

Noninvasive ventilation series

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NIV is rapidly gaining acceptance around the world as the preferred choice of treatment over invasive ventilation. These series discussing several titles upon daily practice on NIV which be detailed in every section.

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Noninvasive ventilation series

Noninvasive ventilation (NIV) refers to the administration of ventilatory support without using an invasive artificial airway (endotracheal tube or tracheostomy tube). NIV is rapidly gaining acceptance around the world as the preferred choice of treatment over invasive ventilation. The following topics of NIV series will be discussed starting from current edition and upcoming editions.

Titles of noninvasive ventilation series

- (1) Equipment, interfaces, and circuits of noninvasive positive-pressure ventilation (NPPV).
- (2) NPPV in acute hypercapnic respiratory failure.
- (3) NPPV in acute hypoxemic respiratory failure.
- (4) When to start NPPV at home.
- (5) Weaning and predictors of failure of NPPV.
- (6) Pediatric NPPV.

Equipment, interfaces, and circuits for noninvasive ventilation

Equipment of noninvasive ventilation

The most famous equipment of NPPV are classified into first-generation biphasic positive airway pressure (BiPAP) (Fig. 1), second-generation BiPAP (Figs 2 and 3), and new ICU ventilators (Figs 4–6), which differ from each other in technical (Table 1), software (Table 2), and commercial (Table 3) aspects.

The best equipment for NPPV is characterized by the following:

- (1) Adequate leak compensation.
- (2) Continuous monitoring of pressure–flow–volume waveforms.
- (3) Continuous monitoring of all parameters, including exhaled tidal volume due to the presence of double-limb circuits.
- (4) Oxygen blenders to ensure stable oxygenation.

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- (5) Different levels of adjustment of inspiratory trigger and expiratory cycling to manage patient–ventilator asynchrony.

Bilevel ventilators are the evolution of home-based continuous positive airway pressure devices and derive their name from their capability to support spontaneous breathing with two different pressures: an inspiratory positive airway pressure and a lower expiratory positive airway pressure or positive end-expiratory pressure. These machines were specifically designed to deliver NPPV with their efficiency in compensating for air leaks.

The optimization of patient–ventilator interaction during NPPV is essentially based on the technological efficiency of the machine in detecting the patient's minimum inspiratory effort that triggers the ventilator to deliver pressure support (i.e. inspiratory trigger) and in ending the delivery of support as close as possible to the beginning of the patient's expiration (i.e. expiratory cycling).

Ideally, the inspiratory trigger should be set at the higher sensitivity capable of reducing the patient's effort needed to activate the mechanical support. Bilevel ventilators equipped with flow triggers are associated with a lower work of breathing and shorter triggering delay time. However, a highly sensitive trigger may induce autotriggering during NPPV.

The cycling to expiration optimizes the synchrony between the inspiratory time of the patient and that of the machine. During pressure support ventilation, cycling to expiration is flow dependent and occurs at a threshold, which is the decrease in flow either to a

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Figure 1



First generation BiPAP.

Figure 2



Second generation BiPAP. VPAP/ST.

Figure 3



Second generation BiPAP. Stellar.

default or changeable percentage (usually 25%) of inspiratory peak flow.

Patients with chronic obstructive pulmonary disease cope better with higher inspiratory flow and patients

Figure 4



BiPAP Vision.

Figure 5



V60 with AVAPS.

with neuromuscular problems do better with lower inspiratory flow (i.e. pressure rise time of 0.05–0.2 and 0.4–0.5 s, respectively).

Air leaks are almost a constant feature of NPPV and may interfere with the patient's comfort, patient-ventilator synchrony, and, eventually, the likelihood of success in both acute and chronic patients. Unintentional leaks may occur through the mouth during nasal ventilation or between the interface and the skin with both nasal and oronasal masks. However, the attempt of tightly fitting the straps of headgear to reduce air leaks should be avoided because this may reduce the patient's tolerance and predispose to skin damage. Consequently, it is important to have a ventilator capable of well-compensating air leaks

Figure 6



Purittan Benett 840.

Table 1 Technical differences among noninvasive ventilation ventilators

	Leak compensation	CO ₂ rebreathing	O ₂ blenders
First-generation BiPAP	+++	+++	No
Second-generation BiPAP	+++	+/-	No
New ICU ventilators	+++	-	Yes

- absent; +/-, low or absent; +, moderate; ++, high; BiPAP, biphasic positive airway pressure.

Table 2 Software differences among noninvasive ventilation ventilators

	Trigger and cycling adjustment	Monitoring	Alarms
First-generation BiPAP	-	-	-
Second-generation BiPAP	+++	++	++
New ICU ventilators	+++	+++	+++

- absent; ++, moderate; +, low; +++, high; BiPAP, biphasic positive airway pressure.

Table 3 Technical differences among noninvasive ventilation ventilators

	Costs	Transportability
First-generation BiPAP	+	+++
Second-generation BiPAP	++	+++
New ICU ventilators	+++	+/-

+/-, low or absent; +, low; ++, moderate; +, low; +++, high; BiPAP, biphasic positive airway pressure.

during NPPV. Even though all bilevel ventilators and new ICU ventilators were able to compensate for air leaks, their performance was not uniform.

As excessive air leaks are correlated with treatment failure, the clinician should choose ventilators designed for NPPV with leak compensation capability (i.e. bilevel, and new ICU ventilators); moreover, the chance of setting several parameters and looking at flow-volume-pressure waveforms with newer ventilators may be helpful in improving patient-ventilator synchrony, comfort, and clinical outcome.

Interfaces of noninvasive ventilation

Interfaces connect the ventilator through a circuit to the patient and thereby allow the delivery of pressurized air into the upper airways and subsequently into the lungs. Choosing an appropriate interface is essential for successful NPPV. The interface has to provide a good seal and needs to be tolerated by the patient at the same time.

Types

- (1) Nasal mask: It covers the whole nose but not the mouth (Fig. 7).
- (2) Oronasal mask: It covers the mouth and nose (Fig. 8).
- (3) Total face mask: It covers the mouth, nose, and eyes and seals around face perimeter (Fig. 9).
- (4) Nasal pillow: It is applied externally to the nares (Fig. 10).
- (5) Mouthpiece: It is placed between the patient lips (Fig. 11).
- (6) Helmet: It comprises a transparent hood with collar that covers the whole head and neck (Fig. 12).

Indication of interfaces

- (1) Nasal mask:
 - (a) Chronic respiratory insufficiency due to chronic obstructive pulmonary disease or chest wall diseases such as kyphoscoliosis, neuromuscular disorders, and obesity hypoventilation syndrome.
 - (b) Obstructive sleep apnea syndrome.
- (2) Oronasal mask:

They have been used mainly on patients with acute respiratory failure with mouth breathing due to disturbed conscious level and/or respiratory distress.

- (3) Total face mask:

It is restricted for use after failure of oronasal mask.

- (4) Nasal pillow:

- (a) It is similar to a nasal mask but more comfortable.

Figure 7



Standard nasal mask.

Figure 8



Comfort full oronasal mask.

- (b) It is not used if there is a need for high inspiratory pressure more than 15 cmH₂O.
- (5) Mouthpiece:
 - (a) It is mainly used in patients with neuromuscular disease to decrease work of breathing.
 - (b) The disadvantages are nasal air leaking, and interference with speech and swallowing.
- (6) Helmet:
 - (a) It is used when higher pressure is required for NPPV.

Figure 9



Total face mask (TFM).

Figure 10



Nasal pillow.

Figure 11



Oral interface.

- (b) Adequate fresh gas flow not less than 30 l/min is needed to avoid CO₂ rebreathing.
- (c) It is used in immunocompromised patients to promote better infection control.

Table 4 highlights the advantages and disadvantages of interfaces.

Circuits for noninvasive ventilation

Circuits of NPPV are either single-limb circuit, double-limb circuit, or incomplete double-limb circuit.

First-generation and second-generation BiPAP ventilators are provided with a single-limb circuit through which inspiratory and expiratory pressures are alternately delivered, and the exhalation of the expired air occurs through the whisper swivel, a fixed-resistance, variable-flow, leak port situated in the circuit proximally with respect to the interface. This equipment exposes the patient to the risk for CO₂ rebreathing, which may be detrimental when treating hypercapnic patients. The options that the clinician has to prevent this risk are as follows: (a) keep the conventional whisper swivel and

apply high expiratory positive airway pressure levels, such as 8 cmH₂O, which therefore may be poorly tolerated; (b) use the plateau exhalation valve, which, through its diaphragm, limits air leaks during inspiration and allows unidirectional airflow during expiration; (c) apply an active exhalation valve, which works like a 'true valve' as during the inspiration the balloon is inflated with a full occlusion of the expiratory circuit limb preventing loss of tidal volume, and during the expiration, as the valve is deflated, the air is allowed to be exhaled.

CO₂ rebreathing is also influenced by the site of the exhalation port, being significantly lower when using a facial mask with the exhalation port inside compared with a facial mask with the exhalation port in the circuit.

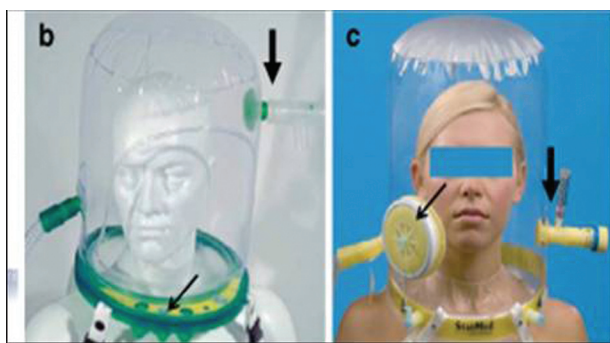
New ICU ventilators have a dual-limb circuit in which a complete separation exists between inspiratory and expiratory lines. Active inspiratory and expiratory valves are incorporated into the ventilator. With separation of the inspiratory and expiratory gases, there is no risk for rebreathing. Another advantage of this dual-limb circuit is the ability of close monitoring of exhaled tidal volume for critically ill patient.

The vented and nonvented interfaces are connected to suitable respiratory circuits as shown in Table 5.

Supplemental oxygen during noninvasive ventilation

New ICU ventilators usually use oxygen blenders in which O₂ from high-pressure sources and room air are

Figure 12



Helmet.

Table 4 Comparable advantages and disadvantages of interfaces

	Nasal	Oronasal	Total face mask	Pillow	Mouthpiece	Helmet
Acute settings	-	+	+	-	-	+
Chronic settings	+	+	+	+	+	-
Use outside ICU	+	+	+	+	+	-
Claustrophobic	-	+	+	-	-	+
More leak	+	+	-	+	+	-
Easier expectoration	+	-	-	+	-	-
Eye irritation	+	+	+	-	-	+
Easy speaking	+	-	-	+	-	+

- absent; +, low.

Table 5 The suitable circuits for vented and nonvented interfaces

Interface	Suitable circuits
Vented	Single-limb circuit
The interface has one or small holes	
Allow CO ₂ removal	
Nonvented	Double-limb circuit (CO ₂ removal through ventilator)
The interface is completely closed	Single-limb circuit nonvented (CO ₂ removal through active exhalation valve at the distal end of circuit)
Requires option for CO ₂ removal	Single-limb vented circuit (CO ₂ removal through a whisper swivel or plateau exhalation valve)

variably mixed, making the fraction of inspired oxygen (FiO_2) controlled and stable as well as providing higher concentrations of oxygen.

Portable BiPAP ventilators commonly used to deliver NPPV do not typically have an oxygen control. These ventilators entrain room air and require supplemental oxygen to the circuit or interface. The concentration of oxygen delivered to the patient depends on ventilator pressures, leak, the site of exhalation port, oxygen flow rate, and the site of oxygen entrainment.

Entraining supplemental oxygen directly through the mask yields higher FiO_2 compared with adding it to other points in circuit. Lower inspiratory pressures tend to be associated with higher FiO_2 but this may reduce the delivered tidal volume [1–11].

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Conflicts of interest

There are no conflicts of interest.

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