NON-INVASIVE VENTILATION IN PICU - CHW

PRACTICE GUIDELINE

KEY POINTS

- **Non-invasive ventilation (NIV)** is the administration of positive pressure ventilatory support through a **non-invasive interface**
- **NIV** can be delivered using a variety of interfaces – Prongs, Masks (nasal, oro-nasal, full-face) & Helmets
- An appropriate **patient-ventilator interface** is crucial - well-fitted, appropriately-sized masks will improve synchrony and reduce the risk of pressure areas
- **NIV** is used to treat acute respiratory failure through a **step-up** (to avoid intubation) or **step-down** (post-extubation to avoid respiratory failure) manner
- The main benefit of **NIV** is to **avoid risks and complications** related to placement of an invasive airway (ETT, tracheostomy tube), the need for sedation +/- neuromuscular blockade and the delivery of invasive mechanical ventilation
- **NIV** modes include Continuous Positive Airway Pressure **(CPAP)**, CPAP/Pressure Support **(CPAP/PS)**, Bi-level Positive Airway Pressure **(BiPAP)** and Spontaneous – Timed **(S/T)**
- Ventilators available in PICU for the administration of NIV are the Viasys™ Infant Flow SIPAP, PHILIPS™ V60, PHILIPS™ Respironics Trilogy 100/202/Evo and the MAQUET™ Servo-u
- For **single limb circuits** (SIPAP, V60, Trilogy 100/202/Evo) use only nasal masks or vented oro-nasal or full-face masks (ensure presence of exhalation port) to avoid asphyxia / CO_2 retention
- For **double limb circuits** (MAQUET™ Servo-u) use only non-vented oro-nasal or full-face masks
- All patients on NIV must have a nasogastric tube (NGT) in situ - placed on free drainage and aspirated regularly to remove air / gastric secretions

Approved by:	SCHN Policy, Procedure & Guideline Committee	CHW PICU Policy Committee
Date Effective:	1st October 2021	**Review Period:** 3 years
Team Leader:	Staff Specialist	**Area/Dept:** PICU - CHW

Date of Publishing: 17 September 2021 2:25 PM Date of Printing: 17 September 2021

CHANGE SUMMARY

- Removed ventilator-specific information (which is now incorporated in the PICU ventilation handbook)
- Removed VIASYS Infant Flow Driver
- Added Initial Settings section
- Added Trouble Shooting section
- Added Sedation section
- Revised text overall
- Added additional key references

READ ACKNOWLEDGEMENT

- This document forms an integral part of patient care at CHW PICU. Staff involved in the care of a patient needing NIV support are expected to be familiar with its content and refer to the document for care
- In case a patient's clinical requirements fall outside this guideline, consensus on an appropriate plan of care must be sought and agreed upon by the PICU, respiratory and other involved teams
- For home ventilated patients the respiratory team MUST be involved and document changes to settings and/or planned investigations (transcutaneous CO2 measurement, bloods, formal sleep study)
- Ventilating a patient through a tracheostomy is considered invasive ventilation. If using a bilevel ventilator on a tracheotomised patient ensure you have an ex halation port built in.

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Mechanism of Action / Physiology

- Decreases a patient's work of breathing (WOB) and thereby energy expenditure
- Maintains respiratory tract patency which facilitates expiratory flow and reduces the risk of obstructive apnoea
- Recruits lung areas by increasing functional residual capacity & decreasing ventilation-perfusion mismatch ultimately improving oxygenation and ventilation
- Increases minute volume (MV) and CO2-clearance thereby reducing acidosis
- Has cardio-respiratory interactions:
    - decreases right-ventricular preload
    - increases right-ventricular afterload
    - decreases left-ventricular afterload
- The **absence** of an ETT results in
    - No risk of injury to pharyngeal, oral, laryngeal / tracheal structures through the process of intubation
    - No risk of subglottic mucosal swelling through prolonged exposure to a moving ETT +/- balloon
    - Better airway clearance / decreased risk of ventilator-associated pneumonia (VAP)
    - Less iatrogenic harm caused by the need for sedation and paralysis (delirium, withdrawal, critical-illness neuro-myopathy, post PICU syndrome)

Patient selection

Essential components
1. A conscious patient
2. A capable ventilator
3. A well-fit interface
4. Absence of an overwhelming leak
5. Absence of contraindications (see below)
6. Well trained staff able to assess success or failure of treatment

Indications

- Failure of low flow O2 / HHFNP
- Status asthmaticus
- Pneumonia
- Atelectasis
- Bronchiolitis
- Pulmonary oedema (cardiogenic and non-cardiogenic)
- Cystic fibrosis (CF)
- Acute chest syndrome in Sickle Cell Disease
- Dynamic upper airway obstruction (Laryngo-, tracheo-, bronchomalacia)
- Obstructive sleep apnoea
- Respiratory failure - including patients with compromised immunity e.g. Post organ or bone marrow transplant (as mortality increases exponentially with ITN)
- Post-operative respiratory failure (including patients with congenital heart disease)
- Post-extubation respiratory failure
- Neuromuscular weakness

Consider **clinical parameters** as **indicators**

- ➔ Moderate to severe dyspnoea not responsive to supplemental oxygen, HHFNP and bronchodilators
- ➔ Persistent tachypnoea and/or tachycardia for age
- ➔ Persistent Hypoxemia
- ➔ Respiratory acidosis (arterial pH <7.35 or venous pH <7.30)

Contraindications

Absolute contraindications

- Cardiovascular Arrest / Coma
- Any condition requiring immediate intubation
- Inability to protect airway (eg. GCS ≤ 8, poor cough, excessive secretions)
- Vomiting
- Pneumothorax
- Oesophageal atresia / Tracheo-oesophageal fistula
- Gastric perforation
- Mid-facial fracture

Relative contraindications

- NEC
- Abdominal surgery
- Abdominal distension
- Maxillo-facial / ENT surgery (eg. Cleft palate repair, Le Fort Osteotomy…) – check with surgeon)

The main risk of NIV is to delay endotracheal intubation!

➔ Treat the trend

➔ Flag / Escalate early

Predictors of NIV failure

- Patients suffering from pneumonia and paediatric acute respiratory distress syndrome (pARDS)
- Patient with primary pulmonary pARDS more likely to avoid intubation than those with extrapulmonary pARDS (due to sepsis, malignancy, immunosuppression, etc.)
- High Paediatric Risk of Mortality (PRISM) and Paediatric Logistic Organ Dysfunction (PELOD) scores
- Rapid progression of the underlying disease
- Inadequate response to NIV
- Poor patient selection, clinician inexperience and lack of appropriate equipment

Complications

Air Leak Syndrome

- Pneumothorax
- Tension pneumothorax
- Other air-leaks include:
  - Pneumopericardium
  - Pneumomediastinum
  - Pulmonary Interstitial Emphysema (PIE)
  - Subcutaneous Emphysema

Atelectasis

Alveolar collapse caused by decreased alveolar ventilation, gas resorption, mucous plugging or sedation

pARDS

Ventilator-induced lung injury (VILI) can cause paediatric acute respiratory distress syndrome

Gastro-Intestinal complications

Bleeds, gastric distension, paralytic ileus, stress-ulcers

Oxygen Toxicity

Oxygen is a drug!

Parenchymal changes can occur with prolonged exposure to O_2

Adjust your FiO_2 to keep saturations within the prescribed lower AND upper range

Cardiovascular compromise

Increases intra-thoracic pressure causes reduced venous return to the right side of the heart, ultimately reducing cardiac output

Skin integrity

Pressure areas from ill fitted masks

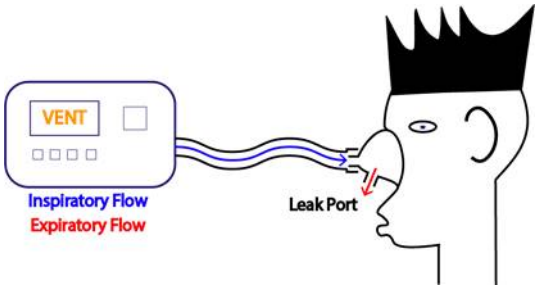
Eye irritation & conjunctivitis from air leakage into eyes

Ventilator Types

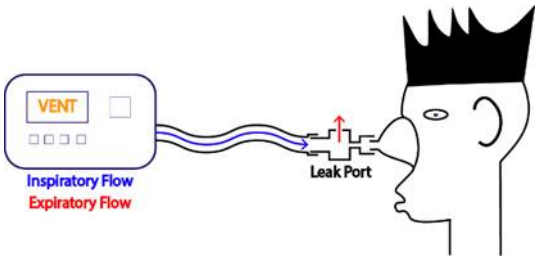
- **Bilevel Ventilators**
  - Single Limb Circuit
  - Passive exhalation port
  - Leak either intentional through passive exhalation port or unintentional in circuit or interface
- **Critical Care Ventilators**
  - Separate inspiratory and expiratory limbs
  - Active exhalation valve
  - Traditionally more leak intolerant – improving with new ventilators, modes and software

Circuit Types

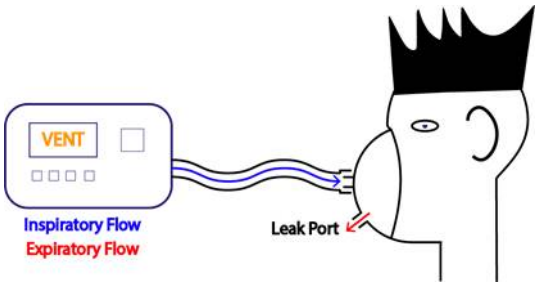
SINGLE LIMB



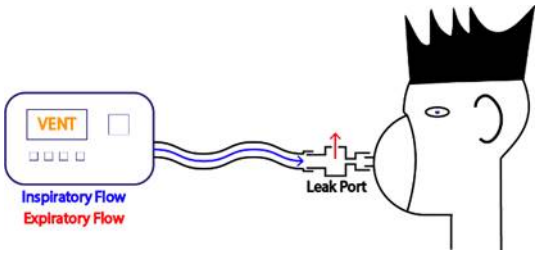
Circuit: **Single limb**
Interface: **Nasal** Mask
Interface Vented: **YES**
Leak Port: **NO**
Comment: Expiration also through mouth



Circuit: **Single limb**
Interface: **Nasal** Mask
Interface Vented: **NO**
Leak Port: **YES**
Comment: Expiration also through mouth

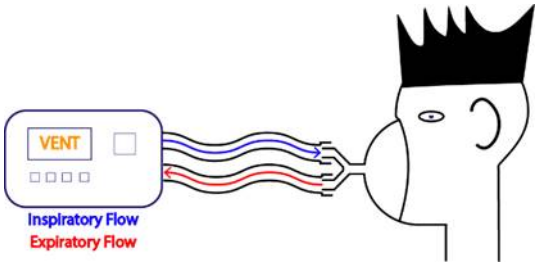


Circuit: **Single limb**
Interface: **Oro-Nasal** Mask
Interface Vented: **YES**
Leak Port: **NO**



Circuit: **Single limb**
Interface: **Oro-Nasal** Mask
Interface Vented: **NO**
Leak Port: **YES**

DUAL LIMB



Circuit: **Double limb**

Interface: **Oro-Nasal & Full-face** mask

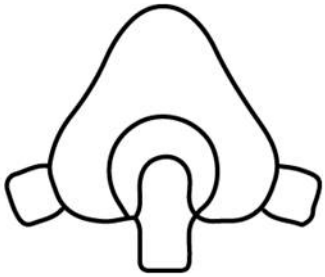
Interface Vented: **NO**

Leak Port: **NO**

Comment: Inspiratory & expiratory limbs have valves to control flow

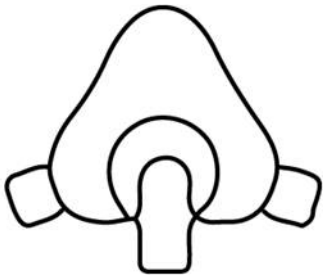
Masks/Interfaces

Nasal Mask



- Covers the nose but not the mouth
- Exhalation port → Use with single-limb circuit

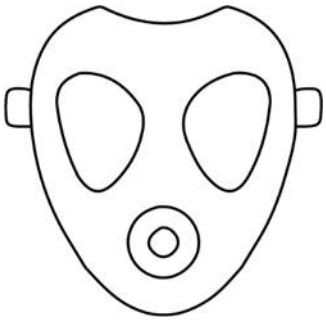
Nasal Mask



- If no exhalation port → Use with dual-limb circuit
- If with exhalation port

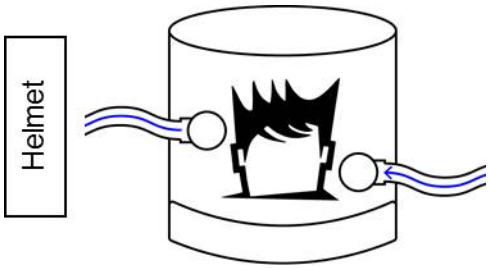
→ Use with single-limb circuit

Full Face Mask



- Covers the mouth, nose and eyes
- No exhalation port

→ Use with dual-limb circuit ONLY

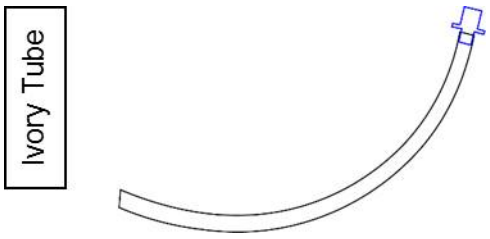


- Covers whole head +/- part of neck
- High dead space volume (V_D)
- Risk of CO2 rebreathing
- Needs high gas flow
- Use with double limb circuit only

- Parts:
    - **Cushion** to form the seal against patient's face
        - Transparent non-inflatable / Transparent inflatable
        - Full hydrogel
        - Full foam
    - Mask **frame** (stiff)
    - **Attachment points** for headgear / harness
- Choice of interface depends on patient size and anatomy, condition, type of respiratory failure, tolerance, and choice of ventilator
- Choose smallest fitting mask to minimise dead space (DS) and optimise triggering
- For single limb circuits use only nasal masks or vented oro-nasal or full-face masks to avoid asphyxia/CO_2 narcosis
- For double limb circuits use only non-vented oro-nasal or full face masks
- Consider face masks in patients with large leak due to mouth opening (eg. Trisomy 21)
- Maximise comfort
    - Avoid over-tightening of mask to prevent pressure areas
    - Mask occlusion pressure needs to be ~ 2cm H2O greater than the peak inspiratory pressure=. Further increase in pressure only does harm.
    - **The two-finger rule**: It should be possible to pass two fingers beneath the straps of the headgear
    - Extra padding (e.g. Duoderm™, Comfeel™ or Lyofoam™) can be used to avoid pressure injuries and to cover developing pressure marks
    - Use padding of NG tube and skin underneath to prevent pressure injury
    - Continue regular Braden Q assessment, pressure area prevention and management plan and clinical skin assessment
- Connection between the mask and the tubing
    - L-connector

- Stiff
- Might cause interface to shift creating a leak

- Flexible tubing
  - Increases dead space which might reduce alveolar ventilation in patients with small tidal volumes (TV)



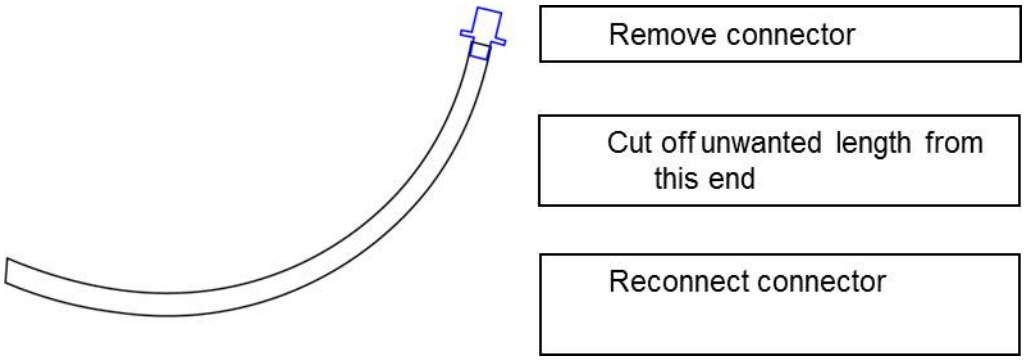
- Used as naso-pharyngeal airway
- Can provide CPAP/BiPAP via ventilator
- Consider in infant not tolerating other interface
- Needs to be cut to appropriate length

Choose appropriate size for age & cut accordingly

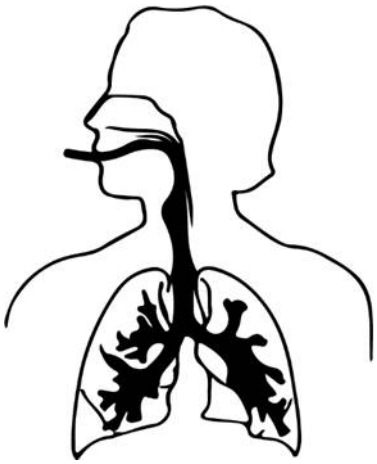
Age	Size
	(Age [yrs]/4) + 4
Newborn	3.0-3.5
3-12 months	4
1 year	4
2 years	4.5
4 years	5
6 years	5.5

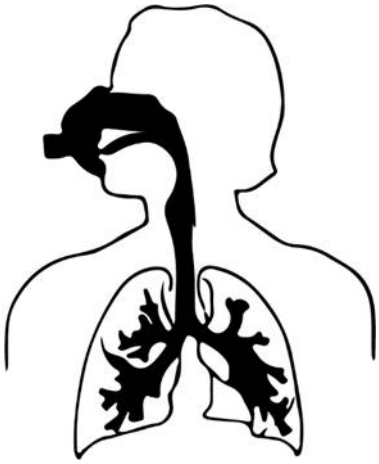
Internal length = distance from corner of nose to tragus

Total tube length = External length (approx. 5cm including connector) + internal length

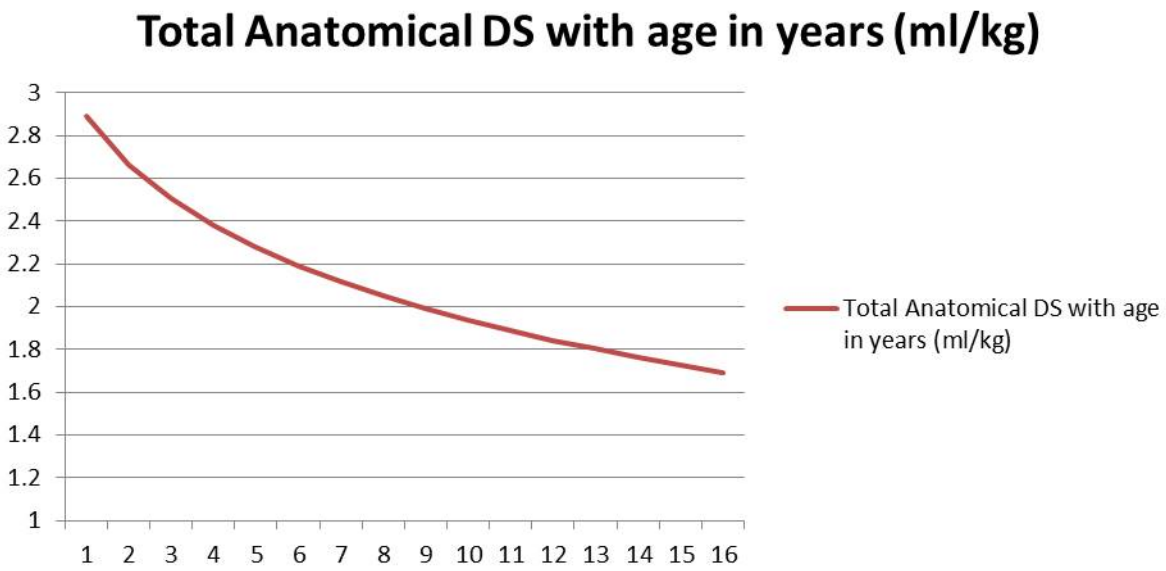


Effect of Interface on Dead Space





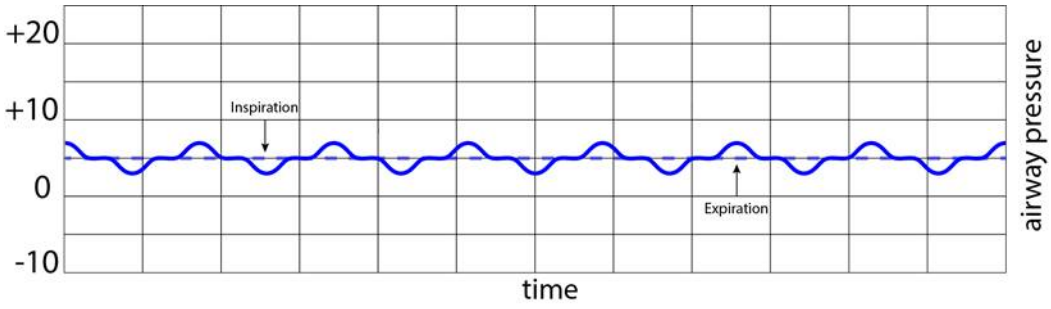
- The smaller the patient and therefore the tidal volume, the bigger the effect of the additional dead space on alveolar ventilation and ability to clear CO2
- In adults, anatomic dead space is 2.2 ml/kg
- In children, total anatomic dead space (in ml/kg) is derived from a formula and decreases with age

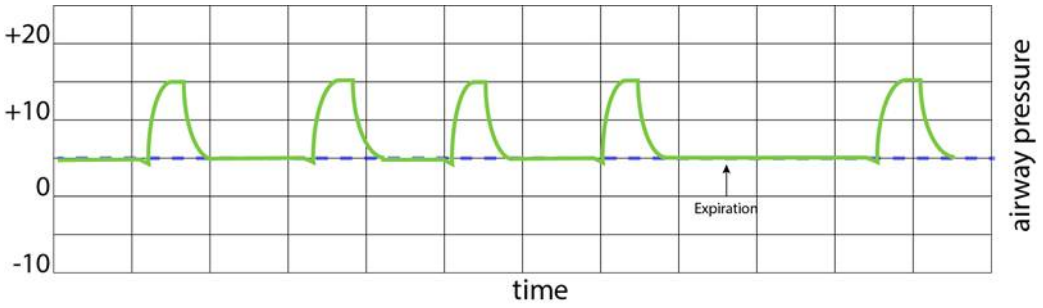


Modes

CPAP - Continuous positive airway pressure

- Positive airway pressure is set at a level called PEEP (Positive end-expiratory pressure)
- PEEP maintains airway patency and lung volume (FRC) and is therefore an anti-derecruitment force – particularly effective in neonates and children as their FRC is close to the closing capacity
- There are mild fluctuations of airway pressure during inspiration and expiration
- This mode is only suitable for patients that have adequate respiratory drive as there is NO back-up ventilation
-





BiPAP - Bilevel positive airway pressure

Spontaneous Mode (S)

- The ventilator cycles between IPAP and EPAP according to patient effort
- Patient determines the onset of each inspiration and expiration
- No mandatory breaths are given
- The clinician sets the inspiratory (IPAP) and the expiratory (EPAP) pressures (similar to CPAP/PS where CPAP is EPAP and PS is IPAP)

Spontaneous Timed Mode (S/T)

- As for Spontaneous mode, but in addition, has a back-up respiratory rate activated in the event the patient fails to initiate a breath or hypoventilates during a set time frame
- When the patient breathes spontaneously above the set back-up rate the device is activated in Spontaneous mode

- When the patient fails to take a breath within a specified time frame, or if he/she hypoventilates, the device automatically changes its mode to Time mode forcing the patient to breathe at the back up rate with programmed IPAP and EPAP set by the clinician

Initial Ventilator Settings

Discuss individual settings with the PICU medical team before initiation

The following is a rough guide:

CPAP	• PEEP 5cmH2O and titrate up relatively quickly aiming at FiO2 < 50% • PEEP safe up to 10cmH2O
BiPAP- (S)or (S/T) Mode	• EPAP 5 - 8cmH2O • EPAP is safe up to 10cmH2O • IPAP 6 - 12cm H2O above PEEP • IPAP is safe up to 20cmH2O • Set back-up rate.
Pressure Support	• PEEP 5 – 8cmH2O • PEEP is safe up to 10cmH2O • PS 5 – 15cmH2O above PEEP

Fraction of inspired oxygen (FiO2)

- Set FiO2 100% while establishing NIV unless patient has parallel circulations
- Wean FiO2 to reach target
- Both hypoxia AND hyperoxia are harmful
- Titrate FiO2 to reach target transcutaneous saturations and tolerate short-lived swings in either direction - Actively treat the trend!
- Discuss the need for change in PEEP if FiO2 > 50% or < 30%

Back-up ventilation

- For patients with bradypnea or hypopnea - set back-up ventilation to provide "full ventilation" for age after a given apnoea period (see below)
- Discuss details with medical team and consider changing to invasive ventilation
- Use Pressure Control Mode as back-up (as volume controlled modes unsuitable given high risk of large leak)
- Set apnoea time to 15 seconds for infants, 20 seconds for paediatric and adolescent patients

Sedation

- Current data suggests that the use of sedation to increase tolerance of NIV is generally well tolerated and not associated with increased risk of apnoea or hypercapnia
- Options include
    - Comfort measures and other non-pharmacological interventions
        - Wrapping
        - Swaddling
        - Dummy
    - Pain relief (Paracetamol PRN as per Meds4Kids dosing)
    - Dummy dipping in EHM
    - Pharmacological treatment
        - Dexmedetomidine infusion (0.2-0.7microg/kg/hr) (AMH & Meds4Kids)
        - See Analgesia and Sedation in PICU Practice Guideline

Alarm settings

- Set ventilator alarm settings according to age and underlying pathology
- Some alarms (TV, apnoea, MV) can be turned off in NIV mode - this avoids continuous alarming but emphasizes the need to assess the patient regularly

Nursing Care Considerations

Patients on NIV warrant the same level of monitoring as children undergoing invasive ventilation including continuous ECG, pulse oximetry, regular blood pressure measurement and ongoing monitoring of ventilation (blood gases)

! Continuous and thorough assessment and re-assessment !

- Optimise patient comfort whilst minimising leakage and risk of pressure injuries
- Elevate patient's head by 30 degrees and suction carefully to reduce risk of aspiration
- Perform 4th-hourly eye cares to avoid corneal ulceration
- Assess patency of nares regularly, consider suctioning
- Set alarm limits appropriately

- Assess for effectiveness
    - Reduction in respiratory and heart rates
    - Reduction in WOB
    - Decreased O2 requirement
    - Blood gas analysis:
        - Assess for hypercarbia and elevated lactate
        - Adjust ventilation settings according to results after discussion with medical team
- Treat the trend, escalate early
- Children on NIV must have a nasogastric tube (NGT) placed on free drainage or aspirated regularly (q4h) to remove air and/or gastric secretions
- Nasogastric or gastrostomy feeding can occur for patients receiving NIV after stabilisation and discussion with the medical team
- Ensure hourly documentation of observations and ventilator settings in the eMR
- During initiation or escalation of NIV patients should be made nil by mouth
- Ensure circuit tubing is supported on the bed using a tubing holder or clamp to avoid dislocation of the mask leading to leakage and occlusion of the nostrils

If NIV is not successful in stabilising / supporting the patient after **1 hour** there is a high likelihood of invasive respiratory support

Flag failure to improve early to medical team to allow for appropriate preparations

Reducing the Risk of Skin Damage during NIV

- Remove mask **at least every four hours** to attend to mouth care, relieve pressure and assess skin integrity
- If patient does not tolerate time off the mask discuss with MO (option to use T-piece and a mask during cares)
- Rotate various types of interfaces
- Proper harness and tightening (REMEMBER: It's about the position, not the amount of pull of the harness!)
- Nasal-Forehead Spacer/Forehead pads

Humidification

Current humidification is via F &P MR850

For Servo/Trilogy

- Humidifier setting should be set to **MASK** mode from the default ETT mode

For V60/SIPAP

- Humidifier setting should be set to **ETT** Mode
- On SIPAP - If excessive condensation in tubing, remove 20cm unheated extension piece on inspiratory limb of F&P circuit unless using in Babytherm heated crib
  - Consider reducing temperature to MASK setting if rainout persists

For Ivory Tubes

- For Ivory tubes the setting should be on **MASK** mode

Troubleshooting

- Rainout often occurs, particularly with the larger bore circuits (V60)
- Care needs to be taken that rainout is tipped back into humidifier bowl and not into patient mask and airway
- If excessive rainout, check humidifier settings as above
- Ensure all heater and temperature wires and probes are connected securely to eliminate air leak

Be mindful that external heating or cooling (e.g. overhead heaters/air conditioning) will affect the humidifier's automatic temperature adjustment functionality and rainout

Changing from ETT Mode to MASK Mode

- To change from ETT to MASK Mode, press and hold the temp button until beeps are heard and the light illuminates next to mask setting

Trouble Shooting

Large leak

Can cause patient ventilator dyssynchrony, reduce efficiency and tolerance of respiratory support and cause sleep fragmentation

In PS mode, a leak may prevent inspiratory cycling off as the flow threshold is never reached!

- Check circuit for (unintentional) leak
- Optimise patient's position and comfort
- Optimise mask position / harness OR consider changing interface

- Consider inflating the mask's cushion, consider "filling material" to increase seal
- Consider sedating the patient while maintaining respiratory effort

Desaturation

- Call for help!
- Disconnect patient from ventilator
- Use T-piece with 100% FiO2 and adequate flow to support patient with PEEP +/- PS though the mask
- Consider oral suctioning (Caveat: Risk of laryngospasm with deep suctioning)
- Consider CXR (? Atelectasis, ? PTx, ? worsening oedema)
- Consider need for intubation and invasive ventilation
- Check ventilator, circuit and mask seal and try to re-establish patient on NIV support

Hypercarbia

- Is the patient over-sedated? → Reduce sedation, consider naloxone, flumazenil
- Has the underlying disease changed? Collapse? PTx? → CXR, blood gas
- Is there excessive dead space ventilation → Reduce interface + tubing dead space
- Do NOT use NIV without PEEP and/or PS as this will cause an increase in dead space ventilation
- Position of the exhalation port → The more proximal to the patient, the better the CO2 clearance
- Discuss need to increase IPAP / PS with medical team

Patient-Ventilator Dyssynchrony

- Check whether patient's chest rise and fall is in synchrony with the ventilator

Associated with suboptimal sedation, mask leak and insufficient leak compensation Most common asynchrony is either auto-triggering or missed trigger

- Minimise the leak (as above)
- Adjust trigger type and sensitivity (if available)
- Adjust flow cycling criteria in PS mode
- Start / adjust sedation
- Consider using different ventilator type
    - Bilevel ventilators ←→ Critical Care Ventilator

Vomiting

- Call for help
- Remove NIV interface, use T-piece and mask to support the patient
- Suction
- Discuss potential need to change respiratory support with medical team

Terminology/Abbreviations

PEEP – Positive End Expiratory Pressure

CPAP – Continuous Positive Airway Pressure

PS – Pressure Support

BiPAP – Bilevel Positive Airway Pressure

IPAP – Inspiratory Positive Airway Pressure

EPAP – End Expiratory Pressure

PIP – Peak Inspiratory Pressure

HHFNP – Humidified High-Flow Nasal Prongs

VILI – Ventilator-Induced Lung Injury

PEEP = EPAP

PIP = IPAP

PEEP + PS = PIP/IPAP

ΔP – Difference between PIP/IPAP and PEEP/EPAP

EHM – Expressed Human Milk

MV – Minute Ventilation

TV – Tidal Volume

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