INTRODUCTION TO MECHANICAL VENTILATION
OF THE NEONATE

by

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INTRODUCTION TO MECHANICAL VENTILATION
OF THE NEONATE

BEHAVIORAL OBJECTIVES

UPON COMPLETION OF THE READING MATERIAL, THE PRACTITIONER WILL BE ABLE TO:

1. Describe the main characteristics of neonatal ventilation:
   - Positive pressure
   - Time cycling
   - Continuous flow
   - Positive pressure ventilation/volume ventilation differences
   - Tidal volume as it relates to pressure limiting

2. Describe the four common modes of newborn mechanical ventilation:
   - CPAP via endotracheal tube and nasal prongs
   - IMV
   - SIMV

3. Describe the other “newer” modes of infant ventilation.

4. Outline the goals, indications and hazards of CPAP/PEEP and mechanical ventilation.

5. Summarize the most important considerations during management of the infant requiring mechanical ventilation.

6. State the suggested initial settings for mechanical ventilation of the neonate.

7. Describe the ability to properly monitor the ventilator/neonate interface to include setting/troubleshooting for alarms:
   - Inspiratory or patient pressure alarm
   - Low PEEP/CPAP alarm
   - Gas pressure failure alarm
   - Ventilator inoperative alarms

8. List and classify the ventilators that combine infant, pediatric and adult ventilation.

9. List and classify the ventilators that are available for infant/pediatric use only.

10. List and describe the calculations that may be helpful in the practice of neonatal and pediatric Respiratory Care.

11. Demonstrate, in a clinical practice exercise, the ability to troubleshoot infant
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ventilator/patient interface malfunctions.

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PREFACE

This course, specifically designed for the Respiratory Therapist just beginning their practice in the Neonatal Intensive Care Unit (NICU), will provide a basic understanding of neonatal ventilation including the main characteristics and the common modes of ventilation. An overview of current ventilators capable of infant modes is included. Also discussed will be monitoring of the ventilator/neonate interface and setting and troubleshooting for alarms. High frequency ventilation is a separate continuing education course, “High Frequency Ventilation of the Neonate”.

INTRODUCTION

A basic understanding of neonatal ventilation is required in any newborn nursery. Goals of ventilation for these newborns are to provide adequate ventilation and oxygenation (alveolar gas exchange) with minimal compromise to the circulatory system and minimal damage to the pulmonary tissues.

MAIN CHARACTERISTICS OF NEONATAL VENTILATION

Most ventilators designed for infants are pressure-limited, time-cycled and have continuous flow. Within the past few years, other modes have increased in popularity. Let us first define the most common terms:

Pressure-limited

The operator limits the maximum pressure exerted against the patient’s airway during the breath. This is called the peak inspiratory pressure or PIP. The level of PIP is one of the determinants of the delivered tidal volume and is changed as needed to alter ventilation. Due to the influence of PIP on mean airway pressure (MAP), PIP also can affect oxygenation. MAP is the average pressure exerted on the airway and lungs from the beginning of inspiration until the beginning of the next inspiration. Unlike volume-cycled ventilators, pressure-limited ventilators deliver a variable tidal volume depending on the patient’s lung compliance. As lung and thoracic compliance worsens, the pressure limit must be increased to maintain the same tidal volume. Conversely, as compliance improves, the pressure limit must be decreased to avoid excessive ventilation and barotrauma. Tidal volume (VT) as it pertains to mechanical ventilation, is the amount of gas entering the patient’s lungs during the inspiratory phase of ventilation.

Time-cycled

Inspiratory time (IT) is set to cycle off the inspiratory breath. This time determines how long the gas is in contact with the alveoli for gas exchange. IT and frequency or rate together determines the I: E ratio. There is a delicate balance of the inspiratory to expiratory time needed to maintain good oxygenation and prevent air trapping. Frequency is the
number of inspirations that will be delivered in one minute. During mechanical ventilation of the infant, generally a 1:2 ratio is desired. Inspiratory times set range from 0.25-0.45 seconds. At this writing, there seems to be no definitive studies as to appropriate inspiratory times for infants, but the trend is to use the shorter times. Longer inspiratory times increase the MAP, which in turn increases the chance of barotrauma. But...increased MAP also increases oxygenation.

Continuous Flow

Since the inspiratory efforts and volumes of newborns are so small, it is technically difficult to achieve sensitive, accurate patient sensing mechanisms. A continuous flow (sometimes called bias flow) of gas past the patient’s airway ensures that when the patient needs inspiratory flow it is already there without having the patient first activate a demand flow system. Flow rates of blended gas are required to achieve the PIP as these ventilators have pneumatically circuits that operate on compressed gas at 40-70 psig. Simply put, without flow, these ventilators will not operate. Flow is usually set at 6-12 LPM depending on neonatologist preference and weight of infant.

There are calculations for I:E ratio, tidal volume and other parameters that may be indicated to appropriately monitor and manage the patient.

COMMON MODES OF NEONATAL MECHANICAL VENTILATION

Continuous Positive Airway Pressure (CPAP)

CPAP applies continuous positive distending pressure to the airways. CPAP is used during spontaneous breathing to prevent the need for mechanical ventilation. CPAP does not have the same risk of barotrauma as does mechanical ventilation. Also, if nasal prongs are used instead of an endotracheal tube, the chance of infection decreases. Less invasive equals less danger to the patient. Endotracheal tubes often create a ridge in the soft palate of the neonate when the need for mechanical ventilation is lengthy.

The main physiological goals of CPAP are to:

- increase the functional residual capacity (FRC)
- increase compliance
- decrease total airway resistance
- decrease respiratory rate

It is the actual increase in FRC that allows the other three goals to occur. CPAP physically holds the alveoli and airways open during exhalation thereby increasing the FRC. An increase in FRC
leads to improved lung compliance, decreased work of breathing, increased PaO₂, and decreased PaCO₂.

**Indications for CPAP:**

- Conditions that decrease FRC:
  - Pneumonia
  - Atelectasis
  - Pulmonary edema
  - Thoracotomy
  - Meconium aspiration
  - Increased mucus
  - Respiratory Distress Syndrome (RDS)
  - RDS Type II/Transient Tachypnea of the Newborn (TTN)
  - Left-to-right shunting

- Airway Collapse:
  - Tracheobronchial malacia
  - Apnea of prematurity (AOP)
  - Obstructive sleep apnea (OSA)

- Traditional Usage:
  - Weaning from mechanical ventilation

- Abnormal Physical Assessment:
  - Increased respiratory rate (30-40%)
  - Retractions
  - Grunting
  - Nasal flaring
  - Cyanosis

- Abnormal Arterial Blood Gas Values:
  - PaO₂ < 50 Torr at an FIO₂ of .60 (with adequate ventilation)

**Hazards of CPAP:**

- Decreased pulmonary blood flow secondary to compression of pulmonary vessels*
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- Reduced cardiac output due to decreased venous return to the heart*

- Renal
  - decrease in glomerular filtration rate
  - decrease in sodium excretion
  - decrease in urine output

- Increase in intracranial pressure (ICP)

- Pneumothorax

- Nasal obstruction (with nasal prongs)

- Gastric distension (orogastric (OG) tube recommended)

- Necrosis or erosion of the nasal septum and nasal deformities from the use of nasal prongs

*Generally associated with high pressures.

Contraindications of CPAP:

- Untreated air leaks

- Cardiovascular instability

- Severely apneic patient

- Patients who cannot maintain an adequate spontaneous tidal volume

- Patients with alveolar instability

- Patients with persistent pulmonary hypertension (PPHN)

- Increased intracranial pressure that can cause intraventricular hemorrhage (IVH)

Intermittent Mandatory Ventilation (IMV)

The definition of Intermittent Mandatory Ventilation (IMV) is a mode of ventilatory support that allows spontaneous breathing in between mandatory breaths from the ventilator. In between the preset frequency or respiratory rate of the ventilator that
delivers a specific pressure, the infant is allowed to breathe warmed, humidified continuous flow gas. The problem with this mode of ventilation is that the timing of the mandatory breaths and the spontaneous breaths are not synchronized. A mandatory breath may be given anywhere in the patient’s respiratory cycle. This asynchrony of breathing may cause the infant to “fight” the ventilator, not to mention the physiologic complications of increased intrathoracic pressures and high airway pressures. This is the reason synchronized intermittent mandatory ventilation (SIMV) was designed.

Synchronized Intermittent Mandatory Ventilation (SIMV)

Synchronized Intermittent Mandatory Ventilation is also a mode of ventilation in which mandatory breaths are given at a preset rate and spontaneous respirations are allowed in-between just as in IMV. The difference is that the patient’s spontaneous respirations are never interrupted. A timing mechanism in the ventilator senses the appropriate time to give the mechanical breath without interfering with the spontaneous breath. This mode of ventilation is beneficial to the spontaneously breathing infant who does not require sedation or paralysis. Many infant ventilators are not flow or pressure sensitive enough to sense patient triggering at the patient airway, therefore abdominal sensors may be used to sense diaphragmatic and chest wall movement.

Remember………there is no need to place an infant who is paralyzed on an SIMV mode.

NEWER MODES AND TERMS NOW BEING USED IN THE VENTILATION OF NEONATES

VOLUME CONTROL (VC)

Historically, volume control has been used for adult and pediatric ventilation and pressure control has been the method of choice for ventilating infants. Recently, though, adults have been receiving more pressure control and infants more volume control. In part, the reason for the emergence of volume control in the infant is our technological advances in ventilators. A stable minute ventilation with a known tidal volume can be achieved, but with any pure volume control, the pressure will vary to maintain the tidal volume set by the clinician. This increases the likelihood of baro and volutrauma. Some ventilators that provide volume control do not have continuous flow; the infant has to “trigger” their flow, possibly increasing their work of breathing. Leaks around endotracheal tubes may be a more significant problem, causing alarming when set tidal volume is not achieved. As you may be aware, infants may “outgrow” their tubes before a new one is placed!

PRESSURE SUPPORT (PS)

Pressure support is patient-triggered (pressure or flow), pressure-limited and flow-cycled. It provides a constant level of positive pressure during a spontaneous inspiration. Tidal volume is variable. The PS is measured above baseline (ZEEP or PEEP).
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PRESSURE REGULATED VOLUME CONTROL (PRVC)

Tidal volume and rate are preset. The minimum inspiratory pressure necessary to provide the ordered tidal volume will be delivered.

PRESSURE SUPPORT VOLUME GUARANTEE (PSVG)

Pressure support with a volume guarantee (pressure limited with a set tidal volume) is not a difficult mode to understand. There are two sets of values-set (tidal volume, inspiratory time, inspiratory pressure limit, rate and PEEP) and measured (spontaneous). The set values are used as an “apnea” back up, otherwise, the infant determines their own inspiratory pressure to meet the set tidal volume. As compliance improves, the PIP will decrease. With this mode, endotracheal tube leaks are compensated for and so is lost volume due to tubing compliance. This is a weaning mode.

OVERVIEW OF NEONATAL MECHANICAL VENTILATION

Goals of Mechanical Ventilation

- Normalization and maintenance of blood gases and acid-base balance (ventilation and oxygenation)
- Prevention of iatrogenic complications:
  - Barotrauma and volutrauma
    Careful regulation of rate and pressures
  - Infection
    Use sterile technique during suctioning
  - Sedation
    Pharmacologic sedation and analgesia as needed to reduce anxiety and pain.
- Support of the Patient’s Respiratory Needs:

Indications for Initiating Mechanical Ventilation

- Increased PaCO₂ with a pH less than 7.20-7.25, PaO₂ less than 50mmHg despite the use of CPAP and FiO₂ 0.60 or greater than with grunting, flaring, retractions, cyanosis and agitation.
- Neurologic conditions that compromise the drive to breathe:
  - Apnea of prematurity (AOP)
  - Intracranial hemorrhage (IVH or ICH)
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- Drug depression
- Congenital neuromuscular disorders
- RDS
- Meconium aspiration syndrome (MAS)
- Pneumonia
- Bronchopulmonary dysplasia (BPD)
- Bronchiolitis
- Diaphragmatic hernia
- Sepsis
- Decreased lung volume as seen on chest x-ray
- Persistent Pulmonary Hypertension (PPHN)
- Post-resuscitation
- Congenital Heart Disease
- Shock
- Postoperative with impaired ventilatory function

Hazards of Mechanical Ventilation

- Oxygen
  - Oxygen toxicity
  - Hyaline membranes (Infant Respiratory Distress Syndrome)
  - BPD (Bronchopulmonary dysplasia)
  - Retinopathy of prematurity (ROP)

- PEEP and CPAP
  - Excessive pressures:
Hypoventilation from excessive FRC
Decreased cardiac output
Barotrauma

- Peak Inspiratory Pressure
- Barotrauma:
  - Air leaks such as:
    - Pneumothorax
    - Pneumomediastinum
    - Pneumopericardium
    - Pulmonary interstitial emphysema (PIE)

- Bronchopulmonary dysplasia
- Hyperinflation:
  - Hyperventilation
  - Respiratory alkalosis
  - Hemodynamic depression

- Respiratory rate
  - Respiratory alkalosis
  - Air leaks
  - Decreased ventilation-to-perfusion ratios
  - Increased intrapleural pressure
  - Decreased pulmonary perfusion
  - Diminished cardiac output

- General hazards
  - Infection

- Hypoxie-ischemic injuries
  - Intracranial hemorrhage
  - Gastric distension
  - Complications of endotracheal intubation
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MONITORING THE VENTILATOR - PATIENT INTERFACE AND TROUBLESHOOTING ALARM SYSTEMS

Inspiratory or Patient Pressure Alarm

This alarm alerts the practitioner to leaks or a patient disconnect. The pressure alarm should be adjusted from between ½ to 2 cmH\textsubscript{2}O less than the peak airway pressure.

Low PEEP/CPAP Alarm

This alarm is similar to the low patient pressure alarm except that it alerts the practitioner to loss of PEEP/CPAP pressure. The alarm should be adjusted to 1-2 cmH\textsubscript{2}O less than the PEEP/CPAP level.

Gas Pressure Failure Alarm

Many ventilators have alarms that alert the practitioner to the loss of oxygen or air pressure. In the event of a gas supply line loss; cylinders may be temporarily used until the supply line problems are corrected. The clinician may wish to check the oxygen or compressed air line pressures if this alarm is actuated.

Ventilator Inoperative Alarms

Some ventilators have a ventilator inoperative alarm. These alarms are not operator-adjustable, but alert the practitioner to serious internal problems that will render the ventilator incapable of supporting the patient. These internal problems include electrical power failures, microprocessor failures and internal mechanical failures.

In order to obtain more sophisticated alarm capabilities and patient monitoring, additional monitors may be employed. This would be particularly advantageous when using older generation ventilators.

A DISCUSSION OF VENTILATOR MANAGEMENT

I understand that when first dealing with these “little ones”, the clinician would find it advantageous to have a sort of recipe for ventilator set-up. As you are well aware, there is no simple cookbook method to assist the clinician in this endeavor. I will attempt, though, to put some common practices on paper.

The first step in management of your infant, is to set realistic goals for oxygenation and ventilation. The goals depend on several factors, mostly the infant’s disease state. For example, the infant on the ventilator due to meconium aspiration syndrome (MAS)/persistent pulmonary hypertension of the newborn (PPHN) will most likely have the FIO\textsubscript{2} kept close to 1.0 in an effort
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to dilate pulmonary vasculature. On the contrary, the premature infant with respiratory distress syndrome (RDS) will likely be placed on an FIO₂ as low as possible to keep their PaO₂ over 50-60 Torr to avoid retinopathy of prematurity (ROP).

It may be difficult to aim for a normal PaCO₂ in the infant who is developing air leak syndromes such as pulmonary interstitial emphysema (PIE). Many clinicians think it is best to tolerate a more acidic pH and a higher PaCO₂ in lieu of the potential of causing a pneumothorax. Remember to consider your source of the blood gas during interpretation.

Initial settings for PIP during pressure ventilation may be derived from blood gases drawn while hand-bagging the infant. Adjustments can be made according to the results of the gases and considering the frequency and pressure and FIO₂ at which the infant was being ventilated manually. When placing the infant on volume ventilation, the initial settings are usually chosen based on minute ventilation requirements. Volume is calculated at 4-8 ml/kg. Rates are generally 20-30 although ultimately determined by ventilation measurements.

Flow rates are generally set between 8 and 12 LPM. Eight for the infants weighing 500 grams and twelve for those appropriate for gestational age (AGA) term infants-somewhere in-between for the others. PEEP ranges from 3 to 5 cmH₂O during conventional ventilation based on the FIO₂ requirements of the infant. Also, during pulmonary hemorrhage, PEEP may be increased to tamponade the bleed. The parameters set during ventilation of the infant depend on the mode of ventilation being used by the clinician. Literature suggests initial settings of:

PIP 15-20 cmH₂O
PEEP 3-5 cm H₂O
Frequency 40
Flow rate 6-8 LPM
I-time of 0.5
I:E 1:1.5 or 1:2

USEFUL CALCULATIONS FOR THE CONVENTIONAL VENTILATOR MANAGEMENT OF THE NEONATE

Delivered Flow Rate

Flow rate = \text{set minute volume} \div \text{I-time %}

Expiratory Time

Example:

What expiratory time is needed to achieve a rate of 30 with an I-time of 0.4 seconds?
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Total breath time = seconds per min/desired breath rate

Total breath time = 60/30

Total breath time = 2.0 seconds

Expiratory time = total breath time (2.0 seconds) – Inspiratory time (0.4 seconds)

Expiratory time = 2.0 – 0.4 = 1.6

Calculation of FIO$_2$

When O$_2$ flow and airflow are known, the FIO$_2$ may be calculated.

$FIO_2 = \frac{O_2 \text{ flow} + (0.21 \times \text{ air flow})}{\text{Total flow}}$

Example:

What is the FIO$_2$ with the following flow rates?

$O_2 = 6$

Air = 4

$FIO_2 = \frac{6 + (0.21 \times 4)}{10}$

$FIO_2 = \frac{6 + 0.84}{10}$

$FIO_2 = \frac{6.84}{10}$

$FIO_2 = .684$

Or $O_2$ % of 68

Tidal Volume During Pressure-limited Ventilation

$VT = I\text{-time} \times \text{flow rate}$

Example:

Inspiratory time = 0.40 seconds

Flow rate = 8 LPM (convert to ml)
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8 LPM = 8,000 ml/min. or 133.3 ml/sec. (8,000 / 60)

VT = 0.4 X 133.3

VT = 53.32 ml.

Calculation of I:E / Determination of I-time

Example:

Ventilator rate = 40 breaths/minute

Desired I:E = 1: 2

Respiratory cycle time = 60 seconds
Set ventilator rate

Respiratory cycle time = 60 seconds
40

Respiratory cycle time = 1.5 seconds

Add the 2 numbers of the desired I:E (1 + 2 = 3)

Divide into the respiratory cycle time (1.5 ÷ 3)

I time = 0.5 seconds

VENTILATORS

Newborn or infant ventilators like adult mechanical ventilators, are for support of the respiratory system using positive-pressure ventilation.

VENTILATORS AVAILABLE IN THE U.S. FOR INFANTS

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<td>eVent Medical Ltd. Inspiration® Infant Ventilation System</td>
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<td></td>
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EXCLUSIVELY NEONATAL/PEDIATRIC

The Sechrist Millennium is for use with infant and pediatric patients weighing less than 50 kg. It uses a triggering flow sensor termed SmartSync™
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Basic Mechanisms

- Pneumatically powered
- Electronically and fluidic valve controlled
- The gas delivered to the patient does not pass through the ventilator. The 50psi source gases are connected directly to the oxygen/air blender located on the side of the ventilator. The blender reduces the pressure of the gases, mixes them and then directs the flow to an attached flowmeter, calibrated from 2 to 32 LPM. The gas flow enters the patient circuit from the flowmeter.
- All functions of ventilation (rate, inspiratory time, PIP and PEEP) are handled by the expiratory valve that is controlled by the ventilator settings. A small portion of the inlet oxygen is diverted internally to the ventilator to power the exhalation valve.
- The Sechrist utilizes two types of fluidic valves, a backpressure switch and an OR/NOR gate. A complex discussion of fluidic gates and OR/NOR valves is not necessary in this module.

Unique Features

- Sine-wave or square wave flow patterns
  - Sine wave by turning a small Allen screw located just above the expiratory block. As the screw is tightened, the normal pathway of flow to the expiratory diaphragm is cut off, forcing the flow of gas from the fluidic valve to pass through a restricted orifice before reaching the expiratory diaphragm slowing the flow and creating a rounded flow.
  - Square-wave is preset unless the Allen screw is adjusted for a sine wave.
- Manual breath button is inline with the flow from the backpressure switch. If button is pressed for a manual breath, the flow is occluded and the inspiratory phase is started. Inspiration lasts as long as the button is held in so carefully monitor the I: E ratio when using this feature.
- Digital display of:
  - I: E ratio
  - Rate
  - Inspiratory time
  - Expiratory time
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- Expiratory timer is adjusted by reading the rate display when determining rate.

VIP BIRD GOLD
Compliments of: Viasys Critical Care

V.I.P. Bird Gold is microprocessor controlled and pneumatically powered. This ventilator has the ability to ventilate neonate to 30 kg. patients. It has a comprehensive graphics monitor with waveforms and loops. The V.I.P. performs mechanical calculations such as compliance and resistance. Modes offered are assist/control and SIMV/CPAP in both volume-cycled and time-cycled settings.

BEAR CUB 750
Compliments of: Viasys Critical Care
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The Bear Cub 750 ventilator has the capability of A/C, SIMV, IMV and CPAP modes. It also has integrated synchronized ventilation and tidal volume monitoring. It provides proximal airway flow triggering. The heated-wire flow sensor provides breath-to-breath measurement of spontaneous and mechanical inspiratory and expiratory tidal volume and percentage of tube leak. A graphics monitor is available to view measurements, waveforms and loops.

Drager Babylog 800
Compliments of: Drager

Drager Babylog 8000 Plus
Compliments of: Drager

DRAGER BABYLOG 800 & 8000 Plus
Compliments of: Drager

This ventilator is microprocessor controlled, pneumatically powered, time-cycled, pressure-limited, constant flow generator designed for infants up to 10 kilograms (22 pounds). It provides A/C, SIMV, PSV, VG, VIVE and CPAP modes of ventilation. It is capable of both volume and pressure ventilation. A flow sensor at the patient wye measures tidal volume and senses airflow.
initiated by the infant allowing triggering of the ventilator cycle. The sensor is able to compensate for small endotracheal tube leaks. The 8000 Plus model (not available in the United States) includes high frequency ventilation and is designed for patients up to 20 kg.

eVent MEDICAL has both an Inspiration™ Infant Ventilation System and an adult, pediatric and infant system; Inspiration™ Ventilator System. Compliments of: eVent Medical
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AGE RANGE FROM INFANT THROUGH ADULT

COVIDIEN (TYCO PURITAN BENNETT) 840
Compliments of: Tyco Puritan Bennett

This ventilator features dual microprocessor electronics and high-performance pneumatics. The 840 is designed to offer adult and pediatric modes of ventilation with an optional NeoMode. NeoMode software allows the 840 to ventilate patients as small as 500 grams without requiring a flow sensor at the patient’s airway.

AVEA
Compliments of: Viasys Critical Care
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It is a fourth generation ventilator, servo-controlled, software-driven ventilator. It has a dynamic range of breathing gas delivery that provides for neonatal through adult patients. The AVEA may be configured as a conventional ventilator or non-invasive positive pressure ventilator. Capabilities include precise delivery of heliox, artificial airway compensation, leak compensation, circuit compliance compensation, and independent lung ventilation. Neonatal ventilation modes available are volume and pressure assist/control, volume and pressure SIMV, time-cycled, pressure limited assist/control and SIMV and CPAP/PSV.

G5
Compliments of: Hamilton Medical

The Galileo Gold and Classic can ventilate all patients, from neonates to adults. The newest offering from Hamilton is the G5 ventilator. Hamilton offers closed-loop controlled mode ASTV (adaptive tidal volume support - not available in the neonate modes), DuoPAP (BiPAP), DuoPAP+ (APRV), tube resistance compensation, the P/V Tool (to find best PEEP) and noninvasive ventilation. The monitoring package includes 26 parameters, lung mechanics with waveform, loop and trend displays on a color screen. It has a built-in nebulizer and internal battery back up.
INTRODUCTION TO MECHANICAL VENTILATION OF THE NEONATE

GE Engstrom Carestation
Compliments of: GE

GE Healthcare, Madison, Wis, provides the Engström Carestation®, a critical care respiratory carestation that offers integration throughout the care process. From the ICU to the step-down unit, users have the ability to integrate ventilation with monitoring modules capable of measuring advanced parameters. The Carestation offers ETCO₂, energy expenditure monitoring, metabolics, gas exchange calculations, volume guarantee, (SBT) spontaneous breathing trial, SpiroDynamics, FRC, PEEP, Lung INview.

Maquet Servo i
Compliments of: Maquet

Maquet Inc, Bridgewater, NJ, provides the Servo i ventilator platform for all patient types, including neonatal and pediatric, as well as invasive and noninvasive ventilation, and support of inter-hospital transport. It offers a comprehensive array of modalities, such as volume support, PRVC, BiVent, Automode®, and Flow-adaptive VC. The Open Lung Tool® provides physicians with parameters to support alveolar recruitment procedures. The Servo i also provides information about end inspiratory pressure (EIP) and PEEP, tidal volume, as well as dynamic...
INTRODUCTION TO MECHANICAL VENTILATION OF THE NEONATE

compliance. Mainstream CO₂ monitoring and two nebulizers are available.

Newport e360
Compliments of: Newport NMI

The Newport e360 is Newport Medical Instruments newest ventilator. The Newport e360 ventilator builds on the design and features of the e500 ventilator. Simple to use, the e360 provides comprehensive mode selections, with graphics and extensive monitoring built into a single compact package. The e360 can easily transition from invasive to noninvasive ventilation for adult, pediatric, or infant patients. It offers weaning tools. TCPL modes are not available at this writing.

NEWPORT E 1001

The Newport E 1001 is a compact universal transport ventilator for infant, pediatrics and adults. It offers assist/control, SIMV and spontaneous modes. An air/oxygen blender and four hour battery may be added for transport.
INTRODUCTION TO MECHANICAL VENTILATION OF THE NEONATE

SUMMARY

The goals of ventilation for infants are focused on providing adequate ventilation and oxygenation with minimal compromise to the circulatory and other systems and minimal damage to the pulmonary tissues. Most infants are ventilated with pressure-limited, time-cycled, continuous flow ventilators. The most common modes of neonatal mechanical ventilation are CPAP, pressure-IMV and SIMV. Alternative modes are becoming more popular. These include, high frequency, volume control, pressure support, pressure regulated volume control (PRVC) and pressure support volume guarantee (PSVG).

The three main goals of mechanical ventilation are normalization and maintenance of blood gases, prevention of iatrogenic complications and support of the patient’s respiratory needs. The list of indications for initiating mechanical ventilation. Hazards of mechanical ventilation generally stem from oxygen administration, excessive pressures, bronchopulmonary dysplasia, hyperinflation, hyperventilation, hypoxic-ischemic injuries and infection.

Essential alarms during mechanical ventilation include, but are by no means limited to peak inspiratory pressure, gas pressure failure and ventilator inoperative. Other useful alarms and indicators are low pressure, low expired tidal volume, low expired minute volume, low PEEP, high respiratory rate, low respiratory rate; the list is almost endless depending on the clinician’s perspective and the mode of ventilation being employed.

Literature suggests initial ventilator settings for the neonate, but there are numerous variables to consider. The clinician may wish to use a few simple calculations to assist them in the management of their neonatal patient. The most useful (depending on the ventilator used) are delivered flow rate, expiratory time, FIO₂, tidal volume and I:E.

Ventilators that are specific to neonatal and pediatric ventilation are the Infant Star, Sechrist, Babybird, V.I.P. Bird, Bear BP 200, Bear Cub, Sensormedics 3-10, Newport Breeze, Drager Babylog and Bio-Med MVP-10. Ventilators designed to ventilate infants through adults include the Siemens 300A, Puritan-Bennett 840, Viasys Avea, Hamilton Galileo and Newport E 1001. With all these ventilators, the clinician’s ability to troubleshoot the patient-ventilator interface is essential.
# INTRODUCTION TO MECHANICAL VENTILATION OF THE NEONATE

## TROUBLESHOOTING AT A GLANCE

<table>
<thead>
<tr>
<th>PROBLEM</th>
<th>POSSIBLE SOLUTION (S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whistling or hissing sound from ventilator</td>
<td>Gas leak Check psi connections</td>
</tr>
<tr>
<td>Blender alarm or gas pressure failure</td>
<td>PSI of air and/or oxygen reduced to less than 45 psi Check source gas psi. Call Engineering.</td>
</tr>
<tr>
<td>Ventilator inoperative alarm</td>
<td>Serious internal ventilator Malfunction Hand-bag patient</td>
</tr>
<tr>
<td>Inspiratory or patient pressure alarm</td>
<td>Leak or patient disconnect Reconnect patient-correct leak</td>
</tr>
<tr>
<td>Low PEEP/CPAP alarm</td>
<td>Loss of PEEP/CPAP Correct leak</td>
</tr>
<tr>
<td>Sudden drop in CPAP level to zero</td>
<td>Disconnection at patient or in breathing circuit. Check all connections and reassemble break.</td>
</tr>
<tr>
<td>CPAP level drops more than 2cmH$_2$O during inspiration</td>
<td>Inadequate flow Increase flow</td>
</tr>
<tr>
<td>During CPAP, patient demonstrates an increased use of accessory muscles or work of breathing (WOB)</td>
<td>Inadequate flow Increase flow</td>
</tr>
<tr>
<td>Inadvertently high CPAP/pt. having difficulty exhaling</td>
<td>Too high of flow Decrease flow</td>
</tr>
<tr>
<td>Increased CPAP reading</td>
<td>Plugged nasal prong(s) Suction patient and clean prongs</td>
</tr>
<tr>
<td>Drop in oxygenation, increase in Respiratory rate, and/or retractions during CPAP</td>
<td>Airway obstruction Suction patient and clean prongs</td>
</tr>
</tbody>
</table>

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INTRODUCTION TO MECHANICAL VENTILATION OF THE NEONATE

CLINICAL SCENARIO QUESTIONS

1. Baby Boy Smith, 24 week, appropriate for gestational age (AGA) infant, is on the Star Ventilator in the demand IMV mode set at 30 breaths per minute, flow of 7 liters, I-time of .40, PIP of 15cmH₂O and PEEP of 3cmH₂O. The high peak pressure alarm is activated several times. What is your appropriate response?

2. Infant Girl Jones is being weaning from mechanical ventilation. She has been placed on the CPAP mode at a PEEP of 5 cmH₂O via nasal CPAP prongs. Although expected to do well on this modality, Baby Girl Jones is showing signs of irritation and cannot fully exhale. The manometer intermittently reads much higher than the PEEP you originally set. What would you do?

3. You just received the message from engineering that the piped in compressed air will have to be turned-off to repair the compressor. There is no back-up source. How would this affect your infants on ventilators and what course of action should you take?

4. You are in a 10 bed NICU with 2 infants on ventilators. One of the ventilators begins alarming. The ECG on the infant shows a cardiac rate of 50 beats per minute. What would be your course of action?
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5. Upon assessment of Baby Girl Flowers, you note that unlike your previous observations, she has increased work of breathing demonstrated by grunting, retractions and use of accessory muscles of respiration. You placed her on a CPAP of 6 via nasal prongs earlier today and now the digital reading indicates a drop of greater than 2 cmH₂O during inspiration. What is the appropriate remedy?

6. You have just assisted the RN in turning and positioning Baby Boy Bunting who is intubated with a 3.5 ETT and is being ventilated via a Sechrist ventilator. You have reconnected the adapter to the ETT but the inspiratory or patient pressure alarm continues to sound. What should you do?

7. The gas source alarm is sounding on the ventilator of Baby Dickson. What does this indicate and what would be your course of action?

CLINICAL SCENARIO QUESTIONS DISCUSSION

1. The increased peak inspiratory pressure (PIP) alarm was activated. On an Infant Star, an AO1 message for the high pressure notifies the clinician that the PIP was detected 5 cm H₂O above the PIP set point. Assess the infant, including observation and breath sounds. This may indicate an obstructed tube. This level of increased pressure usually indicates activity, the need for suctioning, or if rhythmic, that the infant has the hiccoughs.

2. Assess the infant, including observation and breath sounds. The cause of this problem is generally too high a flow set. The suggested starting point for setting the continuous flow is from 8-12 LPM. 8 for the smaller infants and 12 for the term infants. 10 is for those in-between. For example, if you do not set a high enough flow on the Sechrist, you may not be able to obtain the indicated pressure. (Answer: decrease flow.)

3. Most infant ventilators are pneumatically controlled, thereby making us dependent on a gas source. The infants will be on an FIO₂ of 1.0 when the compressed gas source is turned off. Your facility may have compressed air cylinders or air compressors to temporarily replace the piped-in air gas source.
4. Assess the infant. Reconnect the ventilator and possibly increase rate, PIP and FIO$_2$ until the infant is stable, then wean. Some facilities prefer that the infant is hand-bagged. If the ventilator shows a ventilator inoperative alarm, there is a serious internal ventilator malfunction and the patient must be removed from the ventilator and hand-bagged until a functional replacement is obtained.

5. If, during CPAP, the infant demonstrates increased work of breathing and/or the CPAP level drops to greater than 2 cmH$_2$O during the infant’s inspiration, the flow is generally inadequate. Correction: increase flow.

6. Look for another disconnection! Then proceed from there. The ventilator worked fine before the re-positioning so the ventilator is probably still fine. The most likely problem at this point is another disconnection from manipulating the tubing during the repositioning.

7. The gas source alarm indicates that the PSI of the air or oxygen sources has decreased to less than 45 PSI (exact number may be dependent on the ventilator). Check for loose connections and that your 50-PSI tubing is in place. If readily available, check the PSI readings near the oxygen and air mains for your area. Call engineering. But...most of all ensure the safety of your infant. Hand-bag until the situation is resolved.
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SUGGESTED READING AND REFERENCES

American Association for Respiratory Care Clinical Practice Guideline “Neonatal”

American Association for Respiratory Care Clinical Practice Guideline
  “Application of continuous positive airway pressure to neonates via nasal prongs or nasopharyngeal tube.” Resp Care 39(8): 817-23 (1994).

American Association for Respiratory Care Clinical Practice Guideline “Patient-Ventilator System Checks” www.rcjournal.com/cpgs/mvsccpg.html

Argavest, Inc. 6813 Hobson Valley Drive, Suite 105 Woolridge, IL 60517


General Biomedical Service, Inc. 1900 25th St. Kenner, LA 70062 (800) 558-9449

Hamilton Medical, AG, Via Nova, CH-7403 Rhazuns, Switzerland.


University of Washington, Children’s Hospital and Regional Medical Center, NICU-WEB. Mechanical Ventilators, revised 2002.

Viasys Healthcare Critical Care, 1100 Bird Center Drive, Palm Springs, CA 92262-8066 www.viasyshealthcare.com
INTRODUCTION TO MECHANICAL VENTILATION
OF THE NEONATE


INTRODUCTION TO MECHANICAL VENTILATION OF THE NEONATE

POST TEST

DIRECTIONS: IF COURSE WAS MAILED TO YOU, CIRCLE THE MOST CORRECT ANSWERS ON THE ANSWER SHEET PROVIDED AND RETURN TO: RCECS, 16781 VAN BUREN BLVD, SUITE B, RIVERSIDE, CA 92504-5798 OR FAX TO: (951) 789-8861. IF YOU ELECTED ONLINE DELIVERY, COMPLETE THE TEST ONLINE – PLEASE DO NOT MAIL OR FAX BACK.

1. Hazards of CPAP include:
   a. Pneumothorax
   b. Gastric distension
   c. Decreased cardiac output
   d. Increase in ICP

   a. I, II, III
   b. II, III, IV
   c. II & III only
   d. All of the above

2. Goals of mechanical ventilation include:
   a. Careful regulation of ventilating pressures
   b. Maintenance of acceptable arterial blood gases
   c. Prevention of iatrogenic complications
   d. Support of the neonates respiratory needs

   a. I, II, III
   b. II, III, IV
   c. II & III only
   d. All of the above

3. Demand flow on the Infant Star ventilator establishes a 4 L/min continuous flow to the ventilator circuit.
   a. True
   b. False
4. The ventilator inoperative alarms sounds on your patient. You should:
   a. Check for leaks in the system
   b. Suction the infant
   c. Hand-bag the infant
   d. Check PSI connections

5. The main physiological goals of CPAP are:
   I. Increase compliance
   II. Decrease airway resistance
   III. Increase inspiratory rate
   IV. Increase FRC
   a. I, II, III
   b. II, III, IV
   c. I, II, IV
   d. All of the above

6. Indications for mechanical ventilation of the neonate include:
   I. Pneumomediastinum
   II. Meconium aspiration syndrome
   III. PIE
   IV. RDS
   a. I, II, III
   b. II, III, IV
   c. I & III only
   d. II & IV only

7. Ventilator inoperative alarms are operator-adjustable.
   a. True
   b. False

8. The Sechrist ventilator is controlled:
   a. Electronically and pneumatically
   b. With a fluidic valve
   c. By a microprocessor
   d. Electronically and with a fluidic valve
9. The maximum pressure exerted against the infant’s airway during each breath is defined as:
   a. MAP
   b. PIP
   c. PCWP
   d. VT

10. Indications for the use of CPAP on the neonate include:
   I. Non-severe apnea of prematurity
   II. An increase of respiratory rate by 30%
   III. Persistent pulmonary hypertension
   IV. Cardiovascular instability
   a. I, II, III
   b. II, III, IV
   c. I & II only
   d. All of the above

11. Gas pressure alarms alert the clinician to air and oxygen pressures in excess of 60 PSI.
   a. True
   b. False

12. Hazards of mechanical ventilation in the neonate include:
   I. Congenital diaphragmatic hernia
   II. Air leak syndromes
   III. IVH
   IV. BPD
   a. II & IV
   b. I & III
   c. II, III, IV
   d. All of the above

13. The AVEA is capable of ventilating neonates, pediatrics and adult patients.
   a. True
   b. False
14. Most neonatal ventilators are classified as:
   a. Electrically controlled, pressure-cycled, volume-limited
   b. Pneumatically controlled, pressure-limited, time-cycled
   c. Microprocessor controlled, time-limited, volume-controlled
   d. None of the above

15. The inspiratory time determines how long the gas is in contact with the alveoli for gas exchange.
   a. True
   b. False

16. Which of the following ventilators IS NOT capable of adult ventilation?
   a. VIP Gold
   b. Carestation
   c. G5
   d. 840

17. Which of the following ventilators are used primarily for transport of the neonate?
   a. Sechrist Millennium
   b. Newport E1001
   c. Maquet Servo i
   d. VIASYS VIP Gold

18. A mode in which the tidal volume and rate are present and the minimum pressure necessary to provide the tidal volume will be delivered is:
   a. Volume ventilation
   b. Pressure support volume guarantee
   c. Pressure regulated volume control
   d. Pressure support

19. The suggested “initial” settings for neonatal ventilation DO NOT include:
   a. PIP 25-30
   b. PEEP 3-5
   c. Frequency 40
   d. I:E of 1:1.5 or 1:2
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20. The first step in management of your infant (other than initial resuscitation measures) is to:

- a. Interpret the chest X-ray for hyper expansion
- b. Set realistic goals for oxygenation and ventilation
- c. Place the infant on a transcutaneous monitor
- d. Assess the infant for congenital anomalies
INTRODUCTION TO MECHANICAL VENTILATION
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ANSWER SHEET

NAME____________________________________ STATE LIC #_______________________

ADDRESS_________________________________ AARC# (if applic.)___________________

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2.   a  b  c  d     17.   a  b  c  d
3.   a  b     18.   a  b  c  d
4.   a  b  c  d     19.   a  b  c  d
5.   a  b  c  d     20.   a  b  c  d
6.   a  b  c  d
7.   a  b
8.   a  b  c  d
9.   a  b  c  d
10.  a  b  c  d
11.  a  b
12.  a  b  c  d
13.  a  b
14.  a  b  c  d
15.  a  b

SL:  Test Version C
INTRODUCTION TO MECHANICAL VENTILATION
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Was the material interesting? ________ ________

Were the illustrations, if any, helpful? ________ ________

Would you recommend this course to a friend? ________ ________

What was the most valuable portion of the material?
____________________________________________________________________

What was the least valuable portion of the material?
____________________________________________________________________

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