Fetal Atrial Septal Interventions in Hypoplastic Left Heart Syndrome

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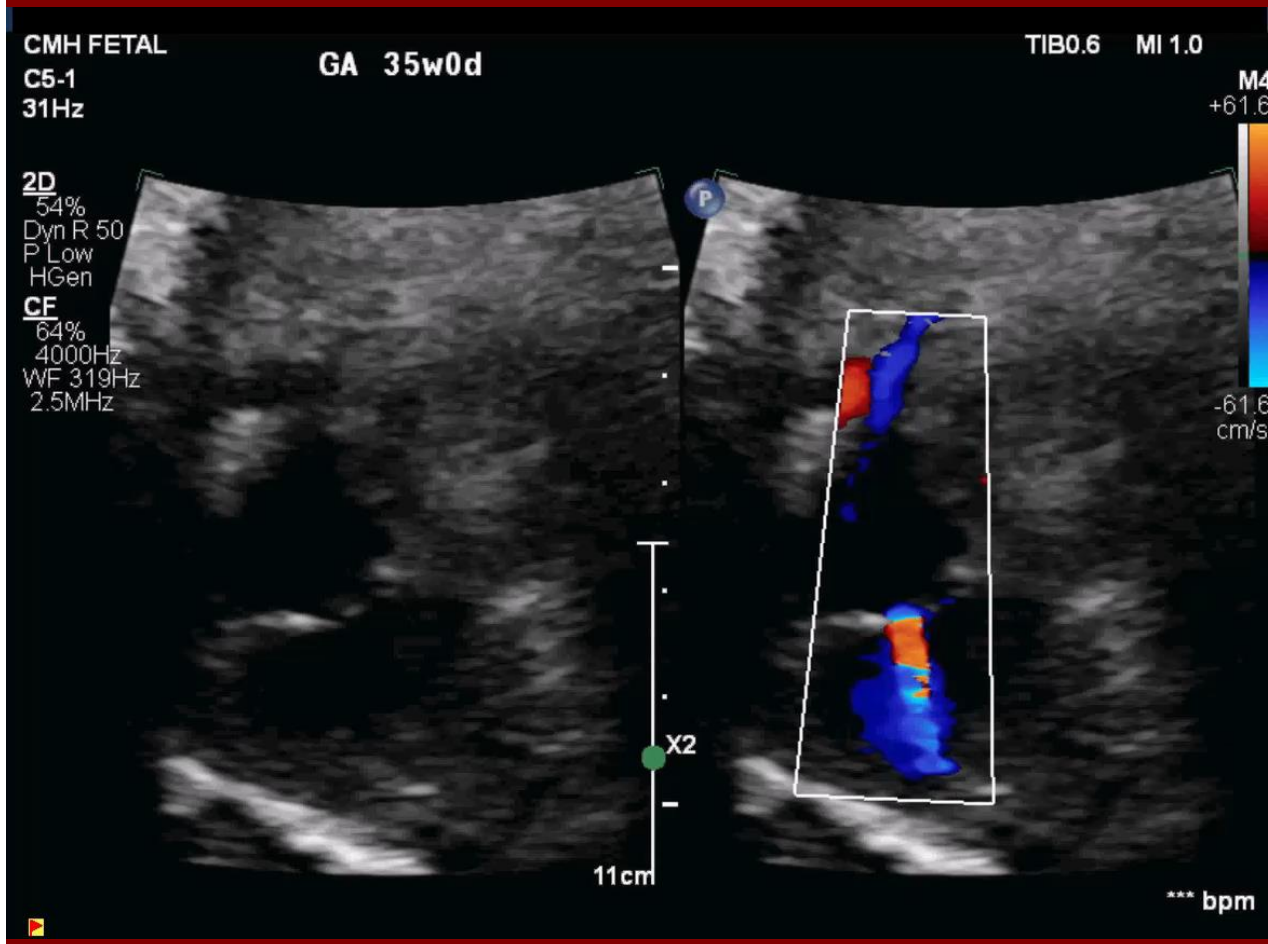
Objectives

- Understand the pathophysiology of hypoplastic left heart syndrome (HLHS) and the role of the atrial septum in fetal circulation.
- Identify the indications, techniques, and potential benefits of fetal atrial septal intervention in HLHS with restrictive or intact atrial septum.
- Recognize the risks, challenges, and ethical considerations associated with fetal cardiac interventions.

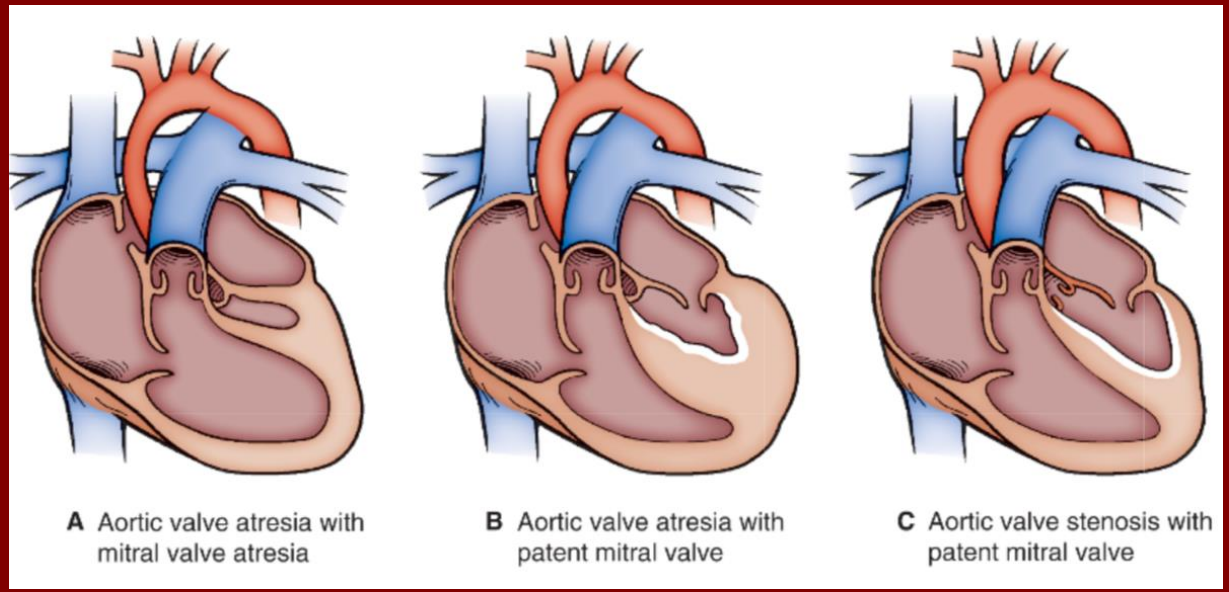
Conclusion

- Fetal atrial septal intervention should be considered and incorporated into fetal counseling for patients with HLHS and restrictive atrial septum
- HLHS with restrictive atrial septum is high-risk lesion associated with poor outcomes
- Restriction causes high left atrial pressure and damage to pulmonary vascular bed
- Maternal and fetal risks need to be weighed against evidence of improved outcomes for those with fetal intervention



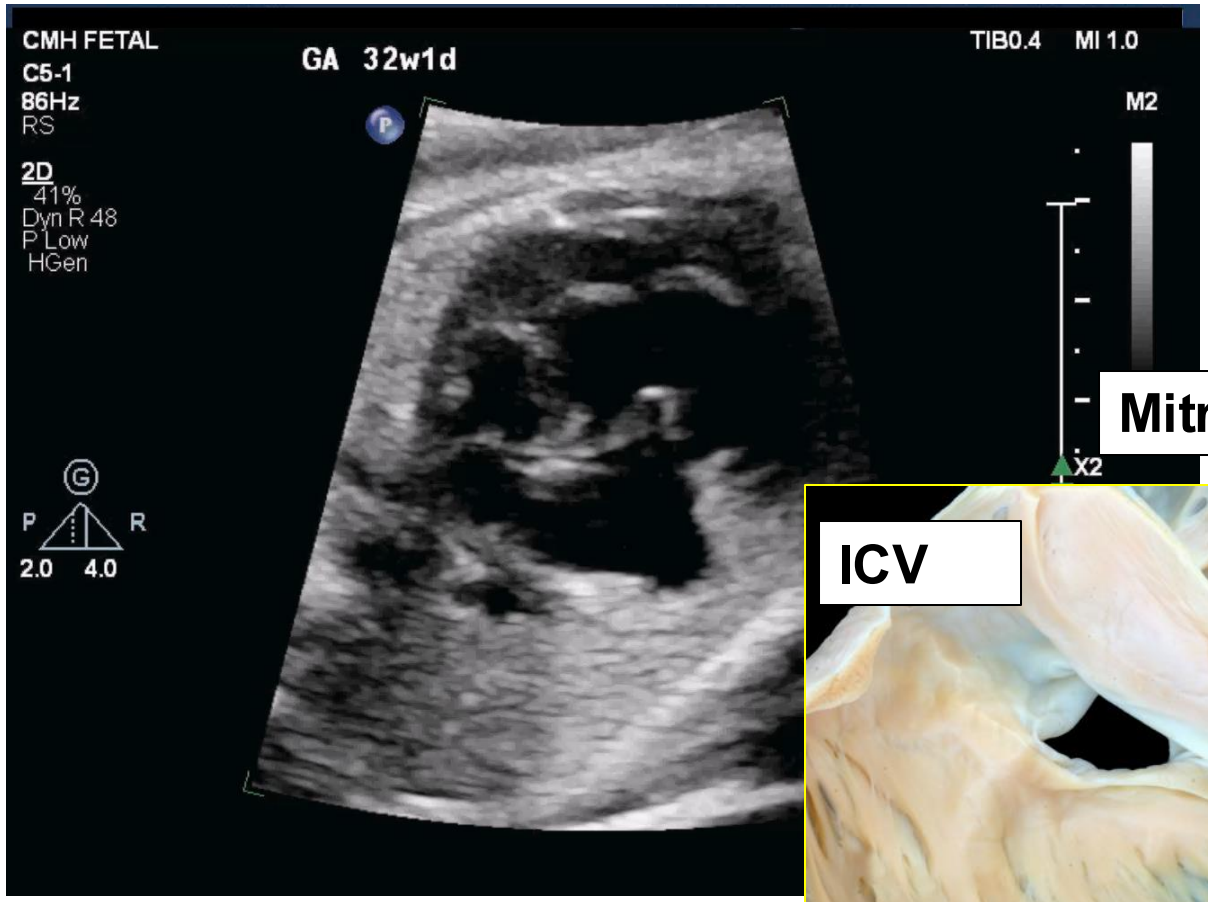
Definition HLHS

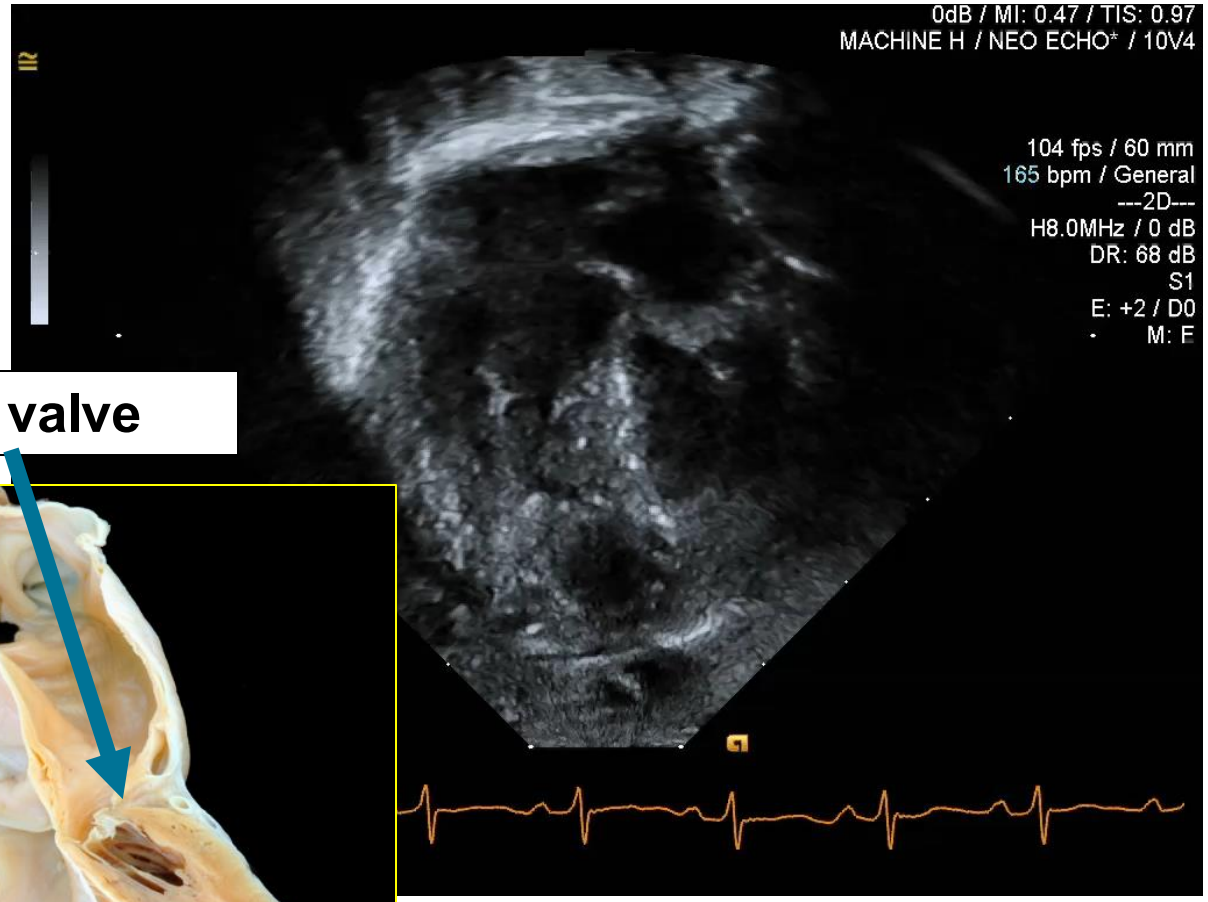
- “A spectrum of congenital cardiovascular malformations with normally aligned great arteries without a common atrioventricular junction, characterized by underdevelopment of the left heart with significant hypoplasia of the left ventricle including atresia, stenosis, or hypoplasia of the aortic or mitral valve, or both valves, and hypoplasia of the ascending aorta and aortic arch”
    - ISNPCHD-WHO ICD-11 CHD Terms IPCCC
- There is inadequate development of the left sided heart structures to support the systemic circulation
- Generally fall into three categories based on the status of the aortic and mitral valve
    - Aortic atresia and mitral atresia (AA, MA)
    - Aortic atresia and mitral stenosis (AA, MS)
    - Aortic stenosis and mitral stenosis (AS, MS)

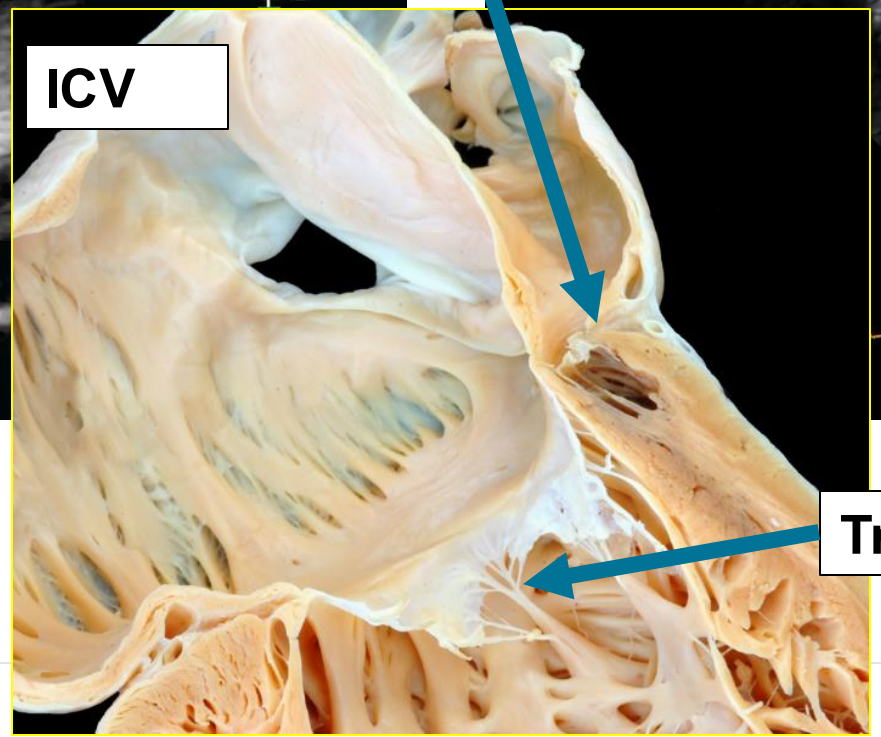


Fetus

Postnatal







Fetal

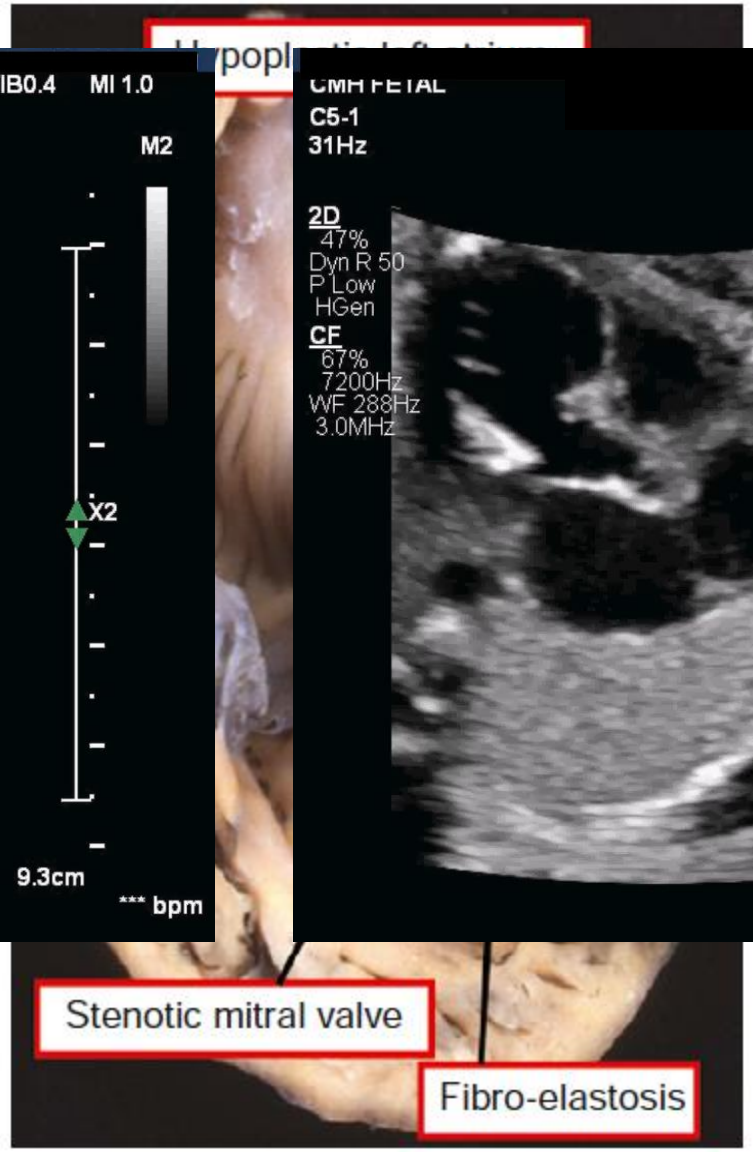
- Fetal echocardiography offered new insight into the development of HLHS
- Patients originally diagnosed with critical aortic stenosis showed development of HLHS
  - Hence the no flow no grow paradigm
- Limitations/alterations in LV outflow or LV inflow
  - Aortic stenosis
  - Mitral stenosis
  - Restriction at the oval foramen

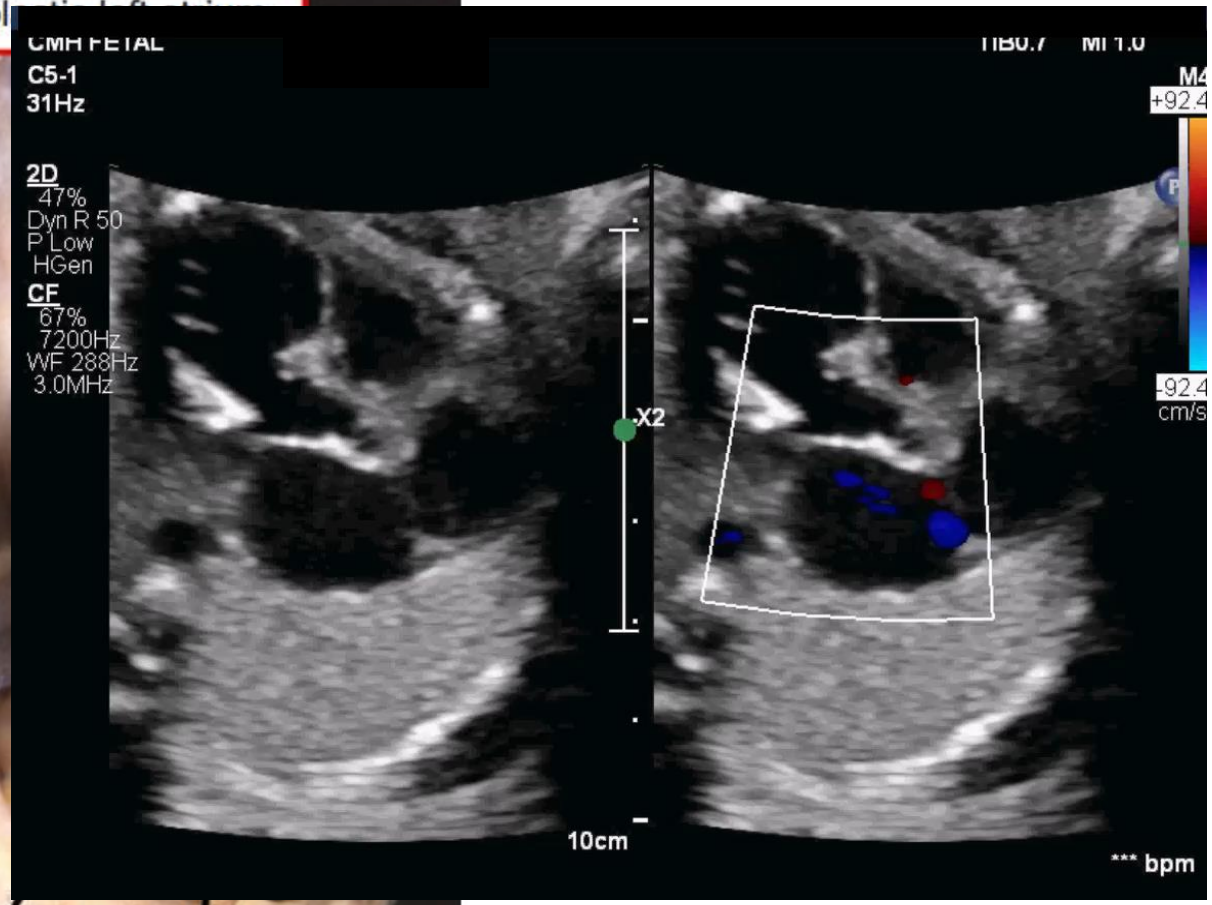
Fetal

- Relatively easily made diagnosis with fetal echocardiography
- Now challenge is evolution into HLHS (consideration of fetal intervention) and diagnosing restrictive or intact atrial septum
- Therefore, particular need for follow up during fetal life for the development of HLHS especially in aortic stenosis

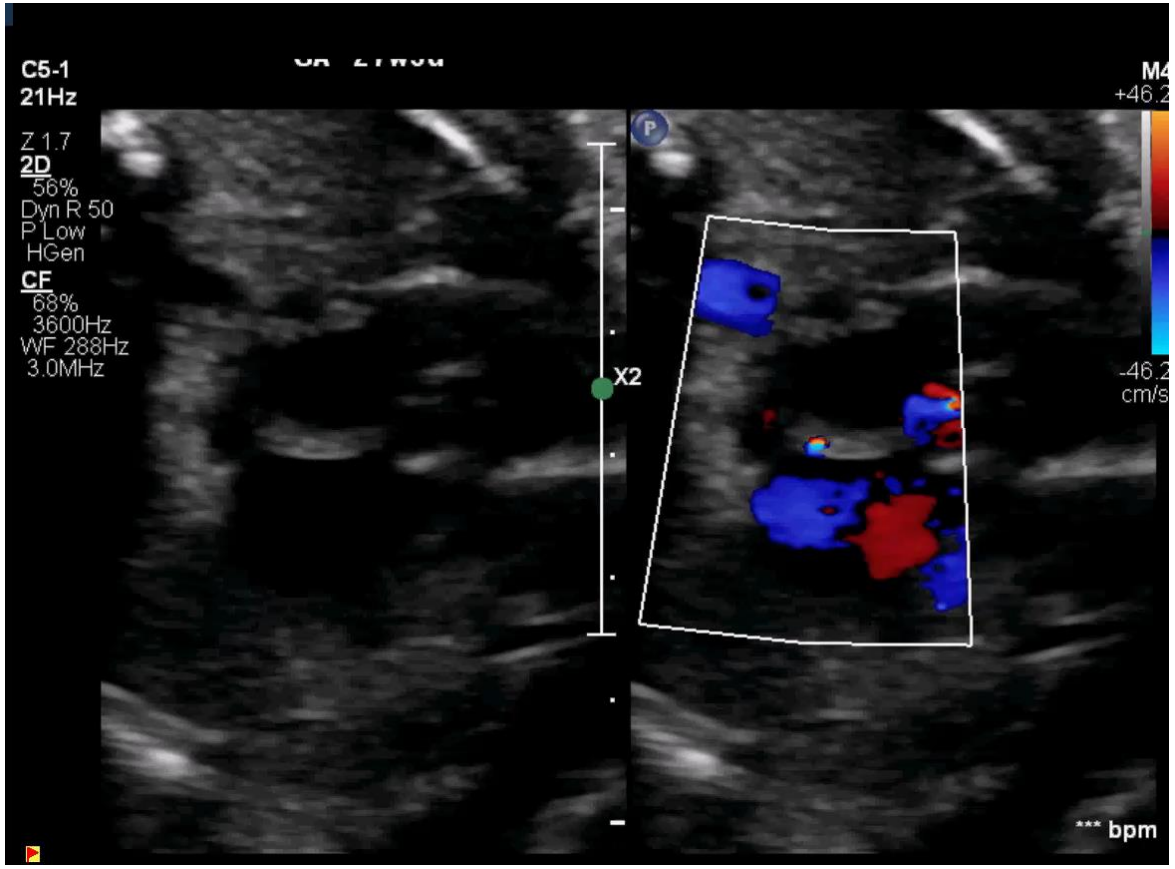
HLHS (MS, AS)

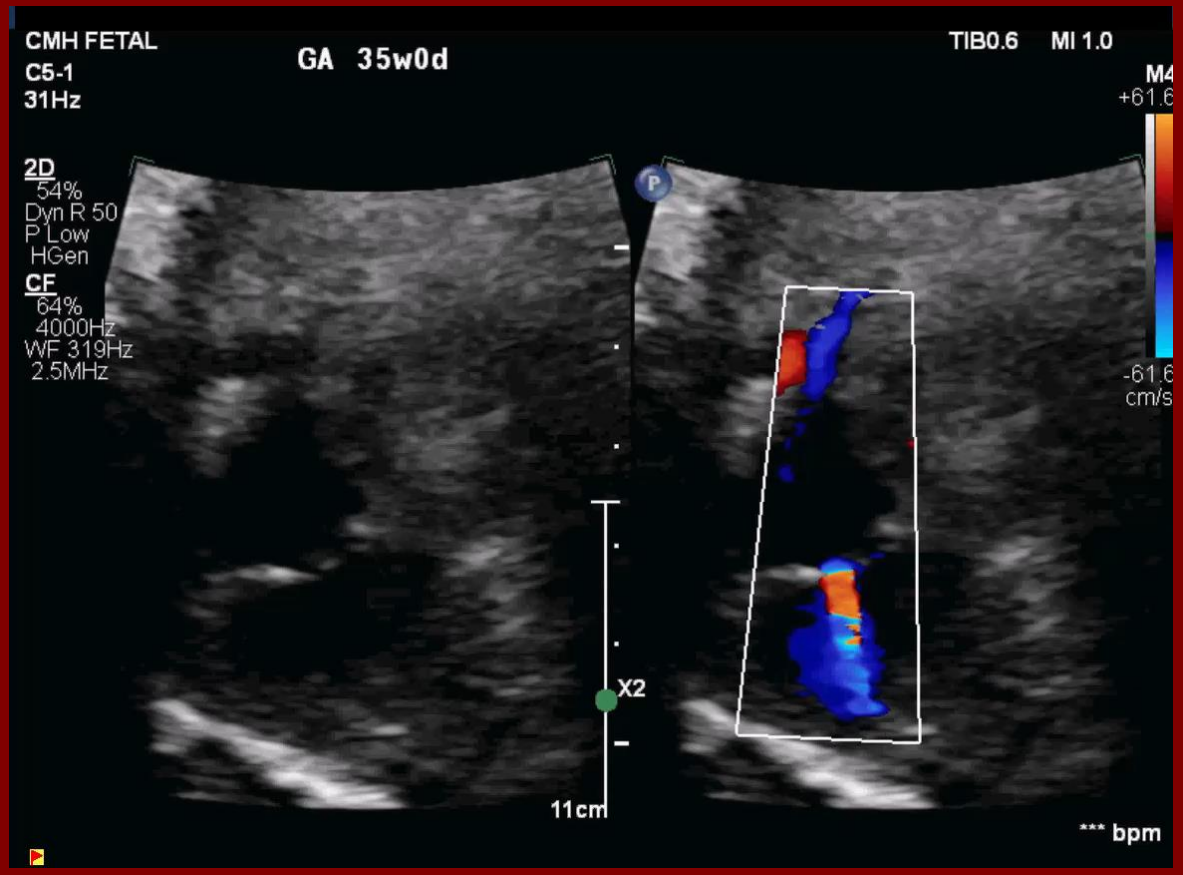

CMH FETAL
C5-1
86Hz
RS
2D
41%
Dyn R 48
P Low
HGen
GA 32w1d
TIB0.4 MI 1.0
M2
X2
9.3cm
*** bpm
P
R
2.0 4.0


Stenotic mitral valve
Fibro-elastosis


C5-1
31Hz
2D
47%
Dyn R 50
P Low
HGen
CF
67%
7200Hz
WF 288Hz
3.0MHz
X2
10cm
*** bpm

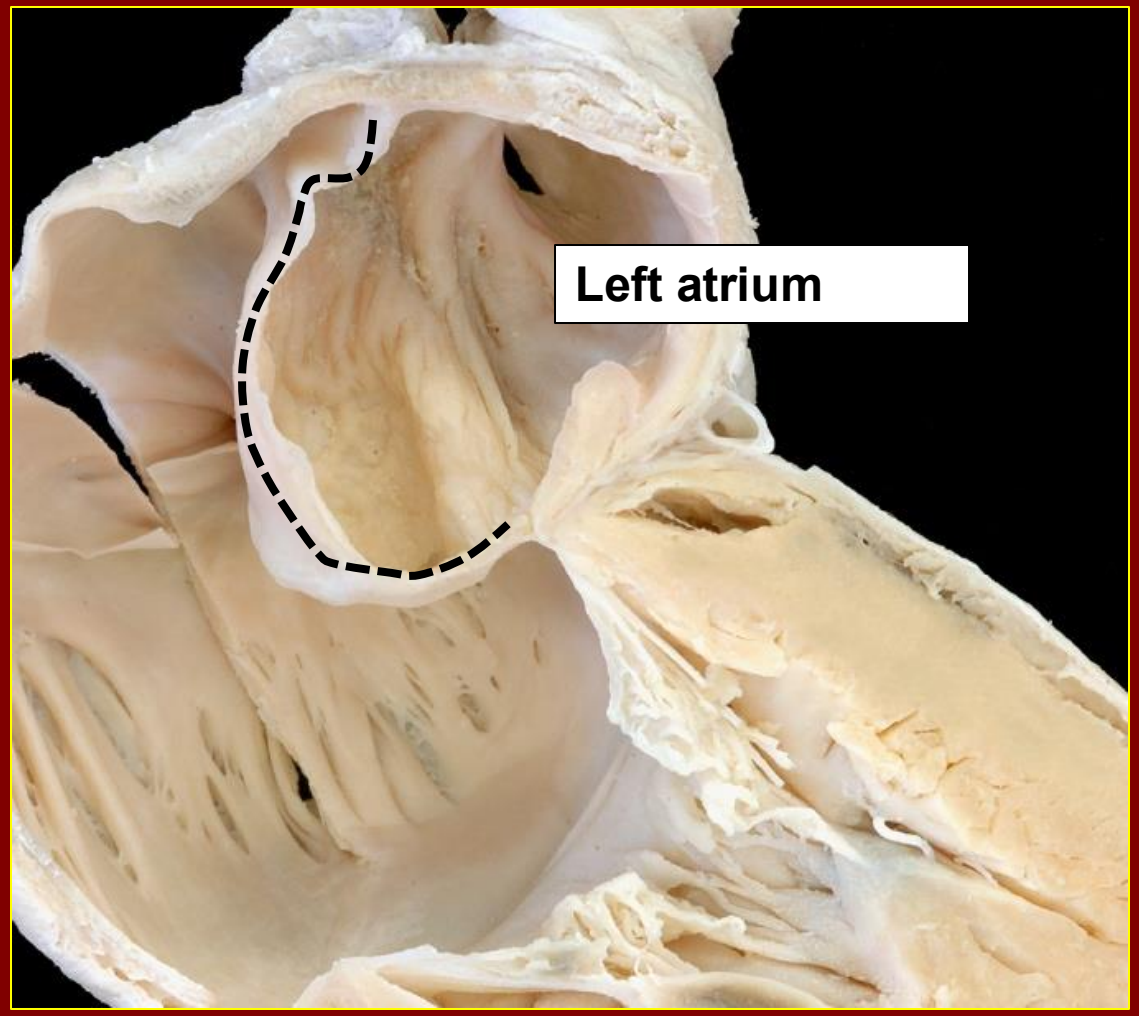
HLHS with intact or restrictive atrial septum





HLHS with intact or restrictive atrial septum

- Rationale is not to prevent progression of disease during fetal life but to
  - avoid severe neonatal hypoxia and death
  - Prevent worsening lung disease due to chronic pulmonary venous hypertension
- Incidence of IAS w/HLHS is 6% and restrictive septum 22%
- Outcomes significantly worse compared to unrestrictive atrial septum

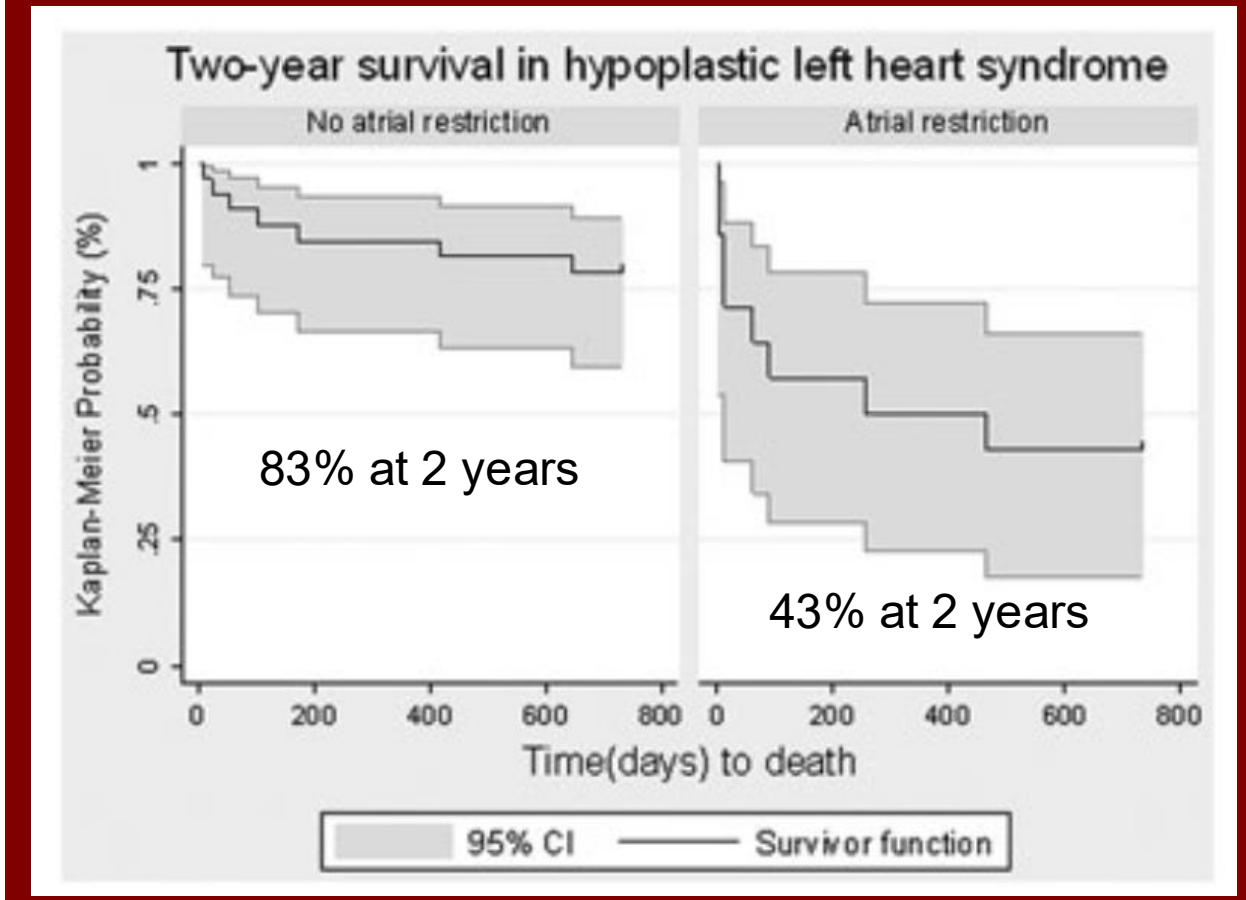


Premature closure of PFO

Prenatal diagnosis of atrial restriction in hypoplastic left heart syndrome is associated with decreased 2-year survival

Alexander Lowenthal[1], Alaina K. Kipps[1], Michael M. Brook[1], Jeffery Meadows[1], Anthony Azakie[2] and Anita J. Moon-Grady[1,3]*

- 49 patients from 1999-2009
  - 35 without restriction (83% at 2 years)
    - 6 deaths. 3 in hospital follow in stage 1 palliation, 3 interstage. 29 survivors.
  - 14 with restriction survival (43% at 2 years)
    - 5 had emergent procedures.
      - 4 deaths. 1 survived to stage 1 but died interstage
    - 7 with severe restriction/intact atrial septum. 5 deaths, 1 transplant, 1 alive without transplant
    - 7 with mild-moderate restriction. 2 interstage deaths, 5 alive without transplant



Hypoplastic Left Heart Syndrome With Intact or Highly Restrictive Atrial Septum: Surg… Experience From a Single Center

- 32 patients diagnosed in fetal life
- 9 patients with fetal atrial septal intervention
  - 3 of which did not require any further intervention after birth before stage 1
  - The 29 other patients had urgent atrial septoplasty before stage 1
  - 14 of the 29 had atrial stent
- Mortality
  - 10 in hospital
  - 5 interstage
  - 2 after Fontan
  - 17 of 32 made to Stage 2 (53% survival)
- Hospital survival
  - 11 of 14 (79%) for those with fetal intervention (5 had aortic valvuloplasty)
  - 11 of 18 (61%) no fetal intervention

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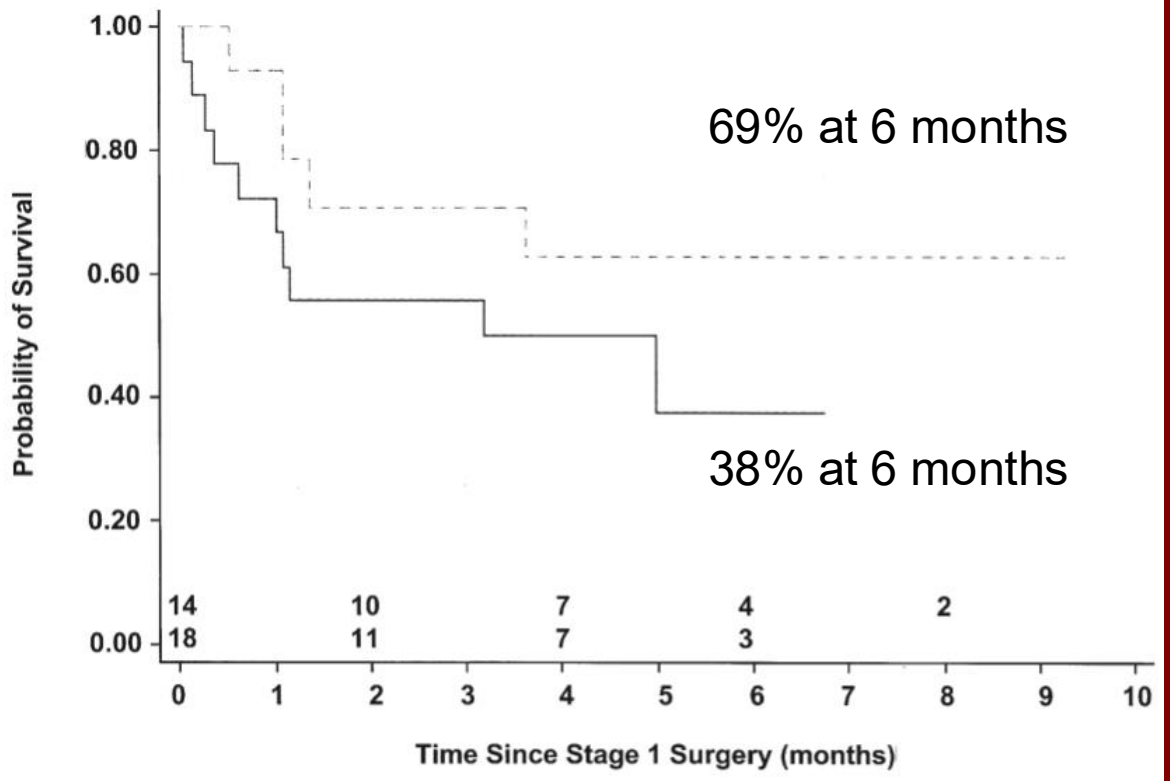

Fig 3. Kaplan-Meier estimates of survival according to fetal intervention (patients who had fetal intervention = upper dotted curve; patients who did not have fetal intervention = lower solid curve; p = 0.2).

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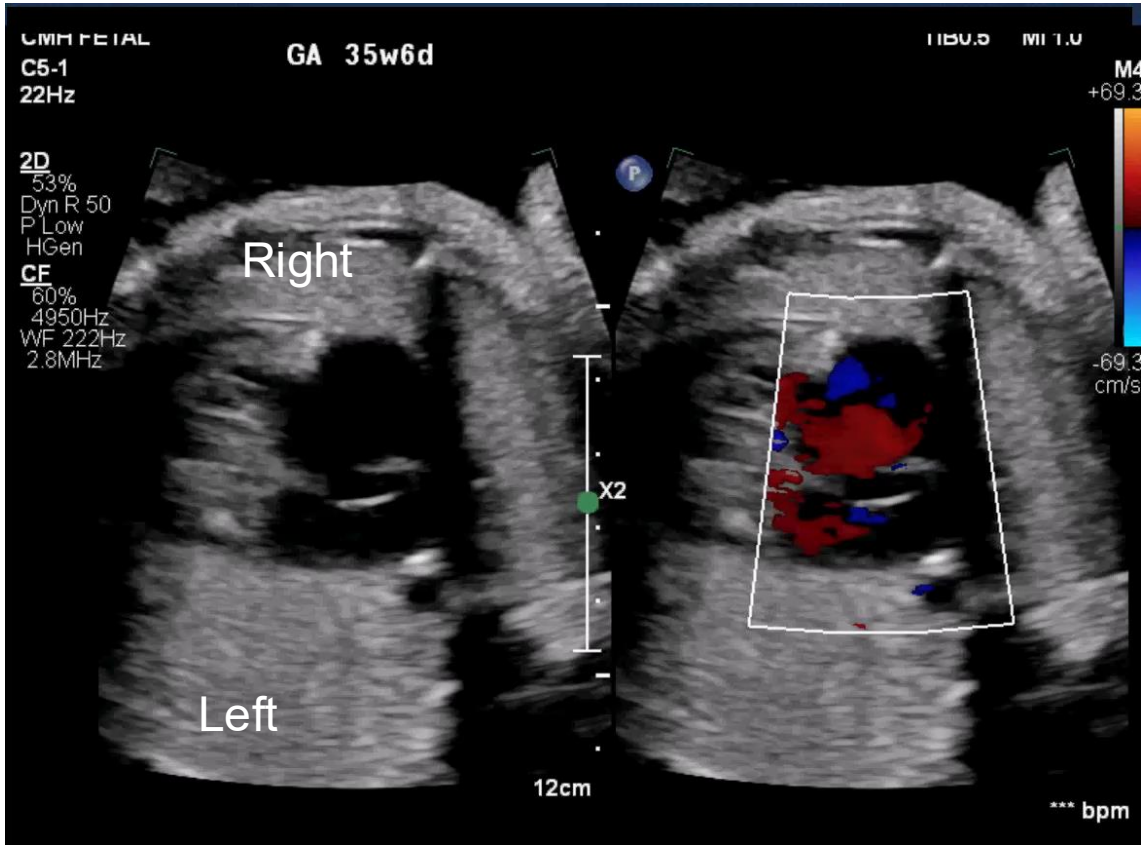
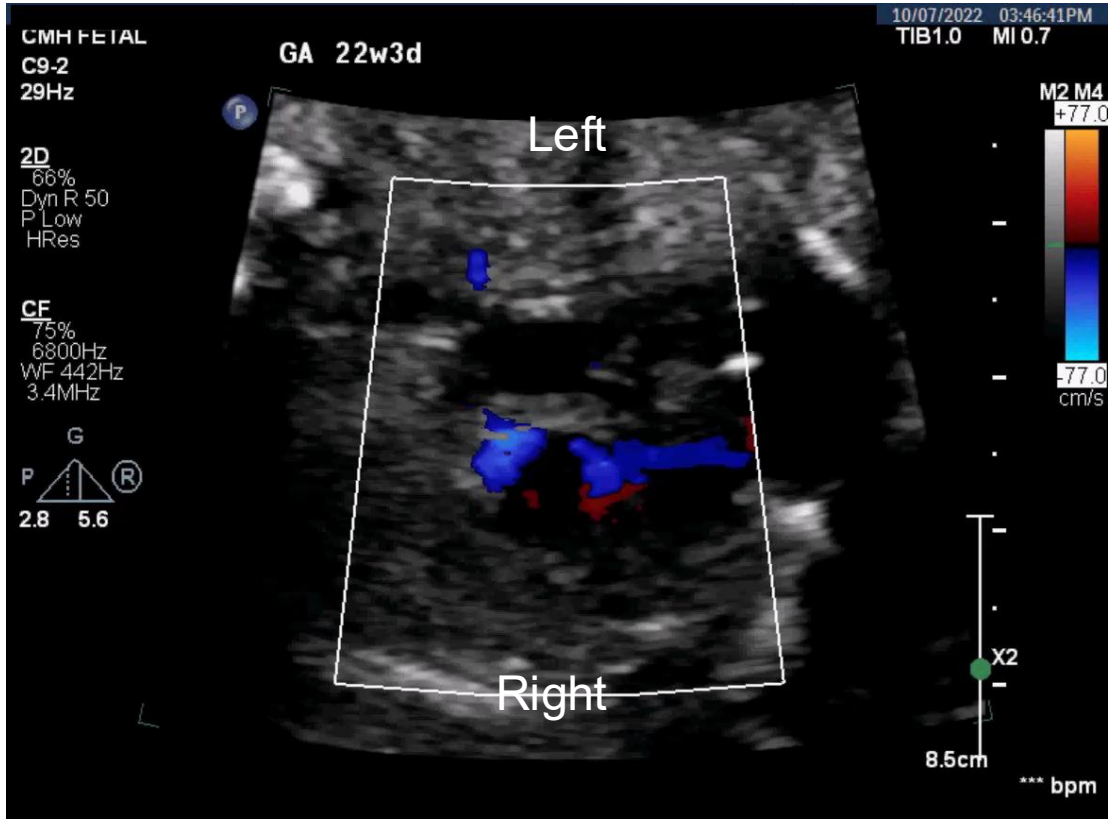
Atrial septum

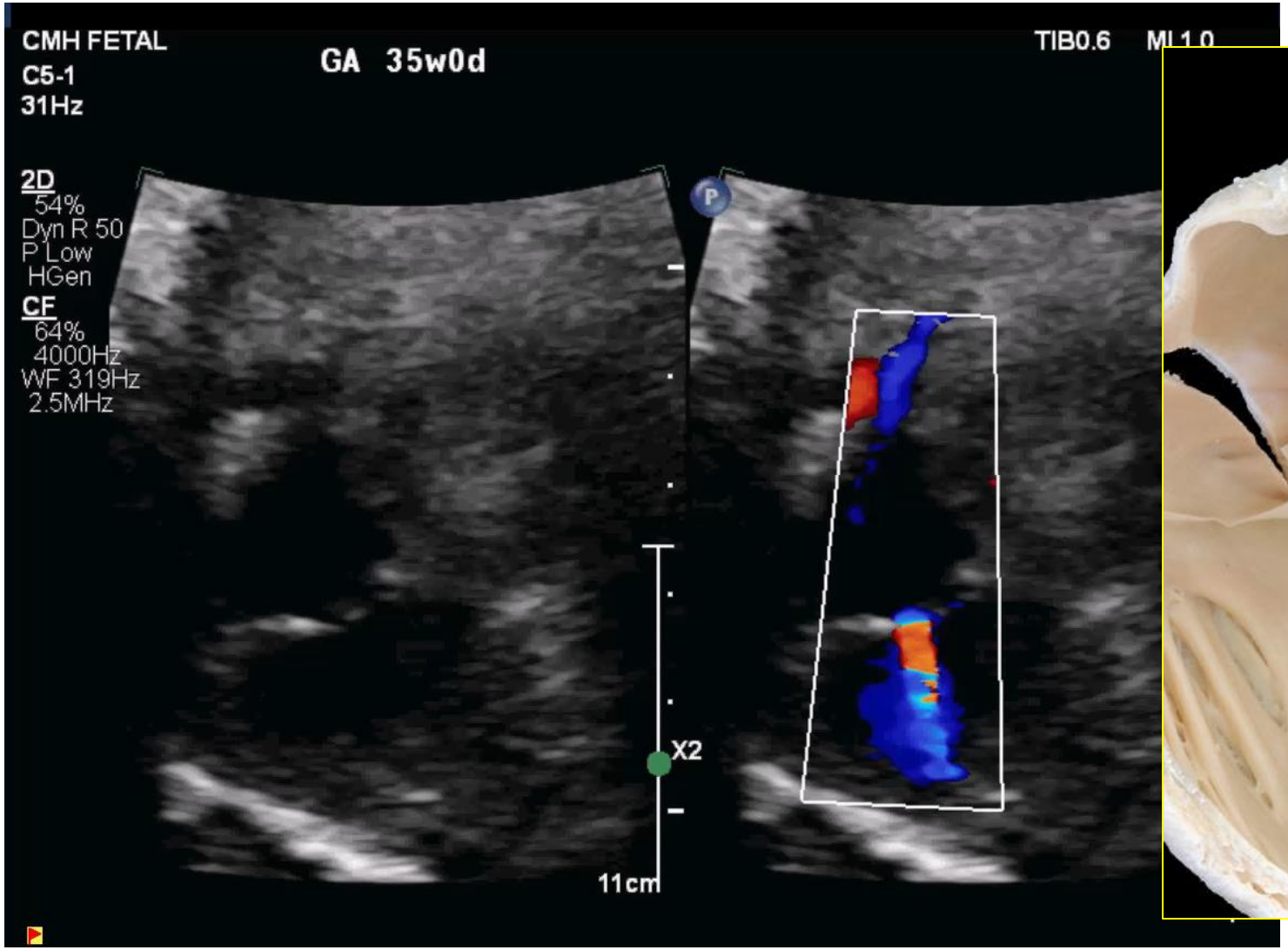
Normal (right to left)

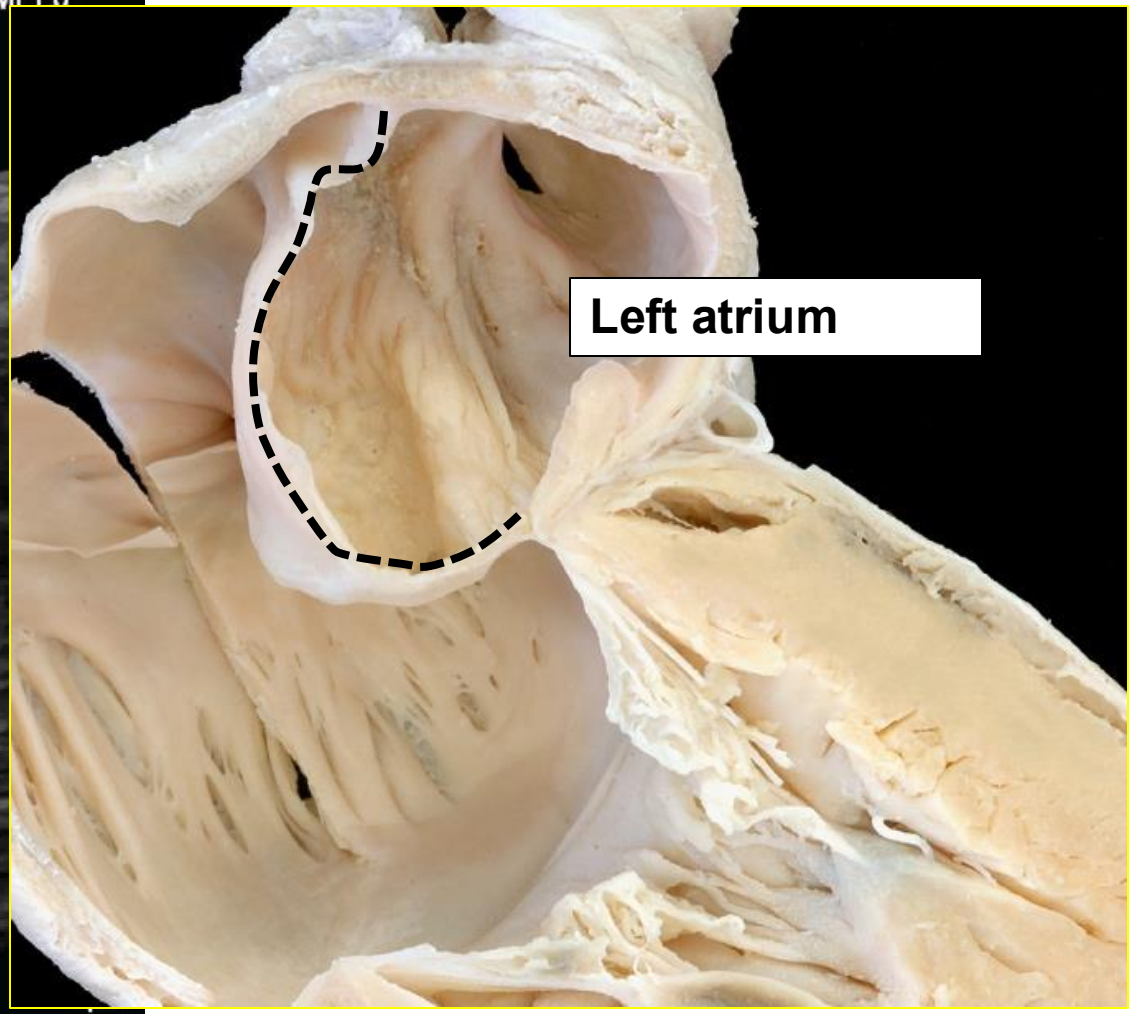


Abnormal (left to right)



Definition of Restriction





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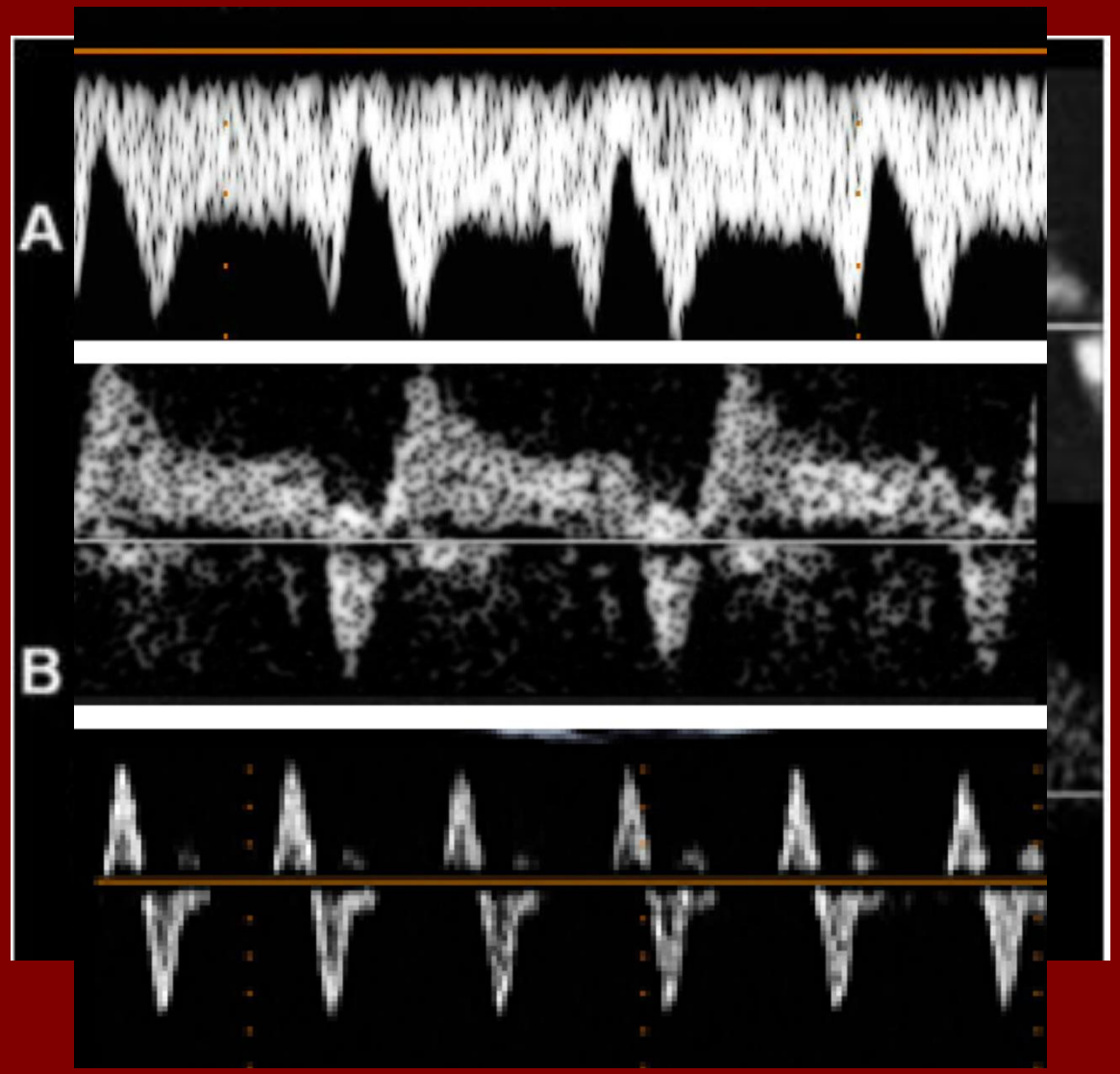
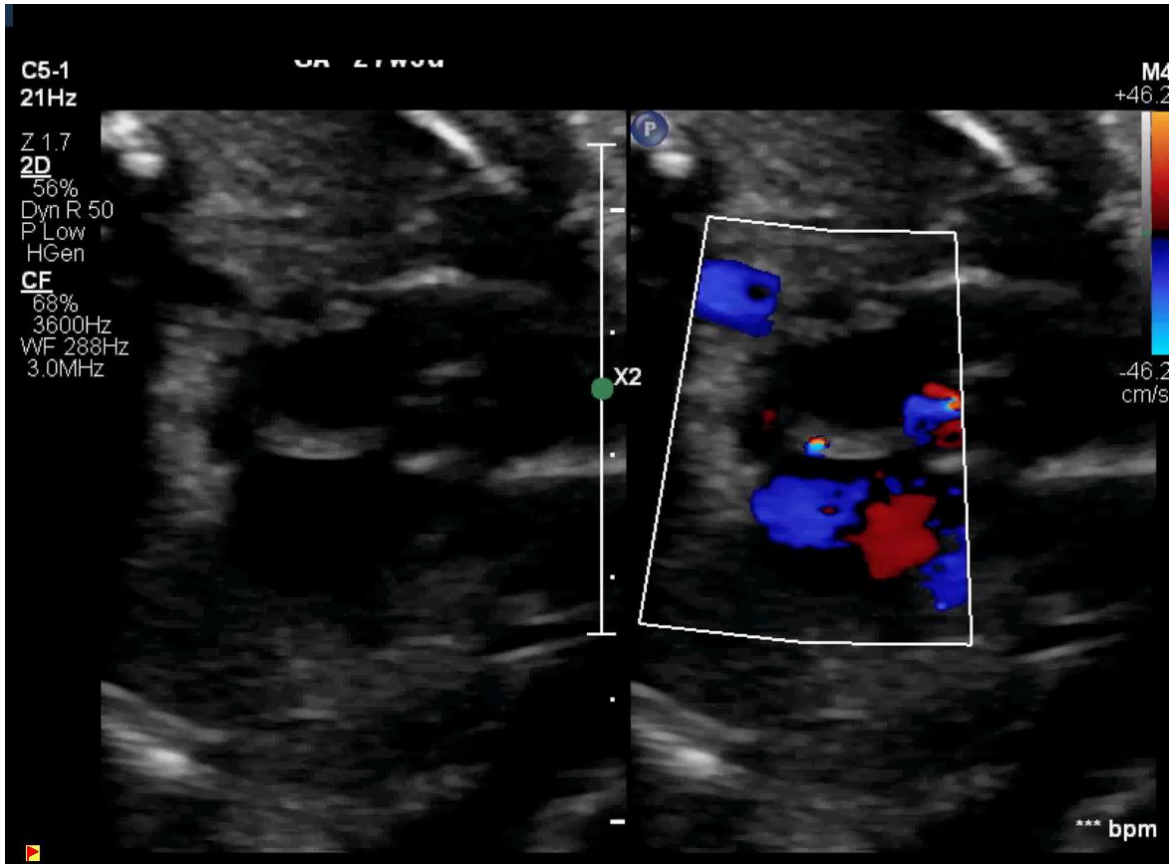
Premature closure of PFO

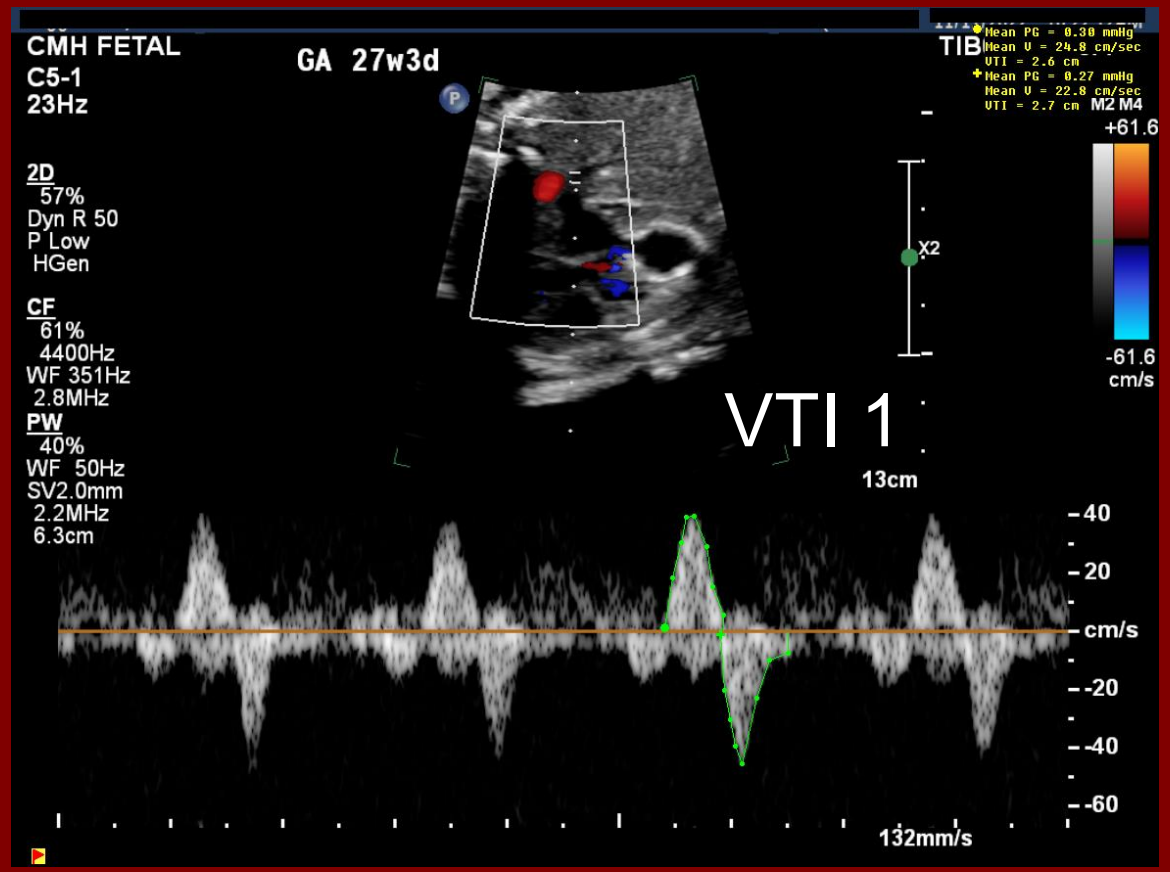
Definition of Restriction

- Velocity-time integral
- In the fetus with HLHS, a pulmonary vein doppler forward/reverse VTI ratio of <5 is the strongest predictor of the need for emergent atrial septostomy in the newborn period
  - Dividing forward flow VTI by reverse
  - Severe generally <3



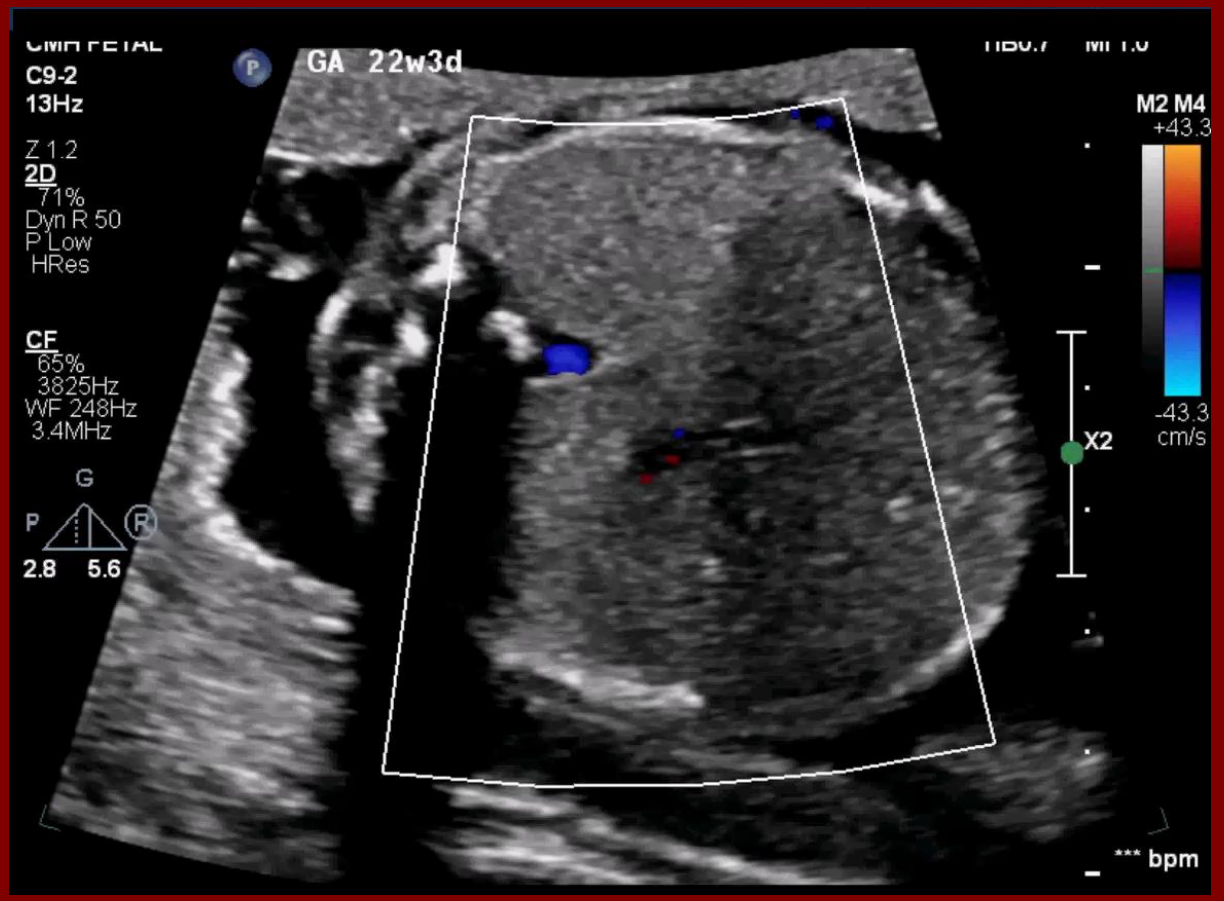
Definition of Restriction



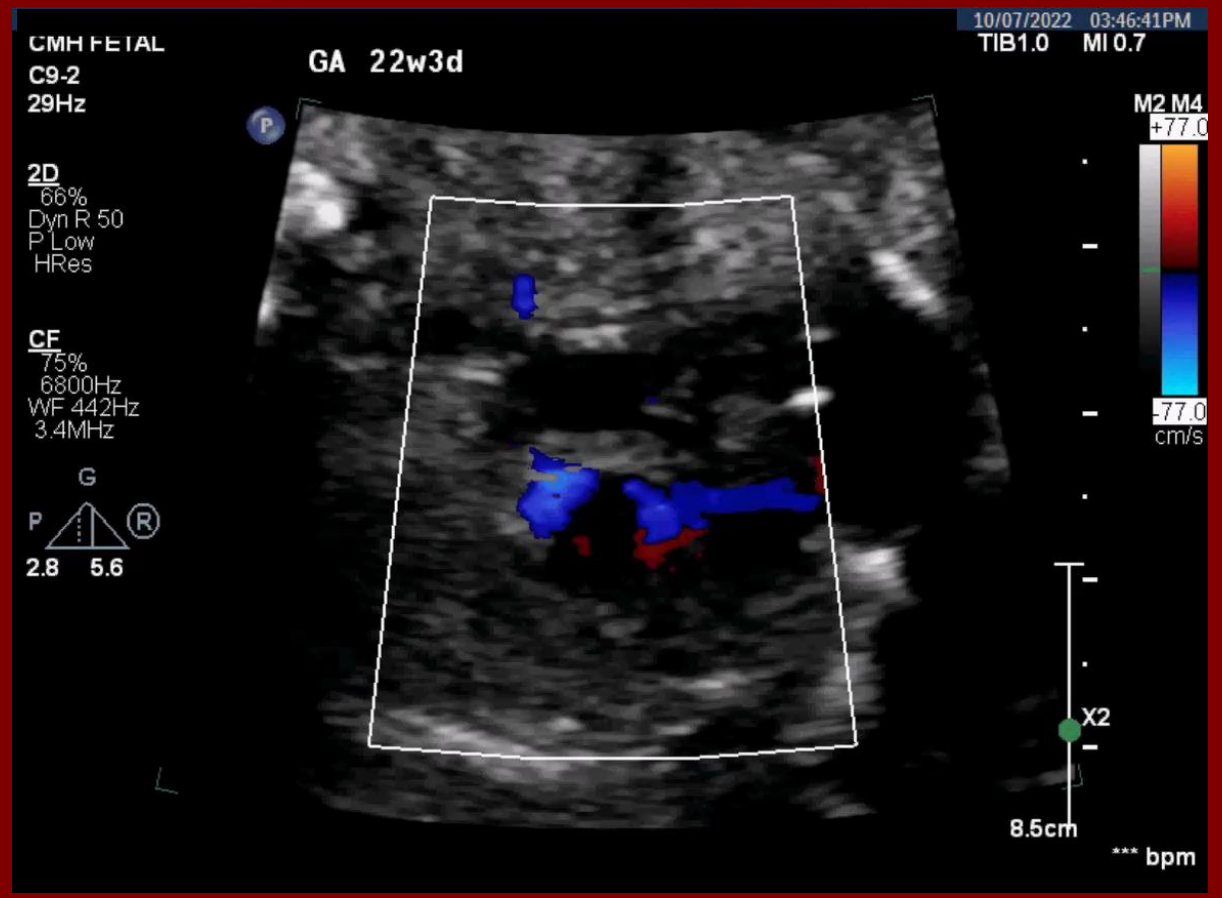


Case

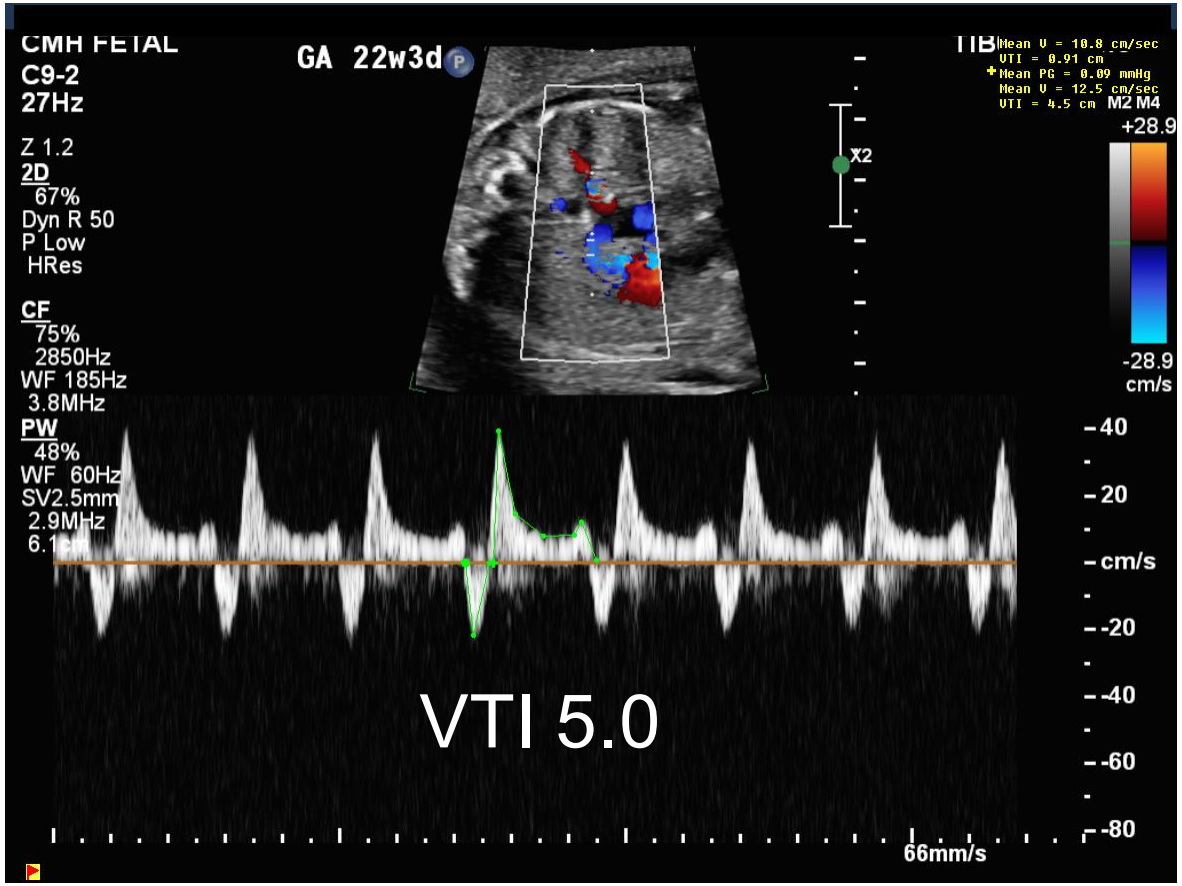
Initial sweeps

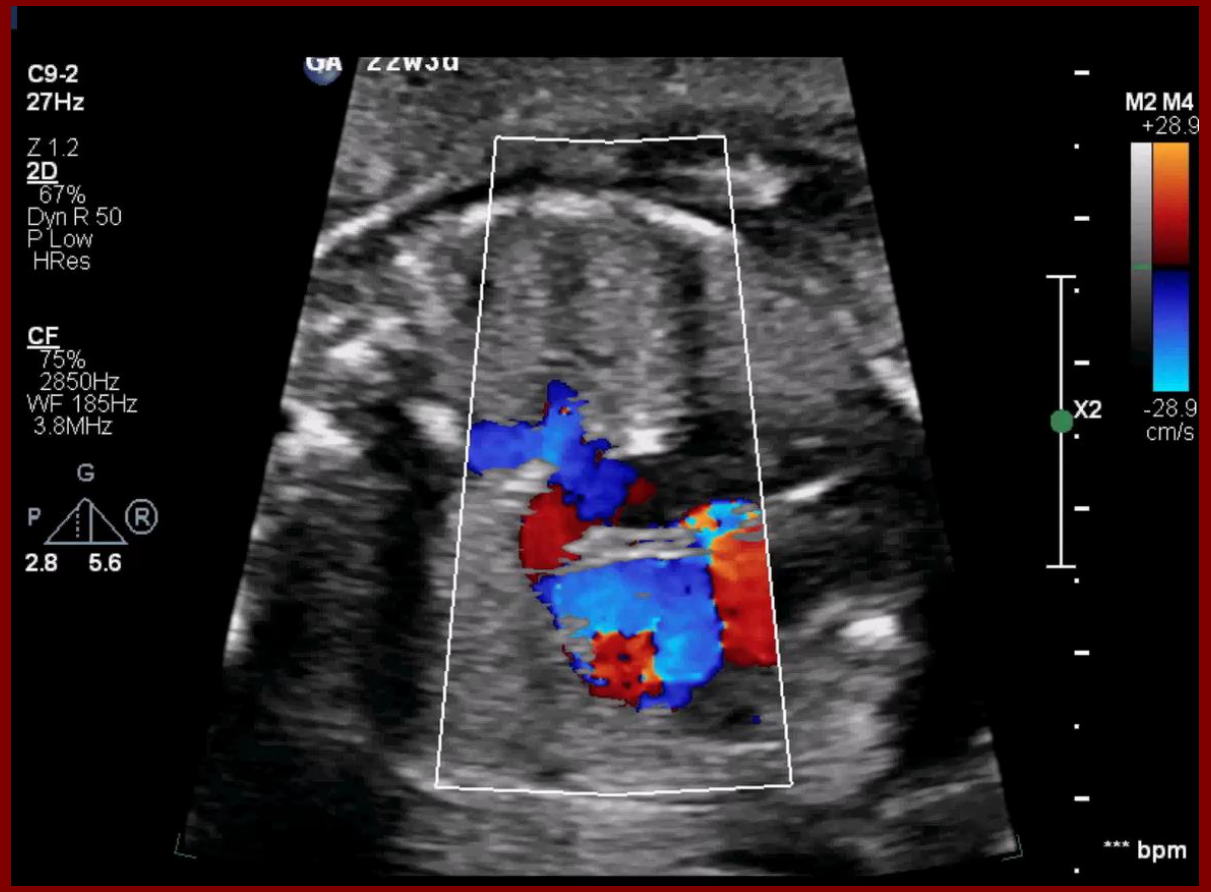


Atrial septum

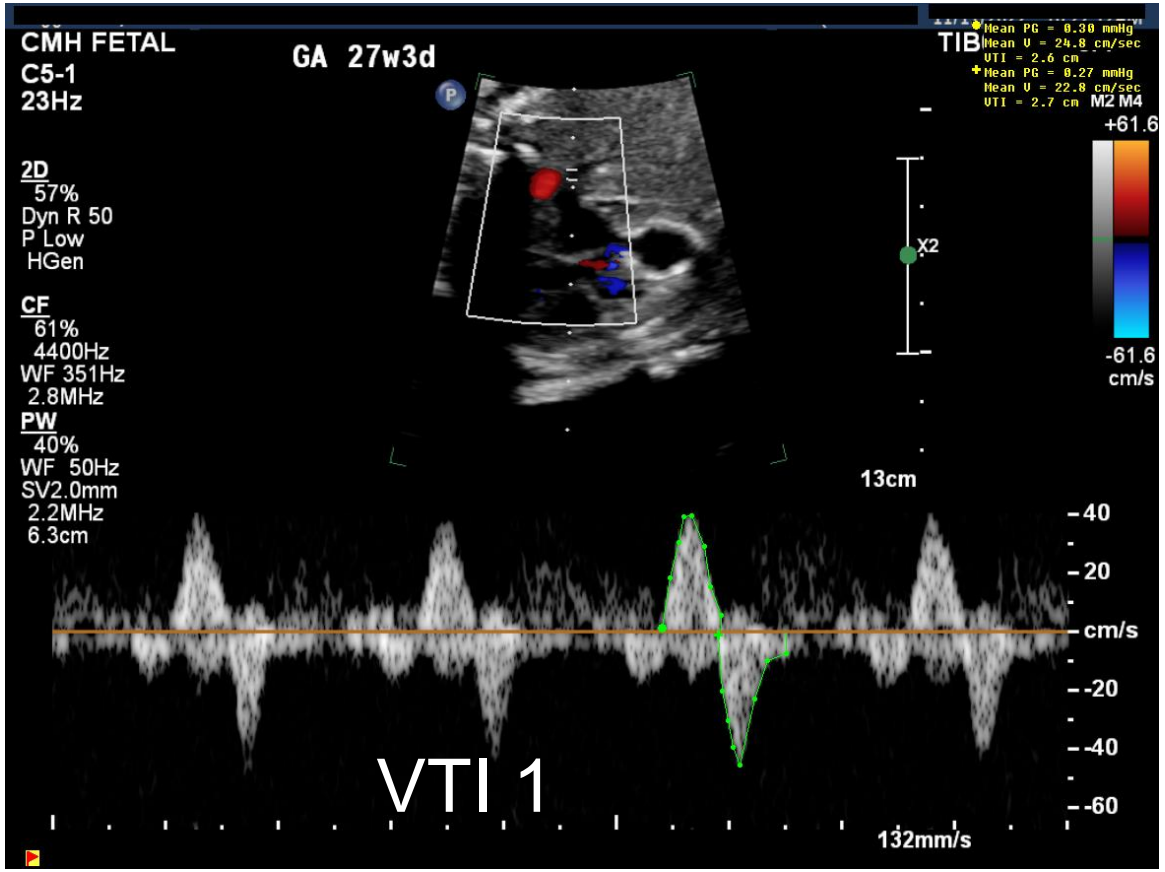


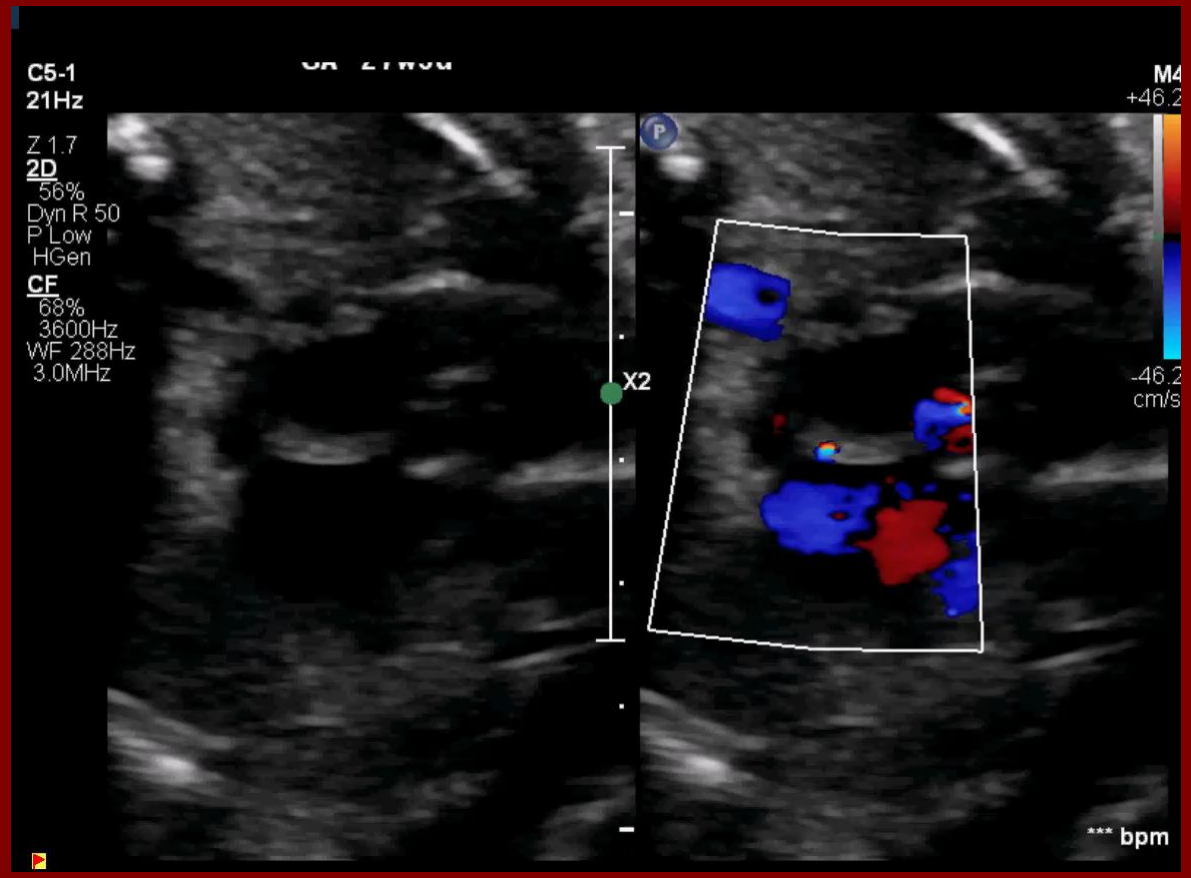
Pulmonary veins





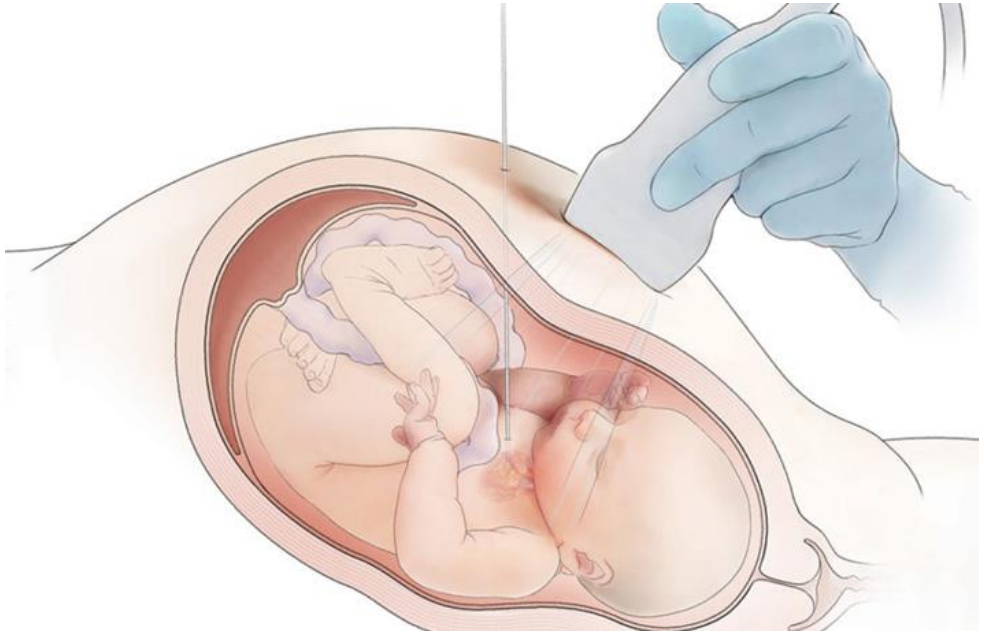
Pulmonary veins in follow up

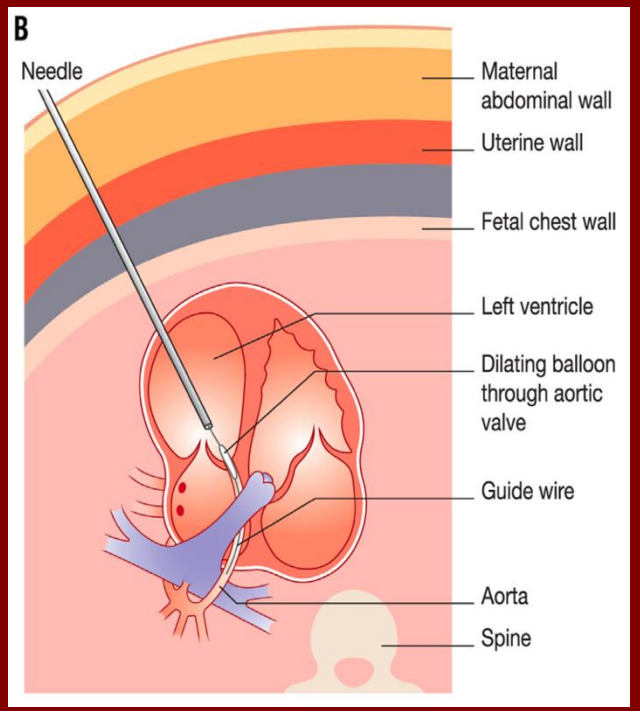


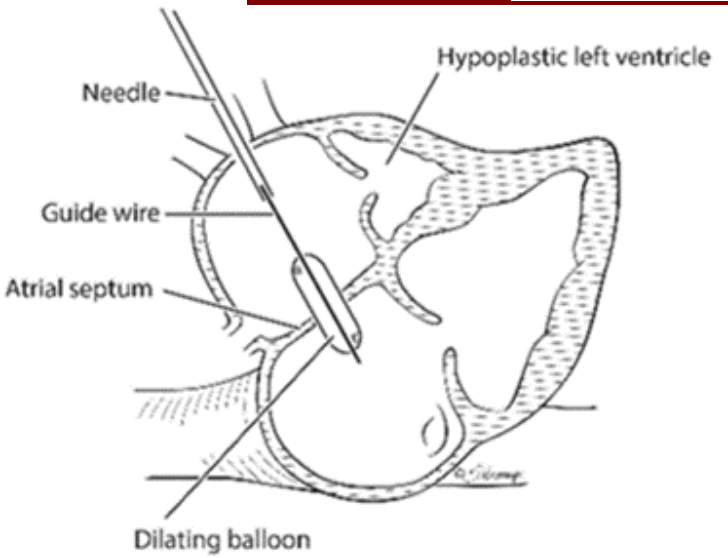


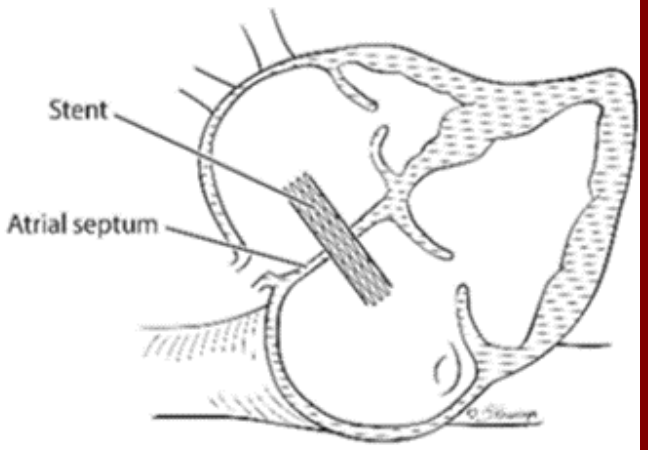
Fetal interventions

- Aortic valvuloplasty
- Atrial stent



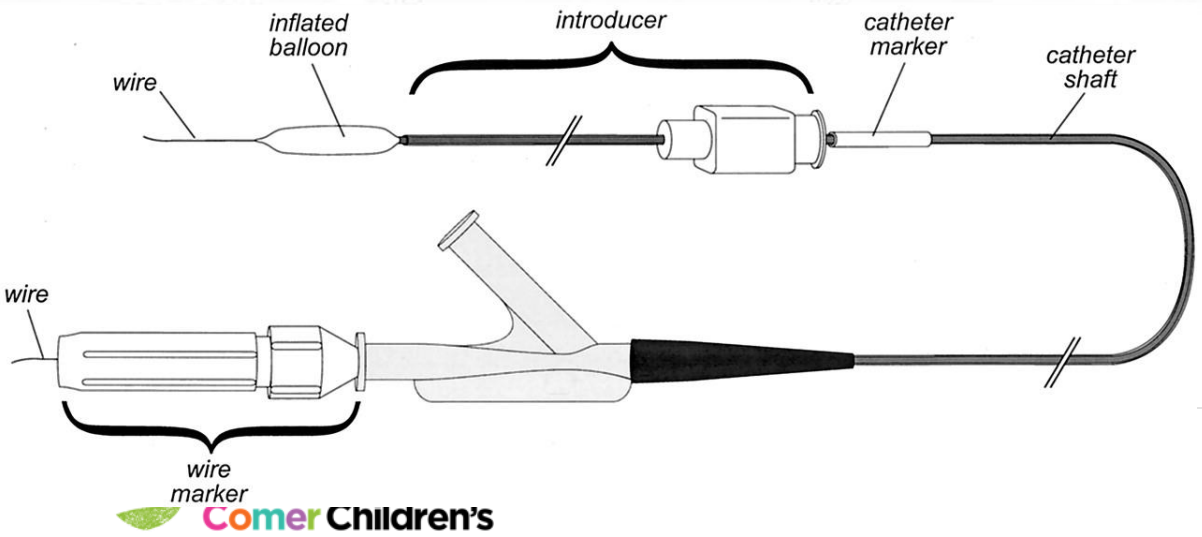


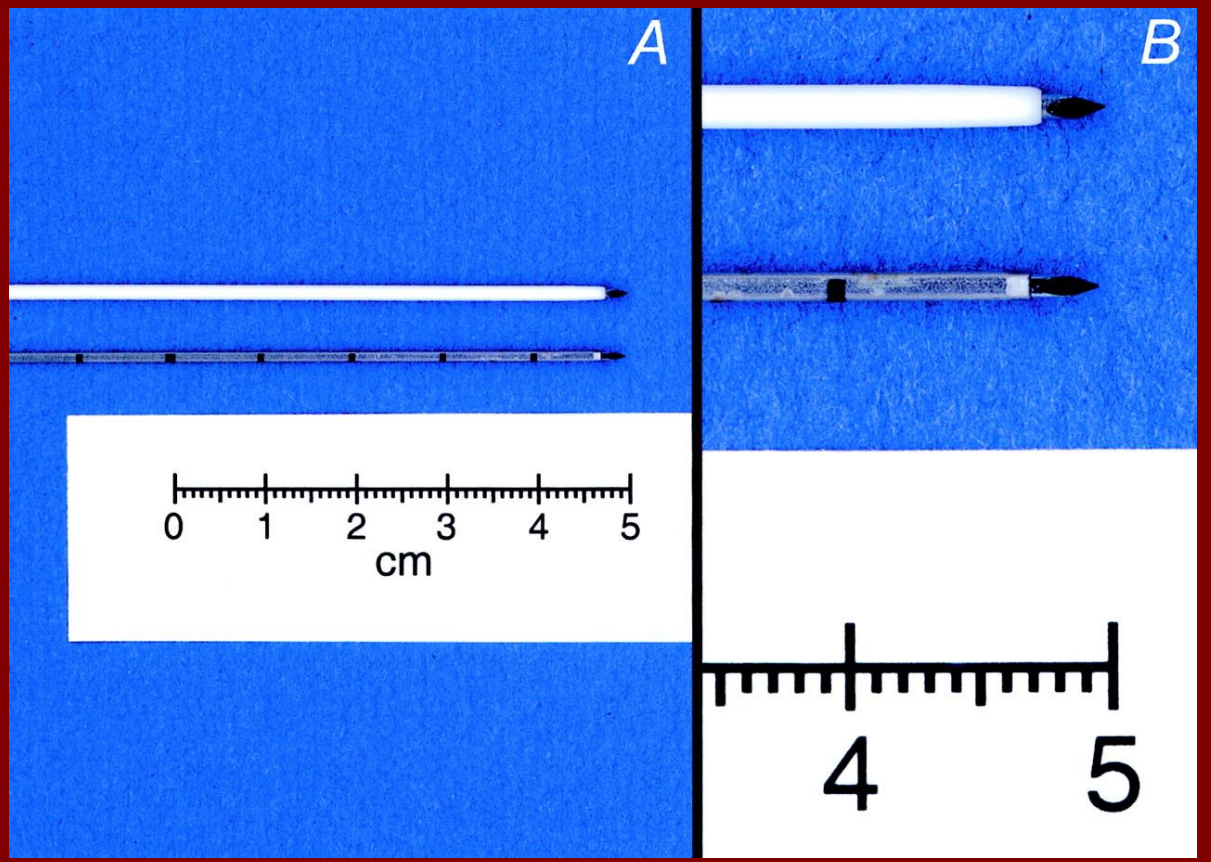




Creation of an Atrial Septal Defect In Utero for Fetuses With Hypoplastic Left Heart Syndrome and Intact or Highly Restrictive Atrial Septum

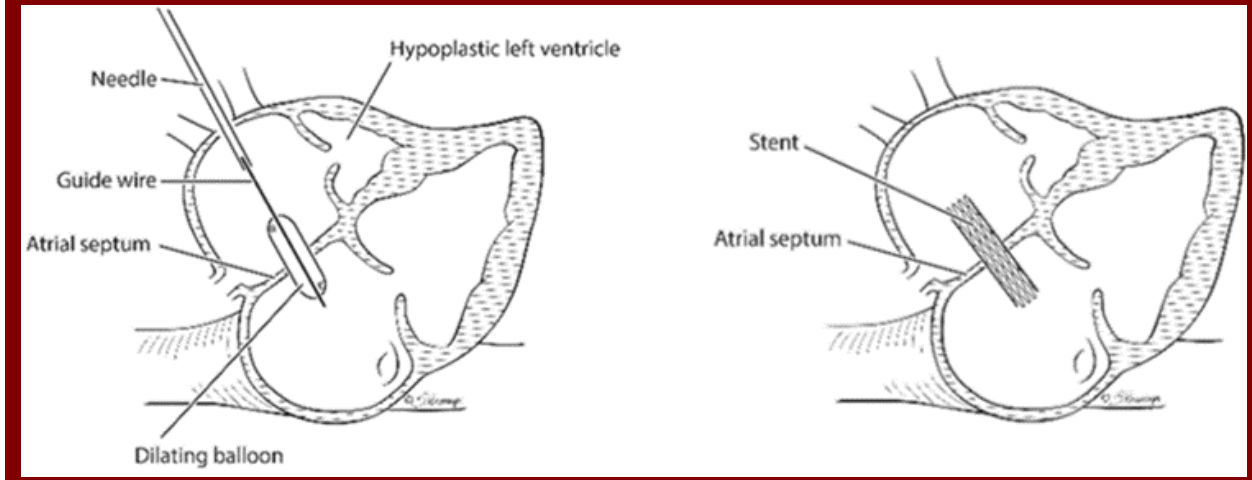
Audrey C. Marshall, MD, Mary E. van der Velde, MD, Wayne Tworetzky, MD, Carlen A. Gomez, MD, Louise Wilkins-Haug, MD, PhD, Carol B. Benson, MD, Russell W. Jennings, MD, and James E. Lock, MD





Patient selection

- Echocardiographic features of intact or severe atrial septal restriction
  - Foramen ovale <2 mm or intact
  - Pulmonary vein spectral Doppler concerning for high left atrial pressure
    - VTI < 3:1
    - To-fro flow
- Anatomic subtype
  - Left atrium large enough to perforate the atrial septum and insert balloon or stent
  - Very small left atrium, thick atrial septum, cor triatriatum or anomalous pulmonar venous drainage may not be candidates secondary to technical concerns
- Significant extracardiac anomalies my not be candidates either
  - Monosomy X for example



Maternal Hyperoxygenation

- A newer diagnostic technique is maternal hyperoxygenation
  - 100% oxygen via nonrebreather for 10 minutes
  - Echo at baseline, after hyperoxygenation and then in recovery
- An increase in pulmonary blood flow has been seen in those with open atrial septum and not in those with septal restriction that needed immediate intervention after birth
- Echocardiographically measured as pulsitility index as a surrogate for vascular impedance
- Those that lack pulmonary reactivity, recommend IMPACT procedure

Hypoplastic Left Heart Syndrome V
Intact or Restrictive Atrial Septum

A Report From the International Fetal Cardiac Interver

- Largest series of fetal atrial septal interventions
- 72 patients included, 47 which had fetal atrial septal intervention
- No statistical improvement in early mortality
- 18/24 patients had follow up data
  - 59% 1 year actuarial survival for those with non-restrictive atrial septum vs 19% non – intervention group

Table 1. Procedural and Outcome Registry* Data for Hypoplastic Left Heart Syndrome with Restrictive or Intact Atrial Septum, Fetal Cardiac Intervention and Non-Intervention

	All Patients (N=72)	No FCI† (N=25)	FCI (N=47)	*P* Value
Pregnancy Outcome, n (%)				
Procedural death+TOP	7 (10)	0	6+1 (15)	0.57 (livebirths)
Preterm (<37wks)	16 (22)	5 (20)	11 (23)	
Term	49 (68)	20 (80)	29 (62)	
Pregnancy complication reported, n (%)	9 (13)	3 (12)	6 (13)	1.00
Type of delivery‡, livebirths§, n (%)				
Cesareanǁ	31/44 (70)	18/21 (86)	13/23 (57)	0.049
IMPACT or EXIT	17/44 (39)	14/21 (67)	3/23 (13)	<0.01
Gestational age§, wk, median (IQR)	38.4 (36.9–39.0)	38.4 (37.3–39.0)	38.4 (36.9–39.0)	0.95
Birth weight,§ g, median (IQR)	2953 (2589–3408)	3100 (2805–3536)	2863 (2468–3068)	0.09
Neonatal resuscitation,§ n (%)	24/50 (48)	15/23 (65)	9/27 (33)	0.046
Mechanical ventilation,§ n (%)	33/44 (75)	17/21 (81)	16/23 (70)	0.49
ECMO before surgery,§ n (%)	3/45 (7)	1/21 (5)	2/24 (8)	1.00
Clinically nonrestrictive FO at delivery,§¶ n (%)	23 (38)	6 (22)	17 (50)	0.03
First procedure,§ n (%)				
Atrial decompression	21 (34)	13 (48)	8 (24)	0.13
Hybrid	10 (16)	2 (7)	8 (24)	
Norwood	19 (31)	7 (26)	12 (35)	
None	10 (16)	5 (19)	5 (15)	
Unknown	1 (2)	0 (0)	1 (3)	
Neonatal outcome,§ n (%)				
Alive at 30 d	32 (52)	12 (44)	20 (59)	0.31
Alive at discharge	24 (39)	9 (33)	15 (44)	0.44

Hypoplastic Left Heart Syndrome W Intact or Restrictive Atrial Septum

A Report From the International Fetal Cardiac Interven

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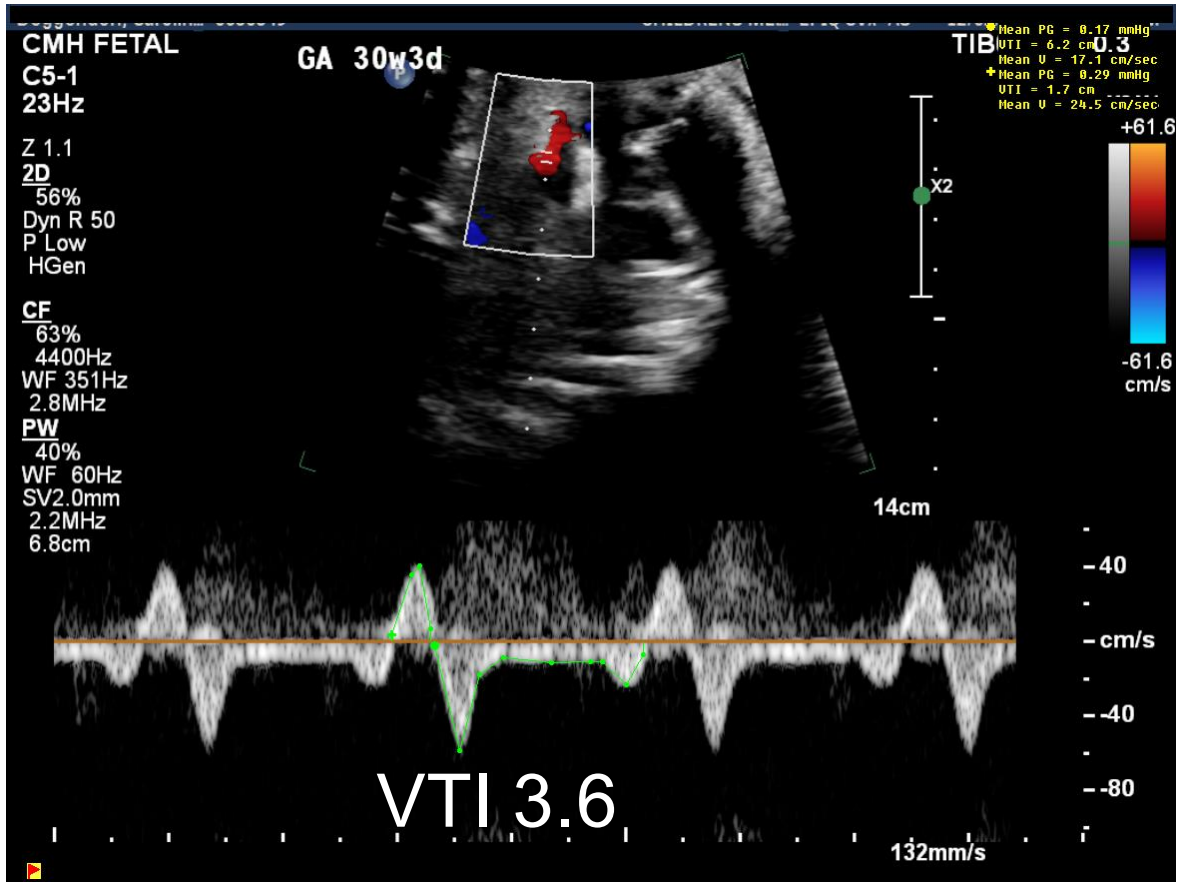
  - 59% 1 year actuarial survival for those with non-restrictive atrial septum vs 19% non – intervention group
- Complications common (~65%)
- Procedure related demise in 6 (13%)

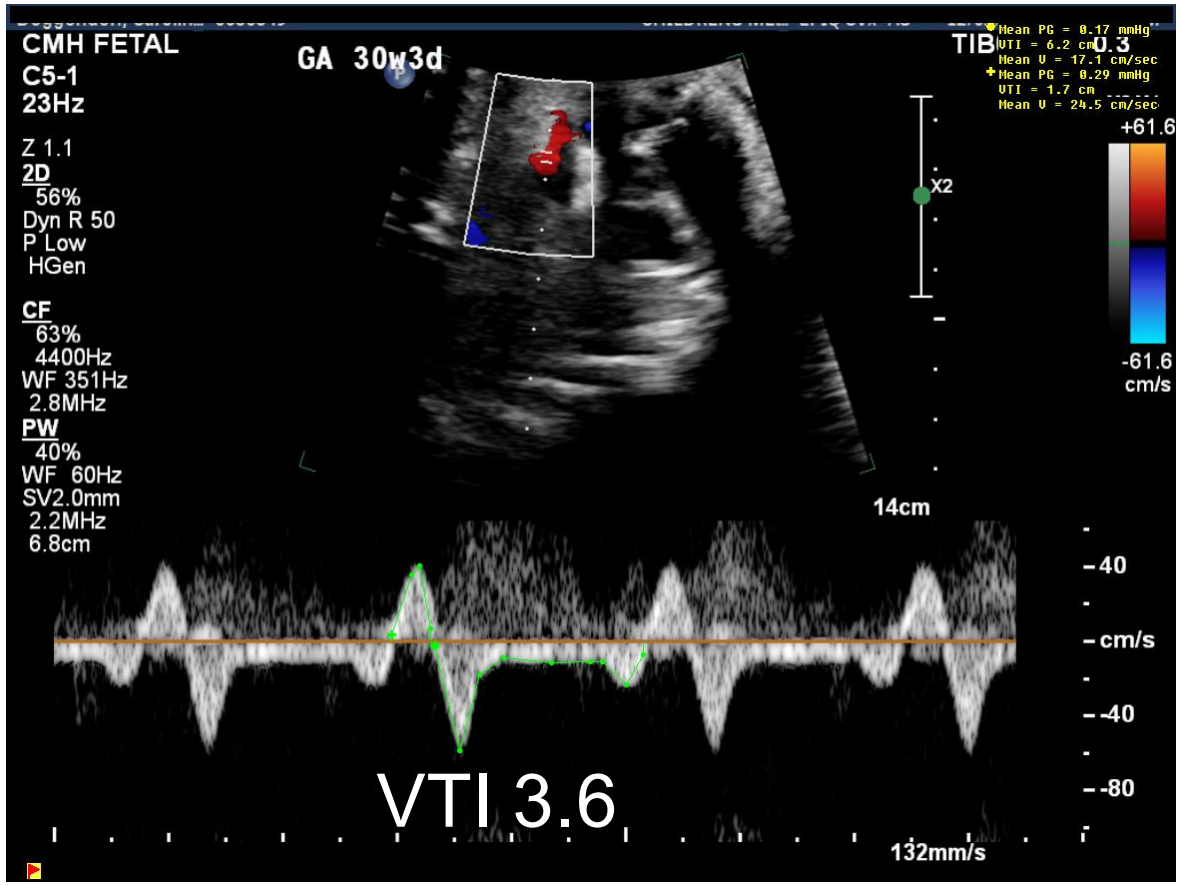
Table 2. Fetal Cardiac Intervention Procedural Details and Outcomes

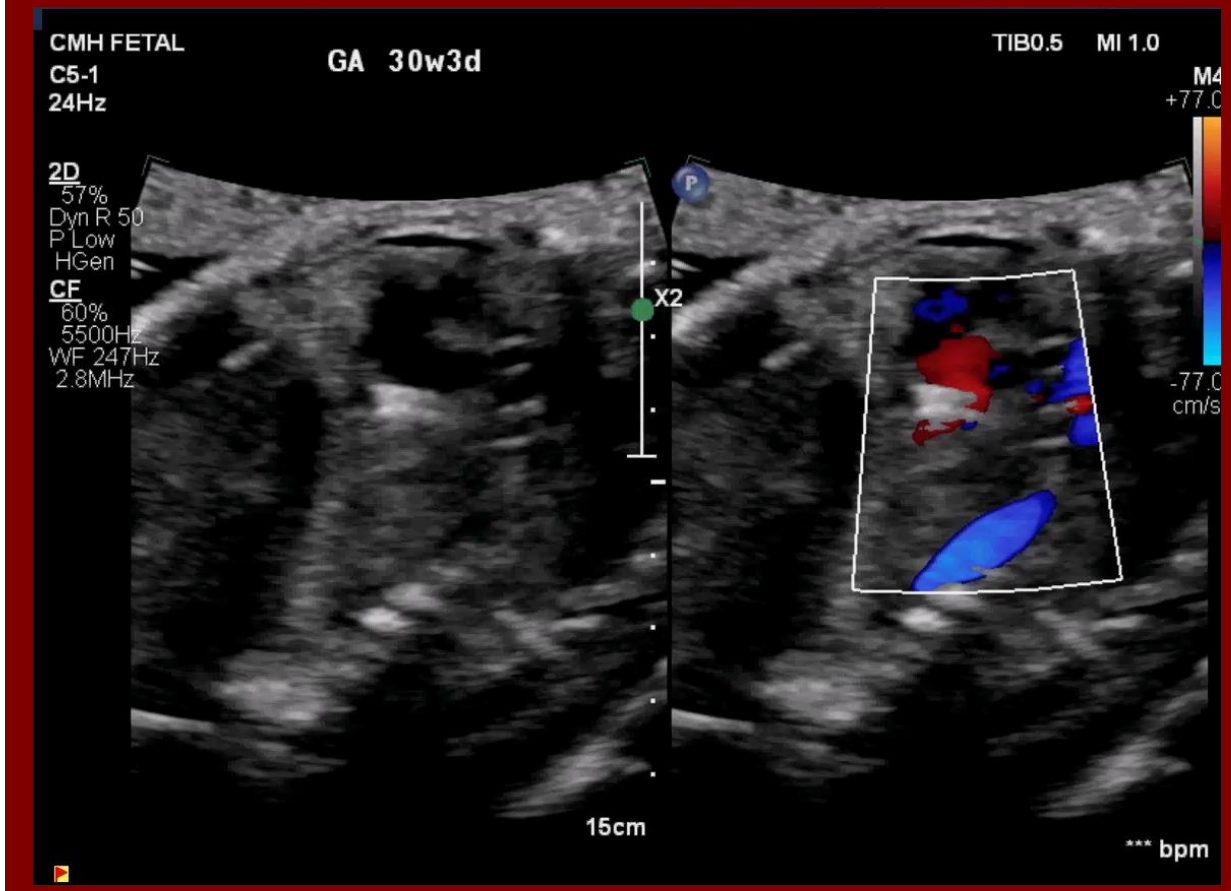
	Atrial Septoplasty (N=27)	Atrial Stent (N=20)	*P* Value
Gestational age at FCI, wk, mean (SD)	29.0 (2.7)	29.3 (3.8)	0.76
Procedural complications, n (%)			
Any complication	17 (63)	13 (65)	1.00
Fetal bradycardia	7 (26)	4 (20)	0.74
Pericardial effusion	13 (38)	11 (55)	0.77
Hemothorax	3 (11)	3 (15)	1.00
Balloon rupture	1 (4)	4 (20)	0.15
Stent embolization	n/a	5 (25)	n/a
Fetal demise	1 (4)	1 (5)	1.00
Fetal resuscitation medication given, n (%)	6 (22)	5 (25)	1.0
Fetal complication within 48 h (excludes intraprocedural), n (%)			
None	14 (52)	15 (75)	0.14
Pericardial effusion	1 (4)	0 (0)	1.00
Hemothorax	0 (0)	2 (10)	0.17
Fetal demise	2 (7)	2 (10)	1.00
Procedural success,* n (%)	23 (85)	13 (65)	0.16

Fetal atrial stent

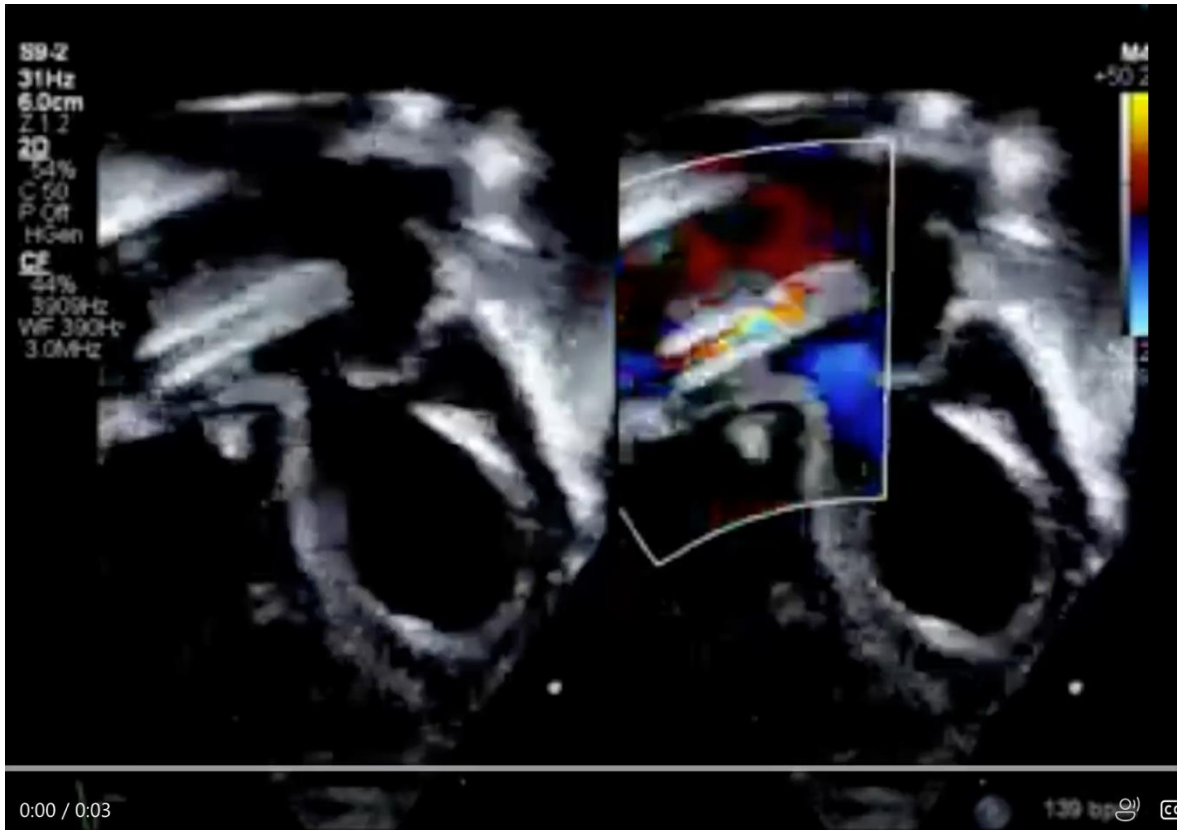


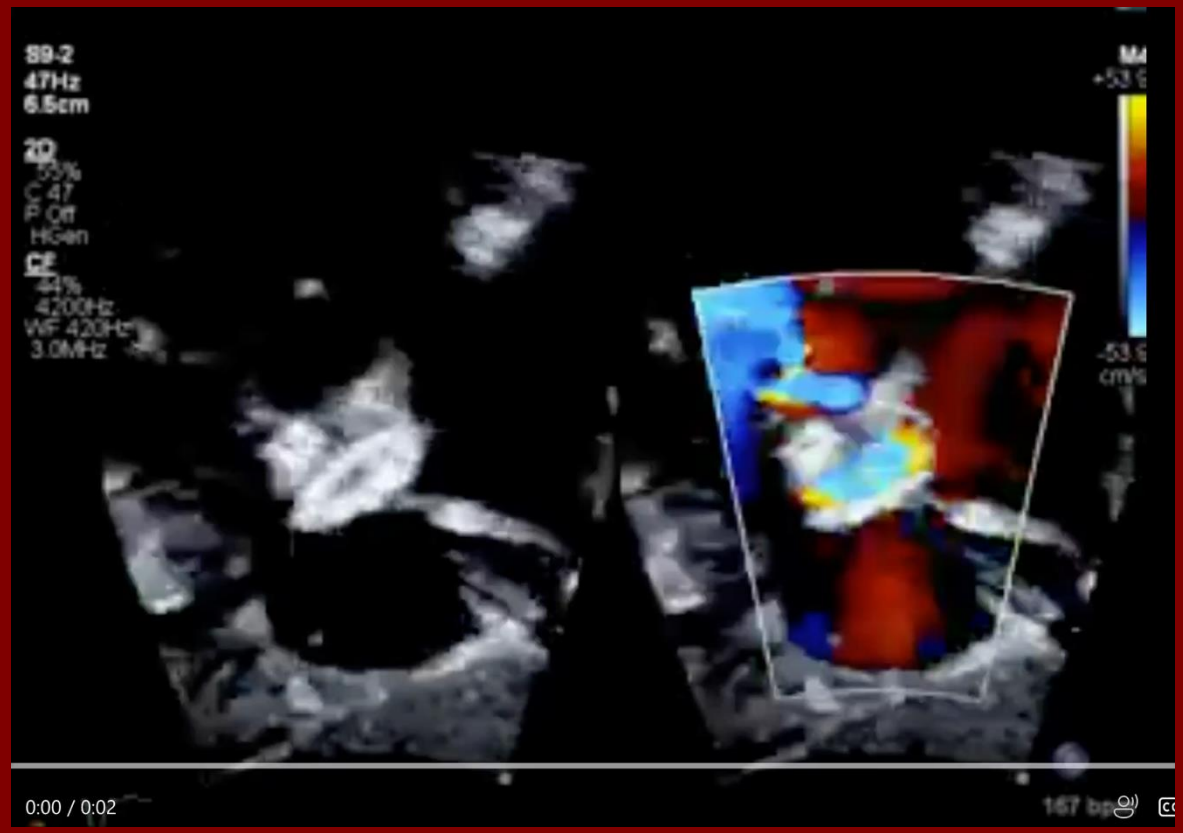
Fetal atrial stent





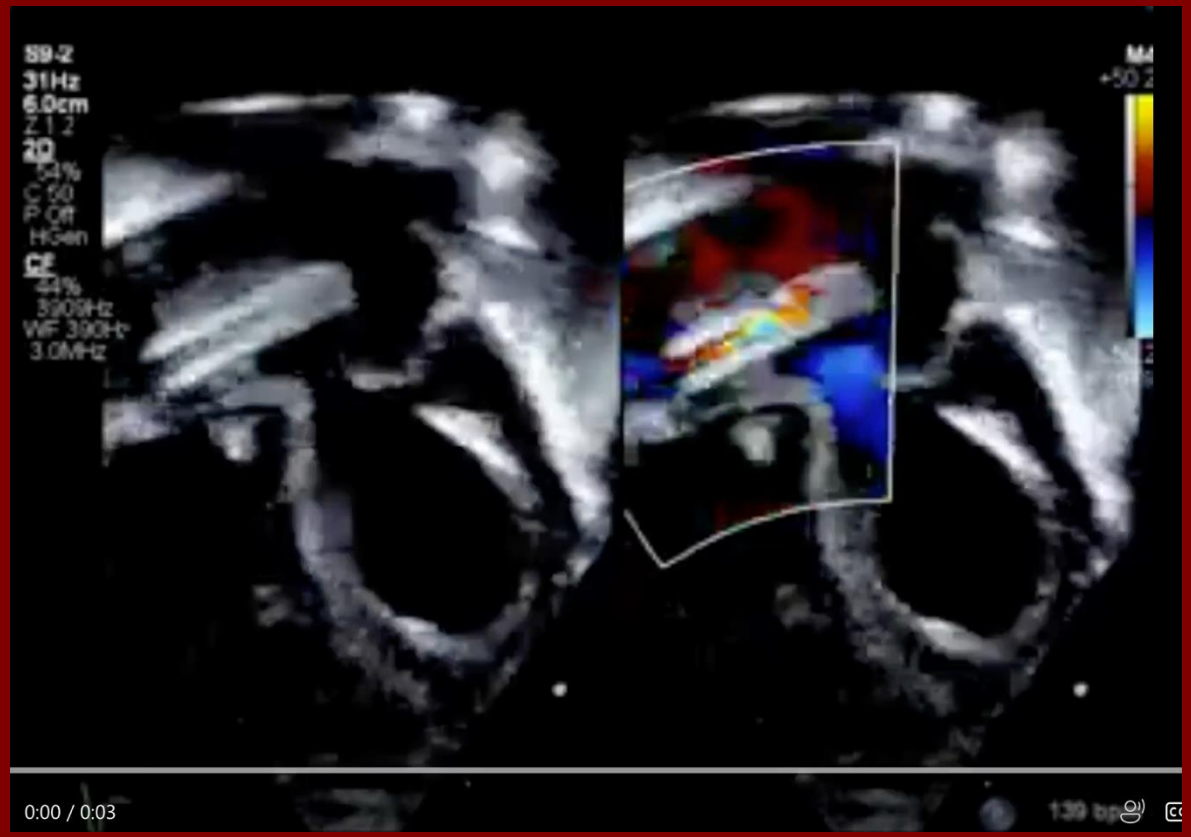
Post natal





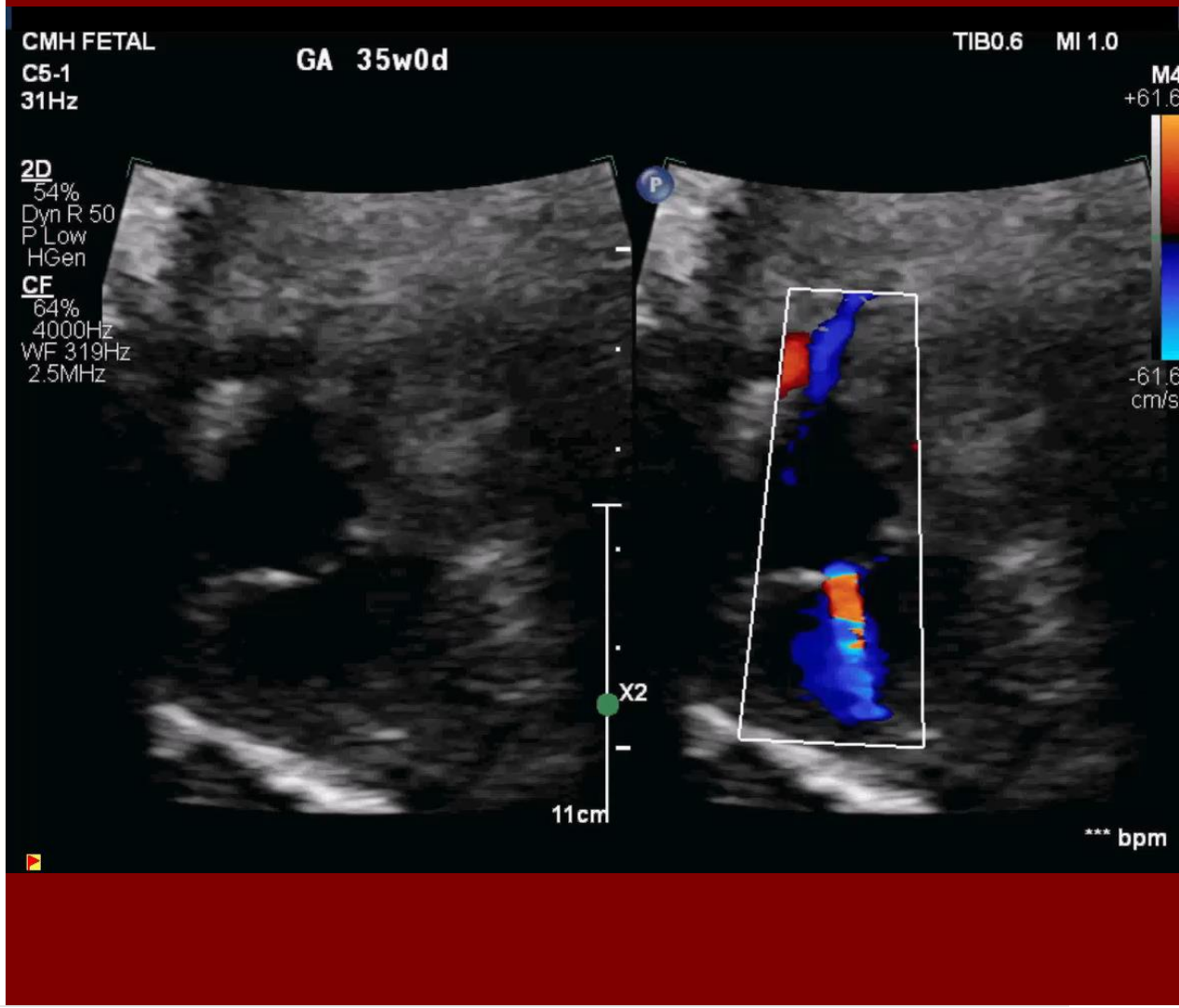
Follow up

- Had vaginal induction birth without coordinated delivery
- Had stage 1 surgery at 4 days of life without prior atrial septal intervention
- Has had issues with systolic and diastolic ventricular dysfunction
- Has not had Stage 2 procedure



Conclusion

- Fetal atrial septal intervention should be considered and incorporated into fetal counseling for patients with HLHS and restrictive atrial septum
- HLHS with restrictive atrial septum is high-risk lesion associated with poor outcomes
- Restriction causes high left atrial pressure and damage to pulmonary vascular bed
- Maternal and fetal risks need to be weighed against evidence of improved outcomes for those with fetal intervention



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