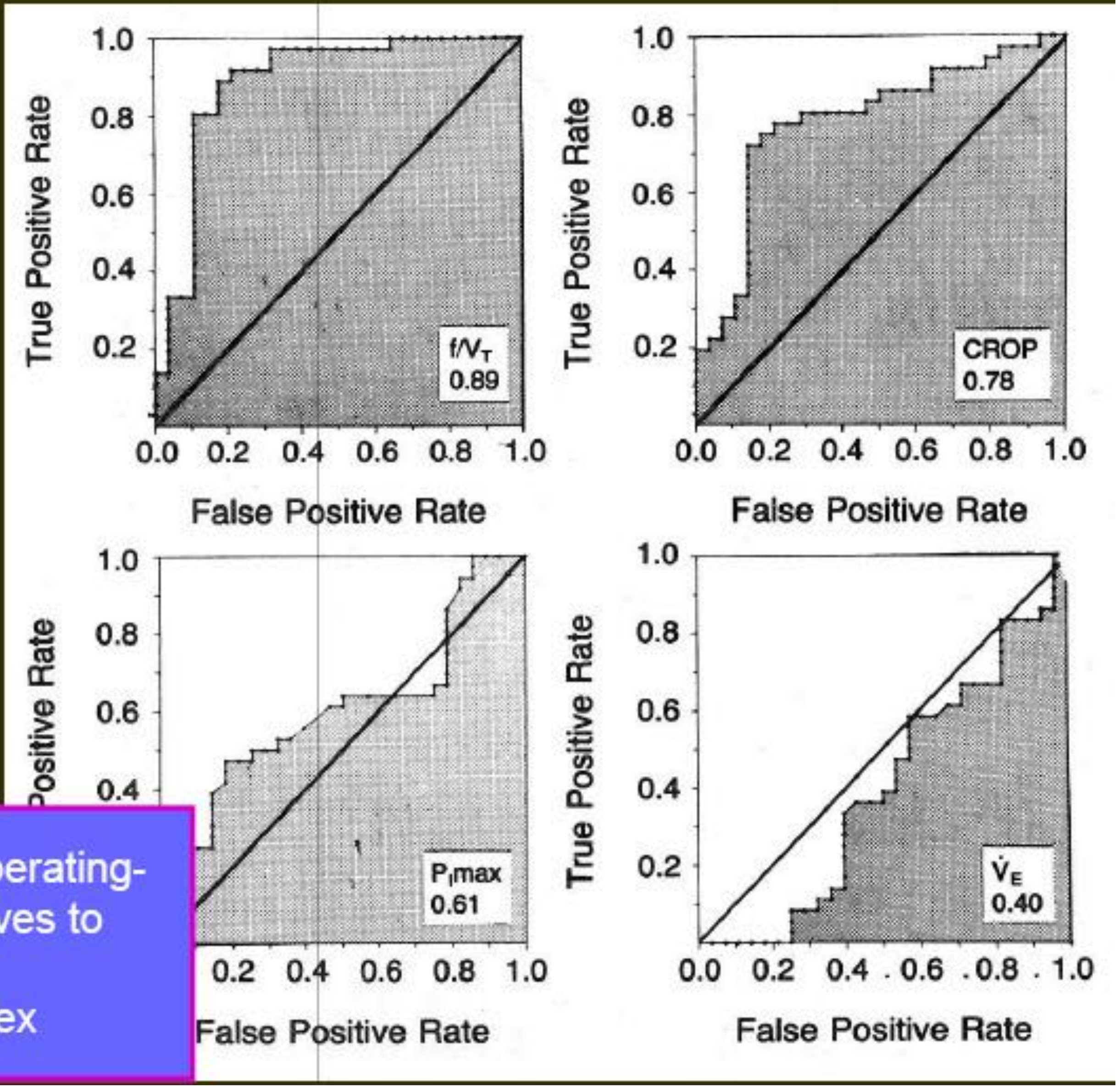

We also used receiver-operating-characteristic (ROC) curves to measure the predictive performance of each index

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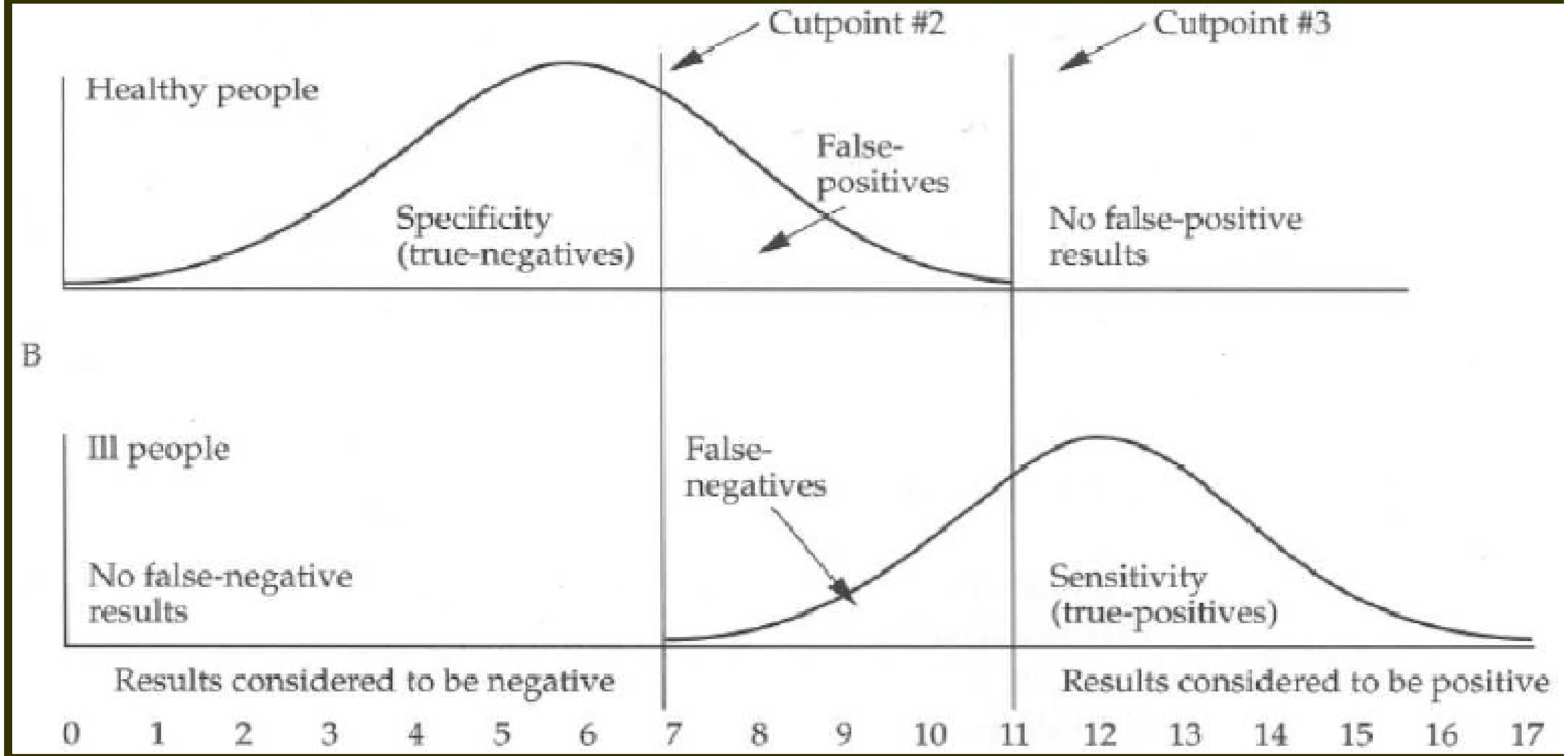
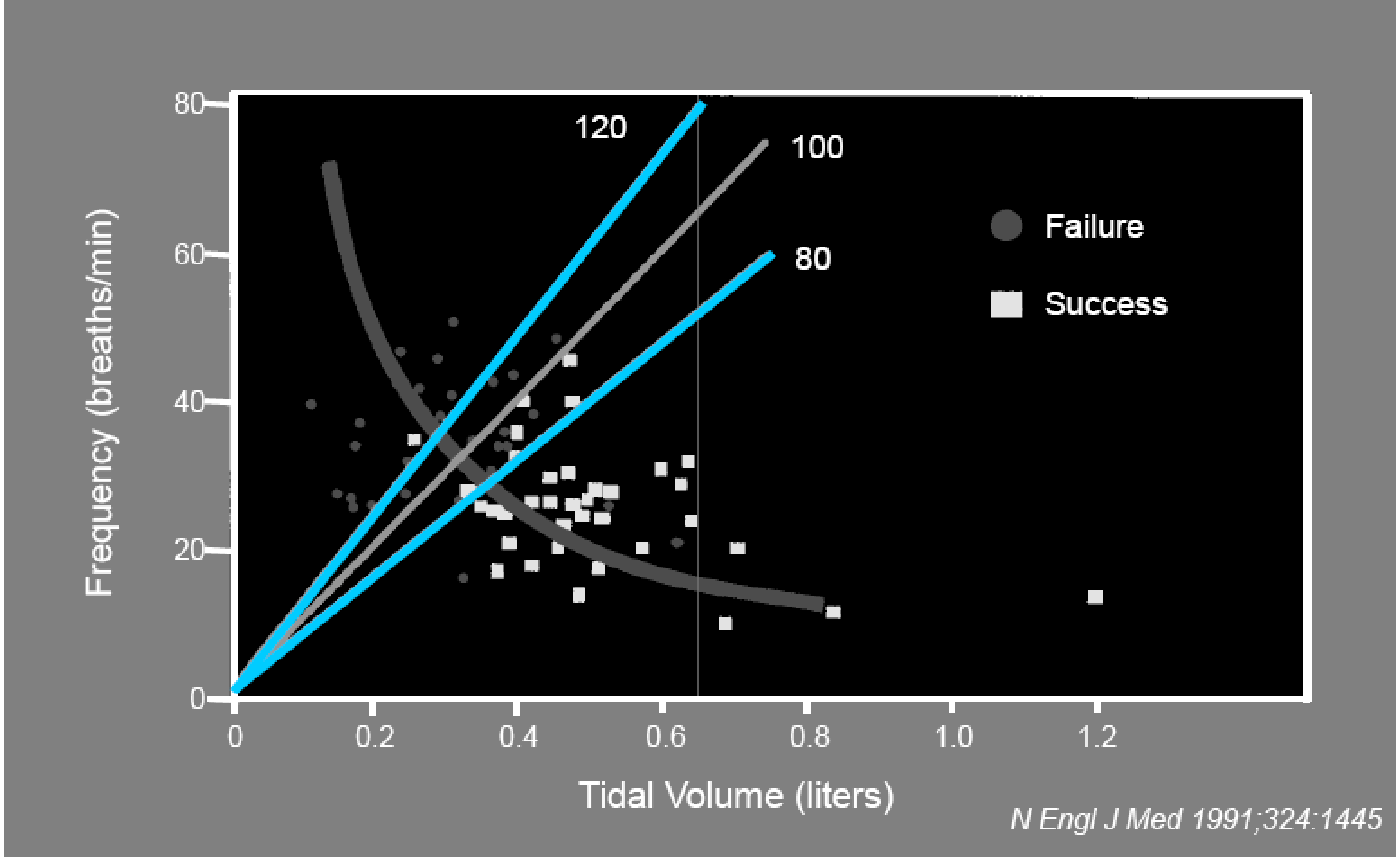


Unlike calculation of sensitivity and specificity, ROC-curve analysis does not depend on a single threshold value



Fortuitously, the threshold that provided the best separation between weaning-success and weaning-failure patients was an easy to remember number, 100

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Assistance

First, I wish I had emphasized that spontaneous breathing means breathing without any assistance

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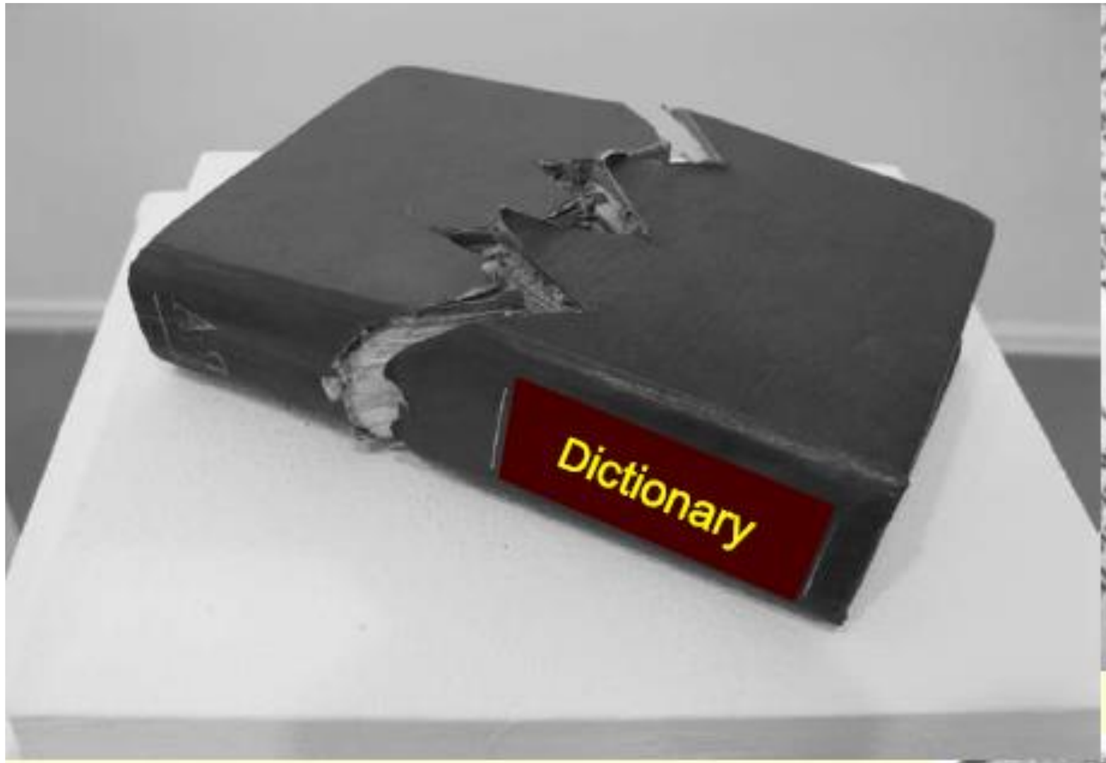

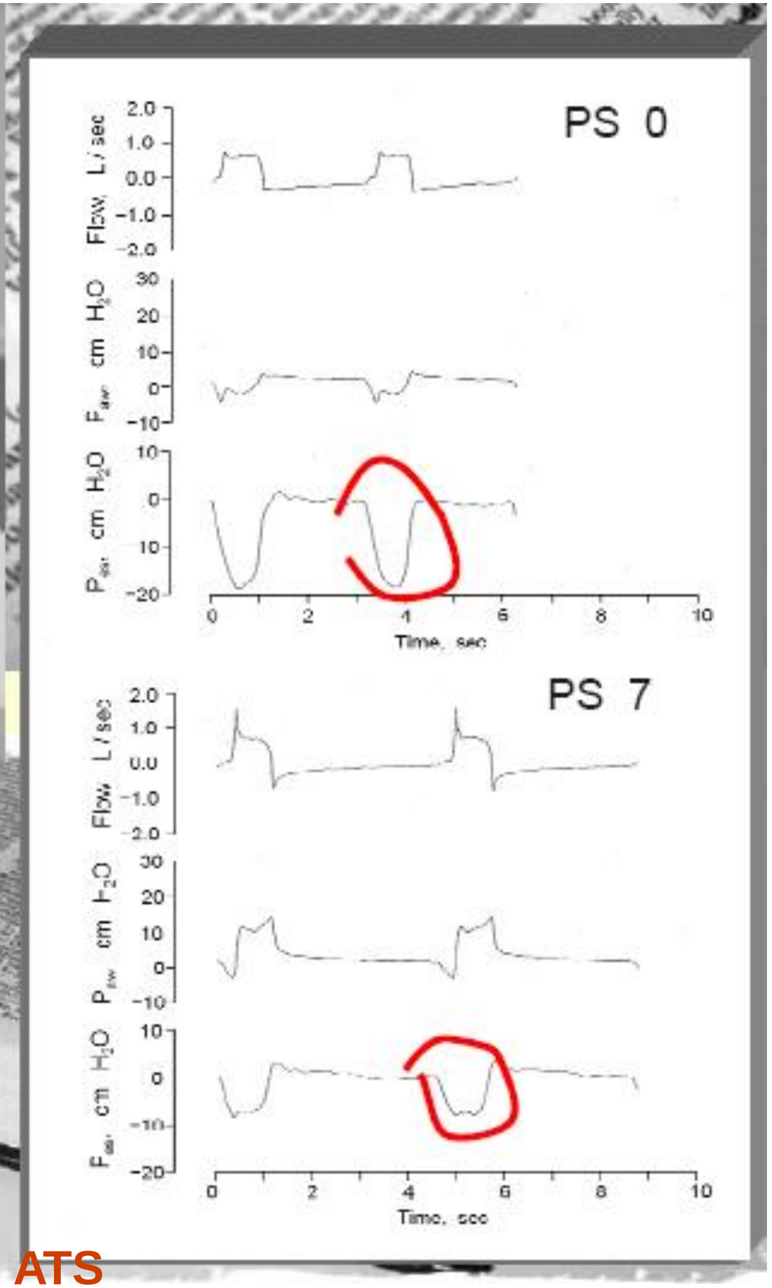

I did not foresee that subsequent researchers would bend the English language and interpret spontaneous breathing to also include pressure support and CPAP

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$P_I max$.[10] After the discontinuation of mechanical ventilation, the patient breathed room air spontaneously for one minute, while $\dot{V}_E$ and f were measured with a spirometer; the spontaneous V_T was calculated by dividing $\dot{V}_E$ by f. Both the V_T corrected for the pa-

s described in our paper, we measured V_T and RR while the patient was completely disconnected from the ventilator circuit (and from supplemental oxygen), using a handheld spirometer attached to the end of the endotracheal tube

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A PROSPECTIVE STUDY OF INDEXES PREDICTING THE OUTCOME OF TRIALS OF WEANING FROM MECHANICAL VENTILATION

measured and widely applied. The purposes of such indexes are to identify the earliest time that a patient can resume spontaneous breathing and to identify pa-

criminated best between a successful and an unsuccessful outcome of weaning were determined in 36 patients, and the predictive accuracy of these values was then tested prospectively in an additional 64 patients. Sensitivity and specificity were calculated, and the data were also analyzed with receiver-operating-characteristic (ROC) curves, in which the proportions of true positive results and

index (0.78, $P<0.05$), $P_I$max (0.61, $P<0.001$), and V_E (0.40, $P<0.001$).

Conclusions. Rapid shallow breathing, as reflected by the f/V_T ratio, was the most accurate predictor of failure, and its absence the most accurate predictor of success, in weaning patients from mechanical ventilation. (N Engl J Med 1991; 324:1445-50.)

ALTHOUGH an experienced physician may be able to foretell the likely outcome of trying to wean a patient from mechanical ventilation, it is desirable to have predictive indexes that can be easily measured and widely applied. The purposes of such indexes are to identify the earliest time that a patient can resume spontaneous breathing and to identify patients in whom a trial of weaning is likely to fail, so that cardiorespiratory distress or collapse can be avoided. In addition, such indexes assess many different physiologic functions and may provide insight into the reasons for dependence on a ventilator.[1]

more recent ones may be due to sev
ing differences in patient populat
niques of measurement,[10] and th
criteria to define weaning outcon
why a predictive index may perfo
does not accurately reflect the tru
determinants of the outcome of w
Since many factors can be respo
of an attempt to wean a patient fr
tilation, we reasoned that accurate
likely with an index that integrates
ologic functions.[11] We developed

In the paper, we said that the purpose of weaning indexes is to identify the earliest time that a patient can resume spontaneous breathing
– that is, a screening test

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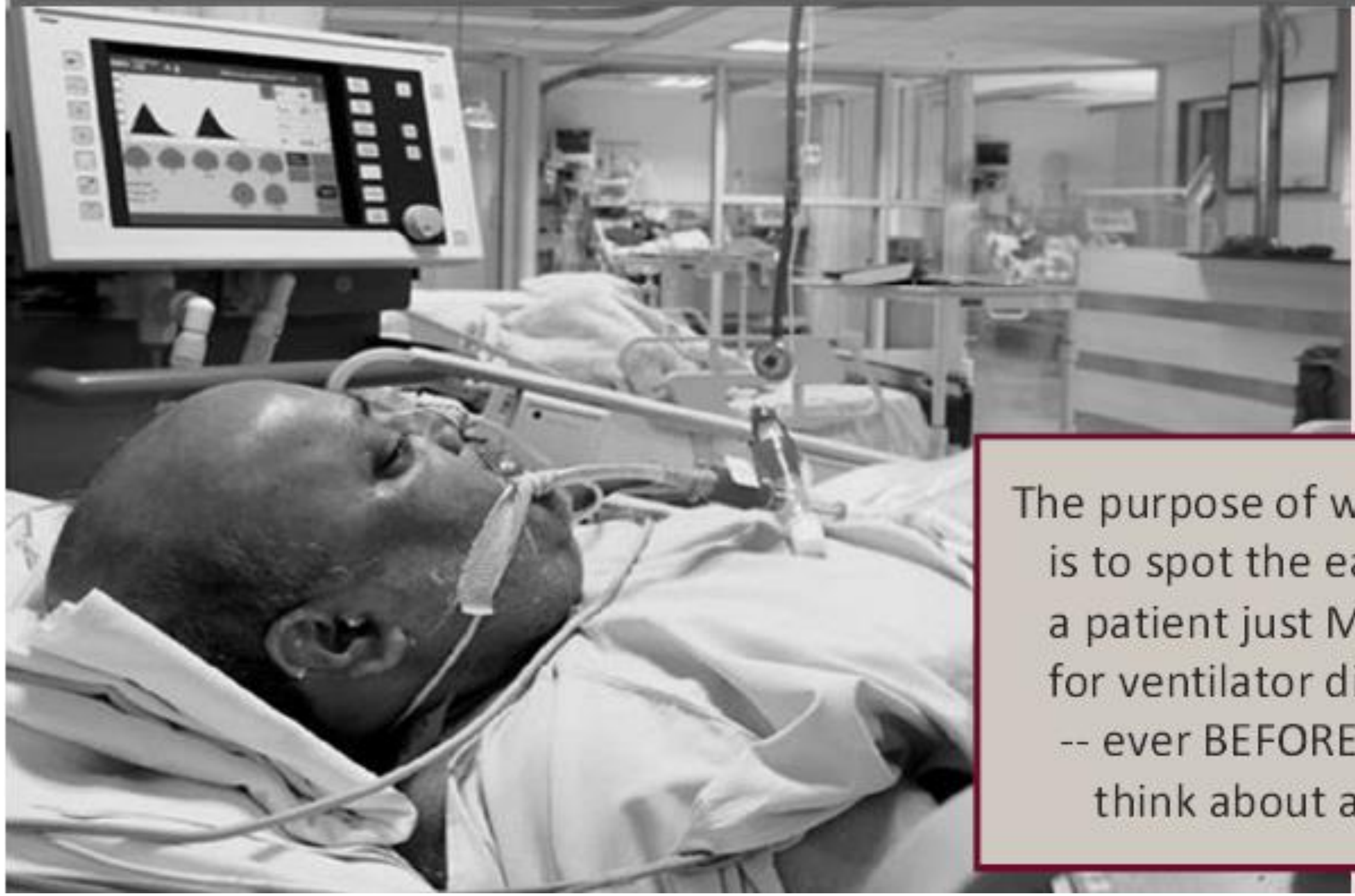
measured and widely applied. The purposes of such indexes are to identify the earliest time that a patient can resume spontaneous breathing and to identify pa-



The purpose of weaning predictors is to spot the earliest time that a patient just MIGHT be ready for ventilator disconnection -- ever BEFORE you begin to think about a T-tube trial

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Weaning predictors are not designed to predict which patients will fail an extubation attempt – that is the purpose of a T-tube trial

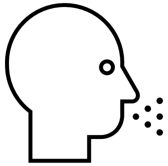
Principles and Practice of Mechanical Ventilation, McGraw-Hill, 1st ed, 1994, p1192

IDENTIFYING WEANING SUCCESS

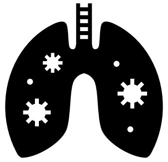
- — Regardless of the weaning strategy used
- the clinician must determine whether weaning was a success or failure.
- Objective criteria that may indicate weaning failure include
  - tachypnea,
  - respiratory distress (use of accessory muscles, thoracoabdominal paradox, and diaphoresis),
  - hemodynamic changes (tachycardia, hypertension),
  - oxyhemoglobin desaturation,
  - and changes in mental status (somnolence, agitation)

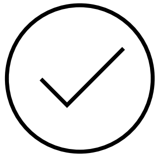
DECIDING WHETHER TO EXTUBATE

- If it is determined that weaning was successful, the decision must be made about whether to remove the endotracheal tube (ETT).



- This requires an assessment of
  - whether the patient can protect their airway (ie, has a sufficient cough and adequate level of consciousness),
  - the volume of respiratory secretions,
  - and whether the airway is patent (ie, a cuff leak is present)



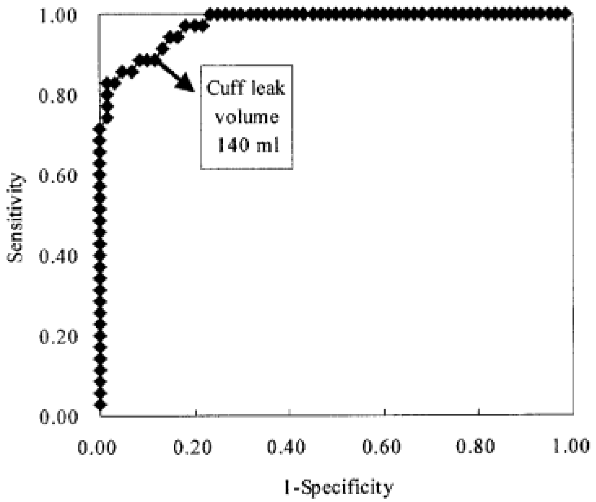


The cuff-leak test is a simple tool to verify severe laryngeal edema in patients undergoing long-term mechanical ventilation

Yu-Hsiu Chung, MD; Tung-Ying Chao, MD; Chien-Tung Chiu, MD; Meng-Chih Lin, MD

Identifying patients at risk for severe laryngeal edema could help eliminate possible predisposing factors and enable initiation of appropriate therapies.

Crit Care Med 2006; 34:409–414



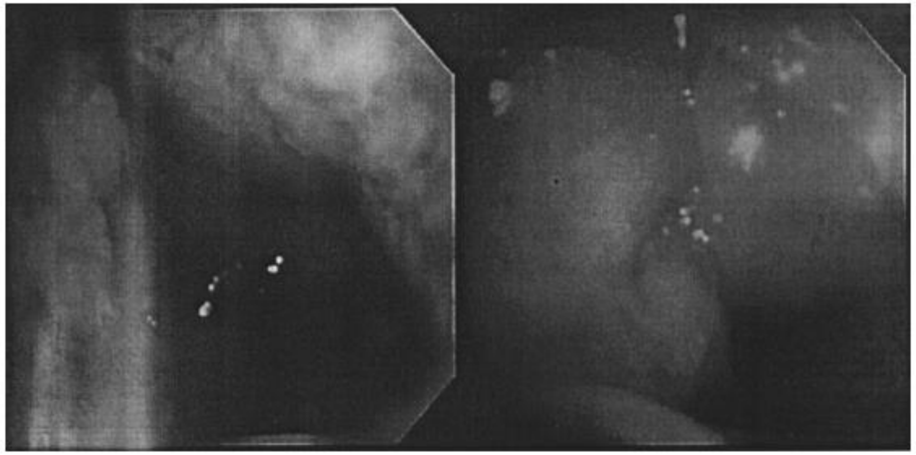


Figure 1. Video bronchoscopic findings. *Left*, negative findings; tracheostomy tube in trachea was seen. *Right*, positive findings; severe laryngeal edema was defined as swelling of the bilateral vocal cords, which as a result might attach to the opposite side of the airway and cause near-total occlusion of the airway.

WEANING FAILURE

- The etiology of weaning failure should always be sought.
- Common causes include the
  - underlying source of the respiratory failure not being fully corrected (with an imbalance between work of breathing and respiratory muscle capacity), volume overload,
  - cardiac dysfunction,
  - neuromuscular weakness,
  - delirium, anxiety, metabolic disturbances, and/or adrenal insufficiency.
- Once the likely cause of weaning failure has been identified, it should be corrected and then weaning resumed

- When a patient fails weaning, the reason for failure should be sought and corrected.

- Meanwhile, the patient should be assessed daily for readiness to wean
  - We suggest weaning such patients via once-daily SBTs, rather than SBTs multiple times daily, PSV, or IMV

weaning

pneumonia

Acute respiratory failure

The Scientific World Journal
Volume 2012, Article ID 547241, 10 pages
doi:10.1100/2012/547241

The ScientificWorldJOURNAL

Clinical Study

Factors Predicting Ventilator Dependence in Patients with Ventilator-Associated Pneumonia

Chia-Cheng Tseng,[1,2] Kuo-Tung Huang,[1,2] Yung-Che Chen,[1,2] Chin-Chou Wang,[1,2,3] Shih-Feng Liu,[1,3] Mei-Lien Tu,[2,3] Yu-Hsiu Chung,[1,3] Wen-Feng Fang,[1,2,3] and Meng-Chih Lin[1,2,3,4]

weaning

TABLE 4: Predictors of ventilator dependence in patients with ventilator-associated pneumonia by multivariate logistic regression analysis.

Predictors	Odd ratio (95 % CI)	P values
Congestive heart failure	15.58 (1.97–123.54)	0.009
Initial oxygenation index	1.44 (1.01–2.06)	0.04
SOFA[a] score	1.67 (1.12–2.50)	0.01
APACHE[a] II score	1.35 (1.04–1.74)	0.02

[a]APACHE: Acute Physiological Assessment and Chronic Health Evaluation, SOFA: Sequential Organ Failure Assessment.

TABLE 5: Comparison of cutoff value, sensitivity, specificity, AUC[a], and *P*-value between physiological severity scores.

Factors	Cutoff value	Sensitivity	Specificity	AUC	*P*-value
SOFA[a] score	8.5	0.83	0.67	0.81	<0.001
Oxygenation index	12.01	0.68	0.89	0.79	<0.001
APACHE[a] II score	23.5	0.82	0.57	0.66	0.009

[a]APACHE: Acute Physiological Assessment and Chronic Health Evaluation, AUC: area under curve, SOFA: Sequential Organ Failure Assessment.

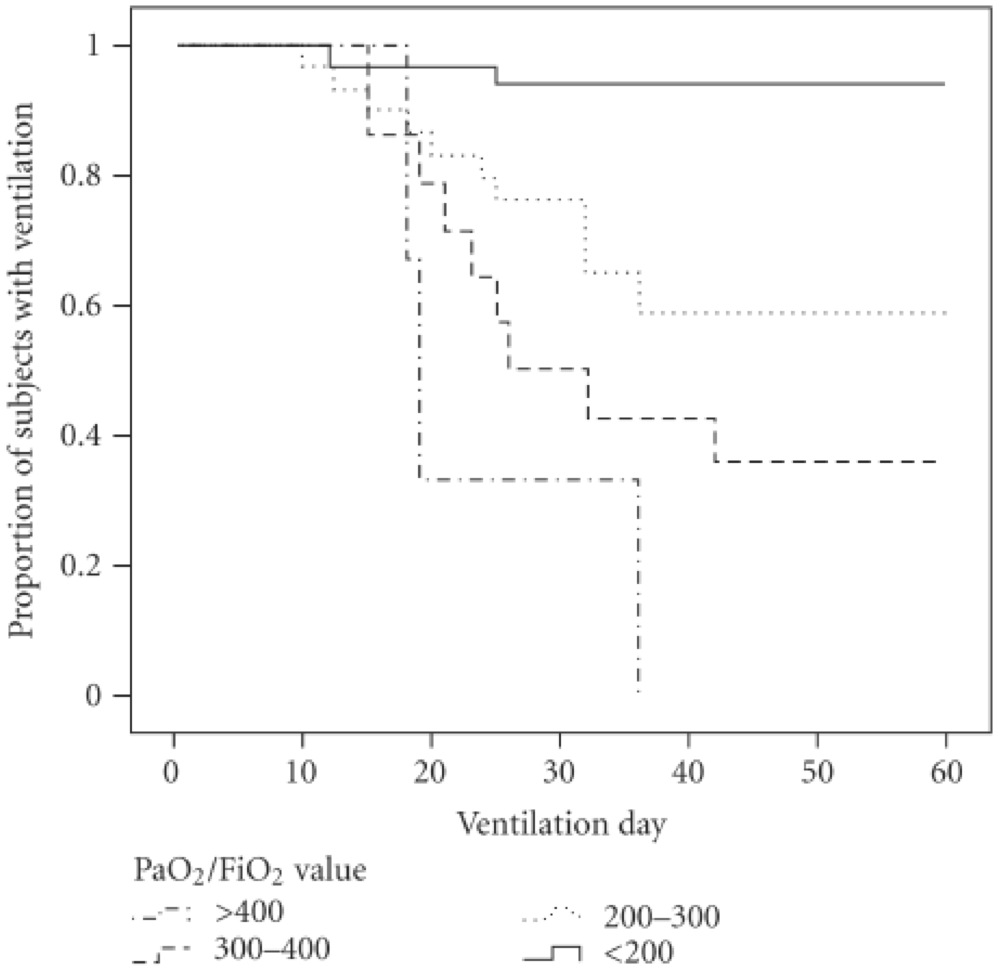


FIGURE 3: Kaplan-Meier curve showing the proportion of patients with ventilation over time according to stratified PaO2/FiO2 values.

difficult-to-wean

1

- Patients are considered to have undergone simple weaning if they pass their first spontaneous breathing trial (SBT)

1

- They are considered difficult-to-wean if they fail their first SBT and then require up to three SBTs or seven days to pass a SBT

3

- Finally, patients are considered to have undergone prolonged weaning if they fail at least three SBTs or require more than seven days to pass a SBT

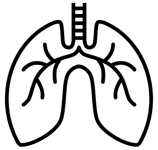
Eur Respir J 2007; 29:1033

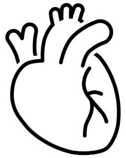
IDENTIFY AND CORRECT THE CAUSE

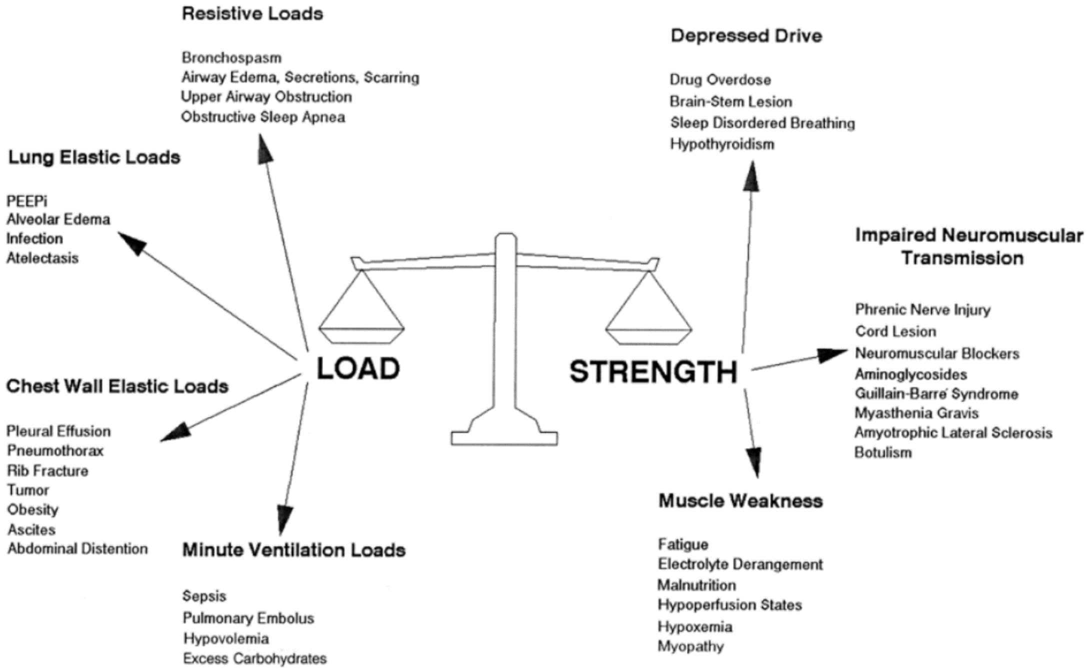
- Repeatedly unsuccessful attempts at weaning usually signify incomplete resolution of the illness that precipitated mechanical ventilation
- and/or the development of one or more new problems
- Further weaning attempts should be withheld once a patient has failed multiple attempts at weaning until the potential causes of the ongoing ventilator dependency are identified and corrected

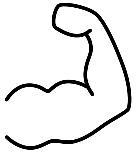
potential causes of difficult weaning

- The potential causes of difficult weaning can be categorized according to whether they are respiratory/ventilatory or cardiac









Source: Hall JB, Schmidt GA, Wood LDH: *Principles of Critical Care*, 3rd Edition: http://www.accessmedicine.com

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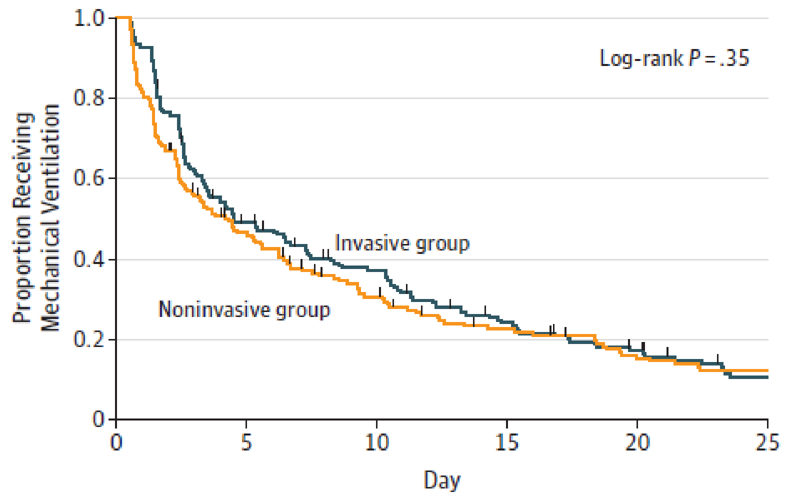
The balance between the load on the respiratory system and the strength of the system determines progression to and resolution of ACRF.

JAMA | Original Investigation | CARING FOR THE CRITICALLY ILL PATIENT

Effect of Protocolized Weaning With Early Extubation to Noninvasive Ventilation vs Invasive Weaning on Time to Liberation From Mechanical Ventilation Among Patients With Respiratory Failure
The Breathe Randomized Clinical Trial

Gavin D. Perkins, MD; Dipesh Mistry, PhD; Simon Gates, PhD; Fang Gao, MD; Catherine Snelson, MB; Nicholas Hart, PhD; Luigi Camporota, PhD; James Varley, MB; Coralie Carle, MB; Elankumaran Paramasivam, MB; Beverley Hoddell; Daniel F. McAuley, MD; Timothy S. Walsh, MD; Bronagh Blackwood, PhD; Louise Rose, PhD; Sarah E. Lamb, DPhil; Stavros Petrou, PhD; Duncan Young, DM; Ranjit Lall, PhD; for the Breathe Collaborators

Figure 2. Time to Liberation From Mechanical Ventilation by Treatment Group



No. at risk	0	5	10	15	20	25
Invasive group	182	86	61	37	24	12
Noninvasive group	182	79	48	32	21	17

Hash marks indicate each censoring time. Median time to liberation from ventilation was 4.5 days (95% CI, 3.46-7.25 days) in the invasive group and 4.3 days (95% CI, 2.63-5.58 days) in the noninvasive group.

Among patients requiring mechanical ventilation in whom a spontaneous breathing trial had failed, **early extubation to noninvasive ventilation** did not shorten time to liberation from any ventilation.

JAMA. 2018;320(18):1881-1888

UAO , balloon

Weaning intervention

Acute respiratory failure

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

Chien-Tung Chiu, MD; Yu-Hsiu Chung, MD; Hung-I Lu[1], MD; Meng-Chih Lin, MD

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%

Chang Gung Med J 2005;28:829-36

AMERICAN THORACIC SOCIETY DOCUMENTS

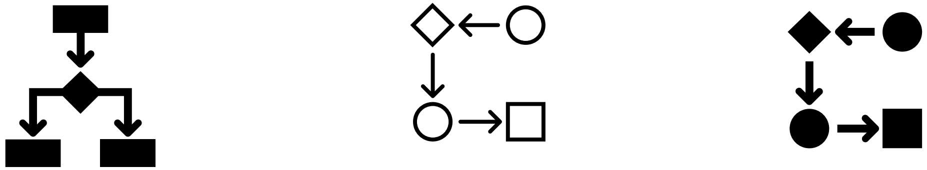
An Official American Thoracic Society/American College of Chest Physicians Clinical Practice Guideline: Liberation from Mechanical Ventilation in Critically Ill Adults

Rehabilitation Protocols, Ventilator Liberation Protocols, and Cuff Leak Tests

Timothy D. Girard, Waleed Alhazzani, John P. Kress, Daniel R. Ouellette, Gregory A. Schmidt, Jonathon D. Truwit, Suzanne M. Burns, Scott K. Epstein, Andres Esteban, Eddy Fan, Miguel Ferrer, Gilles L. Fraser, Michelle Ng Gong, Catherine L. Hough, Sangeeta Mehta, Rahul Nanchal, Sheena Patel, Amy J. Pawlik, William D. Schweickert, Curtis N. Sessler, Thomas Strøm, Kevin C. Wilson, and Peter E. Morris; on behalf of the ATS/CHEST *Ad Hoc* Committee on Liberation from Mechanical Ventilation in Adults

This official clinical practice guideline of the American Thoracic Society (ATS) and the American College of Chest Physicians (CHEST) was approved by the ATS Board of Directors, December 2016, and by the CHEST Board of Regents, October 2016

Am J Respir Crit Care Med Vol 195, Iss 1, pp 120–133, Jan 1, 2017



patients managed with a ventilator liberation protocol spent 25 fewer hours on mechanical ventilation (95% CI, 12.5–35.5 fewer hours) than did patients managed without a protocol.

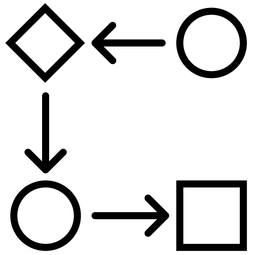
In addition, management with a ventilator liberation protocol led to being discharged from the ICU 0.96 days earlier (95% CI, 0.24–1.7 d) than management without a protocol.

Ventilator liberation protocols, however, had **no significant effect on overall mortality** (22.3 vs. 22.2%; odds ratio [OR], 1.02; 95% CI, 0.82–1.26) or reintubation rates (10.6 vs. 11.9%; OR, 0.74; 95% CI, 0.44–1.23)

Cochrane
Library

Cochrane Database of Systematic Reviews

Protocolized versus non-protocolized weaning for reducing the duration of mechanical ventilation in critically ill adult patients (Review)



Blackwood B, Burns KEA, Cardwell CR, O'Halloran P

There is evidence of reduced duration of mechanical ventilation, weaning duration and ICU length of stay with use of standardized weaning protocols.

Reductions are most likely to occur in medical, surgical and mixed ICUs, but not in neurosurgical ICUs. However, significant heterogeneity among studies indicates caution in generalizing results.

Cochrane Library

Cochrane Database of Systematic Reviews

Automated weaning and spontaneous breathing trial systems versus non-automated weaning strategies for discontinuation time in invasively ventilated postoperative adults (Review)

Burns KEA, Lellouche F, Lessard MR, Friedrich JO

Post OP

While it reduced the time to undergo the first test of spontaneous breathing, it did not reduce the time to the first successful spontaneous breathing test compared to a written weaning protocol applied by physicians

Cochrane Library

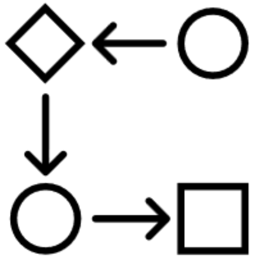
Cochrane Database of Systematic Reviews

Automated weaning and SBT systems versus non-automated weaning strategies for weaning time in invasively ventilated critically ill adults (Review)

Burns KEA, Lellouche F, Nisenbaum R, Lessard MR, Friedrich JO

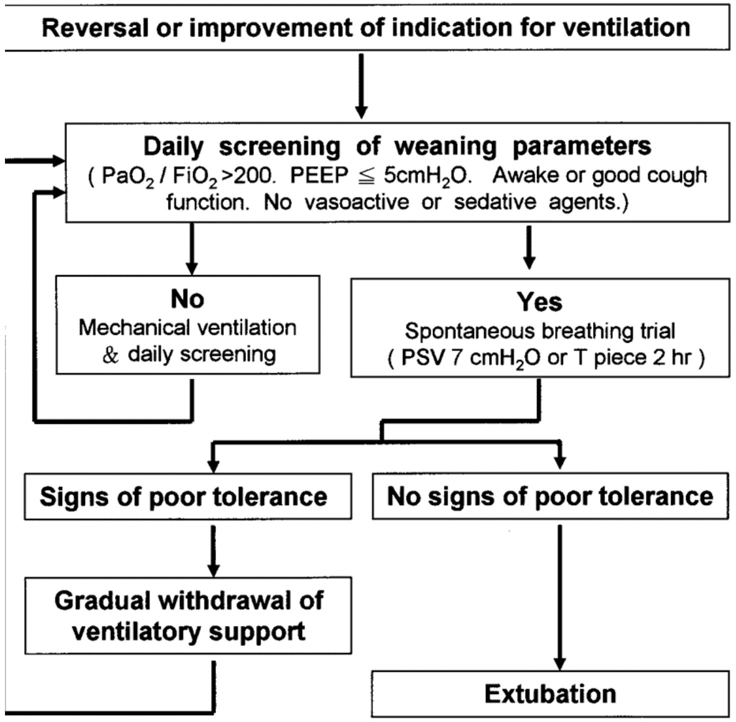
Critically ill

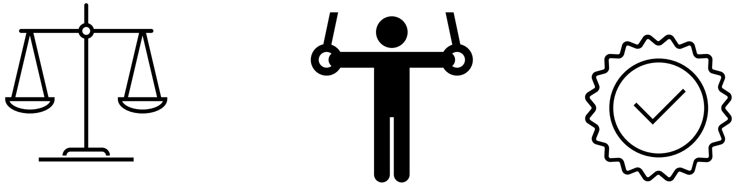
Compared with non-automated strategies, SmartCare™ significantly decreased weaning time, time to successful removal from breathing machines and time spent in the ICU, with fewer patients receiving breathing machine support for longer than seven days and 21 days, and no increase in adverse events.



- Once it is felt that the likely cause of ventilator dependency has been corrected, readiness testing can be performed to determine whether weaning is ready to resume

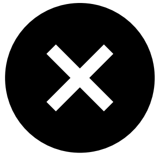
- Patients who are deemed ready to resume weaning should be psychologically prepared for the weaning process because psychological issues (eg, anxiety) can be significant impediments to successful weaning





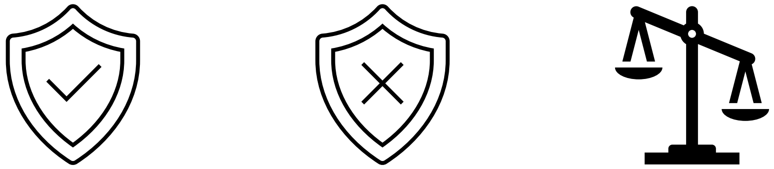
- Patient with weaning-induced cardiac dysfunction should receive a spontaneous breathing trial on a T-tube or pressure support without PEEP

- It is important that a weaning trial be terminated if the patient is failing the trial, since respiratory muscle fatigue may develop.



- Rest is the only treatment for such fatigue and recovery can take several days, delaying further weaning.

- Mechanical ventilation between weaning trials can have a profound effect.
- Appropriate ventilator settings allow the muscles to rest and recover from fatigue caused by the weaning trial



Patient's respiratory status

- The patient's respiratory status should be optimized both during and between weaning trials.

  - This includes suctioning airway secretions before every weaning trial
  - and as-needed, administering a short-acting bronchodilator prior to every weaning trial
  - and as-needed, placing the patient the posture that they prefer,
  - and quickly correcting ventilator circuit problems



- Early mobilization and nutrition support may improve weaning success

nutrients

MDPI

Article

Insufficient Nutrition and Mortality Risk in Septic Patients Admitted to ICU with a Focus on Immune Dysfunction

Kai-Yin Hung [1,2,†], Yu-Mu Chen [1,3,†], Chin-Chou Wang [1,4], Yi-Hsi Wang [1], Chiung-Yu Lin [1], Ya-Ting Chang [1], Kuo-Tung Huang [1], Meng-Chih Lin [1,4] and Wen-Feng Fang [1,4,*]

Avoid unnecessary sedation

Diaphragm-protective ventilation to prevent respiratory muscle complications of MV

High tidal volumes, excessive inspiratory efforts and patient-ventilator asynchronies are associated with both lung and diaphragm injuries. The effort-dependent lung injury has been termed “patient self-inflicted lung injury” (PSILI)

Intensive Care Medicine volume 46, pages2461–2463 (2020)

Clinical practice guidelines for the prevention and management of pain, agitation/sedation, delirium, immobility, and sleep disruption in adult patients in the ICU. Crit Care Med 46:e825–e873

Risk of airway-related vs non-airway-related risk factors for reintubation within 48 h following extubation (defined extubation failure)

airway failure

female sex,
duration of ventilation > 7 days,
copious secretions)

non-airway failure

non-obese status,
SOFA score ≥ 8

Crit Care Lond Engl 22:236.

- Some patients remain difficult-to-wean even though their acute illness has resolved and they are otherwise stable.
- The care of such patients may be transferred to specialized weaning units.

long-term ventilator dependence

- For patients who are facing possible tracheostomy and long-term ventilator dependence, a meeting with the patient is essential to review their goals and preferences in the context of their expected prognosis and quality of life.

- If the patient is not able to participate in decision making,
  - meet with their designated decision-maker, or in the absence of a patient designated decision-maker, with the patient's family.

www.nature.com/scientificreports

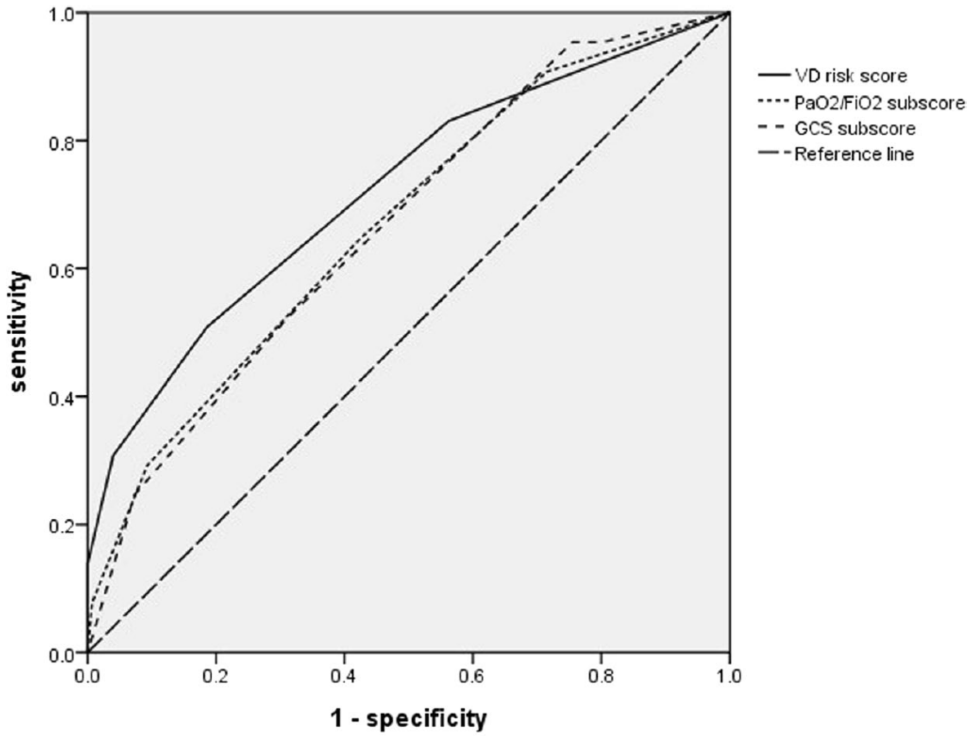
SCIENTIFIC REPORTS

OPEN

Ventilator Dependence Risk Score for the Prediction of Prolonged Mechanical Ventilation in Patients Who Survive Sepsis/Septic Shock with Respiratory Failure

Received: 16 January 2018
Accepted: 26 March 2018
Published online: 04 April 2018

Ya-Chun Chang[1], Kuo-Tung Huang[1,2], Yu-Mu Chen[1,2], Chin-Chou Wang[1], Yi-Hsi Wang[1], Chia-Cheng Tseng[1,3], Meng-Chih Lin[1,3,4] & Wen-Feng Fang[1,3,4]



Variables for ventilator dependence risk score	Value	Points
Previous stroke	Previous stroke event	1
Platelet amount on admission day 7	≤150,000/μL	1
pH value on admission day 7	≤7.35	2
FiO_2 on admission day 7	≥39%	2
VD risk score = previous stroke + Plt 7 + 2*pH 7 + 2*FiO_2 7	Score range	0–6

The Scientific World Journal
Volume 2012, Article ID 957126, 6 pages
doi:10.1100/2012/957126

The ScientificWorldJOURNAL

Clinical Study

Reinstitution of Mechanical Ventilation within 14 Days as a Poor Predictor in Prolonged Mechanical Ventilation Patients following Successful Weaning

Mei-Lien Tu,[1] Ching-Wan Tseng,[1] Yuh Chyn Tsai,[1] Chin-Chou Wang,[1,2] Chia-Cheng Tseng,[2] Meng-Chih Lin,[1,2] Wen-Feng Fang,[1,2] Yung-Che Chen,[2] and Shih-Feng Liu[1,2]

(*Crit Care Med* 2016; 44:e940–e948)

Structure, Organization, and Delivery of Critical Care in Asian ICUs*

Yaseen M. Arabi, MD[1]; Jason Phua, MBBS[2]; Younsuck Koh, MD[3]; Bin Du, MD[4]; Mohammad Omar Faruq, MD[5]; Masaji Nishimura, MD[6]; Wen-Feng Fang, MD[7]; Charles Gomersall, MD[8]; Hussain N. Al Rahma, MD[9]; Hani Tamim, PhD[1]; Hasan M. Al-Dorzi, MD[1]; Fahad M. Al-Hameed, MD[10]; Neill K. J. Adhikari, MD[11]; Musharaf Sadat, MBBS[1]; and the Asian Critical Care Clinical Trials Group

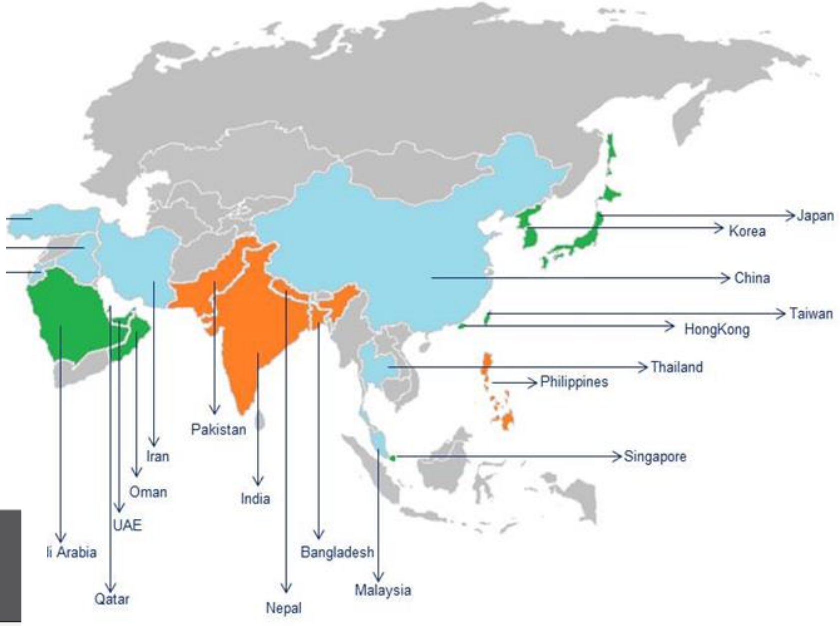


TABLE 1. Hospital Organizational Characteristics According to the 2011 World Bank Classification of the Country Income

Variables	Total *n* = 335	Low Income *n* = 83	Middle Income *n* = 99	High Income *n* = 153	*p*
Chronic ventilation unit	68 (20.3)	6 (7.2)	18 (18.2)	44 (28.8)	0.38
Physiotherapists	174 (51.9)	58 (69.9)	26 (26.3)	90 (58.8)	0.19
Clinical pharmacist	165 (49.3)	19 (22.9)	42 (42.4)	104 (68)	0.07
Respiratory therapists	136 (40.6)	23 (27.7)	32 (32.3)	81 (52.9)	0.29
Social workers	120 (35.8)	18 (21.7)	17 (17.2)	85 (55.6)	0.14
Infection control practitioners	201 (60)	35 (42.2)	67 (67.7)	99 (64.7)	0.60
Dieticians	160 (47.8)	44 (53)	23 (23.2)	93 (60.8)	0.27

Low Income (< $4,035)	Middle Income ($4,036 to $12,475)	High Income (> $12,475)
	China	Hong Kong
Nepal	Iran	Japan
Philippines	Iraq	Korea
India	Jordan	Oman
Pakistan	Malaysia	Saudi Arabia
Bangladesh	Thailand	Singapore
	Turkey	UAE
		Qatar
		Taiwan

孟加拉　　台灣

Table S4: Written protocols and policies.

Variables	Total N=335	Low Income N=83	Middle Income N=99	High Income N=153	P value
Severe sepsis and septic shock	245 (73.1)	43 (51.8)	90 (90.9)	112 (73.2)	<0.0001
Insulin and glucose control	268 (80)	56 (67.5)	87 (87.9)	125 (81.7)	0.002
Acute lung injury/ acute respiratory distress syndrome	218 (65.1)	38 (45.8)	85 (85.9)	95 (62.1)	<0.0001
Admission and discharge criteria	259 (77.3)	45 (54.2)	89 (89.9)	125 (81.7)	<0.0001
Do-not-resuscitate (DNR)	196 (58.5)	41 (49.4)	53 (53.5)	102 (66.7)	0.02
Sedation/analgesia	238 (71)	46 (55.4)	82 (82.8)	110 (71.9)	0.0003
Weaning from mechanical ventilation	216 (64.5)	41 (49.4)	77 (77.8)	98 (64.1)	0.0004
Venous thromboembolism prophylaxis	224 (66.9)	42 (50.6)	78 (78.8)	104 (67.9)	0.0003
Intravenous heparin	194 (57.9)	29 (34.9)	69 (69.7)	96 (62.8)	<0.0001

Intensive Care Med (2018) 44:2079–2090
https://doi.org/10.1007/s00134-018-5432-1

ORIGINAL

Professional burnout among physicians and nurses in Asian intensive care units: a multinational survey

Kay Choong See[1*], Ming Yan Zhao[2], Emiko Nakataki[3], Kaweesak Chittawatanarat[4,18], Wen-Feng Fang[5], Mohammad Omar Faruq[6], Bambang Wahjuprajitno[7], Yaseen M. Arabi[8], Wai Tat Wong[9], Jigeeshu V. Divatia[10], Jose Emmanuel Palo[11], Babu Raja Shrestha[12], Khalid M. K. Nafees[13], Nguyen Gia Binh[14], Hussain Nasser Al Rahma[15], Khamsay Detleuxay[16], Venetia Ong[17], Jason Phua[1], SABA Study Investigators and the Asian Critical Care Clinical Trials Group

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sion. The high levels of stress (physicians 46.9%, nurses 47.3%) and possible depression (physicians 29.7%, nurses 32.8%) call for further action to manage these. In nurses, burnout was additionally associated with decreased agreement and keenness to adhere to treatment guidelines, which might then lead to poorer patient outcomes [24], emphasizing the clinical importance of burnout mitigation.

Characteristics	All (*N* = 4092)	Participants with burnout (*N* = 2110)	*P* value
Country or region, by World Bank income group (2015)			
Low and lower-middle			< 0.001
Bangladesh (% within each country/region)	341	118 (34.6)	
India (% within each country/region)	177	98 (55.4)	
Indonesia (% within each country/region)	61	30 (49.2)	
Philippines (% within each country/region)	97	39 (40.3)	
Upper-middle			
China (% within each country/region)	855	523 (61.2)	
Thailand (% within each country/region)	171	81 (47.4)	
High			
Hong Kong (% within each country/region)	260	160 (61.5)	
Japan (% within each country/region)	309	131 (42.4)	
Saudi Arabia (% within each country/region)	799	371 (46.4)	
Singapore (% within each country/region)	354	181 (51.1)	
Taiwan (% within each country/region)	420	267 (63.5)	

孟加拉

台灣

Crit Care Med 2020; epub

Critical Care Bed Capacity in Asian Countries and Regions

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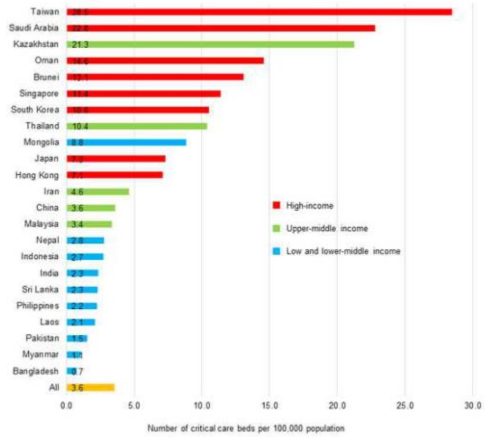

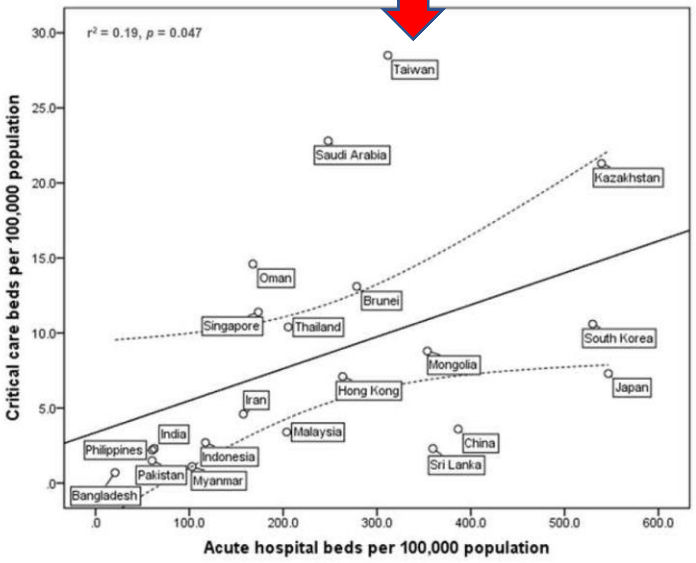

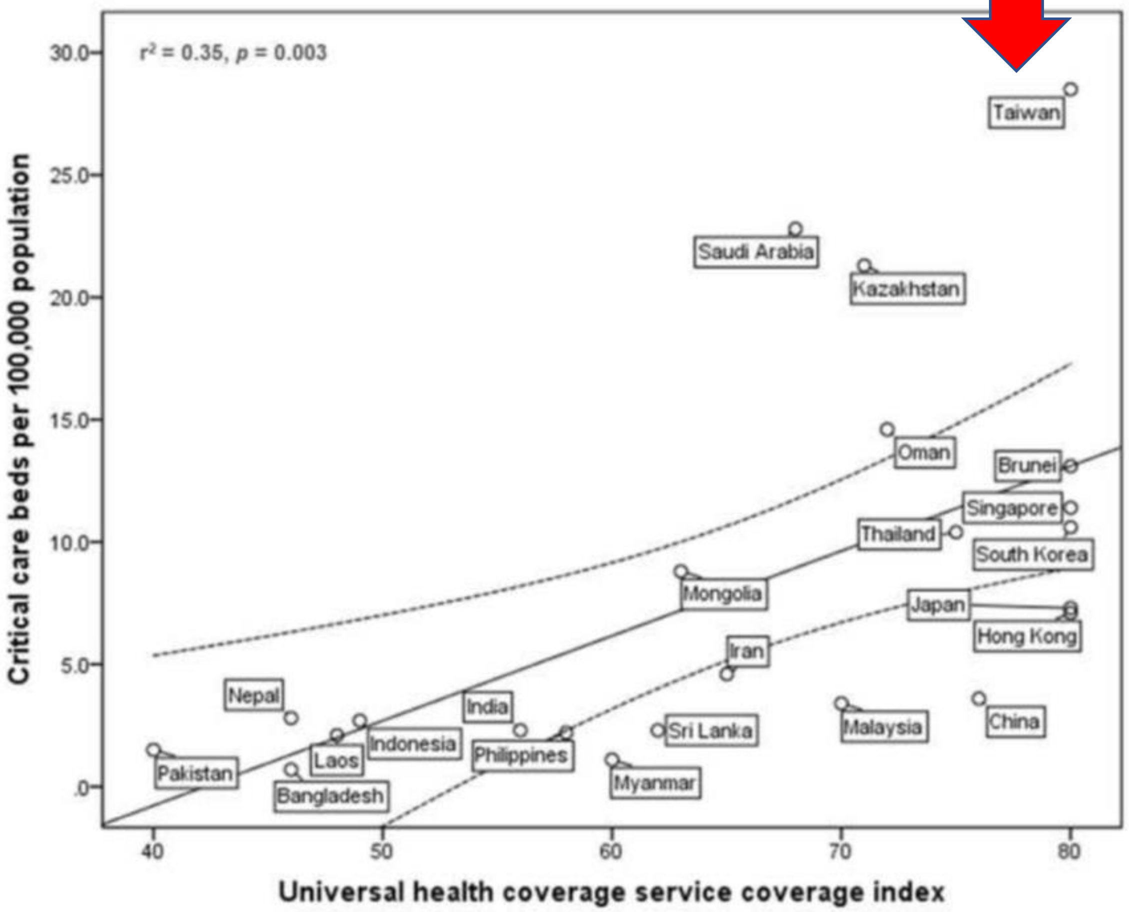

Country and Region	ICUs	ICU Beds	IMCUs	IMCU Beds	Critical Care Beds[a]	Critical Care Beds/ 100,000 Population	Critical Care Beds as % of Acute Hospital Beds
Low and Lower-Middle Income Countries and Regions							
Bangladesh	84	878	41	296	1,174	0.7	3.6
India	[b]	29,997	[b]	[b]	29,997	2.3	3.7
Indonesia	1,910	7,094	[b]	[b]	7,094	2.7	2.3
Laos	22	152	[b]	[b]	152	2.1	[b]
Mongolia	43	271	0	0	271	8.8	2.5
Myanmar	68	331	38	255	586	1.1	1.0
Nepal	67	578	22	237	815	2.8	[b]
Pakistan	114	3,142	[b]	[b]	3,142	1.5	2.5
Philippines	450	2,315	2	20	2,335	2.2	3.7
Sri Lanka	100	519	0	0	519	2.3	0.6
Upper-Middle Income Countries and Regions							
China	3,569	49,453	0	0	49,453	3.6	0.9
Iran	426	3,769	2	21	3,790	4.6	2.9
Kazakhstan	582	3948	0	0	3,948	21.3	3.9
Malaysia	105	1060	[b]	[b]	1060	3.4	1.7
Thailand	1221	7,100	[b]	[b]	7,100	10.4	5.1
High-Income Countries and Regions							
Brunei	5	58	0	0	58	13.1	4.7
Hong Kong	24	287	41	224	511	7.1	2.7
Japan	590	5973	401	3,268	9,241	7.3	1.3
Oman	26	196	61	303	499	14.6	8.7
Saudi Arabia	600[c]	6,515	[b]	[b]	6,515	22.8	9.2
Singapore	28	335	30	336	671	11.4	6.6
South Korea	581	5,402	0	0	5,402	10.6	2.0
Taiwan	344	5,758	65	943	6,701	28.5	9.1

ICU = intensive care unit, IMCU = intermediate care unit.
[a] Critical care beds refer to the sum of IMCU beds and ICU beds.
[b] Data not available.
[c] Number of ICUs estimated from the number of ICU beds.

Taiwan	+	Respiratory care centre or sub-acute respiratory care unit

A dedicated space within the hospital with a higher nurse to patient ratio than a regular ward, equipped to monitor vital signs and oxygen saturation intensively and the electrocardiogram continuously, and to provide non-invasive ventilation, short-term invasive mechanical ventilation, or simple mechanical ventilation for stable chronically ventilated patients.

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weaning be initiated once the following criteria are satisfied

- Evidence for some reversal of the underlying cause for respiratory failure
- Adequate oxygenation (eg, PaO_2 / FiO_2 ratio >150 to 200 on ventilator settings that include ≤8 cm H_2O of PEEP and an FiO_2 ≤0.5)
- Adequate pH (eg, ≥7.25)
- Hemodynamic stability, defined as the absence of active myocardial ischemia and clinically significant hypotension
- Capable of initiating an inspiratory effort

- patients requiring PMV be weaned by gradually increasing the duration of spontaneous breathing

- Patients who fail spontaneous breathing should be placed on a non-fatiguing, comfortable mode of ventilation and the cause of failure determined and corrected.

- daily spontaneous breathing resume after the cause of failure has been corrected

The most successful weaning strategies include a daily assessment of the patient's readiness to wean