Non Invasive Ventilation

PULMONARY MEDICINE SEMINAR

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Ways of Ventilatory Support

- **Invasive:** Tube placed in the airway and pressure applied through it.

  ET tube and TT tube

  No negative pressure equipment's
- **Non invasive:** There is no direct access to patient’s airway

Types of NIV

✓Negative pressure NIV

✓Positive pressure NIV

The Journey

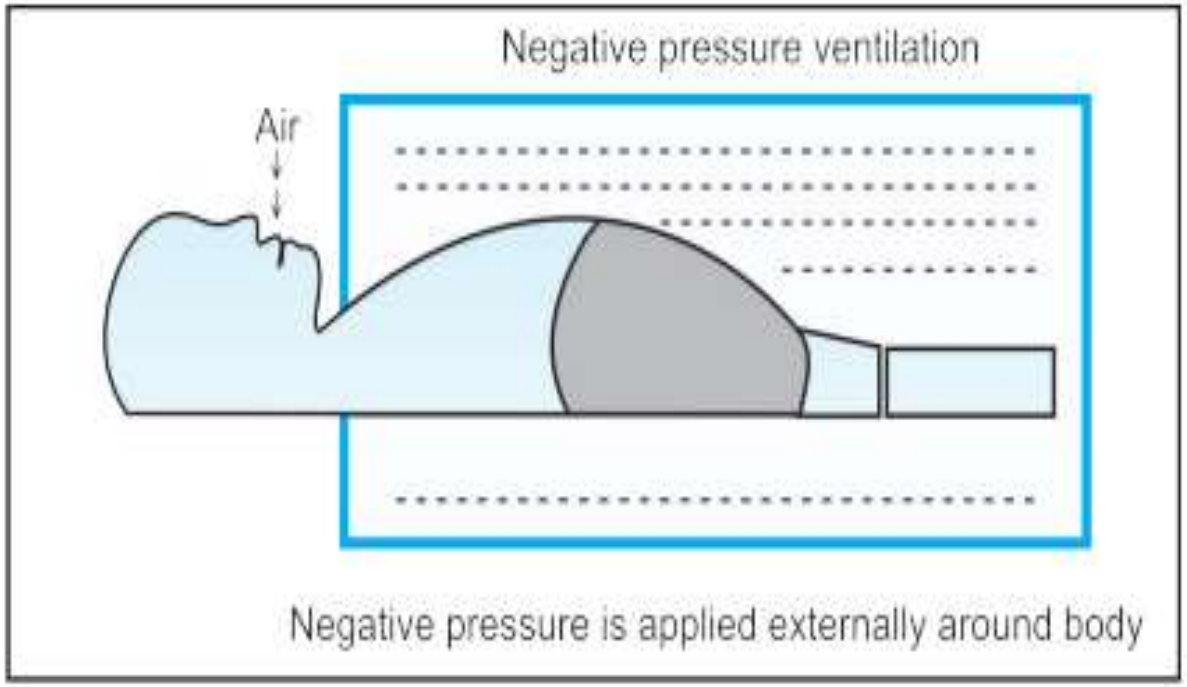
- 1838 – first use of non invasive body ventilators. They were named so because negative pressure was applied around body, consisted of an air tight box in which patient had to sit with head protruding outside.

- Early 1960s – NIV was successfully used to treat patients with neuromuscular diseases

- Early 1980s – CPAP was used to treat sleep apnea

- 1990 onwards NIV gained widespread acceptance and popularity

Negative pressure NIV



- A negative pressure is applied outside the body
- This results in decrease of pressure in chest and air flows into lungs and augments tidal volume.
- Patient lies down in the device while his head rests outside the tank
- Chest expands and air flows in and out of lungs of patient

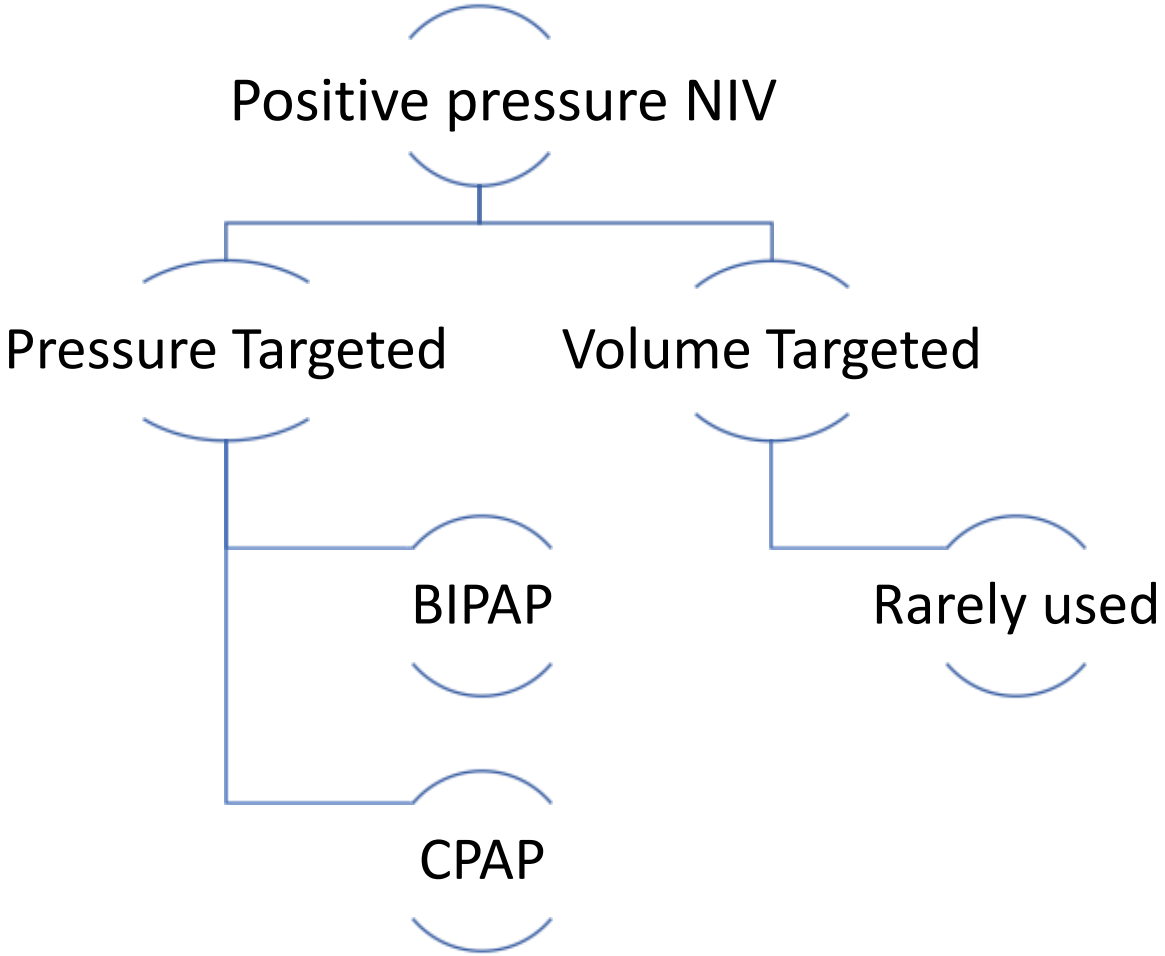
Types of external negative pressure ventilator

- **Tank ventilator or iron lung**: Whole of the trunk is enclosed in metallic body. Material of enclosure is metal.
- **Cuirass ventilator**: Half of the chest is enclosed. Material of enclosure is usually plastic.
- **Pneumo-jacket**: Only chest is enclosed. Material of enclosure is usually nylon

Disadvantages of Negative pressure NIV

- Poorly tolerated and low acceptability by patient
- Bulky in size
- Patient has to lie in supine position
- Can cause musculoskeletal discomforts in some patients
- Nursing care is difficult if patient is on such a ventilator
- Due to lack of portability, patient has to be confined to place of ventilation

POSITIVE PRESSURE NIV



Advantages of pressure targeted ventilation

- The pressure delivered is constant and this avoids the sudden and uncomfortable pressure increase that occurs with volume control
- Pressure-targeted ventilation compensates for air leak which is an inevitable consequence of NIV
- Positive pressure throughout expiration (EPAP) flushes exhaled CO2 from the mask and distal ventilator tubing

Physiological Effects of NIV

- Increases Tidal volume
- Decreases venous return
- Decreases cardiac output
- Pulmonary artery hypertension

Aims of NIV

- Increase Pao2
- Decrease PaCO2
- Reduce work of breathing
- To relieve upper airway obstruction as in sleep apnea
- To reopen the atelectatic lung
- Stabilization of ribcage

Prerequisites for NIV

Related to Patient

conscious patient who is spontaneously breathing.

Clinical status justifying the need for ventilatory support.

Absence of any contraindications to NIV

Related to Hospital

Should have facility for invasive ventilation as well

Skilled staff

Facility for monitoring

Related to Equipment

Provision of supplemental O2 and humidification

Appropriate interface of proper size

Capable of providing adequate pressures to meet the demand of patient

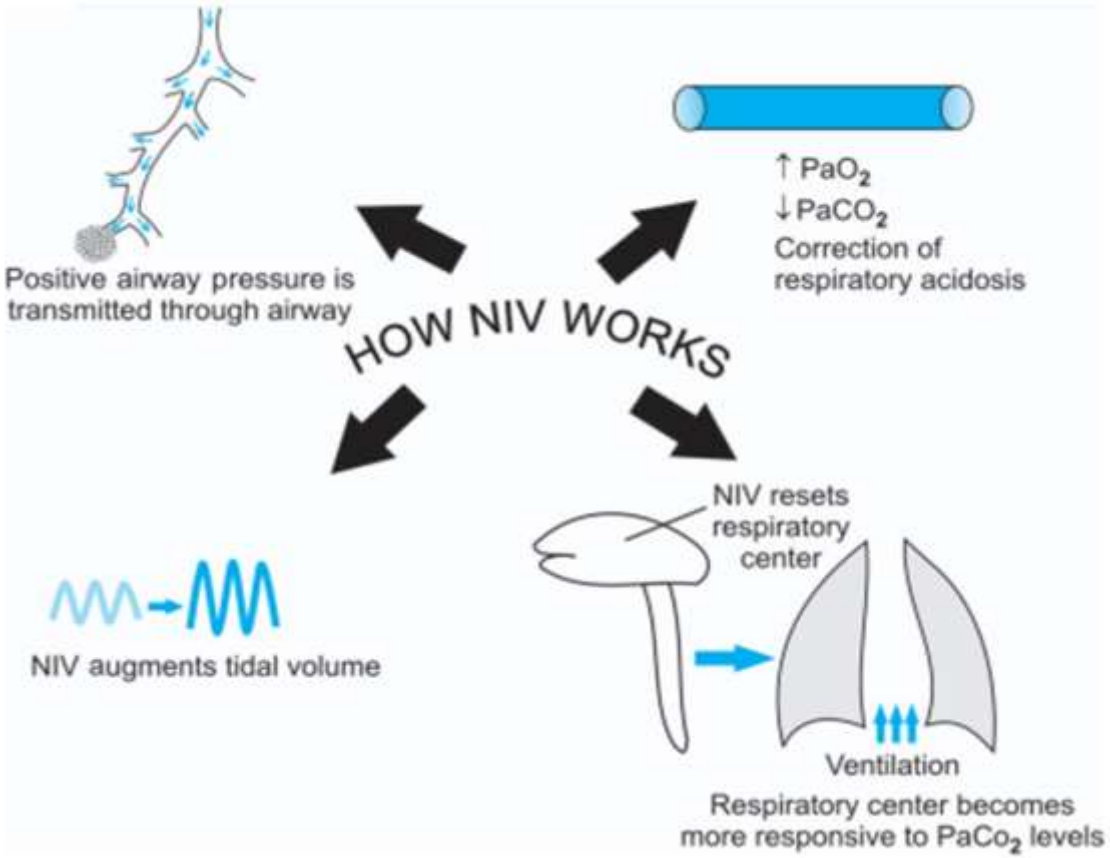
Related to Disease

Mild to moderate respiratory failure

OMT has failed and needs ventilatory support

Patient not requiring urgent intubation

How does NIV work



Indications Of NIV

- **Strong evidence**

✓Hypercapnia with COPD exacerbation

✓Acute cardiogenic pulmonary edema

Moderate evidence

- ✓ Postoperative respiratory failure
- ✓ Weaning in hypercapnic patients
- ✓ Obstructive sleep apnea
- ✓ Immunocompromised
- ✓ Palliative care
- ✓ Restrictive diseases

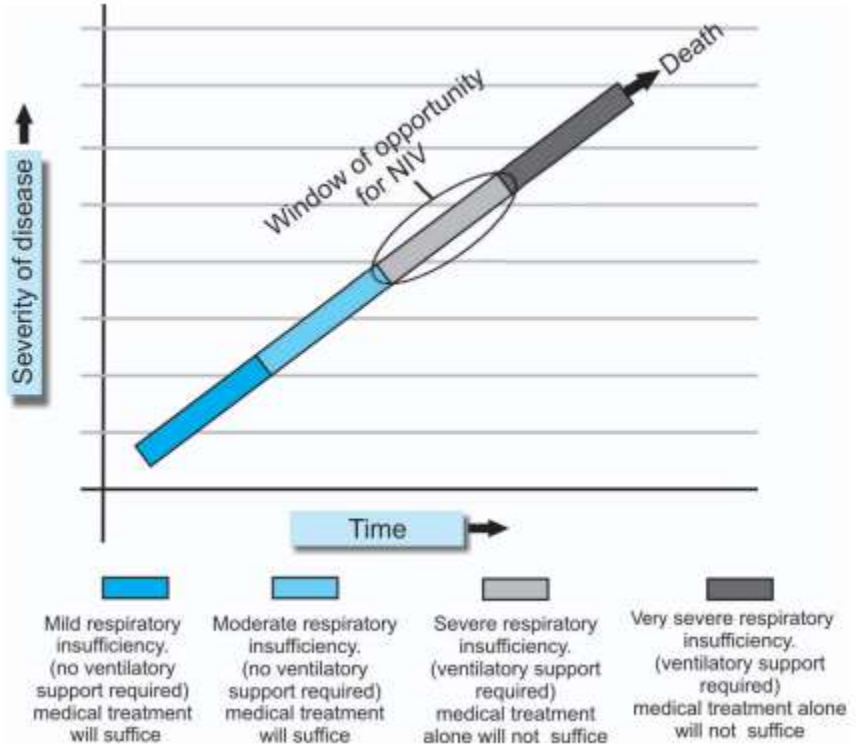
Low evidence

- ✓ Prevention of hypercapnia in COPD exacerbation
- ✓ Post extubation respiratory failure
- ✓ Post extubation in high risk patients

Eur Respir J. 2017 Aug 31;50(2):1602426. doi: 10.1183/13993003.02426-2016

Window of Opportunity

- Becoming distressed enough to take ventilatory support to progressing to severe forms of respiratory failure.
- Appropriate timing is one of the key factors for success of noninvasive ventilation



Contraindications

- Inability to protect the airways –
  - Comatose patients, Confused and Agitated patients
  - Cerebrovascular Accident (CVA) with bulbar involvement
- Hemodynamic instability
  - Uncontrolled Arrhythmia
  - Patient on very high doses of Inotropes or Vasopressors with presence of shock
- Inability to fix the interface
  - Facial abnormalities
  - Facial burns, Facial trauma, Facial anomaly
- Severe GI Symptoms –
  - Severe Vomiting, Obstructed bowel, Severe Hematemesis
- Massive Hemoptysis
- Copious secretions
- Post-cardiac Arrest

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Modes of NIV

BIPAP - Bi-level pressure support ventilation in which the pressure support differs during inspiration and expiration

- Modes of BIPAP
  - ✓ Spontaneous(S)
  - ✓ Spontaneous/timed(ST)
  - ✓ Timed (T)

CPAP - in which the constant same pressure support is given during inspiration and expiration

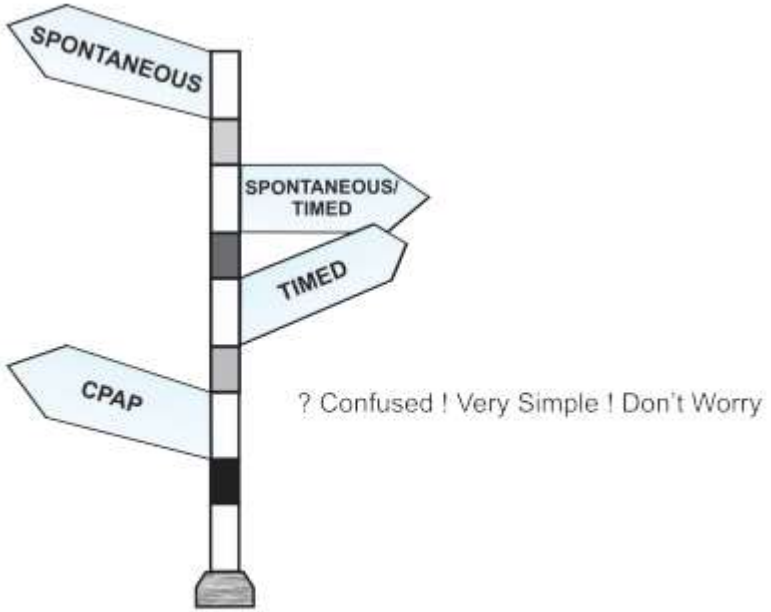

Figure 8.1: Modes of NIV: Spontaneous, spontaneous/timed, timed, CPAP

Spontaneous(S)

- Also known as assist mode
- The ventilator delivers assisted breaths in response to patient inspiratory effort
- If the patient fails to make adequate inspiratory effort, no ventilator support is delivered
- Spontaneous mode is used in patients with good spontaneous respiratory drive.

Timed(T)

- Also known as control mode
- The ventilator delivers breaths at a rate set by the operator regardless of patient’s inspiratory effort
- Timed mode is used in patients with inadequate spontaneous respiratory drive.

Spontaneous/timed(ST)

- Also known as assist control
- A backup rate is set by the operator.
- If the patient’s RR is slower than the backup rate, machine-determined breaths will be delivered (controlled ventilation).
- If the patient breathes faster than the backup rate, no machine determined breaths will be delivered and all breaths will be triggered (or assisted)

CPAP

- Continuous positive airway pressure
- Fixed set pressure is delivered during inspiration and expiration
- CPAP mode is used to treat sleep apnea or cardiogenic pulmonary edema
- It is also used in hypoxemic respiratory failure where there is no CO2 retention

Choosing the Mode

- **In neuromuscular diseases, central hypoventilation, obesity hypoventilation**

✓spontaneous/timed or timed mode is preferred as there are chances of going in to apnea

✓In these patients IPAP values of 8 to 12 may suffice as underlying lungs are normal

- **In pulmonary diseases**

✓spontaneous or spontaneous/ timed mode is preferred as there are less chances of going into apnea

✓In these patients higher values of IPAP may be required as underlying lungs are diseased.

Equipment of NIV

- Consists of ventilator, interface and accessories.

✓Ventilator delivers positive airway pressure to the patient

✓Interface is the connecting system between patient and ventilator

✓Accessories include adaptors, oxygen tubing, humidifier, etc

Ventilators

	Bilevel ventilators	*Critical Care Ventilators*	*Intermediate non-invasive ventilators*
Gas Source	Compressor / Electronic turbine pump	High pressure Gas Source	Compressor / Electronic turbine pump
Circuit	Single limb	Dual limb	Single/ Dual Limb
Exhalation valve	Passive exhalation valve (Whisper Swivel)	Active exhalation valve	Active exhalation valve
Type of ventilation	Old models provided only pressure targeted ventilation. Newer models provide volume targeted ventilation as well.	Volume and pressure targeted ventilation	Volume and pressure targeted ventilation
Advantages	• Portable. • Easy to use. • Most Home Ventilators	Predictable FiO2 delivery	Predictable FiO2 delivery
Disadvantages	• Unpredictable FiO2 delivery, as lacks a blender. May fail in patients with high O2 requirement. • Risk of rebreathing, due to single limb.	• Lack of leak compensation, affects the smooth functioning. • Newer ICU ventilators have "NIV modes" with leak compensation	Some have an incomplete dual limb circuit, in which the expiratory limb is only a short tube with a PEEP valve. This has negative effects on triggering and cycling.

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ResMed

Interface

- Interface is the boundary between ventilator circuit and patient
- Without appropriate interface, efficiency and outcome of NIV will suffer

Types of Interface

oronasal

nasal

pillows

total face

mouthpiece

helmet

Steps of Interface usage

- Choose an appropriate size oronasal or full face NIV mask
- Non-vented mask should be used for a standard ventilator
- Vented masks should be used with a BIPAP machines, which have a single limb for inspiration and expiration
- The mask should comfortably rest over the nose and cover the mouth but should not extend beyond chin
- The mask is secured tight enough over the face such that one should be able to insinuate two fingers between the straps and the patient’s head.

IPAP

- IPAP refers to higher pressure given during inspiration to patients on noninvasive ventilation

✓IPAP augments tidal volume

✓Initially set at a lower level. As patient becomes comfortable, gradually it can be increased to higher level for better gas exchange

✓High IPAP pressures can cause leak.

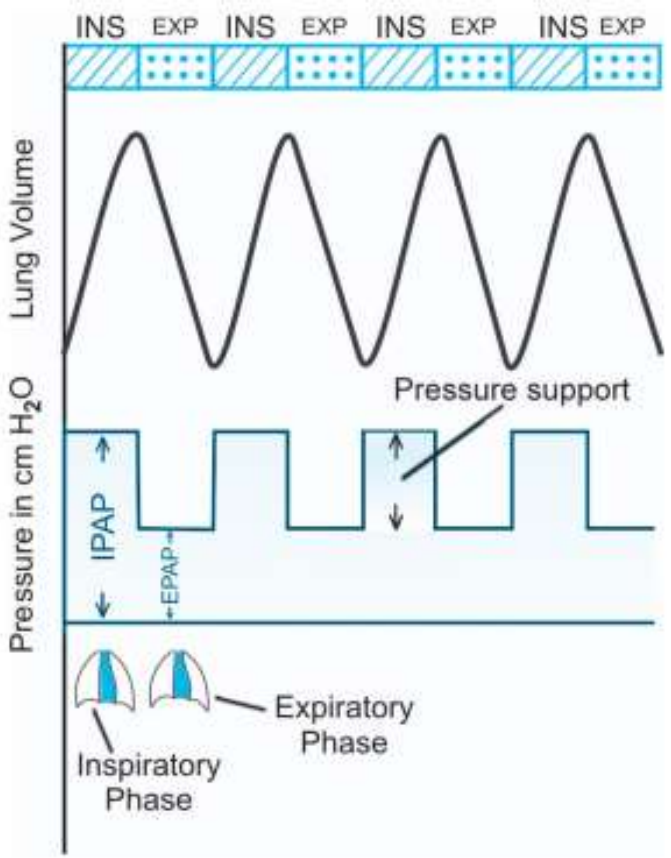
EPAP

- EPAP refers to lower pressure given during expiration to patients on noninvasive ventilation

✓EPAP opens the atelectatic parts of lung.

✓It overcomes intrinsic PEEP.

✓It decreases inspiratory work to trigger inspiration. Therefore in patients of COPD with auto peep, triggering is easier with application of EPAP.



Pressure support:

- Difference between IPAP and EPAP.
- It is the amount of pressure support which increases the tidal volume, not the IPAP alone.
- Higher the pressure support, higher will be the augmentation in tidal volume and minute ventilation

Trigger sensitivity

- Trigger sensitivity refers to the effort required by the patient to initiate, or trigger, the ventilator.
- The lower the trigger sensitivity, the greater effort the patient needs to make to trigger a supported breath
- Flow trigger is preferred over pressure triggering in assisted modes, as it provides better patient ventilator synchrony

- **Ti control, inspiratory time control:**
  - ✓Duration of time during which the patient gets IPAP while receiving noninvasive ventilation

- **IPAP Min, minimum inspiratory time:**
  - ✓It is minimum duration of time, the patient spends on IPAP while receiving noninvasive ventilation.
  - ✓If it is set more than inspiratory time, the patient will continue to inspire to the point of minimum inspiratory time.

- **IPAP max, maximum inspiratory time:**
  - ✓It is maximum duration of time, the patient spends on IPAP while receiving noninvasive ventilation.
  - ✓If it is set shorter than inspiratory time, the patient will not be able to continue inspiration beyond that point

- **Obstructive Lung disease:**

✓ Usually have much inspiratory time.

✓ In these patients, when the maximum inspiratory time is fixed, the patient will not be able to continue inspiration beyond that point. Therefore, he will spend adequate time for expiration to wash CO2

- **Restrictive Lung disease:**

✓Have shorter inspiratory time and insufficiently oxygenated.

✓By setting the minimum inspiratory time, the patient will inspire to point of minimum inspiratory time. Their inspiration will not terminate spontaneously.

✓This will facilitate proper oxygenation and correction of hypoxemia.

- **Rise time:**

✓It is time taken by machine to achieve set IPAP pressure.

✓It should be set less than IPAP max time.

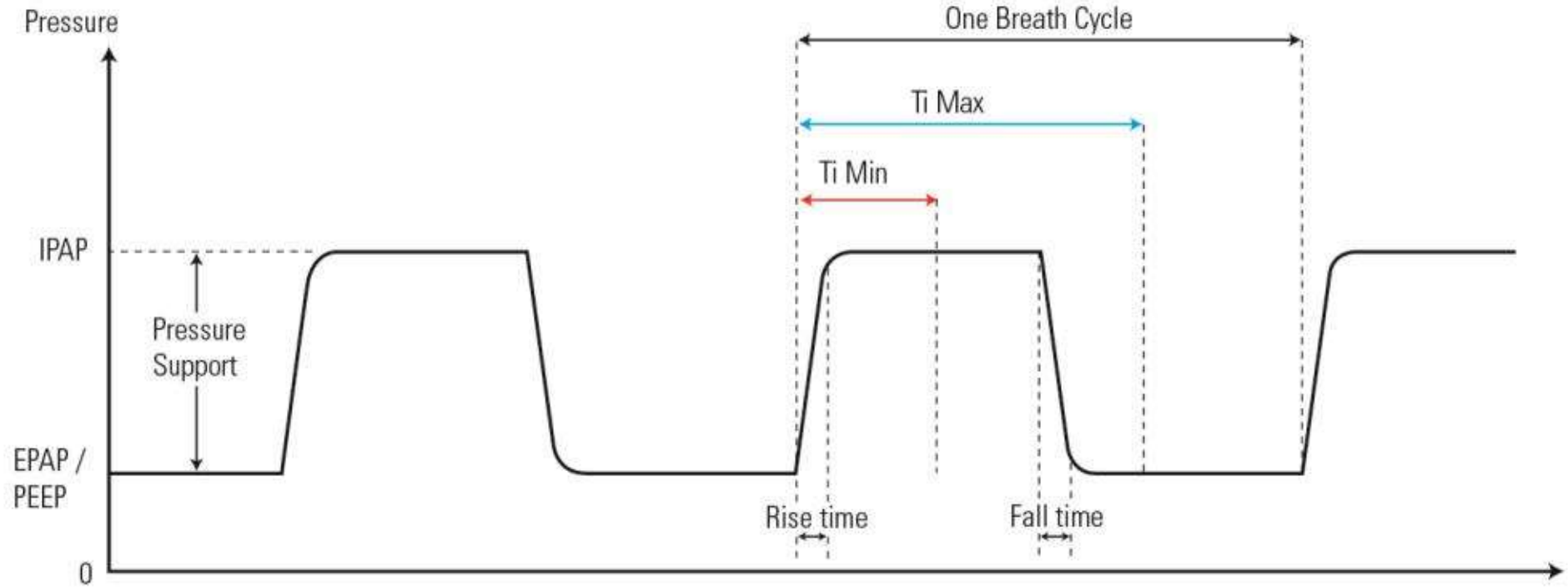
✓If you set rise time above IPAP or IPAP max time, set IPAP pressure will never be achieved.

- **Auto PEEP:**

✓Air is entrapped due to incomplete expiration, e.g. in COPD patients, tachypneic patients.

✓Work of breathing is increased due to auto PEEP.

✓Main causes of auto PEEP are bronchoconstriction, mucous plugging and inadequate expiration.


Pressure
One Breath Cycle
Ti Max
Ti Min
IPAP
Pressure
Support
EPAP /
PEEP
Rise time
Fall time
0

Initiation Of NIV

- Initial IPAP adjusted to achieve a tidal volume of 6-8 mL/kg ideal body weight, respiratory rate < 30/min, with relief of dyspnea
- EPAP should be started at 4 cmH2O and titrated along with FiO2 to achieve SpO2 between 89-92%
- A minimum difference of pressure of 4 cm of H2O between IPAP and EPAP should be maintained
- The maximum IPAP and EPAP should not generally exceed 20 cmH2O and 10 cmH2O, respectively
- Patients may be allowed intermittent periods off the NIV, for eating or expectoration of secretions
- During such periods, oxygen supplementation can be administered through nasal cannula, targeting SpO2 between 89-92%

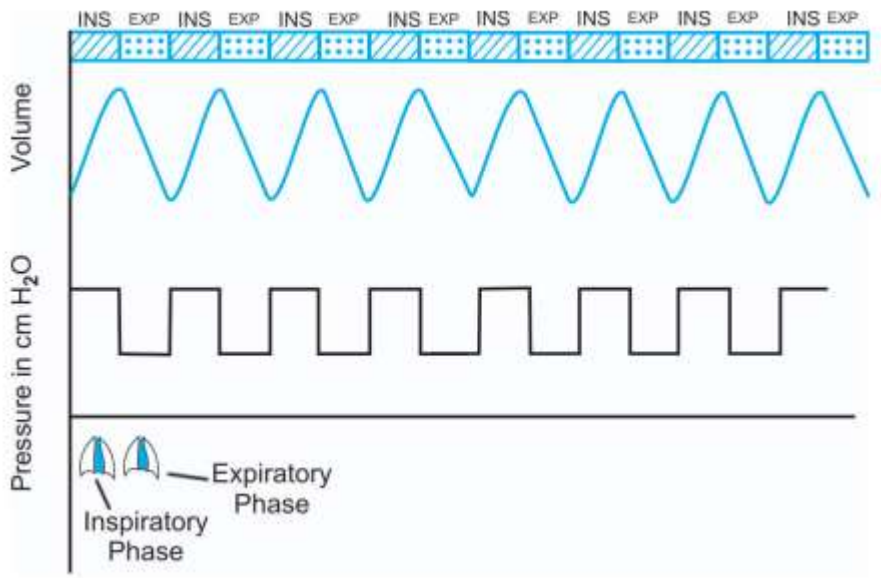
Leak during NIV

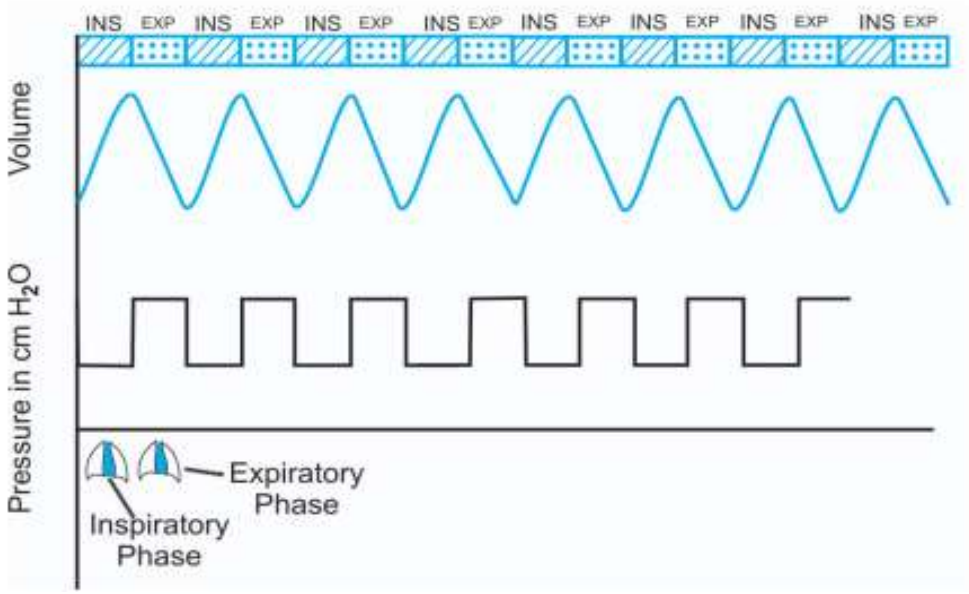
- Leak is of 3 types
  - ✓Intentional leak—Through vent holes
  - ✓Leak from ill-fitted mask where it comes in contact with skin of face of patient
  - ✓Mouth leak or leak from the mouth
- Leak from the ill-fitted mask and leak from mouth (mouth leak) constitute unintentional leak
- Large air leaks can cause a significant drop in the delivered intra-alveolar pressure, reduce tidal volume and lead to patient–ventilator asynchrony by affecting trigger functions.

Synchronization

- Synchrony between the delivery of positive pressures and breathing rhythm of patient.
- In a more simplified manner, one can say synchronization is giving of IPAP during Inspiration and giving of EPAP during expiration.
- Important for NIV to be effective
- **Causes of asynchrony:**
  - ✓Improper application of noninvasive ventilation
  - ✓Presence of significant leaks
  - ✓Presence of intrinsic PEEP
  - ✓Application of timed mode
  - ✓Intolerant patient.

Asynchronization





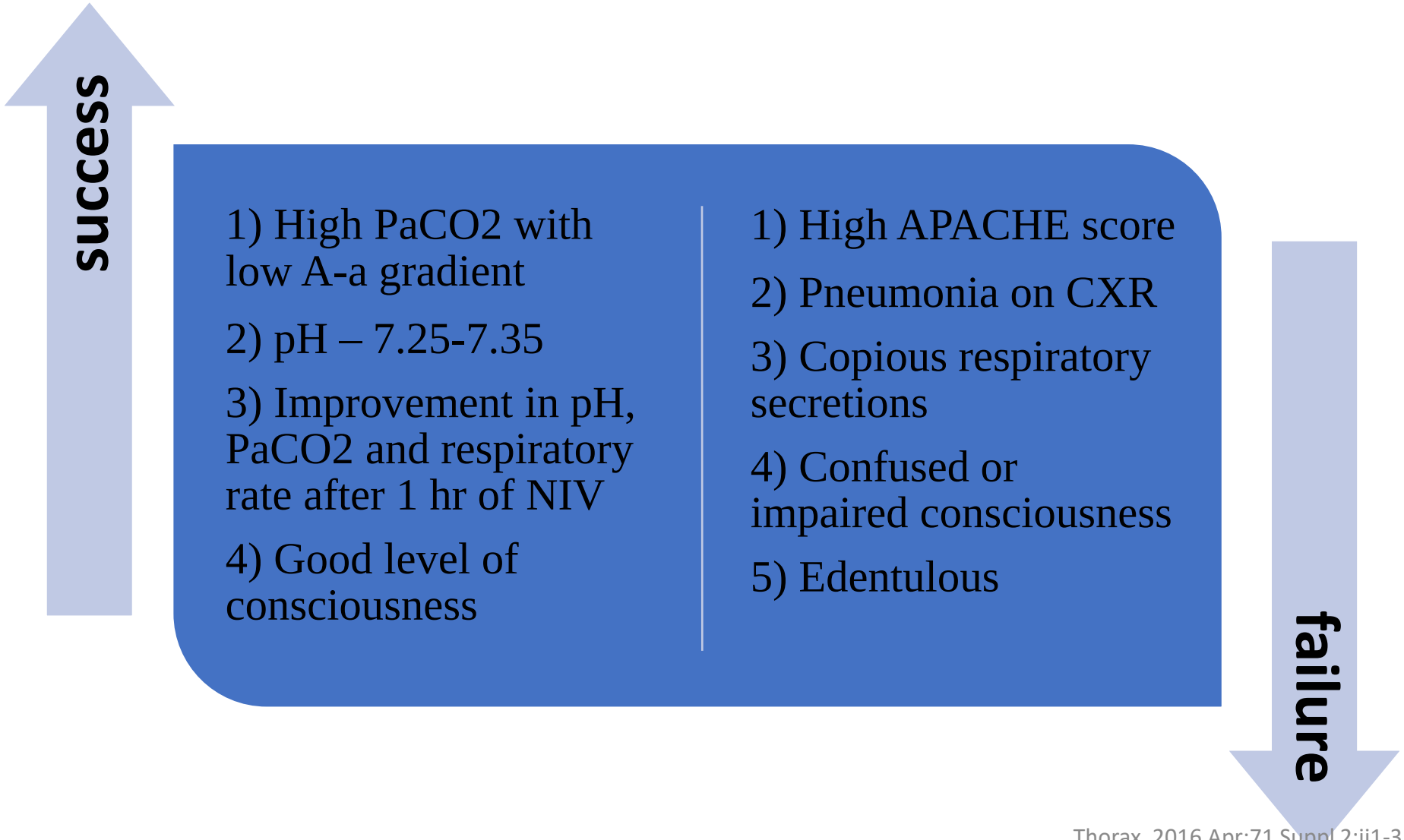
Monitoring Of NIV

- Monitoring during NIV can be divided into:
- ✓ Early intensive monitoring (first four hours)
- ✓ Less intensive monitoring (after four hours).

NIV Monitoring Chart

Parameter	Baseline	1h	2h	4h	12h	24 h	48h
Clinical and vitals							
Sensorium							
Pulse rate							
Respiratory rate							
Blood pressure							
Flaps							
Paradoxical breathing							
SpO2							
Blood gas variables							
pH							
PaO2							
PaCO2							
HCO3							
SpO2							
NIV setting							
IPAP, cmH2O							
EPAP, cmH2O							
FiO2, cmH2O							

Factors for Success and Failure in NIV



Thorax. 2016 Apr;71 Suppl 2:ii1-35. doi: 10.1136/thoraxjnl-2015-208209.

Treatment Failure in NIV

- NIV failure rates range between 18% and 40% in the acute setting
- **Primary failure** – failure of uptake of the technique and control of respiratory failure
- **Secondary failure –** when respiratory failure progresses despite optimal NIV use

Assessing Treatment Failure

- Absence of improvement or a deterioration in clinical state and arterial blood gas parameters 1 hour after initiation of NIV
- Bradycardia (heart rate < 60 beats/min with altered mental status)
- Hypotension (systolic blood pressure < 90 mm Hg)
- Respiratory fatigue or failure to maintain SpO2 >88 % despite a FiO2 of 0.6.
- Pooling/inability to handle secretions
- Inability to tolerate the NIV
- Peak airway pressure of 20 cm of H2O is reached or PEEP of 10 cm of H2O is reached without clinical improvement

HACOR score

- Predicts the risk of NIV failure
- Heart rate, Acidosis, Consciousness, Oxygenation, Respiratory rate
- Score of less than or equal to 5 – low risk
- A score of more than 5 at 1 hour of NIV - >80% risk of NIV failure

When to Wean

- Adequate oxygenation: PaO2/FiO2 ratio >27 kPa (200 mm Hg)
- FiO2 <0.5
- PEEP <10 cm H2O
- Adequate alveolar ventilation (pH >7.3, pCO2 <6.5 kPa)

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How to Wean

- **Once the patient's clinical condition stabilizes**
- Pressure support (PS) can be reduced in steps of 2 cm of H2O every 2 hours taking care to maintain the following: SpO2 >88% at an FiO2 of ≤30%, respiratory rate ≤30 breaths per minute, tidal volume of 6- 8 ml/Kg of IBW. Simultaneously, PEEP can be reduced in steps of 1 cmH2O
- If anytime during the down titration, any of the above parameter is not met, the settings of the previous step are retained
- Reduction of PS and PEEP can be continued in this manner till a PS of <7 cm of H2O and PEEP of <5 cm of H2O is reached
- Once the patient is comfortable on these settings for 4-6 hours, the patient will be taken off NIV and connected to a Venturi mask with FIO2 adjusted to maintain SpO2 between 89-92%

NIV in COPD

- **Indications**

✓ pH<7.35 and pCO2>45mmHg persist or develop despite optimal medical therapy

✓ Severe dyspnea with respiratory muscle fatigue

✓ Persistent hypoxemia despite supplemental O2 therapy

- **Duration**

✓ Discontinued when there has been normalization of pH and pCO2 and a general improvement in the patient's condition

❑ NIV has been shown to accelerate weaning from IMV in patients with COPD failing an SBT

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NIV in OHS

- In patients with OHS, NIV should be started in acute hypercapnic RF, using the same criteria as in AECOPD
- NIV is indicated in some hospitalized obese hypercapnic patients with daytime somnolence, sleep disordered breathing and/or right heart failure in the absence of acidosis
- High IPAP and EPAP settings are required in patients with OHS
- Volume control modes of providing NIV may be more effective when high inflation pressures are required
- Will require long-term domiciliary support

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NIV in Neuromuscular disorders

- **Indications:**

✓Respiratory illness with RR>20 if usual vital capacity <1lit, even if pCO2<45

Or

✓pH<7.35 and pCO2>6.5kpa

- **NIV failure**

✓ Intolerance of the mask and severe dyspnea are less likely to cause NIV failure.

✓ Bulbar dysfunction makes NIV failure more likely.

✓ Deterioration in patients with NMD or CWD may be very sudden.

✓ Difficulty achieving adequate oxygenation or rapid desaturation during a break from NIV are important warning sign

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NIV in cardiogenic pulmonary edema

- Decreased respiratory system compliance and alveolar flooding due to high capillary pressure with or without left ventricular systolic dysfunction
- NIV has the ability to improve respiratory mechanics and facilitate left ventricular function by decreasing left ventricular afterload.
- NIV can be used prior to hospitalization to prevent deterioration in patients with acute respiratory failure due to cardiogenic pulmonary oedema

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NIV in other respiratory conditions

- NIV should not be used in patients with acute asthma exacerbations with acute hypercapnic respiratory failure
- In cystic fibrosis, when ventilatory support is needed, outcome following invasive ventilation is worse than with NIV, especially when infection is the precipitant
- In non CF bronchiectasis, outcome with NIV is no worse than with IMV in selected patients

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Prevention of Infection Transmission with NIV

- Apart from personal protective equipment and hand hygiene, following precautions to be taken when using NIV on a patient with infectious disease:
  - ✓Minimize leaks in the circuit
  - ✓Non-vented face mask, or a helmet – with the best fit to the facial contour
  - ✓Secure the mask, prior to turning on the ventilator. Turn off the ventilator before removing the mask
  - ✓A viral/bacterial filter at the outlet of the ventilator and also at the expiratory side of the circuit
  - ✓Complete decontamination of the ventilator before use in other patients

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Indications of Long term NIV

- Failure to wean from NIV
- Acute hypercapnic respiratory failure secondary to:
  - ✓Spinal cord lesion
  - ✓Neuromuscular disease
  - ✓Chest wall deformity (e.g. scoliosis, thoracoplasty)
  - ✓ Morbid obesity (BMI >30)
- COPD with:
  - ✓ Recurrent AHRF (>3 episodes) requiring treatment with NIV
  - ✓ Intolerance of supplementary oxygen (because of CO_2 retention) with symptomatic sleep disturbance

2002 Mar;57(3):192-211. doi: 10.1136/thorax.57.3.192.

AVAPS

- Average volume assured pressure support
- EPAP is fixed
- IPAP is variable to achieve desired tidal volume
- Fixed backup rate

Advantages of NIV

- Easy to use
- More economic
- Less complex, more acceptable
- Less complications, easier weaning
- Maintenance of defense mechanisms of upper airways
- More comfortable to patient
- Less chances of ventilator associated pneumonias

Disadvantages of NIV

- Less effective as compared to invasive ventilation
- Unprotected airways
- Problems of leak
- Problems of interface
- Abdominal distension, eye irritation
- FiO2 cannot be measured and high FiO2 cannot be given

Complications of NIV

- **Related with interface:**

✓Air leak

✓Mask discomfort

✓Over tight mask

✓Too small or too large mask

- **Related with ventilator**:

✓ Absence of synchronization and fighting with ventilator.

✓ Due to positive pressure. a. Aching of paranasal sinuses. b. Aching of ear, Burning of nose, Oral dryness, Nasal dryness, Oral congestion, Nasal congestion, Gastric distension, Irritation of eyes, Pneumothorax, surgical emphysema, mediastinal emphysema, Hypotension, Nosocomial infections.

Clinical situation 1

- A patient of thoracic trauma with severe lacerations over the face is presented in emergency. Patient is found to be in altered sensorium. Respiration is shallow and blood gases confirm presence of severe type 2 respiratory failure needing urgent ventilatory support

  Will you like to give noninvasive ventilation in this patient?

Clinical situation 2

- A known patient of HIV develops dyspnea, cough with expectoration. His accessory muscles of respiration are working and he is tachypneic. His arterial blood gases show moderate hypoxemia and moderate hypercapnia, say, PaO_2 of 55 mm Hg and $PaCO_2$ of 65 mm Hg.

  What modality of ventilatory support you will use, invasive ventilation or noninvasive ventilation and why??

Clinical situation 3

- Noninvasive ventilation is started to a patient suffering with acute exacerbation of COPD with hypercapnic respiratory failure. Prior to initiation of NIV (Bi PAP ventilation), he is maintaining oxygen saturation of 89% with supplemental oxygen of 2 litres per minute. Oxygen saturation falls to 66% with noninvasive ventilation with same supplemental oxygen of 2 litres per minute.

What do you do next? Is it NIV failure

Clinical situation 4

- Noninvasive ventilation is started to a patient suffering with OHS and hypercapnic respiratory failure. Significant leak is displayed while patient is receiving noninvasive ventilation with nasal mask and supplemental oxygen

What action will you take?

Clinical situation 5

- A 44-year-old woman, who is on home NIV because of an obesity hypoventilation syndrome, presents to the emergency department with a fever and exacerbation of her chronic respiratory failure. She has brought her ventilator and mask with her and is started on this with an increased inspiratory positive airway pressure (IPAP) and the nasal mask that she uses at home. At the higher IPAP, the patient develops a mouth air leak. She refuses to change the mask to an oronasal or total face mask because of claustrophobia.
  - Which of the following can be expected with a persistent mouth air leak?

  a. The expiratory volume increases

  b. The intra-alveolar pressure is not influenced

  c. A further increase in pressure support can partly compensate for the leak

  d. Nasal airway resistance decreases

Take Home Message

- NIV should be used early in respiratory failure
- Choosing of appropriate patient with appropriate interface is a must
- NIV is neither an alternative nor can replace invasive mechanical ventilation, but many times it can obviate the need of intubation

THANK YOU