PAEDIATRIC INTENSIVE CARE – CLINCIAL PRACTICE GUIDELINE

PAEDIATRIC VENTILATION GUIDELINES

1. **Introduction:**
   Mechanical ventilation refers to the use of life-support technology to perform the work of breathing for patients who are unable to do this on their own.

2. **Aim:**
   The overall goals of mechanical ventilation are to optimize gas exchange, patient work of breathing, and patient comfort while minimizing ventilator-induced lung injury.

3. **Objectives of Mechanical Ventilation in the pediatric patient include**:

   - Improved pulmonary gas exchange
   - Relief of respiratory distress (by relieving upper and lower airway obstruction, reducing oxygen consumption, and relieving respiratory fatigue)
   - Management of pulmonary mechanisms (by normalizing and maintaining the distribution of lung volume and providing pulmonary toilet)
   - Provide airway protection
   - Provide general cardiopulmonary support

4. **Parameters of guideline:**
   This guideline is intended for sick children requiring respiratory support.

5. **Indications of Mechanical Ventilation**

   - Respiratory failure – apnea/respiratory arrest, inadequate ventilation, inadequate oxygenation, chronic respiratory insufficiency with FTT.
   - Cardiac insufficiency/shock- eliminates work of breathing and reduces oxygen consumption.
   - Neurologic dysfunction-central hypoventilation/frequent apnea, GCS< 8, and inability to protect airway.

-

6. Initial Ventilator Settings

Initial Ventilator Settings	Premature neonate	Neonate	Infant/child	Adolescent
Mode	*Pressure control*	*Presssure control*	*Volume control with pressure support*	*Volume control*
Rate	*40-50*	*30-40*	*20-30*	*12-15*
PEEP(cm)	*3 -6/7*	*3 - 6*	*3-5*	*3-5*
Inspiratory time(cm)	*0.3-0.4*	*0.3-0.4*	*0.5-0.6*	*0.7-0.9*
PIP	*18-22(if HMD)*	*18 – 20*	*16-18(in increased ICP); 18-25(if low compliance)*	*18-25;35(in severe ARDS)*

a) ***Choose the Mode***-Control every breath if plan for heavy sedation and muscle relaxation. Use SIMV when patient likely to breathe spontaneously. Whenever a breath is supported by the ventilator, regardless of the mode, the limit of the support is determined by :
   - Volume limited: -preset tidal volume;
   - Pressure limited:- preset PIP.

b) ***Fi02***-start at 100% and quickly wean down to a level < or 60%(to avoid O2 toxicity) depending on O2 requirement. 60% may be a starting point.

c) I:E ratio – normally set at 1:2-1:3. Higher inspiratory times may be needed to improve oxygenation in difficult situations (inverse ratio ventilation), increasing the risk of air leak. Lower rate and higher expiratory time-1:3-1:4 may be needed in asthma to allow proper expiration due to expiratory obstruction.

d) ***Trigger Sensitivity***- set at 0 to -2. Setting above zero is too sensitive; triggered breath from ventilator will be too frequent while too negative a setting will increase work for patient to trigger a ventilator breath.

e) ***Volume Limited-***Tidal Volume - 8-10ml/kg with a goal to get to 6-8ml/kg. If leak present around ET tube, set initial tidal volume to 10-12ml/kg.

These lung-protective strategies recruit atelactetic areas while preventing over distention of normal lung parenchyma.

7. ***Maintanence of Ventilation-***

- Fine tuning after initiation is based on blood gases and oxygen saturations. Do not make more than 2 alterations at any one time.
- For oxygenation –adjust FiO2, PEEP, inspiratory time, PIP(tidal volume) – increase MAP.
- For ventilation -RR, tidal volume(in volume limited) and PIP (in pressure limited mode) can be adjusted.
- PEEP is used to prevent alveolar collapse at end of inspiration, to recruit collapsed lung spaces or to stent open floppy airways.

8. ***Gas Exchange Related Problems-***
Hypoxemia, hypercarbia.

What to do if :

a) Hypoxemia-

- Increase FiO2 and MAP. Need to find a balance as per clinical situation
- Increase tidal volume if volume limited mode, PEEP, or inspiratory time.
- Increase PIP/PEEP/ITime if pressure limited mode.
- If O2 worse, get CXR to look for air leak, if increasing PEEP decreases saturations, suspect low cardiac output due to tamponade effect of PEEP(treat by fluids and inotropes) or pneumothorax.
- Other measures- normalize cardiac output(by fluids and inotropes), maintain normal Hb and hematocrit(in neonates), maintain normothermia, deepen sedation/consider neuromuscular block.

Common reasons include:

- hypoventilation,
- dead space ventilation(too high a PEEP, decreased CO, pulmonary vasoconstriction),
- increased CO2 production ,
- hyperthermia,
- high carbohydrate diet,
- shivering.
- Inadequate tidal volume delivery(hypoventilation) occurs with ETTube block, malposition, kink, circuit leak, ventilator malfunction.

b) Hypercarbia-

- If volume limited: increase tidal volume or rate. If asthma- increase expiratory time to >1:3.
- If pressure limited: increase PIP, decrease Positive End Expiratory Pressure (PEEP), increase rate.
- Decrease dead space(increase Cardiac Output, decrease PEEP, vasodilator, shorten ET tube).
- Decrease CO2 production : cool, increase sedation, decrease carbohydrate load.
- Change endotracheal tube if blocked(may be remedied by suction), kinked, malplaced or out, check proper placement.
- Fix leaks in the circuit, endotracheal tube cuff, humidifier.

Note: Increasing ventilator parameters may not be acceptable in conditions like:

i. Patient ventilator dysynchrony –common causes include hypoventilation , hypoxemia, tube block/kink/malposition, bronchospasm, pneumothorax, silent aspiration, increased oxygen demand/increased CO2 production(in sepsis), inadequate sedation.

i. Permissive Hypercapnia-higher paCO2 are acceptable in exchange for limited peak airway pressures, as long as ph>7.25. Otherwise to be discussed with Consultant.

ii. Permissive Hypoxemia- PaO2 of 55-65; SaO2 88-90% is acceptable in exchange for limiting FiO2 <60% , as long as there is no metabolic acidosis. Adequate oxygen content can be maintained by keeping Hct >30%. To be discussed with Consultant.

9. TROUBLE SHOOTING-

If patient fighting ventilator and desaturating immediate measures include: ***-DOPE***

- **D-**Displacement-check tube placement. When in doubt take ET Tube out and start manual ventilation with 100% O2 and with bag and mask.
- **O-**Obstruction-is the chest rising. Are breath sounds present and equal? Changes in examination?. Atelactasis, treat bronchospasm/tube block/malposition/pneumothorax(consider needle thoracocentesis). Examine circulation:?Shock, ?Sepsis.
- **P-**Pneumothorax-check ABG, saturation and CXR for pneumothorax and worsening lung condition.
- **E-**Equipment failure-examine ventilator, ventilator circuit/humidifier/gas source. If no other reason for hypoxemia :- increase sedation/muscle relaxation, put back on the ventilator.

10. DURATION OF VENTILATION-

- Duration varies by nature of disease process: HMD may take 3days to a week, pneumonia 5-7days, ARDS 10days to 3weeks and neurological illness (eg GBS) from 1week to few months. Postcardiac surgery ventilation may vary from 24hrs to 7days or more and postoperative chest or abdominal cases would vary from 24-48hrs.
- Risk of nosocomial infection increases with ventilation >5-7days.

11. WEANING FROM MECHANICAL VENTILATION-

Weaning begins from the moment ventilation is commenced. When FiO2 requirement is down to 40%, improvement in secretions and CXRs, improving clinical condition or primary pathology, muscle relaxant drip is stopped and sedation slowly weaned to get patient moving and awake(may take 24hrs or longer if prolonged use).

When Weaning:-

- Decrease FiO2 to keep SpO2>94,
- Decrease SIMV rate to 10 (reduce by 3-4breaths/min).
- Decrease the PIP to 20cm of water by reducing 2cm H2O each time/tidal volume to no less than 5ml/kg to prevent atelactasis(usually guided by blood gases).
- Ventilator rate and PIP can be exchanged alternately
- If at any time patients oxygen requirement increases greater than 60% or spontaneous ventilation is fast or distressed with accessory muscle use, patient gets agitated or lethargic, hypercarbia on ABGs, pause weaning and increase support level. Patient may not be ready to wean.

12. EXTUBATION CRITERIA-

- SIMV rate of < 10, but can extubate even at rate 20
- Some will need pressure support 5-10 above PEEP with CPAP, while others may need CPAP 5cm water before extubation.
- Infants can usually be extubated from a rate of 5 without any period of endotracheal CPAP before extubation. Infants intubated >3days usually, after extubation, require nasal CPAP, and then nasal prongs.

- there is control of airway reflexes, minimal secretions; patent upper airway(air leak around tube), good breath sounds, minimal O2 requirement <30% with SpO2 >94;. Also, minimal pressure support(5-10 above PEEP), Awake patient, Adequate muscle tone(squeeze examiners fingers/vigorous cough), Minimal/no inotropic support, normal electrolytes and no fluid overload.

Extubation procedure-

- Keep NBM 4hrs before planned extubation
- Suction endotracheal tube and deflate cuff if using a cuffed tube. Suction the oral cavity and nostrils.
- Suction the NGT before removing to empty the stomach
- Keep oxygen by facemask ready. Nasal cannula can be taped to the face even before extubation to avoid immediate hypoxia/stress upon extubation.

- Correct size mask and bag with O2 must be available with a working laryngoscope and correct size ETTube.
- Nebulisation with beta stimulant/adrenaline to be ready immediate post extubation.
- Intravenous steroids dexamethasone 0.6mg/kg iv(maximum dose of 12mg) stat may be used if indicated by extubation stridor and then continued on prednisone orally at 1mg/kg 8-12hrly OR if prolonged intubation or airway edema can give dexamethasone 24hrs prior to planned extubation at 0.15mg/kg and to be continued for 6-8doses.
- Intravenous frusemide may be needed to achieve a negative fluid balance as interstitial edema can occur in patients with relative fluid overload or even mild myocardial dysfunction as soon as the positive pressure is taken off from the lower airways and the alveoli during extubation.
- NIPPV or a CPAP should also be available to avoid reintubation.
- Do blood gas 20mins after extubation; Post extubation CXR not needed routinely but only if clinically indicated by desaturation or increased work of breathing.
- Ideally, ventilator to be on standby at least 24hrs post extubation.
- Anticipate extubation failure in all patients and parents should be made aware earlier on so that there is no disappointment.

- ***COMPLICATIONS OF VENTILATION-***

13.1 Increased airway pressures and lung volumes-

a)Barotrauma/volutrauma(stretch injury):- PIE, pneumothorax, pneumopericardium, pneumoperitoneum, subcutaneous emphysema.
b)Decreased cardiac filling and poor perfusion.
c) Other organ dysfunction-renal, hepatic, and CNS.
d)Pulmonary parenchymal damage.
e) Adverse effects on gas exchange.
f)Increased extravascular lung water.

14.1 ***Endotracheal/tracheostomy tube-***

a)Tracheal mucosal swelling, ulceration or damage.
b)sinusitis/middle ear infection.
c) Laryngeal edema, subglottic stenosis.
d)Granuloma formation leading to airway obstruction.

15.1 Nosocomial infections-

a) Ventilator associated pneumonias.
b)Sepsis.

16.1 ***Pulmonary circulation-***

a)Increased pulmonary vascular resistance.
b)Compression of alveolar vessels.

17.1 Mechanical operational problems-

a)Mechanical ventilator/compressor failure/alarm failure.
b)Inadequate humidification.

18.1 Other systems-

a)Decreased hepatic blood flow.
b)Decreased cerebral venous drainage.

The beneficial effects in the lung are related to improvements in pulmonary mechanics, gas exchange and hemodynamics.

13. WHO NOT TO VENTILATE:-

13.1 Absolute indications:

- *Anencephaly*
- *Hydrancephaly*
- *Trisomy 13, 18*
- *Triploidy*
- *Renal Agenesis*
- *Sirenomelia*
- *Short Limb Dwarfism(eg Thanotropic Dysplasia)*
- *Miscellaneous-like Pterygium Syndrome, Mickel Grugel and Neu-laxova.*
- *Palliative cases – e.g oncology cases where relapses occur or treatment either not available locally or unaffordable abroad, cardiac conditions*

13.2 ***Relative Indications-To be discussed with Consultant-***

- extreme preterm <28weeks with weight<800g,
- Multiple congenital anomaly cases,
- Congenital heart disease with poor chance of long term survival/resources limited-eg Truncus arteriosus, Hypoplastic left heart.
- Cardiomyopathy with ejection fraction < 25% and pulmonary edema unresponsive to Therapy
- Severe chronic lung disease including pulmonary fibrosis, cystic fibrosis, obstructive or restrictive diseases requiring continuous home oxygen or mechanical ventilation use prior to onset of acute illness
- Central nervous system, solid organ, or hematopoietic malignancy with poor prognosis for recovery.
- Liver disease with ascites, history of variceal bleeding, fixed coagulopathy or encephalopathy, acute hepatic failure
- Acute and chronic and irreversible neurologic impairment, which makes patient dependent for all personal cares (e.g.: severe stroke, congenital syndrome, persistent vegetative state, severe dementia etc.).

When there is conflict of interest, e.g family demands ventilation where medical condition falls in the absolute no ventilation or relative indication category the following options are to be taken:

a) consultant is to call consultant on call in another division and present the merits of the case. If the 2 consultants concur that ventilation is not indicated, Consultant in charge of the case to inform the family of the decision.
b) In the event that after a) family still insist on ventilation, then consultant in charge of the case to discuss with medical superintendent of the hospital where patient is admitted.

Note: while a decision is pending as in above, patient is to be bagged either via mask or ET tube

14. ***NURSING CARE-:***

Nursing Guidelines for managing ventilated paediatric patient (adopted from British Columbia's Paediatric Critical Care Guideline

Expected Outcomes	Activities and Interventions	Rationale

1. Adequate oxygenation, ventilation and supported work of breathing	• Assessment of the child receiving mechanical ventilation
	  • *General observations:* comfort of the child, synchrony between patient and ventilator, chest expansion, colour and perfusion, and level of consciousness
	  • *Auscultation*: note symmetry of breath sounds (recall that the thin chest wall of an infant transfer breath sounds to opposite side), evaluate quality of breath sounds, note adventitious sounds or absence of breath sounds
	  • *Work of Breathing*:
	  • *Volume and quality of secretions*- note quantity and characteristics.
	  • *Palpation*- note presence of crepitus, inspiratory crackles, or points of tenderness.
	• Provide additional ventilatory support as indicated by signs of hypoxia, hypercarbia, and hemodynamic instability (manual breaths and/or adjustment in mechanical ventilation)
	• Continuous pulse oximetry to monitor oxygenation (re-site q2-4 hours to avoid burns)
	• Consider utilizing ETCO2 monitoring for additional trending of ventilation therapy.
	• Monitor gastric insufflation and remove air from stomach as indicated. Positive pressure ventilation may lead to increased gas flow to stomach.
		Oxygen consumption is greatly increased with increased work of breathing.
		
		Ventilator Associated Pneumonia is a leading cause of nosocomial infection. Changes in the quality of secretions should prompt additional investigations – especially in the presence of a fever.
		
		Gastric decompression reduces the risk of aspiration.

2. Correct position and patency of artificial airway	• Verify placement of artificial airway utilizing at least 2 of the below methods:
	  • Chest radiograph
	  • Auscultation of breath sounds across the lung fields
	  • End tidal CO2 monitoring
	  • Verify distance marking on tube
		Patient safety.
		
		Airway verification and securement reduces risk of non-intentional extubation.
		
		CXR are important to

	• Ensure artificial airway is secure and stabilized in desired position	verify ETT or trach position and to evaluate pulmonary process. The decision is determined by the individual needs of the patient.
3. Adequate airway humidification; mobilization and removal of secretions	• Ensure adequate humidification of ventilation circuit, monitoring temperature of inspired gas (maintain at 35 – 37 degrees). • Suctioning of the endotracheal or tracheostomy tube should occur when there is evidence of increased airway secretions (coughing, increased PIP, auscultation of upper airway crackles) i. Always pre-oxygenate the patient ii. Suction catheter should be an appropriate size to allow ease of insertion (french size of catheter = 2 X the internal diameter of tube) iii. Aseptic technique to avoid contamination, consider use of inline suction catheters. iv. Insertion distance should be known and documented to avoid suctioning below the tip of the artificial airway. v. Routine instillation of N/S should not be necessary if the humidification is adequate (tenacious secretions may require 0.5 – 1 mL instillation of N/S, followed by several manual ventilation breaths to disperse instillation prior to suctioning)	Patient safety. Low temperatures may cause secretions to become thick and sticky. Body temperature may be altered by high and low temperatures of inspired gas. Suctioning clears airway secretions to maintain airway patency.
4. Maintenance of adequate pH and PaCO2	• Monitor pH and pCO2 through periodic sampling of arterial or capillary blood gases	Arterial and capillary blood sampling are both reliable methods of monitoring pH and pCO2
5. Hemodynamic stability	• Maintain optimal cardiovascular status of patient; hourly assessment of vital signs and perfusion • Ensure continuous ECG monitoring with alarms limits set to appropriate limits per age. • Monitor and optimize perfusion.	Increase in intrathoracic pressure that occurs with mechanical ventilation results in a reduction of venous return BP is a late sign of CV decompensation in child. Capillary refill ought to be≤ 2 seconds
6. Maintenance of fluid & electrolyte balances and	• Calculation and monitoring of all fluid intake. Fluid restriction may be implemented (usually 80% total fluids orders) to reduce fluid retention that is common with positive	Fluid retention may occur related to underlying disease or non-osmotic ADH

	• Monitor urine output. Goal should be ≥ 1mL/kg/hour of urine output. • Monitor fluid and electrolyte status through routine evaluation of lab results. • Daily weights are very important when can be safely performed. • Optimize nutrition through early initiation of feeding via NG or NJ tube.	release related to positive pressure ventilation. Enteral feeding is the preferred method of nutrition and may be initiated even in the absence of bowel sounds.
7. Child remains free of nosocomial infection	• Minimize ventilator sources of infection by emptying condensation in tubing. • Keep HOB elevated at 30 degrees unless contraindicated. • Mobilize patient as able. • Consider removal of additional potential sources of hospital acquired infection on a daily basis (CVL, foley catheter)	Ventilator associated pneumonia (VAP) is a cause of mortality in mechanically ventilated children. Elevating the head of bed reduces incidence of aspiration.
8. Maintenance of skin integrity	• Assess skin integrity every 2 – 4 hours (attention to bony prominences, areas of nose and mouth in contact with ETT). Assess for • Keep skin clean and dry. • Reposition child every 1 – 2 hours (including reposition of head) as tolerated. • Prone positioning every 4-6 hours for all ventilated patients • Maintenance of oral hygiene ▪ Brush teeth, gums and tongue at least twice a day ▪ Moisturize lips every 2-4 hours as required.	Repositioning alleviates pressure points and prevents skin breakdown. Oral care reduces inflammation and plaque (which has been shown to contribute to VAP)
9. Acceptable level of comfort	• Assess the patient's pain and sedation level q 1 – 4 hours using the MAPS and SBS scales (see attached pain and sedation guidelines) • Titrate pain and sedation medications as per protocol • Provide noninvasive comfort measures ▪ Parental presence ▪ Favorite blanket or toy ▪ Ear plugs to reduce noise levels ▪ Dim lights ▪ Distraction techniques	The presence of an artificial airway is uncomfortable

GLOSSARY

Endotracheal tube—Tube inserted into the trachea via either the oral or nasal cavity for the purpose of providing a secure airway and delivery of mechanical ventilation.

Hypoventilation—Reduced gas exchange in the lungs resulting in low oxygen levels and high carbon dioxide levels.

Hypoxemia—Deficient oxygen supply in the blood.

Hypercarbia-High carbon dioxide levels in the blood.

Pharmacological paralysis—Paralysis induced by medication to promote optimal mechanical ventilation.

Pneumothorax—Air in the plerual space that can exert pressure on the heart and opposite lung, leading to decreased cardiac and pleural function.

Pulse oximetry—Measure of the percent of hemoglobin saturated with oxygen.

Tracheostomy—Surgically created opening in the trachea for the purpose of providing a secure airway and long term ventilation assistance

ANNEX-

1. ***See Pediatric Ventilation tool pdf.***

REFERENCES-

1. P. Khilnani, Pediatric & Neonatal Mechanical Ventilation, JP Medical Publishers Ltd, 2006, Pgs 17-38, 80-100.
2. Holbrook P., Textook of Pediatric Critical Care, WBSaunders Co, 1993, pgs 442-462.
3. Shann F., Pediatric Intensive Care Guidelines 3rd ed, 2008, Pgs125-127.
4. Kliegman, Behrman, et all, Nelson Textbook of Pediatrics, 18th ed., WBSaunders Comp, 2008, Pgs 424-428.
5. BC Childrens Hospital Pediatric Critical Care, Nursing guidelines for management of ventilated pediatric patients
6. Pediatric ventilation decision tool pdf.

Scope and Application	This CPG is intended for use by all health care workers in their daily care of paediatric patients
Effective Date	2010
Supercedes Policy Number	Not applicable
Review Responsibilities	The Chairperson of the Paediatric CSN will initiate the review of this guidelines every 3 years from the date of issue or as required.
Further Information	Paediatric CSN Chairperson

RESPONSIBILITY

CPG Owner: National Paediatric CSN

CPG Writer: Ministry of Health **Date: 2010**

Endorsed:

National Medicines & Therapeutic Committee, MOH

Date: 23 November 2010

Endorsed:

National Health Executive Committee, MOH

Date: 25 November 2010