



# Obstetric Critical Care Symposium

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## Mechanical Ventilation in the Obstetric Patient

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# Disclosures

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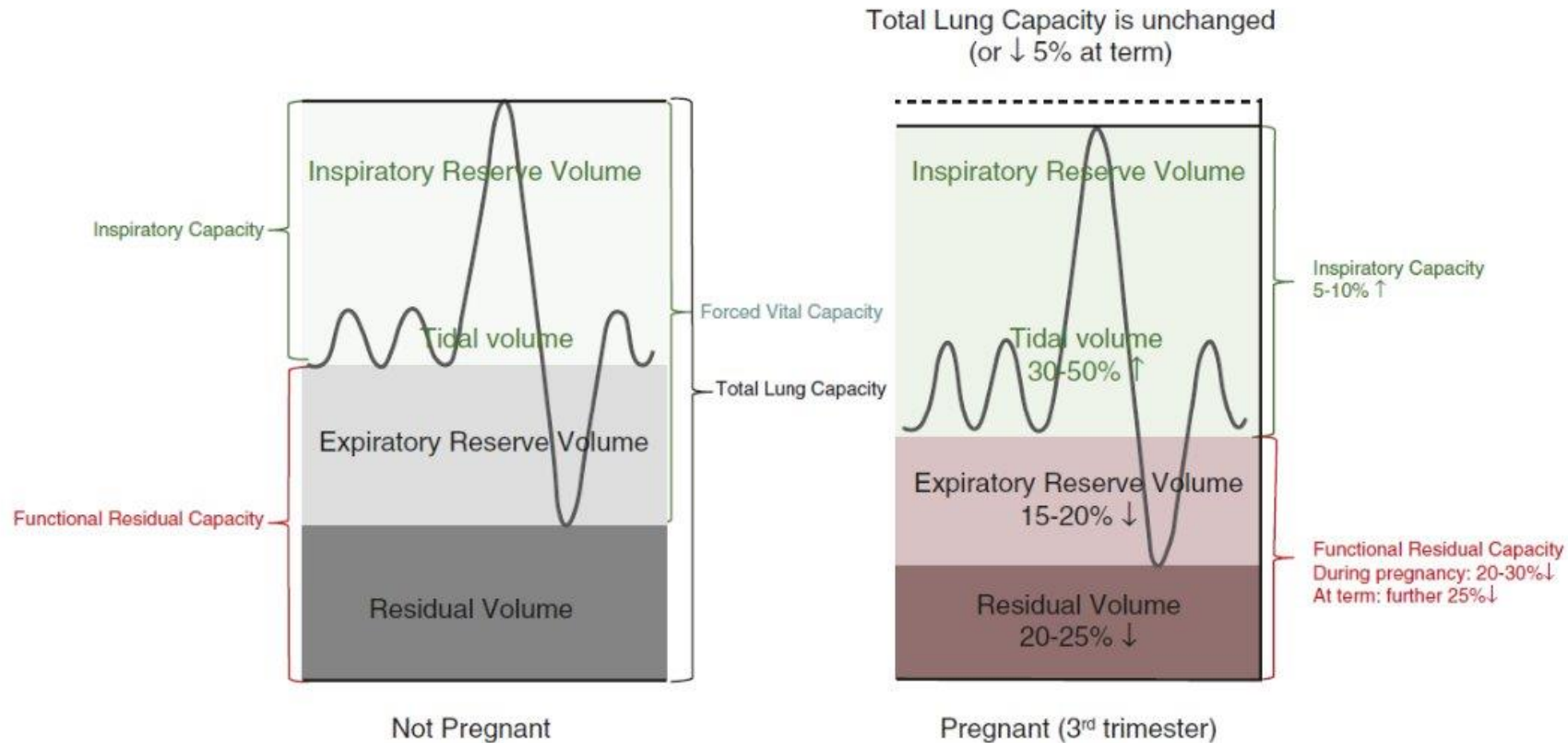
- Biogen, Inc ALS trial
- NFL Unaffiliated neurotrauma consultation

# Objectives

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- Defining the respiratory failure in the context of pregnancy
- Stepwise approach to management
  - Noninvasive mechanical ventilation
  - Invasive mechanical ventilation

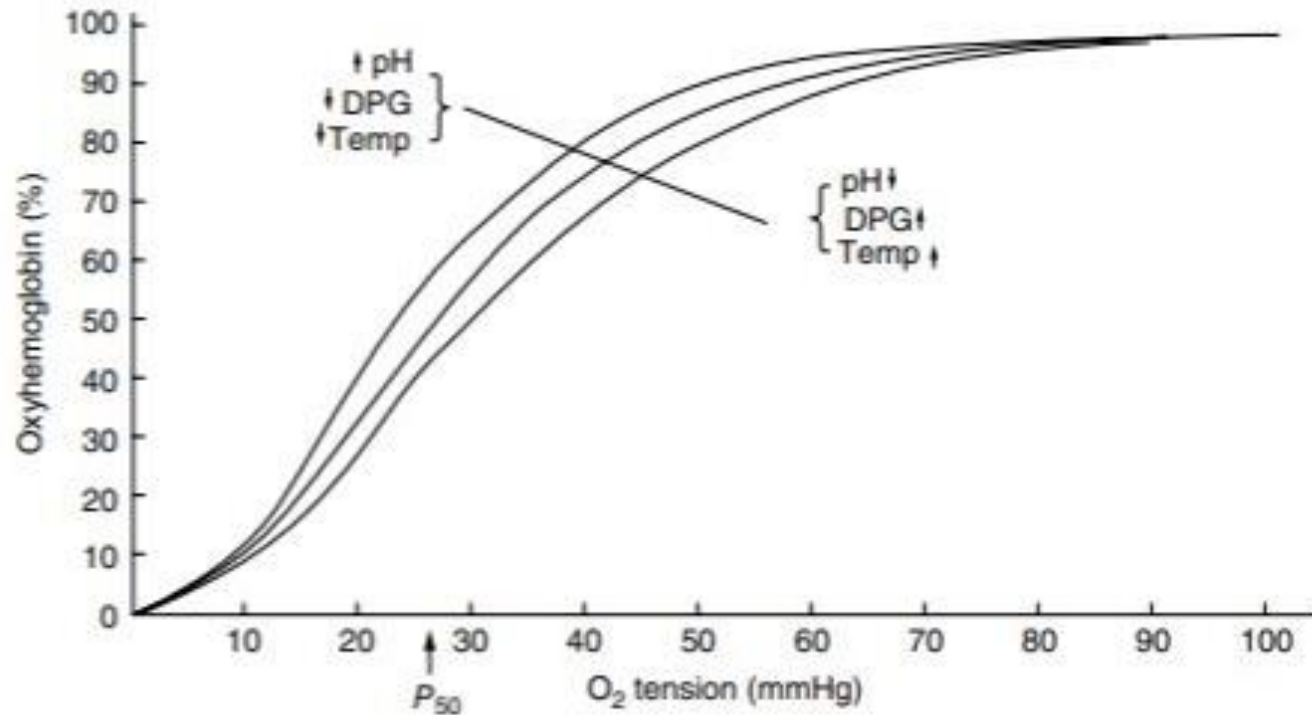
# Physiologic changes during pregnancy



**Fig. 20.2** Changes in lung volumes during pregnancy and at term (modified from Hegewald et al.)



# Stable hemoglobin dissociation in pregnancy



## Causes of impaired oxygen delivery

Low arterial oxygen content

- Anemia
- Hypoxemia
- Carbon monoxide

Hypoperfusion

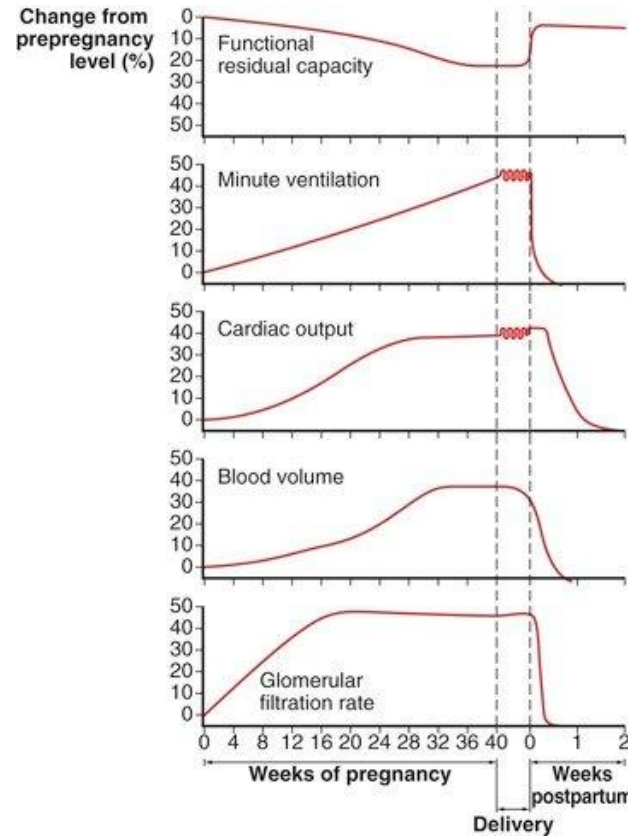
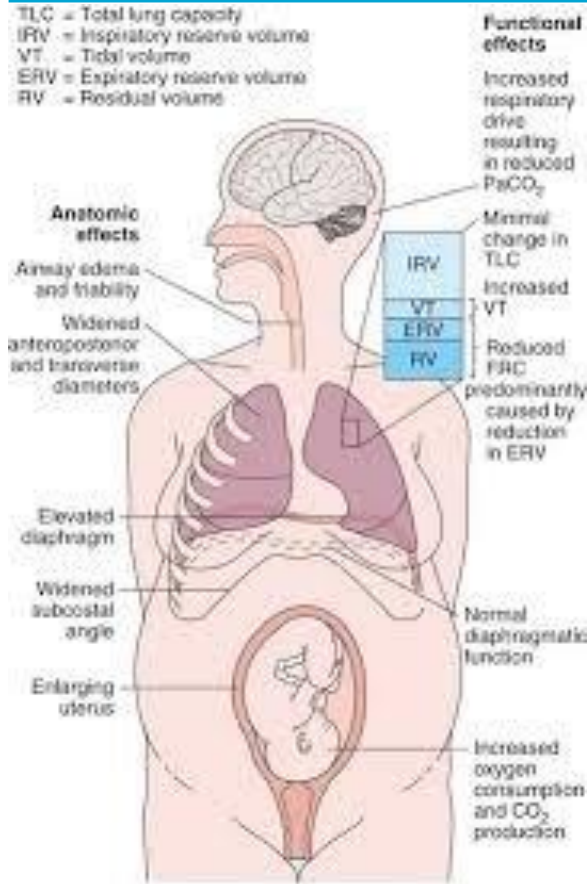
- Shock

# GAS exchange

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- Respiratory alkalosis is NORMAL
  - pH 7.42-7.46
  - PaCO<sub>2</sub> 28-32 ( $\leq 32$ ) mmHg
  - PaO<sub>2</sub> >100mmHg normal a-A gradient
- Bicarbonate 18-21 ( $\leq 22$ ) - renal compensation
- Goal PaO<sub>2</sub> for fetal perfusion is  $\geq 70$ mmHg or SaO<sub>2</sub>  $\geq 95$
- Goal pH 7.25-7.45 (may need to avoid permissive hypercapnia)

# Physiologic changes during pregnancy

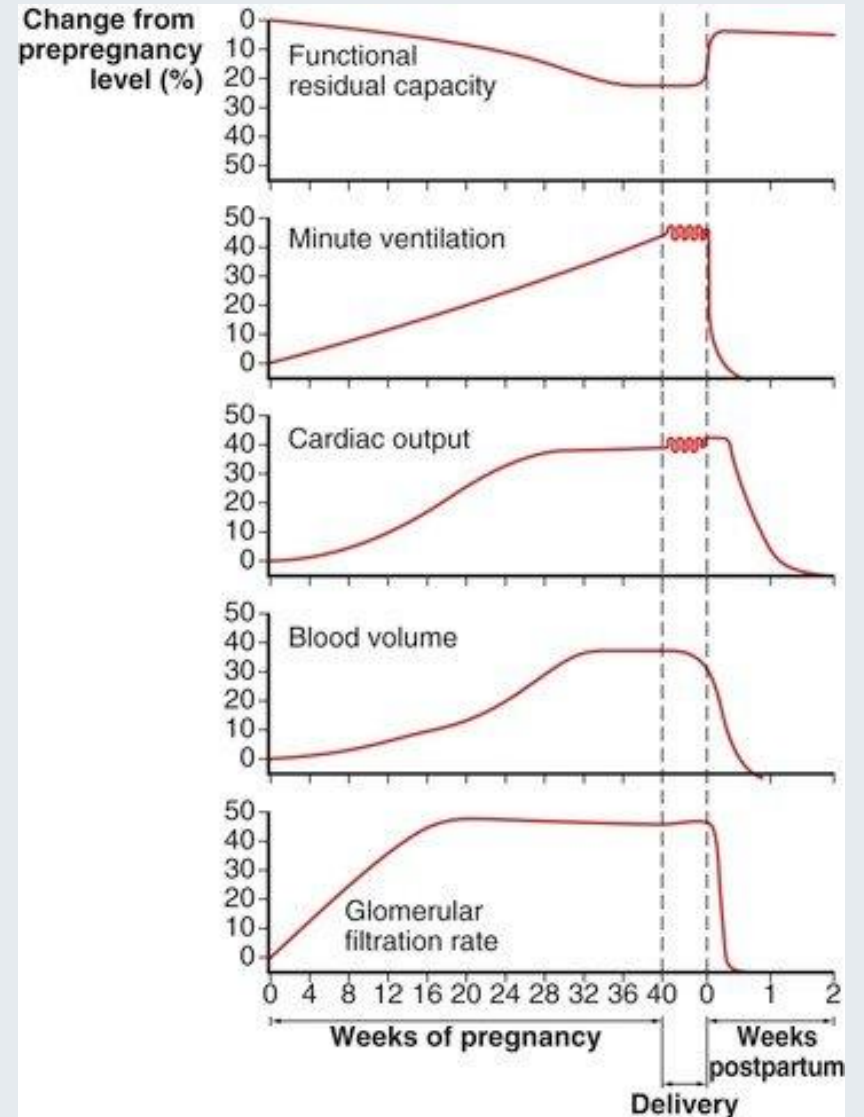


Note the increase in Oxygen consumption and cardiac output in pregnancy, reducing reserve capacity in critical illness.

Critical  $DO_2$  in Pregnancy

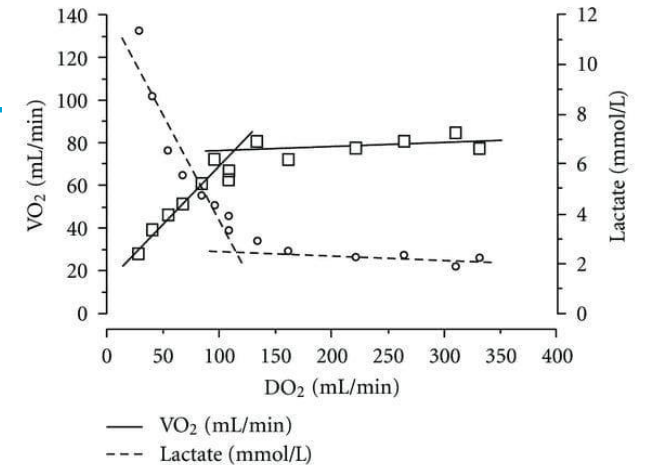
# Critical DO<sub>2</sub>

- Healthy adults 4-8 mL O<sub>2</sub>/kg/min
- Pregnancy
  - INC in cardiac output by 30-50%
  - But oxygen delivery is the same w/ fall in Hb and reduced arterial oxygen content
  - But oxygen consumption INC by 20-33% in 3<sup>rd</sup> trimester
  - Normal pregnancy maintains delivery with enhanced extraction, INC cardiac output, shift in maternal oxyhemoglobin desaturation
- Preeclampsia/Eclampsia
  - Low oxygen delivery and consumption
  - DO<sub>2</sub> and VO<sub>2</sub> reduced, DO<sub>2</sub> doesn't mean tissues can extract what is delivered
- Critical illness in pregnancy
  - INC systemic vascular resistance
  - DEC cardiac output
  - Reduced intravascular volume
  - → DEC DO<sub>2</sub>
  - Dec O<sub>2</sub> extraction
  - Any increased consumption exceeds delivery



# Approach to mechanical ventilation

- Maternal and fetal reserve impaired
- "critical DO<sub>2</sub>"
  - Parameters that may signal respiratory failure
  - FHR patterns: late decelerations, tachycardia, bradycardia, absent variability
- Better outcomes with stabilizing maternal condition rather than intervene on behalf of fetus if rescue can be achieved with mechanical support.
- Unless death imminent/cardiac arrest unresponsive to resuscitation in which case delivery may improve survival



# Respiratory failure

- Hypoxic
- Hypercapnic
- *mechanical failure*

Focus :	Focus :	Focus: Mechanics (Pressure/Work)
Optimize PaO <sub>2</sub> > thresholds based critical DO <sub>2</sub> in preeclampsia/eclam	Normal PaCO <sub>2</sub> 30 mmHg  Decide if hypercapnia	Match respiratory compliance  Relieve  Adequate EPAP or PEEP
	Avoid alkalosis	

Parameter	Normal range	Indication for ventilatory assistance
Mechanics		
Respiratory rate (breaths/min)	12–20	>35
Vital capacity (mL/kg body weight) <sup>a</sup>	65–75	<15
Inspiratory force (cmH <sub>2</sub> O)	(75–100)	<25
Compliance (mL/cmH <sub>2</sub> O)	100	<25
FEV <sub>1</sub> (mL/kg body weight) <sup>a</sup>	50–60	<10
Oxygenation		
P <sub>a</sub> O <sub>2</sub> (torr) <sup>b</sup>	80–95	<70
(kPa)	10.7–12/7	<9.3
P <sub>(A-a)</sub> O <sub>2</sub> (torr) <sup>c</sup>	25–50	>450
(kPa)	3.3–6.7	>60
Q <sub>s</sub> /Q <sub>T</sub> (%)	5	>20
Ventilation		
P <sub>a</sub> CO <sub>2</sub> (torr)	35–45	>55 <sup>d</sup>
(kPa)	4.7–6.0	>7.3
V <sub>D</sub> /V <sub>T</sub>	0.2–0.3	>0.60

FEV<sub>1</sub>, Forced expiratory volume in 1 min; P<sub>(A-a)</sub>O<sub>2</sub>, alveolar–arterial oxygen tension gradient; Q<sub>s</sub>/Q<sub>T</sub>, shunt fraction; V<sub>D</sub>/V<sub>T</sub>, dead space to tidal volume ratio.

<sup>a</sup>Use ideal body weight.





<sup>b</sup>Room air.

<sup>c</sup>F<sub>i</sub>O<sub>2</sub> = 1.0; <sup>d</sup>exception is chronic lung disease.

Source: Reproduced by permission from Van Hook JW. [33]



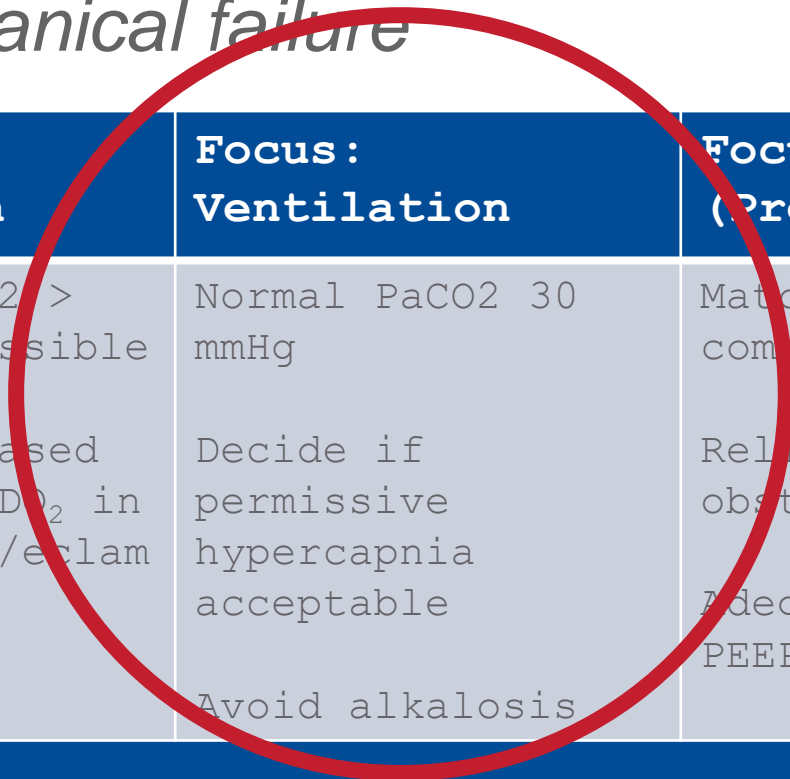
# Oxygen delivery systems

Type	FiO <sub>2</sub> capability	
Nasal cannula	24-~40%	
Venturi mask	24, 28, 31, 35, 40, 50%	
Reservoirs	~90% if fitted	
Heated High Flow	Uncertain and highly dependent on flow	

# Respiratory failure

- Hypoxic
- Hypercapnic
- *mechanical failure*

Focus: Oxygenation	Focus: Ventilation	Focus: Mechanics (Pressure/Work)
Optimize PaO <sub>2</sub> > 70mmHg if possible ; higher thresholds based on critical D <sub>O</sub> <sub>2</sub> in preeclampsia/eclampsia	Normal PaCO <sub>2</sub> 30 mmHg  Decide if permissive hypercapnia acceptable  Avoid alkalosis	Match respiratory compliance  Relieve obstruction  Adequate EPAP or PEEP



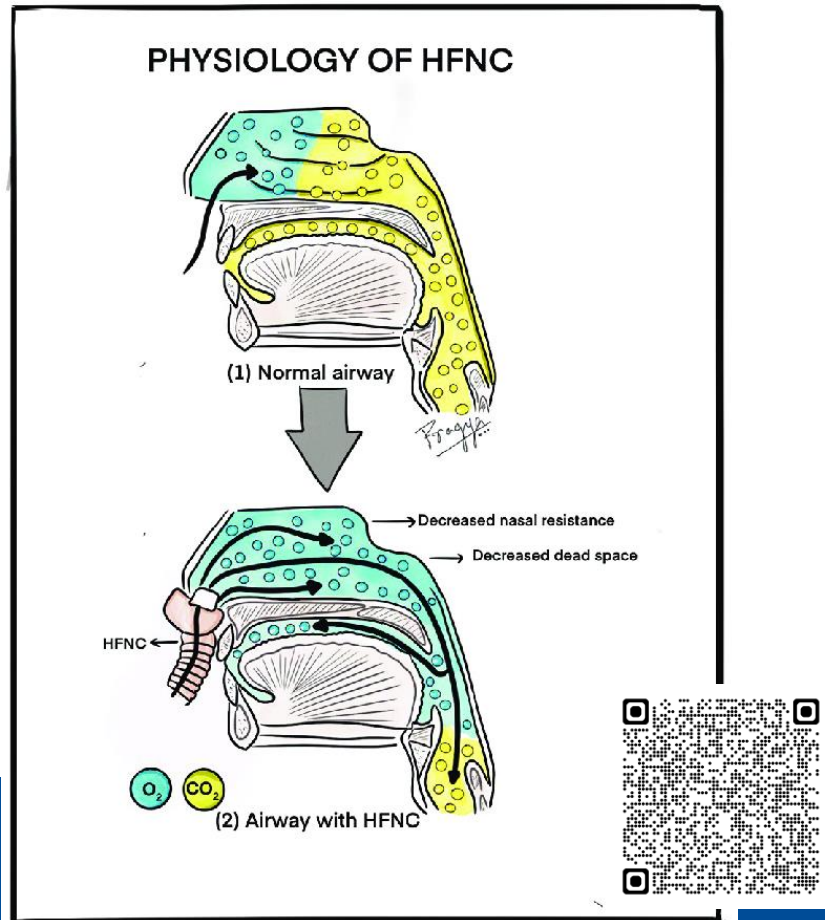
# Ventilatory support

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- CPAP / HFNC
- Noninvasive Ventilation
- Invasive mechanical ventilation
  - IPAP
  - EEP
  - Rate
  - Target PaCO<sub>2</sub>, PaO<sub>2</sub>, pH
  - Precautions
  - Airway considerations

# Ventilatory support

## ■ CPAP / HFNC



- IPAP
- EEP
- Rate
- Target PaCO<sub>2</sub>, PaO<sub>2</sub>, pH
- Precautions
- Airway considerations

Typical settings:  
start 5-8 cmH<sub>2</sub>O  
effective ~8-12 cmH<sub>2</sub>O

# Ventilatory support

---

- CPAP / HFNC
- Noninvasive Ventilation
- Invasive mechanical ventilation
  - IPAP
  - EEP
  - Rate
  - Target PaCO<sub>2</sub>, PaO<sub>2</sub>, pH
  - Precautions
  - Airway considerations

# Noninvasive ventilation in pregnancy

- Indications

- Moderate to severe dyspnea
- Tachypnea ( $>24$  breathes/min in obstructive disease,  $>30$  breaths / min in restrictive disease)
- Acute or acute on chronic hypercapnic respiratory failure
- Acute hypoxemic respiratory failure (use with caution!!)
- Chronic respiratory conditions with ventilatory support needs (NMD/OHS)



# Ventilatory support in pregnancy

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## Conventional ventilation

- Hypocapnia
  - Maternal PaCO<sub>2</sub> <25 mmHg
  - Decreased UBF → fetal hypoxia & acidosis
- Hypercapnia
  - Fetal acidemia due maternal acidemia: not due to fetal hypoxemia
  - Maternal PaCO<sub>2</sub> of 50-60 mmHg seems to be well tolerated
  - Small studies: mild hypoventilation (pH 7.36) better tolerated by the fetus than mild hyperventilation (pH 7.5)

- IPAP
- EEP
- Rate
- Target PaCO<sub>2</sub>, PaO<sub>2</sub>, pH
- Precautions
- Airway considerations

# Considerations of NIV in the pregnant patient

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- IPAP
  - Driver of ventilation volumes.
- EPAP
  - May need higher than normal EPAP due to hypervascular / edema of upper airway / increased secretions
  - Decreased chest wall compliance and downward diaphragm excursion
- Rate
  - Higher than normal progesterone mediated drive: tenuous apneic threshold while asleep / medications
- Targets
  - PaCO<sub>2</sub> normal 28- 32mmHg; mild permissive hypercapnia may be ok, >40 may indicate impending failure
  - PaO<sub>2</sub> increased consumption requires higher FiO<sub>2</sub>, target > 70 mmHg, sat >92-95%; avoid hyperoxygenation (may decrease cardiac output and fetal oxygen delivery \*limited data)
  - pH
- Precautions:
  - decreased FRC results in rapid desaturation during apnea / hypoventilation
  - High pressures exacerbate reflux / aspiration risks
- Airway considerations

# Approach to NIV in the pregnant patient

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- Interface selection (airway, aspiration, secretions)
- Start conservative
  - IPAP 10-12 cm H<sub>2</sub>O
  - EPAP 4-6 cm H<sub>2</sub>O
  - Rate- drive is maintained, tachypnea will resolve with sufficient support

- Targets
- SpO<sub>2</sub> >92-95%
- Adjust up on rate if spontaneous rate falls below normal (~16)
- Adjust up on inspiratory time or IPAP if hypercapnia persists
- Adjust EPAP if hypoxic or for comfort
- Max IPAP in pregnancy unknown

# Intubations



- Indications (do not vary)
- Lower threshold if PaCO<sub>2</sub> reaches 40 in patients with signs of respiratory failure, particularly in asthma
- Anticipate a challenge! Skilled airway management only
  - Higher risk of aspiration (sodium citrate, Sellick's maneuver, avoid overbagging)
  - Hyperemic and vascular airway
  - Avoid nasal intubation if possible
  - May need smaller ETT (#6 or #7)
  - Keep apnea time short! Anticipate precipitous drop in PO<sub>2</sub>
  - No more than 30 seconds bagging
  - CXR to confirm placement of the ETT

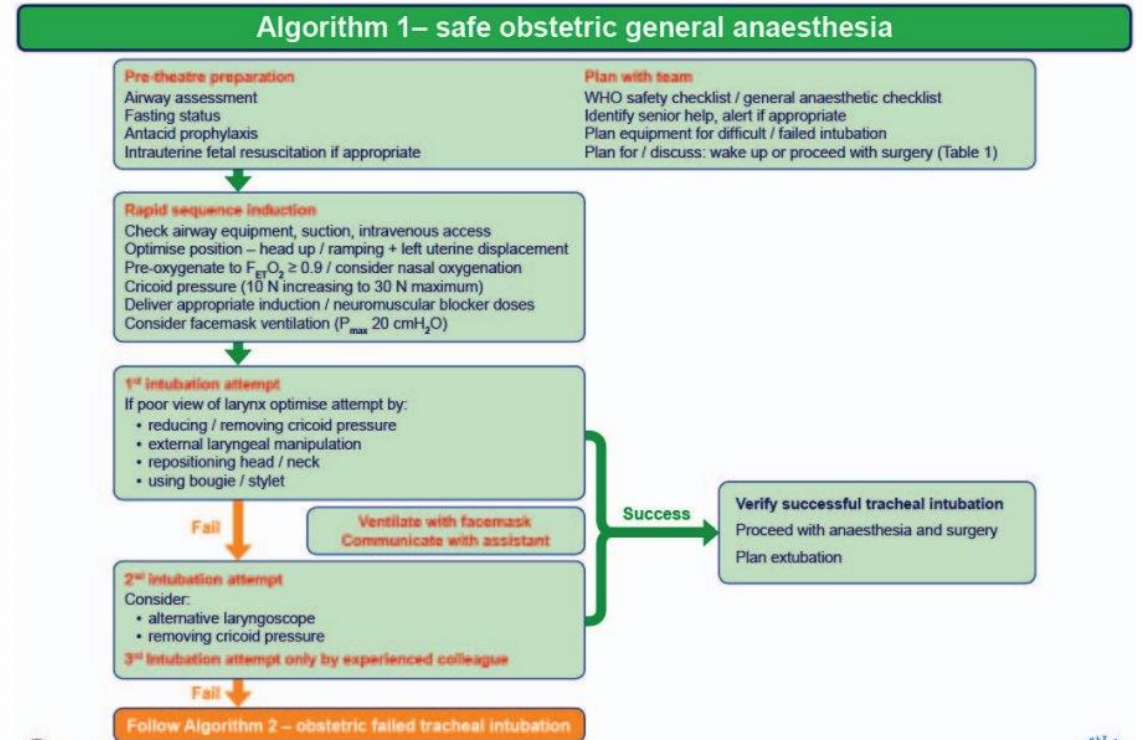


# Airway considerations

Factors to consider	WAKE	←	→	PROCEED
Before induction	<b>Maternal condition</b>	• No compromise	• Mild acute compromise	• Haemorrhage responsive to resuscitation • Hypovolaemia requiring corrective surgery • Critical cardiac or respiratory compromise, cardiac arrest
	<b>Fetal condition</b>	• No compromise	• Compromise corrected with intrauterine resuscitation, pH < 7.2 but > 7.15	• Continuing fetal heart rate abnormality despite intrauterine resuscitation, pH < 7.15 • Sustained bradycardia • Fetal haemorrhage • Suspected uterine rupture
	<b>Anaesthetist</b>	• Novice	• Junior trainee	• Senior trainee • Consultant / specialist
	<b>Obesity</b>	• Supermorbid	• Morbid	• Obese • Normal
	<b>Surgical factors</b>	• Complex surgery or major haemorrhage anticipated	• Multiple uterine scars • Some surgical difficulties expected	• Single uterine scar • No risk factors
	<b>Aspiration risk</b>	• Recent food • In labour • Opioids given • Antacids not given	• No recent food • In labour • Opioids not given • Antacids given	• Fasted • Not in labour • Antacids given
	<b>Alternative anaesthesia</b> • regional • securing airway awake	• No anticipated difficulty	• Predicted difficulty	• Relatively contraindicated • Absolutely contraindicated or has failed • Surgery started
After failed intubation	<b>Airway device / ventilation</b>	• Difficult facemask ventilation • Front-of-neck	• Adequate facemask ventilation	• First generation supraglottic airway device • Second generation supraglottic airway device
	<b>Airway hazards</b>	• Laryngeal oedema • Stridor	• Bleeding • Trauma	• Secretions • None evident

Criteria to be used in the decision to wake or proceed following failed tracheal intubation. In any individual patient, some factors may suggest waking and others proceeding. The final decision will depend on the anaesthetist's clinical judgement.

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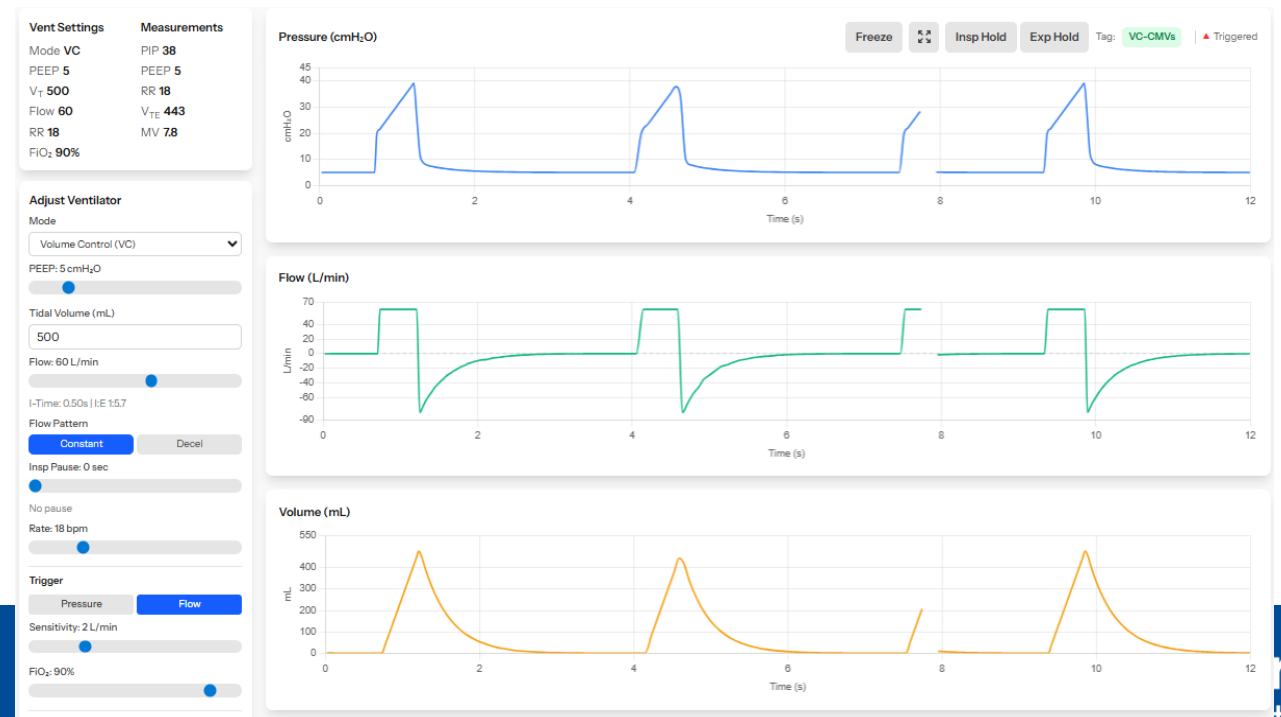
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**Figure 5.** Wake or proceed with surgery? Criteria to be used in the decision to wake or proceed following failed tracheal intubation (table 1 from the OAA/DAS guidelines). This algorithm is reproduced with permission from the OAA and DAS and is available online in pdf and PowerPoint formats.<sup>2</sup>

# Initial ventilator settings

- FiO<sub>2</sub> 0.9-1 and titrate down to PaO<sub>2</sub> above 90 mmHg
- Rate 12-20 breathes per minute depending on pH and CO<sub>2</sub>
- Tidal volume 5-8 mL/kg to prevent excessive alveolar distension
- PEEP minimum 5



# Nuances of IMV in the pregnant patient

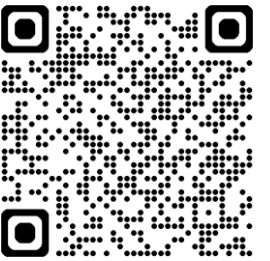
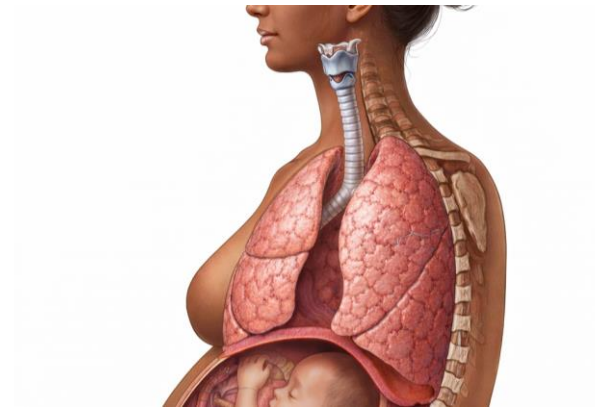
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- Smaller ETT considerations
- Full support
  - Volume vs. Pressure- no evidence
  - Target volume of 5-8mL/kg depending on disease process
  - Start EPAP 5 cm H<sub>2</sub>O
- Targets
  - SpO<sub>2</sub> >92-95%
    - PaO<sub>2</sub> targets may vary depending on presumed critical DO<sub>2</sub>
  - Lung protection strategy in ARDS
  - Avoid atelectasis in hypoventilation
  - Driving pressure <15 cmH<sub>2</sub>O\*
  - PEEP titration approach not evidence based in pregnancy
  - Max IPAP in pregnancy...

# Nuances of IMV in the pregnant patient

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- Respiratory Compliance
- Driving pressures  $<15 \text{ cmH}_2\text{O}^*$
- Recommendations to maintain plateau pressures  $< 30 \text{ cmH}_2\text{O}^*$ 
  - Safety of low-tidal volume ventilation in pregnant and postpartum women with ARDS: ARMA trial



# Additional maneuvers

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- Prone ventilation
  - Evidence says do it, do it early, don't change the ventilation strategy when prone.
  - Bolster to avoid compressing abdomen
- Lung protective strategies
  - With optimal PEEP
  - Consider **neuromuscular blockade** to maintain oxygenation
- ECMO
- Inhaled pulmonary vasodilators
  - Subgroup of patients with pulmonary hypertension related to ARDS may benefit more than just hypoxic response



# Delivery of a pregnant patient with ARDS

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- Impact of delivery on lung function were restricted to retrospective case series
  - Included respiratory failure from many causes
  - Modest benefit in small portion of patients
- Larger case series in 71 patients showed variable benefits with little oxygenation or compliance benefit, more of a benefit in patients with primary need for intubation from preeclampsia/hemorrhage/obstetric condition.
- Oxygenation, driving pressure improved after delivery in obese patients, but some did have deterioration following delivery



# Summary

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Majority of ventilatory support is guided by:

1. Understanding the nuances of physiologic changes in pregnancy
2. Anticipating complications to recognize and intervene early

Lack of strong evidence to guide management, but what evidence there is remains important

High stakes requiring multidisciplinary approach