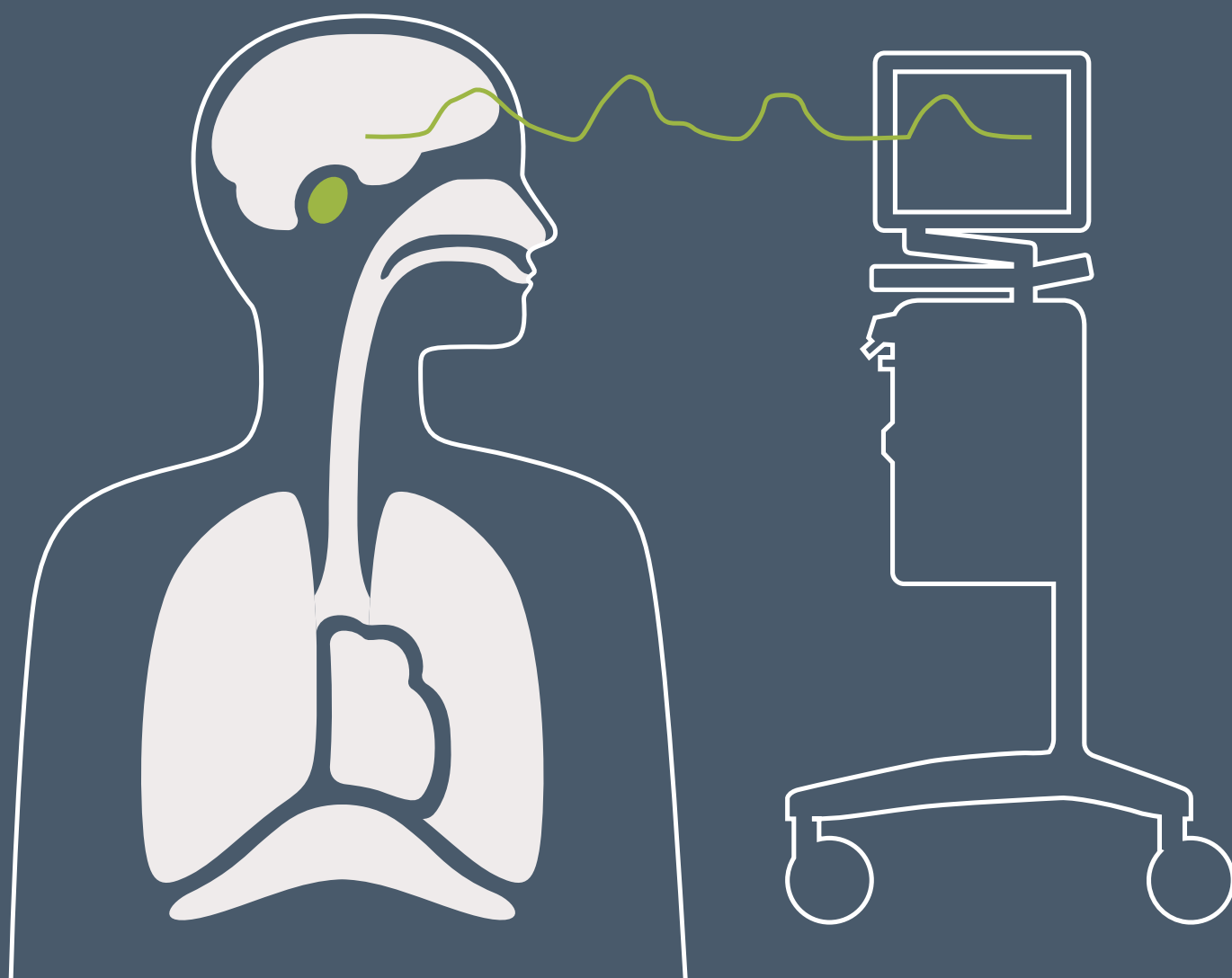




Diaphragm monitoring

helping you improve mechanical ventilation

Respiratory support is a lifesaving intervention in the ICU, but without the right balance, it also increases the risk of detrimental outcomes. This is when diaphragm monitoring can help, because it is the vital sign of breathing and a marker of outcomes such as hospital mortality and prolonged weaning.

The clinical impact of diaphragm injury

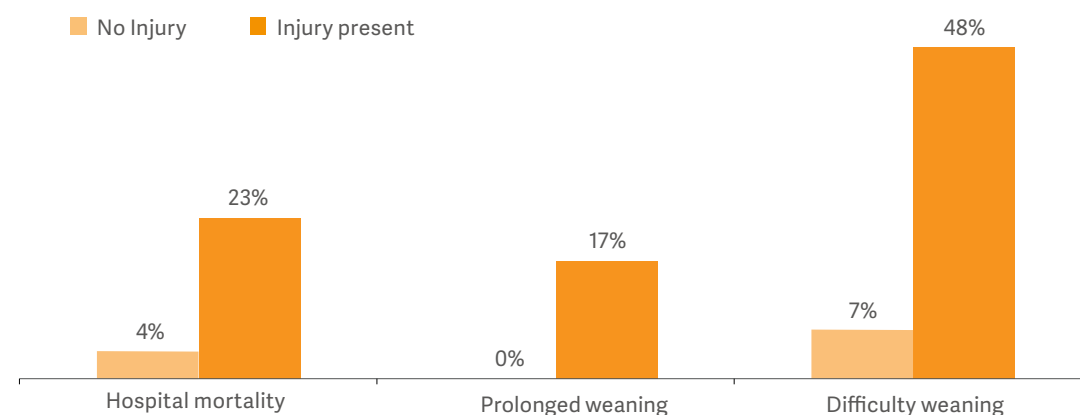


Figure 1

Diaphragm injury significantly increases the risk of worsened outcomes, such as difficult weaning, prolonged weaning, and hospital mortality.^{1,2} Furthermore, 23-84% of patients exhibit significant diaphragm injury at the first spontaneous breathing trial.³ One study showed an average time on ventilation of 576 hours for patients with diaphragm injury, compared to 203 hours for patients without injury.⁴

Main causes are believed to be driven by two factors. In some cases, patients are working too hard to breathe, leading to thickening of the diaphragm. In other cases, patients are working too little, in the wake of atrophy. Both changes impaired outcomes, and the challenge for clinicians today is that commonly used ventilator diagnostics fail to capture this information.

Why current ventilator diagnostics are not enough

Ventilator curves are used to interpret patient respiratory needs, but their primary function is to show what the machine delivers to the patient. This makes it difficult to detect asynchrony, over-sedation, over-assist or underassist during spontaneous breathing. For example, only 21% of clinicians detect asynchrony in the form of missed inspiratory efforts.⁵ A patient on pressure support ventilation can appear to be triggering spontaneous breaths, when in reality they are not adequately triggering any spontaneous breaths at all. Diaphragmatic monitoring will show the lack of patient triggered breaths for the over-assisted diaphragm.^{5,6}

The result is uncertainty about how much breathing effort your patient is exerting and to what extent he or she is at risk of incurring diaphragm injury.

How to monitor the diaphragm

In order to try and safeguard the diaphragm you need to assess the risk of potential injury and monitor its continuous activity.

An ultrasound helps you assess diaphragm dysfunction by measuring its thickness and potential changes to thickness over time. Recent advances in ultrasound imaging enable clinicians to more feasibly assess diaphragm function and potentially protect the diaphragm during mechanical ventilation.⁷

For continuous, breath-by-breath monitoring of diaphragm function there is the electrical activity of the diaphragm (Edi). It is a bedside diagnostic tool obtained through a specially designed feeding tube. The voltage signal is displayed as a waveform alongside the patient's conventional pressure/flow curves, and shows the presence, absence and pattern of breathing.

Edi can help you understand the work of breathing, detect asynchronies and assess the extent to which over-assist or under-assist and sedation are affecting breathing ability.^{8,9} You can also detect changes in effort following interventions.

Arguably, a combination of ultrasound and continuous diaphragm monitoring (Edi) is needed for the complete picture.

How diaphragm monitoring may help protect the patient and simplify weaning

To avoid ventilator induced lung injury you want to avoid invasive ventilation, asynchronies, over- and under-assistance and longer periods of sedation and diaphragm inactivity. Patients 'fighting the ventilator' often lose. Increased sedation, prolonged ventilation and intubation tend to be the result. Diaphragm monitoring may help manage these challenges.¹⁰⁻¹² It may help you see efforts made by the patient, breath by breath. And you can see if the ventilator responds in time, with the appropriate amount of support, because you have an objective, physiological value to guide you.

In non-invasive therapy, this may help you adapt the timing and the support of the ventilator, which may reduce the need to intubate. Good patient-ventilator interaction is one of the key factors of successful NIV.¹¹

Continuous monitoring can also act as a real time indicator of breathing effort, helping you understand when intubation is really necessary. It may even help you optimize the timing of spontaneous breathing trials as well as progress them more successfully, more often.



Diaphragm monitoring may help decrease time on ventilation

■ ≥10% Decrease in thickness ■ <10% Change in thickness ■ ≥10% Increase in thickness

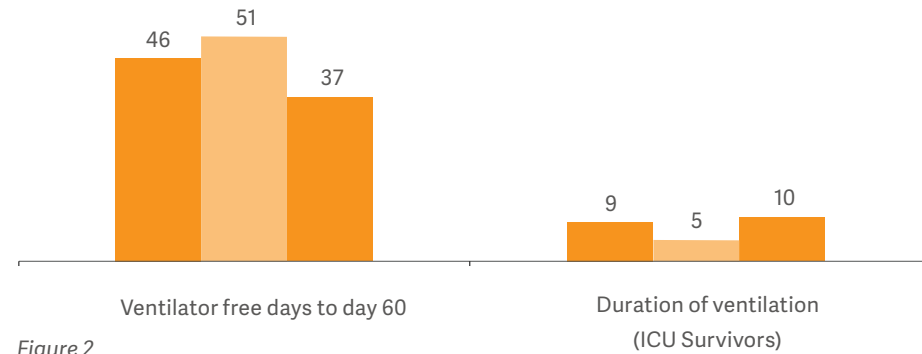


Figure 2

Goligher showed that early change of diaphragm thickness was a marker of ICU length of stay and other complications such as reintubation, tracheostomy, prolonged mechanical ventilation and death.¹ It indicates that staying within a 10-20% thickening fraction may be the optimal way forward. As such it can give you indications of patient risk and help you optimize the treatment. To further understand if the avoidance of diaphragm injury could prevent complications requires randomized clinical trials.

In line with Figure 2, however is the clinical experience from a London hospital, which indicated a significant reduction in time spent on mechanical ventilation when monitoring diaphragm activity.¹³ The non-monitored group had a median of 12 days on mechanical ventilation compared to a median of 9 days for the monitored group (103 patients of 493).

Monitoring the diaphragm may also help you discover disruptions, such as congenital central hypoventilation syndrome and phrenic nerve damage.^{14,15}

Diaphragm monitoring can help you make more informed treatment decisions

Monitoring diaphragm activity can help you make more informed decisions for your patient throughout treatment and provide valuable information at a number of decision points.

Monitor and trend work of breathing

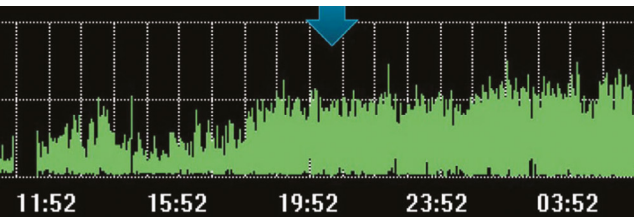


Figure 3
Recent reports indicate that diaphragm monitoring with Edi is useful to monitor breathing effort and patient-ventilator interaction.¹⁶

Of course, Edi monitoring has limitations as a single, isolated value. Like other physiological variables it should be considered in conjunction with other measurements as well as in the context of changes in therapy—a trend over time that can help you determine if your patient is moving in the desired direction. For example, Figure 3 shows an increase of diaphragm effort during a time when the doctor had planned a rest for the patient. The trend indicates it did not occur, visible by the increase in effort made by the patient during this time.

Identifying over-assist or under-assist

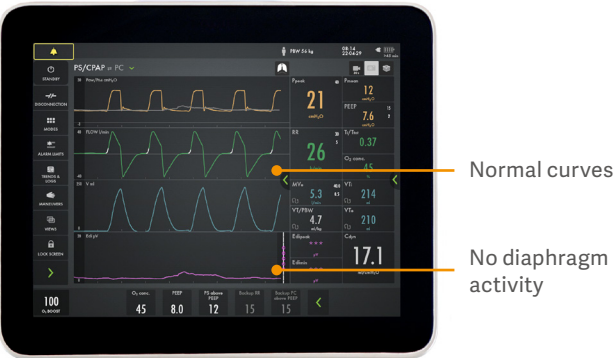
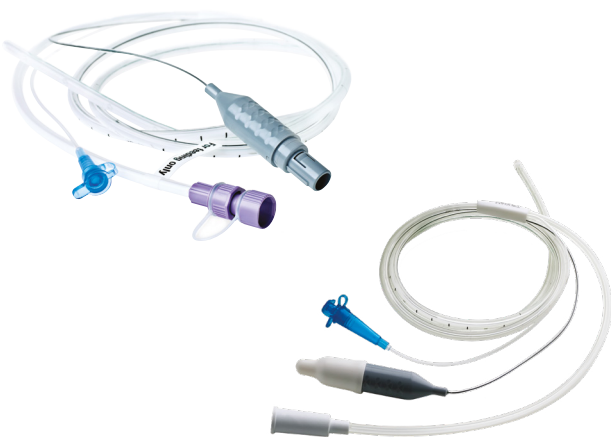


Figure 4
To keep the patient from diaphragm injury, the diaphragm needs to be active at an appropriate level. This is difficult to see without diaphragm monitoring. A patient can appear to be breathing spontaneously with pressure support, but not in fact be using their diaphragm at all. Indicated in Figure 4. This is one example of how over-assistance prevents the diaphragm from working, resulting in diaphragm weakness. The pressure, flow and volume curves look normal, but the pink Edi signal at the bottom is flat, indicating an inactive diaphragm.

The challenge for the under-assisted patient can be the opposite. The patient is exerting too much effort to breathe, resulting in thickening of the diaphragm. This is assumed to be a consequence of muscle fiber inflammation.¹ High levels of breathing effort is perhaps easier to actually observe in the patient, but without an objective value on the ventilator it is difficult to know for sure. Research shows the presence of diaphragm dysfunction is frequent.¹



Identifying patient-ventilator asynchrony

Asynchrony is associated with worse clinical outcomes during mechanical ventilation.¹⁶ In a recent study only 21% of clinicians managed to detect asynchrony in the form of missed inspiratory efforts.⁵ There are many more types of asynchronies easily overlooked: ineffective or excessive efforts, delayed inspiratory effort, delayed cycling off, double triggering and auto-triggering.



Figure 5
Figure 5 shows how the electrical activity of the diaphragm in grey overlays the pressure curve (yellow), making it easy to see differences in what the patient requests and what the ventilator delivers.

Determine mode of ventilation

Your target should be for the patient to sustain an optimal respiratory effort that represents neither too little nor too much effort.¹ By continuously monitoring diaphragm activity, you have an indication of how much the patient is working, if at all. If the diaphragm activity is high and rising, you may have to increase the level of support.^{17,18,19}

If the activity is low or reducing, you may be able to decrease the level of support.¹⁷ It is important to also monitor other diagnostic parameters associated with ventilation before changing the support. Research is growing in this area. In the future, more knowledge about diaphragm parameters may improve assessment further.²⁰

Set an optimal PEEP

There is no standardized way of setting the patient's PEEP during spontaneous breathing. Yet, a well set PEEP can decrease atelectasis, cyclical opening and closing of airways and protect alveoli. This, in turn, optimizes lung mechanics and improves oxygenation.

PEEP titration, with diaphragm monitoring, has shown clear results in neonates, allowing the baby to relax appropriately between breaths and preventing derecruitment of the lungs.¹²

In adult patients, Passath used diaphragm and oxygen monitoring during PEEP changes to allow for identification of a PEEP level at which tidal breathing occurs at minimal effort.²¹ Excessive lowering of PEEP resulted in an increase in work of breathing by 50 to 60% which, in combination with worsening of oxygen, also suggested partial lung derecruitment.

Optimizing management of sedation

The main benefit of monitoring diaphragm activity in relationship to sedation is to try and keep the diaphragm active as much as possible.¹ Simply monitor your patient's diaphragm activity and response to ventilation to find an adequate sedation level with sustained diaphragm activity.

It may require some training to be able to differentiate the effect of the sedation from other physiology that may also impact diaphragm function. However Edi is particularly effective during sedation holds as you can continuously see the changing effort made by the patient.

Trend and monitor the impact of interventions, rest and rehabilitation

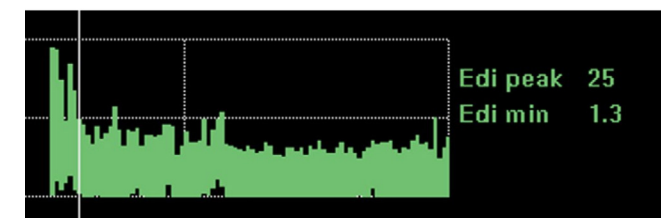


Figure 6

Monitoring diaphragm activity provides further reassurance that the patient can cope with the changes you make. Diaphragm activity is impacted by a range of physiological changes such as rest, sitting up, walking, caffeine treatment and even global rehabilitation and recovery.

If the patient is coping with these changes, diaphragm activity may remain largely unchanged. A worsening of the clinical situation, and a requirement for greater respiratory work, will most likely increase the diaphragm activity. An improved resting position will lower diaphragm activity needed to generate breaths.

Figure 6 shows the continuous diaphragm activity of a patient who was about to be intubated due to acute respiratory distress following pneumonia. Through monitoring diaphragm activity, the clinician managed to optimize the support and turn the situation around.



Get started with diaphragm monitoring

Whether you are interested in trying to limit diaphragm injury, reduce sedation and over-assist, or get better insight on patient-ventilator weaning, diaphragm monitoring can help you move forward.



To learn more scan
the QR code or visit
[Getinge.com/contact](https://getinge.com/contact)



Monitor and trend weaning

As shown below in Figure 7, diaphragm dysfunction is strongly linked to weaning difficulties.⁴ Monitoring diaphragm activity can help you predict weaning readiness and monitor its progress,²²⁻²⁴ from invasive ventilation, to non-invasive ventilation, to high-flow therapy to when all support has been removed.

The ability of your patient to cope with reduced support is trended within minutes and can help you proceed or fine-tune the support. It may be necessary to go back to your previous settings to prevent your patient from relapsing and the complications which often ensue.

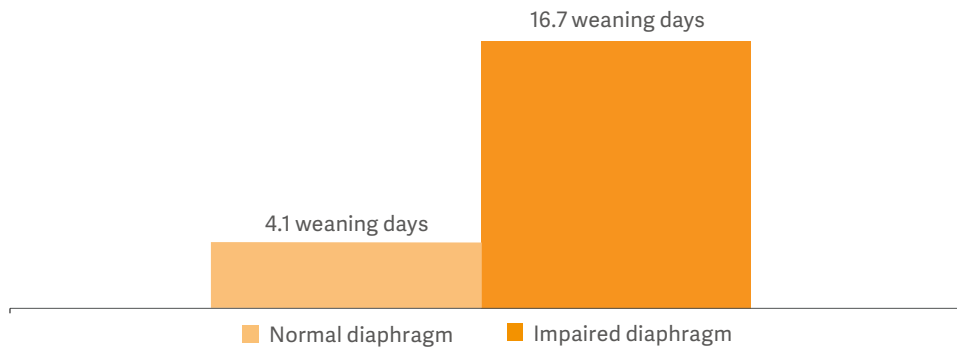


Figure 7

References

1. Goligher EC, Dres M, Fan E, Rubenfeld GD, et al. Mechanical Ventilation-induced Diaphragm Atrophy Strongly Impacts Clinical Outcomes. *Am J Respir Crit Care Med*. 2018 Jan 15;197(2):204-213.
2. Dres M, Dubé BP, Mayaux J, et al. Coexistence and Impact of Limb Muscle and Diaphragm Weakness at Time of Liberation from Mechanical Ventilation in Medical Intensive Care Unit Patients. *Am J Respir Crit Care Med*. 2017 Jan 1;195(1):57-66.
3. Dres M, Goligher EC, Heunks LMA, et al. Critical illness-associated diaphragm weakness. *Intensive Care Med*. 2017 Oct;43(10):1441-1452.
4. Kim WY, Suh HJ, Hong SB, Koh Y, et al. Diaphragm dysfunction assessed by ultrasonography: influence on weaning from mechanical ventilation. *Crit Care Med*. 2011 Dec;39(12):2627-30.
5. Colombo D, Cammarota G, Alemani M, et al. Efficacy of ventilator waveforms observation in detecting patient-ventilator asynchrony. *Crit Care Med*. 2011 Nov;39(11):2452-7.
6. Goligher, E. Diaphragm dysfunction: monitoring and mitigation during mechanical ventilation. Lecture recording, at 23:50: www.criticalcarenews.com/webinars-symposia/diaphragm-weakness-clinical-outcomes-mechanical-ventilation/
7. Goligher EC, Schepens T. Using ultrasound to prevent diaphragm dysfunction. *ICU Management & Practice*, Volume 18 - Issue 4, 2018.
8. Emeriaud G, Larouche A, Ducharme-Crevier L, et al. Evolution of inspiratory diaphragm activity in children over the course of the PICU stay. *Intensive Care Med*. 2014 Nov;40(11):1718-26.
9. Bellani G, Pesenti A. Assessing effort and work of breathing. *Curr Opin Crit Care*. 2014 Jun;20(3):352-8.
10. Bellani G, Coppadoro A, Patroniti N, et al. Clinical assessment of autopoietic end-expiratory pressure by diaphragmatic electrical activity during pressure support and neurally adjusted ventilatory assist. *Anesthesiology*. 2014 Sep;121(3):563-71.
11. Doorduyn J, Sinderby CA, Beck J, et al. Automated patient-ventilator interaction analysis during neurally adjusted noninvasive ventilation and pressure support ventilation in chronic obstructive pulmonary disease. *Crit Care*. 2014 Oct 13;18(5):550.
12. Ducharme-Crevier L, Beck J, Essouri S, et al. Neurally adjusted ventilatory assist (NAVA) allows patient-ventilator synchrony during pediatric noninvasive ventilation: a cross-over physiological study. *Crit Care*. 2015 Feb 17;19:44.
13. A Skorko, D Hadfi eld, A Vercueil, et al. Retrospective review of utilisation and outcomes of diaphragmatic EMG monitoring and neurally adjusted ventilatory assist in a central London teaching hospital over a 3-year period. *Critical Care* 2013, 17(Suppl 2):P146.
14. Rahmani A, Ur Rehman N, Chedid F. Neurally adjusted ventilatory assist (NAVA) mode as an adjunct diagnostic tool in congenital central hypoventilation syndrome. *J Coll Physicians Surg Pak*. 2013 Feb;23(2):154-6.
15. Stein H, Firestone K. Application of neurally adjusted ventilatory assist in neonates. *Semin Fetal Neonatal Med*. 2014 Feb;19(1):60-9.
16. Thille AW, Rodriguez P, Cabello B, et al. Patient-ventilator asynchrony during assisted mechanical ventilation. *Intensive Care Med*. 2006 Oct;32(10):1515-22.
17. Colombo D, Cammarota G, Bergamaschi V, et al. "Physiologic response to varying levels of pressure support and neurally adjusted ventilatory assist in patients with acute respiratory failure," *Intensive Care Medicine*, vol. 34, no. 11, pp. 2010-2018, 2008.
18. Bellani G, Mauri T, Coppadoro A, et al. Estimation of patient's inspiratory effort from the electrical activity of the diaphragm. *Crit Care Med*. 2013 Jun;41(6):1483-91.
19. Liu L, Liu H, Yang Y, et al. Neuroventilatory efficiency and extubation readiness in critically ill patients. *Crit Care* 2012; 16:R143.
20. Jansen D, Jonkman AH, Roesthuis L, et al. Estimation of the diaphragm neuromuscular efficiency index in mechanically ventilated critically ill patients. *Crit Care*. 2018 Sep 27;22(1):238.
21. Passath C, Takala J, Tuchscherer D, et al. Physiologic response to changing positive end-expiratory pressure during neurally adjusted ventilatory assist in sedated, critically ill adults. *Chest*. 2010 Sep;138(3):578-87.
22. Barwing J, Pedroni C, Olgemöller U, et al. Electrical activity of the diaphragm (EAdi) as a monitoring parameter in difficult weaning from respirator: a pilot study. *Crit Care*. 2013 Aug 28;17(4):R182.
23. Liu L, Liu H, Yang Y, et al. Neuroventilatory efficiency and extubation readiness in critically ill patients. *Crit Care*, 16 (2012), pp. R143.
24. Rozé H, Repusseau B, Perrier V, et al. Neuro-ventilatory efficiency during weaning from mechanical ventilation using neurally adjusted ventilatory assist. *Br J Anaesth*, 111 (2013), pp. 955-960.



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