CPAP, Bi-level PAP, AVAPs and iVAPs. Which one and when?

Pratibha Singhal

NIPPV, NPPV or NIV are terms used to describe non-invasive positive pressure ventilation. It is a broad term for any ventilation therapy applied in a non-invasive way, therefore, NIV, or NPPV (Non-invasive Positive Pressure Ventilation), is also very often referred to as "mask ventilation".

This is in contrast to "invasive ventilation", where an endotracheal tube or a tracheal canula serves as an invasive interface between the patient and the ventilator.

History

CPAP was first demonstrated to be useful for OSA in 1981 by Dr Sullivan. In 1990's NIV in restrictive disorders and acute COPD was proven to be effective. From 2000 to 2005 various studies demonstrated usefulness of NIV in other acute hypoxaemic respiratory failure, paediatric disease and motor neuron disease. The latest developments occurred 2014 onwards with demonstration of beneficial effects of long term use of NIV in chronic COPD.

Terminologies in NIV

Inspiratory positive airway pressure - IPAP

This is the pressure delivered by the ventilator when patient is inhaling. This improves ventilation (Vt), decreases work of breathing which clinically results in improving oxygenation, decreasing CO_2 and improving symptoms.

Expiratory positive airway pressure- EPAP

This is the pressure delivered by the machine while patient exhales. This maintains upper airway patency which is important in OSA. This also helps to overcome the inspiratory load in presence of auto PEEP (PEEPi) in COPD patients. EPAP recruits lung volume improving oxygenation. EPAP also prevents CO_2 re-breathing from ventilator circuit (Fig 1).

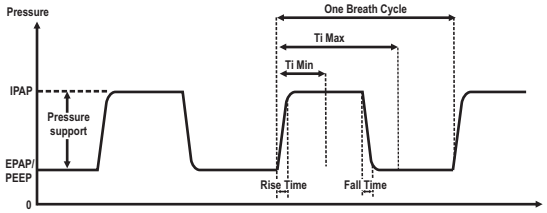


Fig 1: The ventilator assists breathing by providing two pressures in response to the patient flow or a preset fixed time. The difference of the two pressures (pressure support) contributes to improve patient ventilation

Volume

Ability to set Vt to be delivered by ventilator during inhalation by patient.

Back up rate

The ventilator delivers timed breaths if the patients spontaneous breath rate falls This ensures that the minimum breath rate is met. This is especially important in

MD Chest, Consultant Chest Physician, Bombay Hospital, 12 New Marine Lines, Mumbai - 400 020.

central hypoventilation syndrome and in some patients of neuromuscular disease.

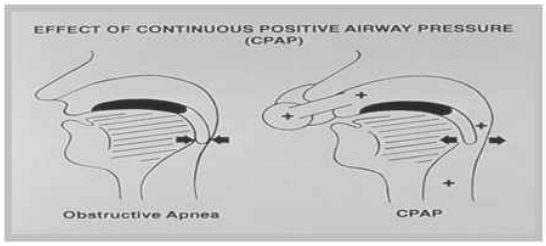
Mode of Ventilation

Continuous Positive airway pressure - CPAP

CPAP = PEEP = EPAP

This provides the same continuous pressure throughout the respiratory cycle. This is most effective in obstructive sleep apnoea (OSA). Other indications are acute cardiogenic pulmonary oedema and upper airway resistance syndrome.

Fig 2.



CPAP is not technically NIV as it does not support the respiratory muscles or assist with Vt delivery. Hence it is not effective in presence of apnoea or hypoventilation. In some patients, the administration of CPAP may eliminate CO_2 and reduce arterial PCO_2 below the apnoea threshold, and consequently lead to ventilatory instability characterised by central apnoeas and periodic breathing. Hence patients worsening on CPAP have to be investigated for this.

Bi level PAP or pressure support Ventilation - BIPAP

In this mode additional support is provided during inspiration. Deliver a higher pressure on inspiration (IPAP) and a lower pressure on expiration (EPAP).

IPAP and EPAP are set which are to be delivered by the ventilator. This can be in (S) or spontaneous/timed (ST) mode. In ST mode when the patients RR falls the ventilator delivers a back up timed breath. A backup rate (i.e., ST mode) should be used in all patients with central hypoventilation, those with a significant number of central apnoeas or an inappropriately low respiratory rate, and those who unreliably trigger IPAP/EPAP cycles due to muscle weakness.

Hence BIPAP S/T should be used in COPD, OHS, complex apnoeas, neuromuscular disorders. BIPAP S mode is used most commonly in COPD patients.

Volume assure pressure support - VAPS is one of newer technologies that combines BIPAP with delivery of an assured minimum level of ventilation by varying the pressure support. The aim is to match the varying ventilator requirements of patients during different activities in the day and sleep. Some VAPS modes also have the facility of auto EPAP which is useful in patients with unstable upper airways.

AVAPS

Average volume assured pressure support was one of the first of this which targets minute ventilation. Breath to breath delivers a fixed Vt. Assures a tidal volume but could land up hypoventilating or hyperventilating a patient.

In trial of AVAPS versus standard BIPAP in OHS there was a small improvement in nocturnal CO_2. In COPD patients results were equivocal.

Intelligent Volume assured pressure support- iVAPS

iVAPS targets alveolar ventilation, which best represents the useful portion of ventilation that reaches the alveoli (This is based on height of patient). This also has auto EPAP and automatic variable back-up rate.

Minute ventilation changes as patients turn, sneeze, cough and move from REM to nREM sleep. As RR changes, TV changes and minute ventilation remains stable. This mode has been shown to be better tolerated in restrictive lung diseases

Interphase selection

In acute phase full face masks are preferred due to mouth breathing. In chronic use nasal masks are preferred by patients. Sometimes in patients who have nocturnal leaks, nasal mask in daytime and face masks at night are more effective. For OSA usually patients prefer nasal masks unless patients are mouth breathers. If patients have nasal bridge trauma temporarily helmet masks can be used although these increase the leak.

Fig 3 a: face mask

Fig. 3 b: nasal mask

Contraindications to NIV

Absolute contraindications

- Coma
- Cardiac arrest
- Respiratory arrest
- Any condition requiring immediate intubation

Other contraindications (rare exceptions)

- Cardiac instability
- Shock and need for pressor support/ Ventricular arrhythmias
- Complicated acute myocardial infarction
- GI bleeding - Intractable emesis and/or uncontrollable bleeding
- Inability to protect airway
- Impaired cough or swallowing
- Poor clearance of secretions
- Depressed sensorium and lethargy
- Status epilepticus
- Potential for upper airway obstruction
- Extensive head and neck tumours
- Any other tumour with extrinsic airway compression

- Status epilepticus
- Potential for upper airway obstruction
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- Any other tumour with extrinsic airway compression
- Angio-oedema or anaphylaxis causing airway compromise

Other considerations that may limit application

- Implementation
- Staff learning curve and time requirements (nursing and respiratory therapy)
- Potential for delay in definitive therapy (limit trials of therapy)

Initiating NIV

Chronic ventilatory failure is a rise in $PaCO_2$ (hypercapnia) that occurs when the respiratory load can no longer be supported by the strength or activity of the system. Patients with hypercapnic respiratory acidosis may derive the greatest benefit from noninvasive ventilation. Most common causes are COPD, obesity hypoventilation, restrictive diseases such as kyphoscoliosis and motor neuron disease. Treatment varies by condition but includes ventilation.

COPD is the most suitable condition for noninvasive ventilation. Noninvasive ventilation is most effective in patients with moderate-to-severe disease. Hypercapnic respiratory acidosis may define the best responders (pH 7.20-7.30). ST Mode (with fixed or variable backup rate) for acute cases, VAPS may be beneficial in chronic cases. Ensure that the EPAP compensates for intrinsic PEEP and preferably have a pressure support of at least 6 cm H_2O. High intensity NIV with IPAP > 20 cm is beneficial in some COPD patients. In patients with concomitant OSA it is important to ensure appropriate EPAP. Select group of patients will benefit with iVAPS mode.

Noninvasive ventilation is well suited for patients with cardiogenic pulmonary oedema. CPAP and BiPAP modalities both are effective, with CPAP possibly being more effective.

NMD/Restrictive diseases that typically require NIV include

- Amyotrophic Lateral Sclerosis (ALS)
- Muscular Dystrophy (MD)
- Spinal Muscle Atrophy (SMA)
- Kyphoscoliosis
- Post Polio Syndrome
- Spinal Cord Injuries

In NMD lesser IPAP (between 10-20) had better outcomes. Nocturnal use may be especially effective for daytime hypercapnia. However it is to be avoided in bulbar dysfunction or excess secretions. iPAPS has shown to be better tolerated overnight.

NIV has proven to be the most effective treatment for OHS. At night breathing rate slightly increases and tidal volume goes down. OHS patients have a 25% higher breathing frequency and 25% lower tidal volume at night compared to patients with simple obesity. Impairment of tidal volume changes is highest in supine position at night. Higher breathing frequencies with lower tidal volumes increase dead space ventilation and reduce alveolar

ventilation. An algorithm providing constant alveolar ventilation like iVAPS is ideal for OHS patients to guarantee effective CO_2 washout at all conditions at night. iBR intelligent backup rate in iVAPS mode ensures adequate breathing if ventilatory drive should fail.

Settings to be prescribed when setting up NIV

- Mode
- EPAP
- IPAP
- Backup Rate / Target Patient Rate
- Inspiratory time (minimum and maximum)
- (Inspiratory) Trigger Sensitivity
- Cycle (Expiratory Trigger) Sensitivity
- Rise Time

Important but often missed

- Mask Type
- Tube Type
- AB Filter

Failure of NIV

A falling pH, rising carbon dioxide, increasing tachypnoea or inability to adequately oxygenate indicate that NIV is failing.

Failure can be classified under three headings

Technical failure

This refers to a failure to achieve adequate ventilation noninvasively. Causes include an inappropriately set ventilator or, rarely, equipment malfunction.

Failure of "noninvasive"

This relates to problems with the interface, either of patient tolerance, usually due to Claustrophobia, or of inability to achieve a satisfactory fit without excessive leaks.

Failure of "ventilation"

This refers to the situation in which, despite patient acceptance, minimal leaks and good patient-ventilator synchrony, it is not possible to ventilate the patient adequately.

Suggested Reading

1. Kohnlein et al, *Lancet Resp Medicine* Sept 2014 Vol. 2 (9) : 698-705
2. Galli et al. *Respiratory Medicine* 2014
3. Dreher et al. *Thorax* 2010; 65: 303-8
4. Windsich W, et al. *Thorax* 2012;67: 663-665.
5. Anita K Simonds. *Thorax* 1995; 50: 604-609.
6. Anita K Smonds. Ers practical handbook Non Invasive ventilation.

Acute rotator cuff tears

Shoulder pain with an inability to abduct above 90° after trauma is a red flag for referral for a same day, plain X-ray assessment.

Refer the following patients urgently to a specialist clinic for consideration of ultrasound or magnetic resonance imaging

Patients unable to abduct the arm above 90° more than two weeks after a shoulder injury

Offer patients with a confirmed acute rotator cuff tear urgent referral to a specialist surgeon to discuss potential surgical repair

Richard Craig, Tim Holt, Jonathan Lloyd Rees, The BMJ, 2018, 35