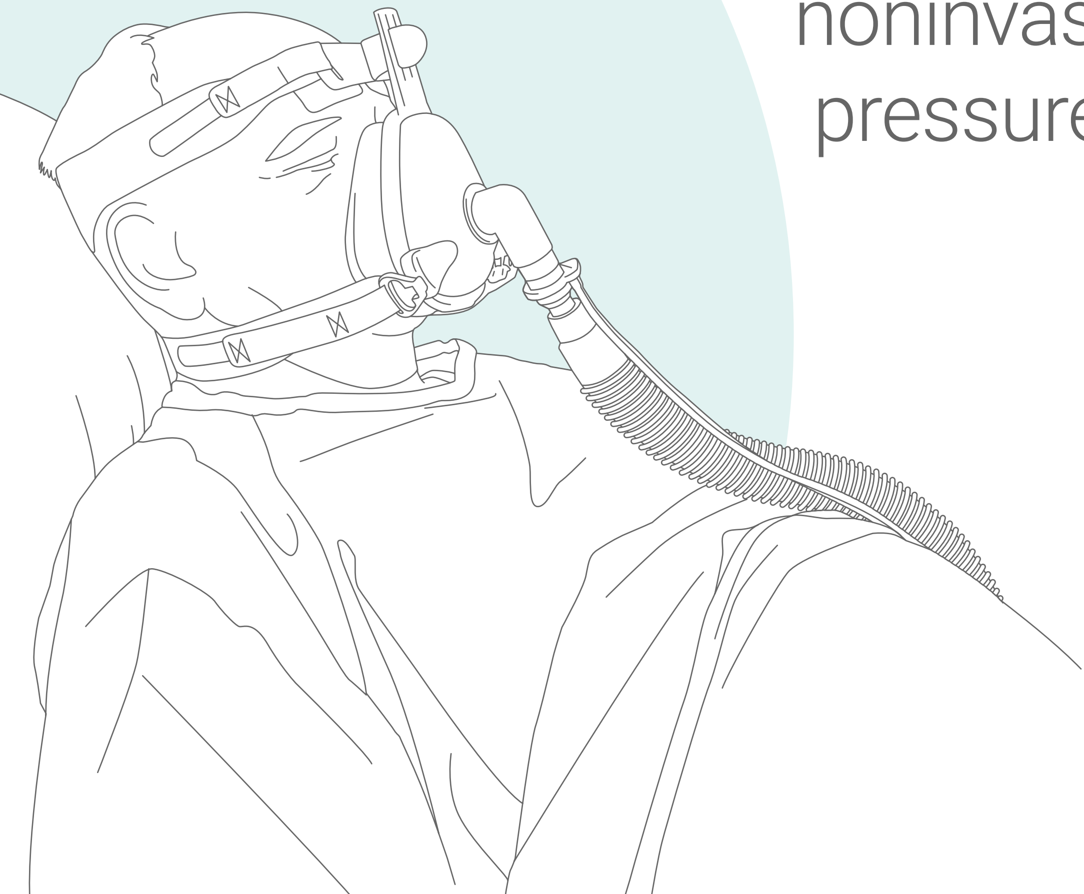
NIV. The basics of noninvasive positive pressure ventilation



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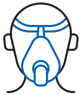
Synonyms and abbreviations



The term noninvasive positive-pressure ventilation (abbreviated NPPV or NIPPV) was previously used to distinguish it from noninvasive negative-pressure ventilation, but given the latter's rarity nowadays, the simpler term NIV is more convenient.

As there is now a range of ventilators available for NIV (and the ICU-ventilator manufacturer Respironics uses it for one of its modes), use of the proprietary product name BIPAP as a generic term for NIV should be avoided.

Synonyms and abbreviations

NPPV	Noninvasive positive-pressure ventilation
CPAP	Continuous positive airway pressure
PSV	Pressure-support ventilation
NIV	Noninvasive ventilation
ST	Spontaneous timed
FRC	Functional residual capacity
PEEP	Positive end-expiratory pressure
Pinsp	Inspiratory pressure
COPD	Chronic obstructive pulmonary disease
ΔPsupport	Pressure support
ETS	Expiratory trigger sensitivity
TI max	Maximum inspiratory time
BIPAP	Bilevel positive airway pressure
IPAP	Inspiratory positive airway pressure
EPAP	Expiratory positive airway pressure
GCS	Glasgow coma scale/score
PaO2	Partial pressure of oxygen
FiO2	Fraction of inspired oxygen
RR	Respiratory rate
SpO2	Oxygen saturation
COVID-19	Coronavirus disease-19
HME	Heat moisture exchanger
P-ramp	Pressure ramp
Vt	Tidal volume
ABG	Arterial blood gases
DMD	Duchenne muscular dystrophy
OHS	Obesity hypoventilation syndrome
OSA	Obstructive sleep apnea
OI	Oxygenation index
KS	Kyphoscoliosis
NM	Neuromuscular disease
CWD	Chest wall disease
BMI	Body mass index

Your ventilation expert

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Introduction

Noninvasive positive-pressure ventilation involves the delivery of oxygen into the lungs via positive pressure without the need for endotracheal intubation. It is used in both acute and chronic respiratory failure, but requires careful monitoring and titration to ensure its success and avoid complications[1].

Over the past century, NIV has improved dramatically and been used to treat respiratory failure from multiple etiologies. It has been proven more effective in preventing intubation compared to standard oxygen therapy in the acute setting[2].

Respiratory support may be delivered using continuous positive airway pressure (CPAP) devices or those that deliver bilevel positive airway pressure (pressure-support ventilation). For the purposes of this document, the name NIV covers both CPAP and PSV[2].

This e-book focuses on the basics of noninvasive ventilation for your daily clinical practice.

What are the benefits?

Goals and benefits of using NIV

We can divide the goals and benefits of NIV into the acute and long-term care setting as follows:

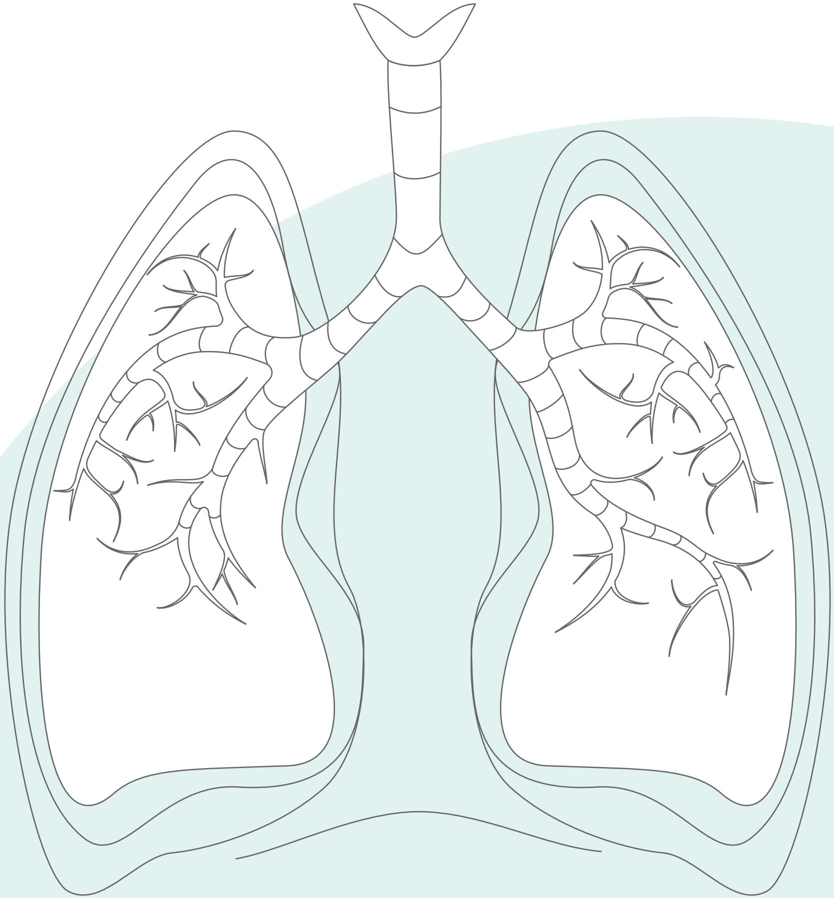
Acute care setting[3]

- ✓ Improve gas exchange
- ✓ Avoid intubation
- ✓ Decrease mortality
- ✓ Decrease length of time on the ventilator
- ✓ Decrease duration of hospitalization
- ✓ Decrease incidence of ventilator-associated pneumonia
- ✓ Relieve symptoms of respiratory distress
- ✓ Improve patient-ventilator synchrony
- ✓ Maximize patient comfort

Long-term care setting[3]

- ✓ Relieve or improve symptoms
- ✓ Enhance quality of life
- ✓ Avoid hospitalization
- ✓ Increase survival
- ✓ Improve mobility

How does NIV work?



How does it work

NIV works by creating positive airway pressure, i.e., the pressure outside the lungs is greater than the pressure inside the lungs. This causes air to be forced into the lungs (down the pressure gradient), lessening the respiratory effort and reducing the work of breathing.

It also helps to keep the chest and lungs expanded by increasing the functional residual capacity (the amount of air remaining in the lungs after expiration) after normal (tidal) expiration; this is the air in the alveoli available for gas exchange[4].

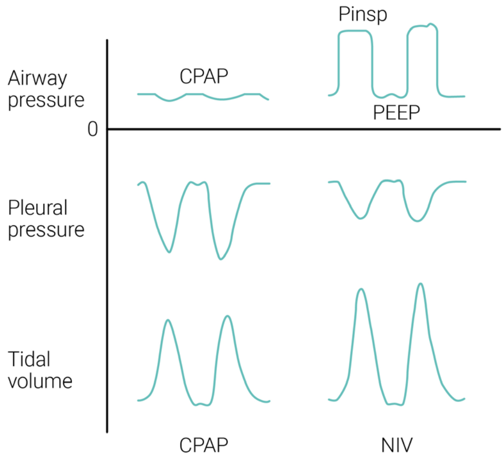
NIV modes

The following modes are noninvasive:

CPAP	NIV (PSV)	NIV-ST Spontaneous/timed (S/T)
✓ Stands for continuous positive airway pressure	✓ Also known as bilevel CPAP mode, or bilevel pressure mode	✓ Stands for spontaneous/timed noninvasive ventilation

CPAP

- Aims to deliver one continuous level of positive pressure throughout both the inspiratory and expiratory phases of breathing
- Improves oxygenation by opening collapsed airways, improving functional residual capacity (FRC), and improving preload and afterload in cardiogenic pulmonary edema[5]
- Improves lung compliance and therefore reduces the effort required for breathing by preventing alveolar collapse and counteracting the excessive intrinsic PEEP seen in obstructive lung conditions such as COPD[5,6]

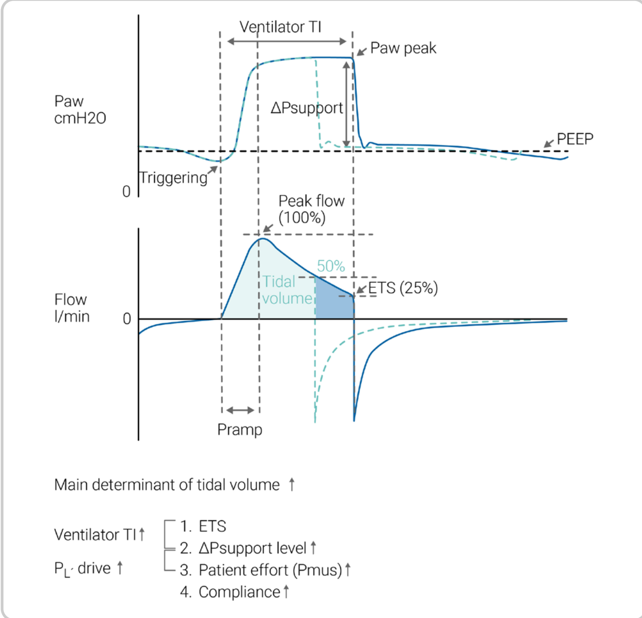


When ΔPsupport /ΔPinsp is set to zero in NIV and NIV-ST, the ventilator functions like a conventional CPAP system.

Adapted from Hess, Dean R., and Robert M. Kacmarek. Essentials of mechanical ventilation. McGraw Hill Education, 2019.

NIV (PSV)

- Aims to deliver two levels of positive airway pressure support
- The lower level is similar to CPAP; however, it is more commonly called positive end-expiratory airway pressure (PEEP) as it is present only at the expiratory phase of breathing
- The patient's inspiratory effort is assisted by the ventilator at a preset level of inspiratory pressure (ΔPsupport). Inspiration is triggered and cycled by the patient's effort
- During NIV, the patient determines the respiratory rate, inspiratory time, and tidal volume

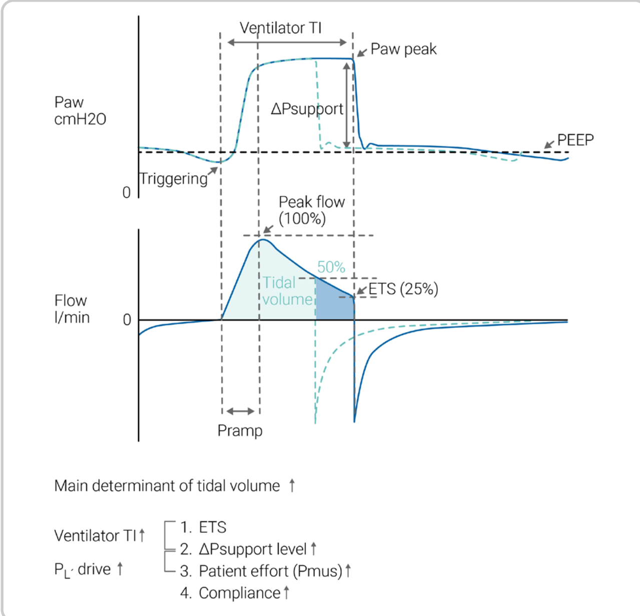


Adapted from Bellani, Giacomo. Mechanical ventilation from pathophysiology to clinical evidence. Cham, Switzerland: Springer, 2022.

NIV (PSV)

- The size of the breath (tidal volume) generated in a particular patient is dependent on the ΔPsupport setting – the higher the ΔPsupport setting, the greater the tidal volume

- ETS determines the spontaneous inspiratory time by cycling to expiration once the inspiratory flow decreases to a preadjusted percentage of the peak inspiratory flow
- In case the ETS criteria are not met (leakage), the inspiratory time can also be limited by TI max

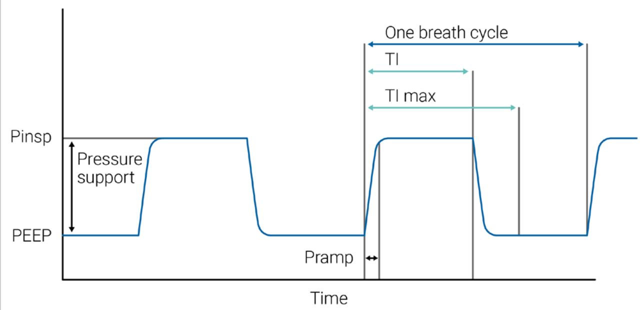


Adapted from Bellani, Giacomo. Mechanical ventilation from pathophysiology to clinical evidence. Cham, Switzerland: Springer, 2022.

NIV-ST

- In S/T mode, the clinician sets the inspiratory pressure (ΔPinsp) and expiratory pressure (PEEP), respiratory rate, and inspiratory time. The patient may initiate breaths that are supported to the ΔPinsp level, as in the NIV mode, but if the patient fails to make an inspiratory effort within a set interval (that is defined by the set respiratory rate), the machine triggers inspiration to the set ΔPinsp level. ΔPinsp then cycles to PEEP based on the inspiratory time period

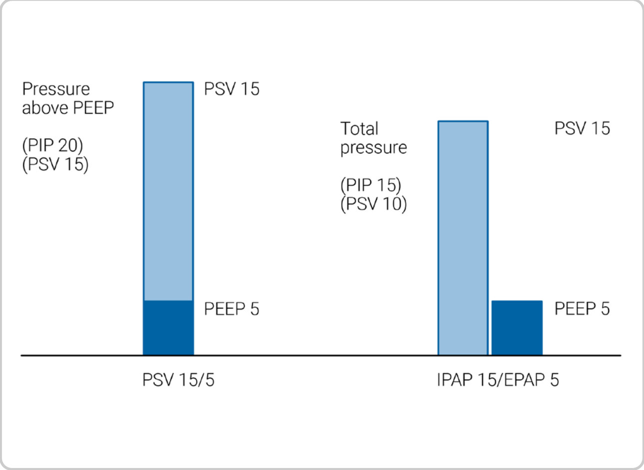
- NIV-ST with the backup rate is useful in the case of apnea or periodic breathing[7]



Pressure-support mode versus CPAP/BPAP

- The NIV and NIV-ST modes are types of noninvasive positive pressure ventilation. Pressure support is generally considered to be the same as CPAP/BIPAP, except that pressure support is delivered by a ventilator and BIPAP through a noninvasive ventilator

- In NIV and NIV-ST, the level of pressure support is applied as pressure above baseline PEEP. However, the approach is different with bilevel ventilators where IPAP and EPAP are set. In this configuration, the difference between IPAP and EPAP is the level of pressure support



Comparison of pressure support ventilation (PSV), such as with critical care ventilators, and inspiratory positive airway pressure (IPAP) with a bilevel ventilator. Note that IPAP is the peak inspiratory pressure (PIP) and includes the expiratory positive airway pressure (EPAP), whereas in PSV, pressure support is provided on top of the positive end-expiratory pressure (PEEP).

When to consider NIV?

- In order to minimize the risk of failure or complications, every patient should be properly assessed for suitability to receive NIV safely.

Indications for NIV use include patients who have:

- ✓ Dyspnea
- ✓ Tachypnea
- ✓ Accessory respiratory muscle use
- ✓ Paradoxical abdominal "belly" breathing
- ✓ $PaCO_2$ > 45 mmHg and pH < 7.35 [8, 9]

- Patients should be closely monitored during the first 24 hours after initiating NIV, as this is the period with the highest rate of treatment failure. Although data points at presentation such as a high RR, low arterial pH values or low PaO_2/FiO_2 can help predict failure, the most robust predictor of treatment failure during this period is failing to show an improvement in these parameters at 1–2 h after initiating NIV treatment[9]

Indications and recommendations for NPPV[10, 11]

Clinical indication	Certainty of evidence	Recommendation
Hypercapnia with COPD exacerbation	High	Strong recommendation for
Cardiogenic pulmonary edema (CPE)	Moderate	Strong recommendation for
Immunocompromised	Moderate	Conditional recommendation for
Post-operative patients	Moderate	Conditional recommendation for
Palliative care	Moderate	Conditional recommendation for
Trauma	Moderate	Conditional recommendation for
Weaning in hypercapnic patients	Moderate	Conditional recommendation for
Post-extubation respiratory failure	Low	Conditional recommendation against
Obesity hypoventilation syndrome (OHS)	Low	Conditional recommendation for
Neuromuscular disease and chest wall disease	Low	Conditional recommendation for
Prevention of hypercapnia in COPD exacerbation	Low	Conditional recommendation against
Post-extubation in high-risk patients (prophylaxis)	Low	Conditional recommendation for
De novo respiratory failure	No certain evidence	No recommendation made
Acute asthma exacerbation	No certain evidence	No recommendation made

Contraindications to noninvasive ventilation[12]

Absolute:

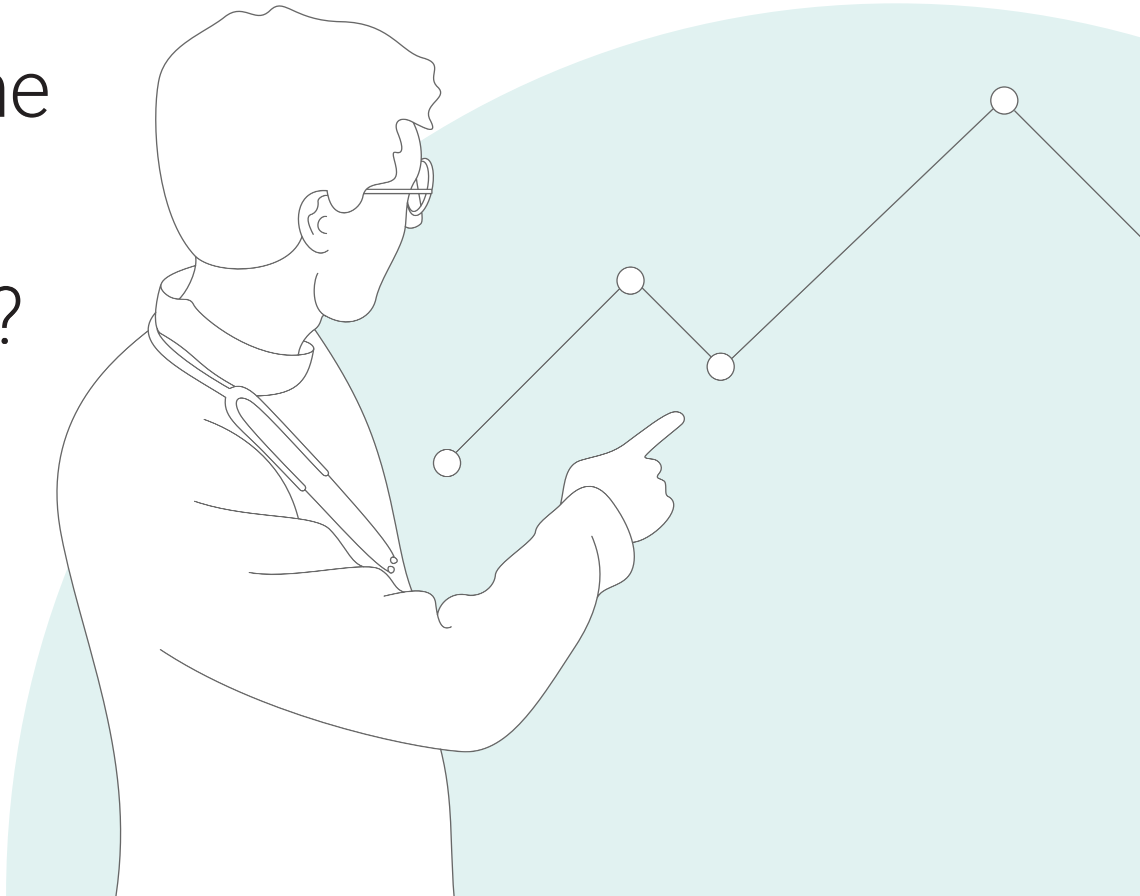
- The need for emergent intubation (i.e., cardiac or respiratory arrest, severe respiratory distress, unstable cardiac arrhythmia)

Relative:

- Non-respiratory organ failure that is acutely life-threatening
- Severe encephalopathy (i.e., GCS < 10)
- Severe upper gastrointestinal bleeding
- Hemodynamic instability
- Facial or neurological surgery, trauma, or deformity
- Significant airway obstruction (i.e., laryngeal mass or tracheal tumor)
- Inability to cooperate, protect airway, or clear secretions (i.e., patients at high risk of aspiration)
- Anticipated prolonged duration of mechanical ventilation (i.e., ≥ 4 to 7 days)
- Recent esophageal or gastric anastomosis*
- Multiple contraindications
- Insufficient staffing support

* GCS: Glasgow Coma Score and esophageal or gastric distension from air may increase the risk of anastomotic dehiscence

What is the clinical relevance?



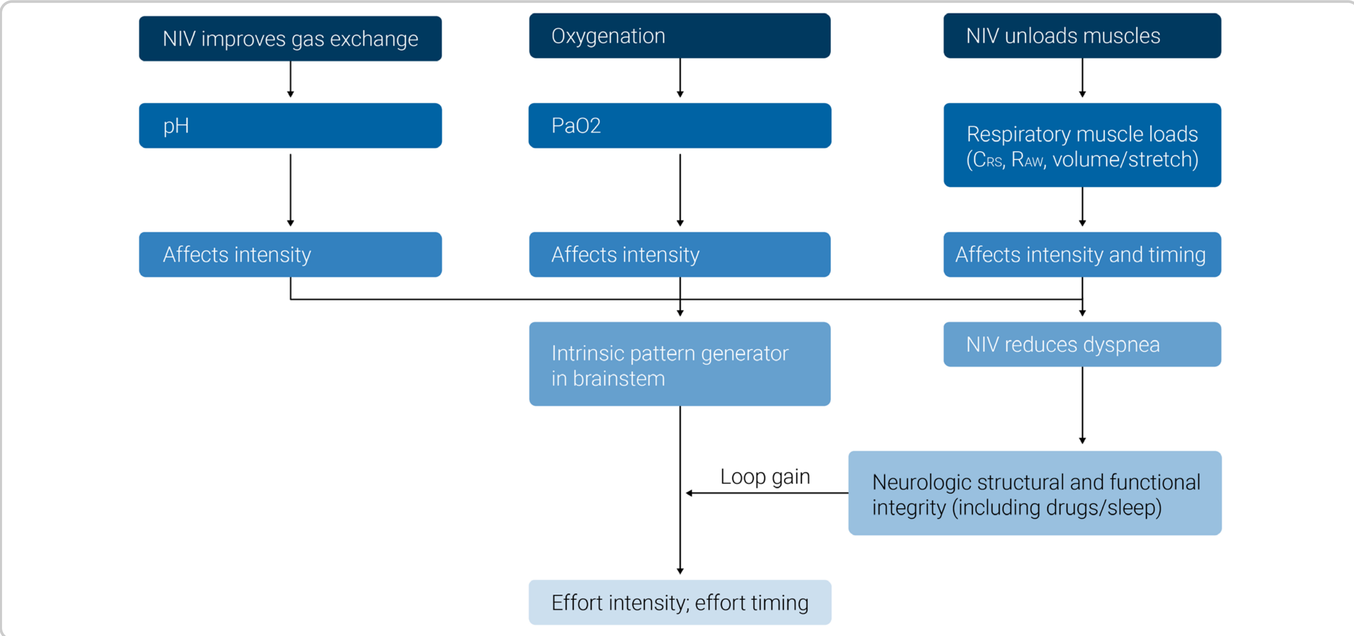
Physiologic effects of noninvasive ventilation[13]

The primary desired effect of NIV is to maintain adequate levels of PO2 and PCO2 in the arterial blood while also unloading the inspiratory muscles.

The physiologic effects of noninvasive ventilation are the following:

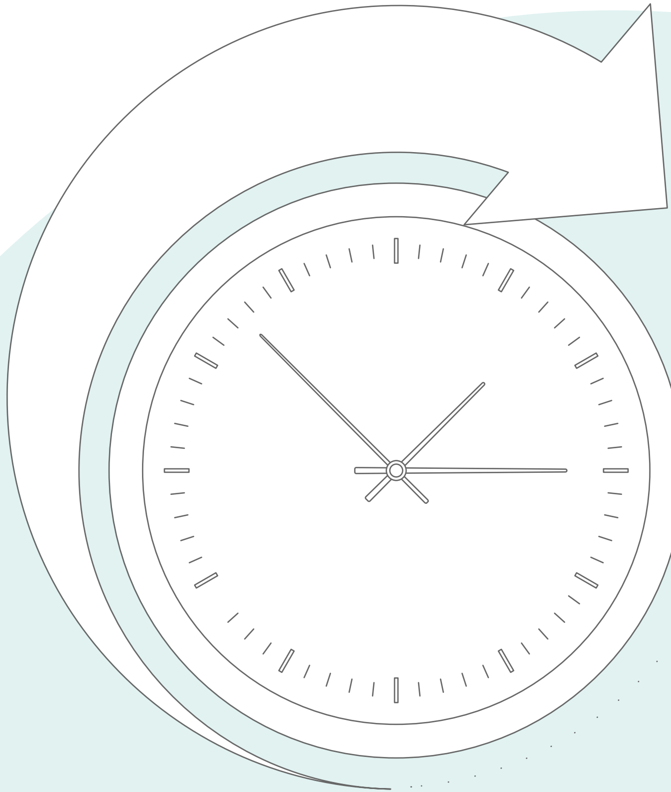
- Augments minute ventilation
- Unloads ventilatory muscles
- Resets the ventilatory control system
- Improves alveolar recruitment and gas exchange
- Maintains upper-airway patency
- Reduces triggering loads from Auto-PEEP
- Reduces the risk of ventilator-induced lung injury

Physiologic effects of noninvasive ventilation[13]



Adapted from MacIntyre, Neil R. Physiologic effects of noninvasive ventilation. Respiratory care 64.6 (2019): 617-628

How to start a patient on NIV?



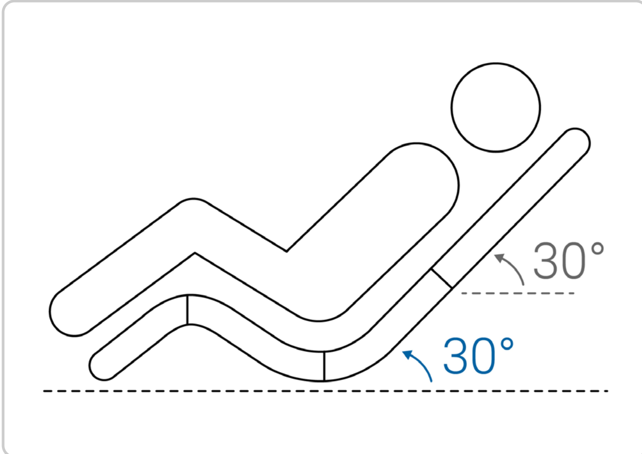
How to start a patient on NIV[14]

1. Education: Plan adequate training for all staff with a calibrated protocol
2. Environment: Choose an appropriate setting for starting NIV according to the severity of ARF
3. Indication: Select patients according to the team's experience, location, availability of intubation, do-not-intubate status, and likelihood of success
4. Information: Explain the technique to competent patients to improve their compliance
5. Equipment: Choose the interface(s) that best fits the facial anatomy; also consider rotating different interfaces to enhance comfort. Choose a ventilator with good air-leak compensation that displays flow/pressure/volume curves
6. Starting ventilation: Choose a pressure mode (i.e., pressure support) with PEEP. Start with low pressures, then increase gradually depending on comfort. Set adequate FiO2 and essential alarms. Tighten the straps of the interface enough to avoid leaks, without making them too tight
7. Monitoring ventilation: Check clinical status, monitor SpO2, measure blood gases periodically. Reset the ventilator according to patient–ventilatory synchrony, comfort, and leaks. Prevent skin lesions (i.e., protective devices, rotating interfaces). Consider humidification. Carefully consider sedation. Consider management of secretions, if required.

Conditions for initiating NIV

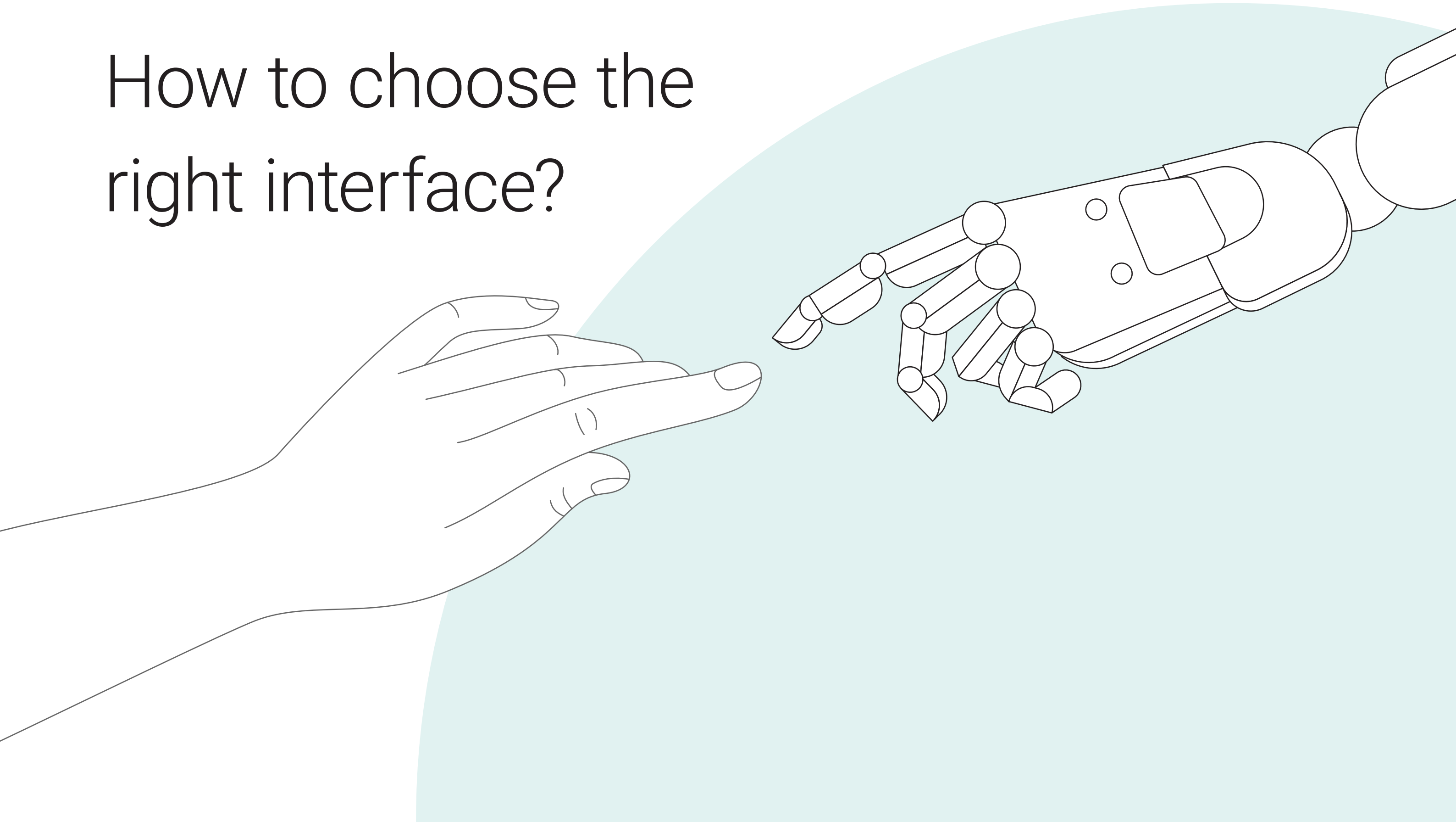
1. Choose a location with appropriate monitoring based on the severity of the patient's condition. At a minimum, continuous pulse oximetry should be provided.

2. Optimizing the patient's position also plays a key role in ensuring comfort during NIV[15]. A sitting or semi-recumbent position is suggested during NIV to ensure a high level of comfort to patients. A side-lying position may help to remove pressure from a pendulous abdomen, as in case of pregnancy or obesity[15]. Recently, the use of the prone positioning has been introduced in patients with ARF, particularly those with COVID-19 disease[16]. The analysis of this rescue therapy is better explained in the last paragraph on the COVID-19 pandemic.



3. Select a ventilator and an appropriately sized interface, and ensure the interface is compatible with the type of ventilator to be used.

How to choose the right interface?



Selection of the interface

- Select the mask designed for use with a critical care ventilator (without entrainment valves or leak port)
- Choose an interface that is the correct size for the individual patient, evaluate the mask fit and placement on the face, and reposition the mask as needed to minimize air leaks

NIV interfaces with entrainment valves are designed for noninvasive ventilators that use a single-limb circuit. The entrainment valve is required to prevent asphyxia if the ventilator fails or the tubing becomes disconnected. Masks with leak ports should only be used with single-limb circuit ventilators and should not be used with Hamilton Medical ventilators.

Selection of the interface

Standard elbow
For use with Hamilton Medical ventilators

BiTrac MaxShield

BiTrac NIV nasal mask* | BiTrac NIV full face mask | BiTrac MaxShield

Pediatric patients** | Adult patients

Anti-asphyxia elbow
For use with BiLEVEL or CPAP application

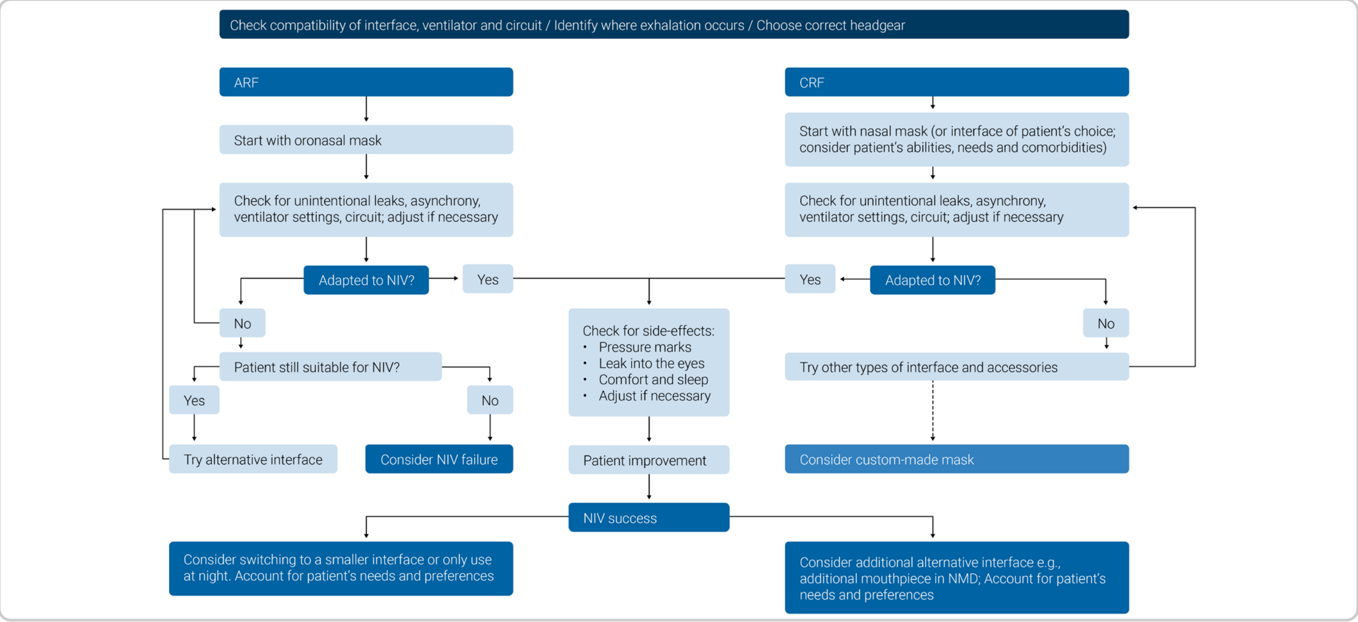
BiTrac MaxShield

BiTrac NIV full face mask | BiTrac MaxShield

Pediatric patients** | Adult patients

* Only available in the US market
** Recommended for patients with a weight >7kg and over the age of 1-year old

Interface strategies for NIV in adult patients[17]



Adapted from Simonds, Anita K., ed. ERS practical handbook of noninvasive ventilation. European Respiratory Society, 2015.

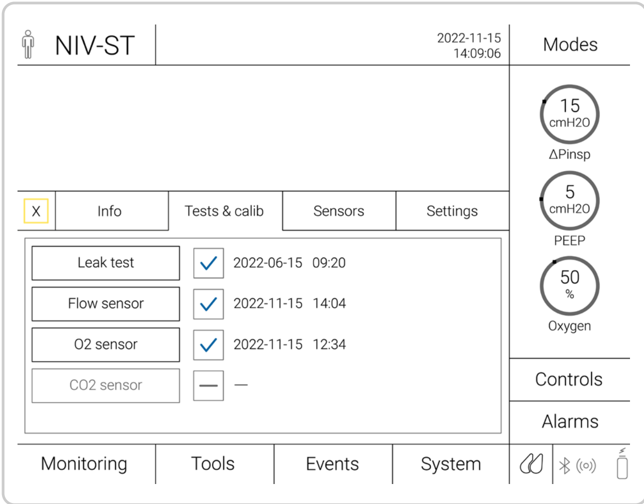
How to set up NIV?

NIV setup

1. Turn on the ventilator and humidifier, then run the calibration and tightness test

2. Connect the interface to the circuit

3. Explain the procedure and reason for therapy to the patient, and answer any questions about NIV before placing the mask on the patient



Humidification during NIV

Recommendations[18, 19]:

- All NIV circuits are to be actively humidified
- HMEs are not recommended for NIV
- Gas temperatures during NIV are to be based on patient comfort
- Humidified gas, heated to a temperature that is comfortable for the patient (usually about 30°C), should be the standard when using NIV

HAMILTON-H900 setting for NIV

- Select NIV mode with the mode key

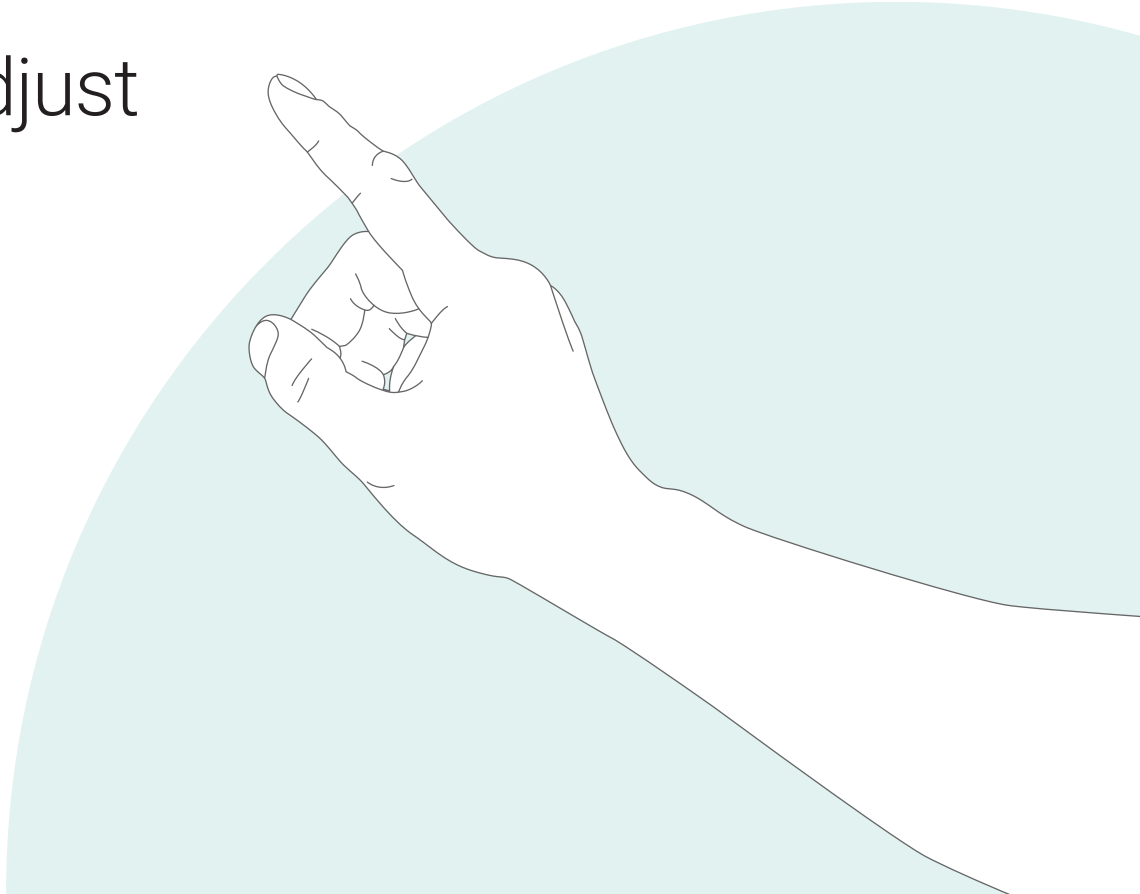
- When changing to NIV mode, the humidifier automatically sets the control settings to Auto noninvasive. Default temperature: 31°C
- Temperature range for NIV mode: 30°C to 35°C
- You can change to manual mode by changing the Chamber exit temperature or Temperature gradient

Patient agreement and motivation

Dyspnea can cause feelings of anxiety and fear. For this reason, the healthcare professional or the patient should hold the mask in place when applying it for the first time.

This way the mask can be removed quickly if the patient begins to panic or needs to communicate. A strategy of starting with low pressures can help patients adjust to NIV more readily.

How to adjust settings?

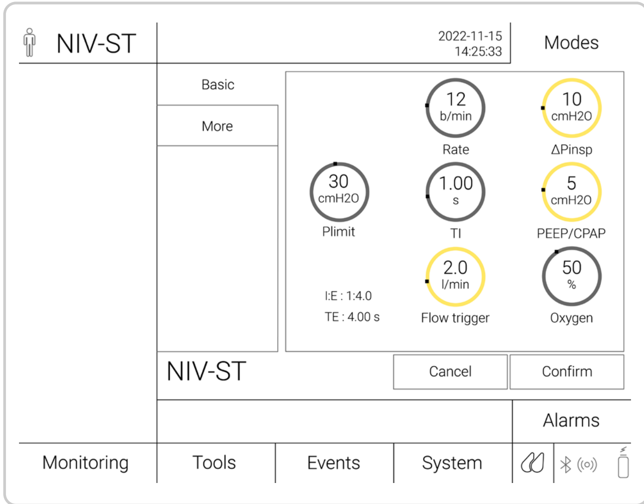


Initial ventilator settings[20]

1. Ventilating pressures should be set as low as possible to start with, especially if the patient is unfamiliar with the sensation of positive pressure ventilation (PEEP 4–6 cmH2O, ΔPinsp 6–10 cmH2O)

2. Ventilating pressures can then be adjusted in small increments over 1 to 2 minutes until exhaled VT is 6 to 8 ml/kg predicted body weight, or respiratory distress improves

3. Adjust FiO2 to keep SpO2 in the desired range (88%–95%)



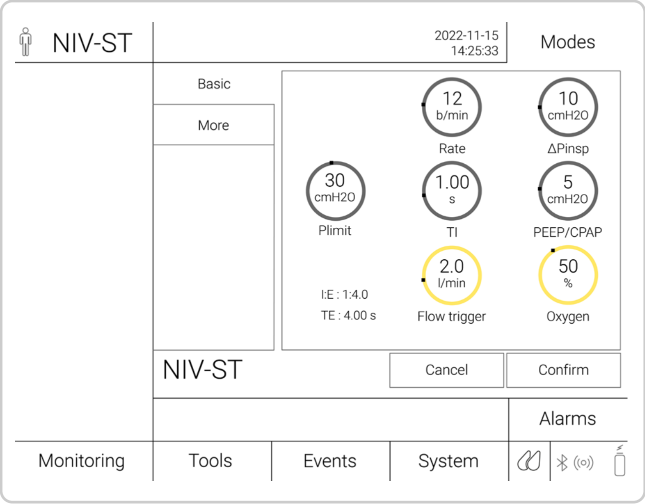
Initial ventilator settings[20]

4. Flow trigger: Set trigger sensitive enough to allow easy triggering without auto-triggering, even in the presence of leaks

5. Peak airway pressures greater than 30 cmH2O are rarely required and are best avoided. Airway pressure settings greater than 30 cmH2O can force air through the esophagus into the stomach*

6. Set the backup rate to 12–16 bpm (2 bpm below resting respiratory rate)

7. Set an appropriate inspiratory time and I:E ratio for the patient's presenting condition**



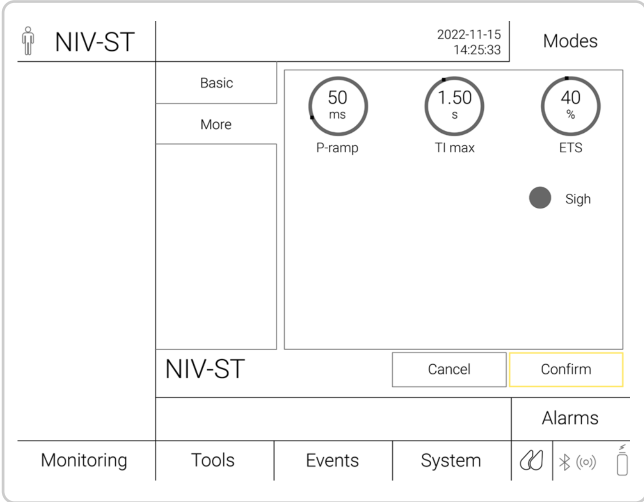
* Plimit should not exceed 30 cmH2O or PEEP 8 cmH2O without expert review
** Ti and I:E ratio (1:2–1:3 (COPD) or 1:1 (NMD/OHS)) set by a competent practitioner

Initial ventilator settings[20]

8. ETS: 40%–50%

9. Pramp: Should be tailored for a faster slope while avoiding excessive peak flow

10. Maximum inspiratory time is set 0.25 s above the actual inspiratory time; if you are unsure start at 1.5 s

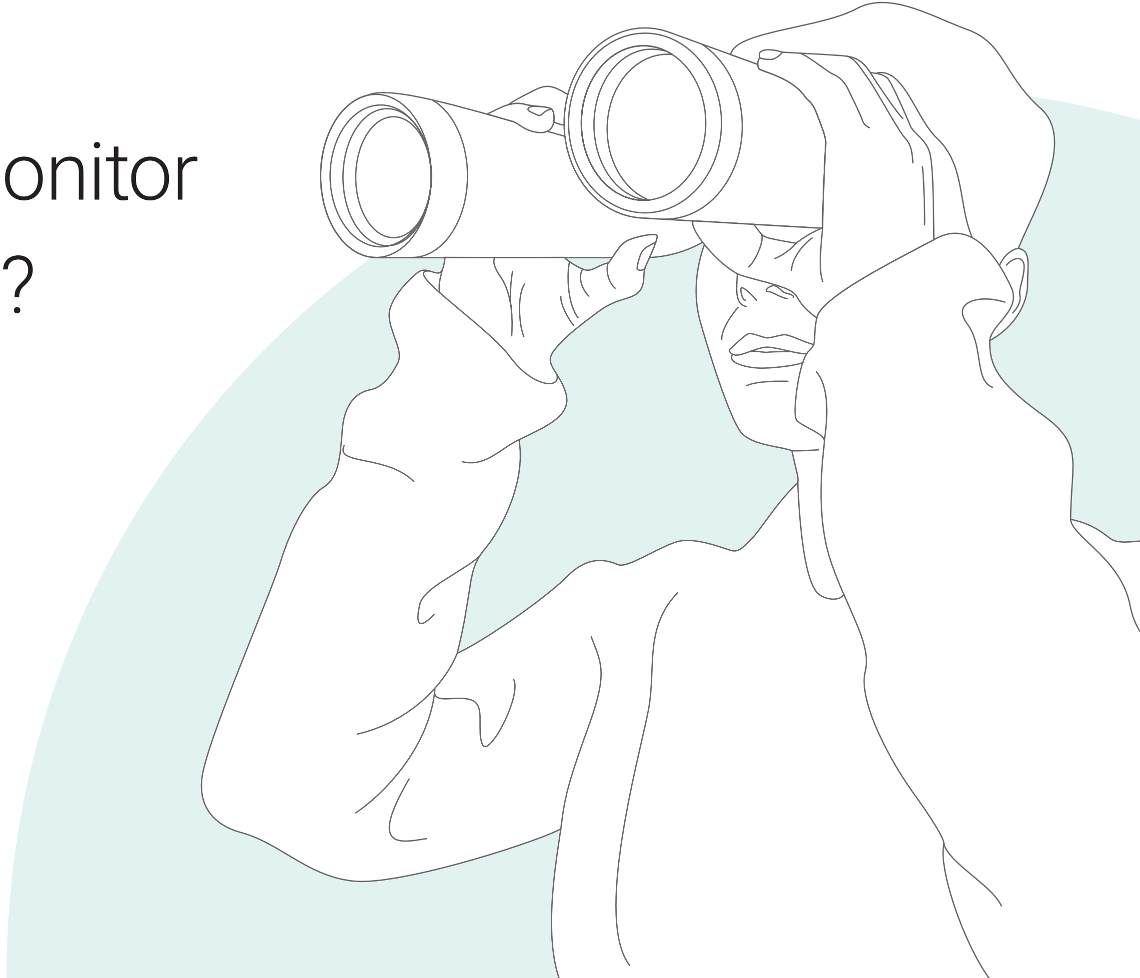


Alarm setup

Emergency alarms are important for recognizing a deterioration in the patient's condition and alert staff in the following situations:

✓ Apnea	when the patient stops breathing
✓ High respiratory rate	when the patient’s respiratory rate goes above set value
✓ Low respiratory rate	when the patient’s respiratory rate goes below a set value
✓ High tidal volume	when the patient’s tidal volume goes above a target value
✓ Low tidal volume	when the patient’s tidal volume goes below a target value

How to monitor treatment?



Monitoring while on NIV[20]

1. Reassess frequently for tolerance and efficacy of NIV (at least every 30 min) for the first 1 to 2 h

2. Continuous cardiac and SpO_2 monitoring for at least the first 12 hours. Ensure $PaCO_2$, PaO_2, and SpO_2 parameters are set

3. Alter NIV settings: If $PaCO_2$ remains high, increase tidal volume (Vt) by increasing ΔPinsp. If the patient remains hypoxic, increase PEEP or FiO_2 (remember you may need to increase ΔPinsp to maintain Vt between 6–8 ml/kg or signs of respiratory distress improve), update NIV prescription, and repeat ABG one hour after any settings are changed*

4. Check the patient's tolerance with the initial settings, and assess for dyspnea and asynchrony

5. Monitor the patient for risk of possible NIV failure

6. Use prespecified criteria for escalation

7. Do not delay an indicated intubation

* Increase ΔPinsp over 10-30 minutes. Ppeak should not exceed 30 cmH_2O or PEEP 8 cmH_2O without expert review

Monitoring failure during noninvasive ventilation

Failure of NIV has usually been defined as a need for intubation due to a lack of improvement in arterial blood gases and clinical parameters, or death[7]. It is very important to identify patients who are at risk of failing NIV, because an inappropriate delay in intubation may cause an increase in morbidity and mortality.

Success predictors

- ✓ Increase in arterial oxygenation
- ✓ Decrease in respiratory rate
- ✓ Decrease in dyspnea
- ✓ Significant increase in PaO2/FiO2

Failure predictors

- ✓ Stable or decrease in arterial oxygenation
- ✓ Stable or rise in respiratory rate
- ✓ Stable or increase in dyspnea
- ✓ Stable or decrease in PaO2/FiO2
- ✓ Stable or increase in OI
- ✓ Presence of contraindication(s) to NIV

HACOR score

- A comprehensive scale developed by Duan J, et al. including heart rate, acidosis, consciousness, oxygenation, and respiratory rate[21]
- In a large prospective cohort study, the HACOR scale predicted NIV failure after 1 h of treatment with high specificity (90%) and good sensitivity (72%)[21]
- A HACOR score > 5 had a failure rate of 87.1% and hospital mortality of 65.2%[21]
- The original HACOR score was recently improved in a multicenter prospective observational study by combining it with data on six baseline variables (pneumonia, CPE, pulmonary ARDS, septic shock, immunosuppression, and SOFA scores). When compared to the original HACOR score, the updated HACOR score had significantly better predictive power for NIV failure and can serve as an important reference point for clinical staff managing NIV[22]

Original HACOR score online calculator

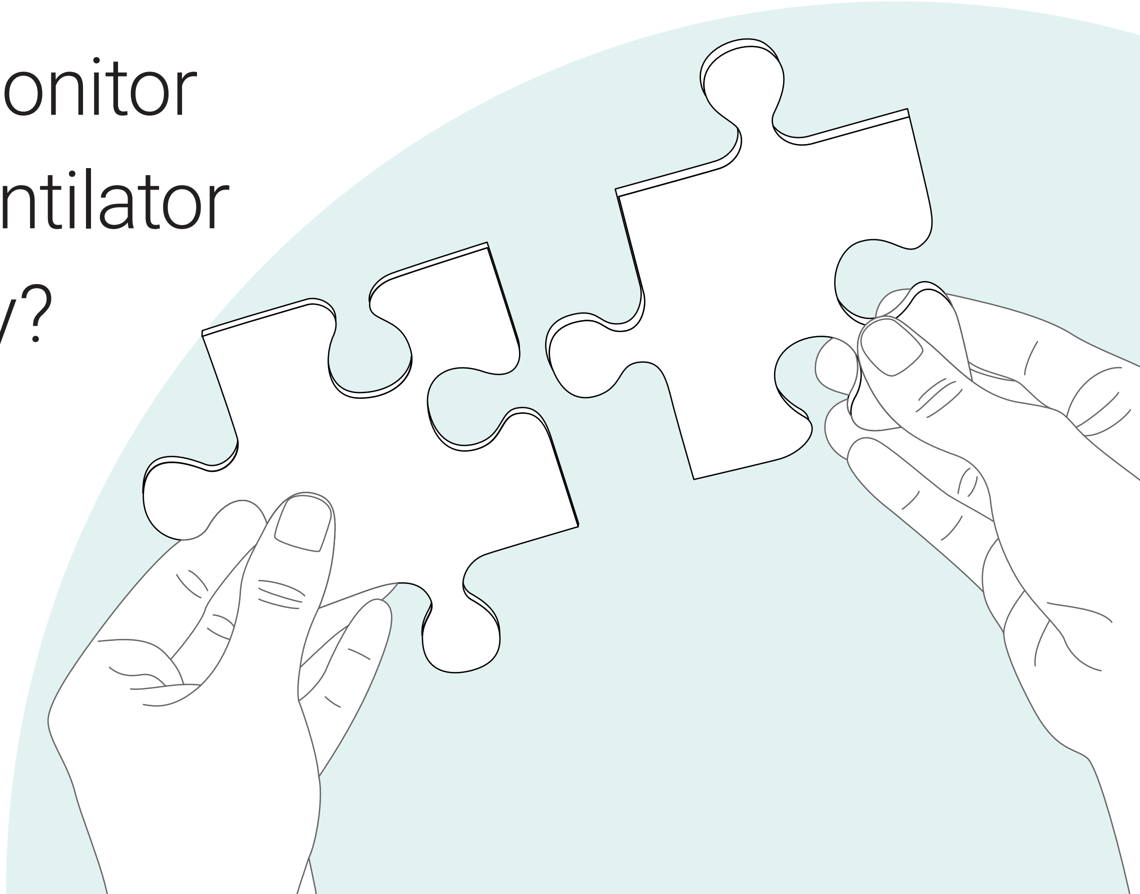
Updated HACOR score[22]

Early intubation can be considered when updated HACOR score assessed after 1–2 h of NIV is high.

Updated HACOR score	Risk for NIV failure	Rate of NIV failure
≤ 7	Low	12.4%
7.5–10.5	Moderate	38.2%
11–14	High	67.1%
≥ 14	Very high	83.7%

The updated HACOR score is as follows: Original HACOR score + 0.5 × SOFA + 2.5 if pneumonia is diagnosed – 4 if CPE is diagnosed + 3 if pulmonary ARDS is present + 1.5 if immunosuppression is present + 2.5 if septic shock is present

How to monitor patient-ventilator synchrony?



Monitoring patient-ventilator synchrony

- Synchrony between the patient and ventilator should be checked frequently. Asynchronies can be detected by observing the patient and asking them simple questions. The most practical method should be analysis of the pressure and flow waveforms[23].

- Hamilton Medical ventilators offer a functionality for leak compensation, IntelliTrig, during the full breath cycle to increase patient-ventilator synchrony and reduce the risk of auto-triggering. Using IntelliTrig, the ventilator identifies the leak by measuring the flow at the airway opening, and uses this data to automatically adjust the gas delivery while remaining responsive to the set inspiratory and expiratory trigger sensitivity.

- Hamilton Medical ventilators also have the optional feature, IntelliSync+, which continuously analyzes waveform shapes and is able to detect patient efforts immediately, then initiate inspiration or expiration in real-time*. For maximum flexibility, IntelliSync+ can be activated for either the inspiratory trigger or the expiratory trigger, or both.

* IntelliSync+ is available on the HAMILTON-G5/S1 and HAMILTON-C6.

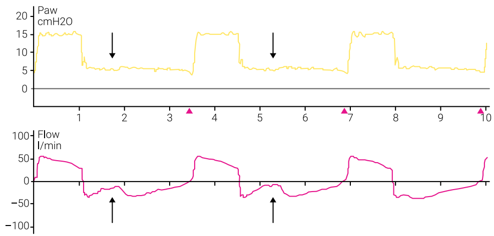
Monitoring patient-ventilator synchrony

Patient-ventilator synchronization is an important issue that can influence the efficacy and success of NIV.

The most common phenomenon is ineffective triggering (patient effort is not recognized by the ventilator; may be secondary to high AutoPEEP or inappropriate inspiratory trigger sensitivity), followed by auto-triggering (delivery of preset pressure in the absence of patient effort) and double triggering (consecutive delivery of two preset pressure support events within an interval of less than half the mean inspiratory time due to the patient's continued effort)[24, 25, 26, 27].

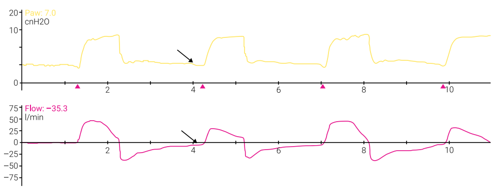
Troubleshooting asynchronies

<table>
<tr><th>Ventilator setting</th><th>How to identify asynchrony</th><th>Description</th><th>Asynchrony</th><th>Action</th></tr>
<tr><td>Inspiratory trigger</td><td>Ask your patient
• Does the ventilator give you a breath each time you want one?
• When you breathe in, do you get a supporting breath?</td><td>If no</td><td>Ineffective trigger</td><td>Increase inspiratory trigger sensitivity and/or PEEP</td></tr>
<tr><td></td><td>Waveform monitoring

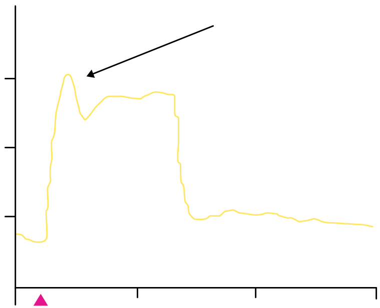


</td><td>Ineffective inspiratory efforts appear on the flow curve as a sudden deviation of the expiratory flow toward the baseline (upward convexity) and a concomitant drop in airway pressure toward the baseline (upward concavity)</td><td></td><td></td></tr>
</table>

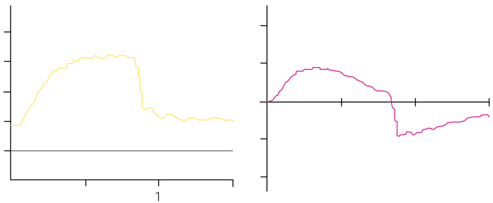
Troubleshooting asynchronies

Ventilator setting	How to identify asynchrony	Description	Asynchrony	Action
Inspiratory trigger	Ask your patient • Does the ventilator give you a breath when you don't want one?	If yes	Auto-triggering	Decrease inspiratory trigger sensitivity
	Waveform monitoring 	The inspiratory flow curve of an auto-triggered breath differs substantially from that of patient-triggered breaths because the patient doesn't make an active inspiratory effort - the peak inspiratory flow is lower, and the inspiratory time is shorter		

Troubleshooting asynchronies

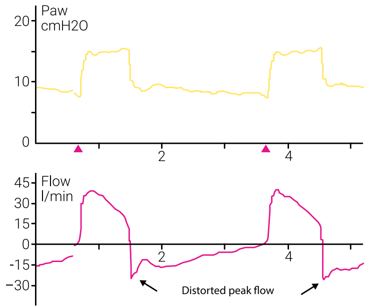
Ventilator setting	How to identify asynchrony	Description	Asynchrony	Action
P-ramp	Ask your patient • Do you feel like you get a blast of air? • Is the breath given too quickly?	If yes	Overshoot	Increase Pramp until slower breath delivery better matches the patient's inspiratory flow
	Waveform monitoring			
		At the start of inspiration, the pressure waveform shows a spike		

Troubleshooting asynchronies

Ventilator setting	How to identify asynchrony	Description	Asynchrony	Action
P-ramp	Ask your patient • Is the breath delivered too slowly/too gently?	If yes	Flow is too slow	Decrease Pramp until faster breath delivery better matches the patient's inspiratory flow
	Waveform monitoring 	Downward concavity in airway pressure usually indicates the rise time is too long (flow is too slow)		

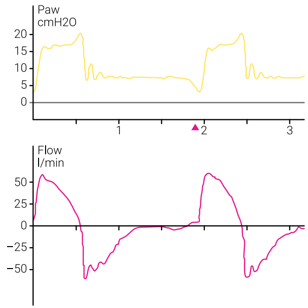
Troubleshooting asynchronies

<table>
<tr><th>Ventilator setting</th><th>How to identify asynchrony</th><th>Description</th><th>Asynchrony</th><th>Action</th></tr>
<tr><td rowspan="2">ETS</td><td>Ask your patient
• Is the breath delivery time too short?</td><td>If yes</td><td rowspan="2">Early cycling</td><td rowspan="2">Reduce ETS gradually until it is better matched with the patient's breath cycling</td></tr>
<tr><td>Waveform monitoring

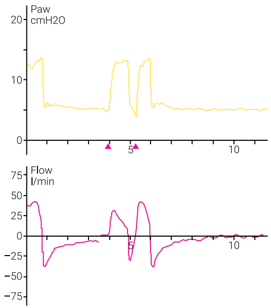


</td><td>Flow waveform: Look for a small bump at the beginning of expiration (after peak expiratory flow) followed by an abrupt initial reversal in the expiratory flow</td></tr>
</table>

Troubleshooting asynchronies

Ventilator setting	How to identify asynchrony	Description	Asynchrony	Action
ETS	Ask your patient • Is it the delivered breath too long or is it hard to breathe out?	If yes	Delayed cycle	Increase ETS gradually until it is better matched with the patient's breath cycling
	Waveform monitoring 	• Pressure waveform: curve rises above the target at the end of insufflation • Flow waveform: Look for a change in the slope of the inspiratory flow: a fast decrease followed by an exponential (less steep) decline		

Troubleshooting asynchronies

Ventilator setting	How to identify asynchrony	Description	Asynchrony	Action
ETS	Ask your patient • Does the ventilator give you two breaths?	If yes	Double triggering	• Reduce ETS gradually until it is more in sync with the patient's breath cycling • Increase the pressure support if it is low
	Waveform monitoring 	Flow waveform: Look for two assisted breaths without expiration between them or with an expiration interval of less than half of the mean inspiratory time (often displayed on the waveform as two inspiratory peaks)		

Test yourself

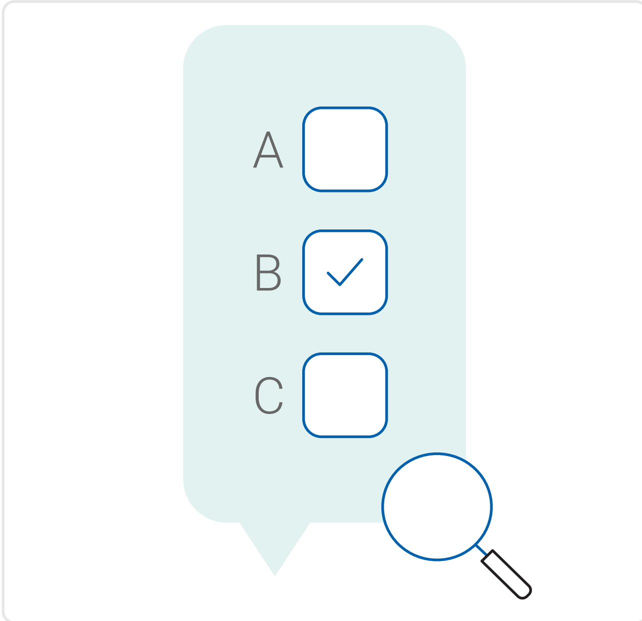
Test your knowledge

Now it is time to put your knowledge to the test. On the following pages you can find several questions about noninvasive positive pressure ventilation and the concepts mentioned in this e-book.

For each question there is only one correct answer.

You can check your answers on page 60 and page 65 (for the clinical case).

Good luck!



Question 1

Which of the following are indications for initiating NIV?

a) Patient complaining of shortness of breath
b) Arterial pH > 7.45
c) Accessory respiratory muscle use
d) PaCO2 < 35 mmHg
e) All of the above

Question 2

Which of the following are contraindications to initiating NIV because they will likely lead to NIV failure?

a) Severe upper GI bleed
b) Recent facial surgery
c) Refractory air leak
d) Hemodynamic instability
e) All of the above

Question 3

A patient presents with pneumonia and is initiated on NIV. Which of the following is the most sensitive predictor of NIV failure?

a) RR > 25 bpm
b) O2 saturation of < 88% on room air
c) PaO2/FiO2 < 150 at the start of NIV
d) PaO2/FiO2 < 150 after 1 h of NIV
e) All of the above are equal predictors of failure

Question 4

Which is the most frequent type of asynchrony during noninvasive mechanical ventilation?

a) Ineffective triggering
b) Double triggering
c) Auto-triggering
d) Premature cycling
e) Delayed cycling

Solutions

Question 1	c)	Accessory respiratory muscle use
Question 2	e)	All of the above
Question 3	d)	$PaO_2/FiO_2 < 150$ after 1 h of NIV
Question 4	a)	Ineffective triggering

Clinical case

Scenario

A 56-year old man presented with congestive heart failure and signs of cardiac decompensation. Upon admission, he was awake and oriented but had fever, tachycardia, hypotension, dyspnea, and oliguria.

Pneumonia was confirmed. Arterial blood gases showed severe hypoxemia with calculated PaO2/FiO2 ratio of 240 on 40% oxygen therapy.

He met all the criteria for NIV use: severe dyspnea with a respiratory rate of 32 breaths/min, apparent use of accessory respiratory muscles, and severe hypoxemia.

Question 1 - Clinical case

Which statement is true?

a) The patient has severe hypoxemia and pneumonia, and should be intubated immediately
b) NIV can be used as a first-line therapy with close supervision

Question 2 - Clinical case

Which ventilation modality usually results in more effective NIV in this patient?

a) CPAP
b) NIV-ST
c) DuoPAP
d) NIV

Question 3 - Clinical case

Which of these initial settings is the most appropriate?

a) ΔPinsp 12 cmH2O, PEEP 10 cmH2O, FiO2 100%, Rate 20, ETS 40%

b) ΔPinsp 8 cmH2O, PEEP 5 cmH2O, FiO2 (adjust to keep SpO2 88%–95%), ETS 40%, RR 18 bpm

c) ΔPinsp 10 cmH2O, PEEP 5 cmH2O, FiO2 (adjust to keep SpO2 88%–95%), ETS 40%, RR 12 bpm

d) ΔPinsp 6 cmH2O, PEEP 5 cmH2O, FiO2 (adjust to keep SpO2 88%–95%), ETS 25 %, RR 12 bpm

Question 4 - Clinical case

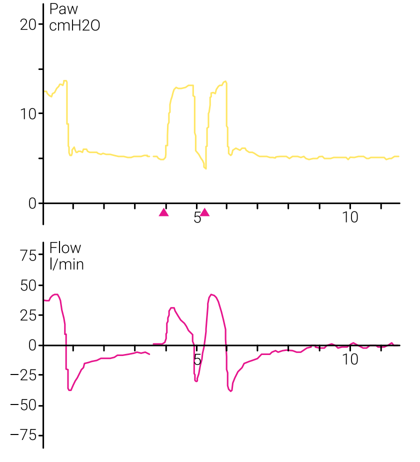
With initial settings, the pressure and flow waveforms looked similar to the shapes below. How can this asynchrony be corrected?

a) Increase ETS

b) Lower the setting for expiratory trigger sensitivity

c) Increase the rise time

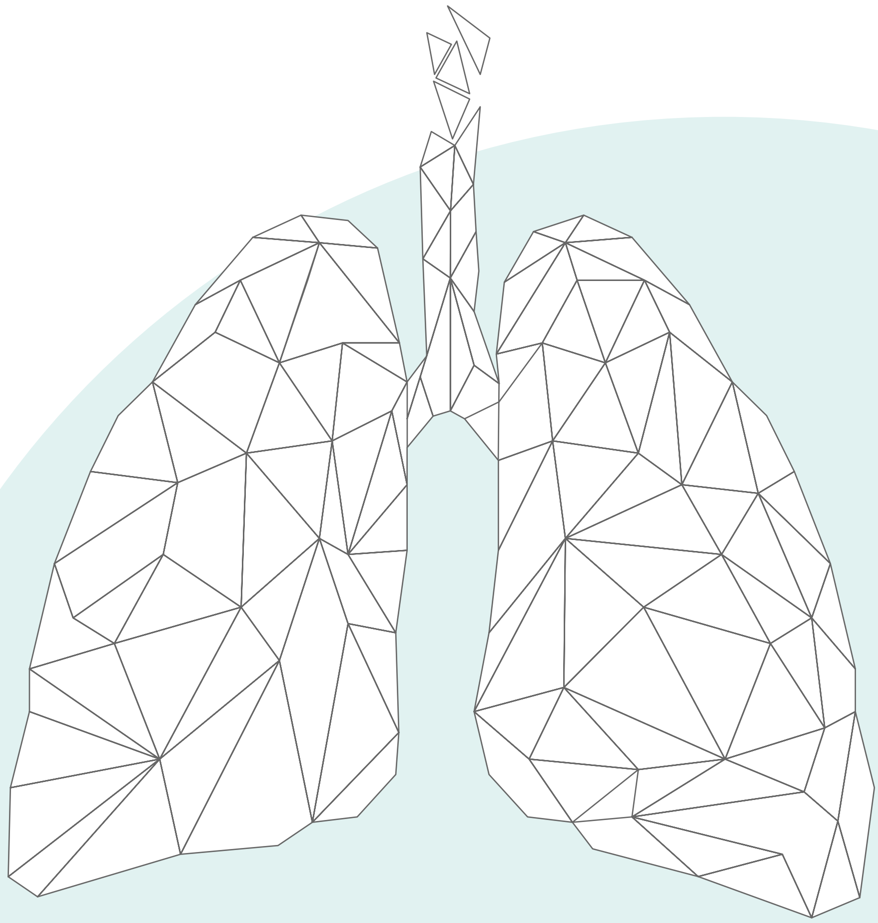
d) Increase PEEP



Solutions - Clinical case

Question 1	b) NIV can be used as a first-line therapy with close supervision
Question 2	b) NIV-ST
Question 3	c) ΔPinsp 10 cmH2O, PEEP 5 cmH2O, FiO2 (adjust to keep SpO2 88%–95%), ETS 40%, RR 12 bpm
Question 4	b) Lower the setting for expiratory trigger sensitivity

Appendix



Indications for NIV

COPD:
- pH < 7.35
- PaCO2 > 48 mmHg
- RR > 23 bpm

If persisting after bronchodilators and controlled oxygen therapy

Neuromuscular disease:
Respiratory illness with RR > 20 if usual VC < 1l even if pCO2 < 48 (6.5 kPa)

or

pH < 7.35 and pCO2 > 48

Obesity:
pH < 7.35, pCO2 > 45 and RR > 23

or

daytime pCO2 > 45 and somnolent

NIV not indicated Asthma/ pneumonia

Refer to ICU to consider IMV if increasing respiratory rate/ distress or pH < 7.35 and pCO2 > 48

Contraindications to NIV

Absolute:
- Severe facial deformity
- Facial burns
- Fixed upper airway obstruction

Relative:
- pH < 7.15 (pH < 7.25 and additional adverse feature)
- GCS < 8
- Confusion/agitation
- Cognitive impairment (warrants enhanced observation)

Indications for referral to ICU:
- AHRF with impending respiratory arrest
- NIV failing to augment chest wall movement or reduce pCO2
- Inability to maintain SaO2 > 85%–88% on NIV

- Need for IV sedation or indication for adverse effects
- Need for closer monitoring and/or possible difficult intubation as in OHS and DMD

NIV setup

Mask:
Full face mask (or own if home user of NIV)

Initial pressure settings:
PEEP: 3 cmH2O (or higher if OSA known/ expected)

- Pinsp in COPD/OHS/KS 12 (18 if pH < 7.25)
- Up titrate Pinsp over 10–30 minutes to Ppeak 20–25 to achieve adequate augmentation of chest/abdominal movement and slow RR
- Pinsp should not exceed 20 or PEEP 8* without expert review

- Pinsp in NM 6–8 (or 5 above the usual setting)

Backup rate:
- Backup rate of 16–20
- Set appropriate inspiratory time

I:E ratio:
- COPD 1:2 to 1:3
- OHS, NM, and CWD 1:1

Inspiratory time:
- 0.8–1.2 seconds COPD
- 1.2–1.5 seconds OHS, NM, and CWD

- Use NIV for as much time as possible in first 24 hours
- Taper depending on tolerance and ABGs over next 48–72 hours

Seek and treat reversible causes of AHRF

* Possible need for PEEP > 8:

Servere OHS (BMI > 35), lung recruitment (e.g. hypoxia) in severe kyphoscoliosis, oppose intrinsic PEEP in severe airflow obstruction or maintaining adequate PS when high PEEP required

NIV monitoring

Oxygenation:
Aim for 88%–92% in all patients

Note: homecare ventilators cannot provide > 50% oxygen

If high oxygen need or rapid desaturation on disconnection from NIV, consider IMV

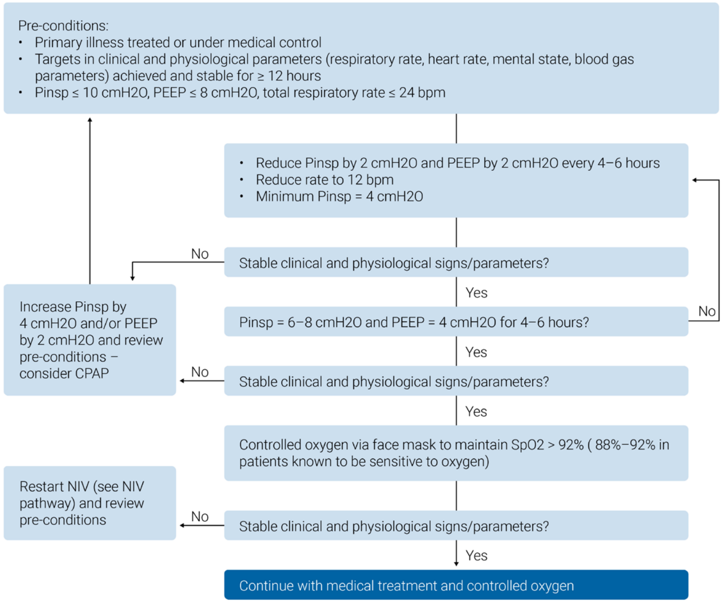
Red flags:
pH < 7.25 on optional NIV
RR persisting > 25
New onset confusion or patient distress

Actions:
Check synchronization, mask fit, exhalation port: apply physiotherapy/ bronchodilators, consider anxiolytics

Consider IMV

NIV recommendations:

Adapted from Davidson AC, Banham S, Elliott M, et. al. BTS/ICS guideline for the ventilatory management of acute hypercapnic respiratory failure in adults. Thorax 2016; 71 (Suppl 2): ii1-35



Notes:
- ✓ The rate of weaning in this pathway is a guide only – some patients can be weaned faster, others more slowly
- ✓ The weaning process may be interrupted in order to promote rest
- ✓ Some patients may be weaned from pressure support onto CPAP, before being weaned off NIV completely
- ✓ Some patients (e.g., with post-operative lung collapse) may continue to require CPAP support overnight in order to overcome nocturnal hypoventilation
- ✓ This pathway is not suitable for patients for whom NIV is being stopped and palliative-only management started

NIV weaning pathway:

Adapted from Clinical Guidelines for Non-Invasive Ventilation (NIV) in Acute Respiratory Failure. South Tess Hospital. 2012.

References

1. Rochwerg B, Brochard L, et. al. Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure. Eur Respir J. 2017 Aug;50(2)

2. Gong Y, Sankari A. Noninvasive Ventilation. 2022 Jun 17. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan–. PMID: 35201716.

3. Kacmarek, R. M., Stoller, J. K., & Heuer, A. (2019). Egan's fundamentals of respiratory care e-book. Elsevier Health Sciences.

4. Rochwerg B, Einav S, Chaudhuri D, Mancebo J, Mauri T, Helviz Y, et al. The role for high flow nasal cannula as a respiratory support strategy in adults: a clinical practice guideline. Intensive Care Medicine. 2020 Dec 17;46(12):2226–37.

5. Bello G, De Santis P, Antonelli M. Non-invasive ventilation in cardiogenic pulmonary edema. Ann Transl Med. 2018 Sep; 6(18): 355.

6.British Thoracic Society/Intensive Care Society (BTS/ICS) Acute Hypercapnic Respiratory Failure Guideline Development Group (2016). BTS/ICS Guidelines for the Ventilatory Management of Acute Hypercapnic Respiratory Failure in Adults. Thorax 71:ii1-ii35.

7. Esquinas, A. M. (Ed.). (2022). Teaching Pearls in Noninvasive Mechanical Ventilation: Key Practical Insights. Springer Nature.

8. Ozyilmaz E, Ugurlu AO, Nava S. Timing of noninvasive ventilation failure: causes, risk factors, and potential remedies. BMC Pulm Med. 2014;14(1):19. https://doi.org/10.1186/1471- 2466-14-19.

9. Scala R, Pisani L. Noninvasive ventilation in acute respiratory failure: which recipe for success? Eur Respir Rev. 2018;27(149):180029.

10. Rochwerg B , Brochard L , Elliott MW et al . Official ERS/ATS clinical practice guidelines: noninvasive ventilation for acute respiratory failure . Eur Respir J 2017 ; 50 .

11. Davidson AC , Banham S , Elliott M et al . BTS/ICS guideline for the ventilatory management of acute hypercapnic respiratory failure in adults . Thorax 2016 ; 71 (Suppl 2): ii1-35.

12. Evans, Timothy W. "International Consensus Conferences in Intensive Care Medicine: non-invasive positive pressure ventilation in acute respiratory failure." Intensive care medicine 27.1 (2001): 166-178.

13. MacIntyre, Neil R. Physiologic effects of noninvasive ventilation. Respiratory care 64.6 (2019): 617-628.

14. Elliott, M., Nava, S., & Schönhofer, B. (Eds.). (2018). Non-invasive ventilation and weaning: principles and practice. CRC Press.

References

15. Sanchez D, Smith G, Piper A, Rolls K. Non–Invasive Ventilation Guidelines for Adult Patients With Acute Respiratory Failure: A Clinical Practice Guideline. Agency for clinical innovation NSW government Version 1, Chatswood NSW, ISBN 978-1-74187-954-4 (2014).

16. Ehrmann S, Li J, Ibarra-Estrada M, Perez Y, Pavlov I, McNicholas B, et al. Awake prone positioning for COVID-19 acute hypoxaemic respiratory failure: a randomised, controlled, multinational, open-label meta-trial. Lancet Respir Med. (2021) 9:1387–95.

17. Simonds, A. K. (Ed.). (2015). ERS practical handbook of noninvasive ventilation. European Respiratory Society.

18. Holanda MA, Reis RC, Winkeler GF, Fortaleza SC, Lima JW, Pereira ED. Influence of total face, facial and nasal masks on short-term adverse effects during noninvasive ventilation. J Bras Pneumol. 2009;35(2):164-73.

19. American Association for Respiratory Care, Restrepo R, Walsh B: Humidification during invasive and noninvasive mechanical ventilation, Respir Care 57:782–788, 2012.

20. Developed from BTS/ICS guidelines. https://www.brit-thoracic.org.uk/document-library/clinical-information/acute-hypercapnic-respiratory-failure/bts-guidelines-for-ventilatory-management-of-ahrf/

21. Duan, Jun, et al. "Assessment of heart rate, acidosis, consciousness, oxygenation, and respiratory rate to predict noninvasive ventilation failure in hypoxemic patients." Intensive care medicine 43.2 (2017): 192-199.

22. Duan, Jun, et al. "An updated HACOR score for predicting the failure of noninvasive ventilation: a multicenter prospective observational study." Critical Care 26.1 (2022): 1-11.

23. Ergan, Begum, Jacek Nasiłowski, and João Carlos Winck. How should we monitor patients with acute respiratory failure treated with noninvasive ventilation? European Respiratory Review 27.148 (2018).

24. de Wit M, Miller KB, Green DA, et al. Ineffective triggering predicts increased duration of mechanical ventilation. Crit Care Med 2009; 37: 2740–2745.

25. Epstein SK. How often does patient-ventilator asynchrony occur and what are the consequences? Respir Care 2011; 56: 25–38

26. Chao DC, Scheinhorn DJ, Stearn-Hassenpflug M. Patient-ventilator trigger asynchrony in prolonged mechanical ventilation. Chest 1997; 112: 1592–1599.

27. Thille AW, Lyazidi A, Richard JC, et al. A bench study of intensive-care-unit ventilators: new versus old and turbine-based versus compressed gas-based ventilators. Intensive Care Med 2009; 35: 1368–1376.

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