Equipment:
Resuscitation of the Newborn and Premature Neonate.

The unique demands and requirement's for this population.

Newborns and Premature Babies Present Unique Challenges in Ventilation

Children ≠ Small Adults
Newborns ≠ Small Children

Curt Partain RRT-NPS
NICU Respiratory Care Clinical Educator
Community Regional Medical Center Fresno, Ca.

7th Edition NRP Guidelines

Oxygen Use:

- **Infants > 35 weeks gestation** begin with 21% oxygen (room air).
- **Infants < 35 weeks gestation** resuscitation should begin w/ 21%-30% FiO2 to maintain appropriate target preductal oxygen saturations. (Class I, LOE B-R)

- Initiating resuscitation w/ higher than 65% FiO2 is not recommended. (Class III HARM, LOE B-R)

- Continued recommendation of the use of 100% FiO2 whenever chest compressions are provided.

7th Edition NRP Guidelines

Positive-Pressure Ventilation: After completing the initial steps, PPV is indicated if a newborn is apneic or gasping or the heart rate is less than 100 beats/min.

- If PPV is required for resuscitation of a preterm newborn, it is **preferable** to use a device that can provide PEEP, such as a T-piece resuscitator or flow-inflating bag, this is preferred over a CPR Bag with PEEP Valve.
- Using PEEP (5-6 cm H_2O) helps to recruit and maintain critical alveolar surface of the baby's lungs between each positive pressure breath.
- **Endotracheal Intubation** & **Laryngeal Masks**: Intubation is strongly recommended prior to beginning chest compressions. If intubation is not successful or not feasible, a laryngeal mask may be used.

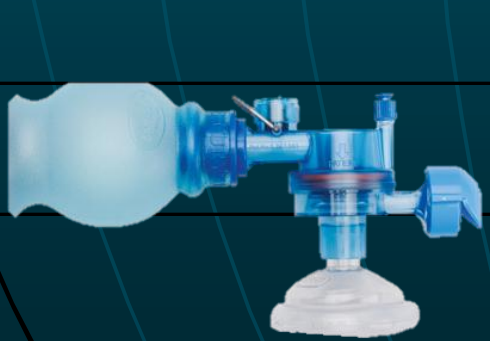
7th Edition NRP Guidelines

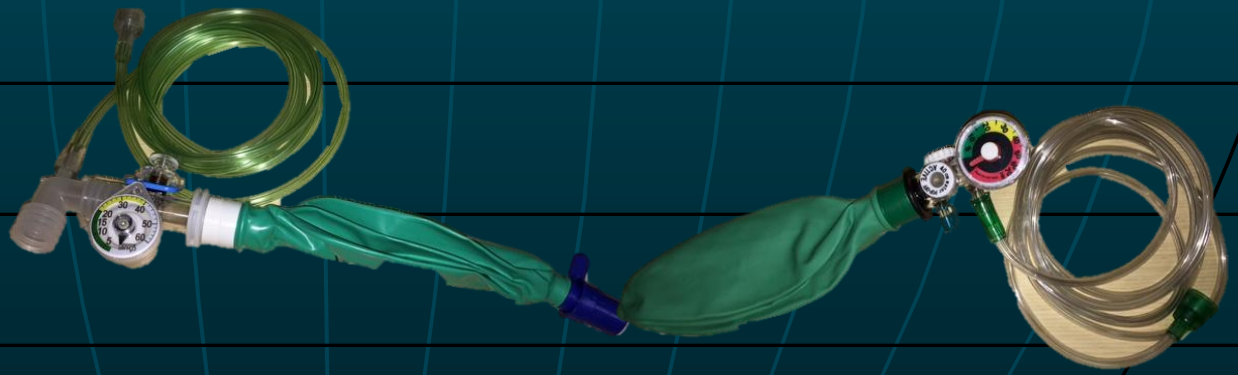
- CO_2 Detectors
  - Recommended as an adjunct for proper ET Tube placement verification.
    - "An increasing Heart Rate and CO_2 detection are the primary methods for confirming endotracheal tube placement". [1]
- CPAP
  - A brief trial of face mask CPAP in the delivery room is becoming common practice. (NRP Instructor Update VOL 21 NO 1 spring/summer 2012)

[1] Neonatal Resuscitation. 5th ed. Elk Grove Village, IL: American Academy of Pediatrics; 2006

CPR/BVM/Hyperinflation Bags

- Are all CPR- BVM - Hyperinflation Resuscitation Bags created equal?
  - **No they aren't .** We must objectively evaluate what we are looking for in a bag be it CPR or Hyperinflation ie.(Flow Inflating) type…
  - And in the **Neonatal Population** we have a few unique aspects that we need to pay attention to …





Its important to pay attention to things like …

- Accurate FiO_2 Control
- Can you easily switch between PPV and Blow by Oxygen if needed
- Create and maintain PEEP
- Provide CPAP
- Ability to easily feel the patients compliance (bag stiff - thick walled)
- Pressure Manometer (being present is one thing accuracy is another!)
- Is there a Pressure Pop off available
  - Pressure Pop off over-ride readily available if needed.
- Where does the Oxygen enter the bag and where does the CO_2 exit?
  - Is there efficient rinsing of exhaled CO_2
- How Much Mechanical Dead Space is present?
  - Mechanical Dead Space must be minimized!

CPR/BVM Bags

Requirements / Attribute's of a good CPR/BVM Bag

- Thin walled or supple enough to allow the Clinician to "feel" Lung Compliance with the squeeze of each ventilation, while maintaining a fast enough re-expansion to allow the delivery of higher respiratory rates seen in Neonates.

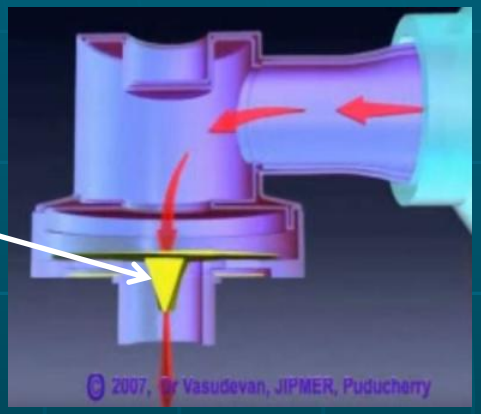
- An onboard ***Accurate*** Easy to See/Read Manometer to gauge PIP and PEEP
- Built in Pressure Pop off & ability to override if needed.
- Critical in the Neonatal Population
  - Minimal Mechanical Dead Space in the valve mechanism

- Extras (Not required but nice to have)
  - Ability to separate at patient valve and allow a flex extension ie Bain Circuit
  - Port for End Tidal CO_2 monitoring

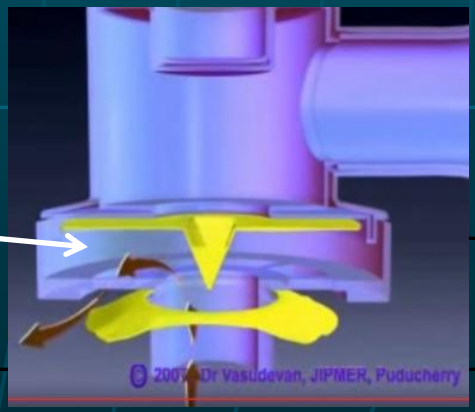
Mechanical Dead Space in a CPR Bag?

- Mechanical Dead Space in a BVM Bag is measured at the patient Valve

  - During Inspiration the inspired gases are driven through the duckbill valve toward the patient.



  - During Exhalation the duckbill valve closes and the expiratory gases exit the past the one way valve. It is in this cavity that the Mechanical Dead Space exists.

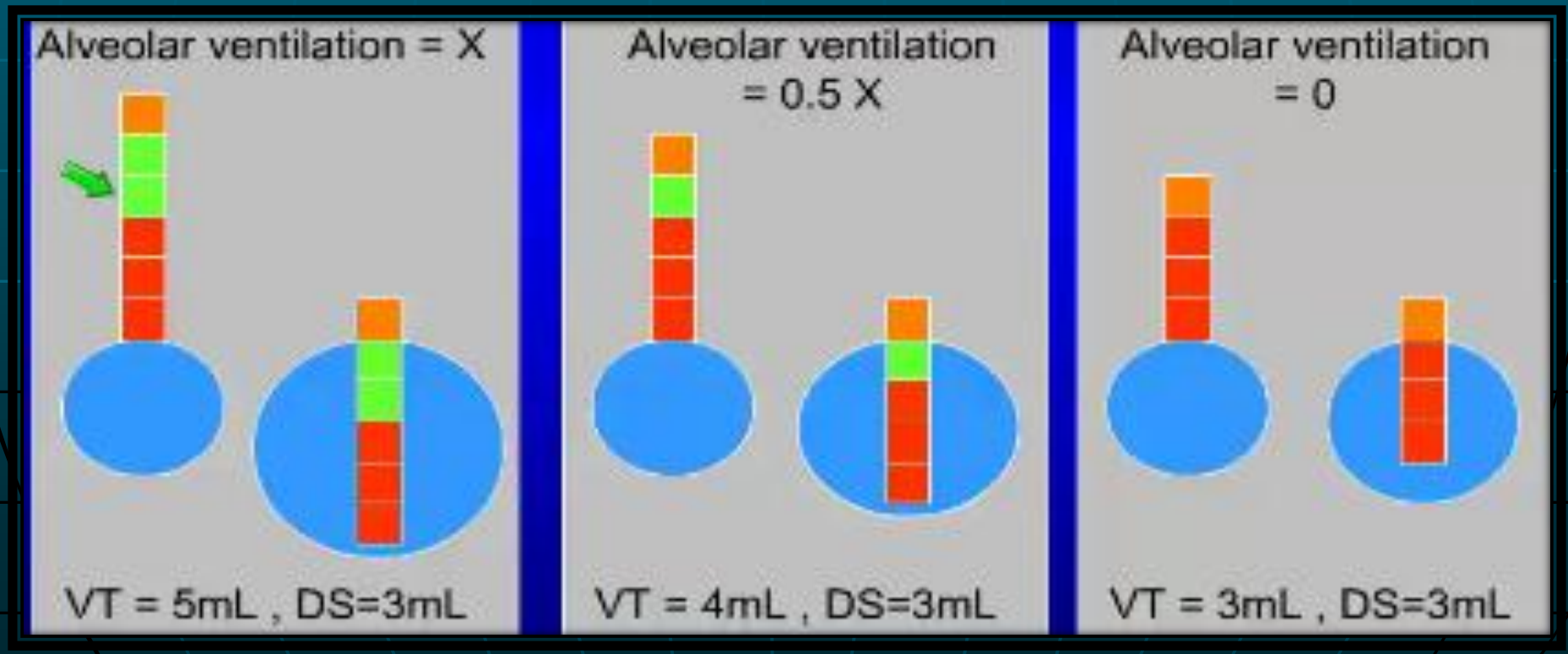


- Dead space **without mask in leading brands**
- 7.8 mL (Allied), 7.0 mL (Mercury CPR-2), 6.8 mL (AirLife), 6 mL in Ambu

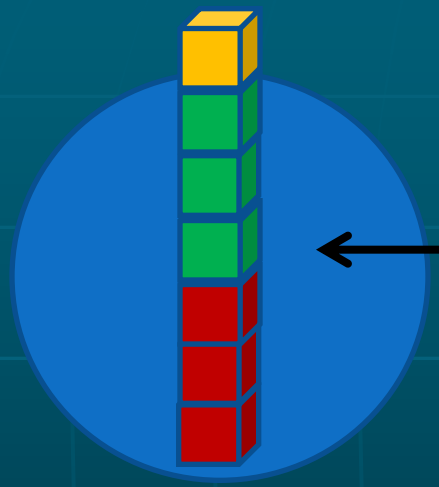
Does Mechanical Dead Space really matter to babies?

- Anatomical Dead Space = 2 ml/Kg. Mech. Dead Space is fixed @ 1 mL
  - Typical 1 Kg infant Anatomical + Mech. Dead Space = 3 mL

- Alveolar Ventilation = (Tidal Volume - Dead Space Volume) X Resp. Rate



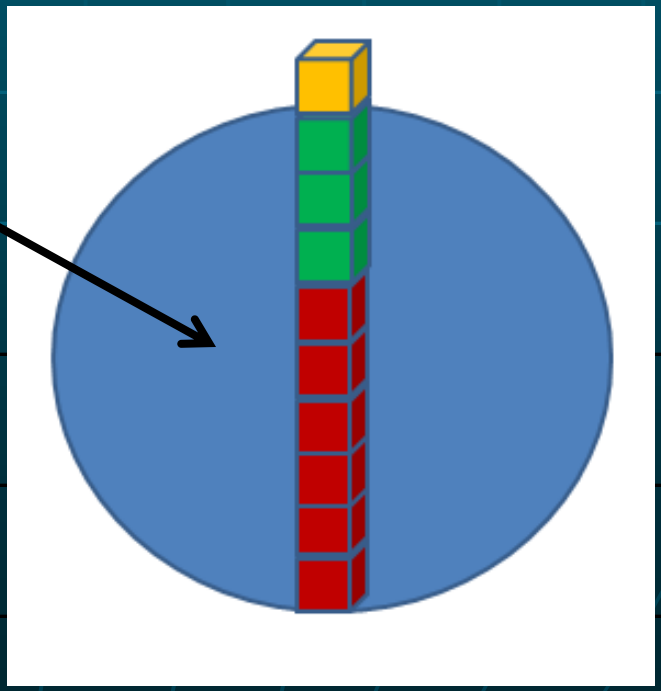
Volume Ventilation



- 1 kg Baby
- ~ 2 mL Anatomical Dead Space + 1 mL of Mech. Dead Space.
- Vt is normally set @ 4-6 mL/Kg
- Set @ 6 mL
  - 3 ml of rebreathed CO_2 & 3 mL of fresh ventilation

What happens when the device offers a greater amount of Mech. Dead Space?

- Same 1 kg Baby
- Same 2 mL Anatomical Dead Space
- 4 mL of Mech. Dead Space.



Volume Ventilation

What do we do to compensate for this increased amount of Mech. Dead Space?

- To maintain the delivery of at least 3 mL's of fresh gas we must increase the overall Vt to compensate for the rebreathed CO_2 (Dead Space).

- Now the Vt must be increased to 9 mL's to have any net ventilation occur.

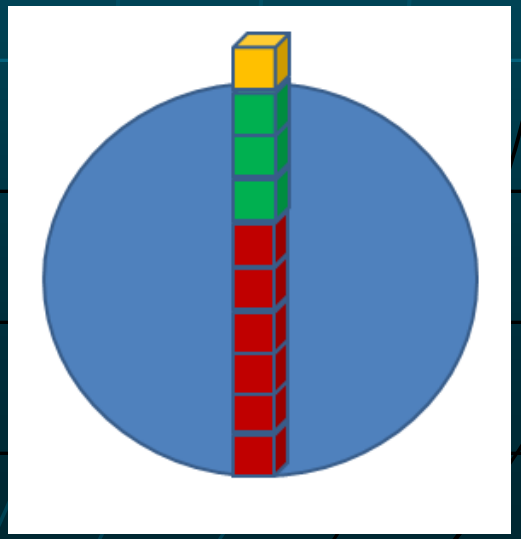
So Yes (DSM) DEAD SPACE Matters !

- There is a stacking affect…
  - Dead Space from device and even the Mask…
    It all stacks up

What happens to the 370gm Micro-preemie when the device has 4 mL's of Mech Dead Space to deal with…?

- It is the tiny tiny ones that I Really Worry About.

- I hope the Manufacturers are listening.



Anatomical Dead Space

Children ≠ Small Adults
Newborns ≠ Small Children

In adults, anatomic dead space is ~ 2.2 ml/kg. Because of the relatively large head size of infants and children total dead space is found to be slightly larger in pediatric subjects. Anatomic dead space is age dependent and is ~ 3 ml/kg in early infancy.

(Numa AH, Newth CJ etal https://www.ncbi.nlm.nih.gov/pubmed/8727530#)

Large tidal volumes provoke hyper-distension of the alveoli, causing lung damage.

Repeated studies have demonstrated that ventilation with large tidal volumes increases the number of neutrophils and cytokines in the lungs and also the permeability of the capillary membrane, leading to pulmonary edema. These inflammatory injuries can be associated with BPD and chronic lung disease.[2]

2 Chiumello D, Pristine G, Slutsky A. Mechanical ventilation affects local and systemic cytokines in an animal model of acute respiratory distress syndrome. Respir Crit Care Med. 1999;160:109-16.

CPR-2 Thermoplastic Disposable CPR Bag (Bag-Valve-Mask)

The CPR-2 is a full line of resuscitators manufactured with new thermoplastic material providing superior lung compliance "feel" with exceptional response.

Advantages

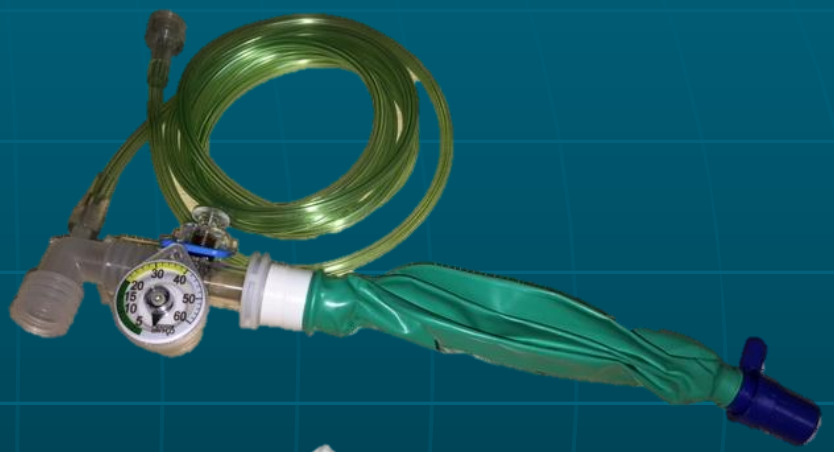
- Optional Color-Coded Manometer
- Monitors both airway & PEEP pressure
- Fast self re-expansion for faster rates when needed
- Latex Free
- Optional CO_2 detector accessory port
- Patient valve detaches to add Omni-Link or Flex-link that's ideal for transport
- Optional PEEP valve and exhalation filter
- CPR Bags must always be available in case of emergency!
  - Can still provide ventilation even if O_2 source is empty or unavailable.

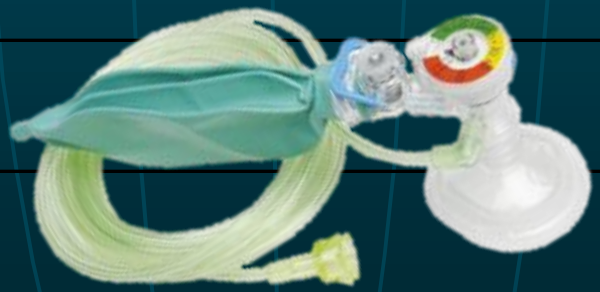
CPR Bag (Bag-Valve-Mask)

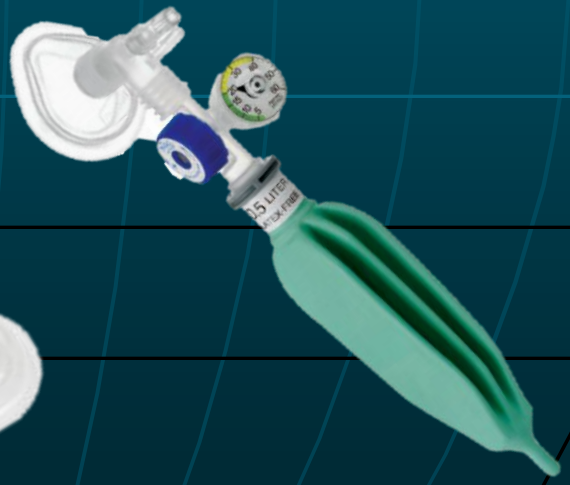
Shortfalls or limitations

- Unable to provide CPAP
- PEEP is somewhat variable as it is dependent upon the patients expiratory flow being dampened by opposing spring tension. Not as effective as with a Hyperinflation bag or T-piece Resuscitator using a continuous gas flow source.
- Lung compliance is harder to sense due to thickness of CPR/BVM Bags etc.
- Unable to accurately measure/guarantee the FiO_2 delivered due to reservoir construction etc.

Hyperinflation/Flow-Inflating Resuscitator Systems







Hyperinflation/Flow-Inflating Resuscitator Systems

- "Flow Inflating" or Hyperinflation System Bags need oxygen flow to fill the bag for delivery to the patient.

- Regardless of the system used – it is imperative to monitor airway pressure via manometer on a breath by breath basis to prevent lung injury.
  - Stacking of breaths, not letting the chest fall to baseline before delivery of another breath, is similar to blowing up a balloon.
  - Additional breaths sooner or later will increase internal lung pressures causing the lung to burst – ie: Pneumothorax.

- The only way for excessive air to escape is via a "Pop-Off" built into the bag.
  - This is particularly important with Hyperinflation Systems that are more technical to use, and flow adjustments are necessary.

Hyperinflation/Flow-Inflating Resuscitator Systems

Requirements / Attributes of a Good Hyperinflation Bag

- Soft Latex-Free Ventilation Bag allowing good transmission of *FEEL* for Lung Compliance.
- An onboard ***Accurate*** Easy to See/Read Manometer to gauge PIP and PEEP
- Pressure Pop off with the ability for override
- Oxygen inlet oriented in a way to minimize Mech. Dead Space as much as possible.
- An easily adjusted Bleed Valve that stays put and allows expiratory gases to efficiently exit the bag, and minimize mixing of dead expiratory gases with the delivery of the following breaths etc.

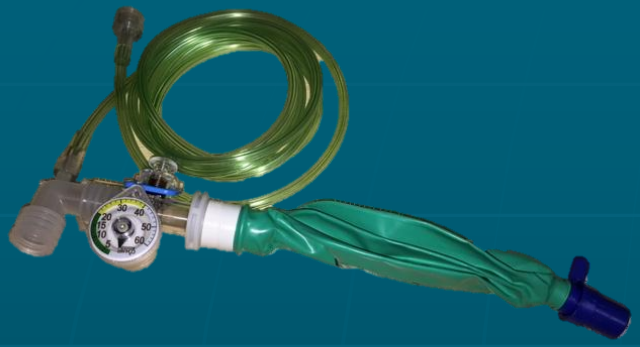
Building a better Hyperinflation/Flow-Inflating Resuscitator

Realizing the different short falls and attribute's of the various brands of Hyperinflation bags available:

- **Hank Perry RRT CRMC NICU Coordinator and I set out to find a vendor willing to manufacture a better Bag!**

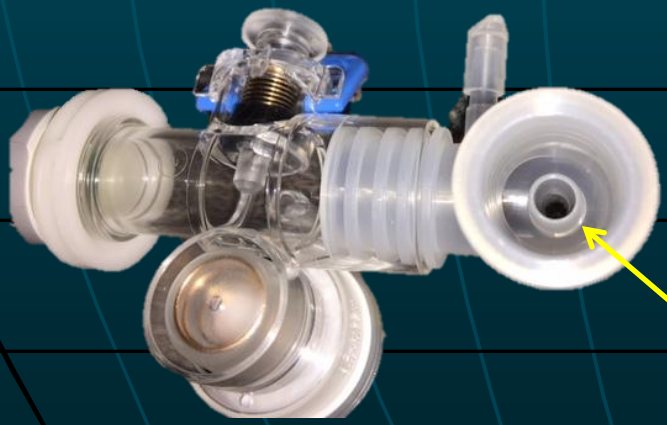
- **Our Goals**
  - **Norman Elbow with Oxygen inlet directed to rinse the patient connector of CO_2 (minimize or even alleviate any mechanical dead space volume)**
  - **A very accurate and easy to read Manometer (Built in)**
  - **A flow control valve located in the rear of the bag to encourage efficient rinsing of CO_2 from the bag and prevent accidental maladjustments.**
  - **Soft 3 pleat bag that allows good tactile communication of lung compliance.**
  - **Pop-off Valve with an override that is easily activated if needed.**
  - **Multiple manufacturers were contacted only one stuck it out and gave us our wishes… it took almost 3 years to become a reality!**

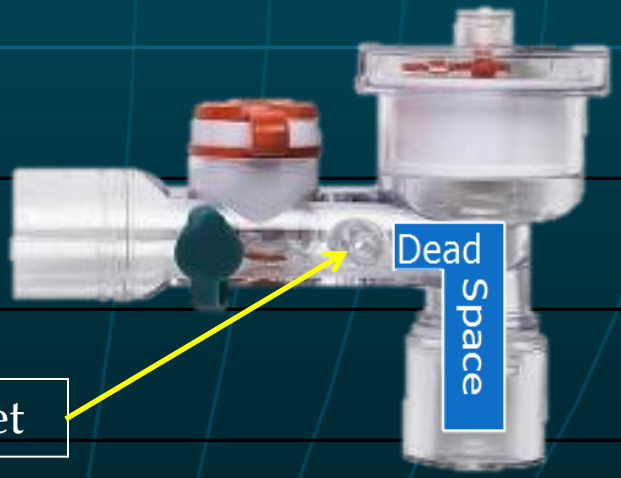
Mercury Medical



Mercury Medical new “Perry Hyperinflation Bag”

- Norman Elbow with Oxygen inlet directed to rinse the patient connector of CO_2 (minimize or even alleviate any mechanical dead space volume)





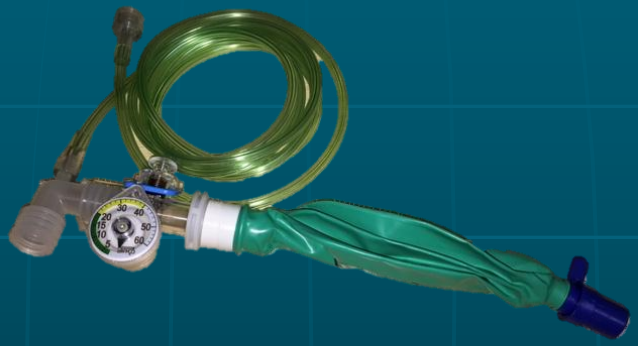
Oxygen inlet

An accurate and easy to read Manometer (Built in)

At CRMC we have found the manometer to be within ~ 1-1.5 cmH_2O from 5-40 cmH_2O

Ambu

Mercury Medical



Ventlab

A flow control valve located in the rear of the bag to encourage efficient rinsing of CO_2 from the bag and prevent accidental maladjustments.

Pop-off Valve with an override that is easily activated if needed.

Flow-inflating bags should only be used by clinicians with specific training and experience.

T-piece Resuscitators

T-piece Resuscitators

- Provide more consistent pressure than either the self-inflating or flow-inflating bag.
- Not subject to operator fatigue.

T-piece Resuscitators

Neonatal Resuscitation: "Raising the Bar."

Finer N.N. and Rich W.D.
Curr Opin Pediatr 2004; 16: 157-162

T-Piece Resuscitators as Opposed to Self-Inflating and Anesthesia Bags:

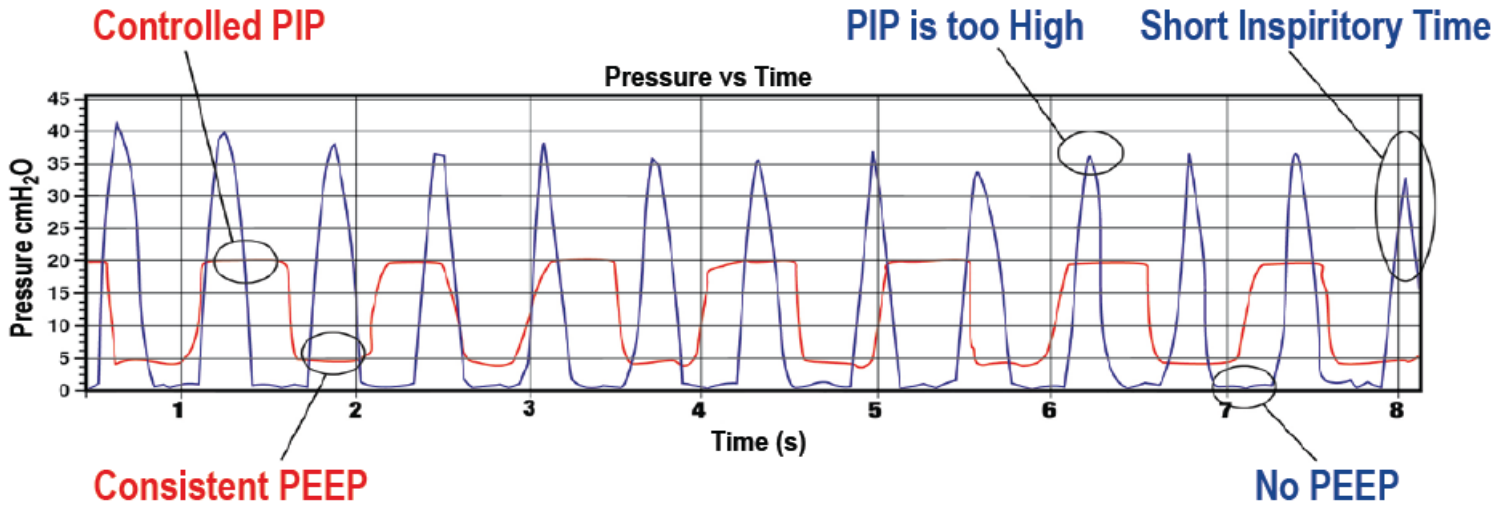
- Deliver ventilation more successfully.
- They are easier-to-use in the untrained hand.
- Provides more consistent positive end expiratory pressure (PEEP) and peak inspiratory pressure (PIP).
- The only devices that can effectively deliver constant prolonged "inflation."
- Reduces potential pneumothorax and Chronic Lung Injury caused by over-inflation of the lungs.

Roehr CC, Kelm M, Fischer HS. Manual ventilation devices in neonatal resuscitation: tidal volume and positive pressure-provision. *Resuscitation.* 2010;81(2):202-205.

T-piece Resuscitators

Optimal Resuscitation

The Neopuff™ Infant T-Piece Resuscitator is an easy to use, manually operated, gas-powered resuscitator that provides optimal resuscitation.

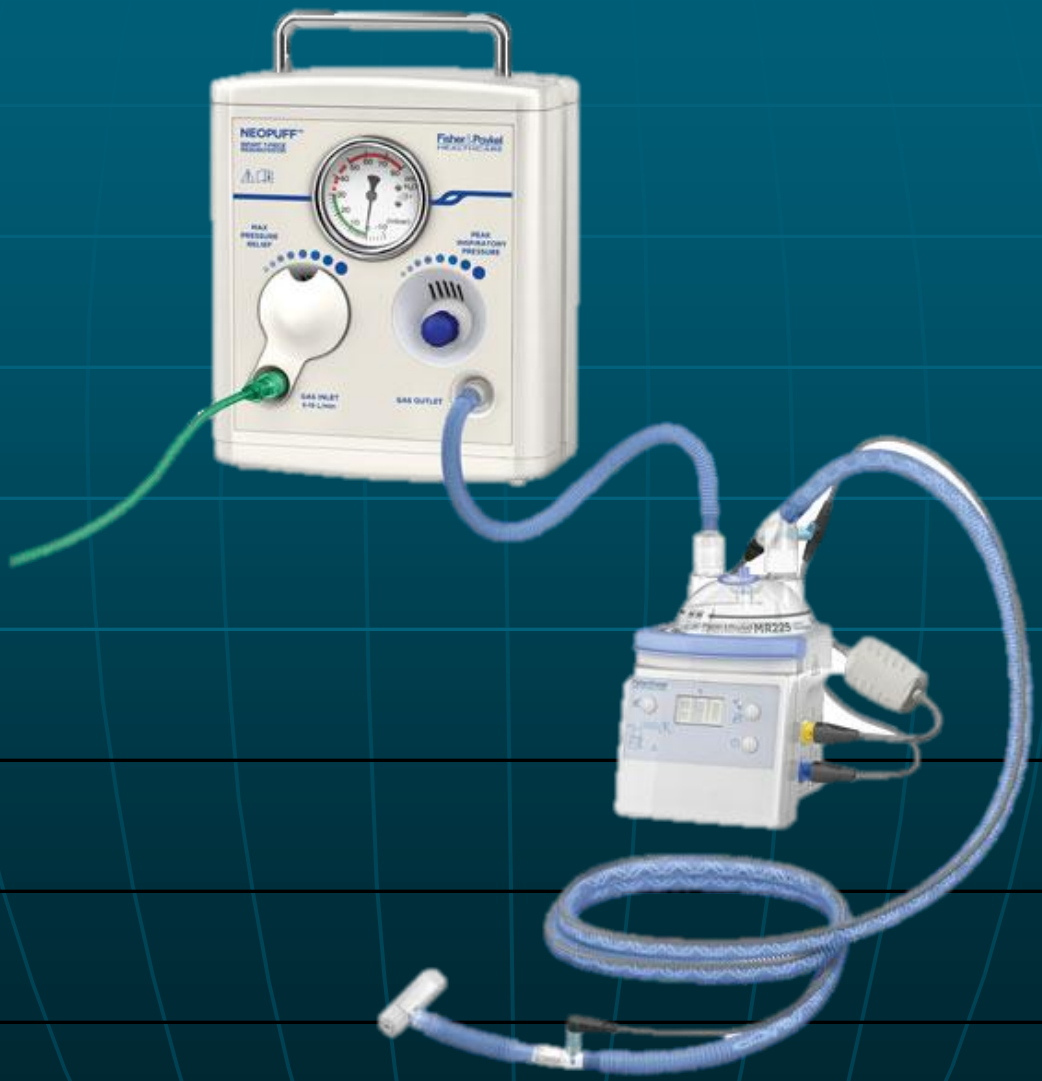


REF: Data from measurements using resus simulator, self-inflating bag and Neopuff by a qualified resuscitator.

Neopuff™ — Self Inflating Bag

Target PIP	20cm H_2O
Target PEEP	5cm H_2O

T-piece Resuscitator with Heated Humidity is it *really* needed?



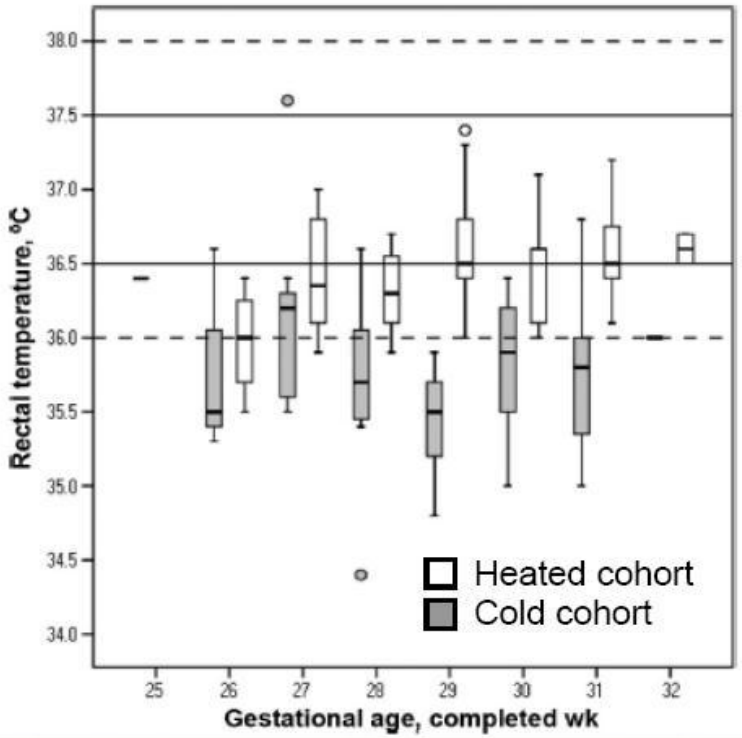
Gas Humidification and Body Temperature on Admit

Optimal Humidity: Clinical Evidence

Humidified and Heated Air During Stabilization at Birth Improves Temperature in Preterm Infants

AUTHORS: Arjan B. te Pas, MD, PhD, Enrico Lopriore, MD, PhD, Ingrid Stoppelenburg, Colin J. Morley, MD, and Frans J. Walther, MD, PhD

- Reduced temperature loss
  - Humidified 36.4°C
  - Non-humidified 35.9°C
- Significant reduction in moderate hypothermia (< 36°C)



Heated Humidified Gases (HHG)

Significantly higher rates of normothermia on admission were observed in preterm infants when HHG was used as initial respiratory support compared with cold, dry gas (Table). Across all infants (n=203), admission temperatures were >37.5˚C in 8 patients (4%) and <36.5˚C in 69 patients (34%). The proportion of infants with temperatures above or below the desired range was not significantly different between groups, although admission temperatures were <35.5˚C in significantly fewer infants in the HHG than cold, dry gas group (Table). **Significantly more infants at <28 weeks' gestation were normothermic in the HHG than cold, dry gas group (Table).**

Outcome	HHG (n=100)	Cold, dry gas (n=103)	Unadjusted OR (95% CI)	P-value
Normothermia[a] (%)	**69**	55	1.8 (1.01–3.19)	NR
Infants <28 weeks' (%)	**69**	42	NR	0.03
Severe hypothermia[b] (%)	**2**	12	NR	0.007

Results are shown as percentages.
CI, confidence interval; OR, odds ratio
a. Defined as an admission axillary temperature of 36.5–37.5°C
b. Admission axillary temperature of <35.5°C

MP MEYER, D HOU, NN ISHRAR, I DITO, AB TE PAS THE JOURNAL OF PEDIATRICS 2015; 166(2): 240-250

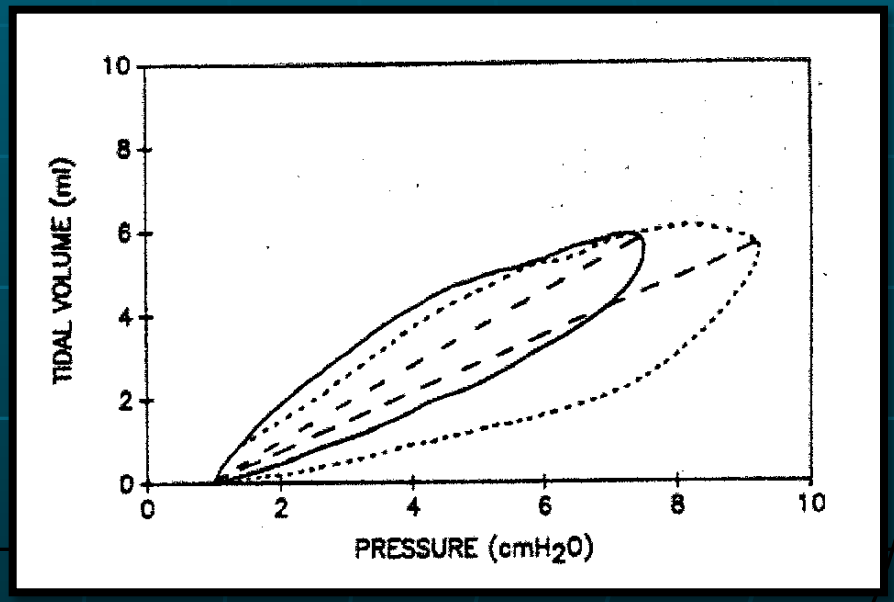
Gas Conditioning and Airway Function

Clinical Research

Greenspan et al 1991

Journal of Pediatrics 118(3), p443-5

- **11 infants on ventilators with inline humidifiers**
- **10 min of breathing Room Temperature**
- **Pulmonary Mechanics measured at BL, 5 min of Room Temperature, 30 post Room Temperature**
- Diminished at 5 min, recovered by 30 min
  - Dynamic compliance ($P < 0.01$); SLOPE
  - Airway Resistance ($p < 0.01$)
  - Elastic WOB ($p < 0.01$); WIDTH



Heater Inline

Room Temperature

Neo-Tee®

Resusa-Tee®

The world's First and Only, disposable, single-patient-use T-Piece Resuscitator on the market with a Color-Coded Manometer on the Tee.

Standard Neo-Tee® w/Controller

In-Line Neo-Tee® w/Controller

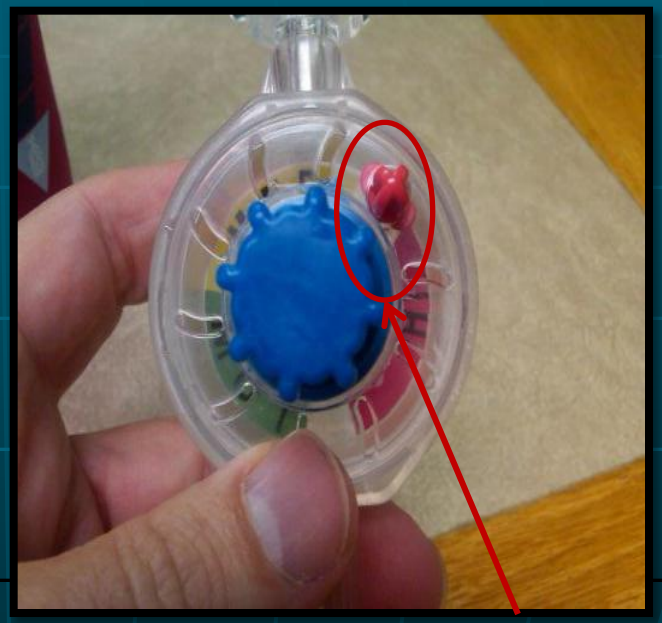
In-Line Resusa-Tee® w/Controller >10 Kg Child and Adult

Neo-Tee Resuscitators

- Reduced cost "no capital equipment cost" affordable at every bedside
- Connects to a flow meter, light weight and easily transported.
- Provide PPV and CPAP with easy control.
- Can be substituted with the normal Neo-puff Circuit to provide visual pressure monitoring without having to look away from patient.
- Increasing / decreasing pressure made easy, easy turn dial stays at preset pressure.
- Space saving design.

Pressure Override

Standard Neo-Tee® Controller with 40 cm H_2O Pressure Relief



New Neo-Tee® Controller with 40 – 60 cm H_2O override button

T-piece Resuscitators

Mechanical Dead Space in a T-piece ?

Yes there is some opportunity for Mechanical Dead Space in a T-piece as well…

- F&P Neo-puff Heated Circuit deadspace
  - Classic t-piece (900RD010) is 5.5ml.
  - The new Ergo t-piece (RD1300) is 3.6ml.

- Mercury Medical Neo -Tee Mechanical Dead Space is 4.0 mL
- Mercury Medical Resusa -Tee Mechanical Dead Space $\leq$ 7.5 mL

(900RD010)

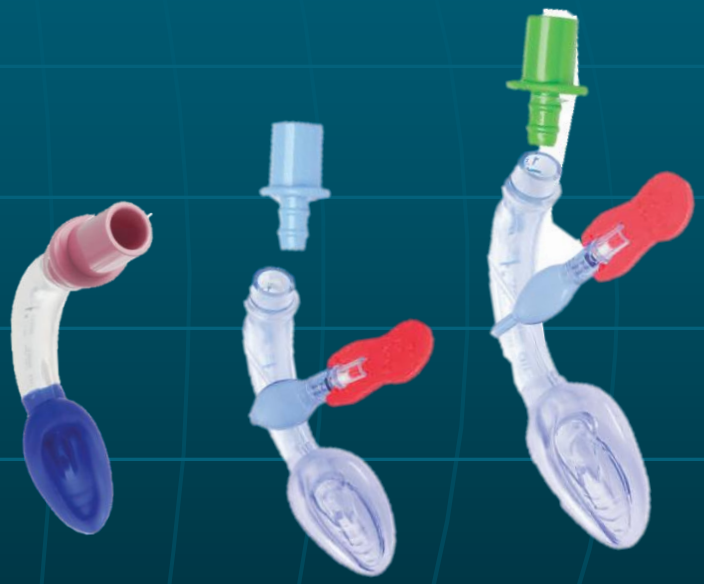
(RD1300)

(Neo-Tee)

Laryngeal Masks

According to NRP Guidelines: One of the latest requirements is that every NICU now stock Laryngeal Masks for rescue airways. per NRP Guidelines "when you can't ventilate and can't intubate, the device may provide a successful airway."

- Mercury Size 1 (Infant)
- Mercury Size 0.5 (< 4 Kg)
  - air-Q LMA 0.5 documented use in a 1.4 Kg neonate.



The LMA has proved to be:

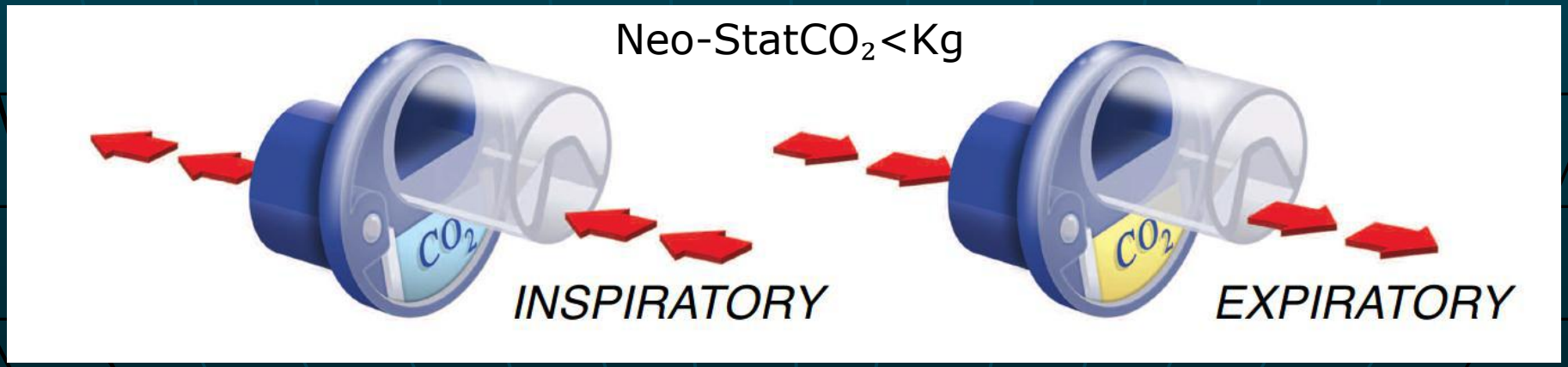
- Simple easy to teach / easy to learn how to use.
- Studies have shown the LMA to have high success rate at placement.
  - 98.6% placed on first attempt.
  - On average LMA's were placed in under 8 seconds.

Are Carbon Dioxide detectors useful in neonates?

NRP Guidelines:

- "Use a CO_2 detector with ET tubes, between mask and PPV device and with Laryngeal airways. As soon as you insert the ET tube, connect a CO_2 Detector and confirm the presence of CO_2 during exhalation".

- Mercury provides the ONLY disposable CO_2 detector for Clinicians to meet this NRP Guideline for Premature Infants below 1 Kg… (Neo-StatCO_2<Kg) reads up to 100 breaths per minute and can operate in 100% Humidity for up to 24 hrs…



Do Carbon Dioxide detectors have Mechanical Dead Space?

Neo-StatCO_2

- CO_2 detector for patient body weight between (0.25Kg and 6.0 Kgs)
- Dead Space = 1mL
- Detects up to 100 breaths per minute and can operate in 100% Humidity for up to 24 hrs…

Mini StatCO_2

- CO_2 detector for patient body weight between (1 and 15 Kgs)
- Dead Space = 3mL
- Detects up to 50 breaths per minute and can operate in 100% Humidity for up to 24 hrs…

End Tidal CO2 Detectors The First Full Line of CO2 Detectors

- 24 hour performance.
- Works in 100% humidity.
- Vivid breath-to-breath color change.
- Detects up to 100 breaths per minute.
- The only CO_2 detector available indicated for use on patients <1 kg.
- 2-year shelf life.
- Reduced Cost.

Neo StatCO_2<1Kg
(0.25Kg – 6Kg)

Mini StatCO_2
(1-15 kg)

StatCO_2
(>15 kg)

Allows clinicians to comply with Neonatal Resuscitation Guidelines requiring CO_2 detectors as an adjunct for proper tube placement verification

Tidal Volume Threshold for CO_2 Detection

Pediatrics Vol. 121 No. 6 June 1, 2008

The objective of this study was to determine the minimal tidal volume that causes a breath-to-breath color change. The **Mini StatCO$_2$®** tidal volume threshold was only **0.83 ml**, making it appropriate for use with any neonate to confirm intubation.


Questions

Mercury Medical®

New Products – Submit Your Product Ideas

Mercury Medical is interested in learning about your new product ideas. If you would like us to review your invention, please call or email George Howe:

* ghowe@mercurymed.com.