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AARC Clinical Practice Guideline

Neonatal Time-Triggered, Pressure-Limited, Time-Cycled Mechanical Ventilation

TPTV 1.0 PROCEDURE:

The application of time-triggered, pressure-limited, time-cycled mechanical ventilation (TPTV) to neonates--this Guideline does not address patient-triggered ventilation.

TPTV2.0 DESCRIPTION/DEFINITION:

The application of time-triggered, pressure-limited, time-cycled mechanical ventilation in the neonate is typically accomplished by the use of commercially available pressure-limited ventilators specifically designed for this population or of multipurpose, multimodal ventilators with the necessary capabilities. These ventilators permit precise management of ventilator settings.(1-8)

Pressure-limited ventilators commonly incorporate continuous flow to deliver a mixture of oxygen and air. The continuous flow supplies the patient with a fresh gas source for spontaneous breathing.(7,9-14)

Mandatory breaths are time-triggered and time-cycled, based on an adjustable frequency and inspiratory time. As the ventilator time-triggers inspiration, the exhalation valve closes, and the continuous flow is directed to the inspiratory limb of the patient circuit for the length of the inspiratory time.(7,11,12,14)

Once the pressure limit has been reached, remaining flow is diverted to a limiting mechanism. As the ventilator cycles to expiration, the exhalation valve opens to ambient and the continuous flow exits the expiratory limb of the circuit.(7,10,14)

Flow continues to enter the patient's lungs until pressure equilibrates or until the inspiratory time has elapsed, resulting in a decelerating flow pattern. Volume delivery is dependent on lung and chest-wall compliance and airway resistance, including the resistance of the endotracheal tube. As these variables change, deceleration of flow is

altered, and the tidal volume (VT) varies.(10,11,15-22) The VT achieved depends on the pressure limit, gas flowrate, inspiratory time (tI), and positive end-expiratory pressure (PEEP). Circuit characteristics that affect VT include compressible volume, presence of condensate, and obstruction of the artificial airway.(3,4,8-10,18,20,23)

TPTV 3.0 SETTINGS:

TPTV is applied by trained personnel in acute care and subacute care hospitals.

TPTV 4.0 INDICATIONS:

The presence of one or more of the following conditions constitutes an indication for TPTV.

4.1 Apnea (24-27)

4.2 Respiratory or ventilatory failure, despite the use of continuous positive airway pressure (CPAP) and supplemental oxygen (ie, FIO2 > or = 0.60)(24,25,28)

4.2.1 Respiratory acidosis with a pH < 7.20-7.25(8,25,29)

4.2.2 PaO2 < 50 torr(8,13,25,29,30)

4.2.3 Abnormalities on physical examination

4.2.3.1 Increased work of breathing demonstrated by grunting, nasal flaring, tachypnea, and sternal and intercostal retractions(5,27,29,31)

4.2.3.2 The presence of pale or cyanotic skin and agitation

4.3 Alterations in neurologic status that compromise the central drive to breathe:

4.3.1 Apnea of prematurity(32)

4.3.2 Intracranial hemorrhage(33)

4.3.3 Congenital neuromuscular disorders(34)

4.4 Impaired respiratory function resulting in a compromised functional residual capacity (FRC) due to decreased lung compliance and/or increased airways resistance,(12,35) including but not limited to

4.4.1 Respiratory distress syndrome (RDS)(1,2,28,36-39)

4.4.2 Meconium aspiration syndrome (MAS)(40)

4.4.3 Pneumonia(41)

4.4.4 Bronchopulmonary dysplasia(42-44)

4.4.5 Bronchiolitis(41)

4.4.6 Congenital diaphragmatic hernia(45)

4.4.7 Sepsis(41)

4.4.8 Radiographic evidence of decreased lung volume(27)

4.5 Impaired cardiovascular function

4.5.1 Persistent pulmonary hypertension of the newborn

(PPHN)(46,47)
4.5.2 Postresuscitation(41)
4.5.3 Congenital heart disease(48)
4.5.4 Shock(6)
4.6 Postoperative state characterized by impaired ventilatory function(45,49)

TPTV 5.0 CONTRAINDICATIONS:

No specific contraindications for neonatal TPTV exist when indications are judged to be present (Section 4.0).

TPTV 6.0 HAZARDS/COMPLICATIONS:

6.1 Air leak syndromes due to barotrauma and/or volume overinflation (ie, volutrauma),(2,11,50-54) including
6.1.1 Pneumothorax(16,55-59)
6.1.2 Pneumomediastinum(55,56,58)
6.1.3 Pneumopericardium(55)
6.1.4 Pneumoperitoneum(55)
6.1.5 Subcutaneous emphysema(55)
6.1.6 Pulmonary interstitial emphysema(56,60-62)
6.2 Chronic lung disease associated with prolonged positive pressure ventilation and oxygen toxicity(63,64) (eg, bronchopulmonary dysplasia(42,43,65-68))
6.3 Airway complications associated with endotracheal intubation
6.3.1 Laryngotracheobronchomalacia(69)
6.3.2 Damage to upper airway structures(66,69,70)
6.3.3 Malpositioning of endotracheal tube (ETT)(69,71)
6.3.4 Partial or total obstruction of ETT with mucus(69,71,72)
6.3.5 Kinking of ETT(69,71)
6.3.6 Unplanned extubation(69,71,73)
6.3.7 Air leak around uncuffed ETT
6.3.8 Subglottic stenosis(69)
6.3.9 Main-stem intubation(69)
6.3.10 Pressure necrosis(74)
6.3.11 Increased work of breathing (during spontaneous breaths) due to the high resistance of endotracheal tubes of small internal diameter(75)
6.4 Nosocomial pulmonary infection (eg, pneumonia(76))
6.5 Complications that occur when positive pressure applied to the lungs is transmitted to the cardiovascular system(77,78) or the cerebral vasculature resulting in
6.5.1 Decreased venous return(77,78)
6.5.2 Decreased cardiac output(77,78)
6.5.3 Increased intracranial pressure leading to intraventricular

hemorrhage(27,33,79)
6.6 Supplemental oxygen in conjunction with TPTV may lead to an increased risk of retinopathy of prematurity (ROP)(80,81)
6.7 Complications associated with endotracheal suctioning(82)
6.8 Technical complications
6.8.1 Ventilator failure(10,83)
6.8.2 Ventilator circuit and/or humidifier failure(38,70) (Condensate in the inspiratory limb of the ventilator circuit may result in a reduction in VT(23,84) or inadvertent pulmonary lavage.)
6.8.3 Ventilator alarm failure(10,38,69,83)
6.8.4 Loss of or inadequate gas supply
6.9 Patient-ventilator asynchrony(85,86)
6.10 Inappropriate ventilator settings leading to
6.10.1 auto-PEEP
6.10.2 hypo-or hyperventilation
6.10.3 hypo- or hyperoxemia
6.10.4 increased work of breathing

TPTV 7.0 LIMITATIONS OF METHOD:

Rapid changes in lung compliance and airways resistance may result in alterations in VT delivery that may significantly alter minute ventilation (VE).(3,4,9,11,19-21)

TPTV 8.0 ASSESSMENT OF NEED:

Determination that valid indications are present by physical, radiographic, and laboratory assessment

TPTV 9.0 ASSESSMENT OF OUTCOME:

Establishment of neonatal assisted ventilation should result in improvement in patient condition and/or reversal of indications (Section 4.0):
9.1 Reduction in work of breathing as evidenced by decreases in respiratory rate, severity of retractions, nasal flaring and grunting
9.2 Radiographic evidence of improved lung volume(41)
9.3 Subjective improvement in lung volume as indicated by increased chest excursion and aeration by chest auscultation(87)
9.4 Improved gas exchange
9.4.1 Ability to maintain a PaO2 > or = 50 torr with FIO2 < 0.60(8,30)
9.4.2 Ability to reverse respiratory acidosis and maintain a pH > 7.258,30
9.4.3 Subjective improvement as indicated by a decrease in grunting, nasal flaring, sternal and intercostal retraction, and respiratory rate(31)

TPTV 10.0 RESOURCES:

10.1 Equipment-recommended equipment based on individual patient need includes the following. (For a given patient, all mentioned equipment may not be necessary.)
10.1.1 Commercially available continuous-flow infant ventilator equipped with TPTV mode or suitably equipped multipurpose, multimodal ventilator, low and high airway pressure alarms, high-pressure release-to-ambient pressure capability, loss of power and gas source alarms, low and high oxygen concentration alarms--alarms may be integral to the ventilator or an add-on.(21,38,83)
10.1.2 Servo-regulated humidifier with low compressible volume chamber and preferably a continuous water source(21,38,83)
10.1.3 Low-compliance infant ventilator circuit with heated inspiratory and expiratory wires compatible with the servo-regulated humidification system is recommended.(19,23,38,83,88,89) Comparable circuits that permit continual drainage of condensate may also be used.
10.1.4 Endotracheal tube with associated intubation equipment or tracheostomy tube with associated insertion and cleaning accessories and supplies for securing the tube
10.1.5 Suction source, suction catheters, and normal saline for instillation to ensure patency of artificial airway(82)
10.1.6 Standby resuscitation apparatus with airway manometer and masks of appropriate size(83) and supplies for chest-tube insertion
10.1.7 Continuous noninvasive monitoring of oxygenation by either transcutaneous monitor or pulse oximeter with high- and low-alarm capabilities(90,91)
10.1.8 Continuous noninvasive monitoring of carbon dioxide by transcutaneous CO_2 monitor with high- and low-alarm capabilities is also recommended(38,92) for the unstable baby requiring frequent ventilator changes. Measurements of end-tidal CO_2 may also be useful in these infants.(93,94)
10.1.9 Continuous cardiorespiratory monitoring (eg, ECG and respiratory rate) with high- and low-alarm capabilities(38)
10.1.10 Appropriate and adequate compressed gas supply
10.1.11 Graphic display of airway pressure, flow, and tidal volume may be useful.
10.2 Personnel: TPTV should be applied under the direction of a physician by trained personnel who hold a recognized credential (eg, CRTT, RRT, RN) and who competently demonstrate
10.2.1. proper use, understanding, and mastery of the technical aspects of management of artificial airways, mechanical ventilators, and humidification systems;

10.2.2 comprehensive knowledge of ventilator management and understanding of neonatal airway anatomy and pulmonary pathophysiology;
10.2.3 patient assessment skills, with an understanding of the interaction between the mechanical ventilator and the patient and ability to recognize and respond to adverse reactions and complications;
10.2.4 knowledge and understanding of intubation equipment;
10.2.5 ability to interpret monitored and measured blood gas parameters and vital signs;
10.2.6 application of Universal Precautions;(92)
10.2.7 proper use, understanding, and mastery of emergency resuscitation equipment and procedures;
10.2.8 ability to evaluate and document results of outcome assessments (Section 9.0);
10.2.9 ability to interpret chest radiographs to determine proper placement of artificial airways and identify complications associated with mechanical ventilation (eg, air leak syndromes).

TPTV 11.0 MONITORING:

11.1 Patient-ventilator system checks should be performed every 2-4 hours and should include documentation of ventilator settings and patient assessments as recommended by the AARC CPG Patient-Ventilator System Checks (MV-SC) and AARC CPG Humidification during Mechanical Ventilation (HMV).(95,96)
11.2 Oxygen and CO_2 monitoring
11.2.1 Periodic sampling of blood gas values by arterial, capillary, or venous route.(1,24,30) PaO_2 should be kept below 80 torr in preterm infants to minimize the risk of ROP.(6,80,97)
11.2.2 The unstable infant should be monitored continuously by transcutaneous O_2 monitor or pulse oximeter.(1,90,91)
11.2.3 The unstable infant should be monitored continuously by transcutaneous(90) or end-tidal CO_2 monitoring.(93,94)
11.2.4 Fractional concentration of oxygen delivered by the ventilator should be monitored continuously.(38)
11.3 Continuous monitoring of cardiac activity (via electrocardiograph) and respiratory rate(98)
11.4 Monitoring of blood pressure by indwelling arterial line or by periodic cuff measurements(24)
11.5 Continuous monitoring of proximal airway pressures including peak inspiratory pressure (PIP), PEEP, and mean airway pressure (Paw)(1,39,99)
11.5.1 Increases in Paw may result in improved oxygenation; however, Paw > 12 cm H_2O has been associated with barotrauma.(8,20,41,99-

102)
11.5.2 The difference between PIP and PEEP (^P) in conjunction with patient mechanics determines VT. As the ^P changes, VT will vary.(16,51,99,100)
11.5.3 PIP should be adjusted initially to achieve adequate VT as reflected by chest excursion and adequate breath sounds(8,29,100) and/or by VT measurement.
11.5.4 PEEP increases FRC and may improve oxygenation and ventilation-perfusion relationship (PEEP is typically adjusted at 4-7 cm H2O--levels beyond this range may result in hyperinflation, particularly in patients with obstructive airways disease [eg, MAS or bronchiolitis](5,29,35,103-105)).
11.6 Many commercially available neonatal ventilators provide continuous monitoring of ventilator frequency, tI, and I:E. If only two of these variables are directly monitored, the third should be calculated (eg, the proportion of the tI for a given frequency determines the I:E).
11.6.1 Lengthening tI increases Paw and should improve oxygenation.(1,2,13,24,41,106,107)
11.6.2 I:E in excess of 1:1 may lead to the development of auto-PEEP and hyperinflation.(5,20,24,37,105,106,108)
11.6.3 Frequencies of 30-60 per minute with shorter tI (eg, I:E of 1:2) are commonly used in patients with RDS.(8,22,41,50,59,85,109-111)
11.7 Depending on the internal diameter of the ventilator circuit, excessive flowrates can result in expiratory resistance that leads to increased work of breathing and automatic increases in PEEP.(17,19,89,98,86,112) Some ventilators are equipped with demand-flow systems that permit the use of lower baseline flowrates but provide the patient with additional flow as needed
11.8 Because of the possibility of complete obstruction or kinking of the ETT and the inadequacy of ventilator alarms in these situations, continuous tidal volume monitoring via an appropriately designed (minimum dead space) proximal airway flow sensor is recommended.(98,113,114)
11.9 Periodic physical assessment of chest excursion and breath sounds and for signs of increased work of breathing and cyanosis.(3,5,21,87)
11.10 Periodic evaluation of chest radiographs to follow the progress of the disease, identify possible complications, and verify ETT placement(21,27,79)
TPTV 12.0 FREQUENCY:

TPTV is intended for continuous use and is discontinued when the

patient's clinical condition improves as indicated by results of outcome assessments (Section 9.0).

TPTV 13.0 INFECTION CONTROL:

No special precautions are necessary, but Universal Precautions as described by the Centers for Disease Control should be employed.(95)

13.1 Ventilator circuits and humidifier chambers should not be changed more frequently than every 48 hours. The Clinical Practice Guideline: Ventilator Circuit Changes, the CDC, and, reported experience(114-116) suggest that use periods of > or = 5 days are acceptable when the humidifying device is other than an aerosol generator.

13.2 External surfaces of ventilator should be cleaned according to the manufacturer's recommendations when the device has remained in a patient's room for a prolonged period, when soiled, when it has come in contact with potentially transmittable organisms, and after each patient use.

13.3 Sterile suctioning procedures should be strictly adhered to.(82)

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