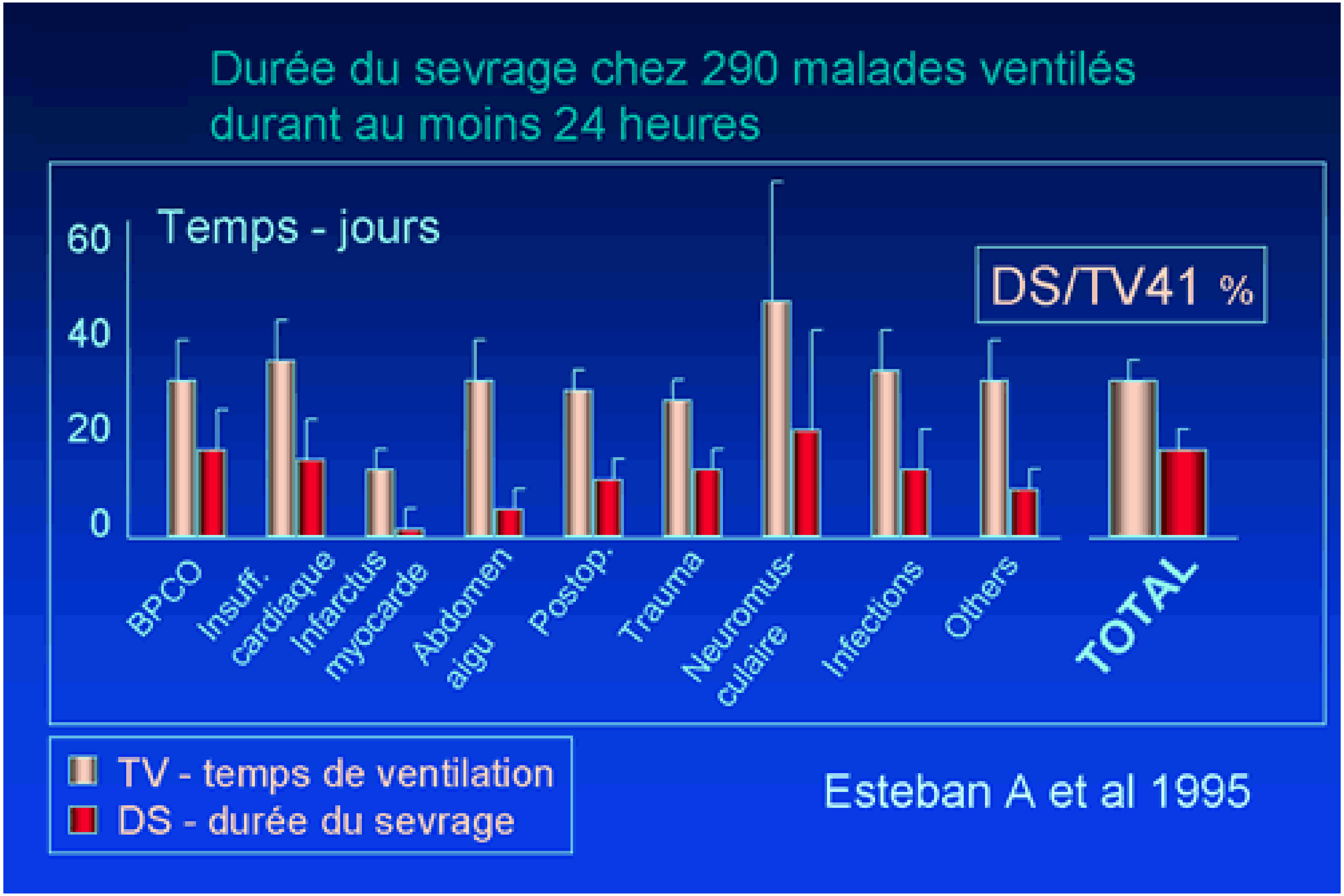
Les déterminants physiopathologiques de l’échec du *sevrage ventilatoire*

Boussarsar M, Ayachi J
Réanimation Médicale, Sousse.

Introduction



Introduction

- Le sevrage est un « art »
- Avancées physiopathologiques

- Pourvoyeur de morbi-mortalité
- Défi diagnostique (critères de sevrabilité)
- Probabilité pré-test (Bayes Theorem)
- Le test prédictif idéal!

Introduction

- Sevrage simple : *réussi dès la 1ère tentative de VS*
- Sevrage prolongé : *> 3épreuves de VS ou > 7 jours*
- **Sevrage difficile :** *jusqu'à 3 épreuves de VS ou 7 jours pour sevrage complet*
- **Echec du sevrage :** *échec de test de VS ou nécessité de ré-intubation dans les 48h*

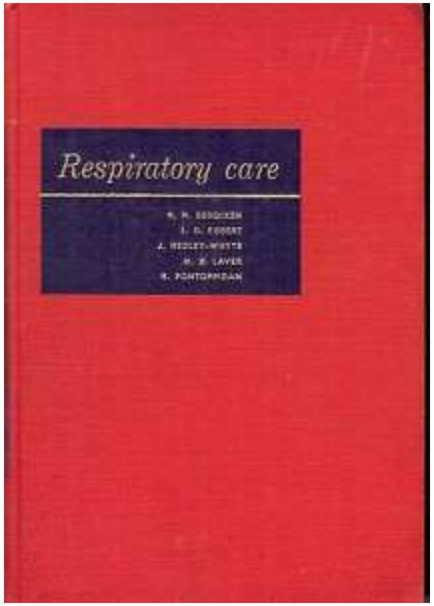
Boles, Eur Respir J 2007; 29: 1033–1056.

Historique

- 1965, Respiratory Care. Bendixin, Pontoppidan.

- Trachéotomie H48

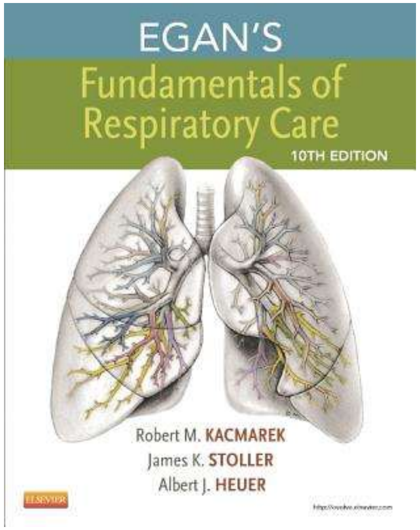
The Bostonians articulated a principle that still holds: "To know the proper timing and rate of weaning from the respirator requires considerable judgment and experience. As a rule, weaning should start as soon as possible" [12].



Historique

- 1977, Egan

Egan advised: "When the patient can breathe unassisted around the clock, and is moving a reasonable amount of air without undue effort, and can walk for short distances consistent with his general physical condition, and when ventilation is satisfactory and stable by blood gas values, it is time to consider removal of the endotracheal tube" [18].



- 1988, Lemaire

In 1988, Lemaire wrote: "Despite the lack of evidence that IMV shortens the weaning period, IMV is extensively used in the majority of ICUs" [21].

Historique

- 1977, Henning

Crit Care Med. 1977 Nov-Dec;5(6):264-8.
The measurement of the work of breathing for the clinical assessment of ventilator dependence.
Henning RJ, Shubin H, Weil MH.

- 1982, Cohen

Am J Med. 1982 Sep;73(3):308-16.
Clinical manifestations of inspiratory muscle fatigue.
Cohen CA, Zagelbaum G, Gross D, Roussos C, Macklem PT.

Historique

- 1986, Tobin

Am Rev Respir Dis. 1986 Dec;134(6):1111-8.

The pattern of breathing during successful and unsuccessful trials of weaning from mechanical ventilation.

Tobin MJ, Perez W, Guenther SM, Semmes BJ, Mador MJ, Allen SJ, Lodato RF, Dantzker DR.

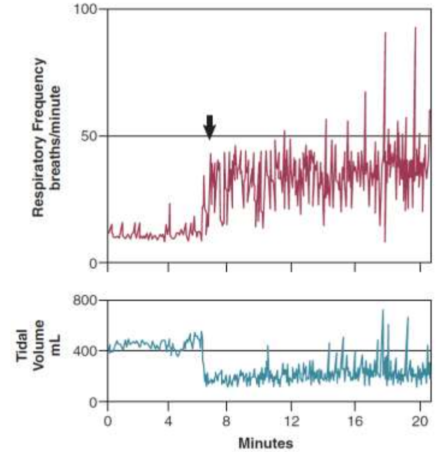


Figure 44-5. A time-series, breath-by-breath plot of respiratory frequency and tidal volume in a patient who failed a weaning trial. The arrow indicates the point of resuming spontaneous breathing. Rapid, shallow breathing developed almost immediately after discontinuation of the ventilator. (Redrawn from Tobin MJ, Perez W, Guenther SM, et al: The pattern of breathing during successful and unsuccessful trials of weaning from mechanical ventilation. Am Rev Respir Dis 1986;134:1111-1118.)

Historique

- 1985, Marini

vanced (weaning) understanding. In 1985, Marini and colleagues reported that subjects receiving assist-control ventilation performed half as much work as done by the ventilator [32]. This was heresy. It had been dogma that connecting a patient to a ventilator lessened work to near zero. In 1988, Marini reported that patient effort was virtually the same during mandatory IMV breaths as during the intervening spontaneous breaths (Fig. 3) [33]. This was blasphemy. By the late 1980s, IMV had been deified as the nonpareil weaning technique [20].

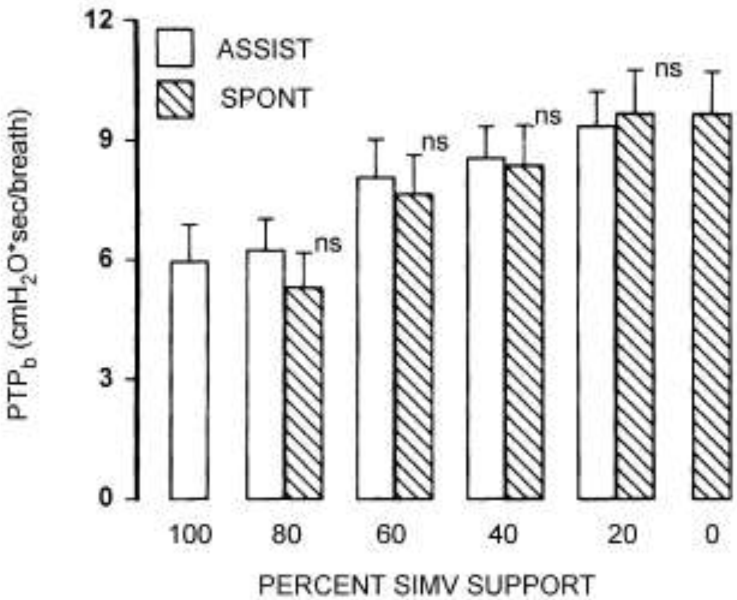


Fig. 3 Inspiratory pressure-time product per breath for assisted, mandatory breaths (*open bars*) and intervening spontaneous breaths (*cross-hatched bars*). Patient effort was equivalent for mandatory and spontaneous breaths at every level of synchronized intermittent mechanical ventilation (*SIMV*). (From Marini et al. [33])

Historique

- 1987,89, Brochard

Am Rev Respir Dis. 1987 Aug;136(2):411-5.
Improved efficacy of spontaneous breathing with inspiratory pressure support.
Brochard L, Pluskwa F, Lemaire F.

Am Rev Respir Dis. 1989 Feb;139(2):513-21.
Inspiratory pressure support prevents diaphragmatic fatigue during weaning from mechanical ventilation.
Brochard L, Harf A, Lorino H, Lemaire F.

Armed with such data, they delineated the pressure-support level that avoided fatigue but still maintained diaphragmatic activity. These studies ensured that misunderstanding about a mode's ability to assuage work, as with IMV, did not recur.

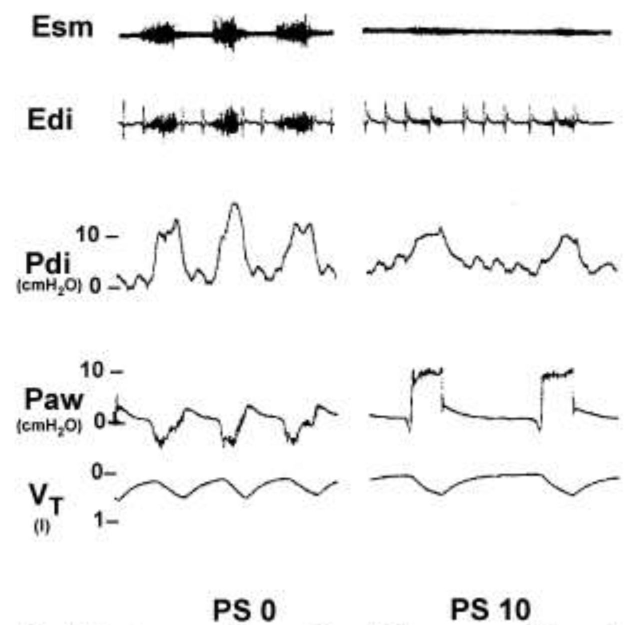


Fig. 4 Electromyographic recordings of the sternomastoid muscle (*Esm*) and diaphragm (*Edi*), transdiaphragmatic pressure (*Pdi*), airway pressure (*Paw*), and tidal volume (V_T) in a ventilator-supported patient. Compared with 0, pressure support of 10 cmH$_2$O decreased (but did not abolish) sternomastoid and diaphragmatic electrical activity, decreased Pdi, increased V_T, and slowed respiratory rate. (From Brochard et al. [35])

Historique

- 1985, Herrera, 1987, Sassoon. *P0.1*
- 1986, Milic Emili *CROP index*

- 1991, Yang *F/Vt*

- 1989, Torres, Rodriguez *RSB/Va/Q*
- 1991, Beydon, Harf, Lemaire *RSB/Va/Q*
- 1998, Tobin, Jubran *SvO2/DO2, EO2*

Historique

- 1998, Vassilakopoulos,

  Raw, AutoPEEP (succès<échecs)

  TTI, F/Vt meilleurs marqueurs de ***fatigue***

- 1994, Goldstone

  Ralentissement de la fréquence max de relaxation de la PTD marqueur de ***fatigue***

Historique

- 2003, Laghi,

Is Weaning Failure Caused by Low-Frequency Fatigue of the Diaphragm?

Franco Laghi, Steven E. Cattapan, Amal Jubran, Sairam Parthasarathy, Paul Warshawsky, Yoon-Sub A. Choi, and Martin J. Tobin

AMERICAN JOURNAL OF RESPIRATORY AND CRITICAL CARE MEDICINE VOL 167 2003

Utilisant la même technique que Goldstone, aucun patient n'a été jusqu'au seuil de fatigue!

Related analyses disclosed why. Failure patients became progressively distressed during the trial, leading clinicians to reinstate ventilator support before patients had breathed long enough to develop fatigue. That is, monitoring clinical signs of distress provides sufficient warning to avoid fatigue.

Physiologie du sevrage

Ventilation spontanée

↑ WOB

↑ VO_2rm

↑ Wc

↑ MVO_2

Ischémie coronaire

Physiologie du sevrage

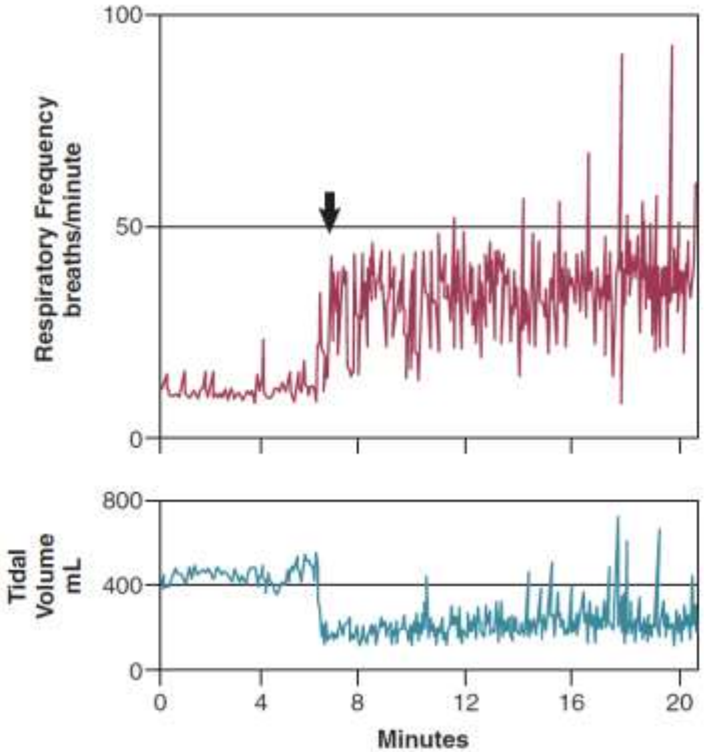
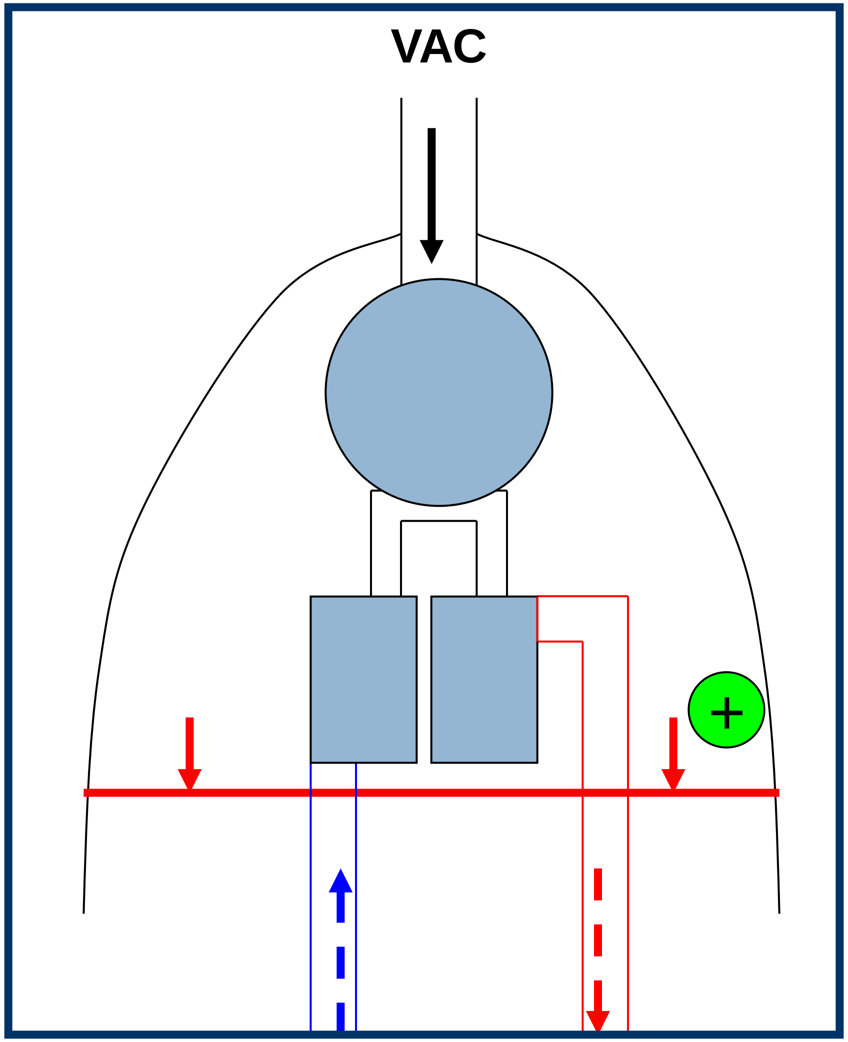


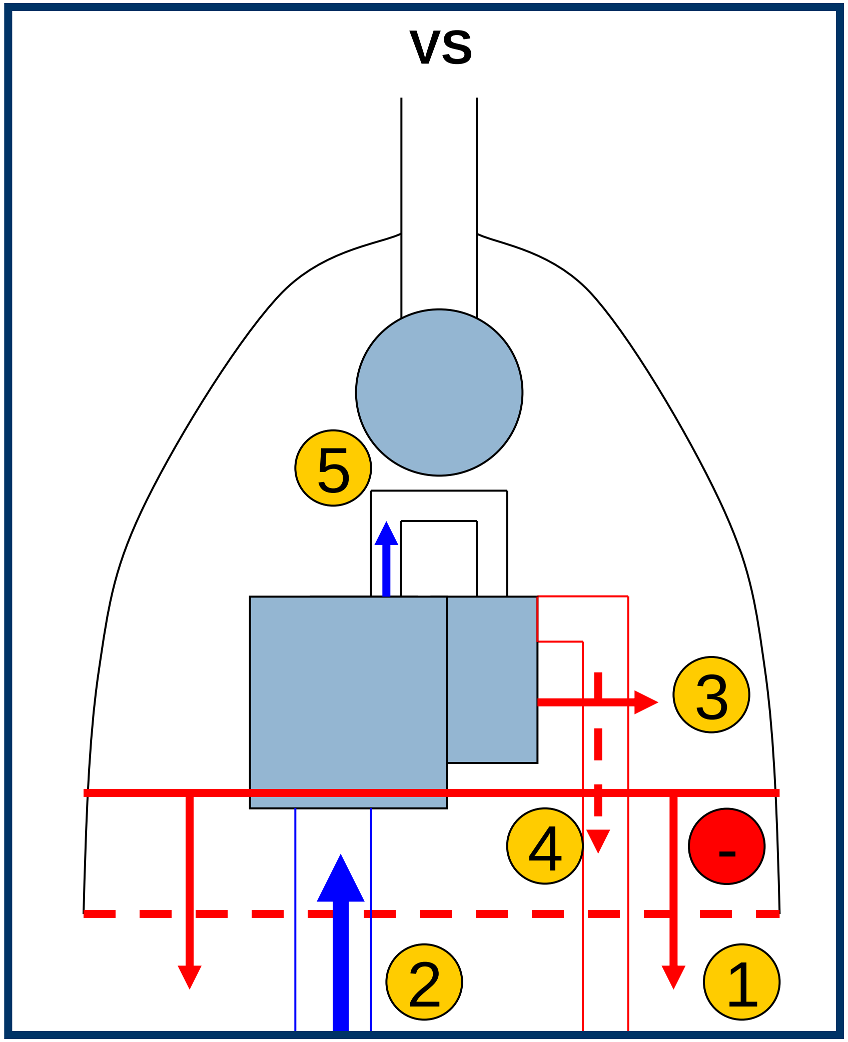
Figure 44-5. A time-series, breath-by-breath plot of respiratory frequency and tidal volume in a patient who failed a weaning trial. The arrow indicates the point of resuming spontaneous breathing. Rapid, shallow breathing developed almost immediately after discontinuation of the ventilator. (Redrawn from Tobin MJ, Perez W, Guenther SM, et al: The pattern of breathing during successful and unsuccessful trials of weaning from mechanical ventilation. Am Rev Respir Dis 1986;134:1111-1118.)

Physiologie du sevrage



Physiologie du sevrage

1. Inversion du régime de pression intra-thoracique.
2. ↑ gradient de pression de retour veineux
3. ↓ gradient de pression d'éjection du VG.
4. ↑ postcharge du VG.
5. OP.



Classification

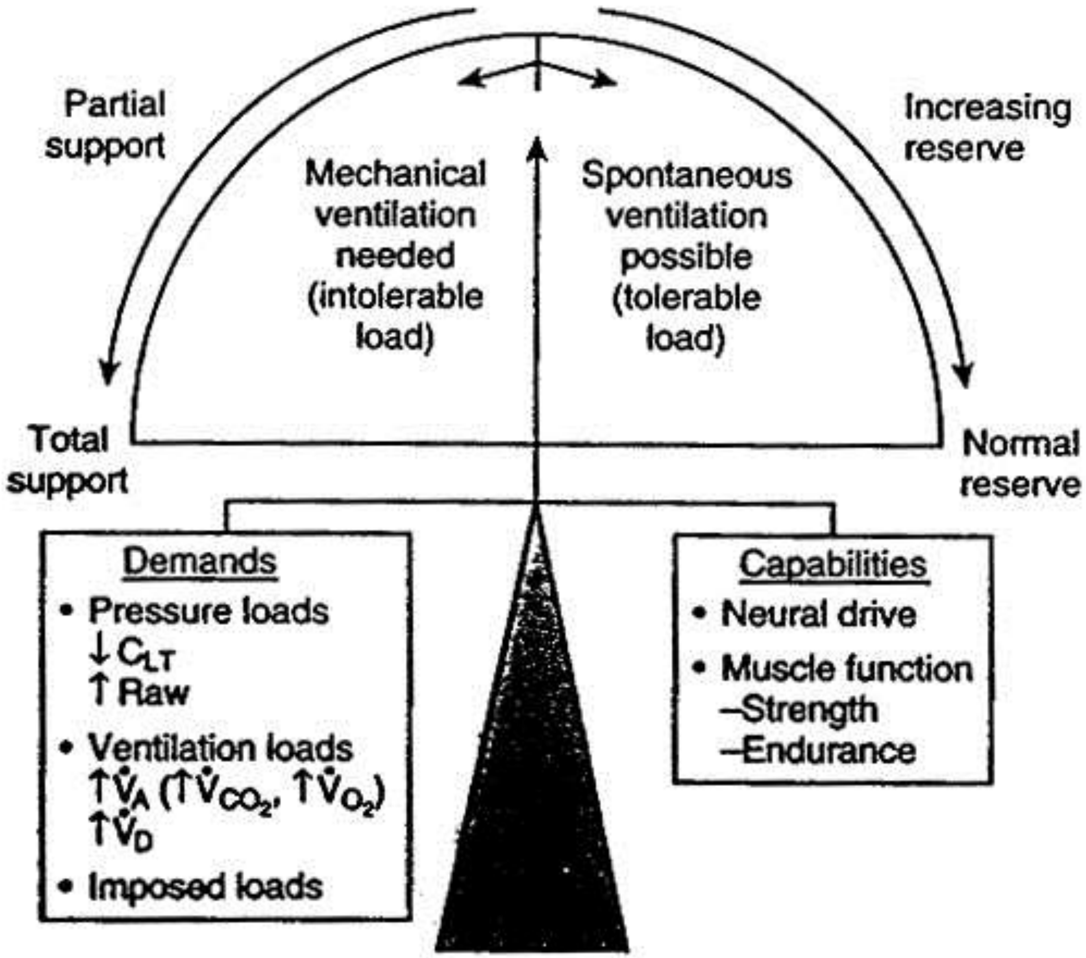
- **A** Airway / Lung
- **B** Brain
- **C** Cardiac
- **D** Diaphragm
- **E** Electrolyte / Endocrine

A Airway / Lung

Table 1. Factors affecting respiratory mechanics

Increased airway resistance	Reduced compliance
Tube (small diameter, sputum retention)	Chest wall
Central airways	Edema
Tracheostomy malposition	Elevated abdominal pressure
Sputum plug	Pleural fluid and ascites
Corpus alienum (after trauma)	Obesity
Tracheomalacia or tracheal stenosis	Lung
Small airways	Intrinsic positive end-expiratory pressure
Asthma and chronic obstructive pulmonary disease	Alveolar filling (edema, pus, and collapse)
Acute respiratory distress syndrome	Pneumonia
	Interstitial lung disease and fibrosis

A Airway / Lung



A Airway / Lung

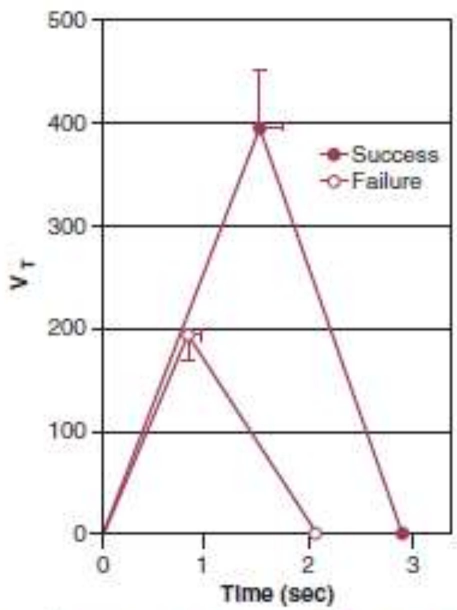


Figure 44-1. The mean respiratory cycle during spontaneous breathing in 7 weaning-failure and 10 weaning-success patients. The early termination of inspiratory time in the weaning-failure patients leads to a decrease in tidal volume (V_T). The decrease in inspiratory time, coupled with a decrease in expiratory time, results in a faster respiratory frequency. Bars represent 1 SE. (Redrawn from Tobin MJ, Perez W, Guenther SM, et al: The pattern of breathing during successful and unsuccessful trials of weaning from mechanical ventilation. Am Rev Respir Dis 1986;134:1111-1118.)

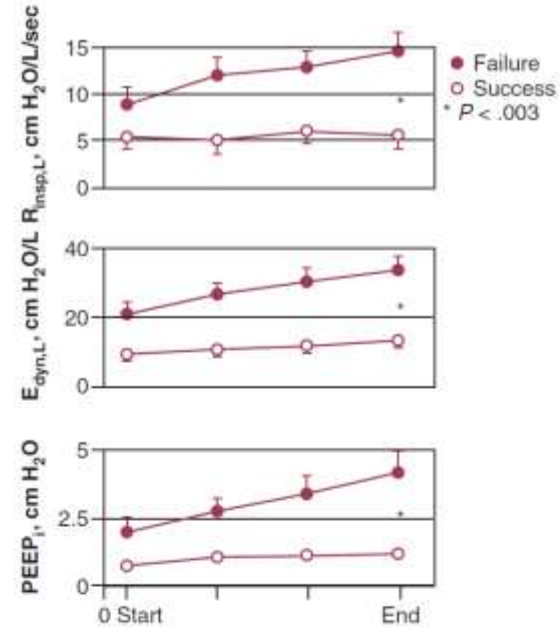


Figure 44-2. Inspiratory resistance of the lung ($R_{insp,L}$), dynamic lung elastance ($E_{dyn,L}$), and intrinsic positive end-expiratory pressure ($PEEP_i$) in 17 weaning-failure patients and 14 weaning-success patients. Data displayed were obtained during the second and last minute of a T-tube trial, and at one third and two thirds of the trial duration. Between the onset and end of the trial, the failure group developed increases in $R_{insp,L}$ ($P < .009$), $E_{dyn,L}$ ($P < .0001$), and $PEEP_i$ ($P < .0001$) and the success group developed increases in $E_{dyn,L}$ ($P < .006$) and $PEEP_i$ ($P < .02$). Over the course of the trial, the failure group had higher values of $R_{insp,L}$ ($P < .003$), $E_{dyn,L}$ ($P < .006$) and $PEEP_i$ ($P < .009$) than the success group. (Redrawn from Jubran A, Tobin MJ: Pathophysiologic basis of acute respiratory distress in patients who fail a trial of weaning from mechanical ventilation. Am J Respir Crit Care Med 1997;155:906-915.)

A Airway / Lung

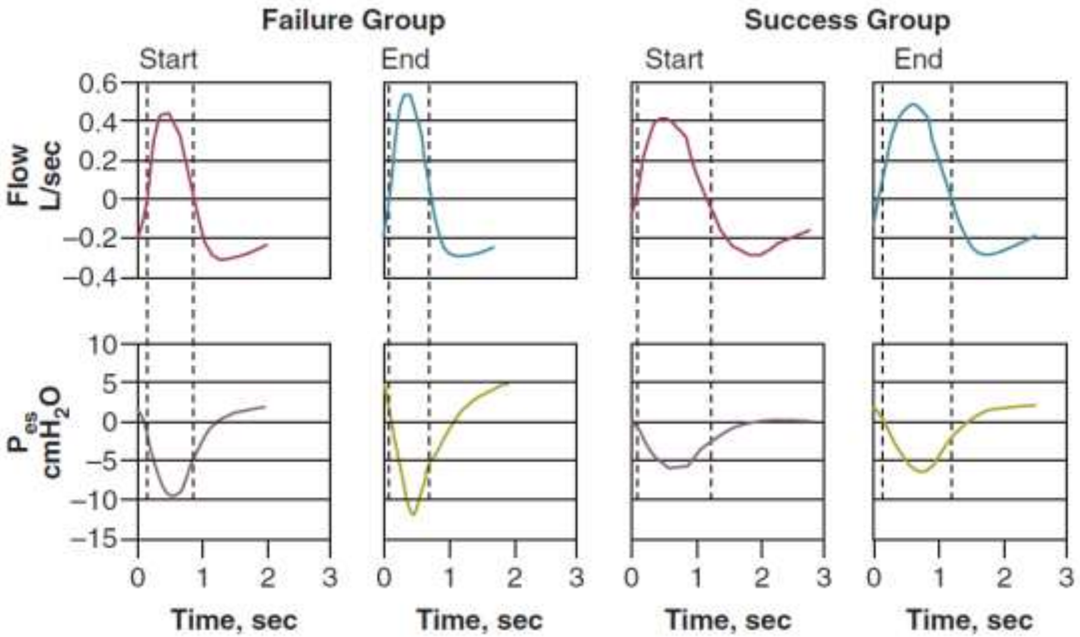


Figure 44-3. Ensemble average plots of flow and esophageal pressure (P_{es}) at the start and end of a T-tube trial in 17 weaning-failure patients and 14 weaning-success patients. At the start of the trial, the inspiratory excursion in P_{es} was greater in the failure patients, and it increased further by the end of the trial. To generate these plots, flow and P_{es} tracings were divided into 25 equal time intervals over a single respiratory cycle for each of the 5 breaths for each patient in the 2 groups. For a given patient, the five breaths from the start of the trial were then superimposed and aligned with respect to time, and the average at each time point was calculated. The group mean tracings were then generated by ensemble averaging of the individual mean from each patient. The same procedure was performed for breaths at the end of the trial. (Redrawn from Jubran A, Tobin MJ: Pathophysiologic basis of acute respiratory distress in patients who fail a trial of weaning from mechanical ventilation. Am J Respir Crit Care Med 1997;155:906-915.)

A Airway / Lung

- Résistance
- Compliance
- Echanges gazeux

A Airway / Lung

- Résistance : *AutoPEEP*
  - Hyperinflation dynamique
  - Diminution de la contractilité du diaphragme
  - Asynchronie patient/ventilateur

A Airway / Lung

- Résistance : AutoPEEP

Crit Care Med. 2009 Oct;37(10):2740-5.

Ineffective triggering predicts increased duration of mechanical ventilation.

de Wit M, Miller KB, Green DA, Ostman HE, Gennings C, Epstein SK.

Am J Respir Crit Care Med. 1997 Mar;155(3):906-15.

Pathophysiologic basis of acute respiratory distress in patients who fail a trial of weaning from mechanical ventilation.

Jubran A, Tobin MJ.

Am J Respir Crit Care Med. 1998 Aug;158(2):378-85.

The tension-time index and the frequency/tidal volume ratio are the major pathophysiologic determinants of weaning failure and success.

Vassilakopoulos T, Zakynthinos S, Roussos C.

A Airway / Lung

- Résistance
- Compliance
- Echanges gazeux

A Airway / Lung

- Compliance

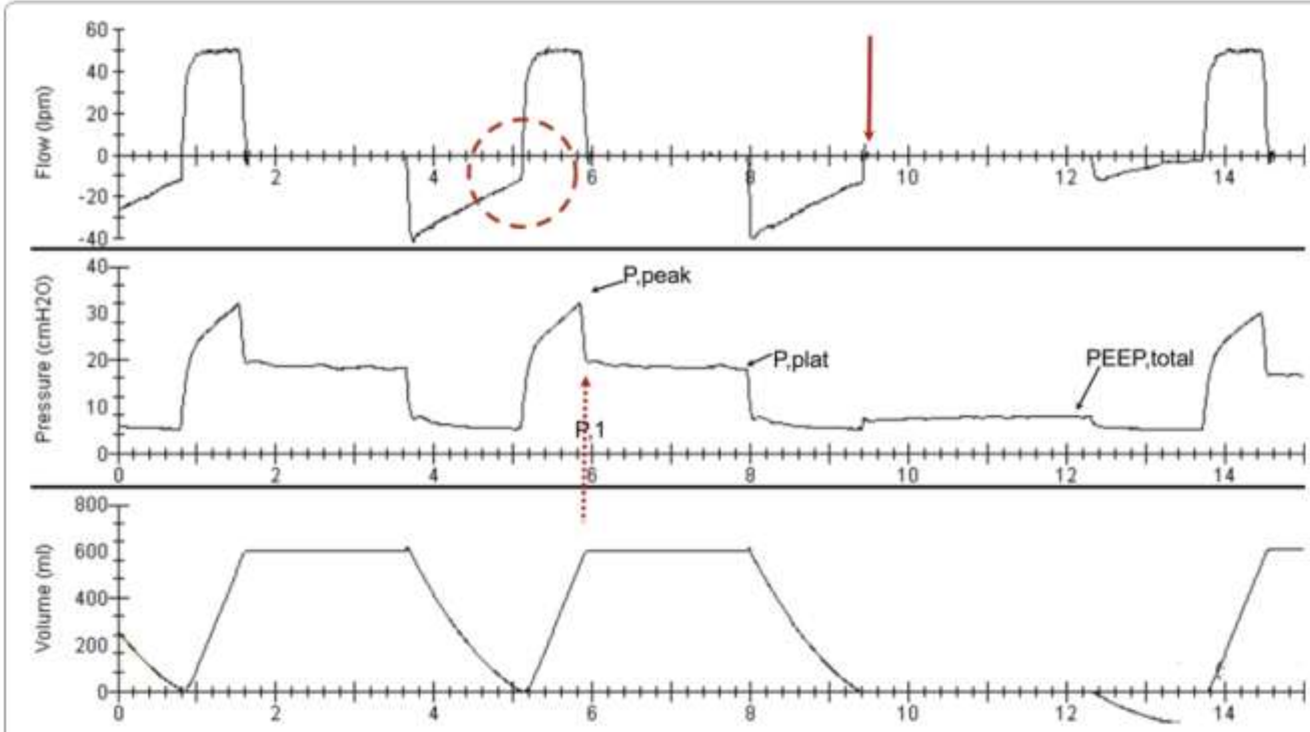


Figure 2. Tracings obtained from ventilator while operating in the volume-controlled mode. Flow, pressure, and volume in time are presented from top ... ositive end-expiratory pressure ... dle panel), reflecting total PEE ... resulting in rapid decay in airw ...

Crs = Vt/(Pplat-PEEP) *[nl=60-100ml/cmH2O]*

A Airway / Lung

- Compliance

Crs plus basse chez les échecs de sevrage d'un SDRA

Am J Respir Crit Care Med. 1998 Aug;158(2):378-85.
The tension-time index and the frequency/tidal volume ratio are the major pathophysiologic determinants of weaning failure and success.
Vassilakopoulos T, Zakynthinos S, Roussos C.

A Airway / Lung

- Résistance
- Compliance
- Echanges gazeux

A Airway / Lung

- Echanges gazeux

  - Impossibilité d'augmenter la ventilation minute en réponse à l'hypercapnie. *(faiblesse musculaire, altération de la mécanique ventilatoire)*

Am Rev Respir Dis. 1986 Dec;134(6):1111-8.

The pattern of breathing during successful and unsuccessful trials of weaning from mechanical ventilation.

Tobin MJ, Perez W, Guenther SM, Semmes BJ, Mador MJ, Allen SJ, Lodato RF, Dantzker DR.

A Airway / Lung

- Echanges gazeux

  - Intérêt de limiter l'espace mort instrumental.

Chest. 1996 Nov;110(5):1294-8.

Comparison of the effects of heat and moisture exchangers and heated humidifiers on ventilation and gas exchange during weaning trials from mechanical ventilation.

Le Bourdellès G, Mier L, Fiquet B, Djedaïni K, Saumon G, Coste F, Dreyfuss D.

B Brain

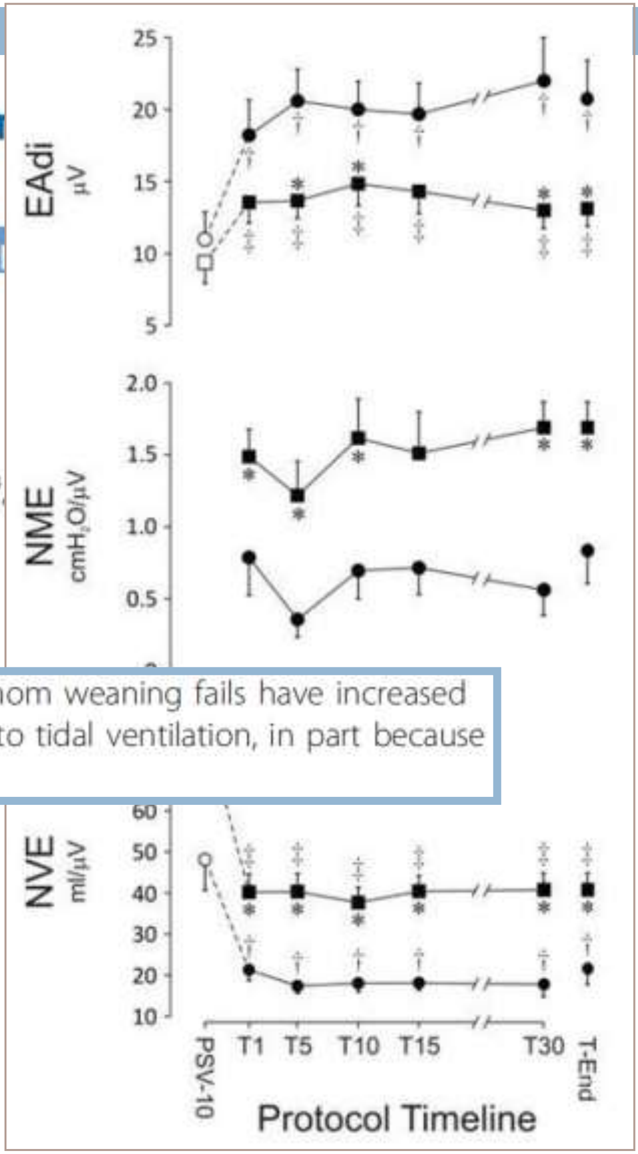
Liu *et al. Critical Care* 2012, **16**:R143
http://ccforum.com/content/16/4/R143

CRIT

RESEARCH

Neuroventilatory efficiency and extubation readiness in critically ill patients

Ling Liu[1], Huogen Liu[1], Yi Yang[1], Yingzi Huang[1], Songqiao Liu[1], Jennifer Beck[2,3], Arthur S Slutsky[2,4],
Christer Sinderby[2,4*] and Haibo Qiu[1]



Conclusions: This study shows that a mixed group of critically ill patients for whom weaning fails have increased neural respiratory drive and impaired ability to convert neuromuscular activity into tidal ventilation, in part because of diaphragm weakness.

B Brain

- Delirium

Intensive Care Med (2004) 30:1334–1339
DOI 10.1007/s00134-004-2231-7

ORIGINAL

Adil Salam
Lisa Tilluckdharry
Yaw Amoateng-Adjepong
Constantine A. Manthous

Neurologic status, cough, secretions and extubation outcomes

4 fois plus de risque d'échec!

B Brain

Troubles dépressifs

Intensive Care Med (2010) 36:828–835
DOI 10.1007/s00134-010-1842-4

ORIGINAL

Amal Jubran
Gerald Lawm
Joanne Kelly
Lisa A. Duffner
Gokay Gungor
Eileen G. Collins
Dorothy M. Lanuza
Leslie A. Hoffman
Martin J. Tobin

Depressive disorders during from prolonged mechanical v

Conclusion: Depressive disorders were diagnosed in 42% of patients who were being weaned from prolonged ventilation. Patients with depressive disorders were more likely to experience weaning failure and death.

J Clin Psychiatry. 2000 Oct;61(10):750-5.

Treatment of depression with methylphenidate in patients difficult to wean from mechanical ventilation in the intensive care unit.

Rothenhäusler HB, Ehrentraut S, von Degenfeld G, Weis M, Tichy M, Kilger E, Stoll C, Schelling G, Kapfhammer HP.

B Brain

- Troubles du sommeil?

Pas de données sur un éventuel effet de l'altération de l'architecture du sommeil sur le sevrage!

C Cardiac

- **L'ischémie myocardique**

- **L'oedème aigu du poumon**
  - *Elévation de la postcharge du VG*
  - *Elévation de la précharge du VG*
  - *Diminution de la compliance*
  - *Hypoperfusion viscérale*

C Cardiac

- **L'ischémie myocardique**

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  - *Elévation de la postcharge du VG*
  - *Elévation de la précharge du VG*
  - *Diminution de la compliance*
  - *Hypoperfusion viscérale*

C Cardiac

- **L'ischémie myocardique**
  - *Volontiers chez les coronariens*

Intensive Care Med. 1991;17(4):199-203.

Plasma catecholamines and oxygen consumption during weaning from mechanical ventilation.

Oh TE, Bhatt S, Lin ES, Hutchinson RC, Low JM.

C Cardiac

- **L'ischémie myocardique**
  - *Volontiers chez les coronariens*
  - *Hypoxémie*

  Hétérogénéité des rapports VA/Q

  Déterminants cardio-vasculaires des échecs du sevrage.
  Castelain V, JL T.
  Réanimation 2001;10:717-22.

  Effet PvO2 basse

  Continuous Recordings of Mixed Venous Oxygen Saturation during Weaning from Mechanical Ventilation and the Ramifications Thereof

  AMAL JUBRAN, MALI MATHRU, DAVID DRIES, and MARTIN J. TOBIN
  AMERICAN JOURNAL OF RESPIRATORY AND CRITICAL CARE MEDICINE VOL 158 1998

C Cardiac

- **L'ischémie myocardique**
  - *Volontiers chez les coronariens*
  - *Hypoxémie*
  - *Tachycardie (diminution du temps diastolique)*
    - La sécrétion accrue de catécholamines ;
    - l'élévation de postcharge consécutive à la diminution de la pression intrathoracique ;
    - l'augmentation du travail cardiaque consécutif à l'élévation de la demande globale en oxygène.

C Cardiac

- **L'ischémie myocardique**

- **L'oedème aigu du poumon**
  - *Elévation de la postcharge du VG*
  - *Elévation de la précharge du VG*
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C Cardiac

- **L'oedème aigu du poumon**
  - *Elévation de la postcharge du VG*
  - *Elévation de la précharge du VG*
  - *Diminution de la compliance*
  - *Hypoperfusion viscérale*

C Cardiac

L'oedème aigu du poumon

- *Elévation de la postcharge du VG*
  - *Effet de la pression intrathoracique (manœuvre de Muller)*

Augmentation de la VO2

Anesthesiology. 1966 Sep-Oct;27(5):584-90.

Hemodynamic effects of intermittent positive pressure respiration.

Morgan BC, Martin WE, Hornbein TF, Crawford EW, Guntheroth WG.

Augmentation de la PAPO

Anesthesiology
69:171–179, 1988

Acute Left Ventricular Dysfunction during Unsuccessful Weaning from Mechanical Ventilation

Francois Lemaire, M.D., Jean-Louis Teboul, M.D.,† Luc Cinotti, M.D.,‡ Guillen Giotto, M.D.,§ Fekri Abrouk, M.D.,§ Gabriel Steg, M.D.,§ Isabelle Macquin-Mavier, M.D.,¶ Warren M. Zapol, M.D.***

C Cardiac

- **L'oedème aigu du poumon**
  - *Elévation de la postcharge du VG*
    - *Effet de la pression intrathoracique (manœuvre de Muller)*
    - *Effet de l'hypertonie sympathique*

Elévation de la postcharge par l'élévation de la pression artérielle.

C Cardiac

- **L'oedème aigu du poumon**
  - *Elévation de la postcharge du VG*
  - *Elévation de la précharge du VG*
  - *Diminution de la compliance*
  - *Hypoperfusion viscérale*

C Cardiac

- **L'oedème aigu du poumon**
  - *Elévation de la postcharge du VG*
  - *Elévation de la précharge du VG*

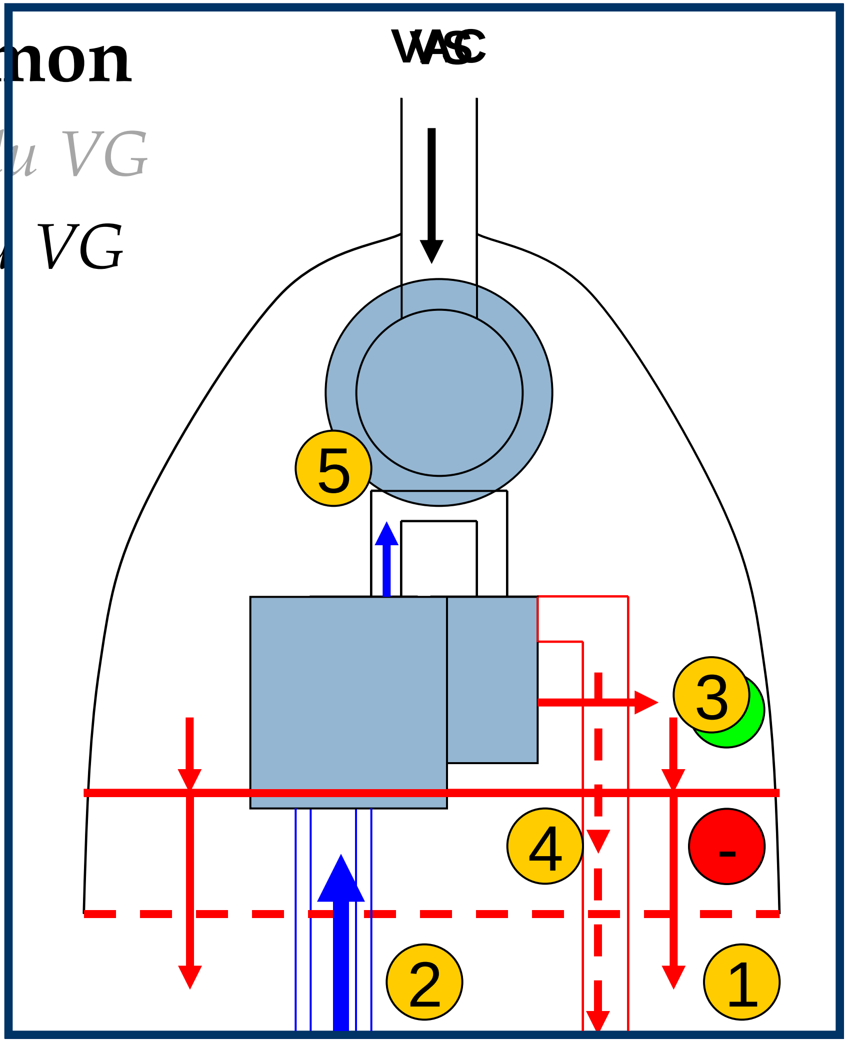
J Appl Physiol. 1984 May;56(5):1237-45.

Determinants of pulmonary arterial flow variation during respiration.

Pinsky MR.

Précharge-dépendance du VD

Cardiopathie gauche préexistante



C Cardiac

- **L'oedème aigu du poumon**
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  - *Elévation de la précharge du VG*
  - *Diminution de la compliance*
  - *Hypoperfusion viscérale*

C Cardiac

- **L'oedème aigu du poumon**
  - *Elévation de la postcharge du VG*
  - *Elévation de la précharge du VG*
  - *Diminution de la compliance du VG*
    - *Interdépendance ventriculaire directe et indirecte (OP/BPCO)*
      - *↑ impédance éjection VD*
      - *Compression des vaisseaux alvéolaires*

    - *Ischémie myocardique*

C Cardiac

L'oedème aigu du poumon

- *Elévation de la postcharge du VG*
- *Elévation de la précharge du VG*
- *Diminution de la compliance*
- *Hypoperfusion viscérale*

Am Rev Respir Dis. 1982 Jul;126(1):9-13.

The oxygen cost of breathing in patients with cardiorespiratory disease.

Field S, Kelly SM, Macklem PT.

Crit Care Med. 2001 Jan;29(1):70-6.

Gastric intramucosal pH and intraluminal PCO2 during weaning from mechanical ventilation.

Hurtado FJ, Berón M, Olivera W, Garrido R, Silva J, Caragna E, Rivara D.

Ann Intern Med. 1993 Oct 15;119(8):794-8.

Gastric intramural pH as a predictor of success or failure in weaning patients from mechanical ventilation.

Mohsenifar Z, Hay A, Hay J, Lewis MI, Koerner SK.

D Diaphragm

- Altération de la commande neurale
- Lésions du phrénique
- « ICU-acquired weakness »

D Diaphragm

- Altération de la commande neurale

Am Rev Respir Dis. 1986 Dec;134(6):1111-8.

The pattern of breathing during successful and unsuccessful trials of weaning from mechanical ventilation.

Tobin MJ, Perez W, Guenther SM, Semmes BJ, Mador MJ, Allen SJ, Lodato RF, Dantzker DR.

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Liu *et al. Critical Care* 2012, **16**:R143
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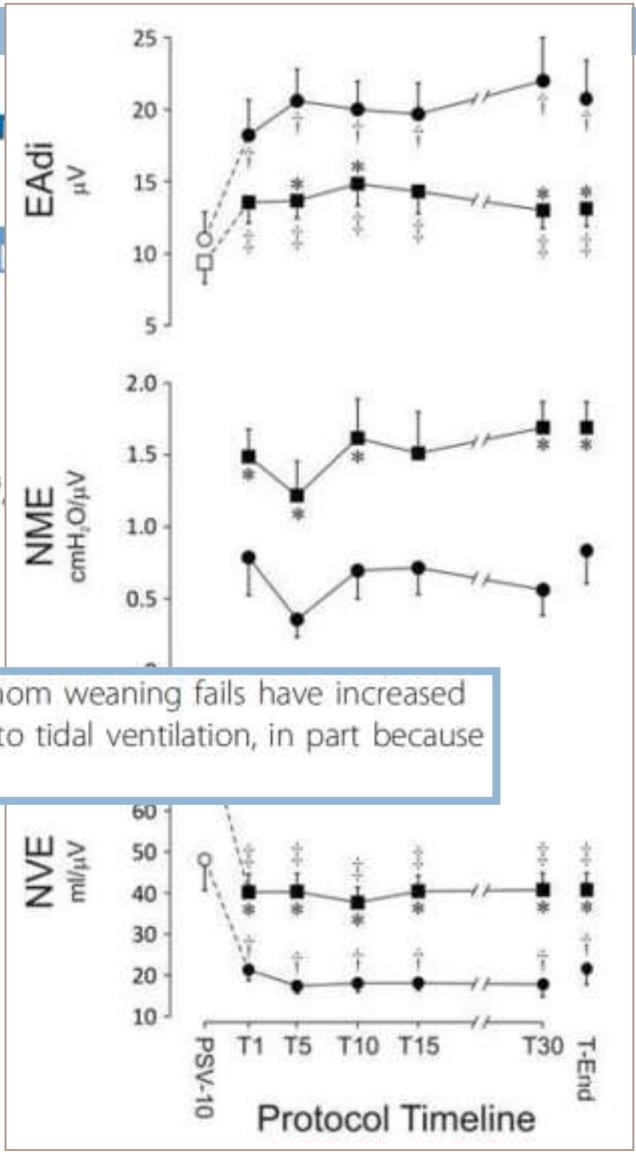


Conclusions: This study shows that a mixed group of critically ill patients for whom weaning fails have increased neural respiratory drive and impaired ability to convert neuromuscular activity into tidal ventilation, in part because of diaphragm weakness.

D Diaphragm

- Altération de la commande neurale
- Lésions du phrénique

  (mécanique ou polyneuropathie de réanimation)

D Diaphragm

- Altération de la commande neurale
- Lésions du phrénique
- « ICU-acquired weakness »

Am J Respir Crit Care Med. 1996 Oct;154(4 Pt 1):1099-105.

Bilateral magnetic stimulation of the phrenic nerves from an anterolateral approach.

Mills GH, Kyroussis D, Hamnegard CH, Polkey MI, Green M, Moxham J.

PTD=35% chez les échecs vs contrôles

D Diaphragm

- « ICU-acquired weakness »

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 MARCH 27, 2008 VOL. 358 NO. 13

Rapid Disuse Atrophy of Diaphragm Fibers in Mechanically Ventilated Humans

Sanfor … M.D.,
Murat T … M.D.,
Seema Son … .D., Ed.D.,

Atrophie profonde des fibres musculaires chez les patients en VMx18-96h.

Muscle weakness in ICU-patients or muscle fatigue in weaning-failure patients?

D Diaphragm

- « ICU-acquired weakness »

Is Weaning Failure Caused by Low-Frequency Fatigue of the Diaphragm?

Franco Laghi, Steven E. Cattapan, Amal Jubran, Sairam Parthasarathy, Paul Warshawsky, Yoon-Sub A. Choi, and Martin J. Tobin

AMERICAN JOURNAL OF RESPIRATORY AND CRITICAL CARE MEDICINE VOL 167 2003

Laghi and colleagues [41] assessed diaphragm force before and 30 minutes after a failed-weaning trial. Surprisingly, these patients did not develop inspiratory muscle fatigue. Possible explanations for these unexpected findings include early reconnection of the patient to the ventilator, recruitment of other inspiratory muscles, or muscle recovery from fatigue within 30 minutes after the weaning trial. Although ICU-acquired weakness is the most

D Diaphragm

- « ICU-acquired weakness »

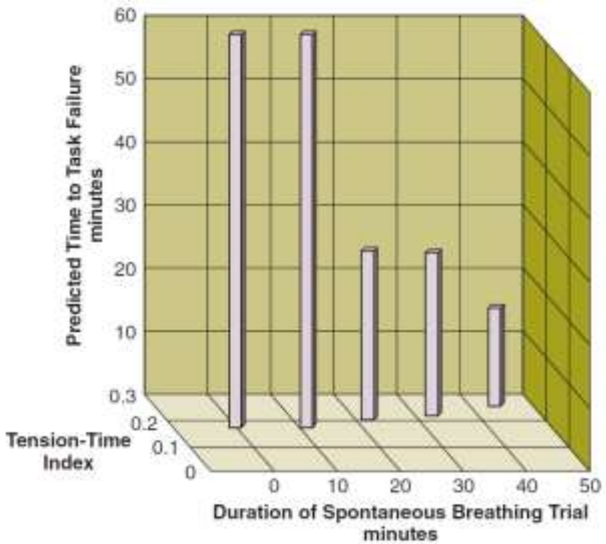


Figure 44-4. Interrelationship between the duration of a spontaneous breathing trial, tension-time index of the diaphragm, and predicted time to task failure in nine patients who failed a trial of weaning from mechanical ventilation. The patients breathed spontaneously for an average of 44 minutes before a physician terminated the trial. At the start of the trial, the tension-time index was 0.17, and the formula of Bellemare and Grassino[16] (see text for details) predicted that patients could sustain spontaneous breathing for another 59 minutes before developing task failure. As the trial progressed, the tension-time index increased and the predicted time to development of task failure decreased. At the end of the trial, the tension-time index reached 0.26. That patients were predicted to sustain spontaneous breathing for another 13 minutes before developing task failure clarifies why patients did not develop a decrease in diaphragmatic twitch pressure. In other words, physicians interrupted the trial on the basis of clinical manifestations of respiratory distress, before patients had sufficient time to develop contractile fatigue. (Redrawn from Laghi F, Tobin MJ: Disorders of the respiratory muscles. Am J Respir Crit Care Med 2003;168:10-48.)

D Diaphragm

Role of the respiratory muscles in acute respiratory failure of COPD: lessons from weaning failure

Martin J. Tobin, Franco Laghi and Laurent Brochard

J Appl Physiol 107:962-970, 2009. First published 30 April 2009;
doi: 10.1152/japplphysiol.00165.2009

D Diaphragm

Ann Intern Med. 2010 August 17; 153(4): 240–245. doi:10.1059/0003-4819-153-4-201008170-00006.

Ventilator-induced respiratory muscle weakness

Martin J. Tobin, MDFranco Laghi, MDAmal Jubran, MD

Ventilation mécanique, sédation

Inactivité musculaire

Lésions sévères et atrophie des fibres musculaires

(Stress oxidatif, protéolyse)

Diaphragm

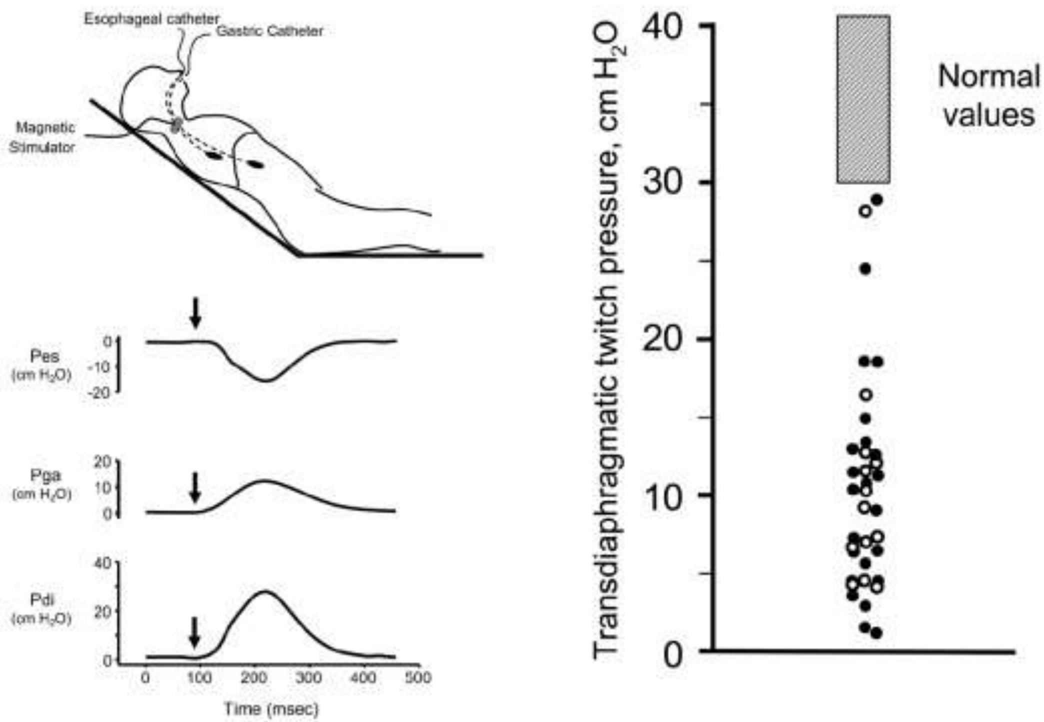


Figure 1.
The *upper-left panel* shows the instrumentation for measurement of transdiaphragmatic pressure is response to stimulation of the phrenic nerves. Balloon catheters are passed through the nose to record esophageal pressure (Pes) and gastric pressure (Pga); transdiaphragmatic pressure (Pdi) is calculated by subtracting Pes from Pga. A special magnet is used to stimulate the phrenic nerves. The *bottom-left panel* shows the fall in Pes and rise in Pga and Pdi in response to phrenic-nerve stimulation (indicated by arrows). The *right panel* shows values of transdiaphragmatic pressure in response to stimulation of the phrenic nerves in patients requiring mechanical ventilation. The boxed area represents the 95% confidence interval of values obtained in healthy subjects. Data represented by open and closed symbols are taken respectively from Cattapan et al (29) and Watson et al (30).

D Diaphragm

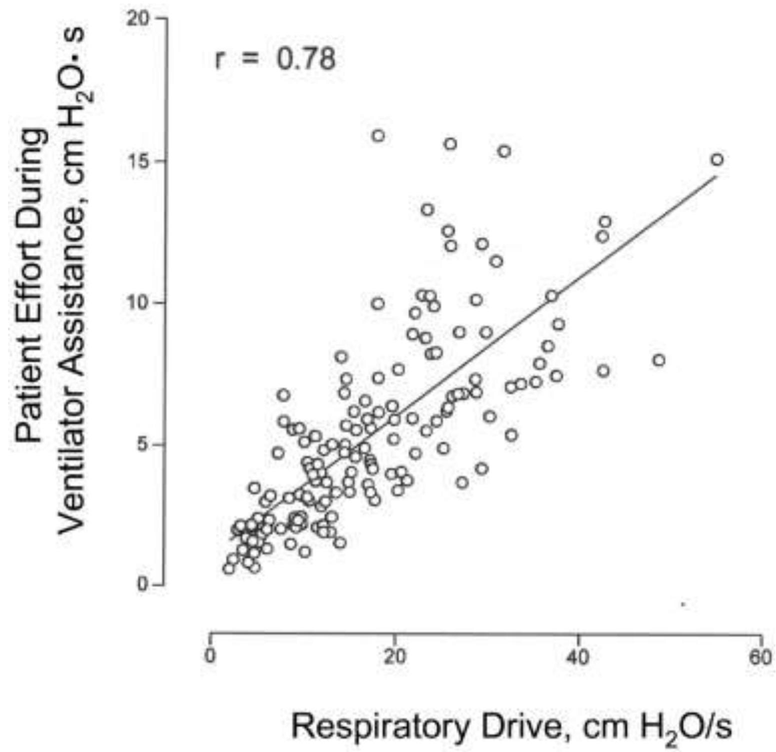
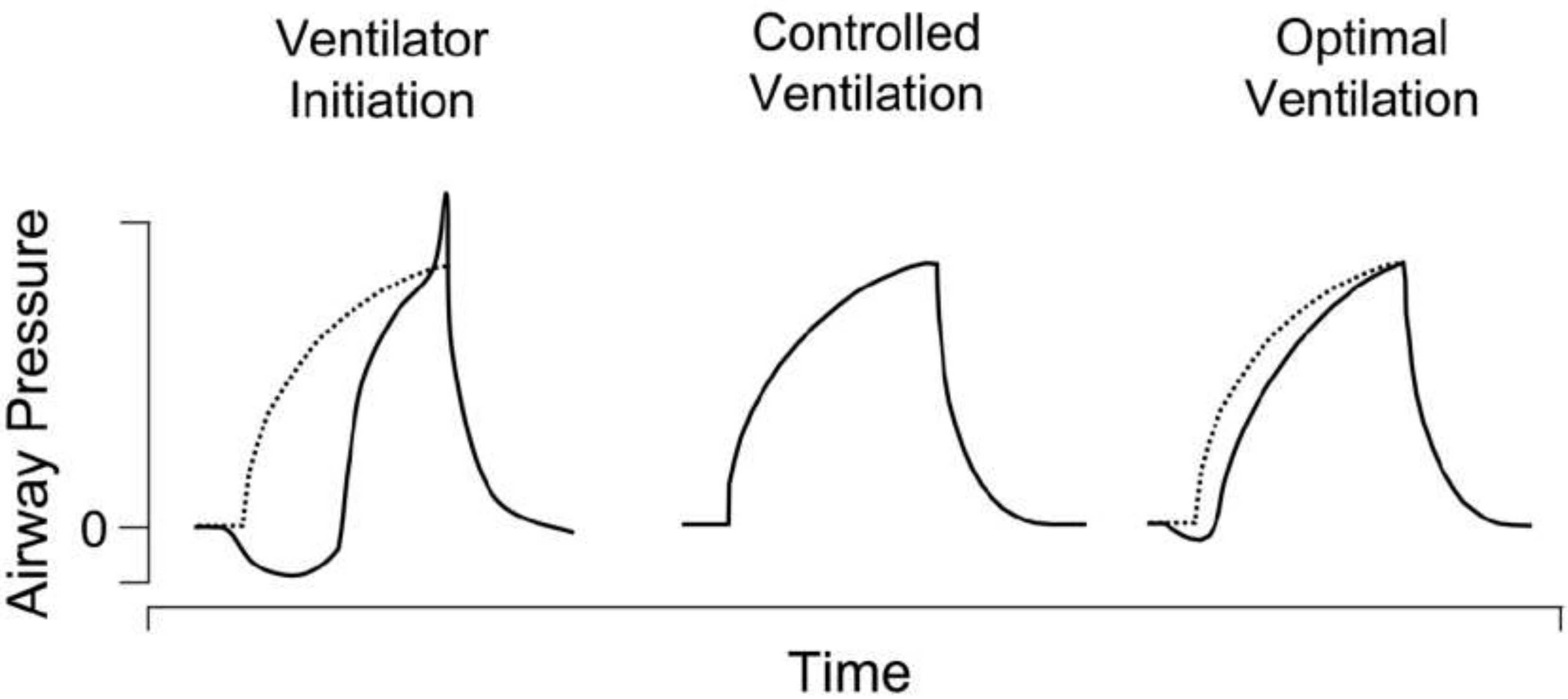


Figure 2.
Patient effort during the time that the ventilator is delivering a breath (measured as inspiratory pressure-time product per breath in cm $H_2O.s$) is closely related to a patient's respiratory drive (measured as dP/dt in cm H_2O/sec) at the moment that a patient triggers the ventilator (r=0.78). The inspiratory muscles of patient who has a low respiratory drive at the time of triggering the ventilator will perform very little work during the remainder of inspiration when the ventilator is providing assistance. Conversely, the inspiratory muscles of a patient who has a high respiratory drive will expend considerable effort throughout the period of inspiration even though the mechanical ventilator is providing assistance. ***(Based on data published in*** (31))

D Diaphragm



Ventilator Initiation
Controlled Ventilation
Optimal Ventilation
Airway Pressure
0
Time

D Diaphragm

Causes of respiratory muscle weakness

Preexisting conditions	Examples or Mechanisms
Neuromuscular disorders	Guillain-Barre syndrome
Hyperinflation	COPD
Malnutrition	Crohn's disease
Endocrine disturbances	Hypo/Hyperthyroidism
Conditions of new onset	
Ventilator-associated respiratory muscle injury	Oxidative stress/Protein catabolism
Sepsis-associated myopathy	Oxidative stress/Protein catabolism
Intensive care unit acquired paresis	Multiple organ failure
Acidosis	Decreased contractility
Electrolyte disturbances	Hypokalemia
Medications	Corticosteroids, aminoglicosides, neuromuscular blocking agents

E Electrolyte / Endocrine

- Insuffisance surrénalienne

Association between Adrenal Insufficiency and Ventilator Weaning

Chung-Jen Huang and Horng-Chyuan Lin

Department of Thoracic Medicine II, Chang Gung Memorial Hospital, Taipei, Taiwan

AMERICAN JOURNAL OF RESPIRATORY AND CRITICAL CARE MEDICINE VOL 173 2006

70 insuffisance surrénale/93 patients difficiles à sevrer.
Traitement de l'IS réduit la durée de sevrage (3.4±2.3 vs 6.5±4.7j)

E Electrolyte / Endocrine

- Hypothyroidism

Hypothyroidism and Failure To Wean in Patients Receiving Prolonged Mechanical Ventilation at a Regional Weaning Center*

Debapriya Datta, MD, FCCP†; and Paul Scalise, MD, FCCP

CHEST / 126 / 4 / OCTOBER, 2004

4 hypothyroïdies/140 patients difficiles à sevrer.

Traitement de l'hypothyroïdie autorise le sevrage chez ¾.

E Electrolyte / Endocrine

- Malnutrition

Intensive Care Med (2000) 26: 518–525

ORIGINAL

C. Faisy
A. Rabbat
B. Kouchakji
J.-P. Laaban

Bioelectrical impedance analysis in estimating nutritional status and outcome of patients with chronic obstructive pulmonary disease and acute respiratory failure

Malnutrition associée au mauvais pronostic et difficulté de sevrage.

E Electrolyte / Endocrine

- Electrolytes
  - Hypophosphorémie
  - Hypomagnésémie
  - Hypocalcémie
  - Hypokaliémie profonde