Brigham and Women's Hospital
Founding Member, Mass General Brigham

Obstetric Critical Care

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CONTINUING MEDICAL EDUCATION
DEPARTMENT OF MEDICINE

HARVARD MEDICAL SCHOOL
TEACHING HOSPITAL

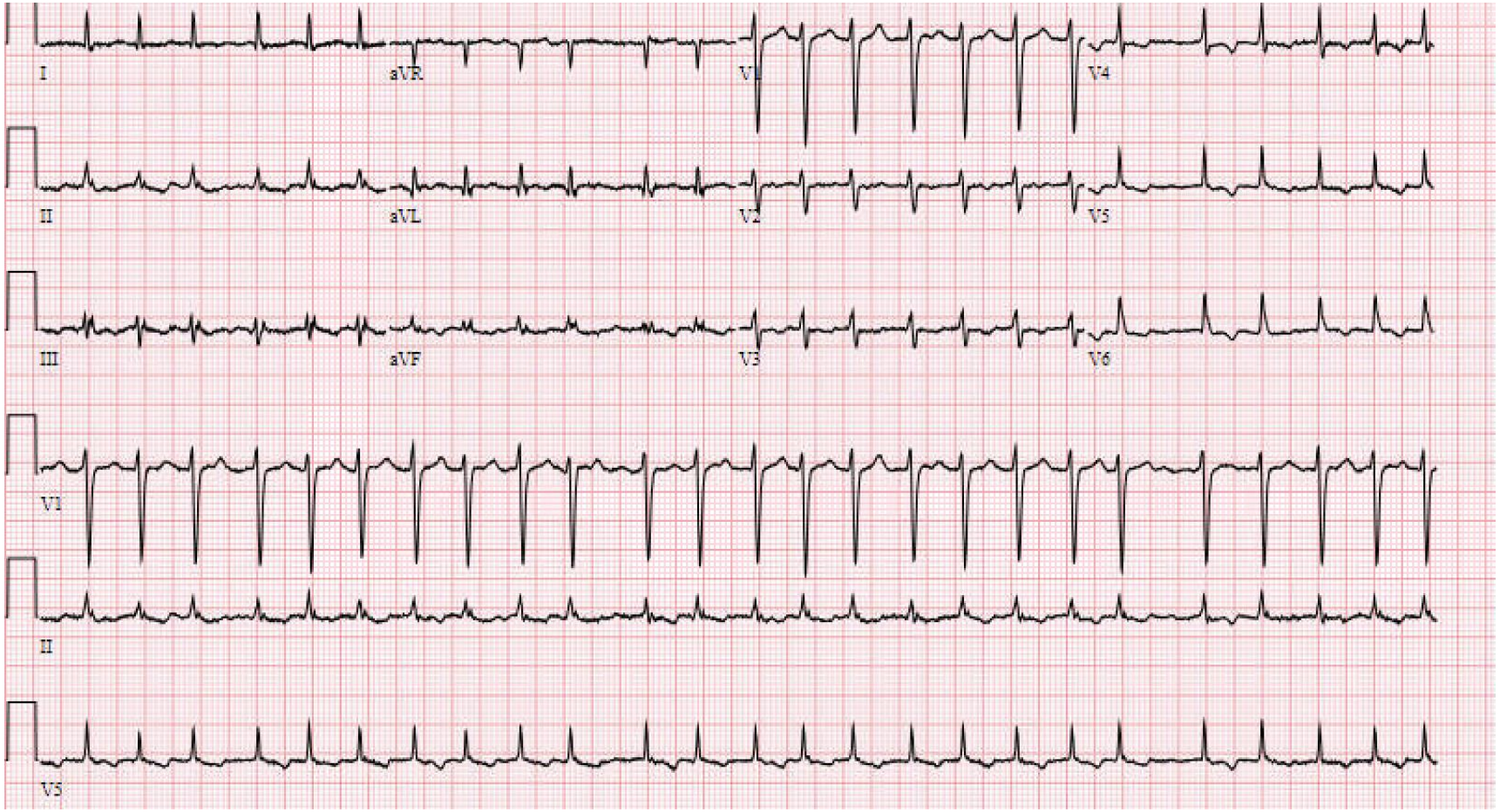
Disclosures

I have no relevant financial relationships with any entity producing, marketing, selling or distributing health care goods or services consumed by, or used on, patients that is relevant to or could be impacted by the content included in this presentation.

33 yo G3P1011 at 30 weeks 4 days with dyspnea

Transferred from referring hospital 4 days after presenting with shortness of breath

VS: Tc 36.2, HR 149, BP 116/79, RR 34, SpO2 98% 4L NC



33 yo G3P1011 at 30 weeks 4 days with dyspnea

Relevant History

History of ASD repaired in childhood at Boston Children's Hospital without need for long-term follow up

Prior vaginal delivery 12 years ago of well grown baby at term

Works bagging groceries in a local supermarket and lives with her sister

Key Data from Transfer

TTE LVEF 40% with mild MR and TR

CXR moderate pleural effusions

Therapy Prior to Transfer

s/p DCCV without cardioversion

s/p bolus IV metoprolol 5 mg IV

s/p bolus IV diltiazem 20 mg IV x 2

Diltiazem IV 15 mg/hr

Betmethasone 12 mg IM Q24 x 2

Furosemide 40 mg PO daily

Enoxaparin 80 mg BID

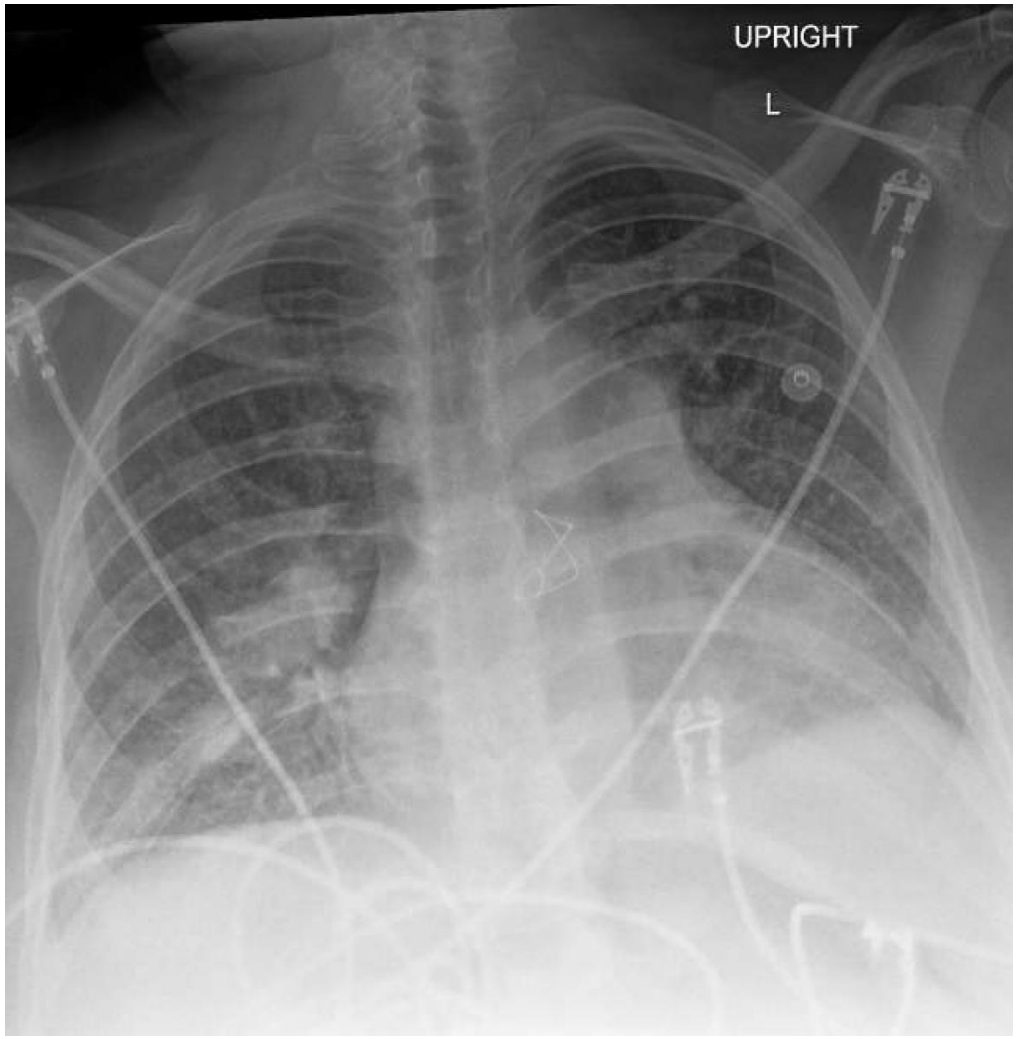
33 yo G3P1011 at 30 weeks 4 days with dyspnea

132	95	37	111
4.6	**16**	**1.32**	

ALT 22
AST 20
Alk Phos 86
Tbili 1.5
Dbili 1.1

	11.2	
8.3		223
	34.3	

Procalcitonin 0.62
UA: Negative
COVID: Negative
Influenza A: Negative
Influenza B: Negative



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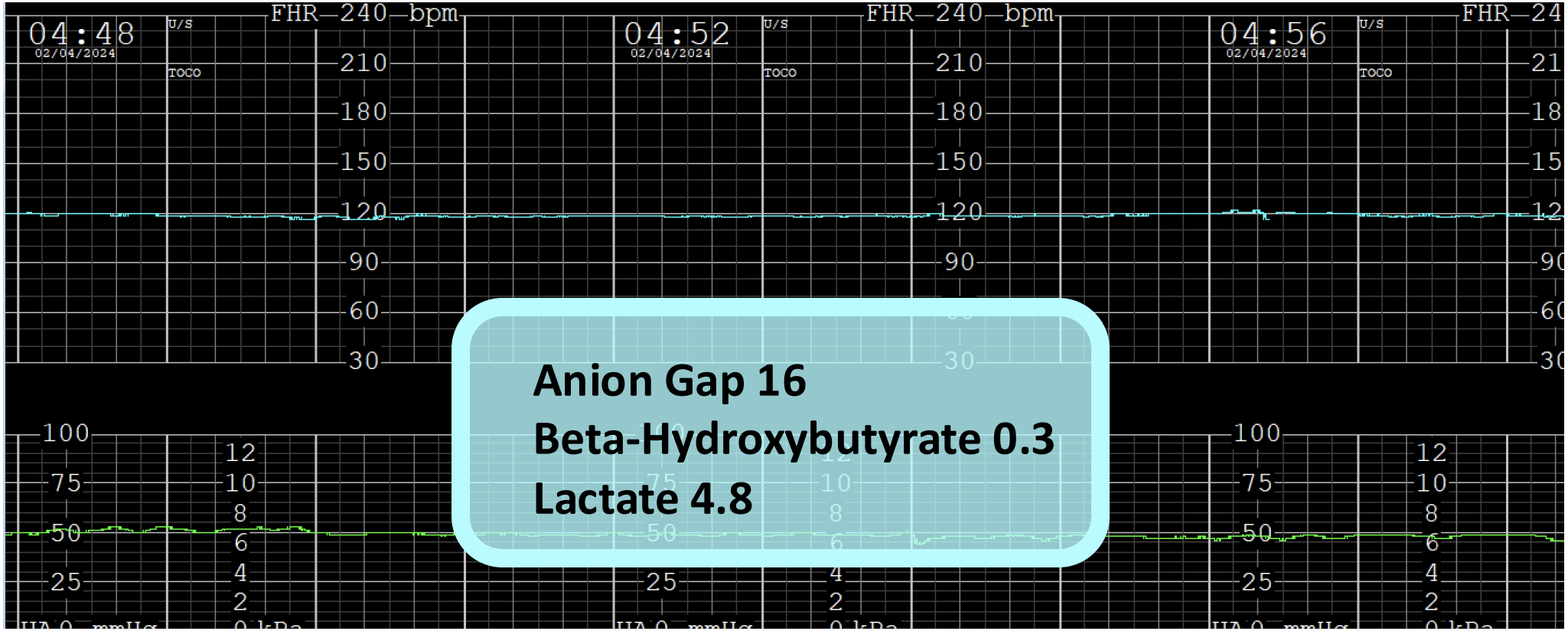
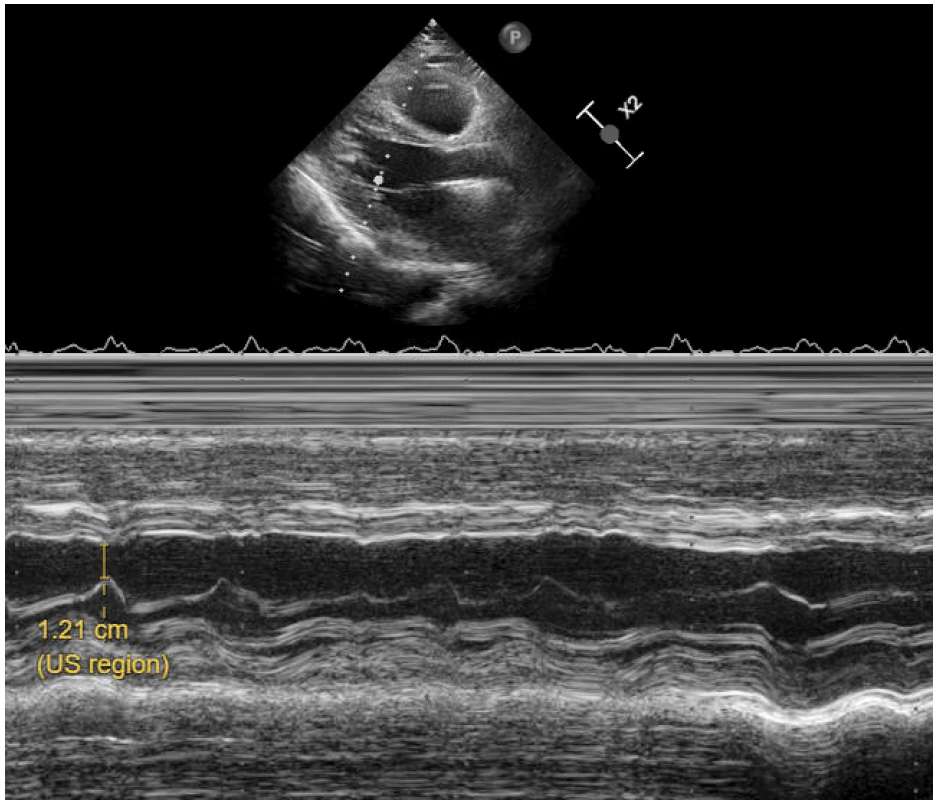


What do you recommend?

a) Diuresis with IV furosemide
b) Initiation of digoxin
c) Amiodarone
d) Preparation for delivery
e) Electrical cardioversion



Limited TTE demonstrates biventricular dysfunction with LVEF estimate of 20%. This image from parasternal long axis view demonstrating E-point septal separation of 12 mm. EPSS > 7 sensitive for LVEF <40%.

Objectives

- Understand key physiologic adaptations of pregnancy relevant to the intensivist.
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Relevance beyond Board Exams

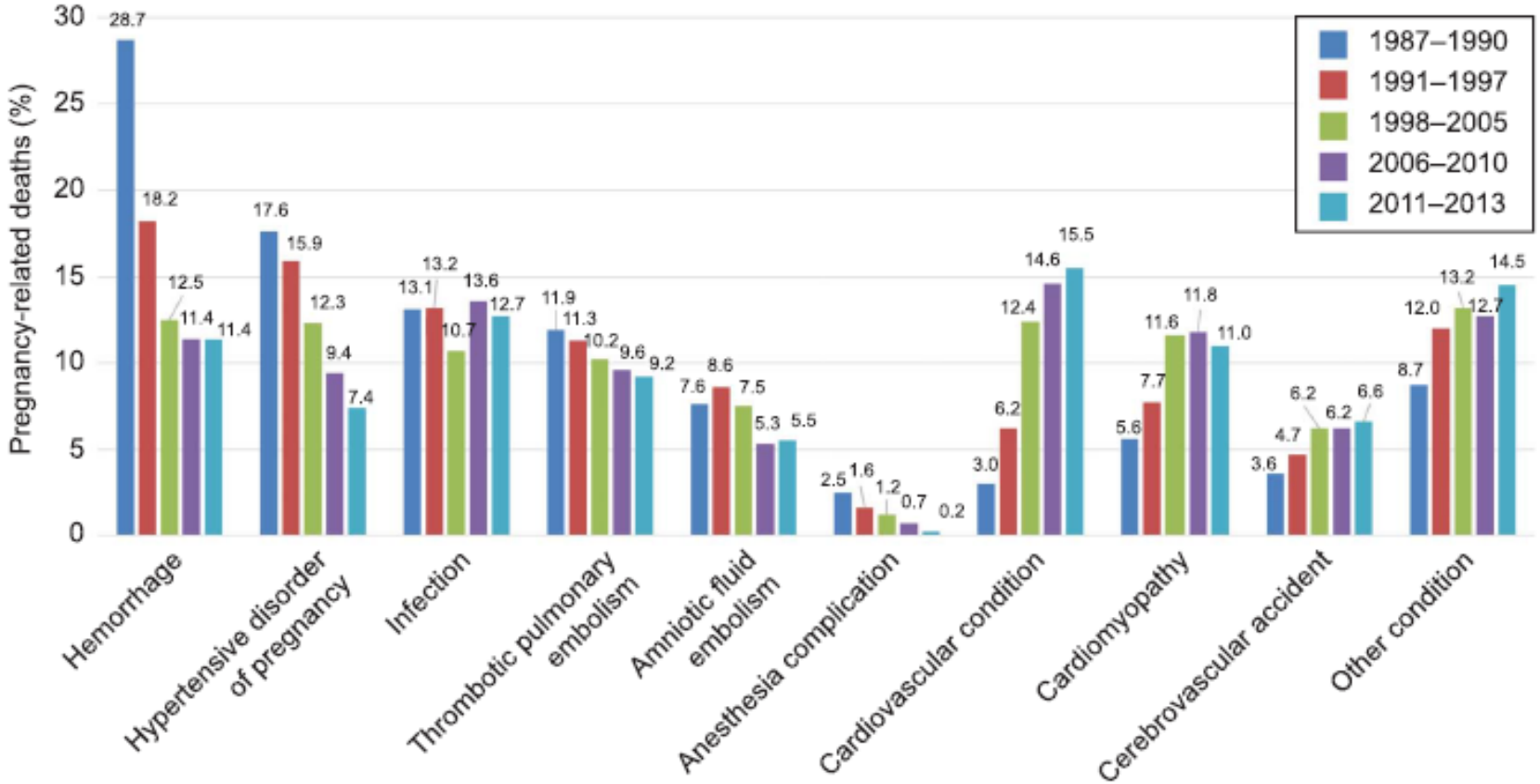
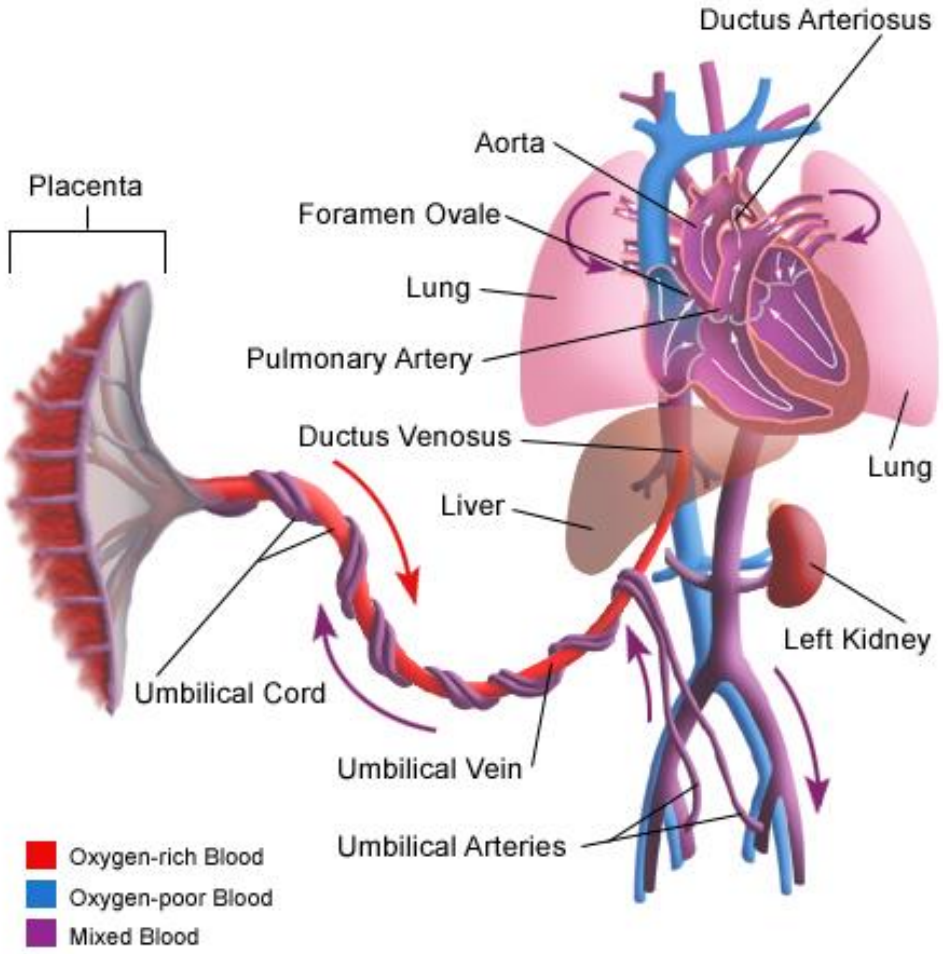


Figure 2. Population-level, cause-specific proportionate pregnancy-related mortality for 1987–1990, 1991–1997, 1998–2005, 2006–2010, and 2011–2013. Results are population-level and can be compared as absolute values.

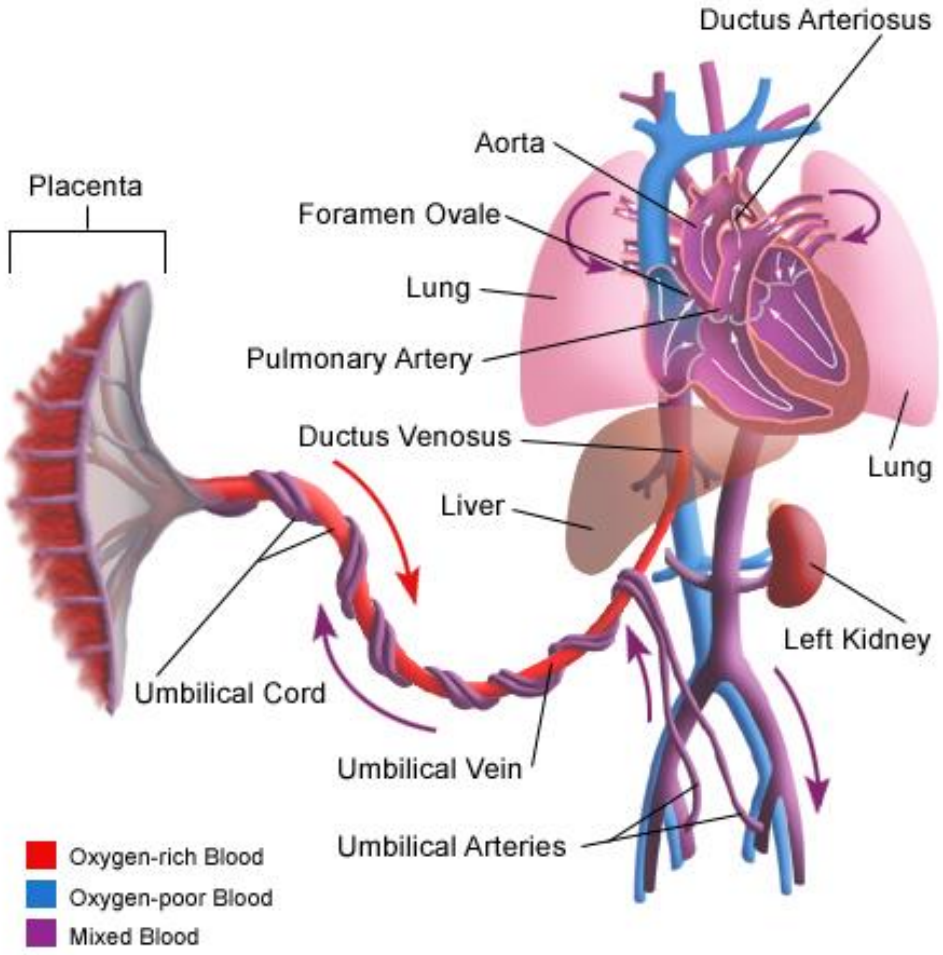
Creanga. Pregnancy-Related Mortality in the United States. Obstet Gynecol 2017.

A New End Organ



- Gas Exchange
- Nutrition
- Thermoregulation
- Waste Elimination
- Immunity

Nature's VV ECMO



Increased Cardiac Output

Blood flow to placenta

Oxygen carrying capacity

Respiratory Alkalosis

Oxygen delivery

CO_2 removal

Aligning Oxygen Consumption and **Delivery**

Increased

Heart Rate

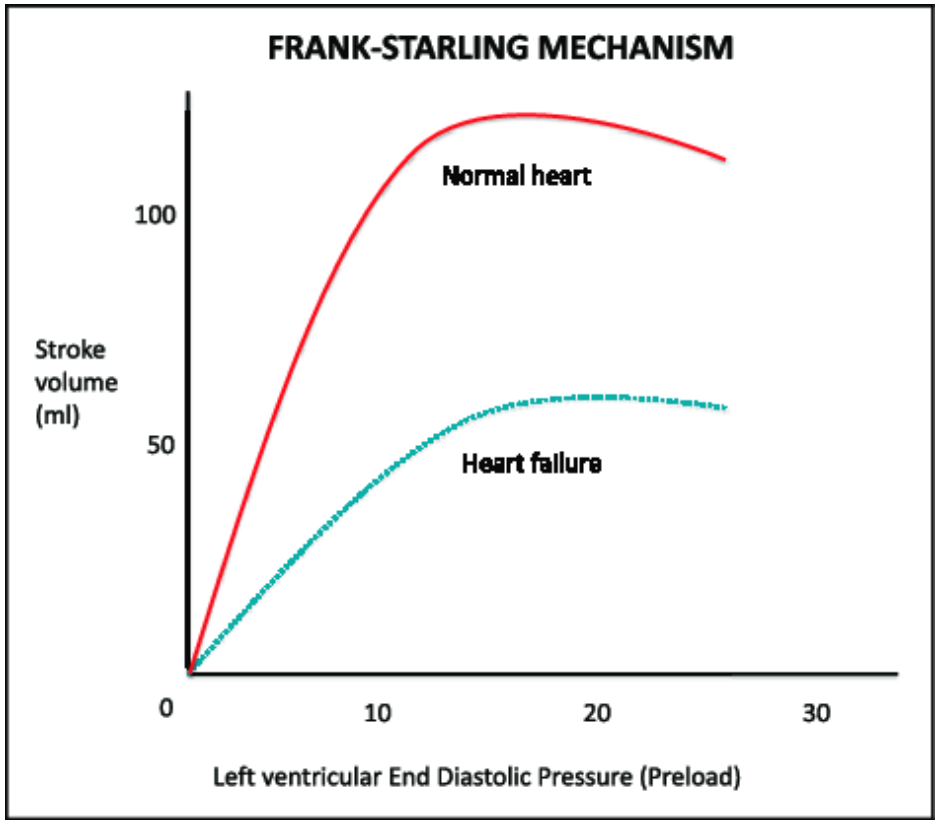
Plasma Volume

Red Blood Cells

Decreased

Systemic Vascular Resistance

Blood Pressure



DO_2 = **Cardiac Output (Q)** x Arterial Oxygen Content (CaO_2)

where CaO_2 = (1.34 x **Hemoglobin** x SpO_2) + (0.003 x **PaO_2**)

Aligning Oxygen **Consumption** and Delivery

Increased

Heart Rate

Plasma Volume

Red Blood Cells

Decreased

Systemic Vascular Resistance

Blood Pressure

VO_2 = **Cardiac Output (Q)** x (Arteriovenous Oxygen Difference)

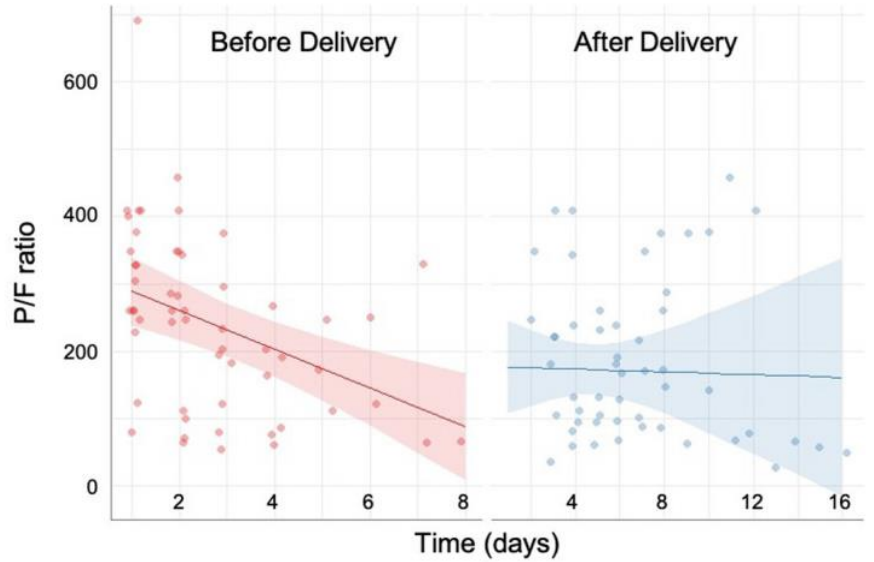
where AV O_2 Difference = 1.34 x Hgb x (SaO_2 – SvO_2)

DOI: 10.1111/1471-0528.16858
www.bjog.org

Research Article
Maternal medicine

The relationship between delivery and the PaO_2/FiO_2 ratio in COVID-19: a cohort study

BL Pineles,[a] A Stephens,[a] LM Narendran,[a] MA Tigner,[b] C Leidlein,[c] C Pedroza,[d] H Mendez-Figueroa,[a] BM Sibai[a]



Compensated Respiratory Alkalosis

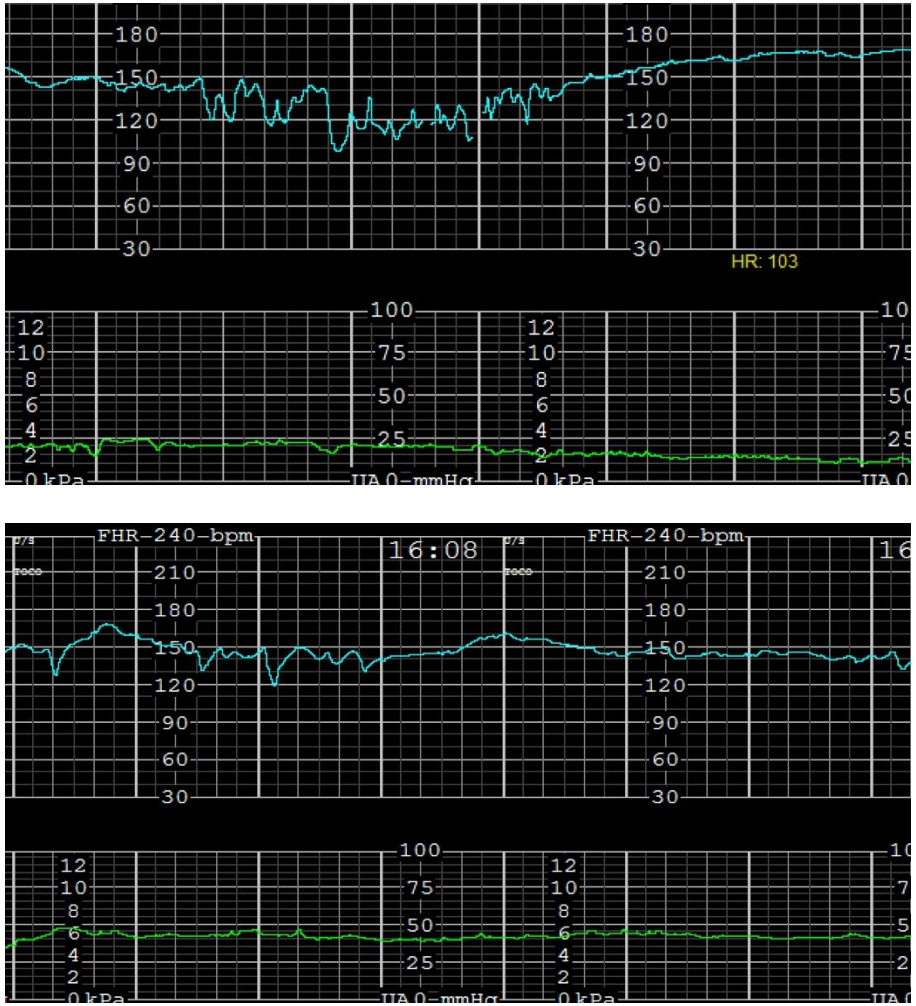
Why it's Cool

Favorable gradient for passive CO_2 diffusion
Shift in Bohr curve enhances oxygen affinity of hemoglobin

Why it's Relevant

Increased tidal volume decreases functional residual capacity
Renal compensation leads to bicarbonate deficient state
Permissive hypercapnea may impact fetal gas exchange

A New End Organ to Perfuse



Parameter	Causes of Abnormalities
Baseline	Maternal heart rate Maternal temperature Medications
Variability	Acidosis Medications Sleep Cycle Hypoxia
Decelerations	Hypoperfusion / hypovolemia Placental insufficiency Cord compression Labor
Accelerations	Reassuring when present Often absent due to sedation

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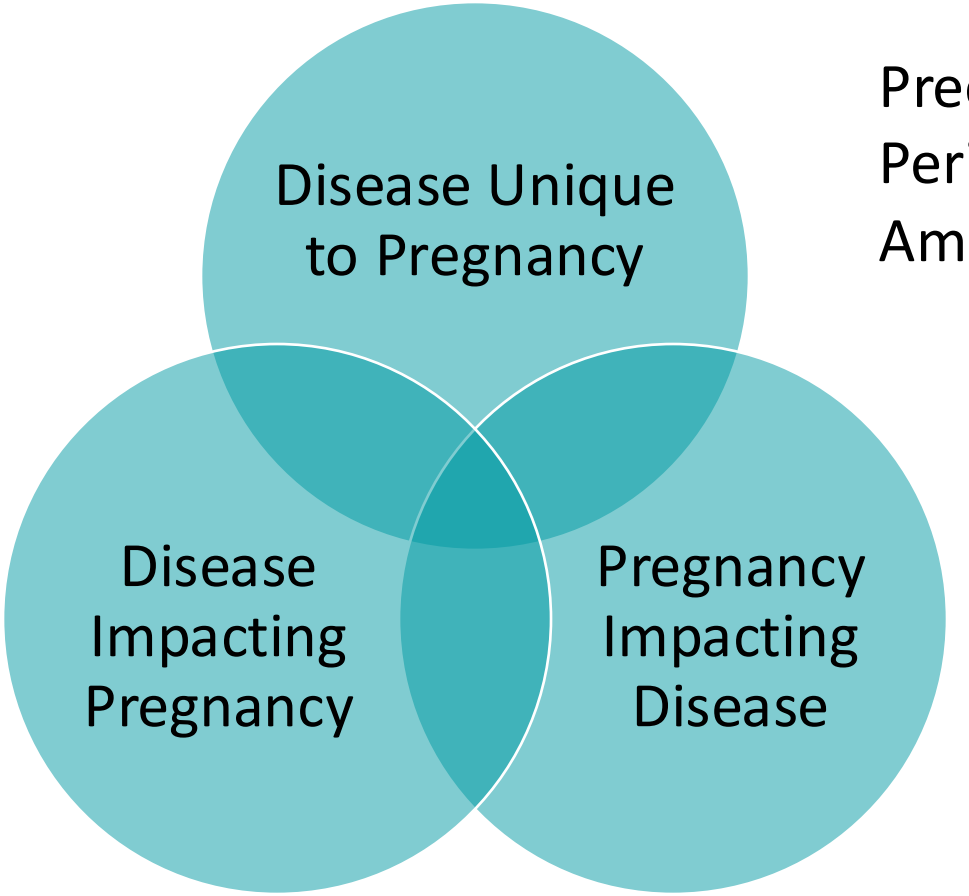
Differential Diagnosis in Pregnancy

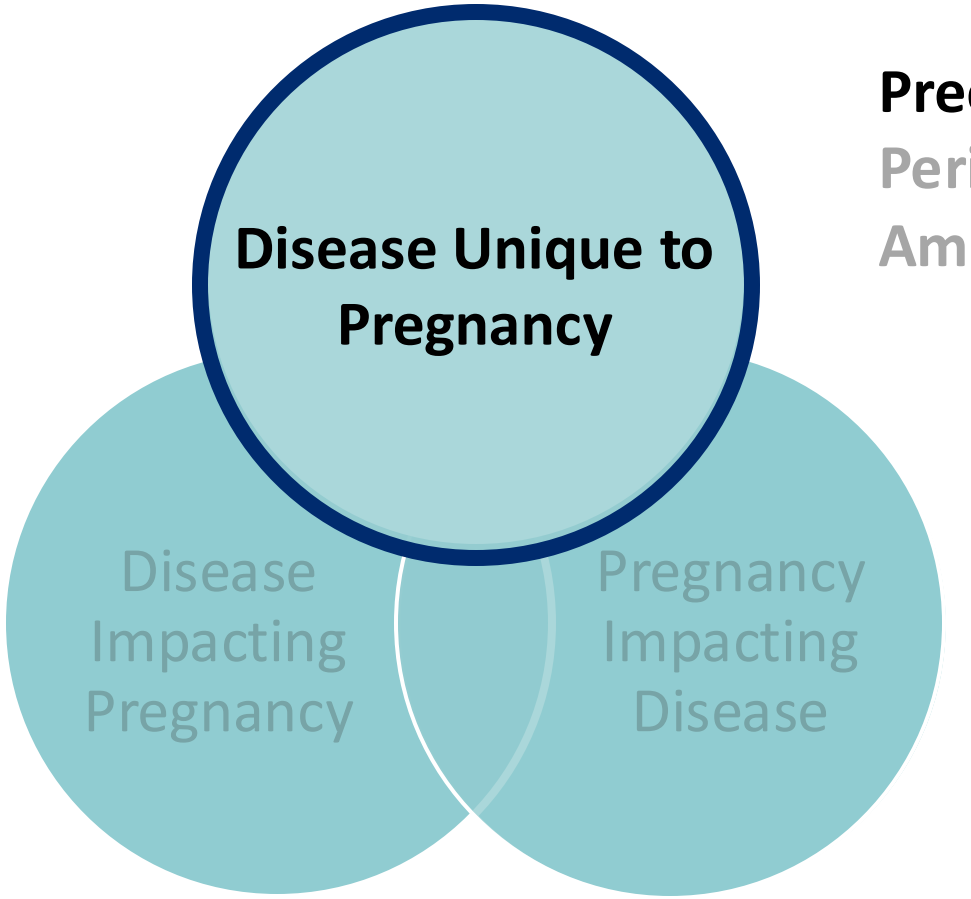


Preeclampsia
Peripartum Cardiomyopathy
Amniotic Fluid Embolism

Cardiovascular Disease
Chronic Kidney Disease
Sickle Cell Disease
Lupus

Listeriosis
Pyelonephritis
Viremia

Differential Diagnosis in Pregnancy



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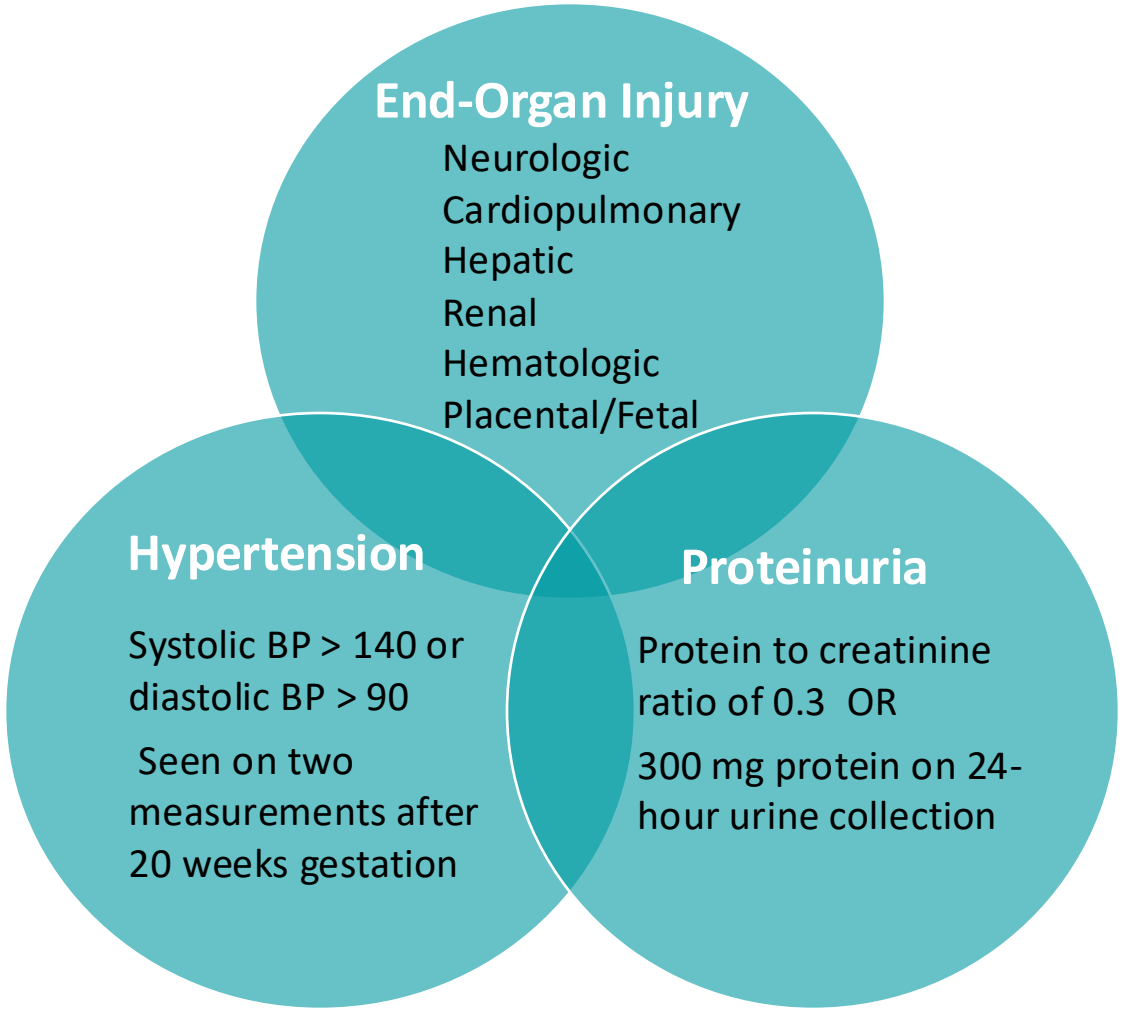
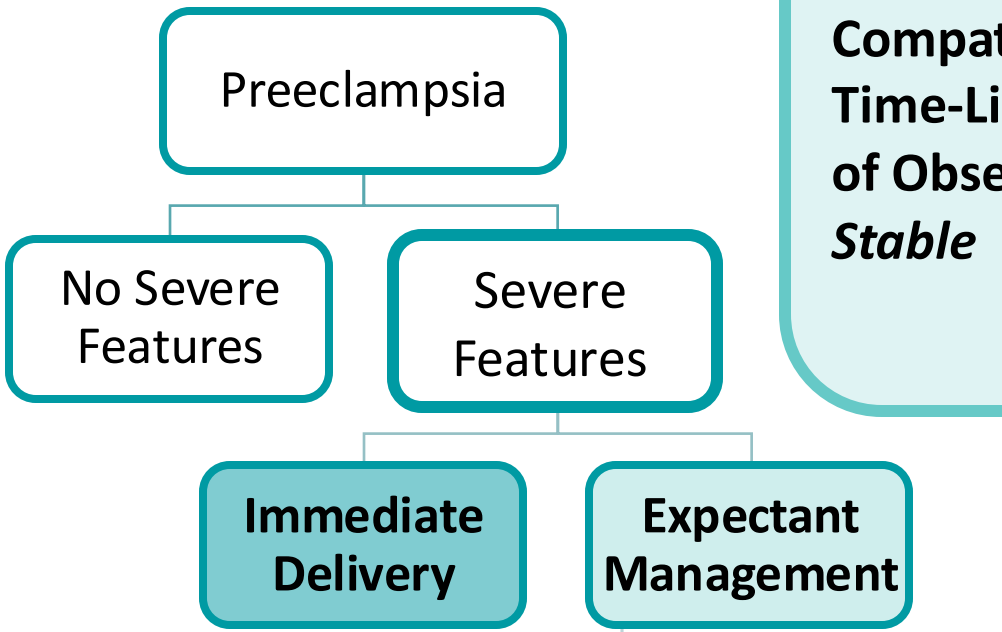
Diagnosing Preeclampsia

- ***Clinical syndrome*** with a range of clinical presentations, including:
  - Hemolysis, elevated liver enzymes, low platelets (HELLP syndrome)
  - Acute fatty liver of pregnancy
- Delivery is "curative" but postpartum presentations are common
  - Posterior reversible encephalopathy syndrome (PRES)
  - Reversible cerebral vasoconstriction syndrome (RCVS)
- Goal to stabilize maternal status to allow for fetal development, when ***appropriate***



Evaluating Preeclampsia



Severe Features Compatible with Time-Limited Trial of Observation if *Stable*

- Systolic BP > 160
- Diastolic BP > 110
- Persistent Headache
- Elevated Creatinine
- Transaminitis
- Abruption
- Thrombocytopenia

Severe Features Precluding Expectant Management (including 48 Hours for Steroids)

- Scotomata
- Stroke
- Pulmonary Edema
- Oliguria
- Epigastric pain
- Stillbirth
- Coagulopathy

Stabilizing Preeclampsia

1. **Manage hypertensive urgency**
   - Systolic BP 140-160
   - Diastolic BP 90-110
2. **Initiate magnesium for seizure prevention**
   - Initiate on presentation until stable
   - Resume during labor and delivery
3. **Monitor for decompensation**
   - Symptoms
   - Labs
   - Volume status
4. **Optimize fetal status**
   - Antenatal corticosteroids
   - Monitoring with NST and ultrasound

Medication	Dose
Labetalol	10-20 mg IV initially
Hydralazine	5-10 mg IV initially
Nicardipine	5 mg/hr IV initially
Nifedipine IR*	10 mg PO initially
Magnesium sulfate	6 gm bolus, 2 gm/hr
Levetiracetam†	500 mg IV BID
Betamethasone	12 mg IM Q24H x 2 doses
Dexamethasone	6 mg IM Q12H x 4 doses

*Listed as a first-line agent in guidelines but half-life, rebound headache, and concerns about coronary perfusion limit use in my clinical practice

†Consider in settings high risk for eclampsia but with contraindication to magnesium (e.g. myasthenia gravis, oliguric renal failure).

Managing Eclampsia

Self-terminating generalized tonic clonic seizure

- Supplemental O_2
- Left lateral position
- Ignore the fetus
- Benzodiazepine okay but unnecessary

Magnesium given for seizure ***prevention***

- Rebolus 2-4 gm if recurrence
- Monitor clinically for toxicity*
- Broaden differential

Deliver the patient when ***stable***

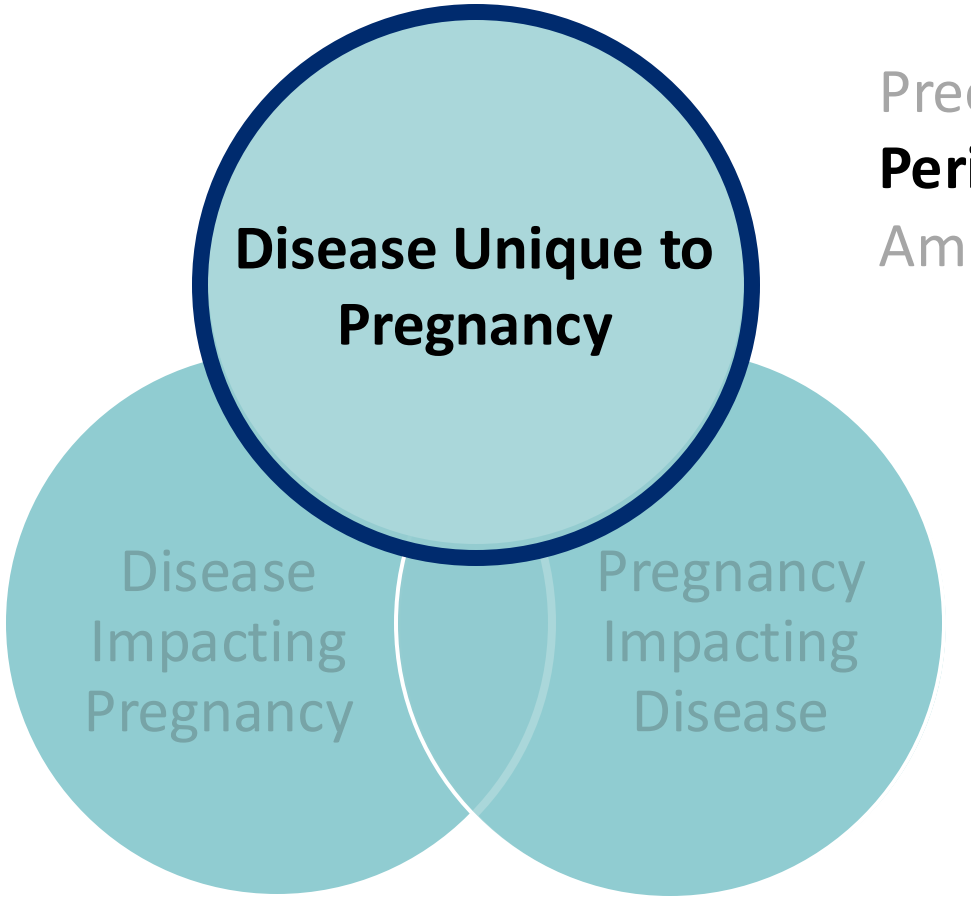
- Not an indication for cesarean delivery
- Consider neuroimaging (especially prior to neuraxial analgesia)

Mg Range†	Clinical Correlate
4-7 mEq/L	Therapeutic*
>7 mEq/L	Patellar reflexes lost
>10 mEq/L	Respiratory depression
>25 mEq/L	Cardiac arrest

*Toxicity rare in the absence of comorbid kidney injury. Plan for bolus without infusion and then monitoring of levels if impaired clearance.

† Laboratory monitoring typically used only in the setting of kidney injury (assessing for adequate or supratherapeutic levels) or recurrent seizures (to assess for subtherapeutic level).

Differential Diagnosis in Pregnancy



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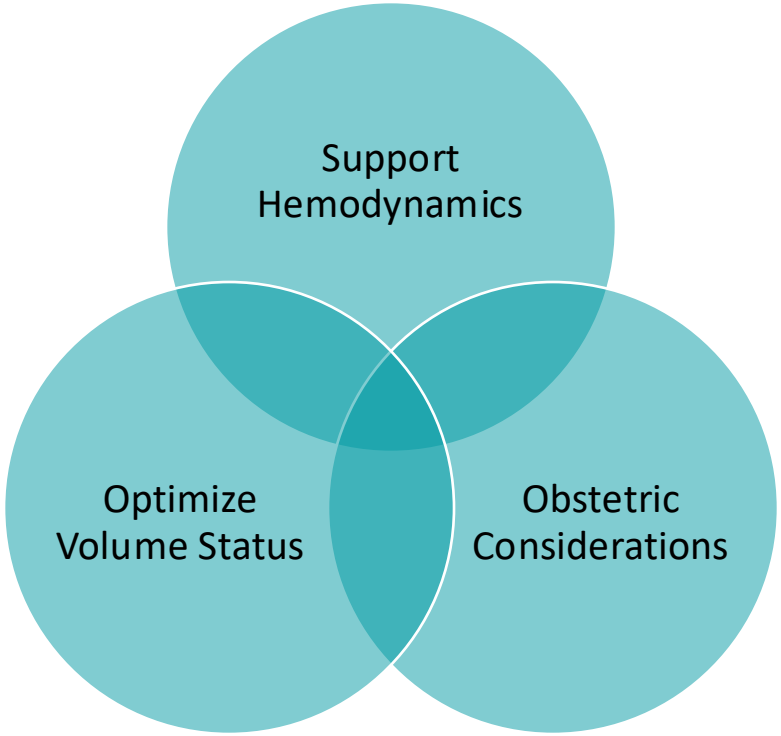
Diagnosing Peripartum Cardiomyopathy

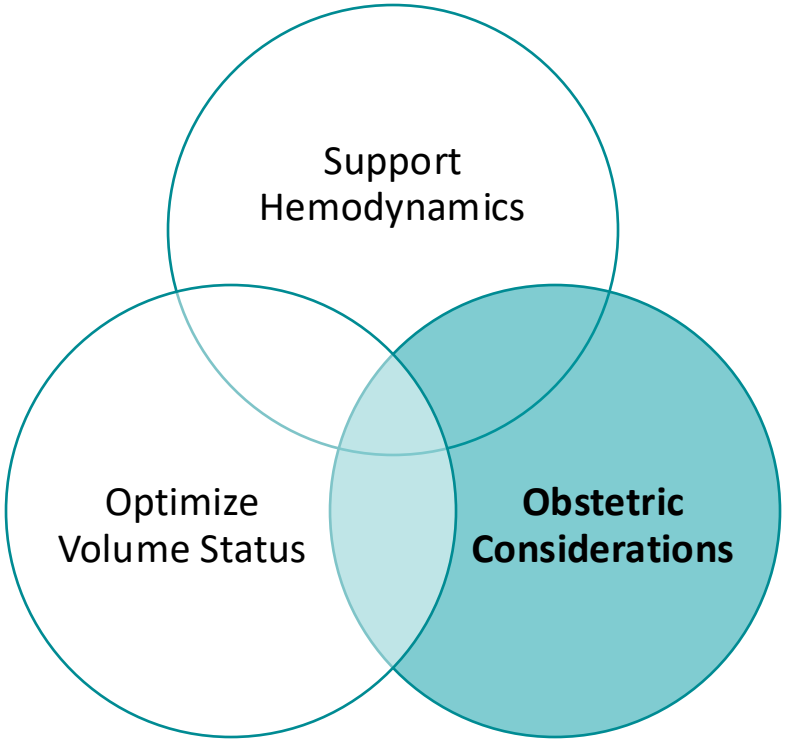


Heart failure secondary to left ventricular systolic dysfunction with left ventricular ejection fraction (LVEF) < 45%.

Occurrence towards the end of pregnancy or in the months following delivery (mostly in the month following delivery).

No other identifiable cause of the heart failure.

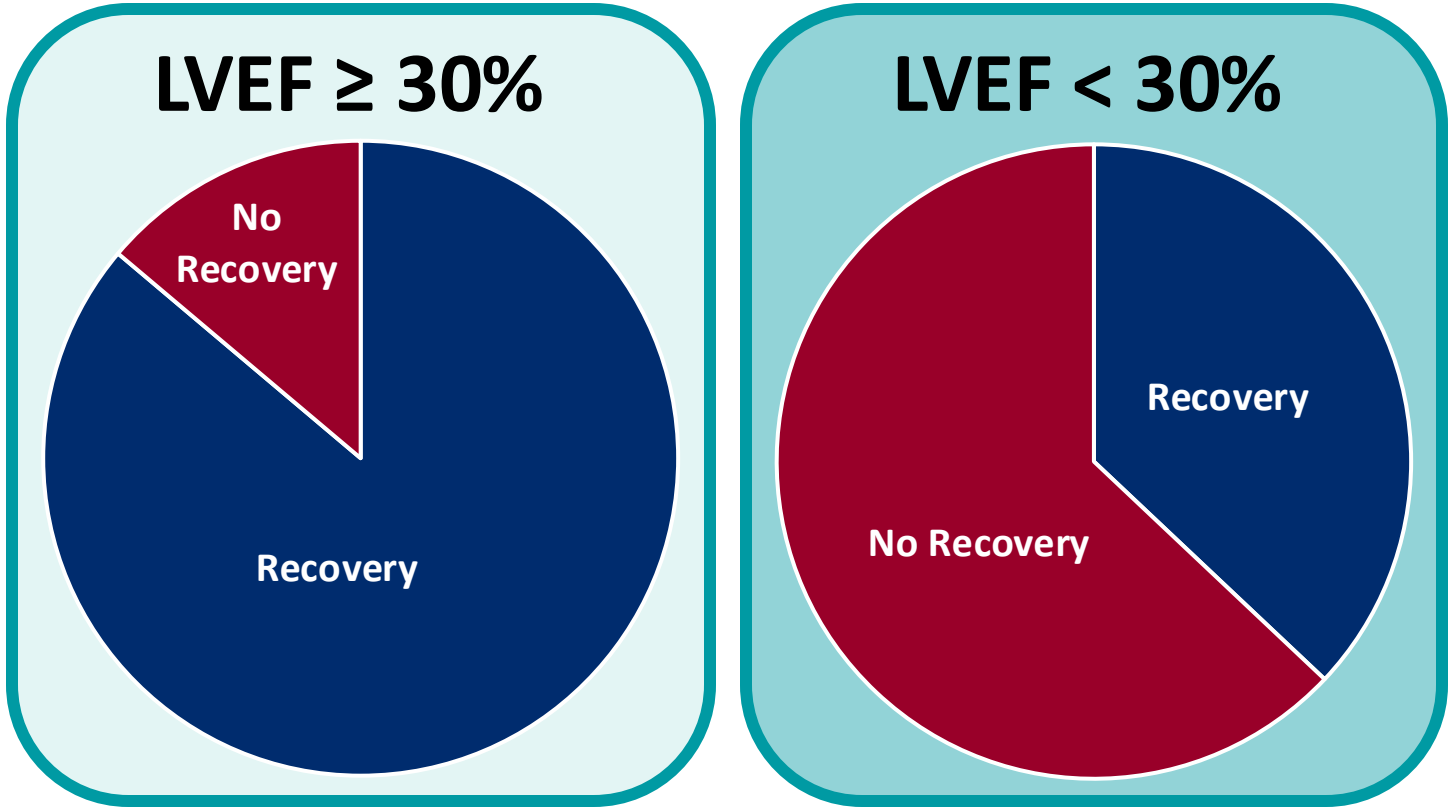
Obstetric Considerations in Peripartum Cardiomyopathy



- Optimize hemodynamics and volume status in anticipation of ***delivery***
- *Consider* bromocriptine
  - Retrospective data suggests improvement in EF with use
  - Small (n=20) person open-label RCT in South Africa showed mortality benefit
  - Experts advise use in LVEF <25% or cardiogenic shock
- Therapeutic anticoagulation
- Provide wearable ICD on discharge
- Ensure ***interconception care***

Interconception Care for Peripartum Cardiomyopathy

- Twelve-month mortality of 2-4%
- Recovery (LVEF ≥ 50%) in 50-80% of people by 6 months
- Left ventricular end-diastolic diameter (LVEDD) > 6 cm and LVEF <30% associated with lower rate of recovery and higher rate of transplant or mechanical circulatory support



LVEF < 50% at 12 months associated with 50% risk of recurrence of acute heart failure informing ESC and AHA guidelines advising against another pregnancy if LVEF does not normalize.

McNamara DM, Elkayam U, Alharethi R, et al. IPAC Investigators. Clinical Outcomes for Peripartum Cardiomyopathy in North America: Results of the IPAC Study (Investigations of Pregnancy-Associated Cardiomyopathy). *J Am Coll Cardiol* 2015;66:905-14.

Genetic Evaluation in Peripartum Cardiomyopathy

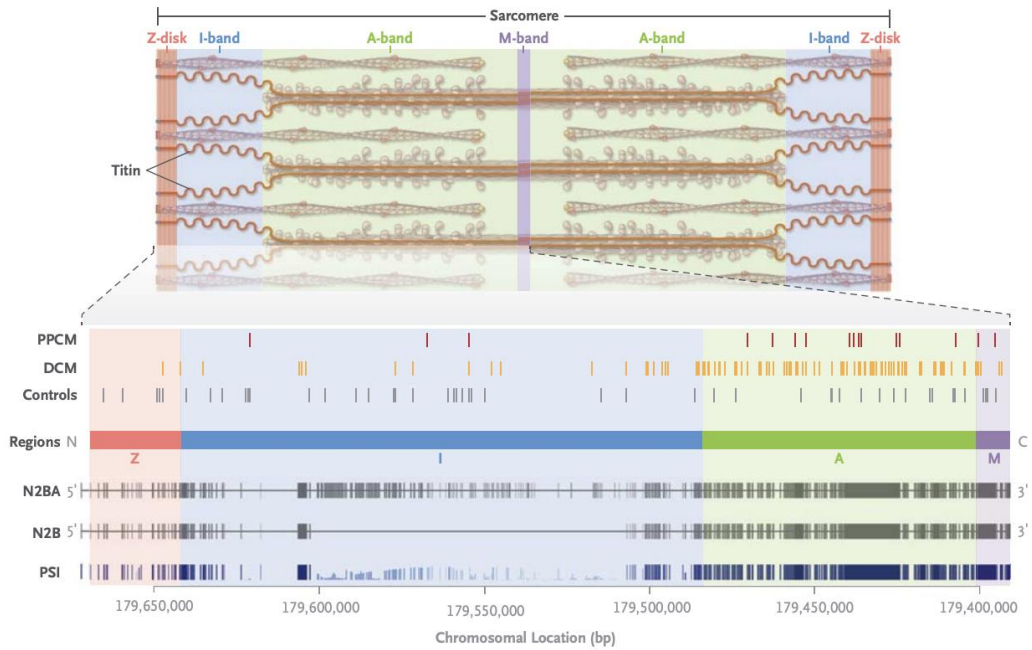


Figure 1. Titin Protein and Spatial Distribution of Variants in the Protein.

Titin, a protein encoded by *TTN*, makes up one of the three major filaments of the cardiac sarcomere, the basic unit of striated muscle tissue. Regions of the sarcomere are designated as the Z-disk (red), I-band (named for its isotropic properties under a polarizing microscope, shown in blue), A-band (named for its anisotropic properties, shown in green), and M-band (from the German *mittelscheibe*, the disk in the middle of the sarcomere, shown in purple). The spatial distributions of the truncating variants that were found in samples obtained from patients with peripartum cardiomyopathy (PPCM) and dilated cardiomyopathy (DCM) are indicated, along with the distributions of such variants in healthy controls. At the bottom of the diagram, the genomic locus of *TTN* is shown. N2BA and N2B denote the exons (vertical lines) encoding the two main cardiac transcripts. For PSI (i.e., the proportion spliced in), the height of the vertical line indicates the proportion of cardiac transcripts obtained from patients with dilated cardiomyopathy that contain the exon. Images are adapted from Herman et al.[6] and Roberts et al.[19]

Table 3. Clinical Characteristics of the Patients with Peripartum Cardiomyopathy in the IPAC Study, According to Variant Status.*

Characteristic	No Truncating Variant (N=68)	*TTN* Truncating Variant (N=11)	P Value
Age — yr	30±6	28±6	0.25
No. of pregnancies	2.8±1.9	2.9±2.3	0.84
No. of births	2.1±1.2	2.1±1.5	0.92
Family history of cardiomyopathy — no. (%)	7 (10)	1 (9)	1.00
Hypertension — no. (%)	35 (51)	1 (9)	0.009
Twin gestation — no. (%)	15 (22)	1 (9)	0.45
Ejection fraction — %			
At enrollment	35±9	30±12	0.14
At 1 yr	54±8	44±17	0.005†

* Plus–minus values are means ±SD.
† P=0.04 by the Wilcoxon rank-sum test.

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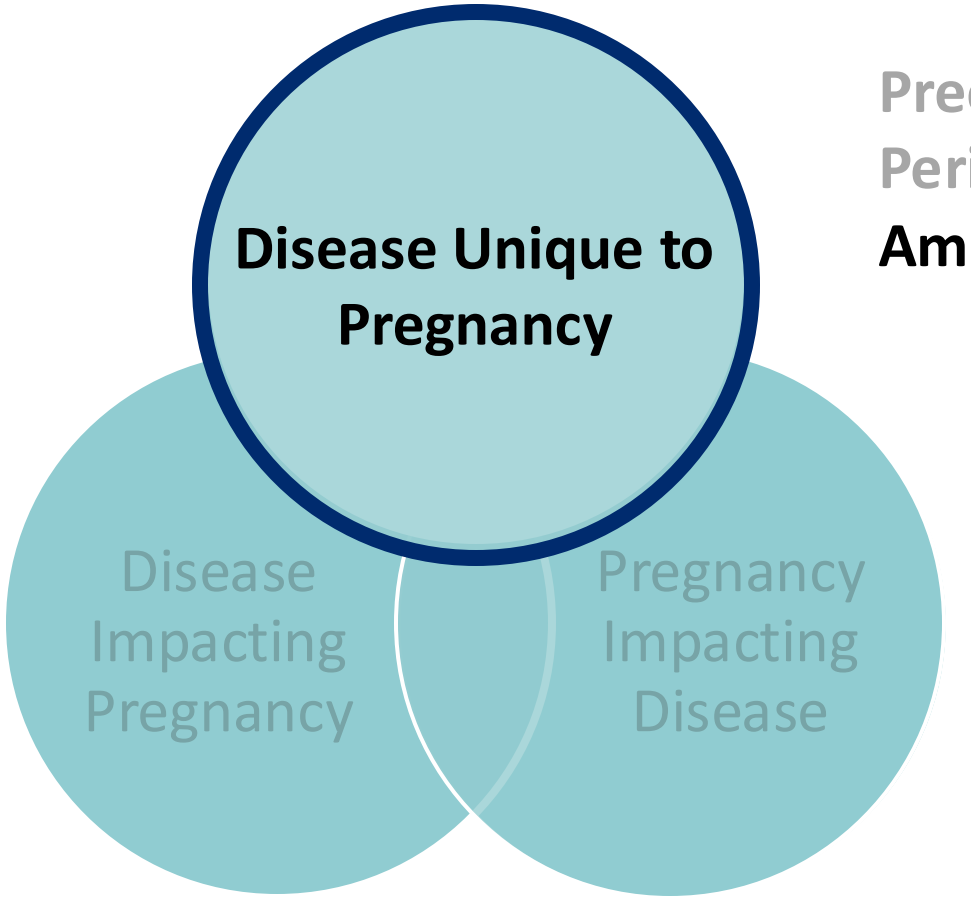
Differential Diagnosis in Pregnancy



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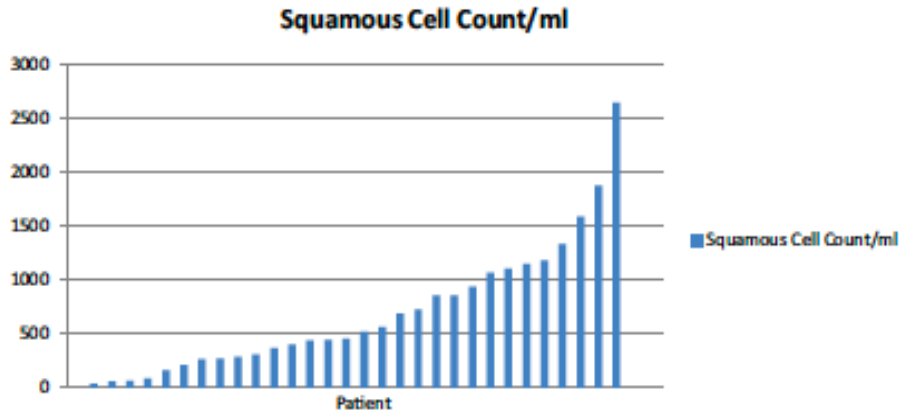
Understanding Amniotic Fluid Embolism

Research Letters

Pulmonary vascular obstruction by squamous cells is not involved in amniotic fluid embolism

FIGURE
Distribution of amniotic fluid squamous cell counts



Funk. Pulmonary vascular obstruction not involved in amniotic fluid embolism. AM J Obstet Gynecol 2018.

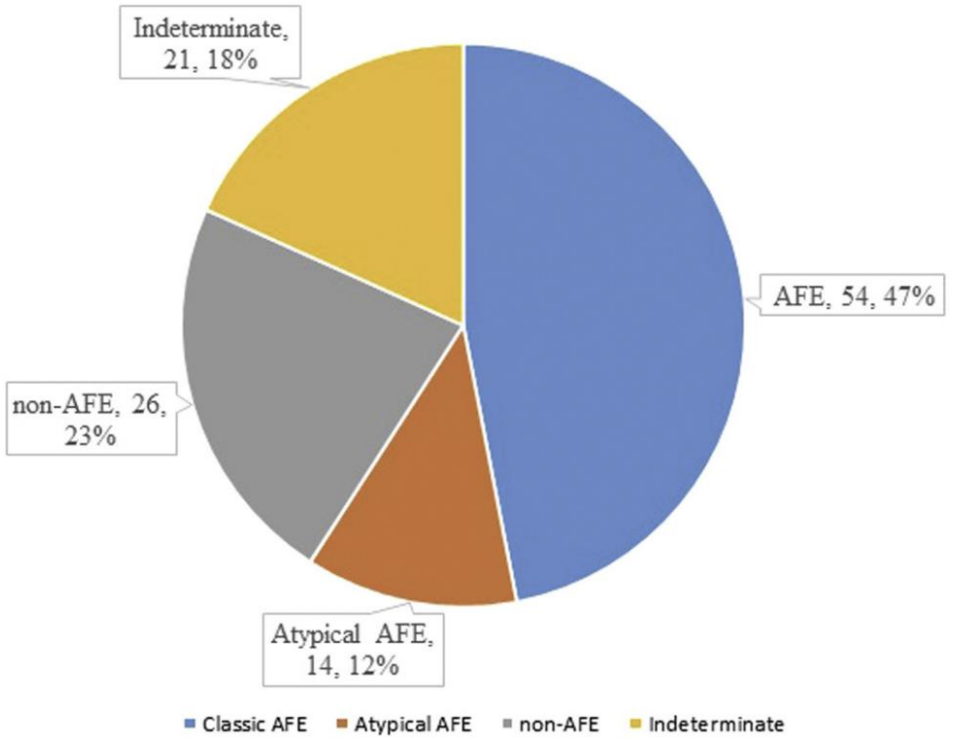
"…even if the entire volume of amniotic fluid were transferred into the maternal central circulation (1000 mL) and each individual squamous cell obstructed a unique pulmonary alveolar capillary, such blockage would result in obstruction of less than 1 in 1 million pulmonary capillary segments, having a potential impact on <0.1% of alveolar units"

…also known as Anaphylactoid Syndrome of Pregnancy

Diagnostic Criteria for Amniotic Fluid Embolism

1. Sudden onset of cardiorespiratory arrest OR hypotension with evidence of respiratory compromise.
2. Documentation of overt DIC prior to hemorrhage to exclude hemorrhage-related coagulopathy.
3. Clinical onset during labor or within 30 minutes of placental delivery.
4. Absence of fever (≥38°C) during labor.

FIGURE
Amniotic fluid embolism classification by diagnostic criteria



Stafford. Research reporting of amniotic fluid embolism. Am J Obstet Gynecol 2019.

Pathophysiology of Amniotic Fluid Embolism

Inciting event

Acute bolus of allogenic material

Tissue factor & endothelin

Acute pulmonary hypertension

Increase in pulmonary vascular resistance

Right ventricular failure

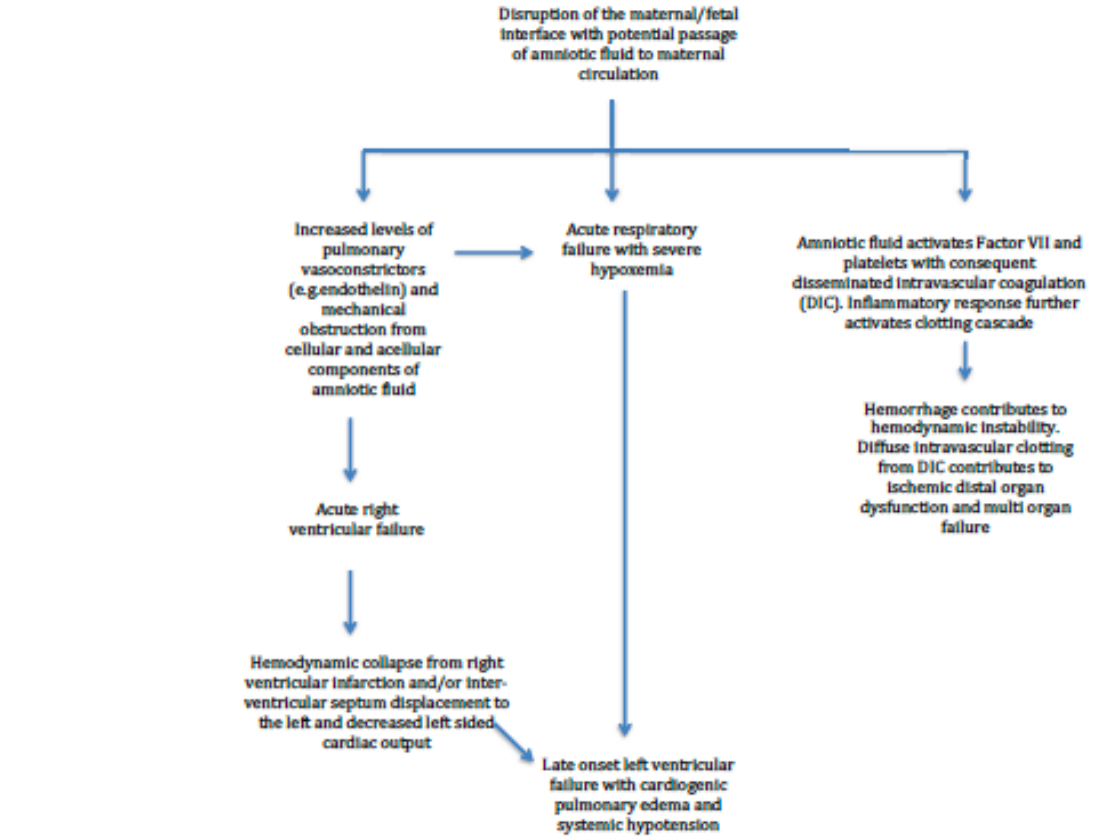
Consumptive coagulopathy

Activation of factor VII and platelets

Microvascular injury from DIC

FIGURE 1

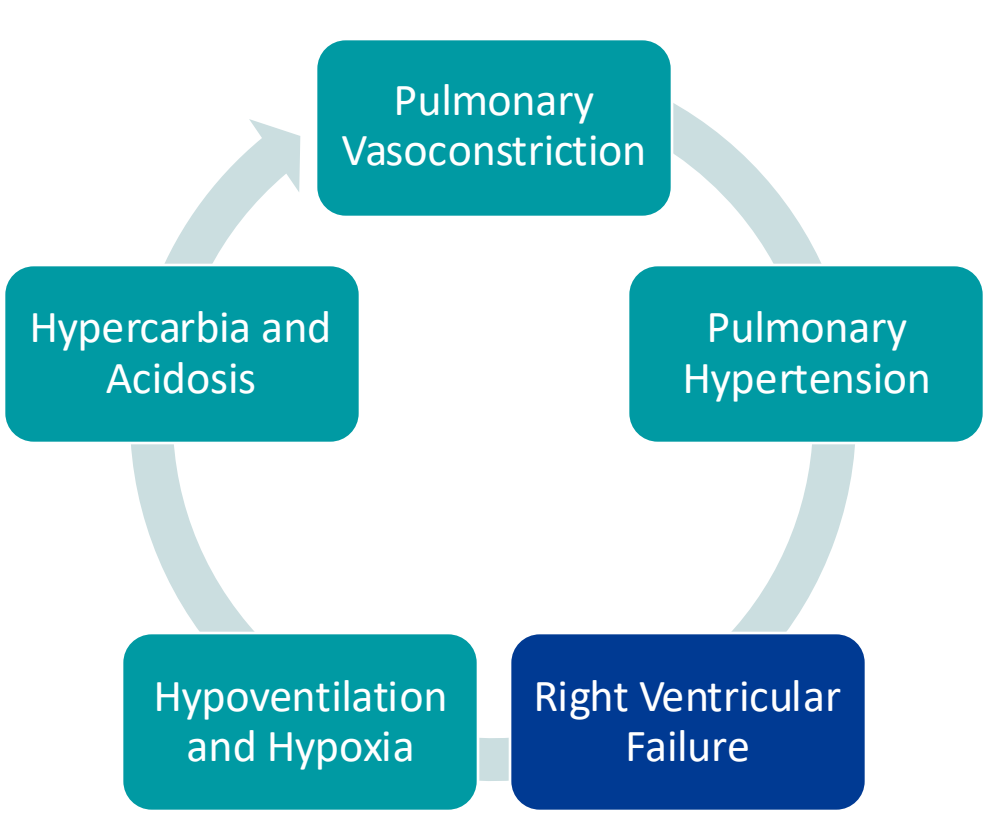
Proposed pathophysiology of amniotic fluid embolism

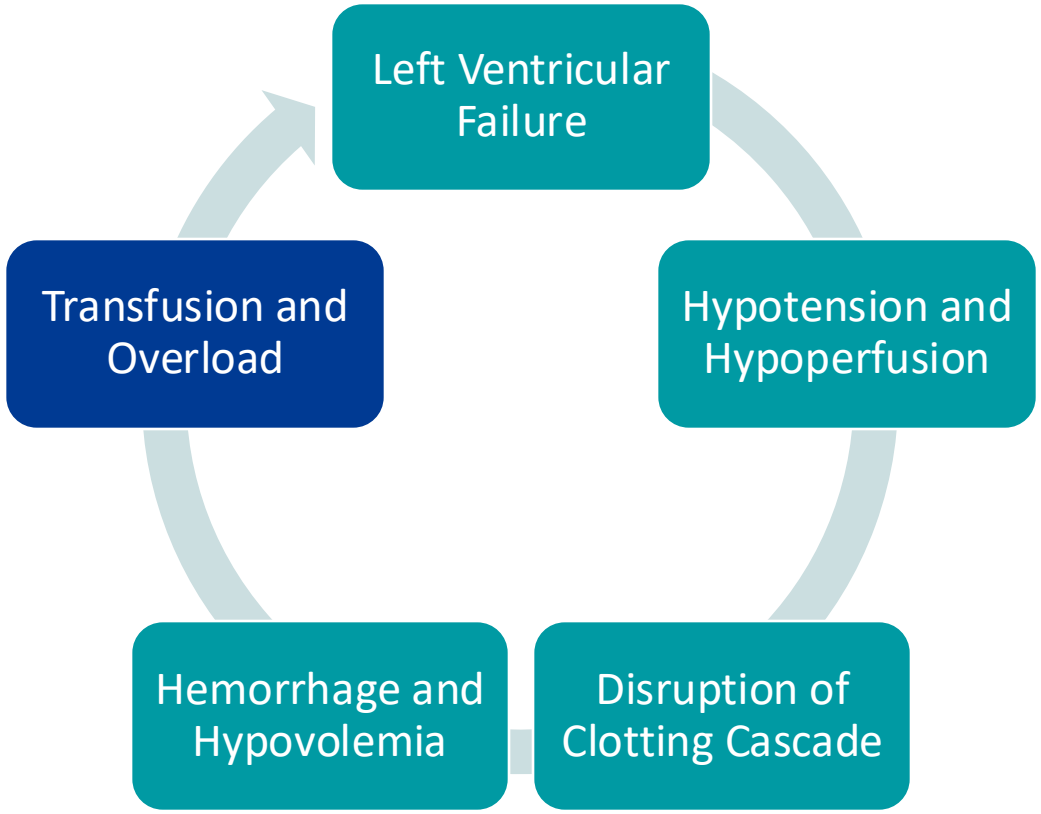


DIC, disseminated intravascular coagulation.

SMFM. Amniotic fluid embolism: diagnosis and management. Am J Obstet Gynecol 2016.

Biventricular Circulation



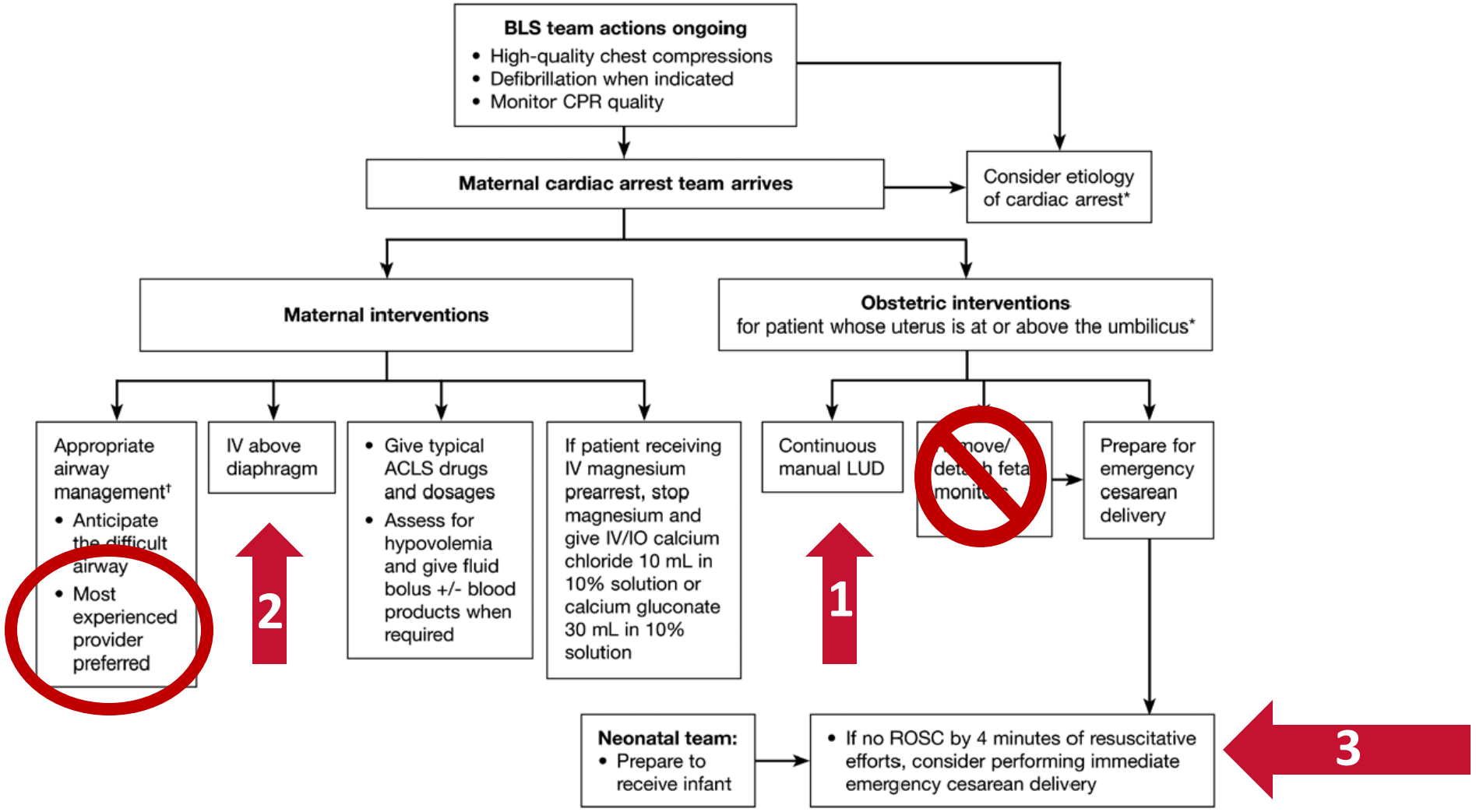


Coordinated Critical Care

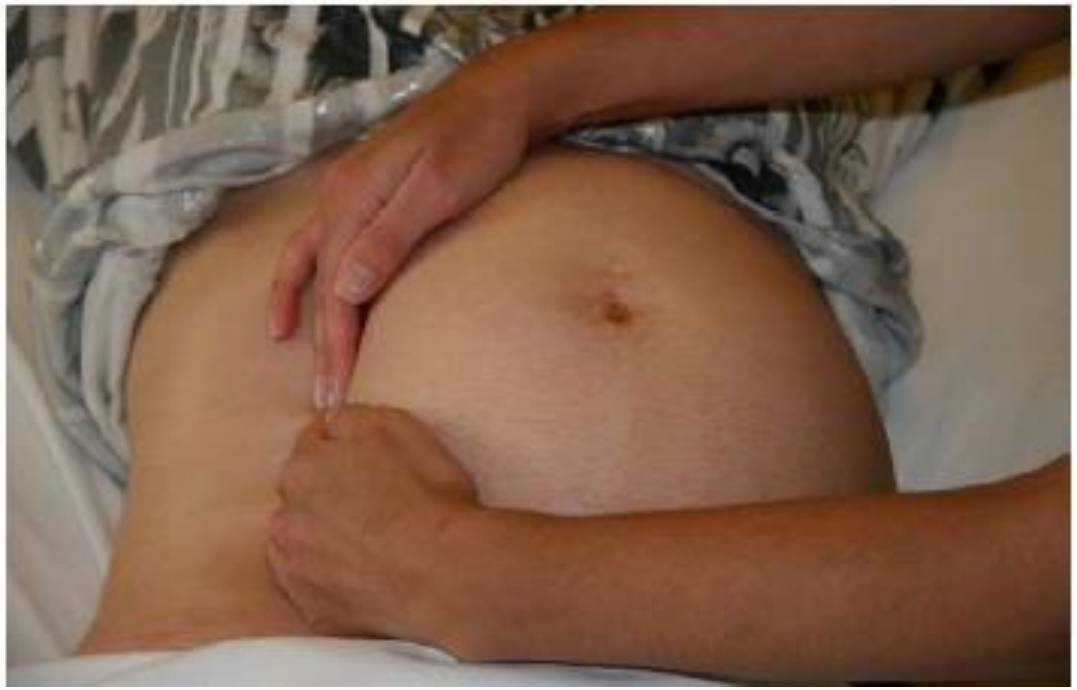
	First Five Minutes	5-10 Minute Update	20-30 Minute Huddle
Cardiac	Norephinephrine 5-20 mcg/kg/min Order echocardiogram	Echo for RV failure and volume Ensure adequate access Review differential diagnosis	Reassess volume status Optimize inotropes Update on cardiac status
	Place arterial line (femoral v. radial) Place central line (right IJ v. femoral)	Start dobutamine or milrinone Call for mechanical support	Address other causes Initiate mechanical support
Pulmonary	Establish airway (intubate)	Optimize PEEP Target pCO_2 <40	Monitor acid base status Correct acidosis
	Initiate PEEP 10-15	Inhaled pulmonary vasodilator	Renal replacement therapy
Hematologic	Activate hemorrhage protocol	Tranexamic acid 1 gm IV Ensure labs in process Surgical plan for hemorrhage	Replete calcium (1 gm calcium gluconate / 5 units) Update on hemostasis
	Call additional surgical support	Start balanced transfusion	Consider hysterectomy if ongoing bleeding

Use ACLS algorithm first in cases of cardiac arrest
Ensure these interventions completed at this time
Consider these interventions, readdress at next check point

ACLS in Pregnancy



Address Aortocaval Compression



Modifications to ACLS Guidelines

1) Provide manual left uterine displacement
2) Place IV above diaphragm
3) Anticipate difficult airway
4) Remove fetal monitors
5) Resuscitative delivery at 4 minutes

Perform **Resuscitative Delivery**

- ✓ Make incision at second pulse check
- ✓ No transport, anesthesia, or skin prep
- ✓ Vertical skin incision
- ✓ Vertical hysterotomy if not experienced
- ✓ Prepare (and hope) for bleeding

DOI: 10.1111/tog.12493 2018;20:151–158 Review
The Obstetrician & Gynaecologist
http://onlinetog.org

Perimortem caesarean section – why, when and how

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Table 2
Logistic regression analysis of variables potentially predictive of maternal survival.

Variable	*n*	Univariable		Multivariable	
		OR (95%CI)	*p*-Value	OR (95%CI)	*p*-Value
Witnessed arrest	84/87	2.80 (0.24–32.10)	0.408	Not in model	
In-hospital arrest location	63/90	6.14 (2.23–16.88)	<0.001	7.42 (1.32–41.60)	0.023
Presenting rhythm (alternative models)					
VT/VF	23/83	1.25 (0.46–3.40)	0.662	Not in model	
PEA	72/83	7.56 (0.92–62.23)	0.060	13.1 (0.95–178)	0.54
Not asystole	59/83	1.95 (0.74–5.12)	0.175	Not in model	
Time from arrest to PMCD (alternative models)					
Yes, at any time	57/57	1.146 (1.06–1.24)	0.001	Not in model	
Within <5 min	4/57	3.625 (0.35–37.14)	0.278	Not in model	
Within <10 min	18/57	11.25 (2.74–46.26)	0.001	5.17 (1.06–25.15)	0.042
Within <15 min	32/57	8.80 (5.57–30.18)	0.001	Not in model	
Gestational age <28 weeks	16/85	1.28 (0.42–3.92)	0.663	Not in model	
Gestational age <30 weeks	20/85	1.135 (0.41–3.15)	0.808	Not in model	

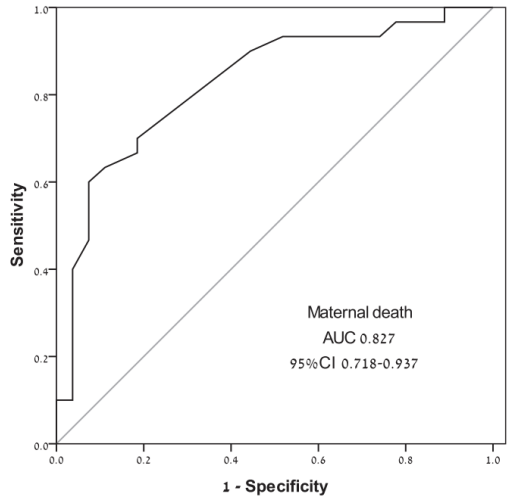
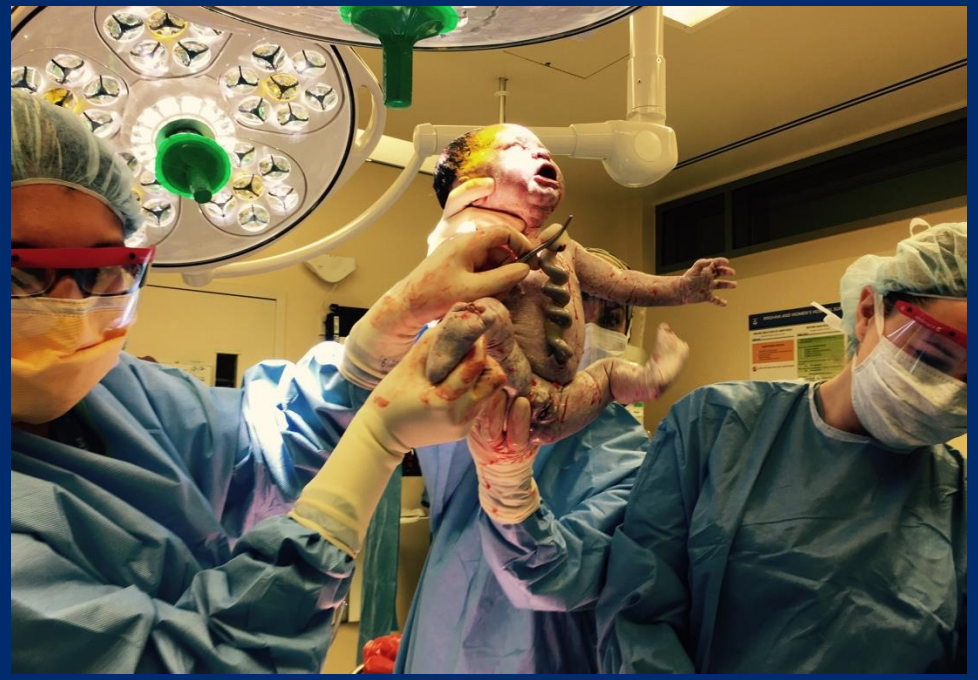


Fig. 3. ROC for predicting maternal death by time from arrest to delivery ($n = 57$). The area under the ROC curve was 0.827 (95%CI 0.718–0.937).

A New End-Organ in Cardiac Arrest

Target < 60 Seconds



Target < 5 Minutes

Preparing for the First Five

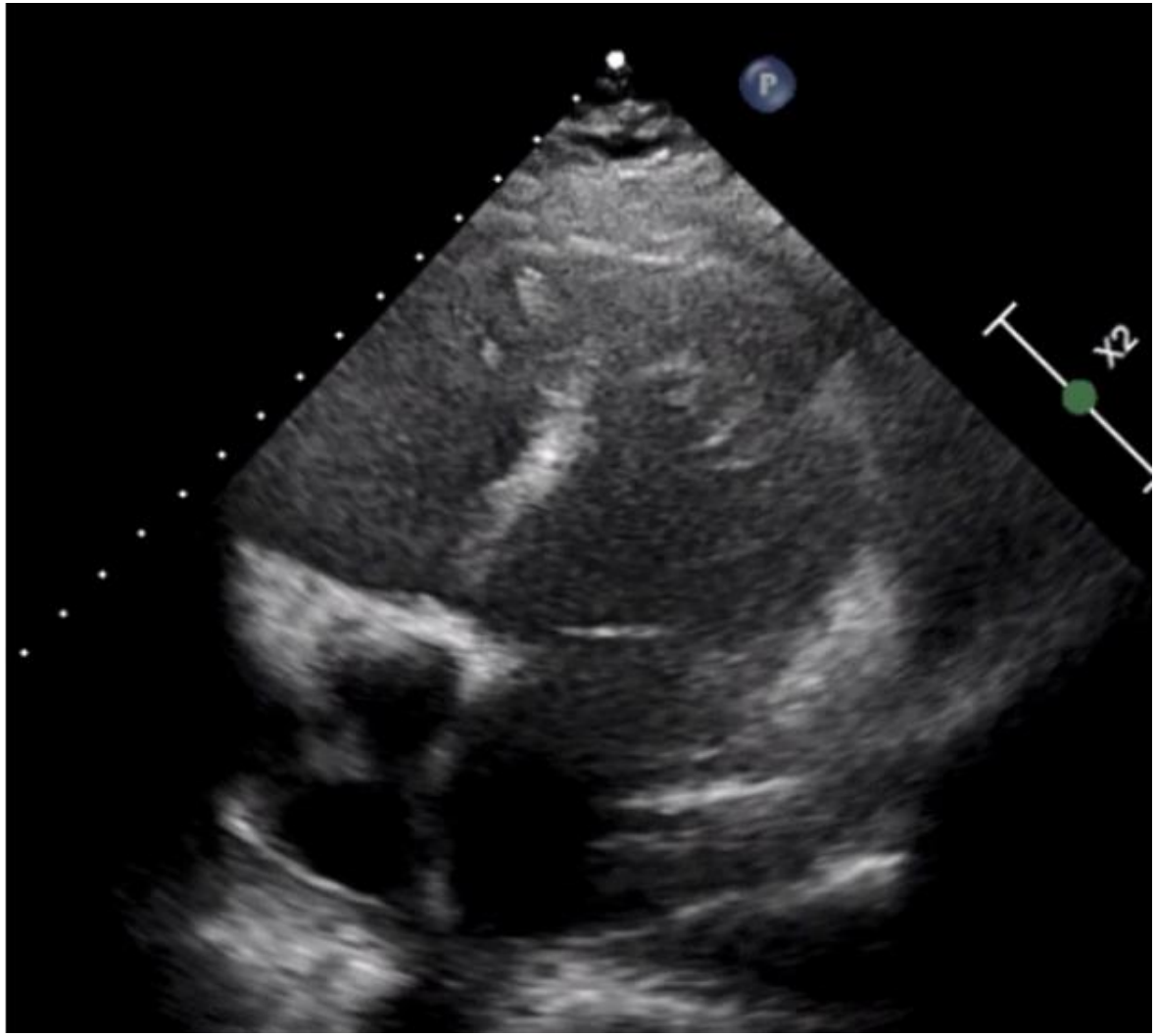
1. **Obstetrics Team**
   - Delivery kit at bedside (scalpel)
   - Hemorrhage medications
   - Uterine tamponade device
   - Temporary closure device
2. **Neonatal ICU Team**
   - Neonatal warmer
   - Neonatal code cart
3. **OB Anesthesia Team**
4. **Critical Care Team**
   - Emergency notification process
   - Key modifications

5. **ECMO or ECLS team**

Inclusion Criteria for ECPR
Age < 70 years
Witnessed arrest
Arrest to first CPR < 5 minutes
Arrest to ECMO flow < 60 minutes
Initial rhythm of VF/pVT/PEA
$EtCO_2$ > 10 mmHg during CCPR
Intermittent ROSC or recurrent VF
“Signs of life” during CCPR
No known aortic valve incompetence
No known life-limiting comorbidities or conflict with goals of care

What did we recommend?

a) Diuresis with IV furosemide
b) Initiation of digoxin
c) Amiodarone
d) Preparation for delivery
e) Electrical cardioversion



33 yo G3P1011 at 30 weeks 4 days with dyspnea

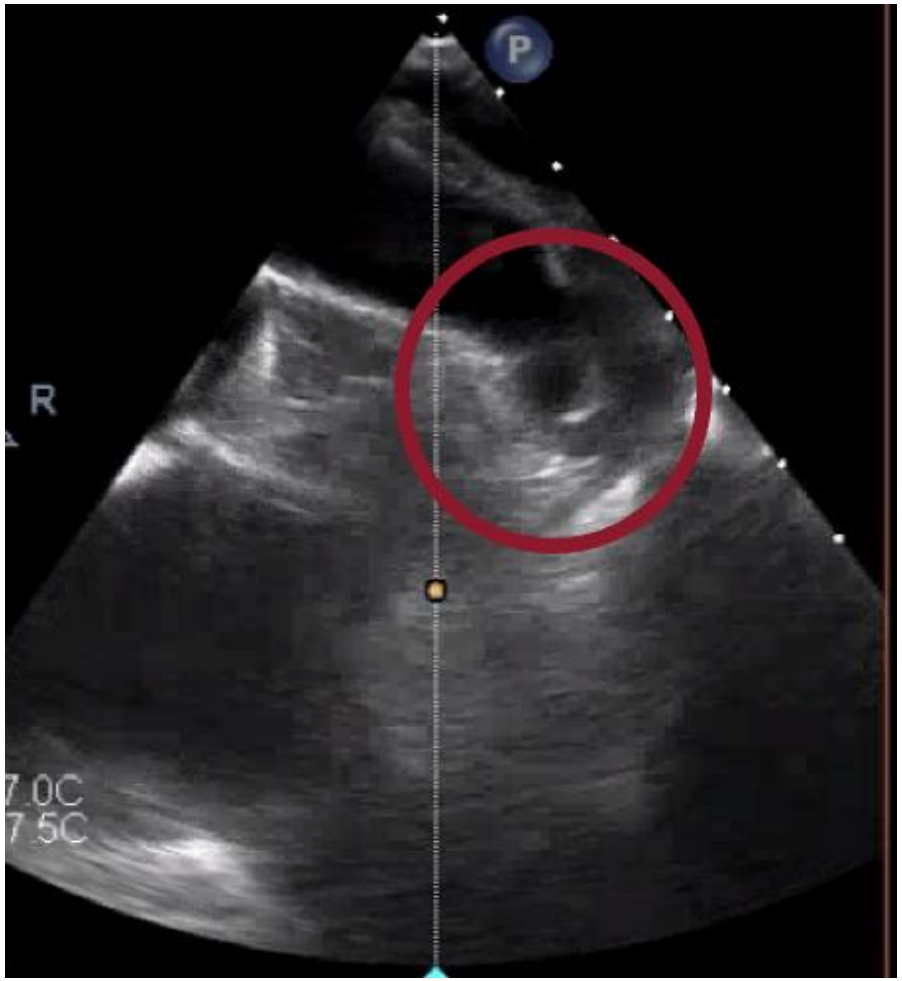
Intubated and sedated with continuous fetal monitoring for TEE with attempted cardioversion

TEE unable to exclude thrombus in left atrial appendage so evaluated with CT

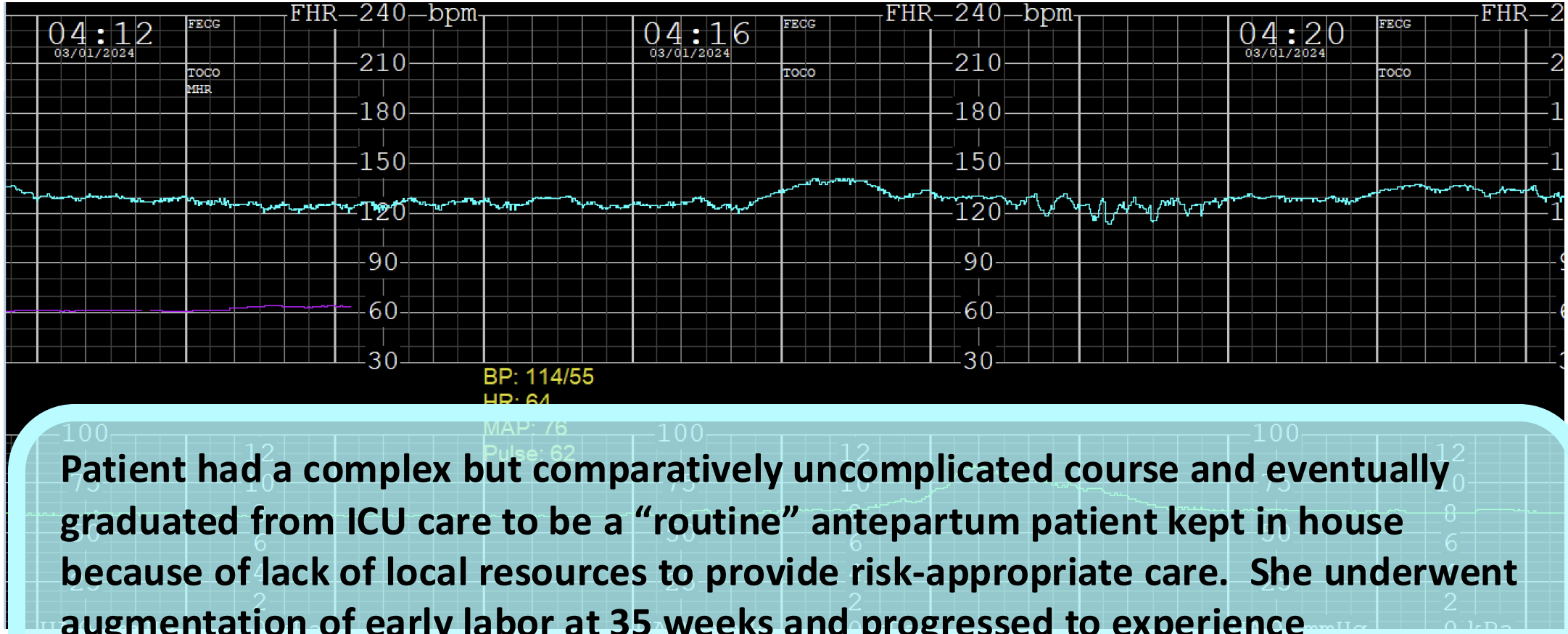
Maintained on milrinone and furosemide infusions while awaiting imaging for inotropic support

Attempted synchronized cardioversion with on labor and delivery successful but not sustained

Loaded with amiodarone with plan to attempt DCCV in 24-48 hours but converted to sinus rhythm in interim

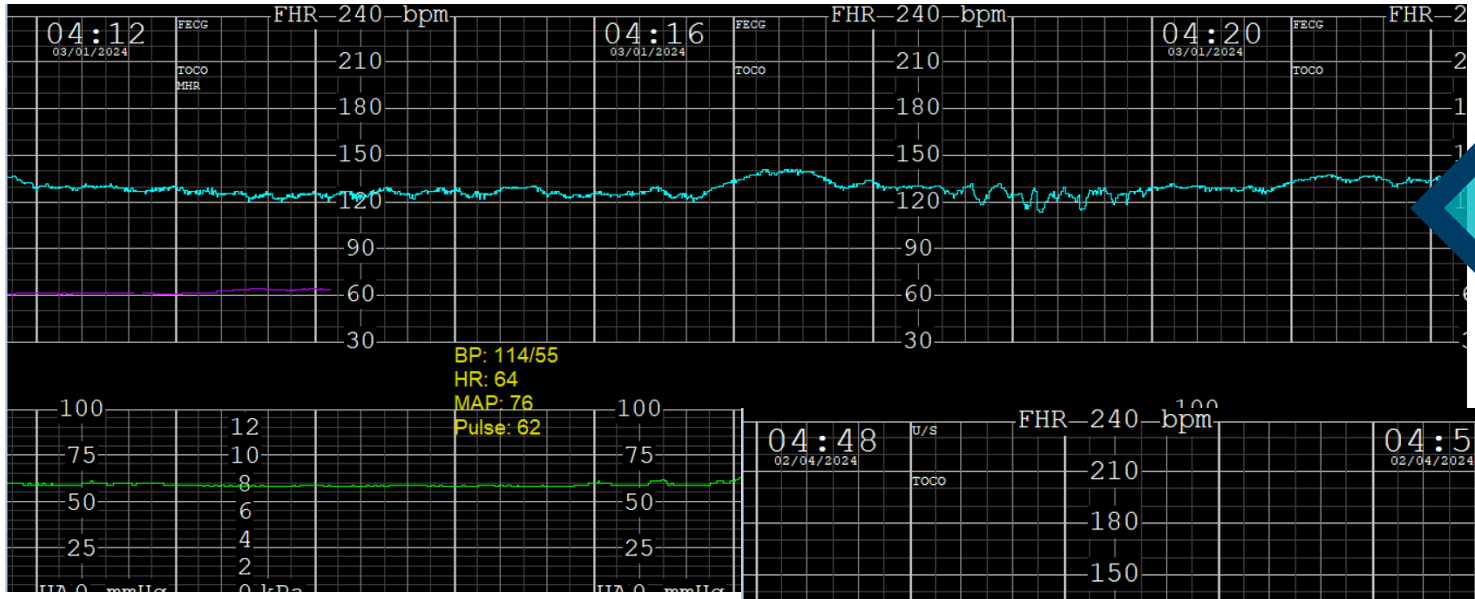


33 yo G3P1011 at 35 weeks 0 days in labor

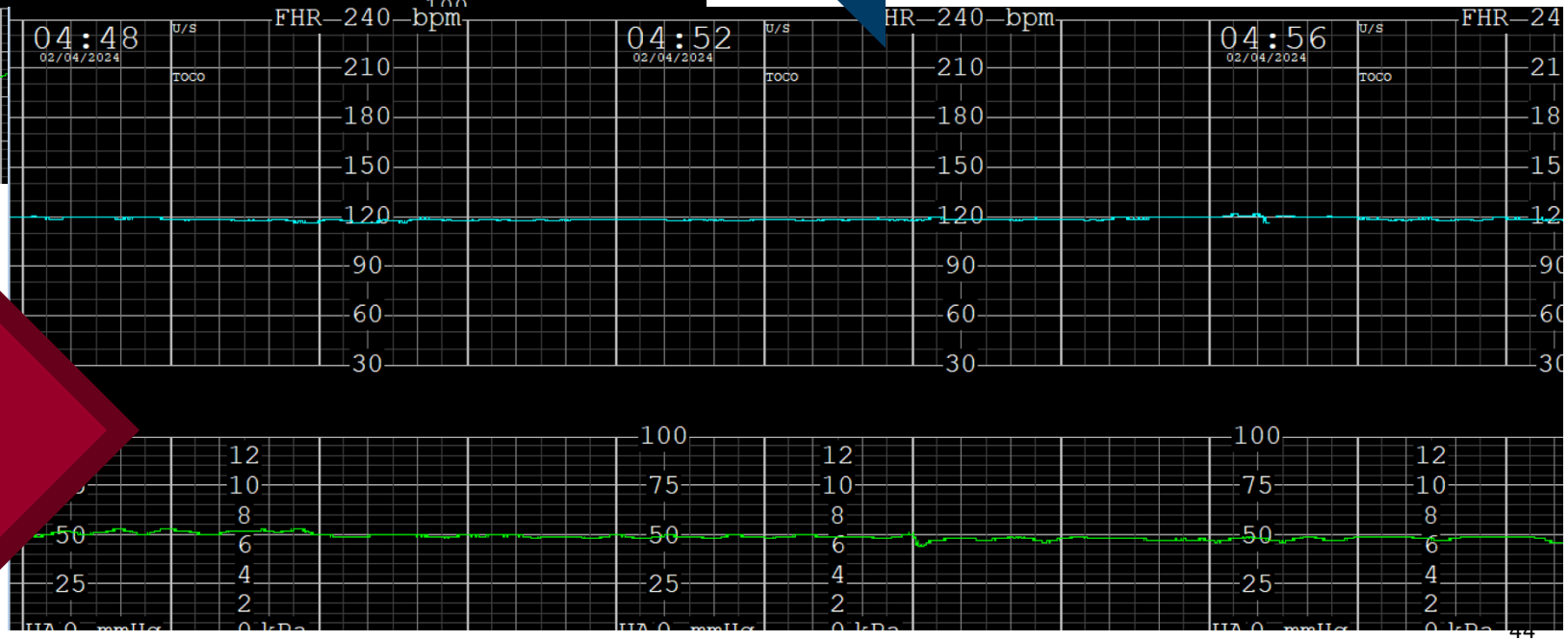


Patient had a complex but comparatively uncomplicated course and eventually graduated from ICU care to be a "routine" antepartum patient kept in house because of lack of local resources to provide risk-appropriate care. She underwent augmentation of early labor at 35 weeks and progressed to experience uncomplicated vaginal birth. She had a routine postpartum course and her daughter spent 48 hours in the NICU per unit policy at this gestational age.

Every medication is safe in pregnancy if it is in the best interest of the pregnant person…



Fetal status at delivery on amiodarone, furosemide, metoprolol, and IV heparin to optimize cardiac output



Fetal status at admission on diltiazem, enoxaparin, and furosemide and in cardiogenic shock

Take Home Messages

- Critically-ill pregnant people should be offered the standard of care with modifications to address physiology—not fetal safety.
- Optimizing hemodynamics is an essential step in management of all diseases—even if the ultimate plan is delivery.
- Addressing obstetric emergencies involves integrating fundamentals of critical care with timely, coordinated, multidisciplinary teamwork.

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