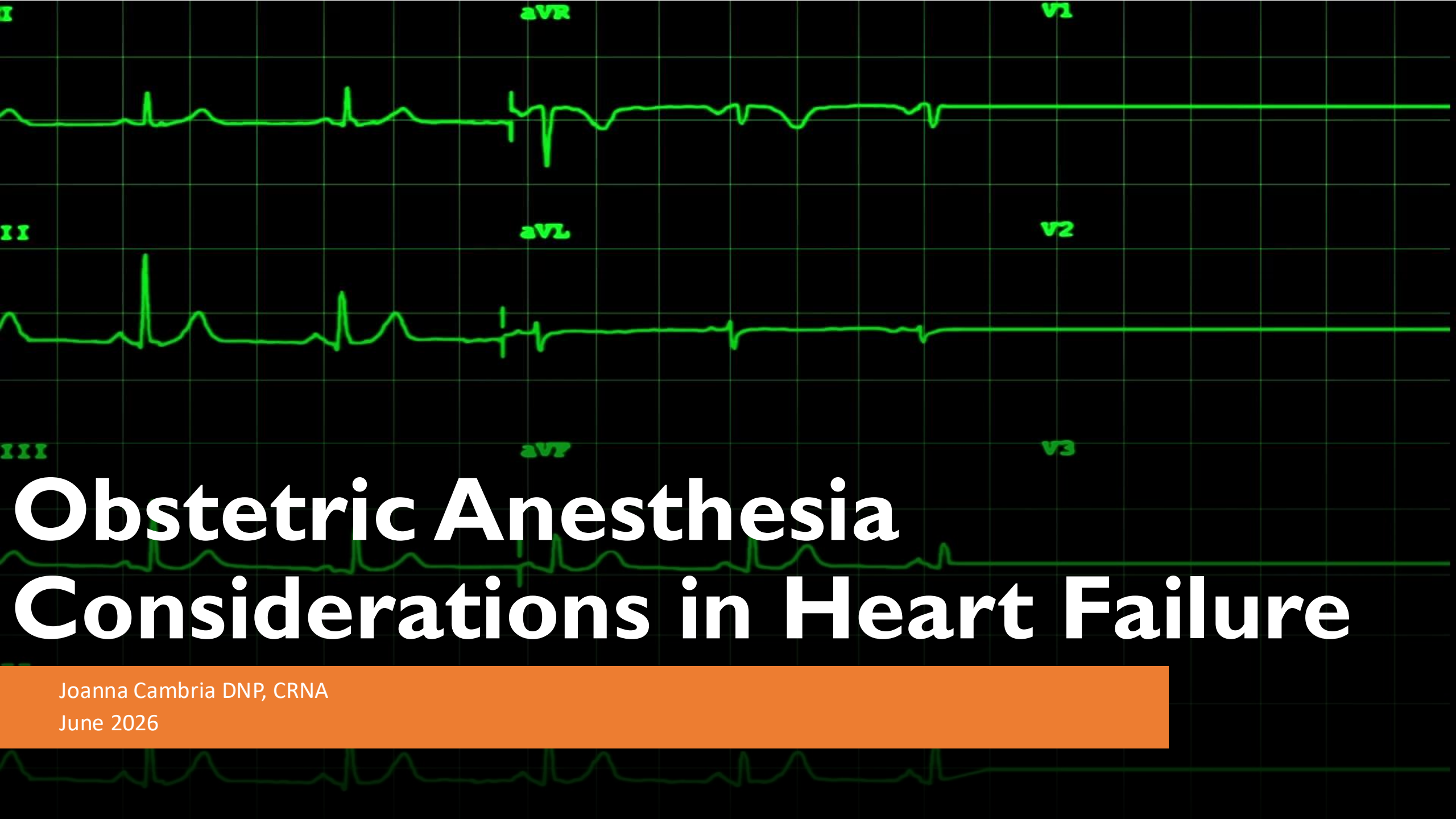

Obstetric Anesthesia Considerations in Heart Failure

Joanna Cambria DNP, CRNA

June 2026

Sarah

25 y/o G2P1
Dx PPCM during 2nd pregnancy
1st misdx as PNA
PP decompensation to LVEF 5%
LVAD → TIA
Heart transplant

"A lot of times, when you hear the words 'heart failure,' you think of the elderly.
As a healthy 25-year-old, never did I expect to hear those two words. And never did I ever expect to hear those two words while pregnant with my second."

https://transplantliving.org/stories/i-only-had-a-2-chance/
https://expectinghearts.com/sarahs-story

Objectives:

- Current Data on Maternal Mortality
- Peripartum Hemodynamics Review
- Maternal Cardiac Risk Scoring Systems & Heart Failure Identification Tools
- Heart Failure from Preeclampsia & Peripartum Cardiomyopathy
- Delivery Management Considerations in:
  - Heart Failure
  - Pulmonary Edema

Objectives:

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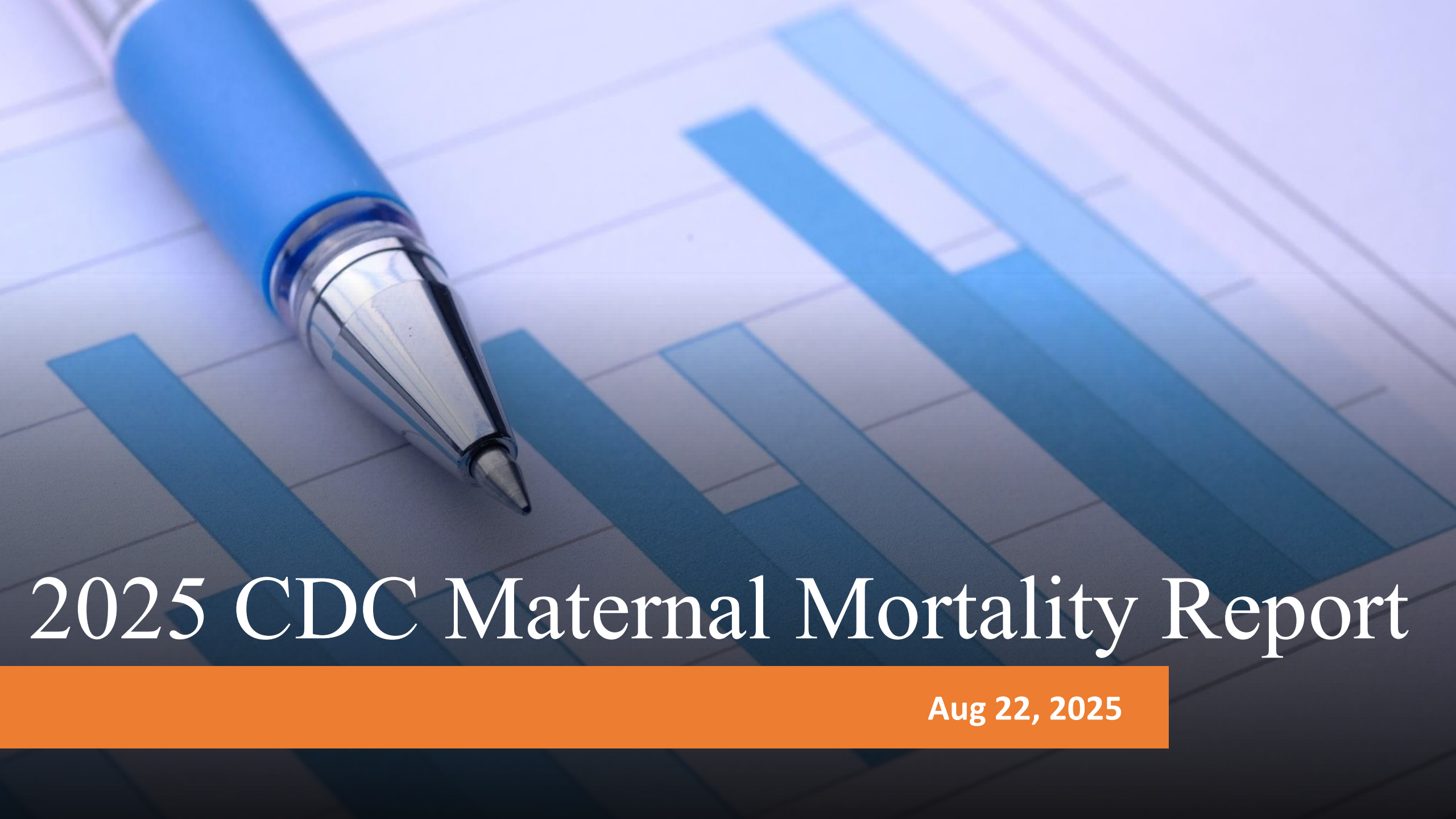

2025 CDC Maternal Mortality Report

Aug 22, 2025

MMRC = Maternal Mortality Review Committee

Among pregnancy-related deaths in 2022, MMRCs determined 94% to be preventable. ($^{768}/_{817}$)

Cardiac disease was 2nd leading cause of Pregnancy-Related Death (PRD) (16.4%)[1]

1. Maternal Mortality Prevention, CDC, 2025

CDC 2025 Maternal Mortality Report

Among CV-related deaths:

- **Cardiomyopathy caused 42%, and 6.9% total PRD**
- **Other CV conditions caused 58%, and 9.7% total PRD**
  - CAD, pulm HTN, acquired & congenital valvular heart dx, vascular aneurysm, CHTN, Marfan dx, conduction defects, vascular malformations, and other CV dx

- ***HTN d/o of pregnancy*** was 6th leading cause of PRD, at **5.1%**

1. Maternal Mortality Prevention, CDC, 2025

CDC 2025 Maternal Mortality Report

Timing of PRD in 2022

Conditions unique to pregnancy	Percentage	Count
During pregnancy	20.9	169
Day of delivery	11.2	90
1–6 days postpartum	9.5	77
7–42 days postpartum	20.6	166
43–365 days postpartum	37.8	305

Among pregnancy-related deaths in 2022:
67.9% occurred postpartum, and **58.4% occurred 7–365 days postpartum (PP).**

1. Maternal Mortality Prevention, CDC, 2025

Objectives:

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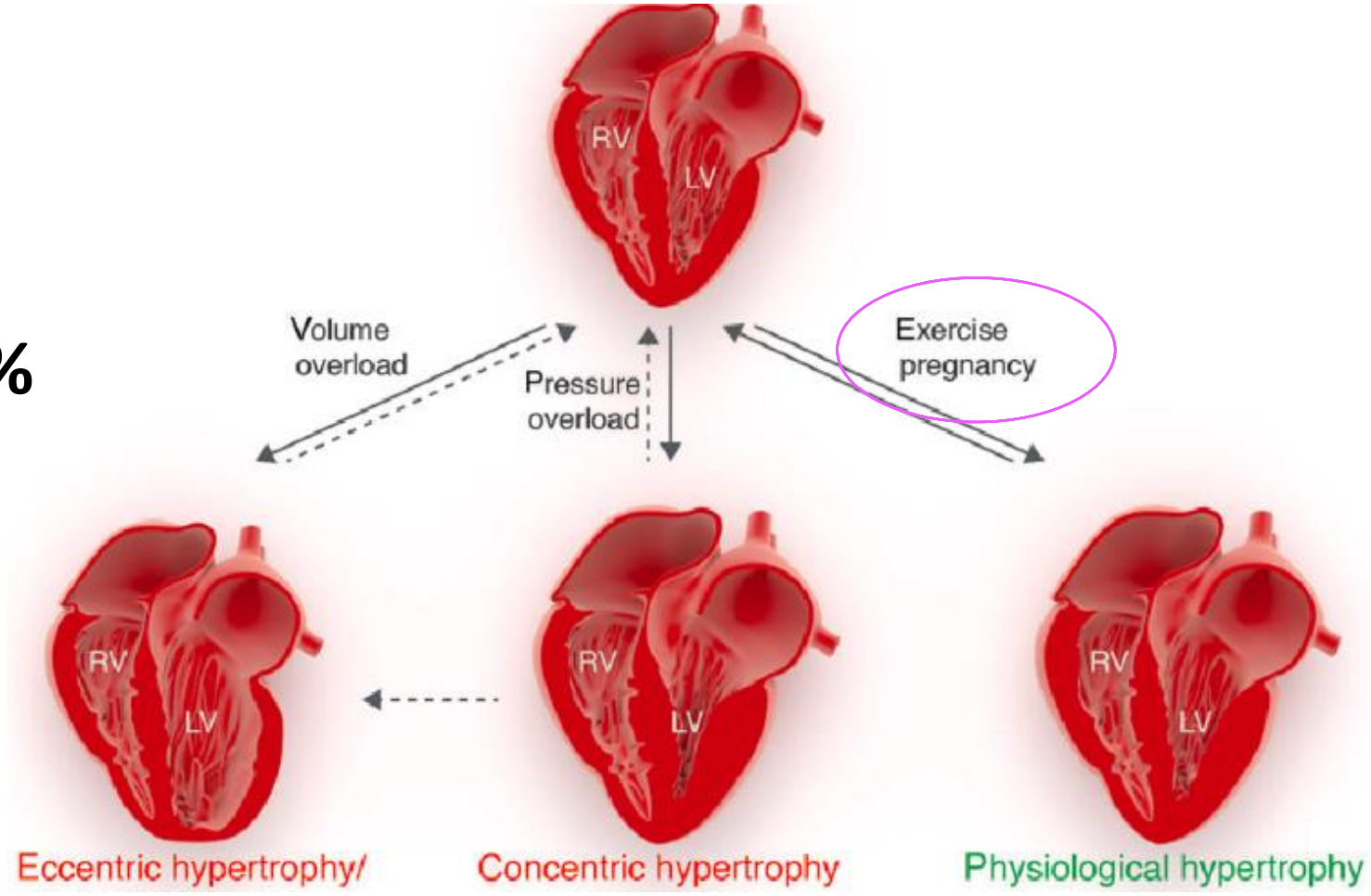
Normal Peripartum Myocardial Remodeling

- **LV wall thickness ↑ 28%**
- **LV mass ↑ 52%**
- **RV mass ↑ 40%**

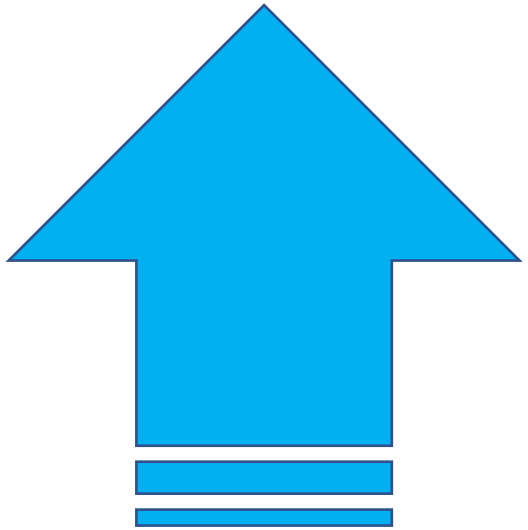


https://www.semanticscholar.org/paper/Pregnancy-as-a-cardiac-stress-model.-Chung-Leinwand/cc0a22da784799b4682cc6befa7937516a76272c

2. Sanghavi & Rutherford, Circulation, 2014.

CO is highest **during labor and immediately after delivery**

- Increases 60 - 80% above pre-labor levels



2. Sanghavi & Rutherford, Circulation, 2014

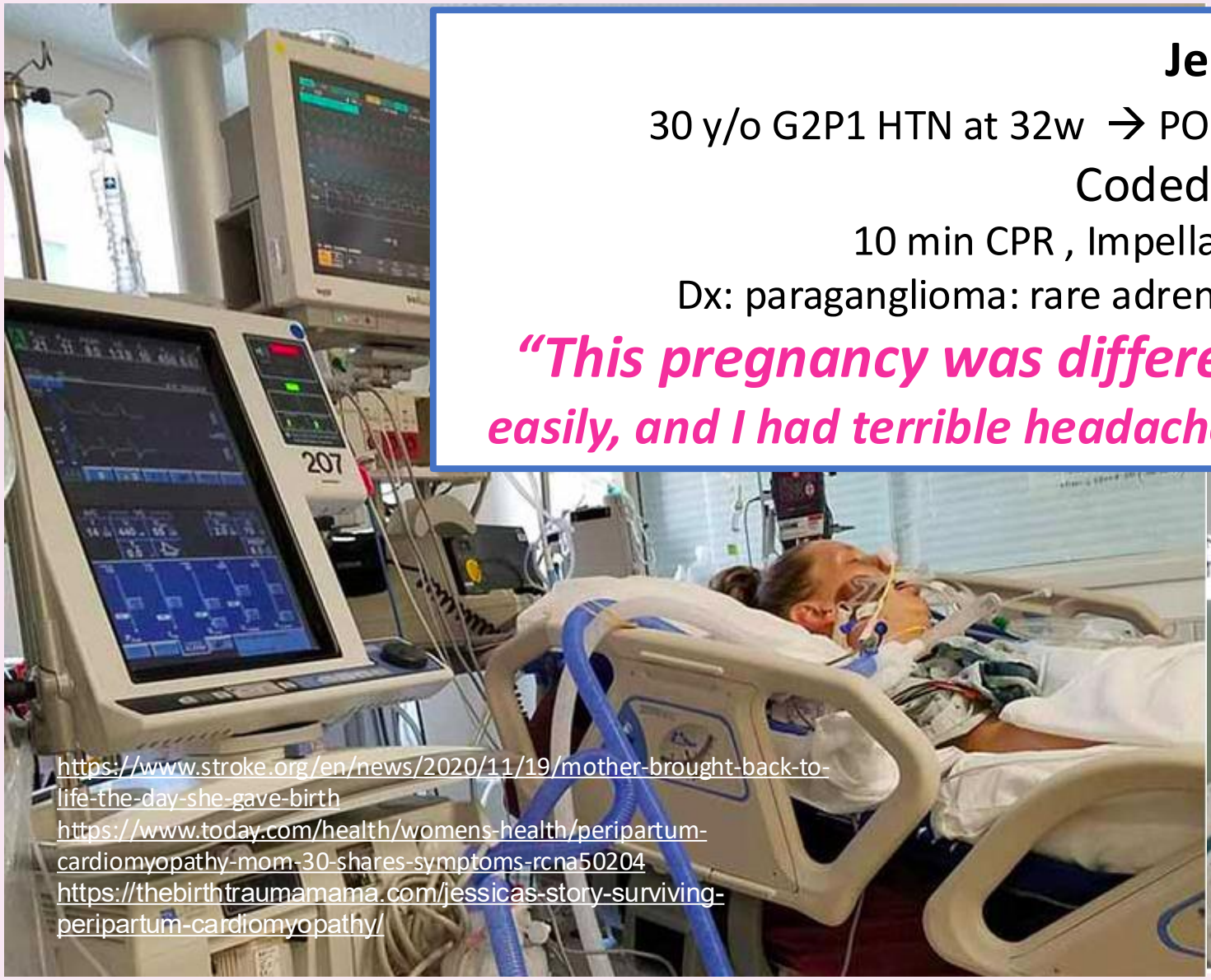
Immediately on Delivery:

- **Increased preload:**
  1) Gravid uterus offloaded from great vessels
  2) Auto-Transfusion from uterine involution
     - On delivery: ~ 500-750cc
       - Can be HUGE stress on failing heart
     - Also occurs during labor cxns, but smaller volume
       - ~ 300-500cc with each cxn

- CO, HR, SV remain significantly elevated for first few days postpartum to accommodate IV fluid shifts.[3]

2. Sanghavi & Rutherford, *Circulation*, 2014
3. Meng ML, Arendt KW, *Anesthesiology*, 2021

The sudden ↑ in preload & C.O. **on delivery/PP** can overwhelm a failing ventricle



Jessica

30 y/o G2P1 HTN at 32w → PO Anti-HTN, IOL 37wk → Breech c/s.

Coded in PACU.

10 min CPR , Impella, then ECMO for 2 wks.

Dx: paraganglioma: rare adrenal tumor likely contributed to HF.

"This pregnancy was different. I was more tired, I got winded easily, and I had terrible headaches when I would lay down at night."

https://www.stroke.org/en/news/2020/11/19/mother-brought-back-to-life-the-day-she-gave-birth
https://www.today.com/health/womens-health/peripartum-cardiomyopathy-mom-30-shares-symptoms-rcna50204
https://thebirthtraumamama.com/jessicas-story-surviving-peripartum-cardiomyopathy/

Objectives:

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Current Maternal Cardiac Risk Scoring Systems

- **mWHO**
- **CARPREG II**
- **ZAHARA**

mWHO

Modified World Health Organization

Classification of Maternal Cardiovascular Risk

Table 2: Modified World Health Organization (WHO) Classification of Maternal Cardiovascular Risk: Application

WHO Pregnancy Risk Classification (Risk of pregnancy by medical condition)	**Cardiovascular Conditions by WHO Risk Class**

WHO Risk Class I
No detectable increased risk of maternal mortality and no or mild increase in morbidity.
	• Uncomplicated, small or mild
	  ○ Pulmonary stenosis
	  ○ Patient ductus arteriosus
	  ○ Mitral valve prolapse
	• Successfully repaired simple lesions (atrial or ventricular septal defect, patent ductus arteriosus, anomalous pulmonary venous drainage).
	• Atrial or ventricular ectopic beats, isolated

WHO Risk Class II (If otherwise well and uncomplicated) *Small increased risk of maternal mortality or moderate increase in morbidity.*	• Unoperated atrial or ventricular septal defect • Repaired tetralogy of Fallot • Most arrhythmias
WHO Risk Class II or III (Depending on individual) *Risk as indicated in Class II (above) or Class III (below).*	• Mild left ventricular impairment • Hypertrophic cardiomyopathy • Native or tissue valvular heart disease not considered WHO I or IV • Marfan syndrome without aortic dilatation • Aorta <45 mm in aortic disease associated with bicuspid aortic valve • Repaired Coarctation
WHO Risk Class III *Significantly increased risk of maternal mortality or severe morbidity. Expert counseling required. If pregnancy is decided upon, intensive specialist cardiac and obstetric monitoring needed throughout pregnancy, childbirth and the puerperium.*	• Mechanical valve • Systemic right ventricle • Fontan circulation • Cyanotic heart disease (unrepaired) • Other complex congenital heart disease • Aortic dilatation 40-45 mm in Marfan Syndrome • Aortic dilatation 45-50 mm in aortic disease associated with bicuspid aortic valve
WHO Risk Class IV (Pregnancy contraindicated) *Extremely high risk of maternal mortality or severe morbidity; pregnancy contraindicated. If pregnancy occurs termination should be discussed. If pregnancy continues, care as for class III.*	• Pulmonary arterial hypertension of any cause • Severe systemic ventricular dysfunction (LVEF <30%, NYHA III-IV)* • Previous peripartum cardiomyopathy with any residual impairment of left ventricular function • Severe symptomatic mitral or aortic stenosis • Marfan syndrome with aorta dilated >45 mm • Aortic dilation >50 mm in aortic disease associated with bicuspid aortic valve • Native severe Coarctation

Cardiac Event Rate Based on mWHO classification

I:	2.5%-5%	No detectable increased risk of maternal mortality No or mild increased risk in morbidity
II:	5.7-10.5%	Small increased risk of maternal mortality Moderate increase in morbidity
II-III:	10%-19%	Intermediate increased risk of maternal mortality Moderate to severe increase in morbidity
III:	19%-27%	Significantly increased risk of maternal mortality Significant increase in severe morbidity
IV:	40%-100%	Extremely high risk of maternal mortality Extremely high risk of severe morbidity

5. Girnius A, Meng ML. *Journal of Cardiothoracic and Vascular Anesthesia*. 2021

ZAHARA & CARPREG II

Table 1: Clinical Factors Identified as Risks in the Current Scoring Tools

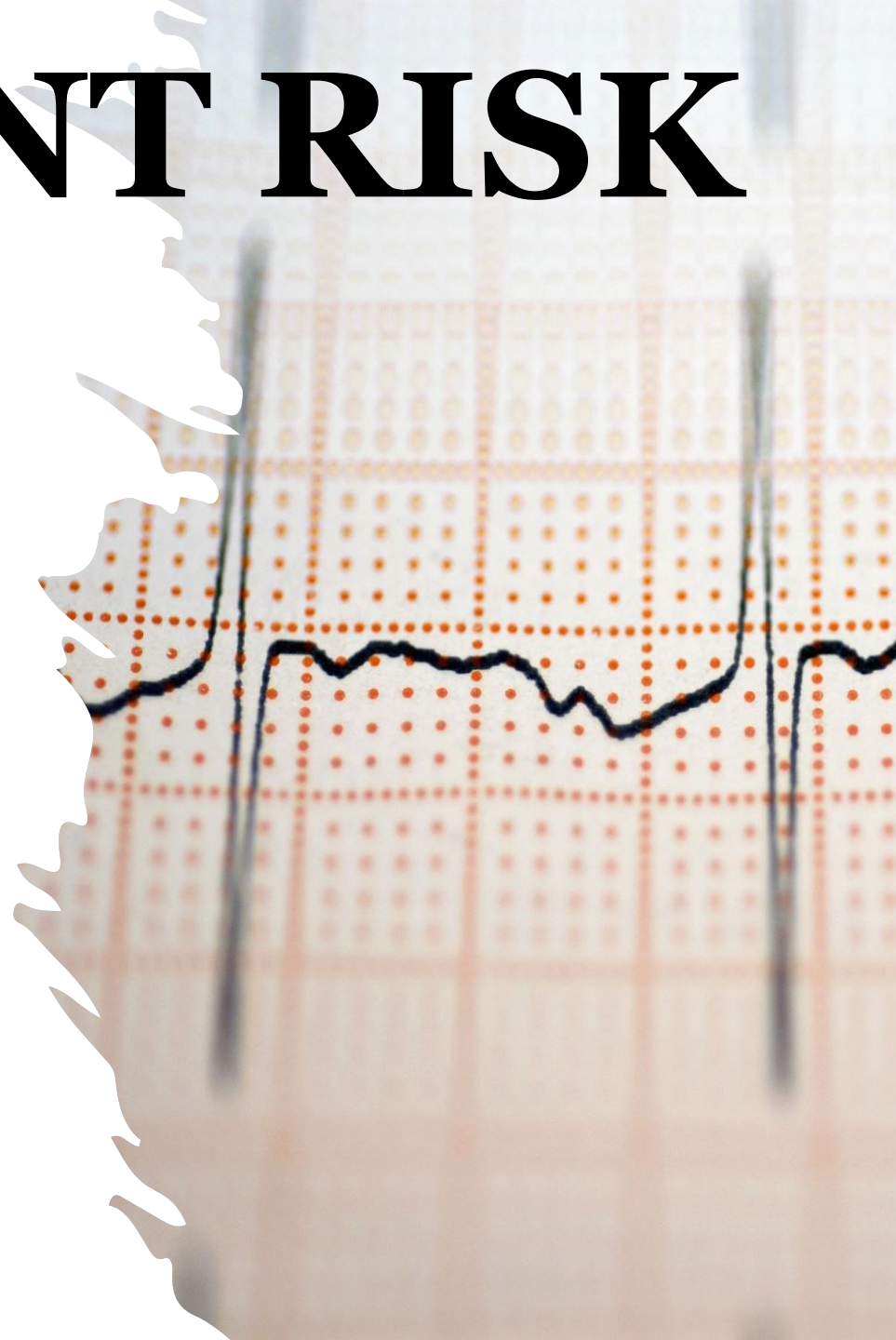
Current Scoring Tools	Points per Factor	Maternal Risk
CARPREG		
• Prior cardiac event (including arrhythmia) • NYHA III/IV or cyanosis • Systemic ventricular dysfunction (EF <40) • Left heart obstruction	1 for each factor	0 points – 5% 1 point – 27% >1 point – 75%
ZAHARA		
• Prior arrhythmia • NYHA III/IV • Left heart obstruction • Mechanical valve prosthesis (strongest weighed) • Cyanotic • Cardiac medication before pregnancy • Moderate/severe AVV regurgitation (systemic) • Moderate/severe AVV regurgitation (sub-pulmonary)	Arrhythmia – 1.5 Cardiac medication – 1.5 NYHA class – 0.75 Left heart obstruction – 2.5 Systemic AVVR – 0.75 Sub-pulmonary AVVR – 0.75 Mechanical valve – 4.25 Cyanosis – 1	>0.5 points – 2.9% 0.51–1.5 points – 7.5% 1.51–2.5 points – 17.5% 2.51–3.5 points – 43% >3.51 – 70%
CARPREG II		
• Prior cardiac event (including arrhythmia) • NYHA III/IV or cyanosis • Systemic ventricular dysfunction (EF <40) • Left heart obstruction • Mechanical valve prosthesis (strongest weighed) • Pulmonary hypertension	Prior event/arrhythmia – 3 NYHA III/IV/cyanosis – 3 Systemic EF <40 – 2 Left heart obstruction – 2 Mechanical valve – 2 Pulmonary hypertension – 2 Coronary artery disease – 2 High risk aortopathy – 2 No cardiac intervention – 1 Late presentation – 1	0–1 point – 5% 2 points – 10% 3 points – 15% 4 points – 22% >4 points – 41%

4. Kulasekaran & Swan, *US Cardiology Review*, 2023

CARDIAC EVENT RISK

Highest risk women are:

- Older
- Identify as Black or African American
- Acquire heart disease during pregnancy
- Have unrecognized cardiovascular disease and become pregnant



5. Girnius A, Meng ML. *Journal of Cardiothoracic and Vascular Anesthesia*. 2021

IDENTIFYING HEART FAILURE IN PREGNANCY

IDENTIFYING HEART FAILURE IN PREGNANCY

- Many symptoms of HF are vague and mimic normal pregnancy symptoms
  - eg: fatigue, SOB, peripheral edema
- Failure to recognize HF contributes significantly to maternal death.

3. Meng ML, Arendt KW. *Anesthesiology*. 2021

"Maternal Wellness Bias"

- Subconscious tendency to assume young, healthy-appearing pregnant women are well, even when S/Sx suggest otherwise.
  - Bias minimizes real medical conditions that can make pregnancy extremely high risk.
  - **Particularly worrisome in a progressively older and obese OB population**, where risks of severe maternal M&M are higher and compounded.
    - **Minimization of concerns voiced by the pt**, dismissal of abnormal VS & labs.
      - Eg: tachycardia often dismissed as "normal pregnancy", SOB attributed to "gravid uterus", postpartum fatigue accepted as "normal" rather than evaluated for possible sepsis or cardiomyopathy [42]

"Normalization of Deviance"

- Safety standards gradually erode over time after repeated encounters without negative outcomes
- Common in **OB** & Pedi, where abnormal outcomes are relatively infrequent and most pts *appear healthy*.
  - Eg: disregarding alarms, bypassing protocols, skipping checklists
    - Over time, unintentional denial, dismissal, & ultimately delays can lead to increased M&M
      - Compounded by unconscious biases toward marginalized populations, widening disparities in Dx & Tx
      - These cognitive traps **delay *recognition & escalation of care***, placing maternal & fetal outcomes at risk [42]

CDC: 94% of maternal deaths in 2022 were preventable[1]

IDENTIFYING HEART FAILURE IN PREGNANCY

ACOG Practice Bulletin No. 212 *Pregnancy and Heart Disease* contains a table of signs and symptoms which, if reported, require cardiac evaluation ASAP.

If (+): Low threshold to obtain further imaging: TTE, CXR, LUS, ECG

Vital Signs	Physical Exam Signs	History and Symptoms
Heart rate ≥ 120 beats/min	Jugular venous pressure visible 2 cm above clavicle at 45°	History of cardiovascular disease
Systolic blood pressure ≥ 160 mm Hg	Loud systolic murmur or S4	Shortness of breath at rest, paroxysmal nocturnal dyspnea, orthopnea, refractory pneumonia, or bilateral chest infiltrates on chest radiography
Symptomatic low blood pressure	Wheezing	Chest pain at rest or minimal exertion
Respiratory rate ≥ 25 breaths/min	Lung crackles	Exertional or unprovoked syncope or palpations associated with near syncope or syncope
Oxygen saturation < 95%	Marked peripheral edema	Extreme fatigue

Modified from American College of Obstetricians and Gynecologists.[14]

3. Meng ML, Arendt KW. *Anesthesiology*. 2021

National Partnership for Maternal Safety

Maternal Early Warning Criteria (MEWC)

- To aid in faster recognition, evaluation, diagnosis, and treatment of signs of developing critical illness, to reduce preventable maternal death.

If (+): Low threshold to obtain further imaging: TTE, CXR, LUS, ECG

Systolic BP (mm Hg)	<90 or >160
Diastolic BP (mm Hg)	>100
Heart rate (beats per min)	<50 or >120
Respiratory rate (breaths per min)	<10 or >30
Oxygen saturation on room air, at sea level, %	<95
Oliguria, mL/hr for ≥2 hours	<35
Maternal agitation, confusion, or unresponsiveness; Patient with preeclampsia reporting a non-remitting headache or shortness of breath	

7. Mhyre JM, D'Oria R, Hameed AB, et al. *Obstetrics & Gynecology*, 2014.

"**Fett Self Test**" for Early Identification of Heart Failure

> 4 pts → further workup (BNP & TTE)[27]

Table 1. Self-test for early diagnosis of peripartum cardiomyopathy.

Symptoms	0 points	1 point	2 points
Orthopnea	None	Need to elevate head	Need to elevate 45 degrees or more
Dyspnea	None	Climbing 8 or more steps	Walking on level
Unexplained cough	None	At night	Day and night
Lower extremity swelling	None	Below knee	Above and below knee
Excessive weight gain during last month of pregnancy	Under 2 pounds per week	2–4 pounds per week	Over 4 pounds per week
Palpitations	None	When lying down at night	Day and night, any position

The presence of 4 or more points should prompt additional investigation.
Data taken from [30].

Davis M, Duvernoy C. *Women's Health*. 2015

In validation study: **100% of women who presented with > 4pts had LV systolic dysfunction**.[27]

26. Davis M, Duvernoy C. Peripartum Cardiomyopathy: Current Knowledge and Future Directions. *Women's Health*. 2015.
27. Fett JD. Validation of a self-test for early diagnosis of heart failure in peripartum cardiomyopathy. *Critical Pathways in Cardiology*. 2011

BNP & NT-proBNP

Reference Intervals in Pregnancy:

- **BNP**: **< 50** pg/ml
- **NT-proBNP**:
  - TM 1&2: **< 200** pg/ml
  - TM 3: **< 150** pg/ml [33, 39]

- **NT-ProBNP** : inactive portion of split BNP protein with longer $Et^1/_2$ = higher plasma levels.
  - **Benefit = *EASIER PROCESSING:*** very stable, can sit out at room temp; whereas BNP is an unstable diva that needs ice, special handling, and quick processing before protein degrades, for accurate results.

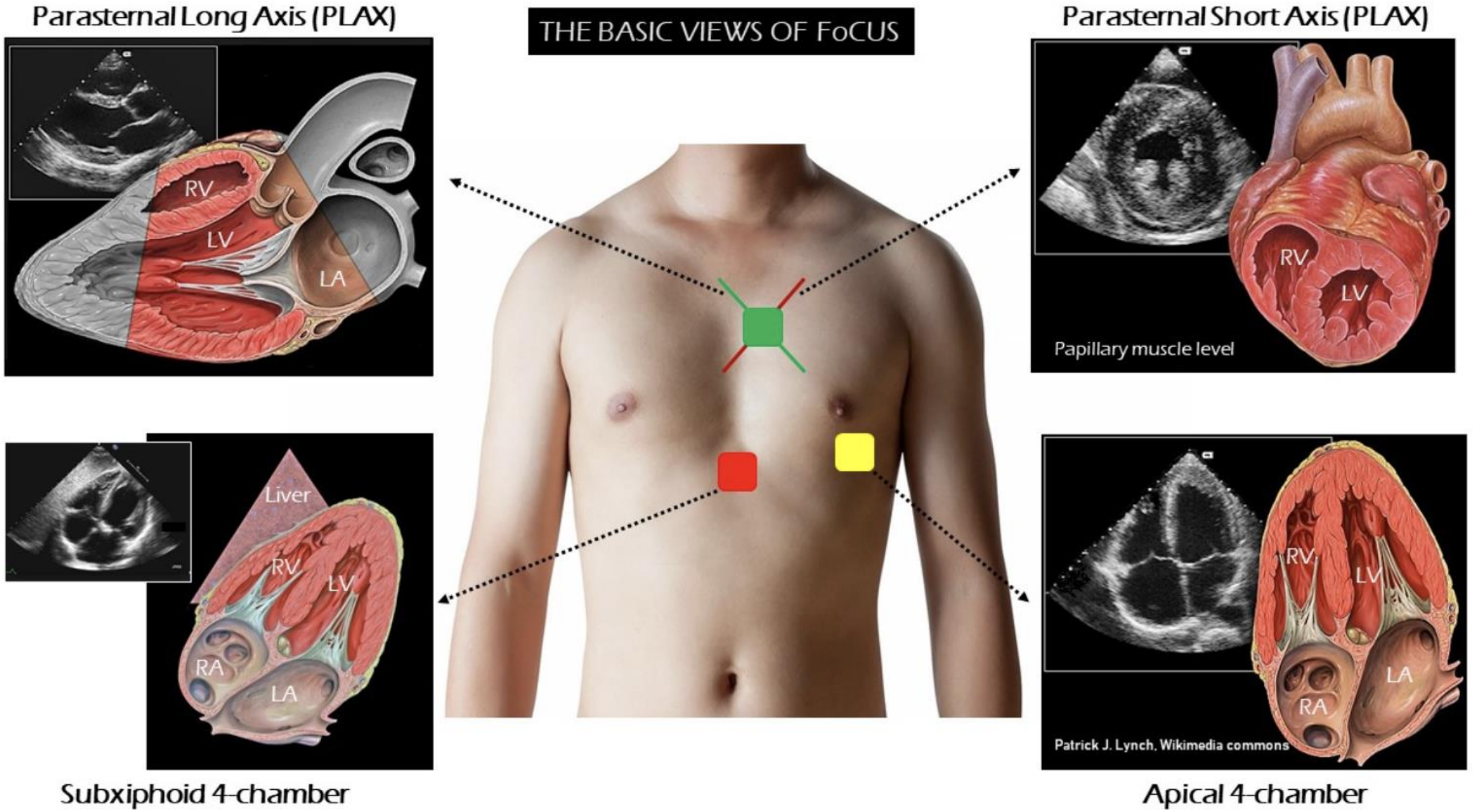
- BNP =/↓ in pregnancy, despite ↑ plasma volume; as normal adaptations of cardiac remodeling and ↓ SVR *leave central filling pressures unchanged,*[13] and both plasma dilution and ↑ GFR will ↓ circulating levels. [33]

- **Pregnant women have LOWER BNP thresholds for further cardiac evaluation** than the traditional guideline of BNP < 100 to rule out HF in non-pregnant patients.

- **BNP ↑ in PreE**… *as a marker of diastolic dysfunction.*[11]

11. Borges VTM, Zanati SG, Peraçoli MTS, et al. *Ultrasound in Obstetrics & Gynecology*. 2018
12. Mueller C, Scholer A, Laule-Kilian K, et al. *N Engl J Med*. 2004
13. Estensen ME, Beitnes JO, Grindheim G, et al. *Ultrasound in Obstetrics & Gynecology*. 2013
33. Stocktree, et al. *J Endocr Soc*. 2021
34. Wang TJ, et al. *Circulation*. 2004
35. Nishikimi T, Nakagawa Y. *Journal of Cardiology*. 2021.
39. Sarma et al. *JACC Advances*. 2022

Basic Views of Cardiac POCUS

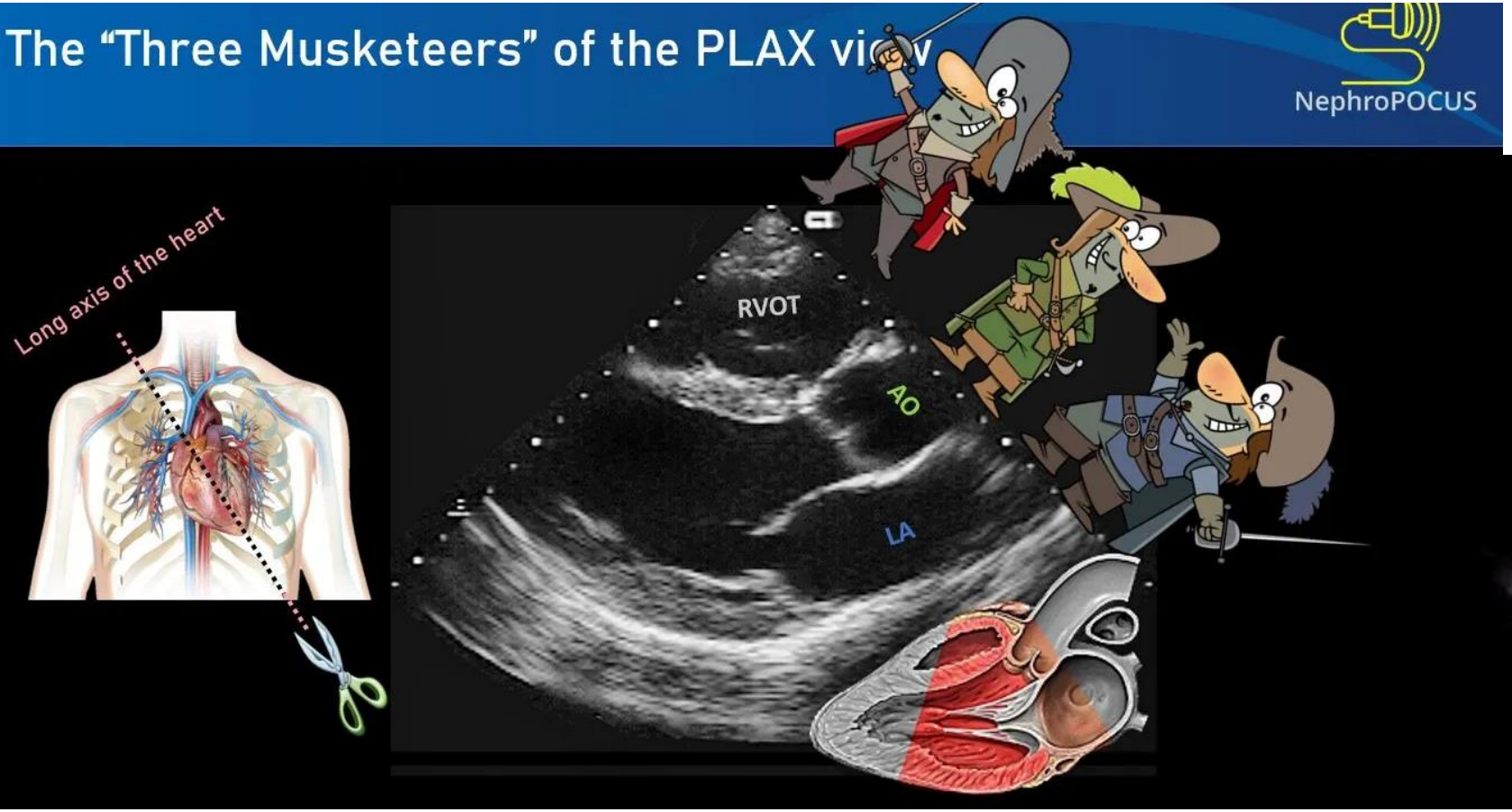


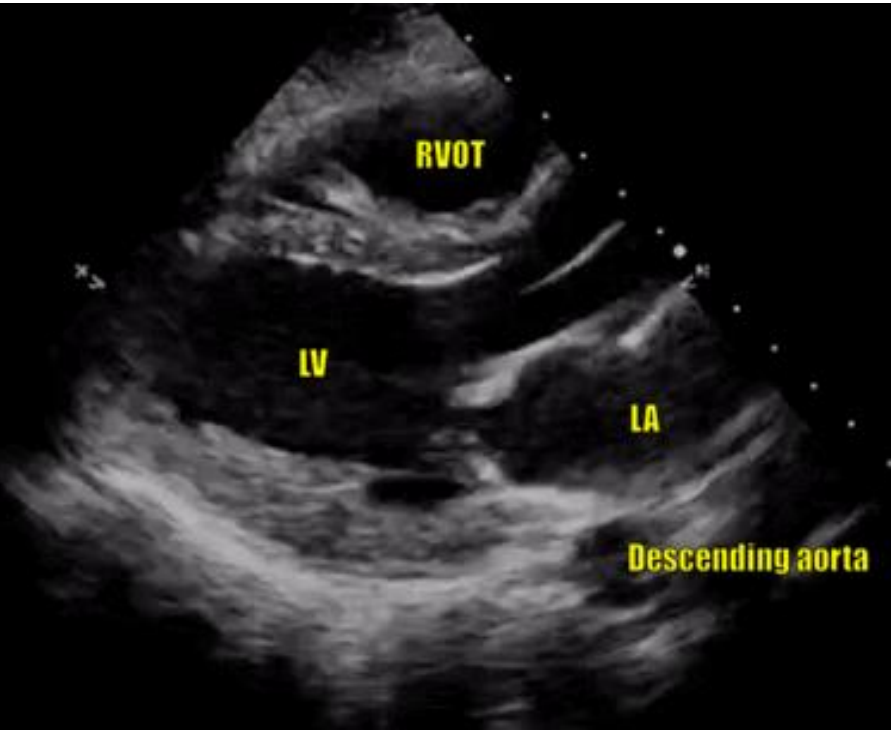
44. Koratala A. Introduction to Focused Cardiac Ultrasound: The Parasternal Long Axis View. Renal Fellow Network. 2019.

Parasternal Long Axis View

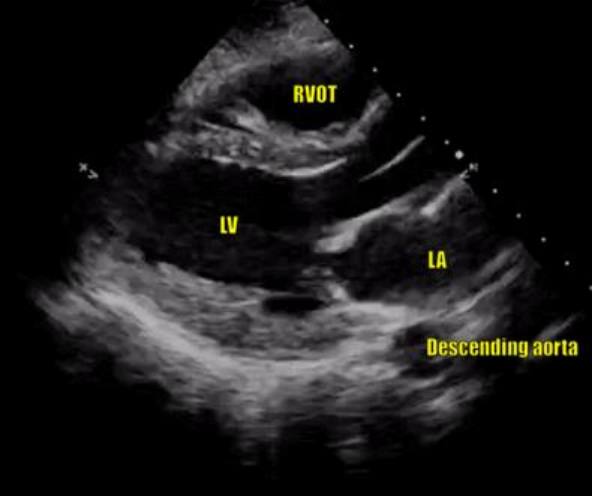
Probe placement:

- **Left of sternum, 3rd of 4th ICS**
- **Indicator points to right shoulder**



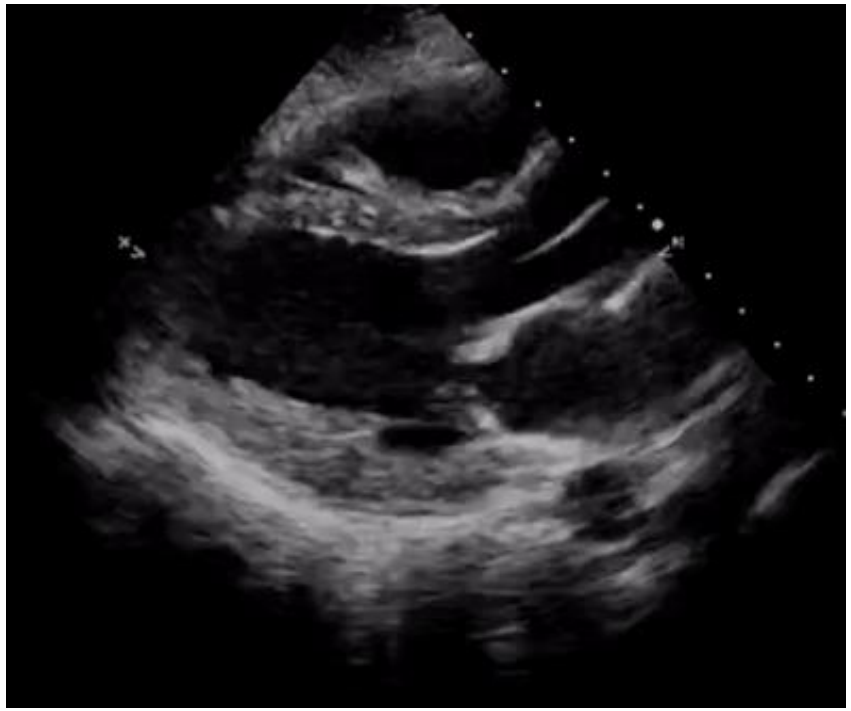


44. Koratala A. Introduction to Focused Cardiac Ultrasound: The Parasternal Long Axis View. Renal Fellow Network. 2019
45. Koratala. A. The three musketeers of the parasternal long axis view. NephroPOCUS. 2021



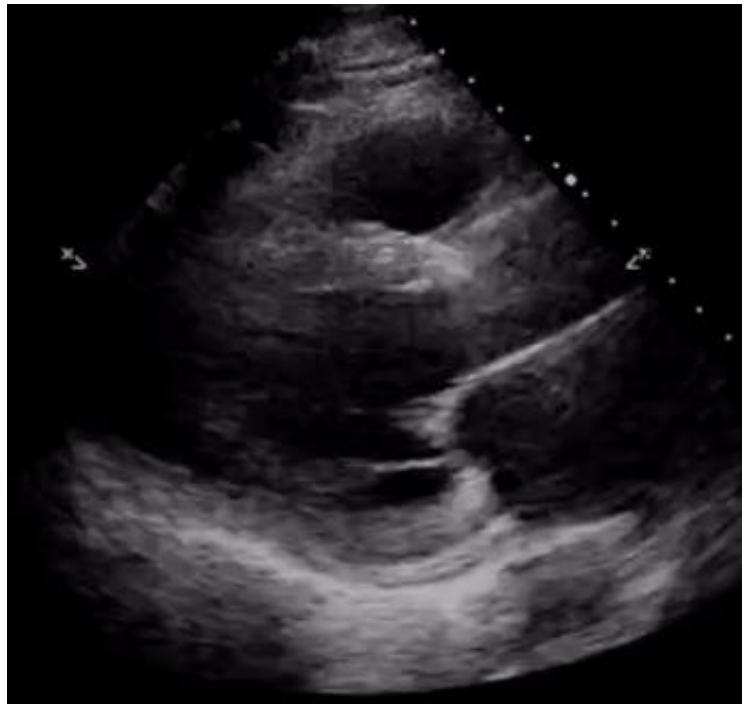
Visual Estimate of EF in PLAX

NORMAL
EF > 50%



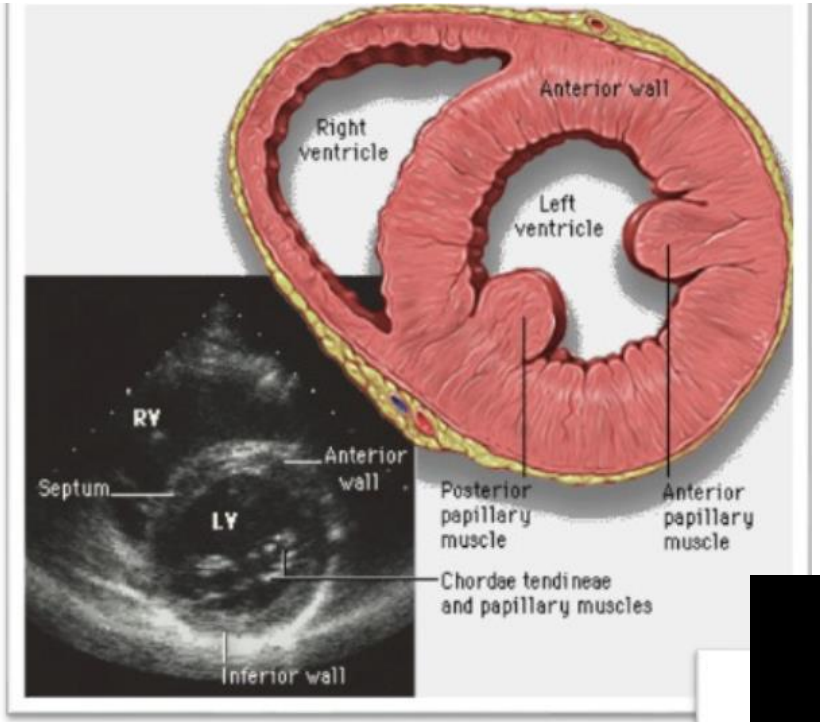
MODERATELY REDUCED
EF ~ 30-40%

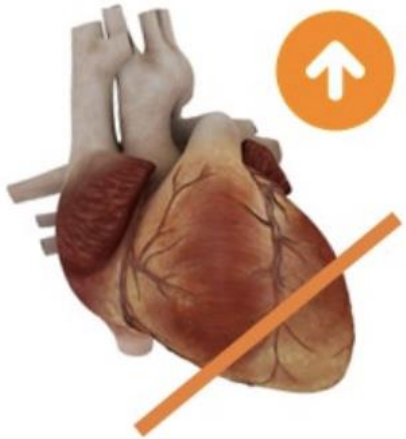
SEVERELY REDUCED
EF < 30%

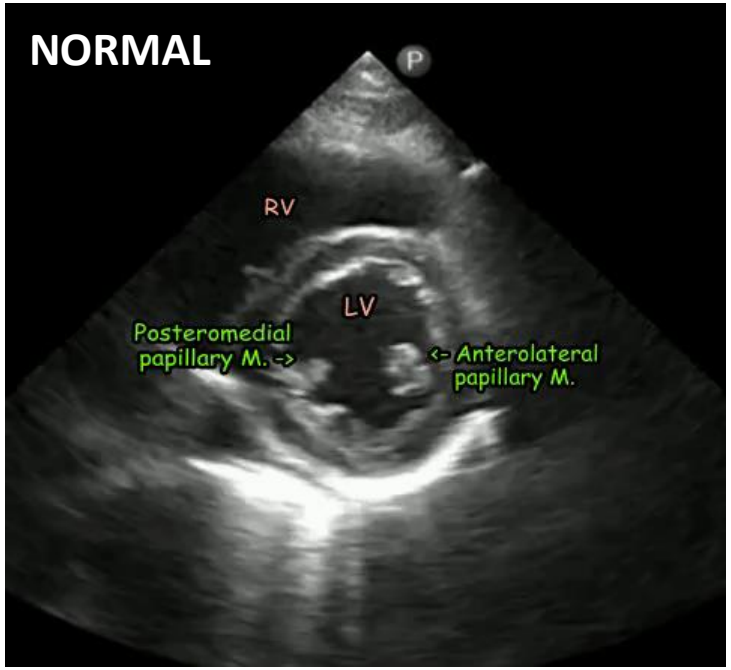


44. Koratala A. Introduction to Focused Cardiac Ultrasound: The Parasternal Long Axis View. Renal Fellow Network. 2019

Parasternal Short Axis View

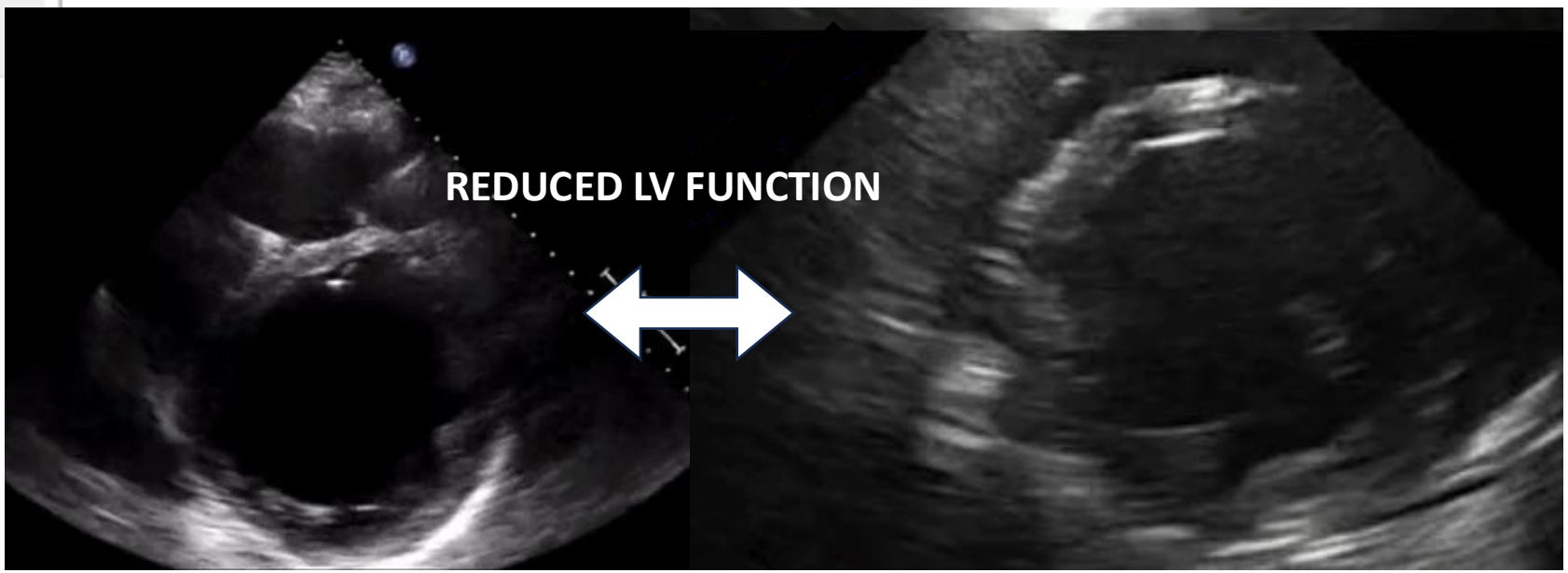






Probe placement:

- **Left parasternal, 4th ICS**
- **Or 90o clockwise turn from PLAX view**
- **Indicator points to left shoulder**
- **Mid-papillary view = mid-ventricle**

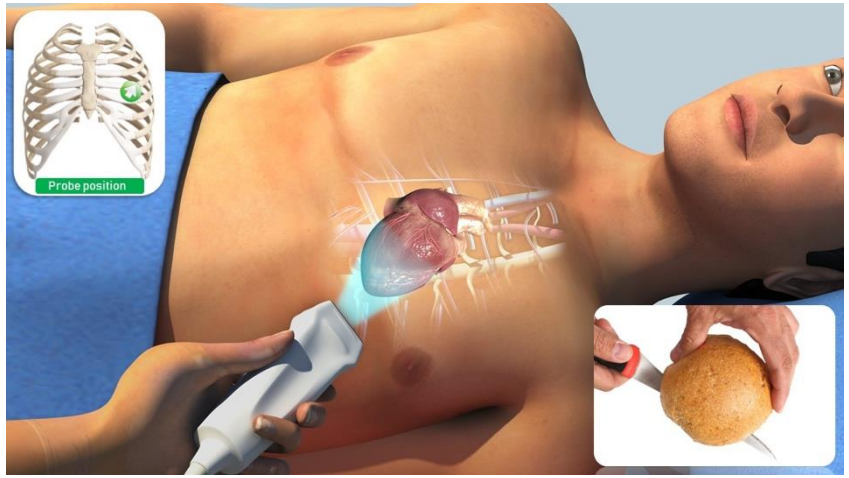


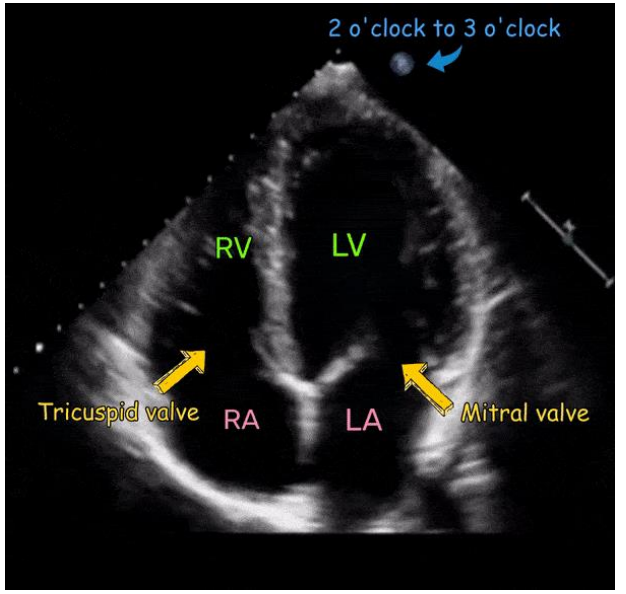
46. Koratala A. Focused Cardiac Ultrasound for the Nephrologist: The Parasternal Short Axis View . Renal Fellow Network. 2019.
47. Kant S, Kant S. Focused Cardiac Ultrasound: Abnormalities on the Parasternal Short Axis View. Renal Fellow Network. 2019

Apical 4-Chamber View

Probe placement:

- **Just below nipple line at PMI**
- **4th-6th MCL**
- **Indicator faces left shoulder, probe points through body to right shoulder blade**





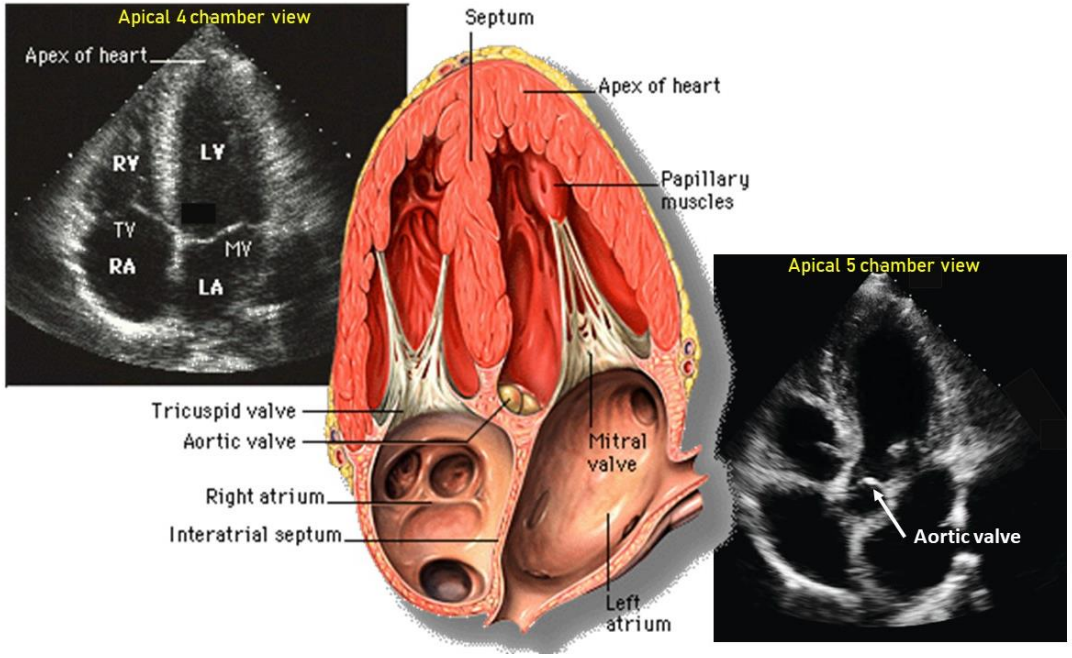
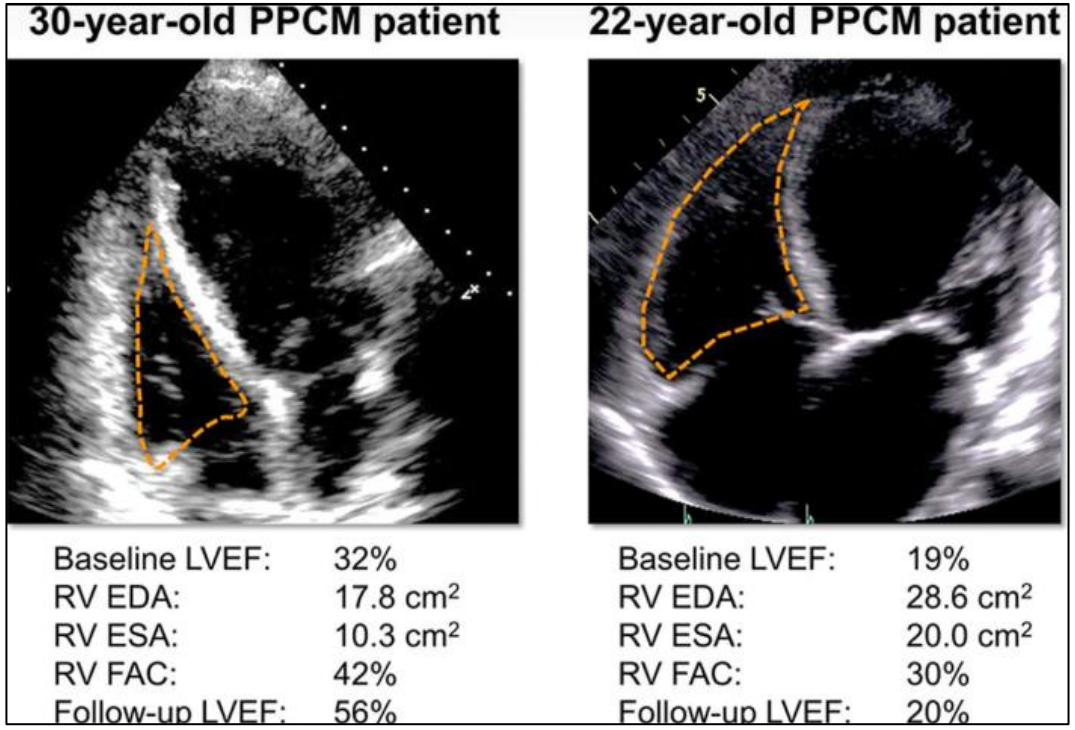


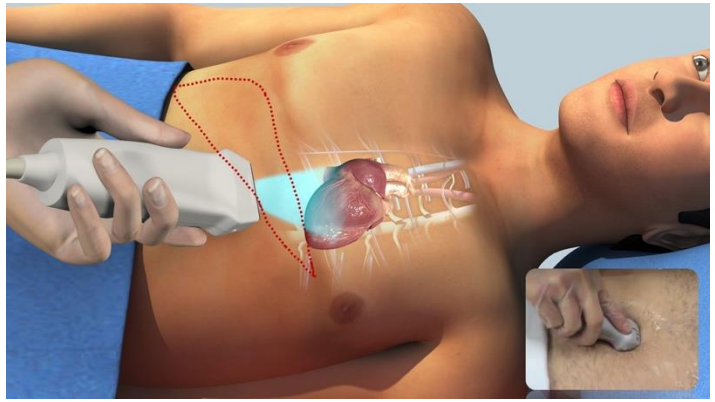
Illustration: Patrick J. Lynch, Wikimedia commons



48. Kant S. Focused Cardiac Ultrasound for the Nephrologist: The apical window. Renal Fellow Network. 2019.

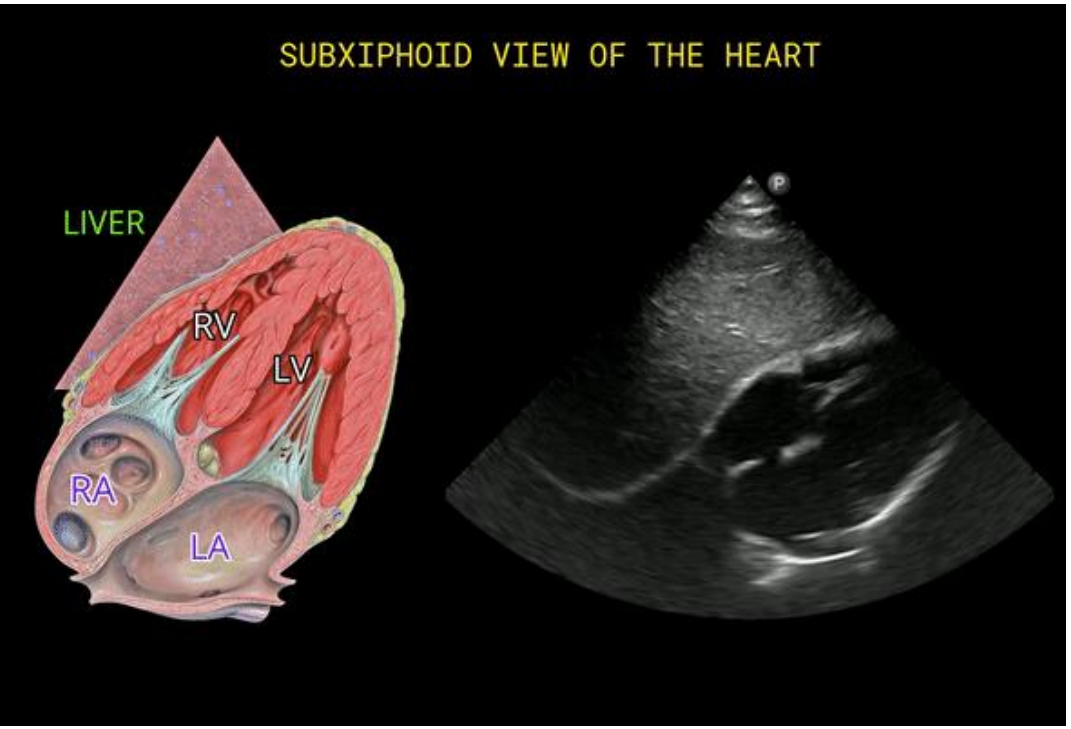
Subxyphoid 4-Chamber View

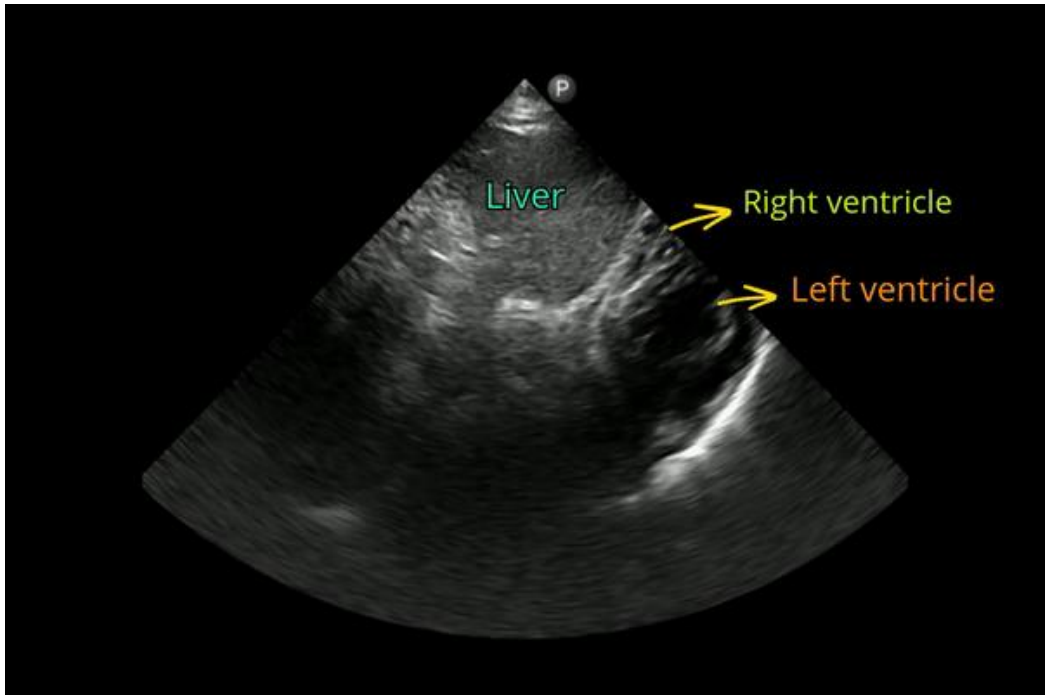
Subxyphoid Short Axis View



Probe position:

- **Pt supine with knees bent to relax abdominal muscles**
- **2-3 cm below XP & direct upwards into chest, indicator points to pt's LEFT (3 o'clock)**
- **Liver at top of the image (looking through liver at heart) w/ R heart close to liver.**
- **SubX view grossly underestimates overall size (volume) of ventricles**
- **Can push probe inward slightly and ask pt to take a deep breath**
- **Cardiac phased array probe best. Curvilinear OK but worse view**
- **Probe rotated 90° counterclockwise for short axis view (indicator to 6 o'clock, and aim probe towards pt's L shoulder)**





49. Koratala A. Focused Cardiac Ultrasound for the Nephrologist: The Subxiphoid View. Renal Fellow Network. 2020.

EARLY IDENTIFICATION

- Chances of full recovery higher when LVEF > 35%;
  - With early detection, LVEF likely to be higher at time of diagnosis and initiation of treatment.

- Most serious complications of PPCM arise when LVEF < 30-35%
  - Ventricular tachyarrhythmias
  - Thromboembolic events
  - Chronic cardiomyopathy[29]

These complications can be either avoided or decreased with earlier diagnosis…

29. Fett JD. *World J Cardiol*. 2014


…But women’s symptoms of heart failure are frequently misdiagnosed, or dismissed as “normal pregnancy symptoms,” which delays treatment and leads to further decompensation.

Rachel

s/s 3rd TM: excessive swelling – dismissed “bc it’s twins”
Leg swelling after delivery – told “it’s nothing”
Cough developed - told “it’s bronchitis”
Workup 1 month PP
LVEF 15%
Ext defib & cardiac rehab - Recovered

“And I kept saying something was wrong, and they told me, 'No, you're just carrying multiples. This is what happens with multiples. There's nothing wrong with you’…
…But come to find out, I was dying.”

https://www.11alive.com/article/news/health/heart-failure-postpartum-cardiomyopathy-pregnant-women/85-283274ce-1242-4b82-8908-a3da5f146f32

Claire

Unable to lie flat & severe cough 6d PP after 1st delivery.

She went to 8 emergency appts, she saw 5 different doctors and was given incorrect dxs of a PE and gastric asthma.

Even despite mentioning she thought her s/s were cardiac and could be PPCM

"I was told I was just a hormonal, overanxious new mother."

S/S worsened: *" SOB, breathless, gasping for air"*

→ ED Echo → EF < 18%

Managed medically

Over 7 years later, EF 48-50%, still medication dependent.

Marian

35y/o

6 months PP: fatigue, bloat, ankle swelling, brief vision loss

1st and 2nd GPs dismissed s/s as viral:

"At the second appointment, the physician emphasized that I was young and healthy"

3rd: ED doc: misdx "severe congestion" as **PNA**

Continued to deteriorate, so called insurance to get referral to another physician

4th GP: finally dx PPCM

EF 15% → AICD

Medically managed, 4 years later EF 46%

https://www.womenshealthmag.com/health/a61161229/peripartum-cardiomyopathy-misdiagnosis/?utm_source=google&utm_medium=cpc&utm_campaign=mgu_ga_whm_md_pmx_hybd_mix_us_17871928004&gad_source=1&gclid=Cj0KCQjwmOm3BhC8ARIsAOSbapWeqy5lJYiu51b-3B0k9MHGO0BS9LyJhliWif459e3iB4mU0bdyMnkaAul6EALw_wcB

Lacresha

31 y/o 2nd child
Gained 10 lbs in 1 wk + SOB

"I couldn't breathe"

Dismissed as "normal pregnancy s/s"
Collapsed at home shortly PP
→ cardiogenic shock & MODS
EF 5%
ECMO, Impella, & CRRT
Now LVAD-dependent

"Though we don't have the medical degree, we know our bodies… And no one knows our bodies better than we do"

https://news.llu.edu/patient-care/underdiagnosed-form-of-heart-failure-women-physician-patients-spread-word

Brittany

39-y/o avid runner noticed increased SOB during 5th pregnancy

5th child: 3rd TM SOB: dismissed twice by providers as "normal pregnancy s/s."

6th child, significant SOB though pregnancy, dx PPCM PP, and began PO meds for HF.

5 months PP - rapid decompensation.

EF 10%

Heart transplant recipient

"I've had five other pregnancies…from the very beginning, I struggled to breathe…"

I just wish …that this would have been caught a little earlier, and maybe things could have been different.."

Objectives:

- Current Data on Maternal Mortality
- Peripartum Hemodynamics Review
- Maternal Cardiac Risk Scoring Systems & Heart Failure Identification Tools
- **Heart Failure from Peripartum Cardiomyopathy & Hypertensive Disorders**
- Delivery Management Considerations in:
  - Heart Failure
  - Pulmonary Edema

https://www.health.harvard.edu/womens-health/research-were-watching-womens-hearts-age-differently-than-mens-do

https://www.nursingtimes.net/clinical-archive/womens-health/pregnancy-1-effects-on-haematological-and-cardiovascular-systems-29-08-2023/

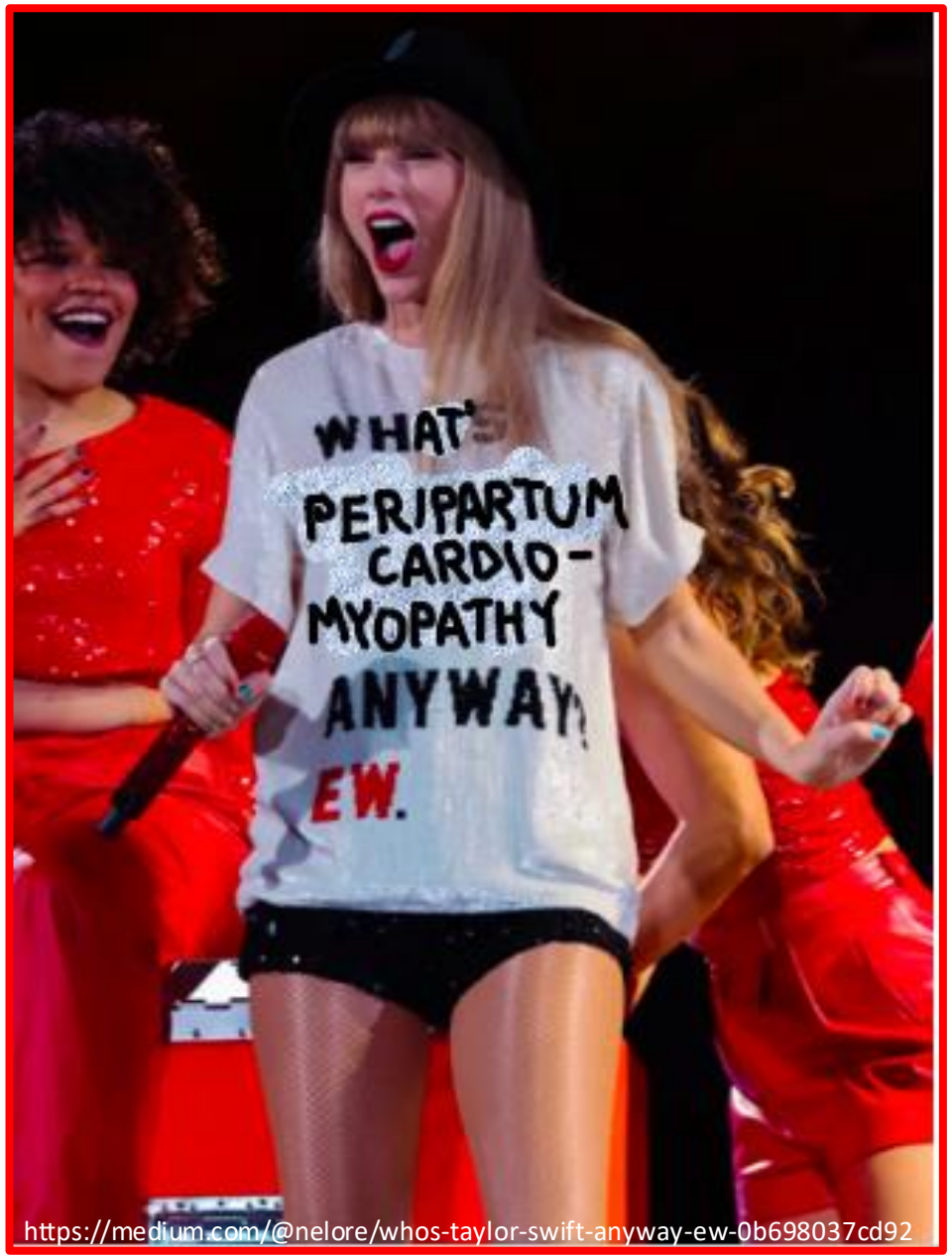
PERIPARTUM CARDIOMYOPATHY

PPCM defined as:

✓ LV systolic dysfunction w/ EF </= 45% during late pregnancy or postpartum with

no prior hx cardiac dysfunction

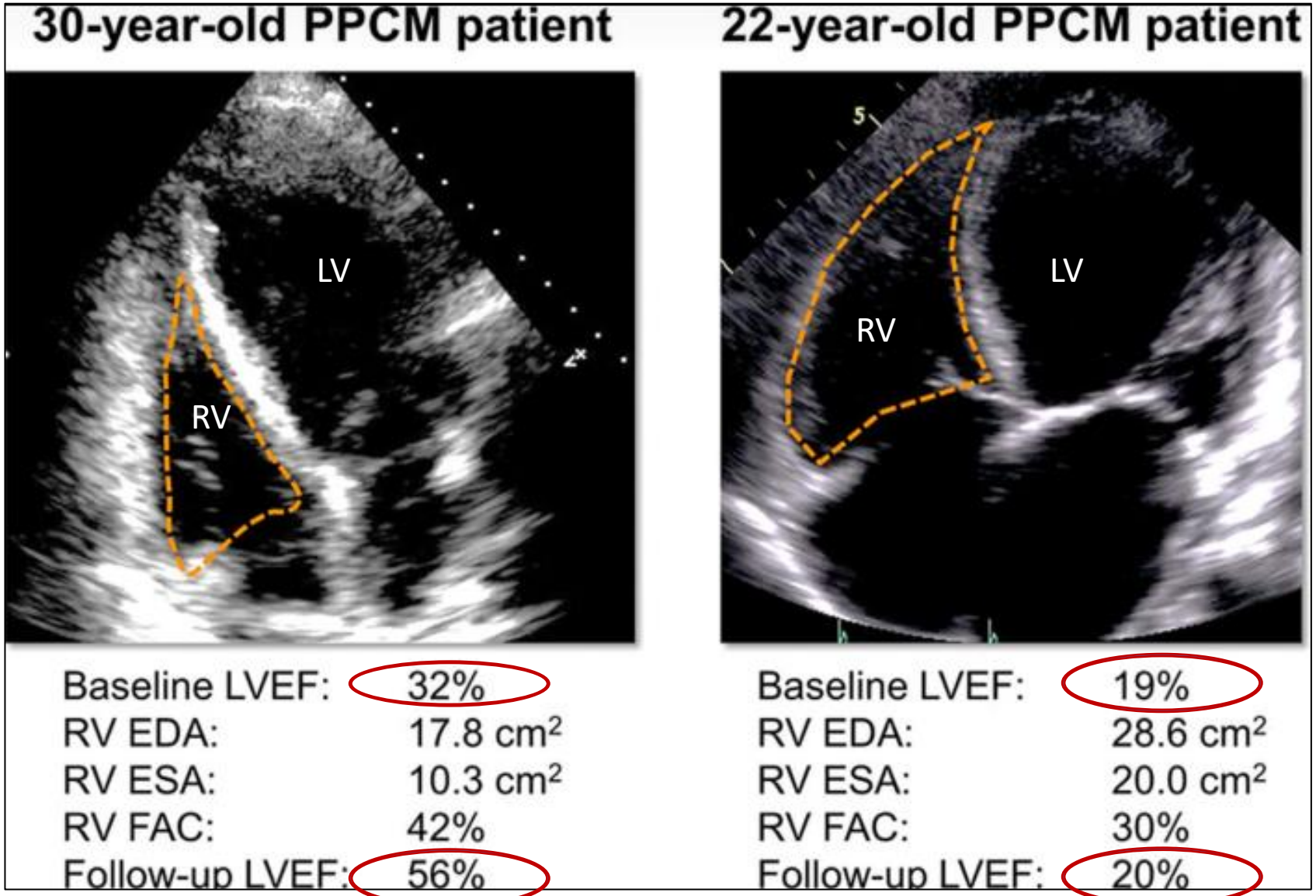
- ✓ Dx by exclusion
- ✓ No serum or biopsy markers:
  - dx by TTE and usually **^BNP**
- ✓ Usually LV dilation, but not always
  - Most similar to non-ischemic DCM [9]
- ✓ Can have RV dysfunction as well, which is a poor prognostic indicator [15]



https://medium.com/@nelore/whos-taylor-swift-anyway-ew-0b698037cd92

9. Zoltan. *N Engl J Med,* 2024.
14.Bauersachs J, König T, Meer P, et al. *European Journal of Heart Failure*. 2019
15. Blauwet LA, Delgado-Montero A, Ryo K, et al. *Circulation-heart Failure*. 2016

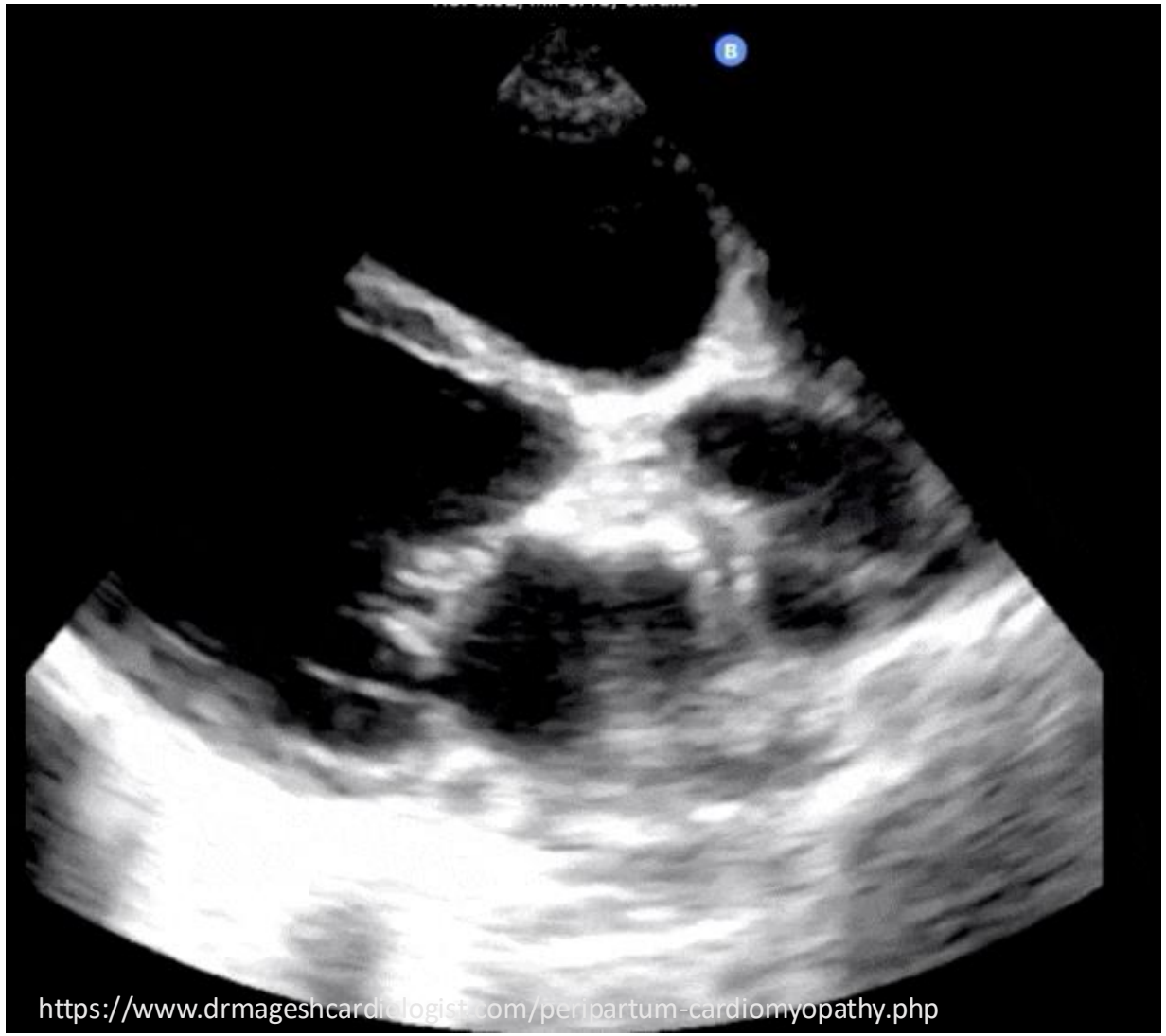
RV dysfunction in PPCM



15. Blauwet LA, Delgado-Montero A, Ryo K, et al. *Circulation-heart Failure*. 2016

Current PPCM pathogenesis theory:

- “Vasculo-hormonal”
- Imbalances in peripartum hormones secreted by pituitary and placenta
- Causes CV dysfunction via antiangiogenic and vasculotoxic substances, with consequent HF in susceptible women.
- Possible genetic links but remains mostly enigmatic.



9. Zoltan. *N Engl J Med*, 2024.

37. Arany Z, Elkayam U, *Circulation*. 2016

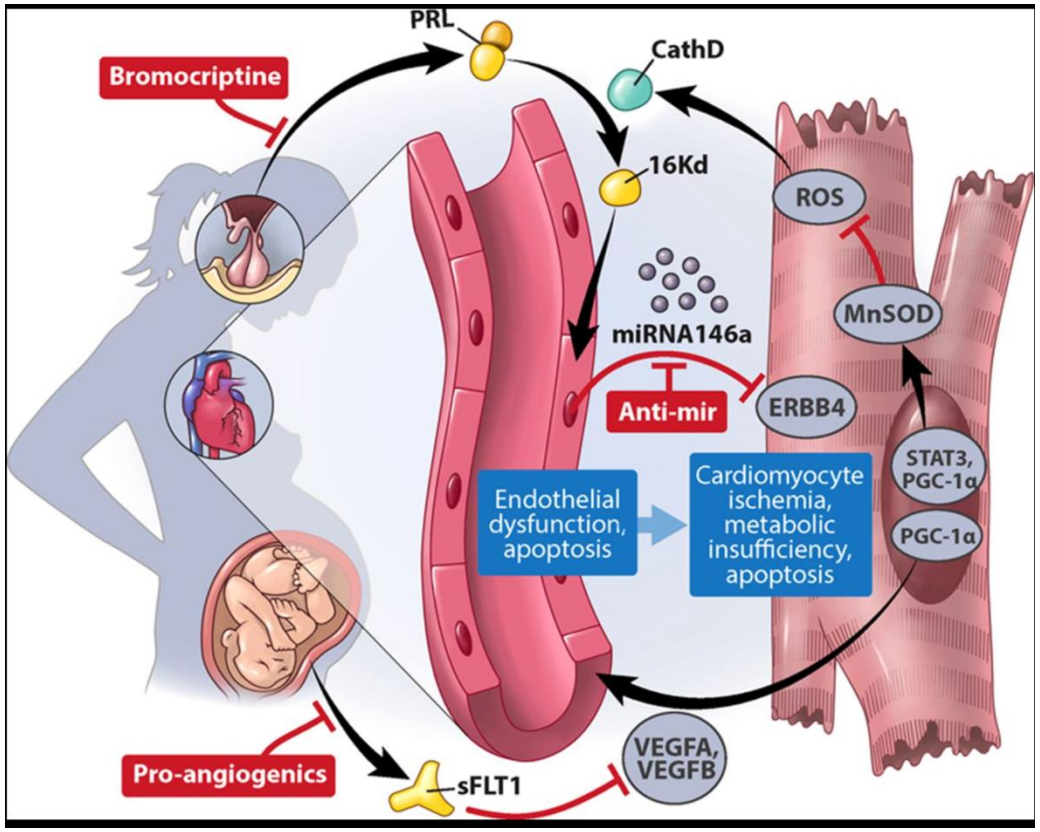


Figure 4. Vasculo-hormonal hypothesis of the pathophysiology of PPCM

9. Zoltan. *N Engl J Med*, 2024

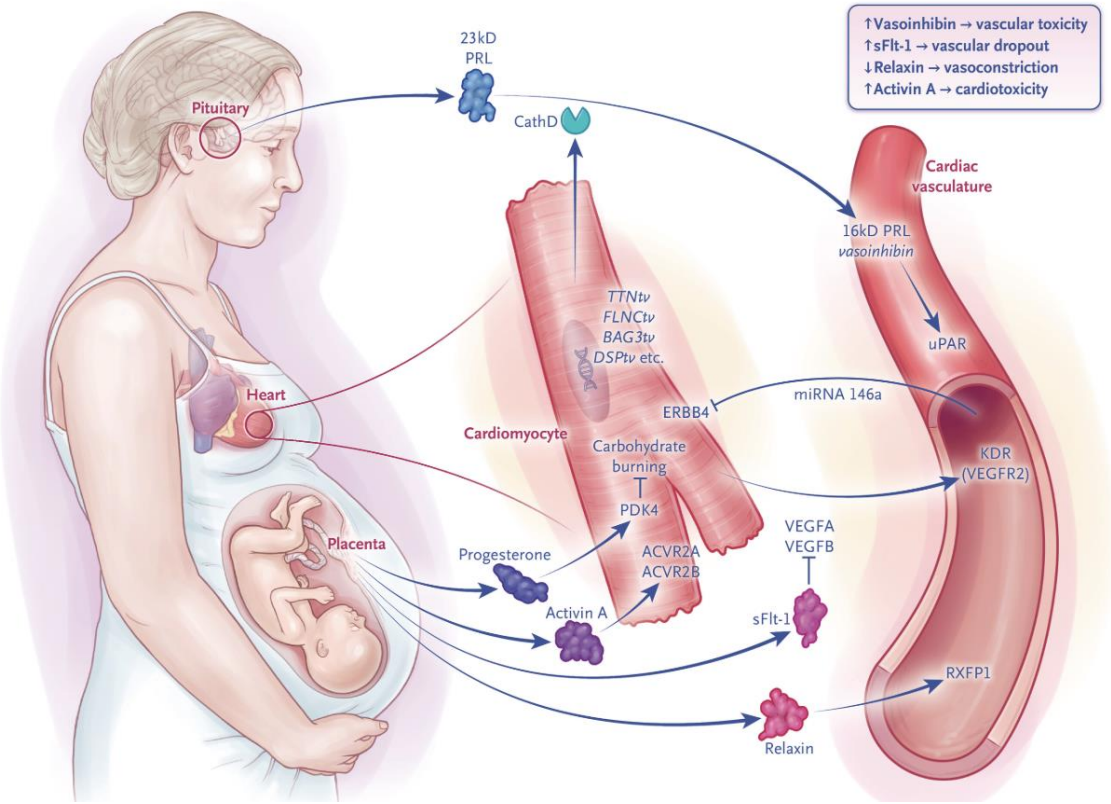
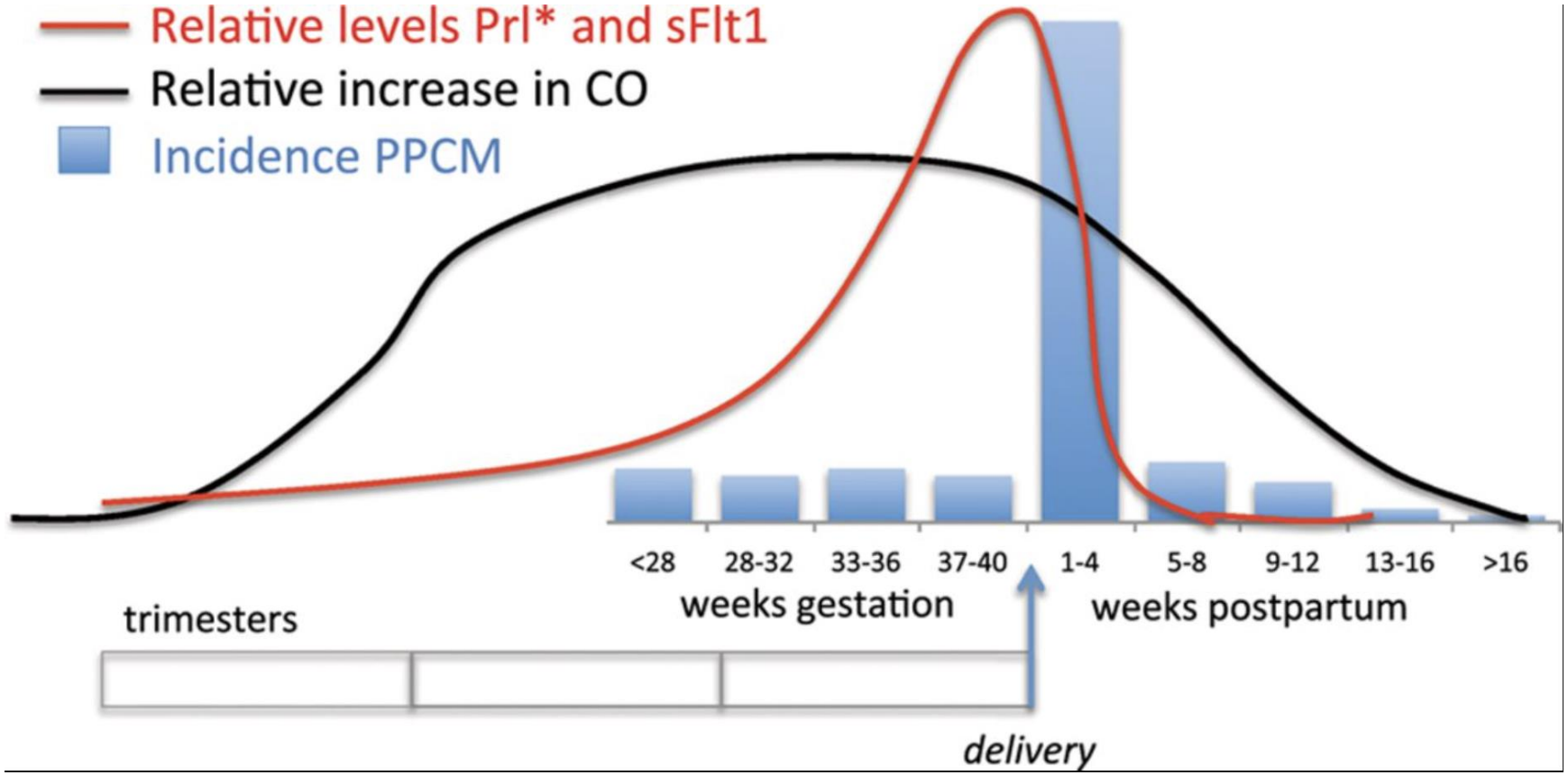


Figure 2. Hormonal Model of PPCM

- sFlt-1 released from placenta inhibits VEGF (vascular endothelial growth factor) by binding to it and reducing its bioavailability, making it anti-angiogenic. (acts as decoy receptor)
  - PPCM pts can have abnormal elevations in sFlt-1, and abnormally low VEGF.

- Prolactin under abnormal oxidative stress can undergo enzyme-driven cleavage from normal full 23 kDa fragment intotruncated cardiotoxic 16 kDa fragment → 1.) potent anti-angiogenic & apoptotic effect on cardiac microvascular endothelial cells, 2.) up-regulates microRNA-146a causing systolic dysfunction, capillary dropout, & cardiac fibrosis[43] → cardiomyocyte damage → HF.
  - Elevated 16 kDa found in PPCM as well as PreE.



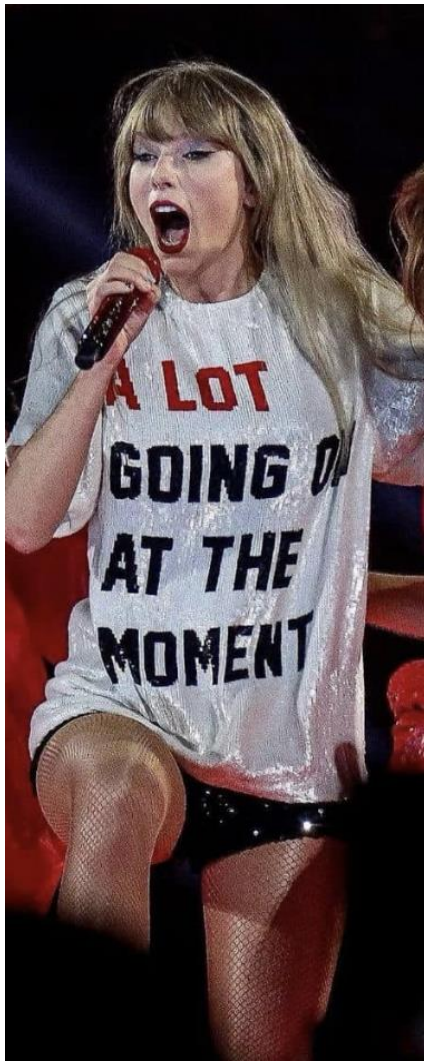


Figure 2. Comparison of timing during and after pregnancy of hemodynamic changes, exemplified as cardiac output (CO; in black), elevations in **prolactin** and **soluble Fms-like tyrosine kinase 1 (sFlt1)** hormones (red), and incidence of peripartum cardiomyopathy (PPCM; blue bars).
*Prolactin levels stay elevated in women who nurse.

37. Arany Z, Elkayam U, *Circulation*. 2016;133(14):1397-1409

PPCM: Onset and Recovery

ONSET:

- *Can develop **RAPIDLY over the course of days*** (to LVEF <45%) [16]
  - *Often presents as clinical congestion 2/2 elevated cardiac filling pressures:*
    - orthopnea, JVD, leg edema [17]
  - Use acute HF treatment guidelines [18]

- Usually during last month of pregnancy or most commonly, postpartum.
  - ***60-90% of cases occur within 1st week PP***
  - ***Can occur up to 5 months PP, or later…*** [9]

16. Karaye et al. *BMC Cardiovasc Disord*. 2016
17. Heidenreich PA, Bozkurt B, Aguilar D, et al. *Circulation*. 2022
18. Regitz-Zagrosek V, Roos-Hesselink JW, Bauersachs J, et al. *European Heart Journal*. 2018
9. Zoltan. *N Engl J Med,* 2024

PPCM: Onset and Recovery

RECOVERY:

- CV function recovers in > 50% of women
  - However, some never recover and need LVAD +/- heart transplant.
- Incomplete recovery:
    - Cardiac cellular and molecular recovery may lag behind LVEF.
      - Despite recovered EF, exercise or dobutamine stress test may reveal persistent cardiac dysfunction.
- **In the US, black women have twice the risk of persistent cardiac impairment, and if recovery is achieved, it can take twice as long.**

9. Zoltan. *N Engl J Med,* 2024

MANY PPCM PATIENTS NEVER RECOVER LV FUNCTION

https://www.heart.org/en/news/2022/02/01/a-joyous-birth-followed-by-heart-failure

Danecia

24 y/o, 1st baby

1 wk PP s/s: chest pain & SOB

EF 25%

AICD

SIX YEARS LATER suffered stroke

Workup: LVEF had declined to 10-15%

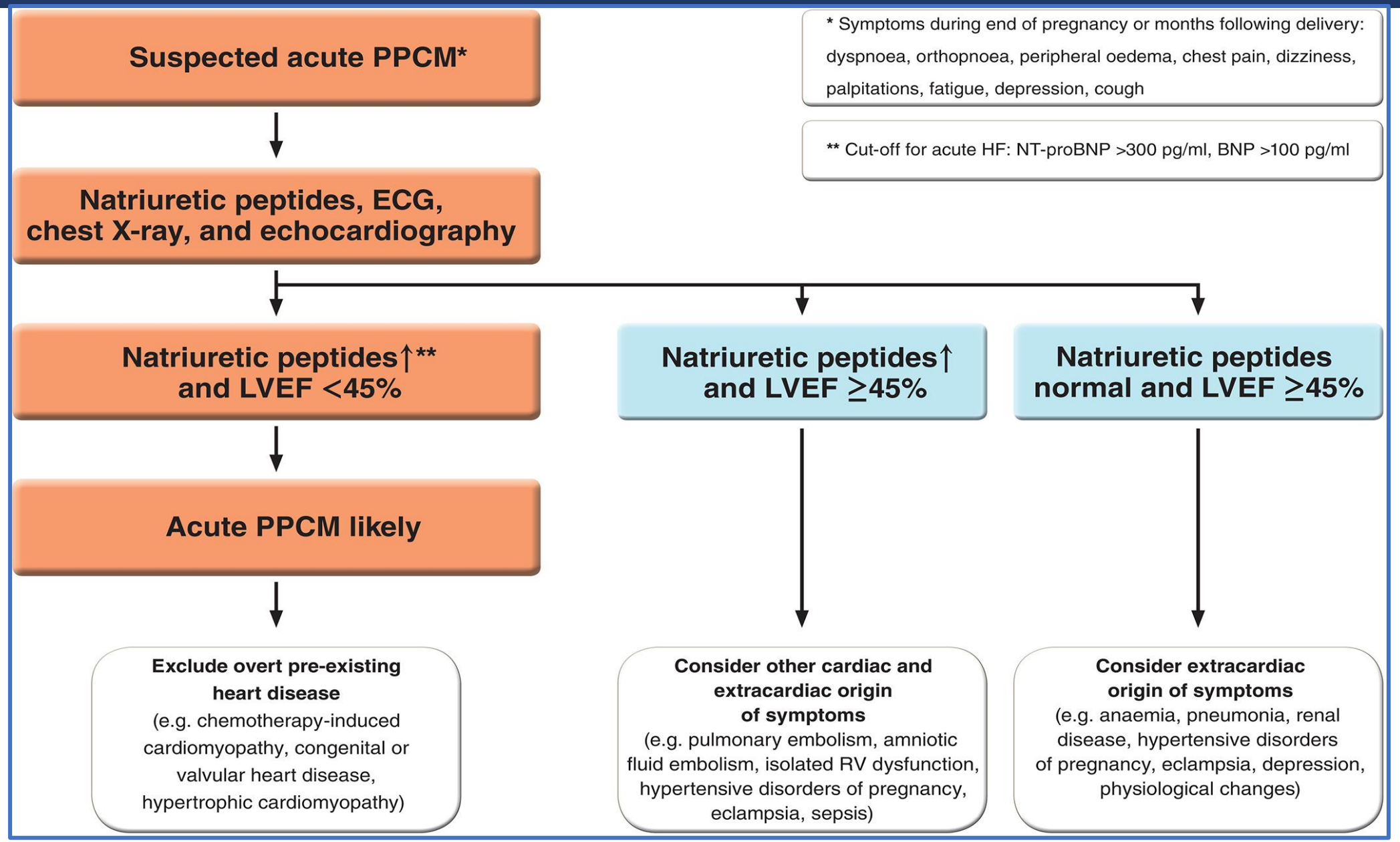
Waited >1yr for heart transplant

LVEF further declined

LVAD while she waited

Then received heart transplant.

PPCM Diagnostic Pathway



15. European J of Heart Fail, Volume: 21, Issue: 7, Pages: 827-843, First published: 27 June 2019, DOI: (10.1002/ejhf.1493)

PreE and Heart Failure

- Well-established that PreE can cause diastolic dysfunction
  - Especially early-onset PreE < 34wks
    - Increased incidence of severe LVH, diastolic dysfunction, and higher BNP levels, compared with late-onset PreE. [10,11]

- ***Despite a brief time period of HTN*, the maternal heart can still adapt to acute and transient ↑ SVR with remodeling and concentric hypertrophy.**[11]
  - In fact, *most women with PreE undergo adaptive myocardial remodeling from ↑SVR,* ***but a small subgroup demonstrate signs of overt decompensation*.**

10. Melchiorre K, Sutherland GR, Watt-Coote I, Liberati M, Thilaganathan B., *Hypertension in Pregnancy*. 2012
11. Borges VTM, Zanati SG, Peraçoli MTS, et al. *Ultrasound in Obstetrics & Gynecology*. 2018

PreE and Heart Failure

- Compared with normal cohorts, PreE has 71% increased risk of CVD mortality
  - 2.5x higher risk of CAD
  - 4x higher risk of heart failure.[8]
    - PreE and PPCM both exhibit upregulation of antiangiogenic and vasculotoxic hormones secreted by placenta[38]
- PreE with PPCM has been associated with a higher incidence of adverse CV outcomes.[9]


https://www.uchealth.com/en/media-room/patient-stories/heart-failure-after-pregnancy-life-saving-lvad-placement

Madi

17y/o
Emergent c/s 25w5d for severe PreE
Decompensated HF: dx PPCM
IABP → ECMO → RVAD & LVAD
Remains with LVAD

8. Mehta LS, Warnes CA, Bradley E, et al. *Circulation*. 2020
9. Zoltan. *N Engl J Med*, 2024.
38. Lewey et al. *Hypertension*. 2020.

PreE and Heart Failure with Preserved EF

9.5 % of PreE women w/ severe features found to have HFpEF

Almost 1 in 10!

- SOB & pulmonary edema are common presenting signs of HFpEF
  - Often precipitated by excess IV fluids → pulmonary edema

32. Dennis et al. *Anesthesiology.* 2025

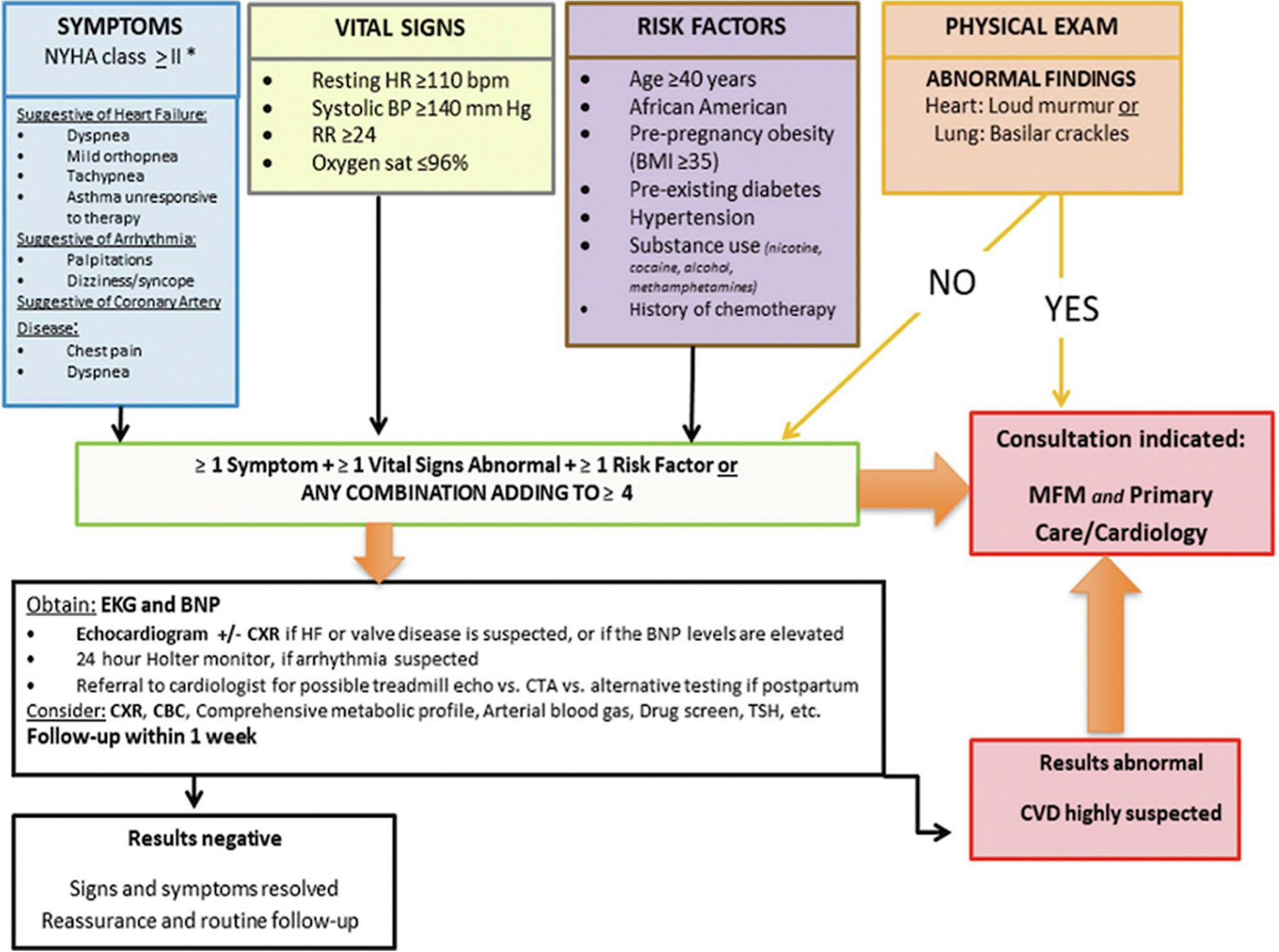
PreE and Heart Failure with Preserved EF

- Prior to decompensation (↓ EF), TTE on PreE women often looks… …*normal…* with normal to increased CO, EF & contractility

- Formal ECHO if symptomatic (SOB, cough, orthopnea, etc.. r/o pulm edema/effusions)

- Further investigation often shows:
  - *Diastolic dysfunction***
  - Increased pericardial effusions
  - Increased LV wall dimensions compared to healthy parturients[32]

32. Dennis et al. *Anesthesiology.* 2025



AJOG: Women with risk factors: **AMA, obesity, CHTN, DM, *or other risk factors for PreE* will benefit from baseline cardiac eval *including ECG & ECHO.***

36. Roberts et al., *AJOG*. 2023

Cynthia

G5P4

"Two weeks after birth, I was back in the hospital with my BP at 215/127.

…I couldn't breathe. Every time I lay down, I felt as though I was drowning."

EF 25%
Ext defib
Medically managed
Full recovery

Objectives:

- Current Data on Maternal Mortality
- Peripartum Hemodynamics Review
- Maternal Cardiac Risk Scoring Systems & Heart Failure Identification Tools
- Heart Failure from Preeclampsia & Peripartum Cardiomyopathy
- Delivery Management Considerations in:
  - **Heart Failure**
  - Pulmonary Edema

Delivery Mode: Vaginal with Neuraxial

Vaginal delivery best with **good neuraxial analgesia.**

- Pain control = ↓ catecholamines = ↓ CV stress
- VD has less severe hemodynamic swings
  - ✓ lower EBL & less neuraxial sympathectomy [5]
- VD has lower risk of infection and thrombotic complications than C/S [8]
- ACOG (No. 212): IOL 39-40 wks for women w/ heart dx if no spontaneous labor [8,19]
  - IOL at 39 wks may reduce rates of C/S and improve maternal outcomes by decreasing risk of HTN disorders of pregnancy[9] (ARRIVE & HYPITAT) [20,21]

5. Girnius, A, Meng ML. *Journal of Cardiothoracic and Vascular Anesthesia*, 2021
8. Mehta LS, Warnes CA, Bradley E, et al. *Circulation*. 2020
9. Zoltan. *N Engl J Med,* 2024
19. ACOG Practice Bulletin No. 212: Pregnancy and Heart Disease. *Obstet Gynecol*. 2019
20. Grobman WA, Rice MM, Reddy UM, et al.*New England Journal of Medicine*. 2018
21. Koopmans CM, Bijlenga D, Groen H, et al. *Lancet*. 2009

Delivery Mode: Vaginal with Neuraxial

Monitors:

- Continuous pulse oximetry & ECG
- NIBP Q 2-5 min after neuraxial analgesia initiated
  - May require A-line, especially before neuraxial to monitor hemodynamic response
    - AS, MS, HOCM, PPCM or PreE w/ severely reduced EF, RV dysfunction, Pulmonary HTN.

- Consider staffing if L&D RNs are not trained for invasive hemodynamic monitoring or continuous vasoactive gtts, etc.

- **Plan for → ICU if inotropes/vasoactive meds needed peripartum, as they should be maintained through postpartum period to assist ventricles with postpartum fluid shifts.**

3.Meng ML, Arendt KW. *Anesthesiology*. 2021.

Delivery Mode: Cesarean with Neuraxial

- **Cesarean** reserved for obstetric or fetal indications (malpositioned/breech, FTP, eRPT c/s, FHR)
  - *Or* high-risk maternal lesions:
    - severe aortopathy, severe AS or MS, or any maternal decompensation.[3,5]
- **Neuraxial anesthesia preferred**
    - Spinal may be well-tolerated in mWHO class 1 & 2 lesions
    - Slowly-dosed epidural best for mWHO class 3 & 4 lesions [3]

- **Plan for → ICU if inotropes/vasoactive meds needed peripartum, as they should be maintained through postpartum period to assist ventricles w/ postpartum fluid shifts.**

3.Meng ML, Arendt KW. *Anesthesiology*. 2021
5. Girnius A, Meng ML. *Journal of Cardiothoracic and Vascular Anesthesia*. 2021

NEURAXIAL ANESTHESIA TECHNIQUE

- Slow-dosed **epidural** offers slower sympathectomy

- **Cesarean:**
  - IT narcotics: fent & duramorph via CSE to improve surgical anesthetic and post-op pain control while minimizing hemodynamic swings
    - then slowly dose epidural.

- **Labor analgesia**:
  - If using CSE, can use IT narcotic (~10-20 mcg fent) if rapid relief needed, then slowly dose epidural.

- Avoid routine pre-procedure IVF bolus as HF places women at higher risk of pulmonary edema
  - If necessary, use smaller ~200cc bolus
  - Manage sympathectomy with pressors

3.Meng ML, Arendt KW. *Anesthesiology*. 2021

Delivery Mode: Cesarean with GA

- **GA** reserved for emergency requiring ETT for cardiopulmonary indication, or a contraindication to neuraxial in necessary c/s.
  - If complex requirements: (eg: TEE, ECMO) use cardiac OR [3]

➢ PPCM possibly 1st sign of rare myopathy:
  - Danon Disease (LAMP2 variants) or Duchenne Muscular Dystrophy variants [9, 22]

3.Meng ML, Arendt KW. *Anesthesiology*. 2021
9. Zoltan. *N Engl J Med,* 2024
22.Ware JS, Li J, Mazaika E, et al. *N Engl J Med*. 2016

Delivery Planning: Maternal Optimization

- **Cardiopulmonary workup**
  - Labs: **BNP** (+ standard CBC/CMP/troponin if CP, etc..)
  - Imaging: ECG, TTE, CXR, LUS

- **Diuresis/Fluid restriction to accommodate PP fluid shift**
  - ➢ Targeted tx tailored to conditions (eg, β-blockers for LVOTO or arrhythmias)
  - ➢ Cautious diuresis in:
    - ➢ Preload-dependent condition (eg. LVOTO) [3]
    - ➢ Pre-E: intravascularly dry 2/2 endothelial damage and capillary leak
    - ➢ Early PP period, where **SVR changes** may create HD instability. [8]

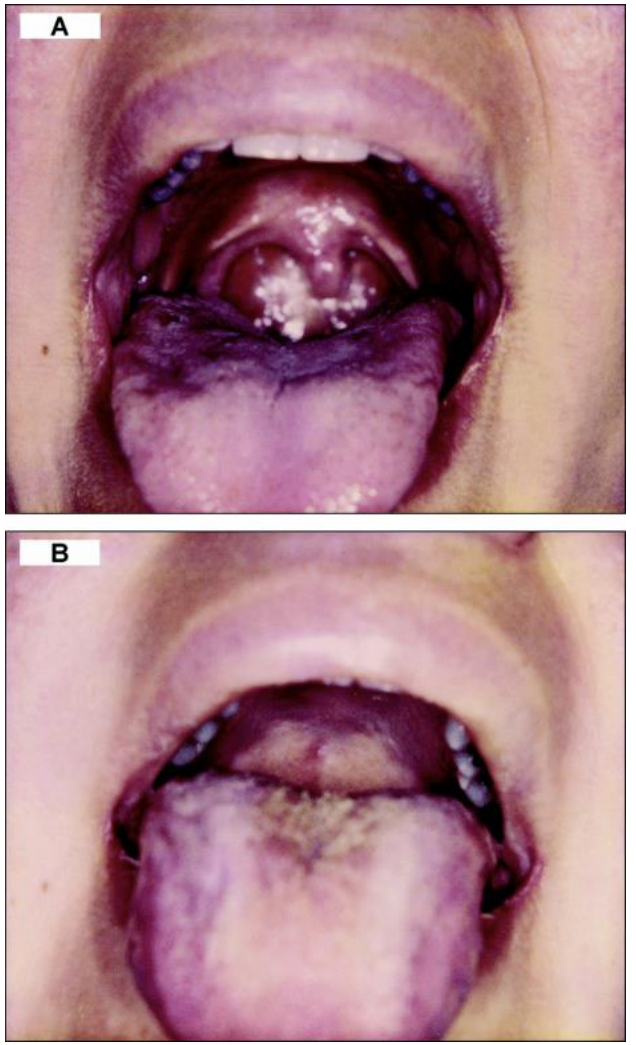
3.Meng ML, Arendt KW. *Anesthesiology*. 2021
8. Mehta LS, Warnes CA, Bradley E, et al. *Circulation*. 2020

Delivery Planning: Maternal Optimization

✓ Assess ability to **tolerate C/S positioning**:

- If unable to lie flat for c/s (↑ SOB, ↑ FiO_2, ↑ agitation)
  - ➢ May need ETT, as PP fluid shifts can acutely worsen condition.
    - ➢ Controlled intubation before emergency occurs.[3]
      - ➢ Higher incidence difficult airway
        - ➢ Airway swelling exacerbated by PreE, labor, & pushing.[30]
          - ➢ ***Airway positioning before case start****

Anesthesiology. 2008;108(3):357-362. doi:10.1097/ALN.0b013e31816452d3



↑ Airway changes in Labor ↑
Same woman before and after labor.

3. Meng ML, Arendt KW. *Anesthesiology*. 2021
30. Kodali et al, *Anesthesiology*. 2008

Delivery Planning: Maternal Optimization

- **Inotropic gtts** available in OR to assist ventricle with PP fluid load
  - ✓ Norepi, Epi, Dobutamine, Dopamine
  - ✓ Milrinone if BP stable (↓ **SVR esp with bolus)**

- Invasive lines: A-line, CVC if needed.
  - ✓ CCO monitor option if A-line in place.
  - ✓ **A-line during labor recommended in:**
    - ✓ RV dysfunction
    - ✓ Severe: LVOTO or MS
    - ✓ PPCM with severely ↓EF
    - ✓ Pulmonary HTN
    - ✓ PreE w HF

- Cardiac OR if ECMO, IABP, LVAD considered

3.Meng ML, Arendt KW. *Anesthesiology*. 2021

INOTROPES

Milrinone

- 0.125 – 0.375 mcg/kg/min
- Phosphodiesterase-3 inhibitor
- Loading dose can decrease SVR
  - Careful in Pre-E or preload – dependent lesion.
    - Slow titration of loading dose preferred

Dobutamine

- 5-10 mcg/kg/min
- Beta adrenergic agonist
  - At low does: Primarily B_1 agonism, some B_2 agonism
- Rapid onset (< 2min)
- Minimal side effects

Dopamine

- Dose - dependent receptor response
  - D1: 1-2mcg/kg/min
  - B2: 2-10 mcg/kg/min
  - A1: >10mcg/kg/min

Epinephrine

- Dose –dependent response
- Predominantly B1 & B2 agonism at lower doses
- 0.02-0.1 mcg/kg/min

Norepinephrine

- ***Low dose Norepi**
- 0.02-0.08 mcg/kg/min OR 1-6 mcg/min for Beta agonism, as levels above this are primarily alpha

Extra points:

- ✓ With contractile dysfunction, maternal heart cannot increase contractility to accommodate increased preload, especially after delivery. May be advantageous to begin inotropes before signs of ventricular failure present (tachycardia, hypoxemia, hypotension). By then, myocytes may be hypoxic and less responsive. ^O_2 demand on an already stressed ventricle..
- ✓ CCO monitoring may be beneficial in guiding and balancing vasoactive/inotropic therapy
- ✓ If parturient started on inotropes at any time peripartum (eg, optimization for pulmonary edema, systolic dysfunction, peri-delivery in anticipation of autotransfusion, etc.. **DO NOT WEAN OFF** after delivery/before case ends. **Maintain gtts and transfer to ICU.** Pt will need **continued inotropic support to manage the *continued increased preload, CO, and fluid volume shifts PP (~ 24-48h) to prevent cardiac decompensation*** [5]

3.Meng ML, Arendt KW. *Anesthesiology*. 2021

PULMONARY VASODILATORS

Nitric Oxide

- **INHALED**: 5-40 ppm

Prostacyclin: Epoprostenol

- **INHALED**: 10-50 ng/kg/min
- **IV**: 1-2 ng/kg/min via central line

Sildenafil

- **PO** 20 mg tablet

41. Combs et al. *American Journal of Obstetrics and Gynecology*. 2021

Significant Cardiac Effects of OB Meds

Oxytocin (Pitocin)

- Usually well tolerated if titrated slowly, but **rapid IV bolus ↓ SVR,** → tachycardia & myocardial ischemia
  - Can give smaller, slower doses to effect. Treat↓ SVR with pressors. [3,5]
  - Ex: *Rule of 3s*: Dilute 10u in 10cc NS0.9% and give 3u slowly (3cc) Q~3 min to effect. [23]
    - Can prevent over-dosing oxytocin. Reduced dose = reduced side effects [3,23]

Methylergonovine (Methergine)

- 5-HT, Dopamine, and α-agonist – increases smooth muscle contraction
  - ↑ SVR and **PVR**
  - Can cause HTN, coronary vasospasm, and myocardial ischemia
  - *Relatively contraindicated in HTN conditions, aneurysms, CAD*.
    - If life-threatening bleeding, can give as small DILUTE IV pushes to effect
      - Ex: dilute 0.2mg into 20cc – 10mcg/cc and give 1-2cc at a time.
  - ***Avoid** in Pulm HTN, intracardiac shunts, ischemic heart dx, aortopathy, right heart failure. [3,5]

3.Meng ML, Arendt KW. *Anesthesiology*. 2021
5. Girnius A, Meng ML. *Journal of Cardiothoracic and Vascular Anesthesia*. 2021
23. Kovacheva VP, Soens MA, Tsen LC. *Anesthesiology*. 2015

Significant Cardiac Effects of OB Meds

Carboprost (Hemabate)

- Prostaglandin $F_{2\alpha}$ agonist
  - **$PGF_{2\alpha}$ induces significant pulmonary vasoconstriction**
    - activates prostaglandin **F** receptor (GPCR on pulmonary vascular smooth muscle)[40]
      - ➢ can double PVR, and increase ↑PAP 125% [3]
      - ➢ vasoconstriction is independent of bronchomotor tone & HPV reflex [40]
  - **Induces bronchoconstriction** - can cause bronchospasm → V/Q mismatch, shunting, ↑ PVR
    - **Avoid** in asthma, Pulm HTN, intracardiac shunts, right heart strain or failure[3]

Misoprostol (Cytotec)

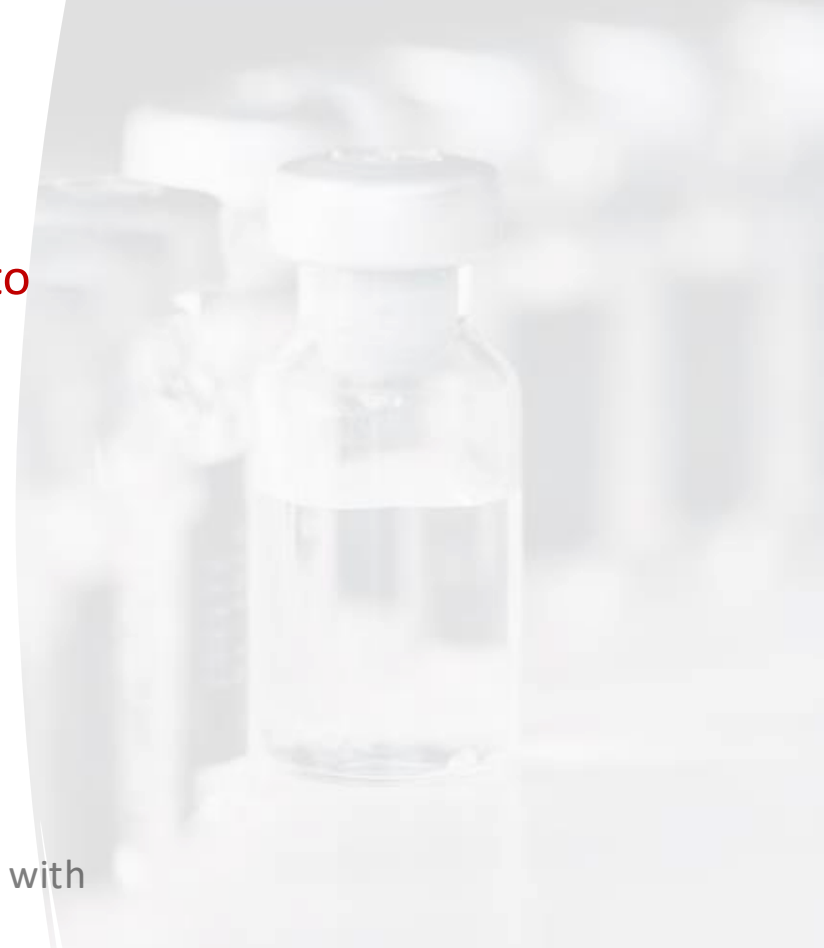
- not for emergency use, no significant CV effects, used prophylactically

3.Meng ML, Arendt KW. *Anesthesiology*. 2021
40. Hussain et al., *Eur J Cardiothorac Surg*. 2017

Significant Cardiac Effects of OB Meds

Terbutaline:

- Uterine relaxant
- Selective B_2 agonist
- ↑HR ↑ contractility ↓SVR
  - Avoid in HOCM, hx tachyarrhythmias, or any condition intolerant to tachycardia (eg: MS, AS, severe aortopathy)
    - *likely will need selective B_1 blocker first (eg: metoprolol)



- **Nitroglycerin:**
- Rapid uterine relaxation via N.O. mediated smooth muscle relaxation
- Rapid ↓SVR, resultant tachycardia
  - Caution in HOCM, AS, R→L shunt, etc
    - *For hemodynamic stability, chase IV 100mcg nitroglycerin dose immediately with combo of ~200mcg phenylephrine, and ~10mg ephedrine.

3.Meng ML, Arendt KW. *Anesthesiology*. 2021

Additional Considerations

Epidural IV Test Dose & Tachycardia:

- Epi 15 - 25 mcg (3-5cc 1.5% lido 1:200,000 epi)
- Risk of tachycardia may be problematic in:
  - hx arrhythmias, HOCM, AS, MS, or severe aortopathy
- *Could instead use fentanyl 50-100 mcg and ask pt to report any s/s of IV opioids.*

Uterine Eversion & RV Strain

- Uterus lifted up and out of abdomen for repair entrains micro air-emboli, which can ↑ **PVR** on entering pulmonary circulation.
  - ➢ Theoretical risk of increasing RV strain.
- Can repair uterus in situ to mitigate risk in pts with RV strain, pulm HTN, or R → L shunt lesions.

3.Meng ML, Arendt KW. *Anesthesiology*. 2021

Education | July 2021

Obstetric Anesthesia and Heart Disease: Practical Clinical Considerations FREE

Marie-Louise Meng, M.D.; Katherine W. Arendt, M.D.

+ Author and Article Information

Anesthesiology July 2021, Vol. 135, 164–183.

https://doi.org/10.1097/ALN.0000000000003833

3.Meng ML, Arendt KW. *Anesthesiology*. 2021

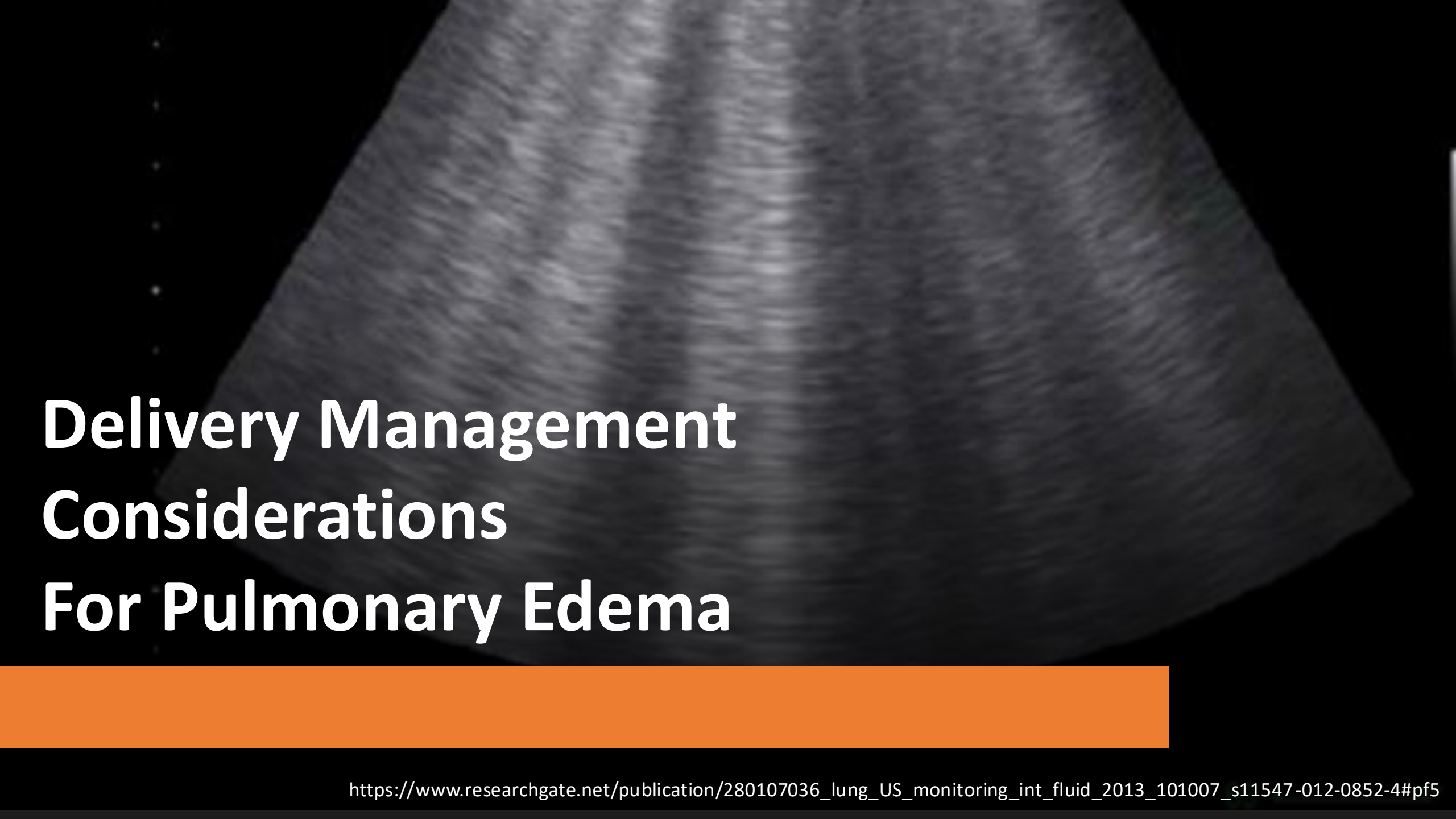
Table 4.
Hemodynamic Effects of Pregnancy and Anesthetic Management Considerations in Specific Cardiovascular Diseases

	Effects of Pregnancy and Delivery	Management Considerations
Coronary artery disease	(-) Decrease in SVR can result in reduced diastolic blood pressure and thereby decreased coronary perfusion pressure (-) Increase in heart rate can result in decreased coronary filling time (-) Cardiac work can increase significantly during labor	Normal heart rate (avoid tachycardia): ➢ Maintain effective neuraxial labor analgesia ➢ Continue β-blockade through labor and delivery ➢ Avoid β-agonist agents (*e.g.*, terbutaline) Maintain afterload: ➢ Consider intraarterial blood pressure monitoring ➢ Consider phenylephrine for vasopressor of choice ➢ Carefully titrate neuraxial anesthesia onset for labor or cesarean delivery ➢ Consider prophylactic phenylephrine infusion for cesarean delivery ➢ Titrate oxytocin carefully ➢ Early recognition and aggressive response to hemorrhage Monitor for and avoid ischemia: ➢ Five-lead electrocardiographic monitoring for cesarean delivery or labor ➢ Avoid methylergonovine ➢ Recognize and carefully treat hypertensive disorders of pregnancy (*e.g.*, consider intraarterial monitoring) Postpartum monitoring: ➢ Monitor for postpartum ischemia or heart failure
Severe left ventricular dysfunction (*e.g.*, dilated or peripartum cardiomyopathy)	(-) Increase in cardiac output and blood volume can result in heart failure and pulmonary edema (-) Decrease in oncotic pressure can result in pulmonary edema (-) Patients with previous episode of peripartum cardiomyopathy are at risk for further deterioration in left ventricular function with subsequent pregnancies (-) Angiotensin-converting enzyme inhibitors are discontinued due to teratogenicity	Normal heart rate (avoid bradycardia): ➢ Treat bradycardia with ephedrine or glycopyrrolate Maintain afterload (avoid hypertension or hypotension): ➢ Consider intraarterial blood pressure monitoring ➢ Maintain effective neuraxial labor analgesia ➢ Carefully titrate neuraxial anesthesia onset for labor or cesarean delivery ➢ Treat hypotension with ephedrine or norepinephrine ➢ Titrate oxytocin carefully ➢ Recognize and carefully treat hypertensive disorders of pregnancy (*e.g.*, consider intraarterial monitoring) ➢ Early recognition and aggressive response to hemorrhage Maintain contractility: ➢ Consider ephedrine for vasopressor of choice ➢ If low cardiac output syndrome develops, consider milrinone or dobutamine with the addition of epinephrine or norepinephrine to maintain blood pressure Prevent and monitor for pulmonary edema: ➢ Careful fluid balance ➢ Continuous pulse oximetry throughout labor and peripartum (including postpartum) Manage pulmonary edema: ➢ Consider diuresis ➢ Administer supplemental oxygen ➢ Labor in upright position ➢ If necessary, consider intubation with positive end expiratory pressure and controlled ventilation Monitor for and avoid ischemia or arrythmia: ➢ Five-lead electrocardiographic monitoring for cesarean delivery or labor Manage automatic implantable cardioverter defibrillator, if present: ➢ Keep antitachyarrhythmia function of automatic implantable cardioverter defibrillator active in labor and may be kept active in the event of emergent cesarean delivery Minimize pulmonary vascular resistance: ➢ Administer supplemental oxygen ➢ Avoid oversedation ➢ Assure well-controlled ventilation if intubated ➢ Avoid carboprost Postpartum monitoring: ➢ Monitor for postpartum heart failure
Pulmonary hypertension	(-) Increased cardiac output may not be accommodated by the fixed pulmonary vasculature resulting in right heart failure (-) Decrease in SVR can result in reduced diastolic blood pressure and thereby decreased coronary perfusion pressure especially in a dilated and failing right ventricle (-) Hypercoagulable state can result in pulmonary emboli which can exacerbate pulmonary hypertension	Minimize pulmonary vascular resistance: ➢ Administer supplemental oxygen ➢ Avoid oversedation, hypercapnia ➢ Maintain effective neuraxial labor analgesia ➢ Assure well-controlled ventilation if intubated ➢ Avoid carboprost Maintain adequate blood volume and venous return: ➢ Strict monitoring of fluid balance ➢ Recognize and carefully treat hypertensive disorders of pregnancy (*e.g.*, consider intraarterial monitoring) ➢ Early recognition and aggressive response to hemorrhage Avoid myocardial depressants: ➢ Avoid β-blockade if possible Monitor for and avoid ischemia or arrythmia: ➢ Five-lead electrocardiographic monitoring for cesarean delivery or labor Maintain afterload: ➢ Consider intraarterial blood pressure monitoring ➢ Careful titration of onset of neuraxial anesthetic for labor or cesarean delivery ➢ Consider phenylephrine for vasopressor of choice ➢ Titrate oxytocin carefully Invasive pulmonary artery catheter monitoring as well as vasoactive agents may be necessary: ➢ Consider partnership with cardiovascular anesthesiologist Postpartum monitoring: ➢ Monitor for postpartum heart failure
History of unstable arrhythmia	(-) Pregnancy, labor, and delivery can incite tachyarrhythmias which can be associated with poor fetal outcome	Minimize maternal plasma catecholamines: ➢ Maintain effective neuraxial labor analgesia ➢ Consider avoiding epinephrine-containing local anesthetics (including in a test dose) ➢ Avoid ephedrine and terbutaline ➢ Recognize and carefully treat hypertensive disorders of pregnancy (*e.g.*, consider intraarterial monitoring) ➢ Early recognition and aggressive response to hemorrhage Identify arrhythmias rapidly: ➢ Five-lead electrocardiographic monitoring for labor, cesarean delivery, and postpartum Cardiovert unstable tachyarrhythmias rapidly: ➢ Cardioversion can be performed in pregnancy ➢ With tachyarrhythmia, consider fetal distress an indication for cardioversion Manage pacemaker/automatic implantable cardioverter defibrillator, if present: ➢ Keep antitachyarrhythmia function of automatic implantable cardioverter defibrillator active in labor and may be kept active in the event of emergent cesarean delivery Postpartum monitoring: ➢ Monitor for postpartum arrhythmia
Aortopathy (*e.g.*, Marfan syndrome)	(-) Pregnancy, labor, and delivery may increase dilation of aortic root and increase the risk of aortic dissection (-) Maternal Valsalva maneuver may result in increased arterial sheer stress	Minimize aortic wall tension: ➢ Maintain effective neuraxial labor analgesia ➢ Continue β-blockade through labor and delivery ➢ Cardio-Obstetrics may recommend cesarean delivery or no Valsalva during second stage Minimize hemodynamic fluctuations: ➢ Carefully titrate neuraxial anesthesia onset for labor or cesarean delivery ➢ Consider intraarterial blood pressure monitoring ➢ Avoid methylergonovine and carboprost ➢ Titrate oxytocin carefully ➢ Recognize and carefully treat hypertensive disorders of pregnancy (*e.g.*, consider intraarterial monitoring) ➢ Early recognition and aggressive response to hemorrhage Postpartum monitoring: ➢ Monitor for postpartum hemodynamic instability
Valvular lesions		
Mechanical prosthetic valve	(-) Hypercoagulable state of pregnancy increases risk of valve thrombosis (-) Vitamin K antagonists (most effective way to prevent valvular clot formation) are teratogenic. Suboptimal anticoagulation regimens may be used during pregnancy	Balance risk of anticoagulation therapy and anesthesia technique: ➢ Perform general anesthesia for cesarean delivery in patients who are anticoagulated Recognize anticoagulation also increases risk of intrapartum and postpartum hemorrhage: ➢ Select and/or titrate uterotonics carefully depending on underlying cardiac disease recognizing that oxytocin decreases SVR, methylergonovine behaves as an adrenergic alpha agonist and carboprost increases pulmonary vascular resistance significantly ➢ Postpartum monitoring ➢ Monitor for postpartum valvular clotting or obstetric bleeding
Mitral stenosis	(-) Elevation in blood volume and heart rate increases left atrial pressure which may lead to atrial fibrillation and pulmonary edema (-) Because of relatively fixed preload to the left ventricle, the heart may not adequately generate increased cardiac output (-) Decreased oncotic pressure further increases risk of pulmonary edema	Normal heart rate (avoid tachycardia): ➢ Maintain effective neuraxial labor analgesia ➢ Continue β-blockade through labor and delivery ➢ Five-lead electrocardiographic monitoring for cesarean delivery or labor ➢ Avoid β-agonist agents (*e.g.*, terbutaline) ➢ Early recognition and aggressive response to hemorrhage ➢ Avo Atrial fibrillation ➢ In new-onset atrial fibrillation, cardioversion should be considered ➢ In failed cardioversion and in cases with chronic atrial fibrillation, treat rapid ventricular rate with medical therapy Prevent and monitor for pulmonary edema: ➢ Careful fluid balance ➢ Continuous pulse oximetry throughout labor and peripartum (including postpartum) ➢ Recognize and carefully treat hypertensive disorders of pregnancy (*e.g.*, consider intraarterial monitoring) Manage pulmonary edema: ➢ Consider diuresis ➢ Administer supplemental oxygen ➢ Labor in upright position ➢ If necessary, consider intubation with positive end expiratory pressure and controlled ventilation Postpartum monitoring: ➢ Monitor for postpartum pulmonary edema
Aortic stenosis/hypertrophic obstructive cardiomyopathy	(-) Decrease in SVR can result in reduced diastolic blood pressure and therefore decreased coronary perfusion pressure to the thickened left ventricle myocardium (-) Left ventricle diastolic dysfunction and excess volume can lead to pulmonary edema	Maintain afterload (avoid hypotension and hypovolemia): ➢ Consider intraarterial blood pressure monitoring ➢ Carefully titrate neuraxial anesthesia onset for labor or cesarean delivery ➢ Treat hypotension with phenylephrine ➢ Avoid nonspecific β-agonist agents (*e.g.*, terbutaline) ➢ Titrate oxytocin carefully ➢ Early recognition and aggressive response to hemorrhage Normal heart rate (avoid tachycardia): ➢ Maintain effective neuraxial labor analgesia ➢ Prevent and monitor for ischemia ➢ Five-lead electrocardiographic monitoring for cesarean delivery or labor ➢ Recognize and carefully treat hypertensive disorders of pregnancy (*e.g.*, consider intraarterial monitoring) Maintain normovolemia: ➢ Strict monitoring of fluid balance ➢ Postpartum monitoring ➢ Monitor for postpartum hypotension or ischemia
Mitral/aortic insufficiency	(+) Decreased SVR results in a lower regurgitant volume (-) Pregnancy can worsen ventricular dilation	Avoid increases in SVR and decreases in contractility: ➢ Maintain effective labor analgesia ➢ Avoid bradycardia ➢ In cesarean delivery under spinal anesthesia, if prophylactic phenylephrine administered, carefully titrate and treat bradycardia. Alternatively, consider norepinephrine Maintain sinus rhythm: ➢ Maintain effective neuraxial labor analgesia ➢ Consider afterload reduction ➢ Neuraxial analgesia/anesthesia typically well tolerated if preserved ventricular
		➢ Recognize and aggressively treat hypertensive disorders of pregnancy (*e.g.*, consider intraarterial monitoring)
Shunt lesions		
Right-to-left shunt (*e.g.*, tetralogy of Fallot, Eisenmenger syndrome)	(-) Decreased SVR increases right-to-left shunting and possible cyanosis (+) In unrepaired tetralogy of Fallot and normal right ventricle function, the increase in blood volume is beneficial because adequate right ventricular preload is necessary to eject blood past the outflow obstruction and increase pulmonary blood flow*	Maintain afterload and recognize worsening cyanosis: ➢ Continuous pulse oximetry throughout labor and peripartum (including postpartum) ➢ Treat cyanotic episodes with phenylephrine ➢ Consider intraarterial blood pressure monitoring ➢ Carefully titrate neuraxial anesthesia onset for labor or cesarean delivery ➢ Titrate oxytocin carefully ➢ Minimize pulmonary vascular resistance ➢ Administer supplemental oxygen throughout labor and delivery ➢ Avoid oversedation ➢ Maintain effective neuraxial labor analgesia ➢ Assure well-controlled ventilation if intubated ➢ Avoid carboprost Maintain adequate blood volume and venous return: ➢ Strict monitoring of fluid balance ➢ Avoid supine position ➢ Early recognition and aggressive response to hemorrhage Avoid myocardial depressants because any decrease in right ventricular contractility can decrease pulmonary circulation: ➢ Avoid β-blockade if possible ➢ Five-lead electrocardiographic monitoring for cesarean delivery or labor If pulmonary vascular disease is present, invasive pulmonary artery catheter monitoring, as well as vasoactive agents, may be necessary: ➢ Consider partnership with cardiovascular anesthesiologist Avoid paradoxical embolism: ➢ Place filters on intravenous lines ➢ Perform epidural loss of resistance technique with saline not air ➢ Postpartum monitoring ➢ Monitor for postpartum cyanosis
Left-to-right shunt (*e.g.*, ventricular septal defect or atrial septal defect)	(+) Decrease in SVR decreases left-to-right shunting (-) Increase in blood volume can precipitate failure because the patient is in a state of compensatory hypervolemia	Avoid excessive fluid administration, overtransfusion, and Trendelenburg position: ➢ Strict monitoring of fluid balance ➢ Early recognition and careful response to hemorrhage ➢ Avoid increases in afterload ➢ Maintain effective neuraxial labor analgesia Avoid paradoxical embolism: ➢ Place filters on intravenous lines ➢ Perform epidural loss of resistance technique with saline and not air

3.Meng ML, Arendt KW. *Anesthesiology*. 2021

Objectives:

- Current Data on Maternal Mortality
- Peripartum Hemodynamics Review
- Maternal Cardiac Risk Scoring Systems & Heart Failure Identification Tools
- Heart Failure from Preeclampsia & Peripartum Cardiomyopathy
- **Delivery Management Considerations in:**
  - Heart Failure
  - **Pulmonary Edema**



Delivery Management Considerations For Pulmonary Edema

https://www.researchgate.net/publication/280107036_lung_US_monitoring_int_fluid_2013_101007_s11547-012-0852-4#pf5

Pulmonary Edema in Pregnancy

Parturients with heart disease are at high risk of pulmonary edema.

- Cardiogenic: heart failure, or fluid overload (can be iatrogenic)
- Non-cardiogenic: increased vascular permeability 2/2 damaged endothelium.
- Mixed: Parturient with PPCM and PreE/Eclampsia

Heart failure can increase pulmonary capillary hydrostatic pressure

- further increased risk of transudation of fluid into pulmonary interstitium.

Preparation for potential emergent delivery in acute pulmonary edema 2/2 heart failure includes:

- Rapid management of hypoxemia to prevent maternal or fetal compromise
- diuresis, +/- inotropic support, O_2 supplementation and possible tracheal intubation.

3.Meng ML, Arendt KW. *Anesthesiology*. 2021

DIAGNOSTIC TESTS

PULMONARY EDEMA

- BNP
  - High BNP suggests HF and warrants further workup → TTE, POCUS
    - BNP > 50*
    - NT- proBNP > 150*
- **TTE**, POCUS: PLA, PSA, 4-chamber view
- POCUS lung US
- CXR
- ECG

15. Bauersachs J, König T, Meer P, et al. *European Journal of Heart Failure*. 2019
* 33. Stocktree, et al. *J Endocr Soc*. 2021

LUNG US vs CXR in HF

JAMA Network Open

Original Investigation | Emergency Medicine

Diagnostic Accuracy of Point-of-Care Lung Ultrasonography and Chest Radiography in Adults With Symptoms Suggestive of Acute Decompensated Heart Failure
A Systematic Review and Meta-analysis

Anna M. Maw, MD, MS; Ahmed Hassanin, MD; P. Michael Ho, MD, PhD; Matthew D. F. McInnes, MD, PhD; Angela Moss, MS; Elizabeth Juarez-Colunga, PhD; Nilam J. Soni, MD, MS; Marcelo H. Miglioranza, MD, MHSC, PhD; Elke Platz, MD, MS; Kristen DeSanto, MSLS, MS, RD; Anthony P. Sertich, MD; Gerald Salame, MD; Stacie L. Daugherty, MD, MSPH

2019 SRMA: 6 prospective cohort studies, 1827 patients

- Lung US more sensitive than CXR for detection of cardiogenic pulmonary edema, with similar specificity:
  - 15% absolute difference in sensitivity found between LUS and CXR (0.88 vs 0.73) ($P < .001$)
    - In other words: Q 100 patients c/c dyspnea 2/2 cardiogenic pulmonary edema, LUS can dx 15 more cases than CXR without increase in false (+).

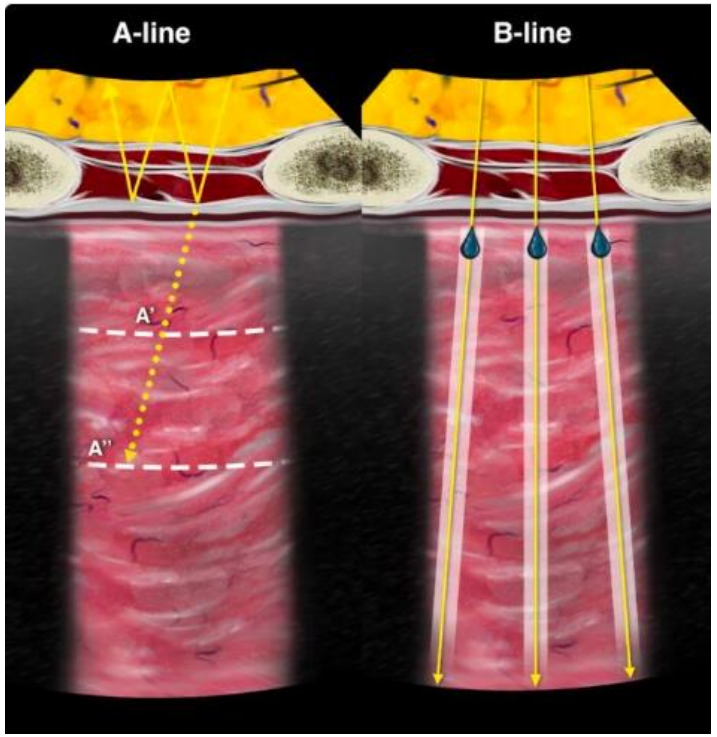
- Additional Benefits: LUS easier to see real-time edema resolution, as confirmatory CXR images can lag behind both development and resolution. There is no radiation exposure, and learning curve for use is quick.

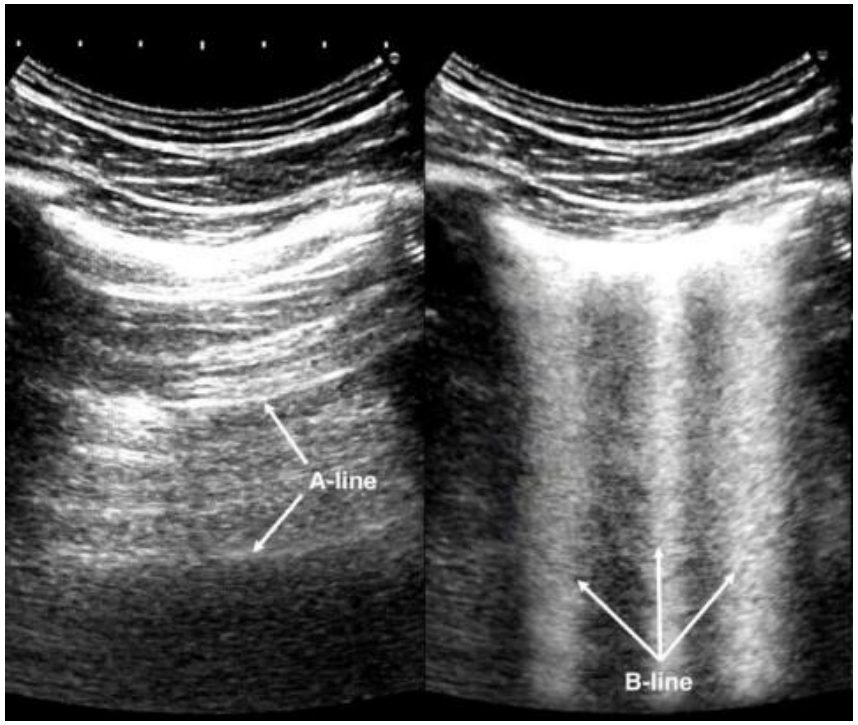
24. Maw AM, Hassanin A, Ho PM, et al.. *JAMA network open*. 2019

POCUS LUNG ULTRASOUND

A-LINE:
horizontal evenly-spaced hyperechoic reverberation air artifacts of the pleural line.

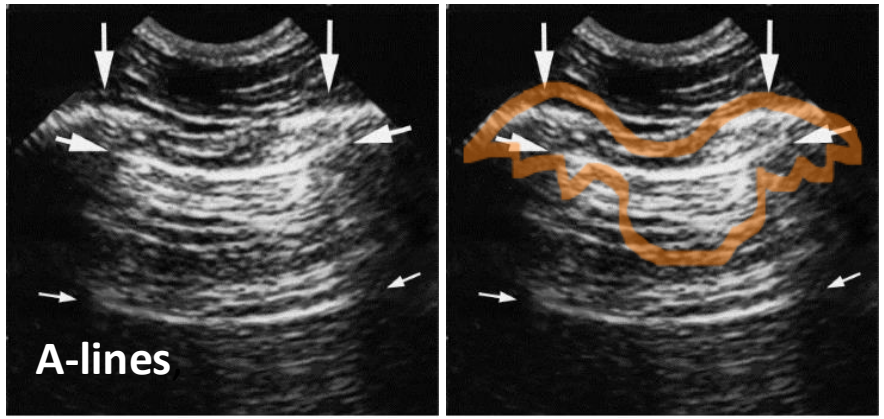
B-LINE:
well-defined, hyperechoic water artifacts extending from the pleural line down to bottom of screen without fading, obliterating A-lines.[25]

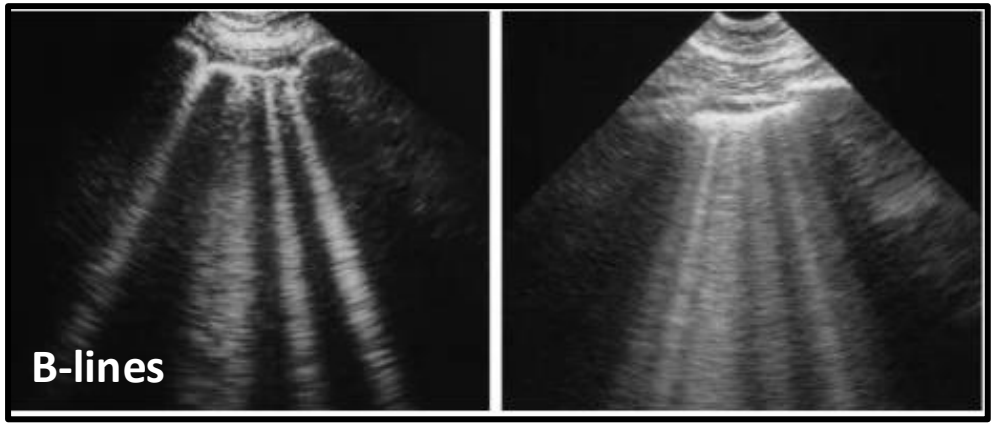




25. NYSORA. Acute respiratory failure: The BLUE protocol. *NYSORA*. 2023.

"bat sign" of rib shadows and pleural line



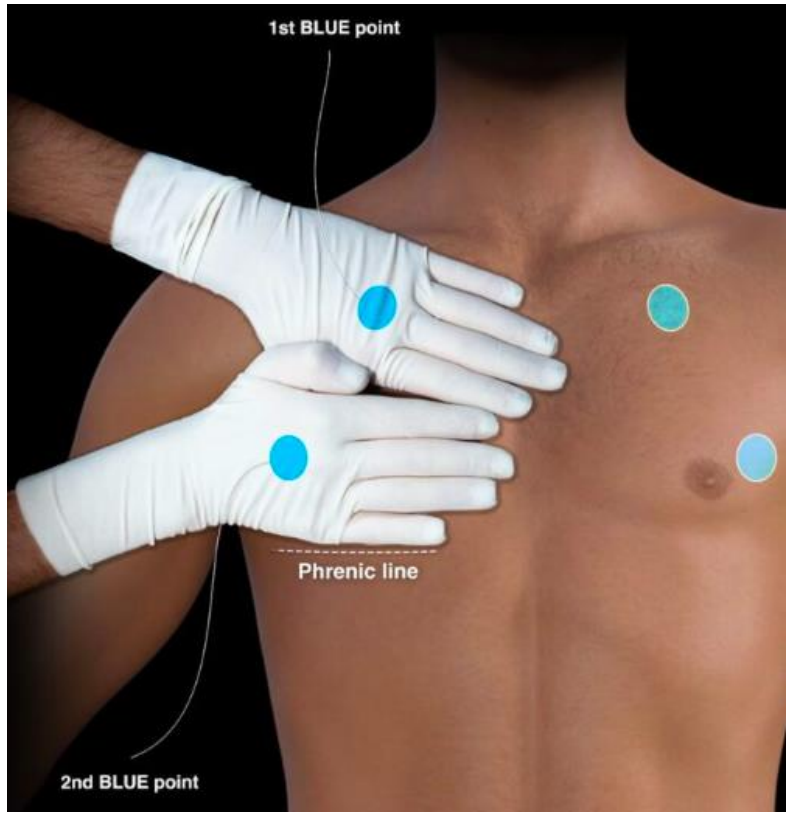


https://annalsofintensivecare.springeropen.com/articles/10.1186/2110-5820-4-1

POCUS LUNG ULTRASOUND

- 3+ B-lines in one field = **"wet" lung.**
  - 1-3 B-lines in bases can be <u>normal finding in pregnancy</u>.

- Visualized lung sliding*, **with**:
  - **3+ B-lines *at all 4 points*** → likely pulmonary edema
    - ➢ lack of lung sliding suggests pneumonia
      - ❖ [**BLUE** protocol – **B**edside **L**ung **U**ltrasound in **E**mergency]



25. NYSORA. Acute respiratory failure: The BLUE protocol. *NYSORA*. 2023.

Pulmonary Edema: *Maternal Optimization*

Diuresis

- Careful with high doses in PreE – intravascularly dry patient 2/2 third spacing

Supplemental O2

- HFNC, CPAP, BiPAP: +PEEP

Fluid restriction during delivery (C/S or VD)

- Careful IVF titration
- Smaller reconstitution doses for antibiotics (eg: 20cc syringe slow IVP vs 250cc NS bag for azithromycin)
- **Pitocin**: (instead of 10u over 10min ~ 166cc in 30u/500cc bag)
  - Instead:
    - "Rule of 3s": 10u Pitocin in 10cc NS: Administer 3u Q3min to effect.
    - OBGYN can give IU Pitocin in C/S in lieu of IV bolus

Pulmonary Edema in **PREECLAMPSIA**

- When **HTN** *causes* ***pulmonary edema,*** **IV NTG** is preferred[18]
  - vs standard 1st line anti-HTN agents: IV Labetalol, hydralazine, or oral nifedipine

- Titrated NTG can offload ventricles without affecting contractility
  - *Especially in LV systolic dysfunction/PPCM*:
    - ➢ Added inotropes (eg: dobutamine) can augment contractility without increasing SVR to improve forward flow
      - ➢ Initiation of high-dose BBs may be detrimental in poor LV contractile function and HR-dependent CO

  - NTG gtt offers tight HD control with rapid onset and short $Et^1/_2$
    - **DOSE: 5 mcg/min, titrate Q 3–5 min to max dose 100 mcg/min.**[18]

IMPORTANCE OF BNP → +/- TTE to assess which agents would be most beneficial if myocardial dysfunction present.

18. Regitz-Zagrosek V, Roos-Hesselink JW, Bauersachs J, et al. *European Heart Journal.* 2018.

Heart Failure: Where to Look

WE MUST BE AWARE OF POSSIBILTY OF HEART FAILURE IF S/S PRESENT PERIOP IN PREGNANT OR POSTPARTUM WOMEN

S/S on labor floor :

- ↓SpO2, tachycardia, positioning, pt c/o not feeling right:
  - ✓ Maternal Early Warning Criteria/ACOG criteria/Fett Self Test.
  - ✓ Pulmonary edema: Cardiac workup, BNP, +/-TTE.

- ✓ Postpartum tubals, D&C for PPH – can occur in days, weeks PP
- ✓ Postpartum non-obstetric elective surgery/procedure
- ✓ Ante-/Postpartum urgent or emergent surgery

Heart Failure: Where to Look

- In women who have had recent pregnancies, it's prudent to ask pointed cardiac questions:
  - ✓ METs, SOB, palpitations, chest pain, abnormal fatigue, s/s at rest vs active, peripheral edema, able to lay flat at night? Etc..

After 6wk PP checkup with OBGYN,
we may be the only other providers women see during PP period who know to look for this.

"**Fett Self Test**" for Early Identification of Heart Failure

> 4 pts → further workup (BNP & TTE)[27]

Table 1. Self-test for early diagnosis of peripartum cardiomyopathy.

Symptoms	0 points	1 point	2 points
Orthopnea	None	Need to elevate head	Need to elevate 45 degrees or more
Dyspnea	None	Climbing 8 or more steps	Walking on level
Unexplained cough	None	At night	Day and night
Lower extremity swelling	None	Below knee	Above and below knee
Excessive weight gain during last month of pregnancy	Under 2 pounds per week	2–4 pounds per week	Over 4 pounds per week
Palpitations	None	When lying down at night	Day and night, any position

The presence of 4 or more points should prompt additional investigation. Data taken from [30].

Davis M, Duvernoy C. *Women's Health*. 2015

In validation study: **100% of women who presented with > 4pts had LV systolic dysfunction**.[27]

26. Davis M, Duvernoy C. Peripartum Cardiomyopathy: Current Knowledge and Future Directions. *Women's Health*. 2015.
27. Fett JD. Validation of a self-test for early diagnosis of heart failure in peripartum cardiomyopathy. *Critical Pathways in Cardiology*. 2011;10(1):44-45. doi:https://doi.org/10.1097/HPC.0b013e31820b887b

"Although it is possible that a fulminant myocarditis/cardiomyopathy can suddenly appear without prior warning and awareness, ***almost all of these women, upon reflection, can recognize that they experienced signs and symptoms earlier by days and weeks***."

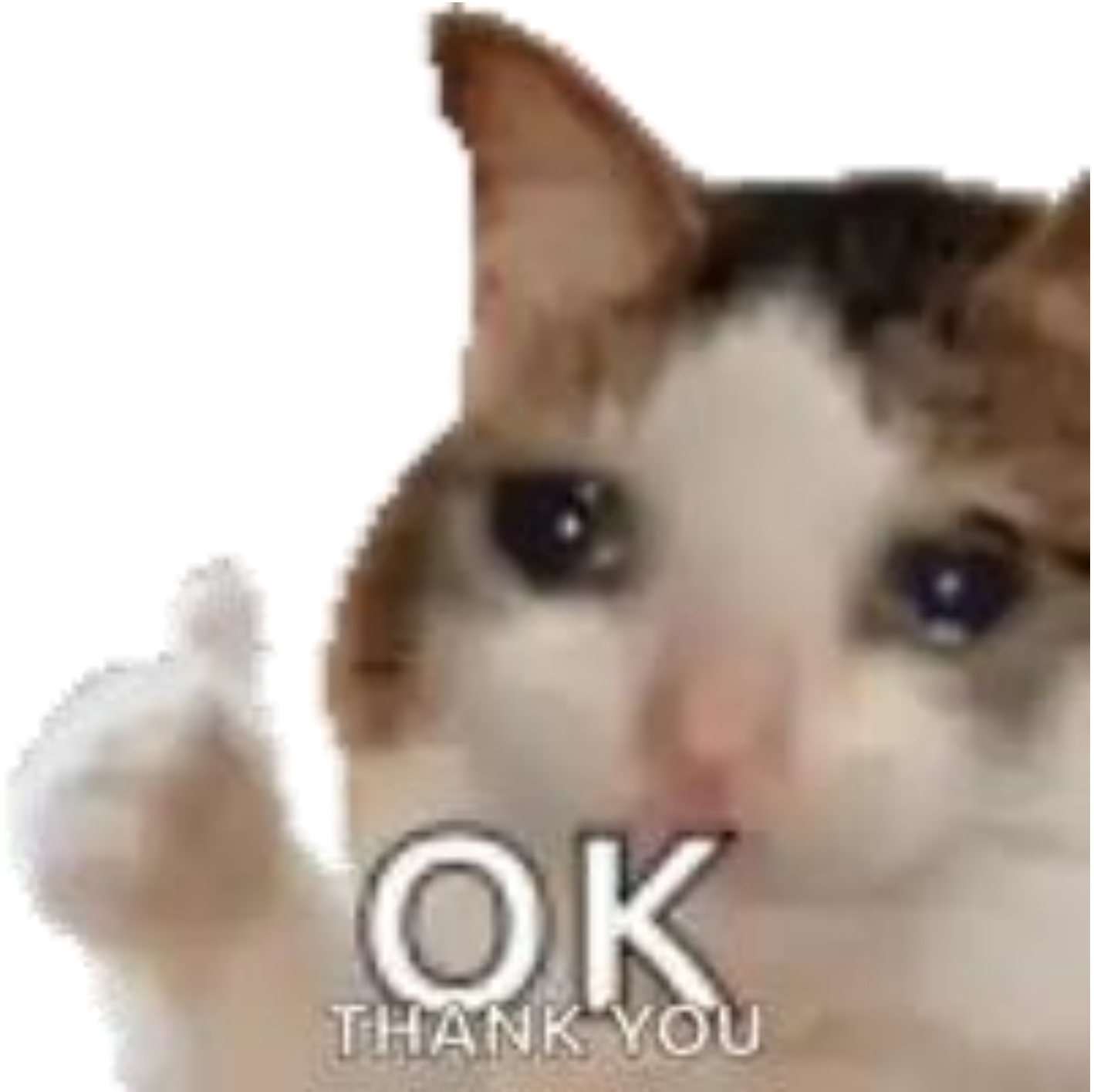
"My incessant theme is this: Physicians, nurses and patients must be alert to the possibility that ***a young woman, despite the lack of any type of heart problem in her medical history, may develop a serious cardiomyopathy with acute onset of heart failure in the setting of pregnancy***"

- James D Fett, MD, MPH

29. Fett JD. *World J Cardiol*. 2014

TLDR: Key Points Summary

- Cardiomyopathy is a significant cause of maternal death in the United States, and globally.
- During pregnancy and postpartum, heart failure from either HTN or PPCM can develop rapidly and acutely over just days, in otherwise low-risk “completely healthy” women. The condition is both under-screened and under-diagnosed.
- BNP/NT-proBNP is an important screening tool
- Pulmonary edema may be presenting sign of heart failure, and pulmonary ultrasound is a fast and reliable diagnostic tool.
- The significantly increased cardiac demands of labor, delivery, and **especially the postpartum period**, can push an impaired ventricle into florid failure.
- Uterotonic and tocolytic agents given peripartum can have **significant and deleterious cardiac effects in women with heart failure ad CVD.**
- Heart failure develops most commonly within 6 months postpartum, so it is prudent to include directed cardiac questions in pre-op eval for women who have recently been pregnant.
    - Fett Test is a useful, validated tool.


OK
THANK YOU

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