

# Noninvasive ventilation series

## Khaled Hussein

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.

*Egypt J Bronchol* 2017 11:173–178

© 2017 Egyptian Journal of Bronchology

*Egyptian Journal of Bronchology* 2017 11:173–178

**Keywords:** circuits, interfaces, non invasive ventilation

### 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.

Department of Pulmonology & Critical Care, Assiut University, Assiut, Egypt

Correspondence to Khaled Hussein, MD, Department of Pulmonology & Critical Care, Assiut University, Assiut, 71111, Egypt;

Tel: +20 106 121 2172;

e-mail: khaldhusein@yahoo.com

**Received** 10 February 2017 **Accepted** 23 February 2017

- (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

---

This is an open access article distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 License, which allows others to remix, tweak, and build upon the work noncommercially, as long as the author is credited and the new creations are licensed under the identical terms.

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 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 cmH<sub>2</sub>O.
- (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 CO<sub>2</sub> 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 CO<sub>2</sub> 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 cmH<sub>2</sub>O, 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.

CO<sub>2</sub> 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.

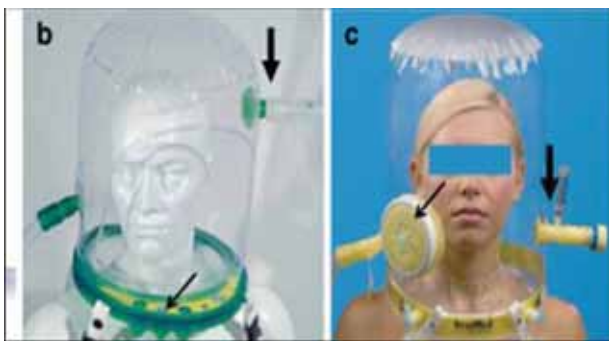
New ICU ventilators have a dual-limb circuit in which a complete separation exists between inspiratory and expiratory lines. Active inspiratory and expiratory valves are incorporated into the ventilator. With separation of the inspiratory and expiratory gases, there is no risk for rebreathing. Another 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 O<sub>2</sub> 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 <sub>2</sub> removal	
Nonvented	Double-limb circuit (CO <sub>2</sub> removal through ventilator)
The interface is completely closed	Single-limb circuit nonvented (CO <sub>2</sub> removal through active exhalation valve at the distal end of circuit)
Requires option for CO <sub>2</sub> removal	Single-limb vented circuit (CO <sub>2</sub> removal through a whisper swivel or plateau exhalation valve)

variably mixed, making the fraction of inspired oxygen ( $\text{FiO}_2$ ) 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  $\text{FiO}_2$  compared with adding it to other points in circuit. Lower inspiratory pressures tend to be associated with higher  $\text{FiO}_2$  but this may reduce the delivered tidal volume [1–11].

#### Financial support and sponsorship

Nil.

#### Conflicts of interest

There are no conflicts of interest.

## References

- 1 Carron M, Freo U, BaHamam AS. Complications of non invasive ventilation techniques: a comprehensive qualitative review of randomized trials. *Br J Anaesth* 2013; **110**:896–914.
- 2 Frat JP, Thille AW, Mercat A, Girault C. High flow oxygen therapy through nasal cannula in acute hypoxaemic respiratory failure. *N Engl J Med* 2015; **372**:2185–2196.
- 3 Nava S, Hill N. Non-invasive ventilation in acute respiratory failure. *Lancet* 2009; **374**:250–259.
- 4 Nava S. Behind a mask tricks, pitfalls, and prejudices for non invasive ventilation. *Respir Care* 2013; **58**:1367–1376.
- 5 Nava S, Fanfulla F. Almost everything you wanted to know about a ventilator. In: Nava S, Fanfulla F, editor. *Non invasive artificial ventilation*. Milan, Italy: Springer; 2014:9–14.
- 6 Scala R, Naldi M. Ventilators for noninvasive ventilation to treat acute respiratory failure. *Respir Care* 2008; **53**:1054–1080.
- 7 Schettino GP, Chatmongkolchart S, Hess DR. Position of exhalation port and mask design affect CO<sub>2</sub> rebreathing during noninvasive positive pressure ventilation. *Crit Care Med* 2003; **31**:2178–2182.
- 8 Schwartz AR, Kacmarek RM, Hess DR. Factors affecting oxygen delivery with bi-level positive airway pressure. *Respir Care* 2004; **49**:270–275.
- 9 Sferarazza Papa GF, di Marco F, Akoumianaki E. Recent advances in interfaces for non invasive ventilation: from bench studies to practical issues. *Minerva Anestesiol* 2012; **78**:1146–1153.
- 10 Storre JH. Oxygen supplementation in non invasive home mechanical ventilation: the crucial roles of CO<sub>2</sub> exhalation systems and leakages. *Respir Care* 2014; **59**:113–120.
- 11 Vignaux L, Vargas F, Roeseler J. Patient-ventilator asynchrony during non-invasive ventilation for acute respiratory failure: a multicenter study. *Intensive Care Med* 2009; **35**:840–846.