Learning Objective:
- Explain special techniques and describe selected devices for respiratory and environmental management of neonates.

Oxygen therapy
- Indication for newborn:
  - PaO2 < 60 mm Hg
  - SaO2 < 90%
  - Except in the presence of:
    - ductal dependent cardiac anomaly
    - left-to-right anatomic shunt

Oxygen therapy
- Associated complications
  - bronchopulmonary dysplasia (BPD)
  - retinopathy of prematurity
  - oxygen-induced hypoventilation
  - closure of DA with ductal-dependent anomaly ==> sudden death

Oxygen therapy
- Requirements for newborns
  - Precise, low-flow delivery - term newborn inspiratory flow = 3-6 L/min
  - Appliances small enough to fit
  - Minimal deadspace
  - Minimal noise production
  - Oxygenation monitoring
    - PaO2 < 80 torr
    - SpO2 low 90s%

FYI - click to see abstract about target SpO2
Infant oxygen hood

- Infants
- FIO2 up to 1.0
- Minimum flow = 7 L/min for CO2 washout

Oxygen Hood

- Equipment
  - Hood
  - sized for infant
  - disposable vs. non-disposable
  - Blender
  - Heated humidifier (NOT nebulizer)
  - maintain 32-34C
  - Thermometer
  - O2 analyzer

Nebulizer should be avoided, due to:
- infection
- noise
- bronchospasm
- reduced viscosity of secretions
- fluid overload

FYI - click for AARC clinical practice guideline on O2 for neonatal and pediatric patients
http://www.rcjournal.com/cpgs/pdf/06.02.707.pdf

Nasal Oxygen

- Cannula or catheter
  - 0.25 L/min ==> FIO2 = 0.24-0.35
  - increments of 0.10 or 0.125 L/min
  - Never use adult range flowmeters

FYI - Click for infant low-flow FIO2 calculator (see menu on left at the web site) Includes downloadable version for PDA
http://www.nicutools.org/

Subambient O2 Therapy

- Goals
  - increase pulmonary vascular resistance
  - prevent closure of ductus arteriosus
- Indication- ductal dependent cardiac anomaly; e.g.:
  - transposition of great arteries
  - tricuspid, mitral atresia
Subambient O2 Therapy

- methods
  - bleed-in nitrogen to ventilator circuit
  - obtain premixed subambient mixture in cylinder
  - titrate FIO2 to SaO2 80-85%
- problem: some O2 analyzers may not measure subambient FO2

O2 analyzers that accurately measure FO2 between 0 and .21
- The Mini-OX III
- Teledyne TED-190

Aerosol Therapy

Aerosolized medications

- Bronchodilators - for reversible obstruction; e.g., BPD
  - albuterol
  - ipratropium
- Furosemide (Lasix)
  - improves lung mechanics
  - no data on outcomes - trials are needed

Inhaled corticosteroids

- do not treat or prevent BPD
- may benefit patients with meconium aspiration
- parenteral dexamethasone (Decadron) after week one may reduce risk for BPD

Agents:
- fluticasone (Flovent)
- budesonide (Pulmicort)

Surfactant

- lucinactant (Surfaxin)
- not FDA-approved (as of 04/09)

Pulmonary vasodilators - replace nitric oxide for pulmonary hypertension

- epoprostenol (Flolan) - continuous administration
- iloprost (Ventavis) - longer acting, intermittent administration
Aerosol generators

- Nebulizer, vs. metered dose inhaler (MDI)
  - equal effectiveness for all patient groups
  - MDI more efficient, less expensive
  - nebulizer necessary for medications that are not available as MDI
  - infants cannot use dry-powder inhalers (DPI)

- wire mesh nebulizer (Aeroneb™) - best for nebulization in ventilator circuits
  - metered dose inhaler
    - valved holding chamber; e.g., Aerochamber
    - tightly fitting mask

Click for video on the Aerochamber™ (2.5)
http://www.5min.com/Video/How-to-Use-an-AeroChamber-160076817

Aerosol delivery interfaces

- ventilator circuit
- mask with valved spacer
- hood - effective, efficient with nebulized medications
- nasal prongs, mask?? - needs study
- blow-by - ineffective

Environments

Rationale for environmental control

- Birth is a traumatic event ==> post-traumatic stress disorder
- Immature organ systems
  - thermoregulatory apparatus
  - auditory, visual organs
  - olfactory - odors are new experience
  - central nervous system
  - immune system
  - epithelium - never been touched

- Threats
  - thermal stress
  - light
  - sound
  - touch
  - odors
  - infection
  - painful procedures - neonates are more sensitive to pain
Goals for environmental control
- Foster physiologic and neurologic development
  - protection from threats
  - nutrition - weight gain

Heat exchange mechanisms
- Conduction - surface contact
- Convection - fluid current
- Evaporation - water evaporation from skin
- Radiation - heat waves to or from distant object (hard to detect)

Preventing heat exchange
- Neutral thermal environment
- Keep infant dry - first resuscitation step
- Insulate contact surfaces
- Keep covered, including the head
- Isolate from air currents
- High ambient humidity (swamp)

Environmental equipment
- Incubator functions
  - isolate from infection, except when contaminated toys are present
  - isolate from noise
  - isolate from light (if covered)
  - provide neutral thermal environment
  - provide ambient humidity - prevents evaporative heat loss

Infant incubator

Environmental equipment
- incubator precautions
  - manipulation can generate serious noise
  - always close the doors
  - drawback - reduced access to infant
  - temperature sensor for servo-controlled humidifier heaters
  - must be outside the incubator
Environmental equipment
- Radiant warmers
  - radiant heat
  - good access to infant
  - drawback - increased exposure
  - need plastic cover

Radiant Warmer
Click to see GE Giraffe™ microenvironments
https://www2.gehealthcare.com/portal/site/usen/menuitem.d9d1e5260a507013d6354a1074c84130/?vgnextoid=9ded3f2ed0530210VgnVCM10000024dd1403RCRD

Environmental equipment
- Plastic wrap/bags
  - effective, inexpensive
  - prevent H2O and caloric loss from convection, evaporation
  - should apply in delivery room so they are in place during transport

Servo - control
- Available for warmers and incubators
- Advantage - adjusts warming to skin temperature
- Precaution - improper placement of probe results in over-warming or underwarming.

Developmental Care
- Rationale - reduce external stimuli that cause:
  - intraventricular hemorrhage (IVH)
  - abnormal neurologic development

Developmental care
- Components:
  - noise reduction
  - light reduction
  - minimal physical stimulation
  - uninterrupted sleep
  - behavior-based care - use cues from neonate guide timing of routine care
**Developmental care**
- Stimulation of infant avoided during:
  - sleep
  - poor oxygenation
  - inapproachability - gaze aversion, grimace
- Many premature newborns do not like to be touched

**Kangaroo care**
- Maternal-infant skin contact
  - for medically stable infants
  - reduces crying in response to heel stick (pain reduction?)
  - stabilizes temperature

**Developmental care**
- Music therapy
  - white noise to protect from NICU sounds
  - may reduce stress

**Airway Management**

Airways and intubation

Considerations for infants

- Delicate mucosa - easily injured
- Short, narrow trachea
- Cords are anterior & cephalad
- Reduced bronchial angle - left mainstem intubation likely

- Germinal teeth under gums - destroyed by trauma
- Dominant vagal tone - strong response to airway stimulation - bradycardia

Orotracheal, nasotracheal tubes - uncuffed

- Tube sizes
  - 2.0-2.5 <1 kg
  - 3.0 for 1-2 kg
  - 3.5 for 2-3 kg
  - 3.5-4.0 term, appropriate weight for gestational age (AGA)

- 00 Miller for extremely low birthweight (ELBW) infants
- 0 Miller for premies
- 1 Miller for term newborns

Strict caution if stylet is used with infants

- Do not hyperextend neck
- May require anticholinergic to block vagal reflex
- Little margin for error => secure tube firmly
- Small air leak is desirable => minimal pressure damage

Suctioning Guidelines

- Suction only when needed
- Do not use saline routinely
- Do not turn head to suction
- Do not hyperventilate
- Preoxygenate only 10%-15% above ventilator setting, unless severely hypoxemic, then use 100%
**Suctioning guidelines**

- Insert catheter only 1 cm beyond ETT tip
- Limit total suction time to 10 sec
- Limit vacuum levels - 50-75 mm Hg for infants
- Observe for:
  - bradycardia
  - cyanosis

**Chest physiotherapy**

- Not indicated for routine care of neonates
  - There is no evidence of benefit
  - There is evidence that it harms neonates; e.g., intraventricular hemorrhage

**Continuous Positive Airway Pressure (CPAP)**

**Definition & rationale**

- CPAP - application of positive pressure throughout ventilatory cycle during spontaneous breathing.
- Rationale - maintain the patient's functional residual capacity and prevent airway closure, while avoiding adverse effects of invasive ventilation
- Note - continuous negative extrathoracic pressure is equally effective

Click to see infant negative pressure ventilator


**Physiologic effects**

- Increases FRC
- Improves V/Q matching ==> reduces shunt
- Increases collateral ventilation
- Increases lung compliance ($C_L$)
- Decreases work of breathing (WOB)
- May enhance surfactant production

**Adverse effects**

- Air leaks; e.g., pneumothorax
- May increase intracranial pressure (ICP)
- May increase right-to-left blood flow across persistent fetal shunts
- Does NOT decrease cardiac output (nCPAP)
- Skin, mucosa breakdown from interface
**Indications**
- Respiratory distress syndrome (RDS)
- Apnea of prematurity
- Transient tachypnea of the newborn (TTN)
- Atelectasis
- Meconium aspiration
- Bronchopulmonary dysplasia
- Cardiogenic pulmonary edema
- Discontinuation of invasive ventilation

**Contraindications**
- Cardiovascular instability
- Frequent apneic episodes, with desaturation and bradycardia
- Frank ventilatory failure
- Upper airway anomalies; e.g., cleft palate

**Outcomes**
- Reduces ventilator days.
- There are mixed results pertaining to CPAP and
  - the rate of BPD
  - mortality
- Increased incidence of pneumothoraces compared to ventilation

**CPAP generators**
- Ventilator
- Bubble device
- Humidified high flow generator for nasal cannula (HHFNC)
- Dedicated CPAP device

**CPAP generators**
- Ventilator
  - advantages
    - monitors
    - graphics
    - alarms
    - measurement of lung mechanics
    - capability of other modes - easy switchover
  - disadvantage - current ventilators are expensive
  - administration of CPAP is a good reason to hang on to the old, time-cycled pressure ventilators
CPAP generators

- Bubble CPAP device - exhalation directed through column of water

Click to Fisher-Paykel bubble CPAP

- Humidified high flow nasal cannula (HHFNC) - CPAP produced by flow
  - high flow = 4 - 6 L/min
  - level of CPAP is determined by:
    - liter flow
    - size of prongs
    - size of the infant

- Dedicated CPAP device; e.g.; Infant Flow™ NCPAP and SIPAP™
  - Fluidic controls
  - advantages:
    - capable of CPAP and bilevel support
    - less expensive than current ventilators
    - compared favorably with Babylog™
    - transportable
  - disadvantage - availability of SIPAP?

Click to see Infant Flow™ devices

CPAP generators

- Bubble CPAP device
  - advantages
    - device simplicity
    - inexpensive
    - bubbling may enhance gas exchange
  - disadvantages:
    - increased WOB
    - infection??

- HHFNC
  - advantages
    - device simplicity
    - less damage to nasal tissues
    - cannulae are easier keep in position
  - disadvantages:
    - inconsistent level of CPAP
    - mixed data on effectiveness
  - need randomized clinical trials

CPAP interfaces

- Nasopharyngeal tube - least desirable
- Nasal prongs - most common
- Nasal cannula - for HHFNC
- Nasal mask - may reduce tissue damage
- Helmet

FYI - Click to download AARC Clinical Practice Guideline on CPAP for neonates
CPAP interfaces

- Helmet
  - currently under study
  - not FDA-approved
  - reduces tissue damage
  - decreases cerebral blood flow
  - will not function with patient-triggered modes

Click to see CPAP helmet
http://farm1.static.flickr.com/80/247084940_023fdc3543_m.jpg

Nasal injuries

- Injuries can lead to significant physical abnormalities
- Injury types:
  - compressed nasal bridge
  - asymmetric nares
  - septal erosion
  - keloid scarring

Click to see INCA™ nCPAP securing system
http://www.coopersurgical.com/ourproducts/Pages/INCACompleteSet.aspx?order1=44-2707&order2=44-2709&order3=44-2710&order4=44-2712&order5=44-2715&lc=Critical%20Care&name=INCA%C2%AE%20Infant%20Nasal%20CPAP%20Assembly&tc=1

Click to see other nCPAP securing systems
http://www.bipapforsma.com/page3.htm

Prevention of nasal injuries

- Remove Q4H to check skin
- Continually monitor positioning
- Alternate prongs with nasal mask
- Apply Duoderm™ over nose and philtrum
- Choose appropriate interface, size and hat

Click to see CPAP helmet
http://farm1.static.flickr.com/80/247084940_023fdc3543_m.jpg

CPAP bottom lines

- Strategy for RDS
  - intubate
  - surfactant
  - extubate to nCPAP
- Favored interface - short nasal prongs
- Pacifier may help by reducing mouth-breathing
- Room air nasal cannula ineffective

FYI - click for abstract on room air cannula

Special considerations

- Tracheal tubes
  - uncuffed ==> leaks are likely
  - small diameter ==> high resistance to flow

Mechanical Ventilation Basics

- Basics
- Special considerations
### Special considerations

**Lung volumes (TV low as .005L)**
- $V_D_{in}$ (dead space) not tolerated
- Compressible gas volume is critical
- Small leaks more critical (volume)

**Lung & chest wall mechanics**
- Low, rapidly changing $C_L$
- Small diameter of airways $\Rightarrow$ high $R_{aw}$ $\Rightarrow$ low inspiratory flows ($V_I$)
- High $C_{TH}$ $\Rightarrow$ lack of skeletal support in face of low $C_L$ $\Rightarrow$ retractions

### Complications of CMV

**Oxygen-related**
- Retinopathy of prematurity
- Pulmonary oxygen toxicity $\Rightarrow$ RDS

**Pressure-related (PIP, Ppt)**
- Pneumothorax, etc.
- Pulmonary interstitial emphysema

**Mean airway pressure - related**
- Reduced cardiac output
- Reduced urinary output
- Intraventricular hemorrhage
- Necrotizing enterocolitis (NEC)

**Pressure-oxygen-time related - BPD**

### Special Issues For Ventilators

**Triggering inspiration**
- Rapid rate $\Rightarrow$ shorter $T_I$, $T_E$
- Ventilator response time may exceed patient’s inspiratory time
- Late response to effort $\Rightarrow$ asynchrony with ventilator

**Complications of asynchrony**
- Barotrauma
- Increased WOB
- Maldistribution of ventilation $\Rightarrow$ V/Q mismatch $\Rightarrow$ hypoxemia
- Increased ICP $\Rightarrow$ IVH
Special Issues For Ventilators

- Triggering mechanisms for selected ventilators
  - Pressure (obsolete)
  - Flow - all current ventilators
  - Motion-sensing (obsolete?)
    - Infant Star- abdominal motion
    - Sechrist IV 200 (SAVI)- thoracic impedance

Pressure targeted ventilation

- Used in time-cycled, pressure-limited ventilation
- Most common because of:
  - cuffless tube
  - lack of volume monitors
  - simple, inexpensive ventilators

Volume-Targeted Ventilation

- Requires precise \(TV_E\) monitoring
- Maintains \(V_E\) despite changing \(C_L\)
- \(R_{AW}\)
- Trial (2008) - favorable long-term effects for VCV
- Trial (2009) - \(TV = 6\) mL/kg to reduce WOB
- Problems:
  - uncuffed tubes ==> leaks
  - greater PIP

Pressure support ventilation

- Overcomes work of breathing due to ET
- Expiratory trigger adjustment important, due to ET leak
- Useful in combination with SIMV

Dual control modes

- Pressure control with volume guarantee (various names)
- Available on current ventilators
- Benefits:
  - volume ventilation
  - reduced peak airway pressure
  - square pressure wave form-
    - increased mean airway pressure
  - decelerating flow wave form
### Initiating and maintaining ventilation

**Initiation**
- Patient hand-bagged (not by a gorilla) to determine PIP, f
- Placed on ventilator with same settings

**Typical initial settings:**
- $\text{PIP} = 20 \text{ cm H}_2\text{O or 6 mL/kg}$
- $\text{TI} = 0.3 \text{ sec.}$
- $\text{FIO}_2 = \text{ for SPO}_2 \ 85-90$
- $\text{VI} = 5-8 \text{ L/min}$
- $f = 40/\text{min}$
- $\text{PEEP} = 2-3 \text{ cm H}_2\text{O (social PEEP)}$

### Ventilator adjustments

**Ventilator settings titrated with:**
- SpO2
- Chest excursion
- Lung sounds - air exchange
- Visual evidence of increased WOB; e.g., retractions
- Blood gases
- Vital signs

### Control over PaO2, SPO2

- $\text{FIO}_2$
- $\text{Paw}$
  - $\text{EEP}$
  - $\text{TI} \Rightarrow \text{I:E}$
  - $\text{PIP}$ or $\text{TV}$

### Controlling PaCO2- VA

- $\text{frequency (f)}$
- $\text{tidal volume}$
- $\text{delta P (PIP-EEP)}$
- increasing $\text{EEP}$ without increasing $\text{PIP} \Rightarrow \text{reduced TV} \Rightarrow \text{increased PaCO2}$
- moderate hypercapnia permitted - permissive hypercapnea

### Weaning

- $\text{Protocol, implemented by RT reduces ventilation time (2009)}$
- $\text{Controls usually are not weaned to zero before extubation} \Rightarrow \text{increased WOB through ETT}$
- $\text{FIO}_2$ reduced to $< 0.4$
- $\text{PIP}$ reduced to nonhazardous level, e.g., 10-12
Weaning
- Rate reduced to 8-12 BPM
- EEP never reduced to 0 before extubation
- Typical settings before extubation:
  - PIP = <12
  - EEP = 2-4
  - f = 10

Summary & Review
- Oxygen therapy
  - requirements
  - devices
  - humidification
  - subambient O2
- Aerosol therapy
  - medications
  - devices
  - interfaces - no to blowby

Summary & Review
- Environments
  - threats from environment
  - incubators
  - warmers
  - neurologic environment
- Airway management
  - special considerations
  - airway devices
  - suctioning
  - CPT - NO

Summary & Review
- CPAP
  - indications, complications
  - devices - pressure generators and interfaces
- Mechanical ventilation
  - special considerations
  - ventilation modes
  - triggering mechanisms
  - ventilator controls
  - extubation

References

END
References


