Newborn Critical Care Center (NCCC) Clinical Guidelines

Conventional Mechanical Ventilation (CMV)

BACKGROUND

Mechanical ventilation is not a cure to underlying illness, but instead can be a lifesaving therapy which supports infants with respiratory failure while the underlying disease process resolves. Conventional mechanical ventilation and high frequency ventilation (HFV) are invasive therapies available for management of respiratory failure, while continuous positive airway pressure (CPAP), high flow and low flow nasal cannula and oxyhood are examples of noninvasive therapies available for management of respiratory distress.

Clinicians should provide infants with the appropriate level of respiratory support to ensure optimal oxygenation and ventilation while simultaneously minimizing injury. Providing infants with inadequate respiratory support may result in morbidity due to hypoxemia, hypercarbia and/or atelectotrauma, while providing infants with extraneous respiratory support may result in morbidity due to hyperoxia, hypocarbia, barotrauma and/or volutrauma.

INDICATIONS

- Respiratory failure secondary to severe respiratory acidosis, hypoxemia or apnea
- Anticipated respiratory failure, such as immediately prior to a surgical procedure or with significant cardiovascular compromise
- Severe metabolic acidosis with concern for impending respiratory failure

PHYSIOLOGY

- Ventilation (CO_2):
  - Minute ventilation is the product of respiratory rate (RR) and tidal volume (Vt)

$$\dot{V} = RR \; x \; V_T$$

  - Ventilation is, therefore, increased by increasing the RR or Vt.
- Oxygenation (O_2):
  - Is dependent on the fraction of inspired oxygen (FiO_2) and the recruitment of lung tissue to participate in gas exchange, which is dependent on mean airway pressure (MAP)
  - Oxygenation is increased by increasing the MAP within limits imposed by lung mechanics and by increasing the FiO_2. The MAP is most effectively increased by increasing PEEP, but may also be increased by increasing the inspiratory time (Ti) and peak inspiratory pressure (PIP), if in a pressure mode.

VENTILATION AND LUNG PROTECTIVE STRATEGIES

Providing excessive or insufficient respiratory support can result in lung injury. The absolute tidal volumes and pressures at which the phenomena below occur are determined by the mechanical properties of the lung, which are dependent on the underlying disease process. Strategies should aim to maintain adequate respiratory physiology in the least injurious manner. The following goals should guide the development of a strategy of ventilation:

	What it is?	How do we prevent it?	Using flow-volume loop
Atelectotrauma	Repeated alveoli deflation and decreased lung volumes	Maintain an end-expiratory lung volume (EELV) equal to or greater than predicted normal FRC (above the P_{inf}) - PEEP - Surfactant	Looking at inflation portion of flow-volume loop, assure that the slope starts increasing almost immediately upon a breath. If the slope is flat, the patient may benefit from increased PEEP (Note Figure 2 below)
Volutrauma	Inflation of the lungs to a volume that approaches the total lung capacity (TLC)	Ventilate with tidal volumes that avoid lung over-distention and utilize the minimum peak inspiratory pressures necessary to achieve targeted tidal volumes - Tidal volumes of 4.5-7 mL/kg - Volume guarantee ventilation	On flow-volume loops and best demonstrated below in Figure 1, the area of high volume lung injury is to be avoided. If this "bird-beaking" is excessive, the patient may benefit from less tidal volume if pCO2 is adequate.
Barotrauma	Overinflation and shearing stresses due to high PIPs, theorized not to occur without accompanying volutrauma		
Synchronization	Synchronize ventilated breaths with spontaneous breaths	Utilization of synchronized modes of ventilation (SIMV, AC, PSV)	N/A

Figure 1 below (shaded areas) depicts areas of atelectotrauma and volutrauma in both a normal newborn and a newborn with RDS. The goal of mechanical ventilation is to ventilate using pressures that achieve lung volumes outside of the zones of lung injury and on the steepest portion of the pressure-volume curve (shaded areas in Figure 2)

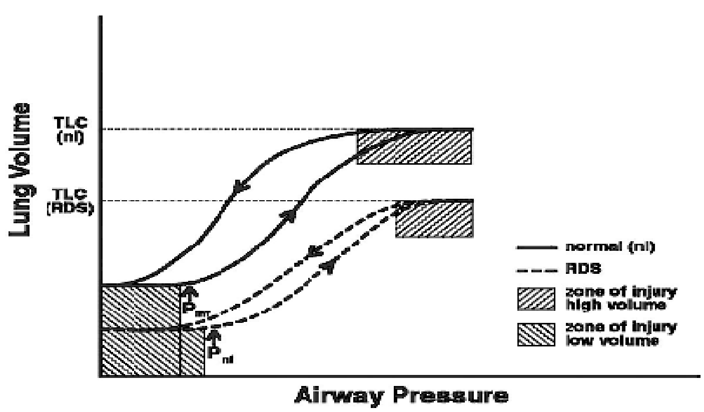

Figure 1. Static pressure-volume curves for infants with normal lungs and infants with RDS. The figure depicts the effects of disease on total lung capacity (TLC) and point of inflection of the inspiratory curve (P_{inf}). Hypothesized zones of lung injury are indicated in the shaded areas.

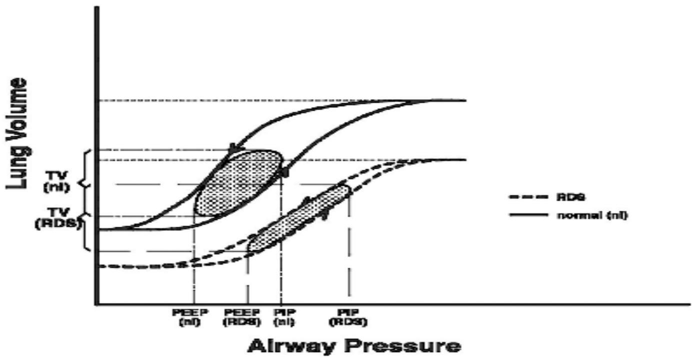

Figure 2. The shaded areas indicate the ideal zones of ventilation.

VENTILATOR MODES

This guideline will focus on the most frequent modes of ventilation, including:

- AC – assist control
- PSV – pressure support ventilation
- SIMV – synchronized intermittent mandatory ventilation
- NAVA – neurally adjusted ventilatory assist (via Maquet SERVO-i ventilator only)

All four modes are pressure ventilation modes. However, PSV, AC and SIMV modes can be used with Volume Guarantee (VG). With VG, the ventilator automatically adjusts the PIP to target a designated tidal volume (Vt).

SETTINGS

The following table summarizes ventilator modes and settings which must be set by providers (Operational), and safety feature settings (Alarm/Pop-off) which are set by the respiratory therapist unless specified by providers.

Mode	How it works	Operational (Provider Sets)	Alarm/Pop-off
AC ± VG*	Every breath is "assisted" or supported to designated tidal volume or pressure, with a set Ti and set backup rate.	Vt (in VG) or PIP, PEEP, Ti, back-up rate, FiO_2	PIP limit (in VG)
SIMV ± VG	Similar to AC but spontaneous breaths above the back-up respiratory rate are supported via a set pressure support (PS).	Vt (in VG) or PIP, PEEP, Ti, rate, FiO_2, +/- PS	PIP limit
PSV ± VG	Every breath is supported by a set pressure (or volume, in VG). The Ti is variable and based on the mechanical properties of the lung.	Vt (in VG) or PIP, PEEP, back-up rate, FiO_2	PIP limit (in VG), Ti
NAVA**	Assists each breath by providing support in proportion to and in synchrony with the infant's own respiratory efforts	*Primary settings:* NAVA level, PEEP, FiO_2 *Back-up settings:* Apnea time, respiratory rate, PC above PEEP	Number of times in backup mode is tracked (Trends)

**** AC + VG is the initial ventilator mode of choice for most infants.***

Typical starting settings include:

Vt	5 mL/kg
PEEP	5 cmH_20 (PEEP 6 cmH_20 if <27 weeks GA)
Ti	Dependent on gestational age and properties of lung (i.e. 0.25 for 25 weeks, 0.40 for term infant)
Rate	40 bpm (back-up rate)
FiO_2	Titrated to maintain target SaO_2

***** NAVA (neurally adjusted ventilatory assist)***

This mode of ventilation assists each breath by providing support in proportion to and in synchrony with the infant's own respiratory efforts. Respiratory efforts are determined by assessment of the electrical activity of the diaphragm, as assessed via a catheter placed in the esophagus and reflected as an **Edi** value. When the infant is apneic, the ventilator provides back-up breaths until spontaneous breaths are again detected. NAVA is a mode of mechanical ventilation that can be provided invasively via an endotracheal tube or non-invasively via RAM nasal cannula.

Adjustable settings include the NAVA level (cmH_2O/uV, which is a factor by which the Edi signal is multiplied to adjust the amount of assist delivered to the infant), PEEP, and FiO_2. Edi (minimum value to trigger the ventilator to assist the infant) is an adjustable setting commonly set by the respiratory therapist. There are two Edi triggers that have to be set....Edi trigger and trigger sensitivity. The Edi trigger is the amount of deflection the Edi curve must exceed before the ventilator is triggered. We always set this at 0.5 as recommended by Maquet and NAVA representatives. The recommendation is based on an evaluation of esophageal pressures and ventilator triggering. According to Drager, a negative deflection in esophageal pressure of 0.5 cm H2O causes triggering of the ventilator. The next trigger we set is trigger sensitivity which is how easy or hard it is for the patient to pull a deflection. Per Maquet and NAVA representatives it is best to use a pressure trigger of -2 to prevent auto-cycling.

When the patient is in NIV-NAVA the only trigger required to be set is the Edi trigger. Adjustable back-up mode settings for when the infant is not breathing spontaneously include the apnea time (time before the back-up mode contributes), back-up respiratory rate, and pressure control above PEEP.

The Edi peak reflects the electrical activity of the diaphragm during inhalation. Goal Edi peak levels are 5-15 uV. A higher NAVA level reduces Edi peak levels. The Edi min is the electrical activity of the diaphragm during exhalation (in order to maintain auto-PEEP). Goal Edi min levels are <2 uV. A higher PEEP setting will reduce the Edi min.

Of note, peak inspiratory pressures provided during each spontaneous breath can be calculated by:

$$PIP = [(Edi\ peak - Edi\ min)\ x\ NAVA\ level] + PEEP$$