Review article

Paediatric mechanical ventilation

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Abstract

Knowledge of paediatric mechanical ventilation is moving forward at an interesting pace. There are no clear or consistent guidelines despite several years of mechanical ventilation on a large number of paediatric populations. Although, the basic principles of physics and gas flow apply to all age groups, anatomical and physiological differences in children play a significant role in selecting the type of ventilator as well as the ventilatory modes and settings. Requirement for respiratory support in children admitted to ICU is common. Respiratory failure or impending failure is usually due to lung pathology or other systemic disease contributing to respiratory compromise. Monitoring vital signs, blood gases, pulse oximeter and end-tidal carbon dioxide are essential to provide optimal care. Positive pressure ventilation with improper settings may result in barotrauma and it is essential to prevent or detect these complications at the earliest.

Keywords: Paediatric, mechanical ventilation, airway, ventilatory care, monitoring.

Introduction

Emerson was the first to describe the use of positive pressure ventilation in 20th century during anaesthesia.[1] In 1950s, during polio epidemic, the use of mechanical ventilation to support respiration became even more popular.[2] Today, almost every intensive care unit (ICU) is equipped with mechanical ventilators that can help support respiration during respiratory failure with or without other organ system failure.

Appropriately timed and managed mechanical ventilator support has improved the outcome of children suffering from respiratory failure by maintaining adequate oxygenation and ventilation till the underlying condition is resolved. The main objective for artificial positive pressure ventilation is to restore normal physiology by normalising oxygenation and alveolar ventilation without causing adverse effects such as barotrauma, volutrauma, biotrauma, ventilator induced lung injury (VILI) and ventilatory associated pneumonia (VAP).

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Uniqueness of paediatric airway

Basic principles of physics and gas flow apply to all age groups. Anatomical and physiological differences play a significant role in selecting the type of ventilator as well as the ventilator modes and settings. The larynx in children is situated cephalad, is funnel shaped with the subglottic area (at level of cricoid ring) being the narrowest compared to the adult where the larynx is tubular with the narrowest part at the vocal cords.[3] Airway resistance increases inversely by fourth power of radius. In an already small paediatric airway, therefore, even one mm of oedema or secretion within the tracheal lumen will

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increase the airway resistance and may contribute to markedly increased turbulent flow necessitating urgent management of airway oedema and institution of measures to control and remove secretions. Further, low functional residual capacity (FRC) in children contributes to reduced oxygen reserve and hence, reduces the safe duration of apnoea in children. In children, respiration is predominantly due to diaphragmatic excursions. The costovertebral bucket handle movement is inadequate in them. Therefore, children increase minute ventilation by increasing their respiratory rate (tachypnoea) rather than increasing the depth of respiration in response to hypoxaemia. Oxygen consumption per kilogram body weight is higher and tolerance of hypoxaemia is lower in children.[4]

Due to high vagal tone, bradycardia is common in response to hypoxia. Pores of Kohn and channels of Lambert (bronchoalveolar and interalveolar collaterals) are inadequately developed making regional atelectasis more frequent.[5] Closing volumes are lower and airway collapse due to inadequate strength of the cartilage in the airways is common making a child particularly susceptible to laryngomalacia, tracheobronchomalacia as well as lower airway closure.

Consequent to the presence of all these differences and uniqueness of the airway, children require smaller tidal volumes, faster rates, adequate endotracheal tube size and adequately suctioned clear airway for proper management of mechanical ventilation.

Normally during breathing, the vocal cords abduct to enhance inspiratory flow. In some respiratory disorders, children attempt to close (adduct) their vocal cords during expiration. Expiration through partially closed vocal cords produces a grunting sound. During the initial phase of expiration, the child closes the glottis, holds gas in the lungs and produces elevated transpulmonary pressure in the absence of airflow. In the last part of the expiratory phase, gas is expelled from the lungs against partially closed vocal cords, causing an audible grunt. Grunting can maintain functional residual capacity (FRC), partial pressure of arterial oxygen (PaO_2) and prevents collapse of distal alveoli thus creating a physiological positive end expiratory pressure (PEEP).[6] This facilitates better gas exchange and is a protective phenomenon seen in pneumonia. In the absence of adequate treatment, disappearance of grunting in a child with bronchopneumonia may be the earliest sign of decompensation.

Indications for mechanical ventilation

Children admitted in the ICU often require respiratory support for impending respiratory failure either due to primary lung pathology such as pneumonia, asthma, acute respiratory distress syndrome (ARDS), inhalation injury, chest trauma, near drowning, haemorrhage and aspiration or respiratory compromise secondary to neuromuscular weakness or other systemic disease. Respiratory failure defined as inadequate exchange of oxygen and/or carbon dioxide results in lung and cardiac dysfunction, neurological abnormalities, multi-organ system dysfunction/failure.

Common indications for mechanical ventilation in children include:[7]

1. Respiratory failure
   a. Apnoea / respiratory arrest
   b. Inadequate ventilation
   c. Chronic respiratory insufficiency with failure to thrive
2. Cardiac insufficiency/shock: Mechanical ventilation reduces work of breathing and oxygen consumption.
3. Neurological dysfunction
   a. Central hypoventilation / frequent apnoea
   b. Comatose patient with low Glasgow coma (GCS) score.
   c. Inability to protect airway in conditions such as Guillain Barre Syndrome with respiratory insufficiency, encephalitis, status epilepticus, myopathy and neuromuscular dystrophy.
   d. Raised intracranial tension

Respiratory rate is the most reliable clinical feature in denoting respiratory ill health in children. More the tachypnoea *(Table 1)*, greater is the severity of respiratory embarrassment.

Table 1: WHO guidelines for defining respiratory distress based on respiratory rate.[8]

Age	Respiratory rate (breaths/min)
0-59 days	> 60
60-365 days	> 50
1-5 years	> 40

Mortality among patients who require mechanical ventilation is widely variable and is dependent on underlying clinical conditions that necessitated the ventilator support. In children requiring mechanical ventilation with rapidly reversible conditions and who are otherwise healthy, mortality rates approach 0 percent, whereas in severe acute respiratory distress syndrome (ARDS), the mortality may vary between 30-60 percent. Mortality may approach 90-100 percent in children with severe multiorgan system failure and/or severe immunodeficiency.[9]

Endotracheal tubes and sizes

Since patients in the paediatric age group vary in age, weight, height and body mass index, the endotracheal tube (ETT) sizes also vary. According to the '2010 paediatric advance life support guidelines', both cuffed and uncuffed tracheal tubes are acceptable for infants and children during emergency intubation.[10] Cuffed tubes may decrease the incidence of aspiration in the paediatric intensive care unit (PICU). When performing tracheal intubation, data suggest that the routine use of cricoid pressure may not protect against aspiration and may make intubation more difficult.[10] With increasing age, the airway becomes more tubular resulting in the vocal cords becoming the narrowest portion of larynx rather than the subglottic space.[11] Cuffed tubes are also useful when ventilation with higher airway pressures is required as in ARDS. Studies have shown that cuffed tubes are not associated with an increased risk of perioperative airway complications.[12,13] However, it is important to remember that cuff pressure must be closely monitored using a cuff manometer and maintained below 20 cm H_2O in order to avoid subglottic stenosis.[14] In case the manometer is not available, the cuff must be inflated only to a level required to just avoid air leak during ventilation. This may be assessed by palpation and auscultation over the trachea (minimal occlusion technique).

Appropriate uncuffed tracheal tube internal diameter in mm = (age in years/4) + 4.

For cuffed tubes, the size of the endotracheal tube is determined by Khine's formula.[15] The internal diameter (ID) can be reduced by 0.5 mm (to compensate for cuff) and hence the formula can be redefined as ID in mm = (age in years/4) + 3.

After the age of two, it is reasonable to estimate the cuffed tracheal tube size with the formula given above. If resistance during insertion is encountered during endotracheal intubation, a tube with 0.5 mm smaller ID should be used.[10] Proper positioning after insertion of the tube is important. The tube tip should ideally be midway between the vocal cords and the carina so as to minimise the risk of either endobronchial migration or accidental extubation during neck movements. For children, the optimal depth of ETT insertion for oral intubation can roughly be estimated by using the *'lip-to-tip'* formula:[10]

Paediatric ETT position (cm) as measured at the upper incisors = 12 + (age in years/2)

or

Depth of insertion (cm) = Internal diameter of ETT x 3

Endotracheal placement of the tube can be confirmed by the following methods: Auscultation of the chest, passage of the endotracheal tube into the trachea under vision using either direct laryngoscopy or using a fibreoptic scope, observation of chest wall movement, condensation in the endotracheal tube during exhalation, improving colour, heart rate and oxygen saturation with ventilation. Waveform capnography is considered the most accurate method. A disposable colorimetric carbon dioxide detector can easily detect carbon dioxide concentration as low as 0.5 percent.[16] Approximate position of the tube tip as seen in the chest x-ray should be at T_2-T_3 level.

If the endotracheal tube is not secured properly, it may become displaced to the right main bronchus causing one lung ventilation. Endobronchial migration of the tube can also occur with neck flexion. This may lead to complications such as over ventilation of one lung with collapse of the other and even air leak. It is important to document the level of fixation of endotracheal tube to detect displacement.

Ventilator

The ventilator is an automatic mechanical device designed to move gas into and out of the lung. Air and oxygen are mixed in the required proportion using a blender in the ventilator to obtain the desired inspired oxygen concentration. These gases are then humidified using either a passive or an active humidifier and delivered to the patient *via* the breathing circuit. The breathing circuit consists of inspiratory and expiratory limbs, a water trap in each limb to collect condensed water vapour, a 'Y' connector to connect the two limbs to the catheter mount and the standard 15 mm endotracheal tube adaptor.

Conventional ventilation

Mechanical ventilation can be given invasively or noninvasively *(Figure 1)*. Invasive ventilation can be either pressure controlled or volume controlled. When **pressure is held constant**, the delivered volume will vary with change in lung characteristics such as compliance and resistance. When **volume is held constant**, airway pressure will vary with change in lung characteristics. For example, in volume-controlled ventilation in a child weighing five kg, if a tidal volume of seven mL/kg is selected, 35 mL of volume will be delivered with every breath irrespective of changes in lung conditions. If the

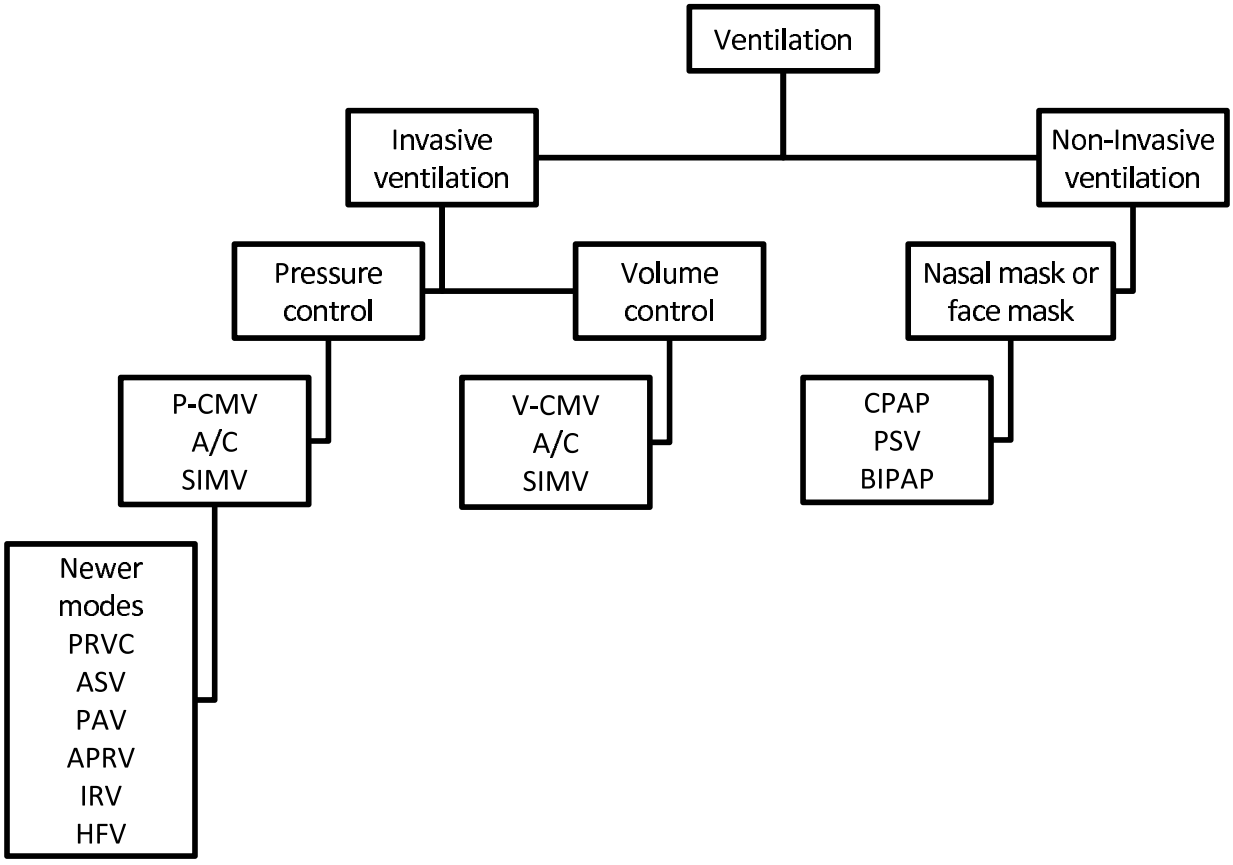

Figure 1: *Ventilatory modes*

lung compliance is low or airway resistance is high, the airway pressure will rise.

Controlled mandatory ventilation (CMV): In this mode, the ventilator delivers the preset tidal volume/ pressure at a set time interval (time triggered respiratory rate). In this mode, the patient cannot change the ventilatory rate or breathe spontaneously. It is useful in patients who are medicated with sedatives and neuromuscular blockers. The ventilator does not provide any additional gas flow if there is spontaneous inspiratory effort by the patient and hence is not a suitable method to ventilate such patients.

Assist control (A/C): It is a mode where every breath of the patient is assisted in addition to delivery of the preset respiratory rate. Each breath provides the patient with a preset tidal volume or peak inspiratory pressure. The AC mode allows the patient to control the respiratory rate and therefore the minute volume required to normalise the patient's PCO_2.

Intermittent mandatory ventilation (IMV): It is a mode in which the ventilator delivers controlled breaths and allows the patient to breathe spontaneously in between the mandatory breaths. The mandatory breaths are delivered at a preset rate and tidal volume whereas the spontaneous breaths are unassisted. Since IMV breaths are delivered at a rate independent of the patient's spontaneous respiratory rate, breath stacking may occur. This occurs when the patient is taking a spontaneous breath and the ventilator delivers a time-triggered mandatory breath at the same time. On the other hand, the ventilator may deliver a breath while the patient is exhaling. This may lead to patient-ventilator asynchrony.

Synchronised intermittent mandatory ventilation (SIMV): It is a mode in which the ventilator delivers the set mandatory breaths. In addition, the patient may breathe spontaneously although unassisted. The mandatory breaths may be either time-triggered or patient-triggered (synchronised with patient's efforts) thus avoiding breath stacking. The synchronisation window is the time interval just prior to time triggering in which the ventilator is responsive to the patient's spontaneous inspiratory effort. The advantages of this mode are that it reduces patient-ventilator asynchrony, maintains respiratory muscle strength/avoid muscle dystrophy, reduces ventilation perfusion mismatch, decreases mean airway pressure and facilitates weaning.

Newer modes

Pressure regulated volume controlled (PRVC) ventilation: The ventilator evaluates the exhaled tidal volume on a breath by breath basis and will reset the pressure support level as needed to guarantee the tidal volume, thus delivering an assured tidal volume even with changing pulmonary mechanics. The guaranteed tidal volume and lowest peak inspiratory pressure ensures decreased work of breathing. This mode of ventilation is of benefit in children with pulmonary hypertension.

Adaptive support ventilation (ASV): It is a newly developed dual controlled mode, where in tidal volume and respiratory rate are automatically adjusted using measured dynamic compliance and time constant to achieve the preset minute ventilation.[17]

Proportional assist ventilation (PAV): It is a mode of assisted ventilation where the pressure is applied by the ventilator in proportion to the patient-generated flow and volume. Flow assist reduces the inspiratory effort needed to overcome airflow resistance (obstruction). Volume assist reduces the inspiratory effort needed to overcome the systemic elastance (restriction). With PAV there is no targeted flow, volume or pressure during mechanical ventilation. The pressure is variable and it is proportional to the patient's breathing effort.[18] PAV improves ventilation, reduces both neuromuscular drive and work of breathing and provides good patient-ventilator synchrony.

Airway pressure release ventilation (APRV): It is a mode of ventilation in which the baseline airway pressure (P_{high}) is elevated. This is periodically and briefly released to facilitate exhalation. The patient can breathe spontaneously around the elevated baseline pressure. The long duration (T_{high}) of

elevated pressure increases mean airway pressure and contributes to improved oxygenation. Ventilation is achieved with exhalation of gases during the brief release ($T_{low,}$ usually one second or less) of high airway pressure to a lower airway pressure (P_{low}). This mode can provide effective ventilatory support with lower peak airway pressure than that provided by PSV and SIMV.

Inverse ratio ventilation (IRV): This mode improves oxygenation by decreasing intrapulmonary shunting and dead space and by improving ventilation-perfusion matching. Shanholtz *et al* stated that this mechanism can be achieved in conventional modes with higher PEEP.[19]

High frequency ventilation (HFV): The basic concept of this mode is to use smaller than physiological tidal volume at ventilatory rates of more than 150 breaths per minute. The limitation of delivered tidal volumes and optimisation of alveolar recruitment minimises atelectrauma and volutrauma and has become one of the important strategies of mechanical ventilation in patients with ARDS. Both inspiration and expiration are active in high frequency oscillatory ventilation.

Majority of the children can be managed with conventional ventilation and newer modes of assisted ventilation are used in conditions such as severe ARDS.

Noninvasive ventilation

The advent of positive pressure ventilation delivered through a nasal or face mask has greatly expanded the use of noninvasive ventilation. Such ventilation has a role not only in the management of acute respiratory failure but also chronic respiratory failure as in cystic fibrosis, neuromuscular diseases (anterior horn cell disease, Guillain–Barre syndrome, myasthenia gravis), phrenic nerve palsy and kyphoscoliosis.

Continuous positive airway pressure (CPAP): It is positive end-expiratory pressure applied to the spontaneously breathing patient's airway. This is

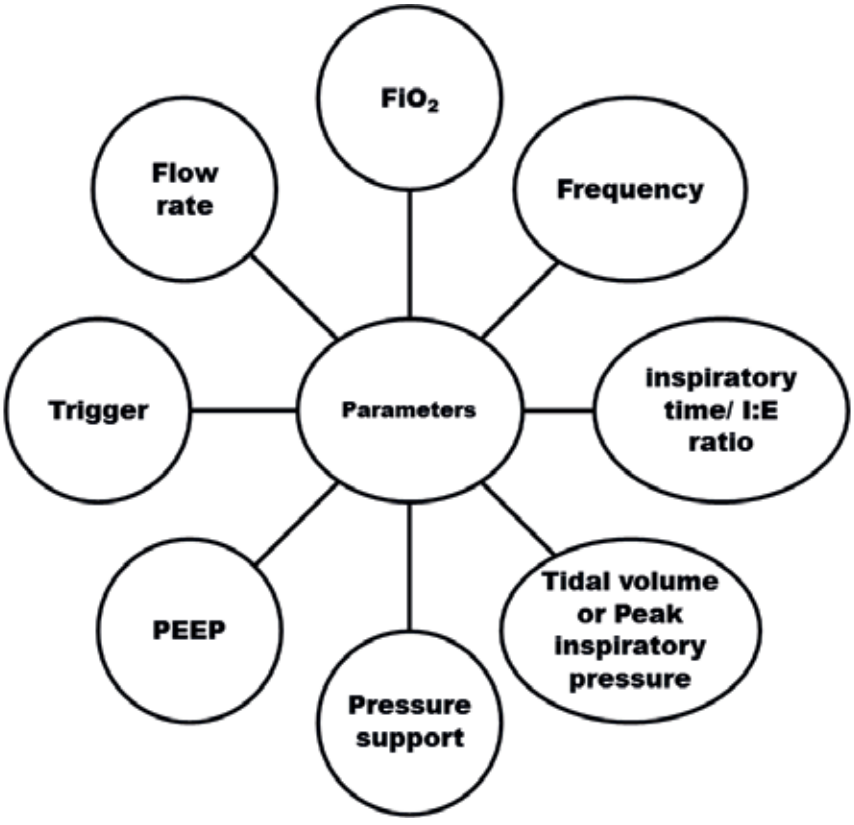

Figure 2: Parameters to be set during paediatric ventilation

not a form of ventilation *per se* but facilitates gas exchange by alveolar recruitment.

Bilevel positive pressure ventilation (BiPAP): This allows ventilation at two levels of pressure. This has a low impact on pulmonary circulation, improves oxygenation and recruitment when used continuously. The elevated airway pressure improves oxygenation by increasing functional residual capacity and enhancing alveolar recruitment.

Pressure support ventilation (PSV): This is the most common mode used for noninvasive mechanical ventilation. Pressure support ventilation is patient-triggered, pressure limited and flow cycled. It delivers the gas flow when patient effort is detected by change in pressure or flow (pressure or flow-triggered). Termination of higher pressure and cycling to exhalation occurs when the ventilator detects a fall in flow rate below threshold value (usually 25 – 30 percent of initial flow rate).

An understanding of the parameters required to initiate mechanical ventilation is essential *(Figure 2)*.

Ventilatory parameters

Fraction of inspired oxygen (FiO_2): Adequate FiO_2 should be administered to maintain SpO_2 of more than 95 percent. High concentrations of oxygen (> 60 percent) can produce lung injury and hence should be avoided if possible.

Respiratory rate (RR) or Frequency (f): The number of breaths per minute is set depending on the child's age and underlying lung condition. Increased frequency will increase minute ventilation and a decrease will cause hypoventilation if tidal volume remains unchanged.

Inspiratory:Expiratory ratio (I:E ratio): The I:E ratio affects the mean airway pressure. The appropriate inspiratory time and I:E ratio depends on the patient's ventilation and oxygenation status as well as on the level of spontaneous breathing. Normal ratio is 1:2.

Tidal volume (V_T): A tidal volume of 6 - 8 mL/kg may be set. Alternately, in some ventilators, the flow rate and the I:E ratio may determine the delivered tidal volume.

Peak inspiratory pressure (PIP): Peak inspiratory pressure determines the tidal volume in pressure controlled ventilation. The PIP may be set according to the lung condition (lung compliance and airway resistance). The lowest PIP required to achieve adequate ventilation of the lungs must be used. High PIP may impede venous return and lower cardiac output.

Pressure support (PS): The ventilator supplies pressure support at a preset level but respiratory rate is determined by the patient. Expiration begins passively when the inspiratory flow decreases below the preset level in the ventilator. Pressure support can decrease work of breathing by providing flow during inspiration for patient triggered breaths.[20]

Positive end expiratory pressure (PEEP): This is used to stabilise alveoli, with functional residual capacity above the closing pressure at the end of exhalation. The level of PEEP depends on clinical circumstances. Application of PEEP results in higher mean airway pressure and better oxygenation.

Trigger: The initiation of inspiration may be triggered using either pressure, volume, flow or time. Inspiration begins when one of these variables reaches a preset value. Most ventilators have either flow or pressure trigger.

Flow rate (V): The flow rate is an important determinant of peak inspiratory pressure, waveform, I:E ratio and in some cases respiratory rate during mechanical ventilation. The minimum flow rate should be at least two times the minute ventilation. If low flow rates are used, inspiratory time may be unduly prolonged. In many modern ventilators, the flow rate is automatically adjusted by the ventilator as required.

In conditions such as status asthmaticus, maintenance of airway patency and ventilation is important despite maximal drug therapy. Controlled ventilation using SIMV or Assist control mode where plateau

pressure is limited to < 35 cm H_2O and tidal volume of 6-8 mL/kg may be used.

Care while on ventilator

Chest physiotherapy (CPT): CPT consists of postural drainage, percussion, vibration of chest wall and coughing or suctioning off secretions. *Postural drainage* is a procedure done with the use of gravity to move secretions from peripheral airway to the larger bronchi so that they can be easily expectorated. This procedure should be performed for at least 1-10 minutes depending on the severity of the patient's condition.[21] *Percussion*, used for loosening secretions from the bronchial wall is given at 5-6 Hz (300 to 360 breaths/minute). Some clinicians recommend slow rhythmic clapping.[22] *Vibration* is an external transmission of energy through the chest wall to loosen or move secretions to the central airway.

Suctioning: This sterile invasive procedure is performed to maintain airway patency and assist effective cough reflex. It can also be used to obtain specimens for diagnostic purpose. To perform this procedure, it is very important to assess the indication of suctioning in order to avoid complications such as haemorrhage and fluctuation of airway pressure. A negative vacuum pressure of -80 to -100 mm Hg for paediatric age group is required. Appropriate size of the suction catheter (in French gauge) is given by the formula:[10]Endotracheal tube ID (mm) x 2. It is important to ensure that the tip of the suction catheter has passed beyond the tip of the endotracheal tube. During insertion of the suction catheter, negative pressure should not be applied. When the predetermined length of the catheter is in tube, intermittent suction is applied for at least five seconds using thumb port after withdrawing 0.5-1.5 cm. Rotating the catheter during withdrawal is necessary to clear the secretions present along the wall of the endotracheal tube.

Duration of each suctioning should not be > 10 s when applying vacuum to prevent hypoxemia and atelectasis. The patient is preoxygenated before starting the procedure and inflation is given *via* a self-inflating bag for alveolar recruitment. Monitoring of vitals and oxygen saturation is very important during this procedure.

If secretions are thick, 2 – 5 mL of normal saline is instilled followed by manual ventilation and suctioning.[23] Other detergents such as sodium bicarbonate and mucolytic (N-acetylcysteine) can be given. These agents when instilled allow dispersion throughout the lung fields to liquefy and loosen secretions. Closed suctioning is used in conditions where frequent suctioning is required. This system may prevent alveolar collapse associated with loss of PEEP during suctioning and hence may reduce pulmonary complications.

Nebulisation with mechanical ventilation: Nebulisation can be given while the patient is still connected to ventilator. Many factors affect aerosol therapy such as patient interface, breath configuration, airway and environment. Placement of nebuliser 30 cm proximal to the ETT in the inspiratory limb is more efficient.[24] The medications used for nebulisation along with the doses are as shown in *Table 2*.[25]

Table 2: Medications administered by nebulisation and their doses

Nebulisation drugs	*Dosage*
Salbutamol (Asthalin)	0.15-0.25 mg/kg/dose (minimum dose of 2.5 mg).
Terbutaline	0.01-0.03 mL/kg mixed in 2-3 mL of normal saline every 4-6 h
Ipratropium bromide	0.5-1 mg/kg (max,15 mg) every 8 h
Racemic epinephrine	0.05 mg/kg (max, 15 mg) every 4-6 h

Humidification: Inspired gas at 37° C is 100 percent saturated and corresponds to 44 mg H_2O/L. It is recommended that inspired gases may be humidified to ≥ 33 mg H_2O/L.[26] Though heat and moisture exchangers (HME) provide adequate humidification, they should not be used in children as they increase dead space and add resistance to the circuit.[27]

Trouble shooting: If the patient is 'fighting the ventilator' (patient-ventilator asynchrony) and

desaturating, immediate measures taken are to rule out displacement, obstruction, pneumothorax and equipment failure (mnemonic D-O-P-E).

Firstly, endotracheal tube placement is checked. When in doubt, remove the endotracheal tube and start manual ventilation with 100 percent oxygen with bag and mask. Then re-intubate if required. Secondly, examine the patient for chest rise, bilaterally equal breath sounds, atelectasis, bronchospasm, tube block, malposition and pneumothorax. Thirdly, check arterial blood gases and chest x-ray for worsening lung condition and evaluation of pneumothorax. Finally, examine the ventilator, ventilator circuit, humidifier and gas source. If no other new reason for patient-ventilator asynchrony is detected, increase sedation, increase FIO_2 appropriately and ventilate the child.

Sedation in ventilated children

To minimise patient discomfort in the intensive care unit (ICU), sedation has become an integral part of critical care practice. Sedation reduces the stress response, provides anxiolysis, improves tolerance to mechanical ventilation and facilitates nursing care.[28] Unfortunately, sedatives have adverse effects, have the potential to prolong mechanical ventilation and may increase health care costs. Common sedatives used in the intensive care unit are midazolam, fentanyl and morphine (*Table 3*).[29]

Table 3: Drugs used for sedation of a paediatric patient

Drugs	Dosage (intravenous)
Midazolam	0.05-0.15 mg/kg
Morphine	0.1-0.2 mg/kg
Fentanyl	1-2 µg/kg

Monitoring

When the child is receiving positive pressure ventilation, monitoring is essential to prevent complications and adverse effects. Monitoring vital signs, blood gas analysis, pulse oximetry and end-tidal carbon dioxide will enable proper monitoring of the patient's condition. While on ventilator, it is important to observe the depth, rhythm of the chest movements with each breath. Asymmetry or decreased air entry, conducted sounds, rhonchi need prompt attention and evaluation. Repeat chest x-ray and arterial blood gas analysis have to be done judiciously.

Pulse oximetry: The percentage of oxygen saturation in arterial haemoglobin is reflected by SpO_2 measurement. Pulse oximetry estimates the arterial oxygen saturation by measuring the differential absorption of light by oxyhaemoglobin and reduced haemoglobin.

Capnography: The arterial to end-tidal carbon dioxide ($ETCO_2$) difference in normal healthy individuals is < 5 mm Hg representing normal dead space. Capnography helps in the early detection of displacement of endotracheal tube (oesopheageal intubation, accidental extubation and ventilator disconnection) apart from providing information on status of ventilation (hypo or hyperventilation).

Noninvasive monitoring with pulse oximeter and capnography has reduced the need of frequent arterial blood gas analysis.

Complications of mechanical ventilation

Mechanical ventilation has saved and supported thousands of children with disease conditions such as respiratory failure and other systemic organ disease which suppress respiration. If the supporting parameters are set above or below the optimal level of requirement, mechanical ventilation can cause various complications. For example, if pressure control is higher than what the alveoli can sustain, it may lead to overdistension and barotrauma. Similarly large tidal volumes can cause volutrauma. Increased frequency or higher tidal volumes or both can lead to high minute ventilation and hypocapnoea. Decreased minute ventilation can lead to hypoventilation and hypercapnoea with or without hypoxia. Repetitive opening and closing of the terminal lung unit leads to atelectrauma. Overdistension can also cause decreased static compliance, increased work of breathing, increased dead space and increased air leak around endotracheal tube.

Extrapulmonary leak in the form of pneumothorax, pneumomediastinum, pneumoperitoneum and subcutaneous emphysema are the most common complications and are results of over distension of alveolar and peribronchial tissue.[30] Treatment consists of detecting leak, decreasing tidal volume, decreasing PEEP and relieving the leak to a chest tube. Permissive hypercapnoea may be useful for treatment of airleak.[31]

Mechanical ventilation also reduces urine output as a result of an increase in antidiuretic hormone (ADH) and reduction of atrial natriuretic factor (ANF). This results in decreased fluid output and fluid retention. Other complications include post extubation stridor, development of chronic lung disease and ventilator associated pneumonia.

Conclusion

This review on paediatric ventilation provides salient points to be remembered during clinical practice. Sound knowledge about mechanical ventilation, modes and parameters is essential and should be practiced judiciously. Optimal support and close monitoring of patients would prevent complications and improve survival.

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