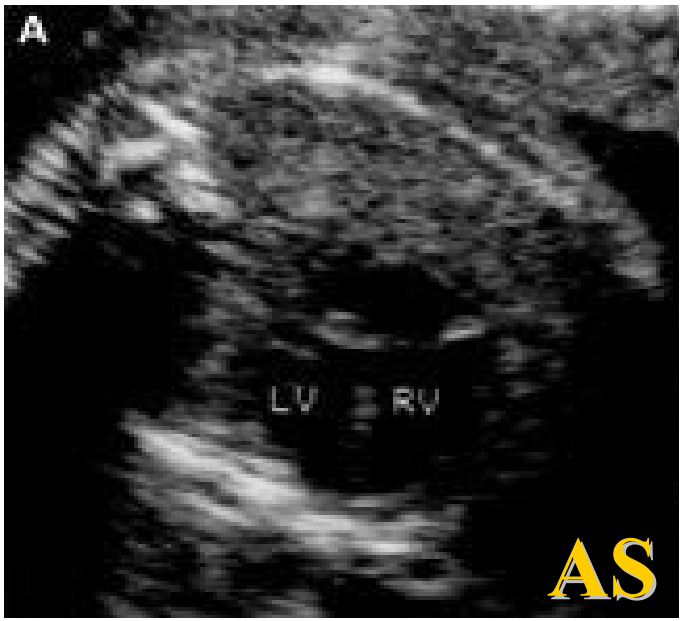
# Cardiac Intervention in Fetus

*Gyeong-hee Yoo, M.D.*
*Department of Pediatrics*
*Soonchunhyang University*
*Cheonan Hospital*

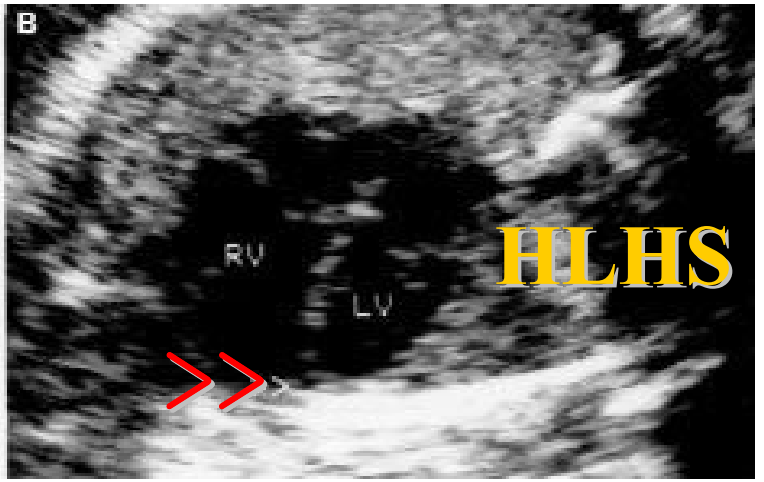
SOON CHUN HYANG UNIVERSITY HOSPITAL CHEONAN

# Fetal echocardiography

- Serial f/u → intrauterine course of disease
  - Cardiac anomaly
    - AS → HLHS
    - PS → PA/IVS
  - Arrhythmia
    → Hydrops fetalis




**24 weeks of gestation**




**33 weeks of gestation**

**Simpson JM, et al.** ***Heart 1997;77:205-210.***

# Intrauterine treatment

- Drug
- Fetal cardiac intervention
- Fetal cardiac surgery

# History

| Year | | No of case | Fetal cardiac intervention | Hospital |
|---|---|---|---|---|
| 1991 | Maxwell D | 2 | Balloon dilation of the AoV | Guy's hospital, London |
| 2000 (1989 ~1997) | Kohl T (unversity of Lübeck medical school, Germany) | 12 | Percutaneous US-guided BVP with severe AoV obstruction | World experience |
| 2002 | Tulzer G | 2 | Pulmonary valvuloplasty for critical PS or atresia with intact septum | Children's hospital of Linz, Austria |
| 2004 (2000 ~2004) | Tworetzky W | 20 | Dilation of severe AS in the fetus | Children's hospital, Harvard medical school, Boston |

# Rationale

- Flow-related theory

  Embryo mishaps(primary morphogenesis)

  : semilunar valve obstruction

  ⇒ Abnormal flow

  ⇒ chamber hypoplasia(secondary morphogenesis)

- Intervention in the early third trimester may significantly alter the course of secondary morphogenesis, leading to improved outcomes for a variety of complex congenital heart disease

# Examples of *in utero* progression of cardiac defects

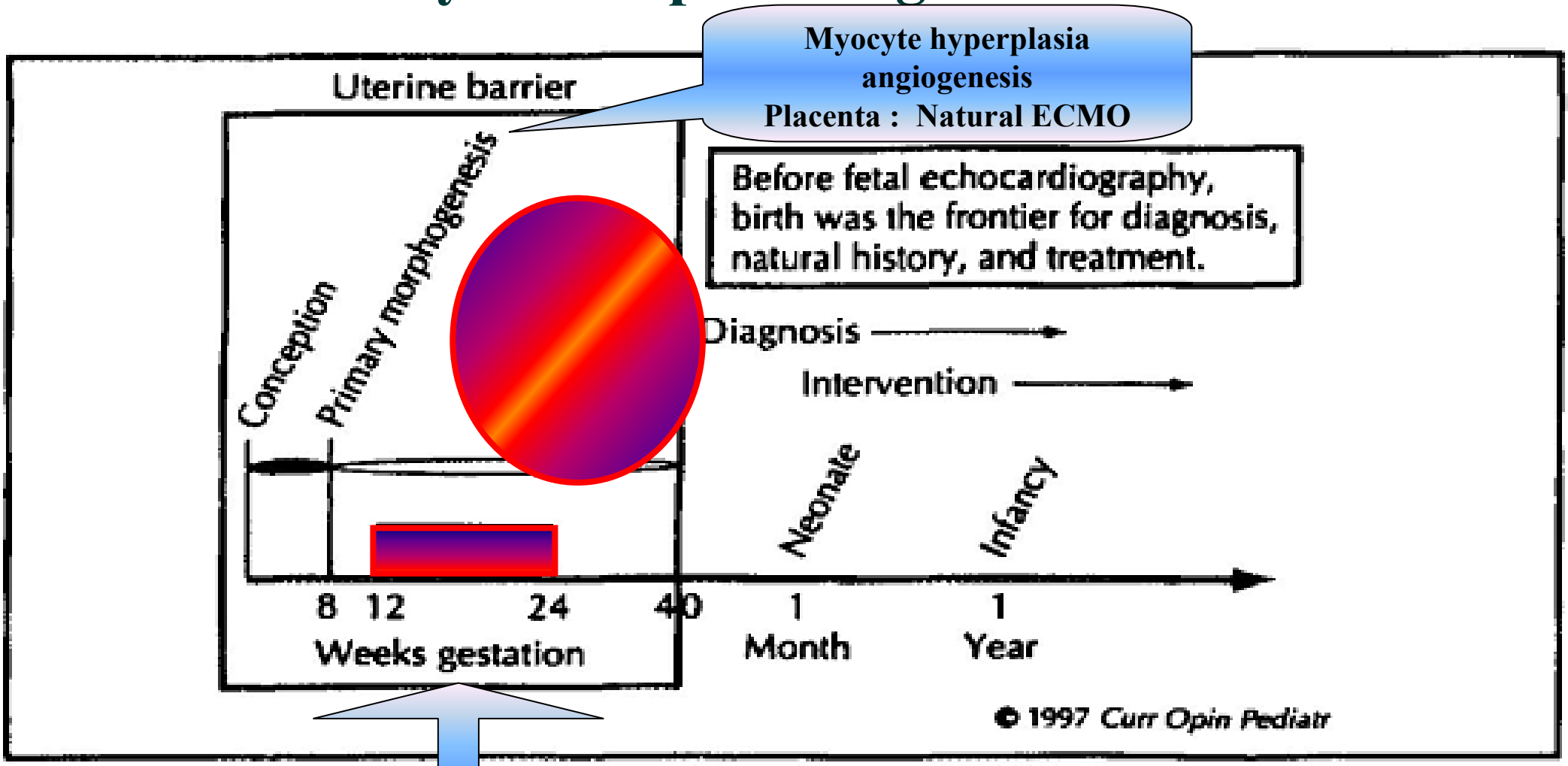
| Primary lesion<br>Simple<br>Early | Altered flow | Secondary lesion<br>Complex<br>Gradual |
|---|---|---|
| Critical AS | LVOTO | Left heart hypoplasia and dysfunction<br>EFE |
| Critical PS | RVOTO | Hypoplastic RV and dysfunction, VCCs, pulmonary parenchymal hypoplasia |
| Absent/restrictive PFO | Reduced LV inflow | Hypoplastic LV/Ao |

**LVOTO = left ventricular outflow tract obstruction**
**PA IVS = pulmonary atresia with intact ventricular septum**
**RVOTO = right ventricular outflow tract obstruction**

**EFE = endocardial fibroelastosis**
**PFO = patent foramen ovale**
**VCC = ventricle coronary connection**

**Hanley FL. *Adv Card Surg 1994;5:47-74.***

# Intervention may lead to improved outcomes for a variety of complex congenital heart disease




**Fetal cardiac intervention : 20~26 weeks**

Reddy VM et al. *Curr Opin Pediatr 1997;9(5):530-5.*

# Diseases of Indication

- Severe AS, Severe PS, Absent/restrictive PFO
  - Univentricular ⇒ biventricular
    - Impaired neurodevelopmental outcome
    - Inexorable deterioration in cardiovascular function
      - Arrhythmia, PLE, Thrombotic cx, Progressive systemic ventricular failure
- Refractory fetal arrhythmia
  - For survival

**Kleinman CS.** ***Circulation 2006;113;1378-81.***


Benefit
Risk

# Benefit

- Severe semilunar valve obstruction
  - Biventricular circulation
  - better prognosis
- Therapy refractory arrhythmia
- imperforate atrial septum
  - life-saving

# Risk

- Technical failure
- Maternal
  - Premature labor
- Fetal
  - Intrauterine death
  - bradycardia

**Demographic, Anatomic, and Physiological Data at Diagnosis and Late Gestation in Fetuses With [redacted]**

| Variable | HLHS (n=17) | | Biventricular Circulation (n=6) | |
|---|---|---|---|---|
| Gestational age, wk | | | | |
| LV length Z-score | | | | |
| MV diameter Z-score | | | | |
| AoV diameter Z-score | | | | |
| AAo diameter Z-score | | | | |
| RV length Z-score | | | | |
| TV diameter Z-score | | | | |
| PV diameter Z-score | | | | |
| Retrograde TAA flow | 17/17 (1[illegible] | [illegible]/14 (100)* | 0/6 (0)†‡ | 0/6 (0)†§ |
| Left-to-right FO flow | 15[illegible] (88)* | 14/14 (100)* | 1/6 (17)†‡ | 1/5 (20)†§ |
| Monophasic MV inflow | 10/11 (91)* | 8/8 (100)* | 0/4 (0)†‡ | 0/2 (0)†§ |
| Moderate to severe LV dysfunction | 16/17 (94)* | 14/14 (100)* | 0/6 (0)†‡ | 1/6 (17)†§ |

Severe AS that evolved to HLHS

- Retrograde TAA flow
- Left-to-right FO flow
- Monophasic MV inflow
- Moderate to severe LV dysfunction

AoV indicates aortic valve; AAo, ascending aorta; RV, right ventricle; TV, tricuspid valve; PV, pulmonary valve; and FO, foramen ovale. Data are presented as mean±SD or n (%).

*Percentage represents sensitivity of the variable for identifying patients who will progress to HLHS

†Percentage represents 100%-specificity of the variable for identifying patients who will progress to HLHS

‡$P<0.01$ vs HLHS at diagnosis.

§$P<0.01$ vs HLHS at late gestation.

‖$P<0.05$ vs biventricular circulation at diagnosis.

**Mäkikallio K, et al. *Circulation 2006;113;1401-5.***

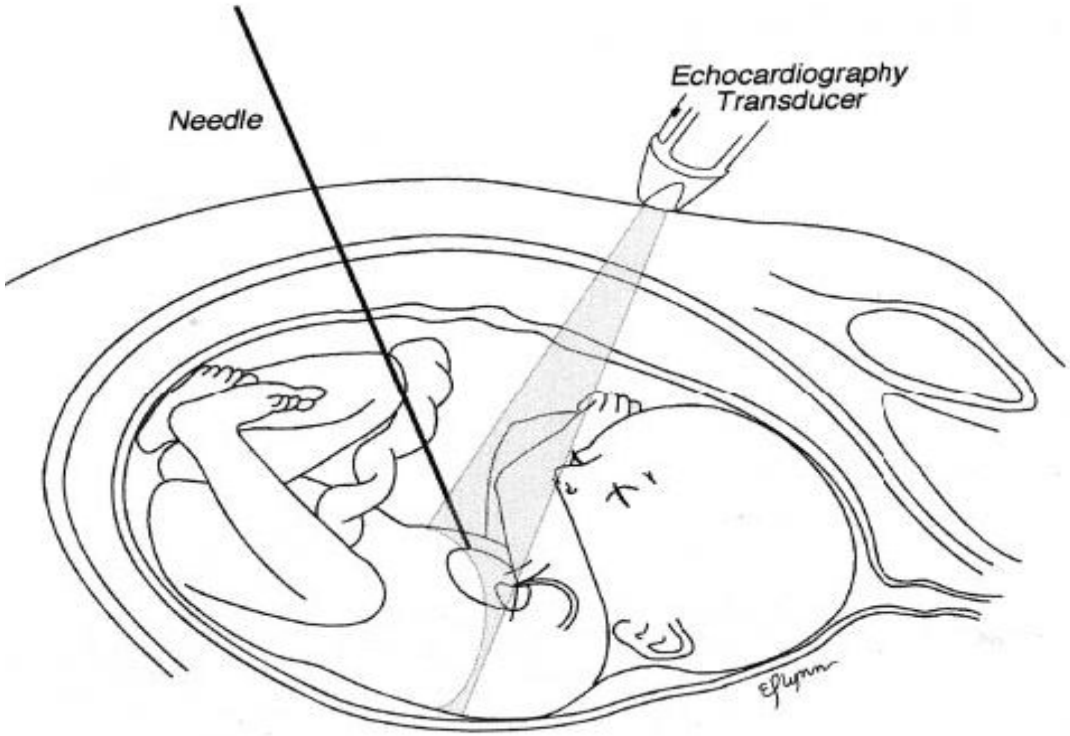
# Severe PS

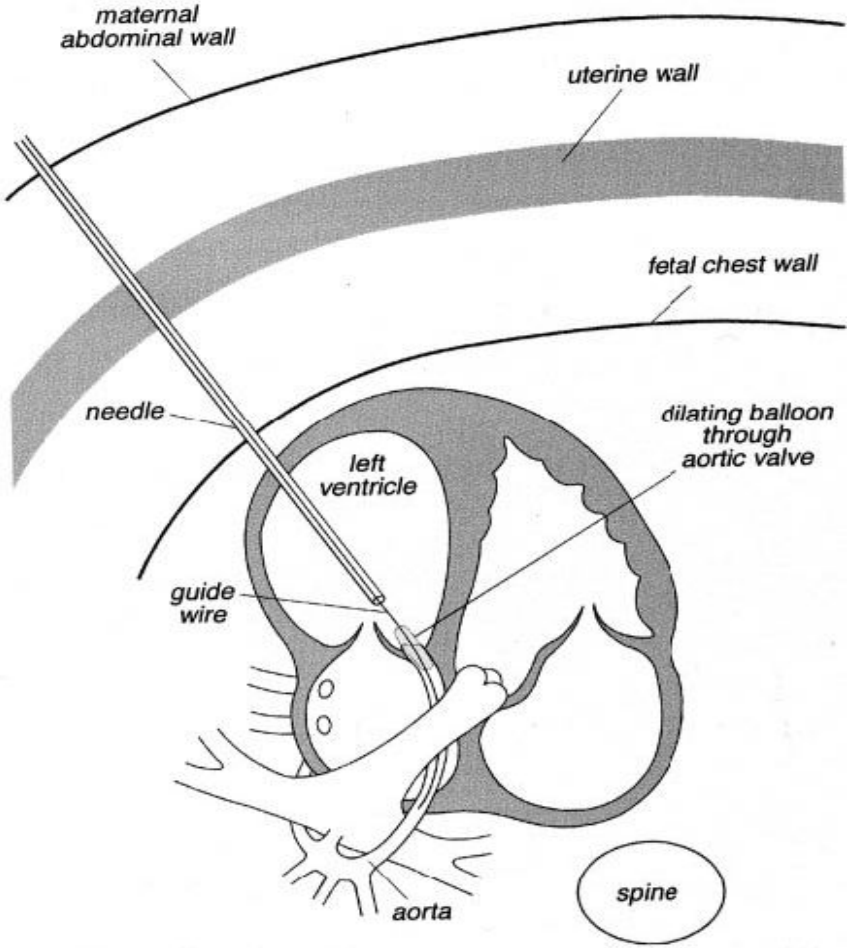
1. Absent PFO : for life saving
2. Abnormal ductus venosus doppler
3. Retrograde ductus arteriosus flow
4. Significant pressure gradient
   across the stenotic semilunar valve or TR jet
5. TR
6. PR

# Preparation

- General anesthesia
- Maternal positioning
  - Supine, left decubitus down
- Fetus positioning ⇒ IM anesthetics, muscle relaxant

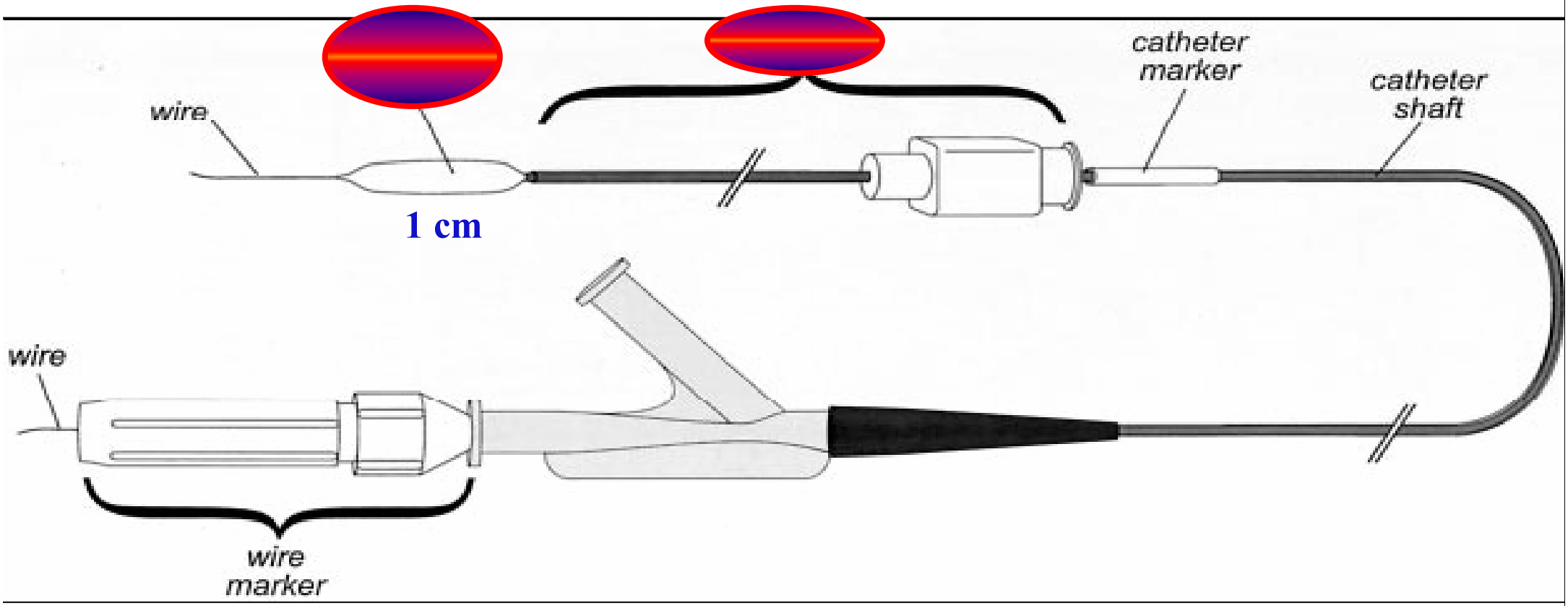
# Ideal fetal position and cannula course

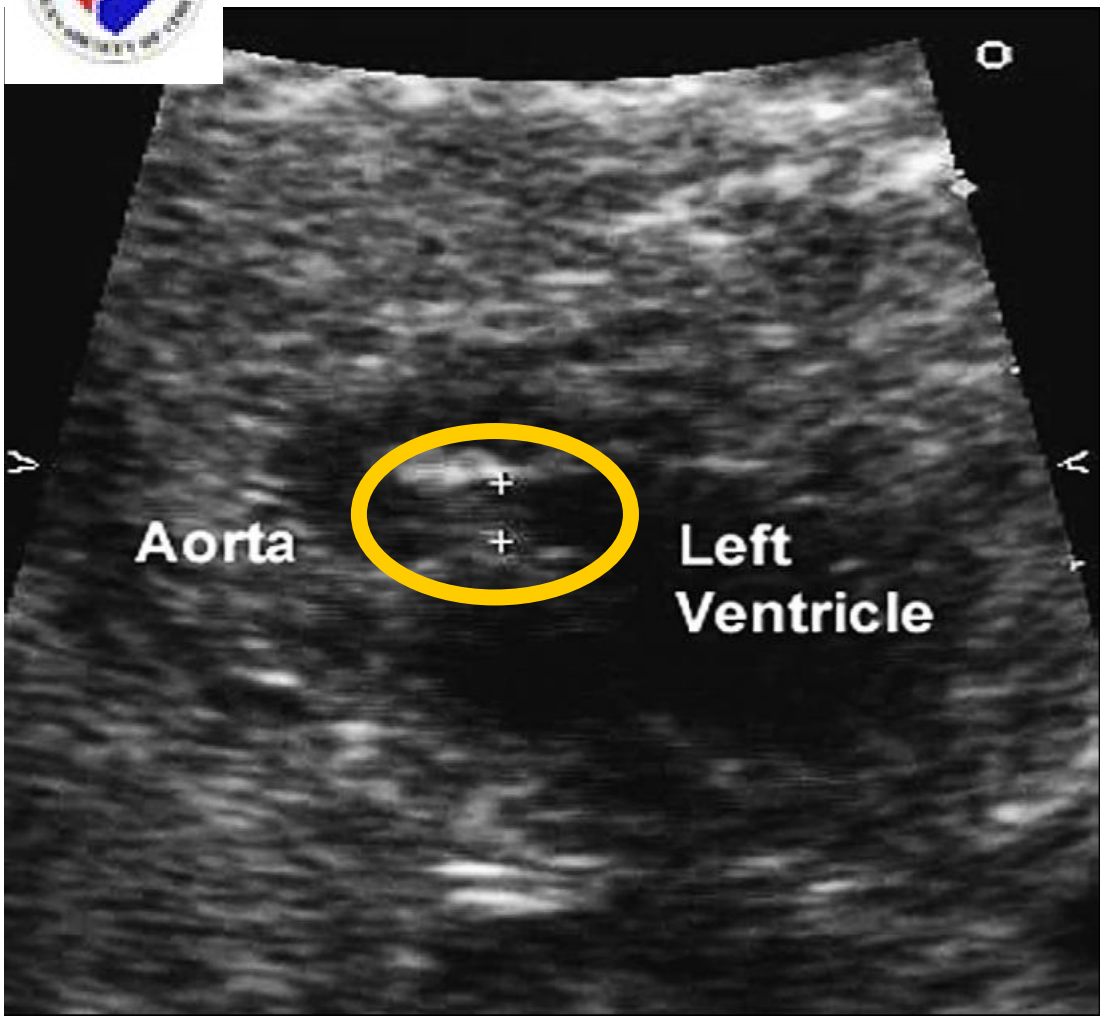


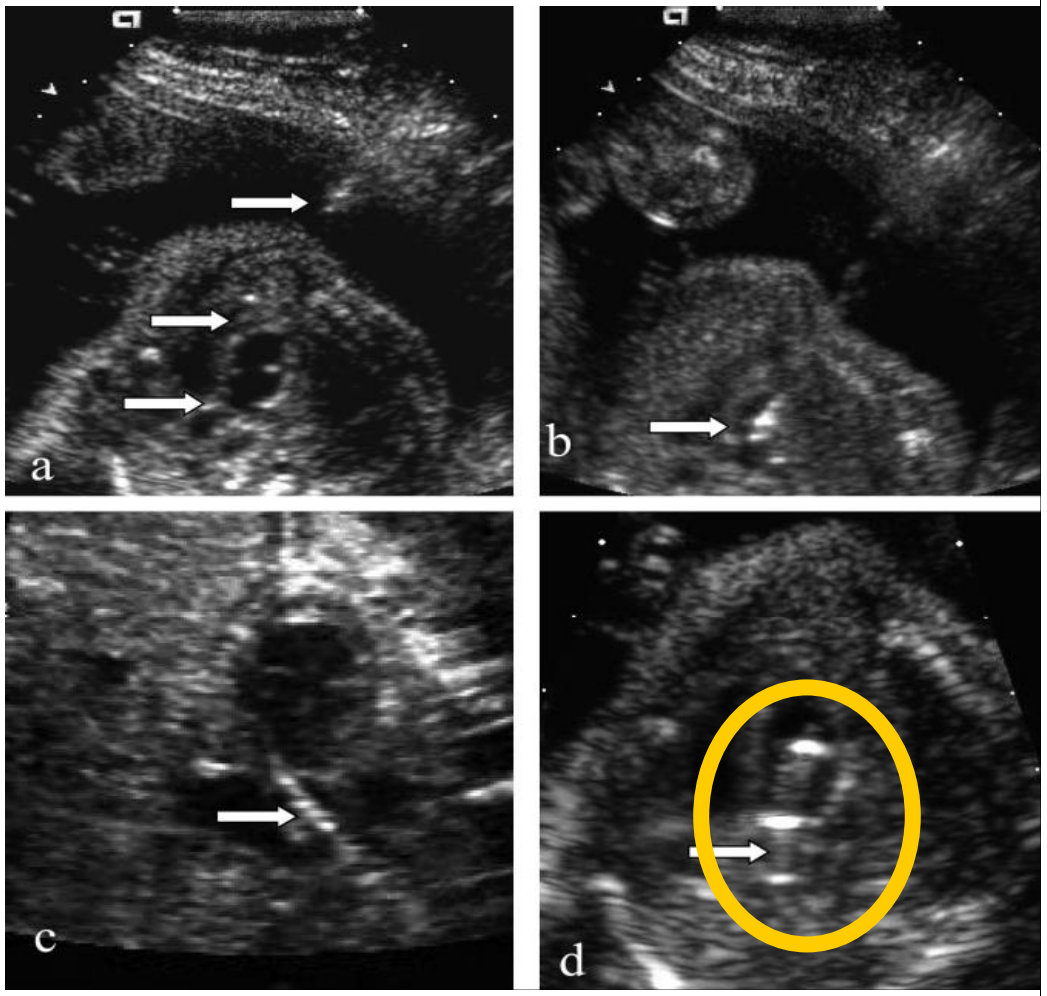




**Tworetzky W et al.** ***Circulation 2004;110:2125-31.***

# System for premeasuring and marking catheter in preparation for procedure



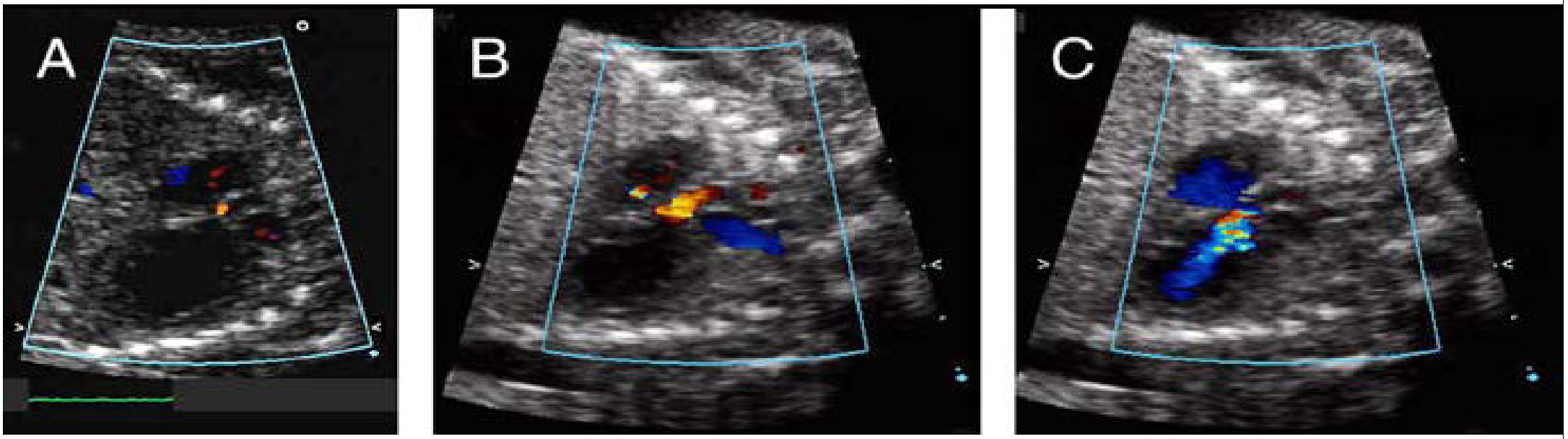



**Oversized balloon**
**:x 1.1 ~ 1.2**

Marshall AC, et al. *J Pediatr 2005;147:535-9.*

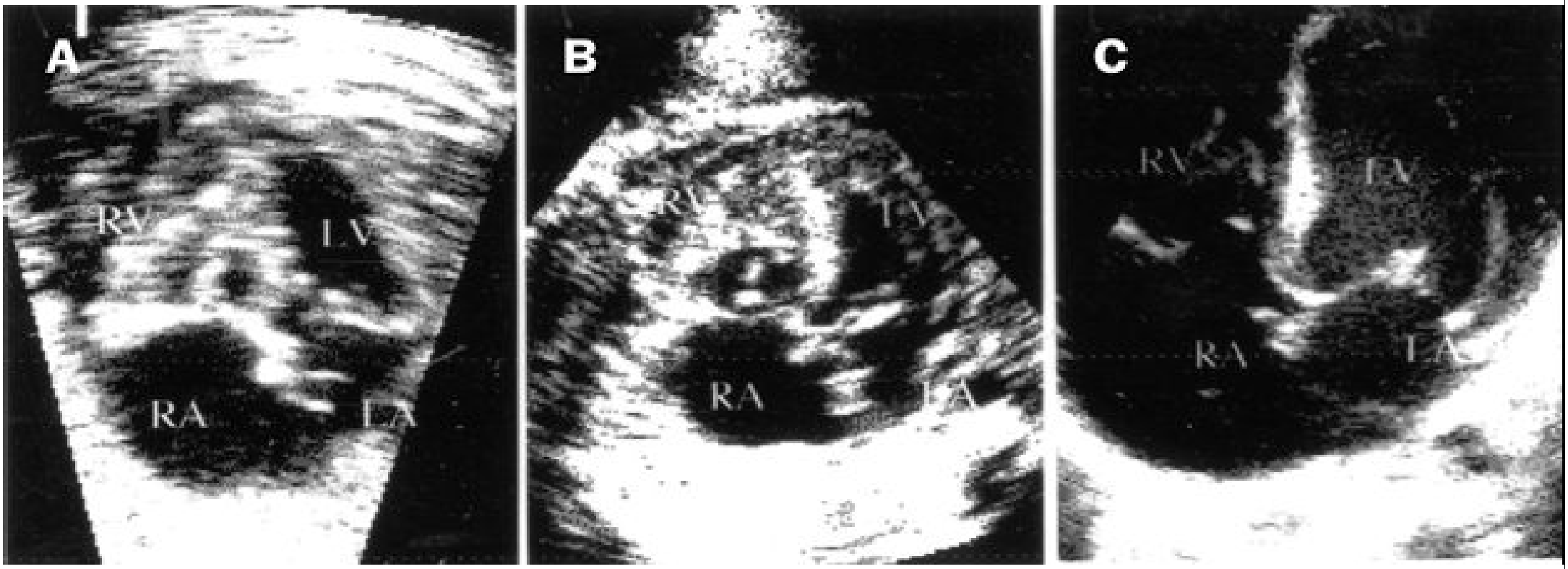
# Ultrasound images of technically successful percutaneous in utero aortic valvuloplasty




**Before intervention** **After AoV Balloon dilation**

**Marshall AC, et al. *J Pediatr 2005;147:535-9.***

# Growth of the small RV after successful balloon dilation of the pulmonary valve

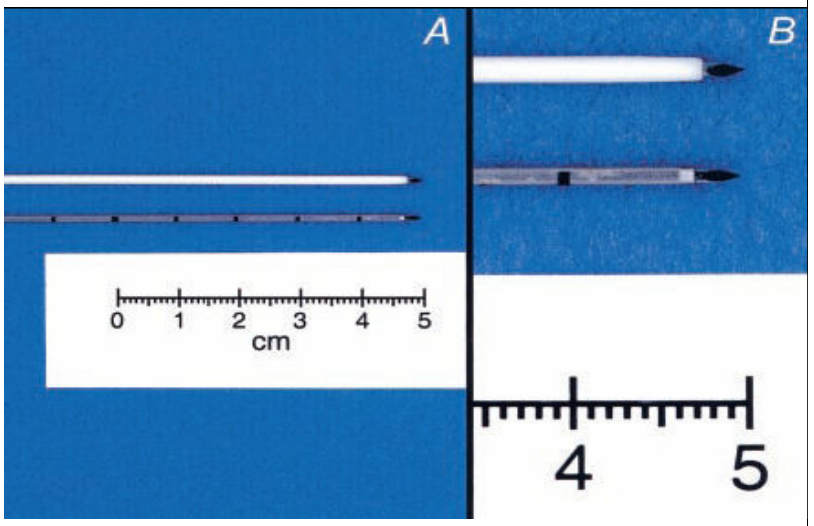



**Before procedure** **6 weeks after procedure** **After birth**

Tulzer G et al. *Lancet 2002;360:1567–8.*

# Fetal atrial septoplasty fetal LA decompression

**Marshall AC, et al.** ***Circulation 2004:110;253-258.***





**Before atrial septal puncture**


**During septal puncture with Chiba needle**


**Dilation with 3 mm coronary balloon**

# Complication

- Fetal
  - Persistent bradycardia
  - Bleeding
  - Pericardial effusion
  - Injury to cardiac and extracardiac structure
  - Infection
- Maternal
  - Bleeding
  - Embolism
  - Choriamnionitis
  - Placental abruption
  - Premature labor

# Fetal access(Animal experiment)

- Fetoscopic and open transumbilical fetal cardiac catheterization

  (Kohl T, et al. *Circulation 1997;95:1048~1053.*)

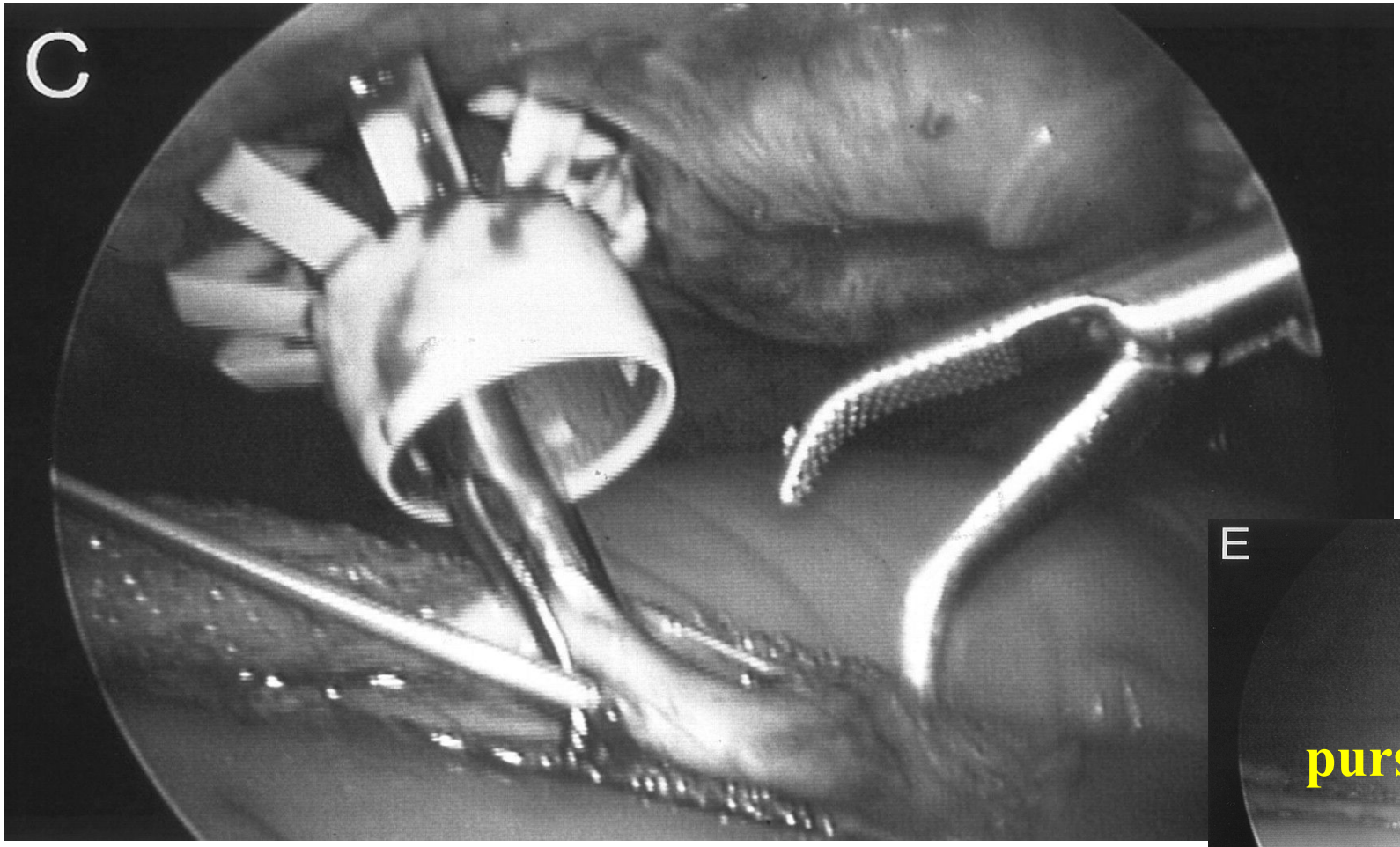
- Fetoscopic direct fetal cardiac access

  (Kohl T, et al. *Circulation 2000;102;1602~1604.*)

- Transhepatic ultrasound-guided cardiac catheterization

  (Jouannic JM, et al. *Circulation 2005;111;736-741.*)

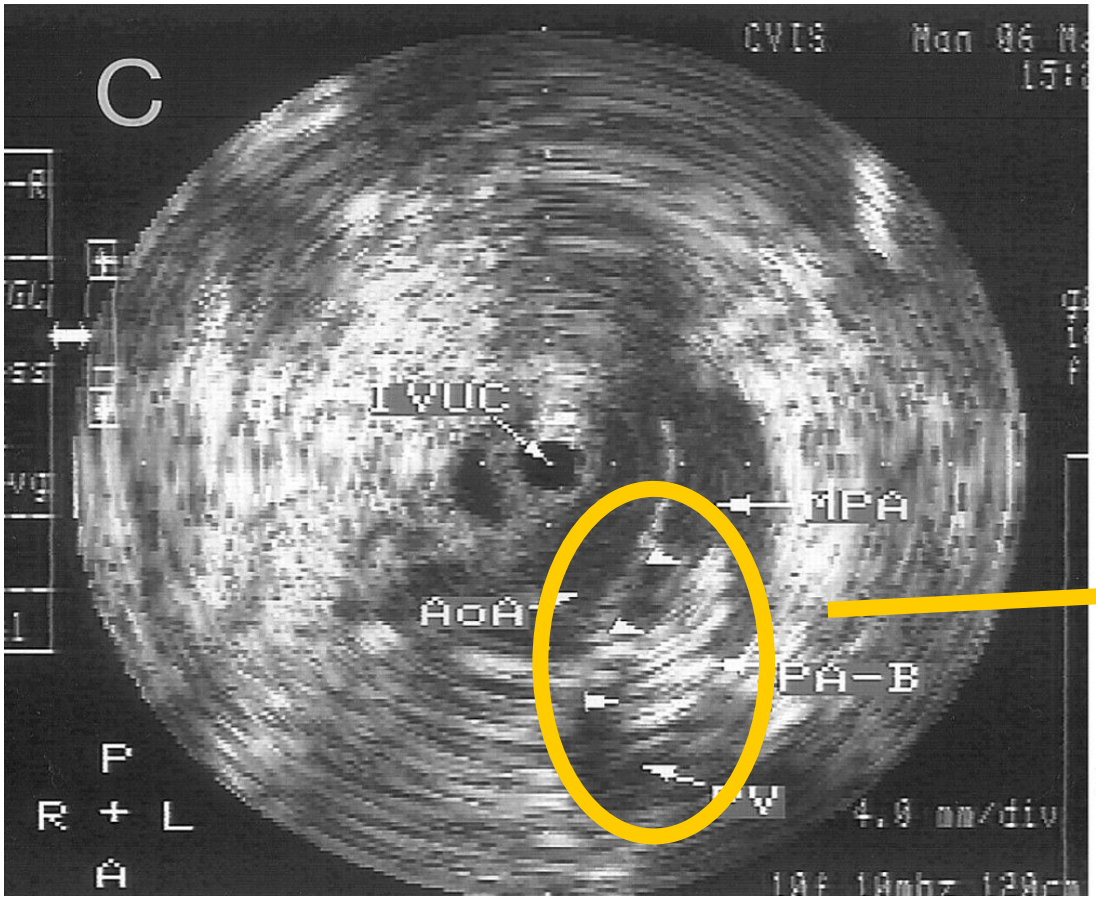
# Fetoscopic transumbilical fetal cardiac catheterization



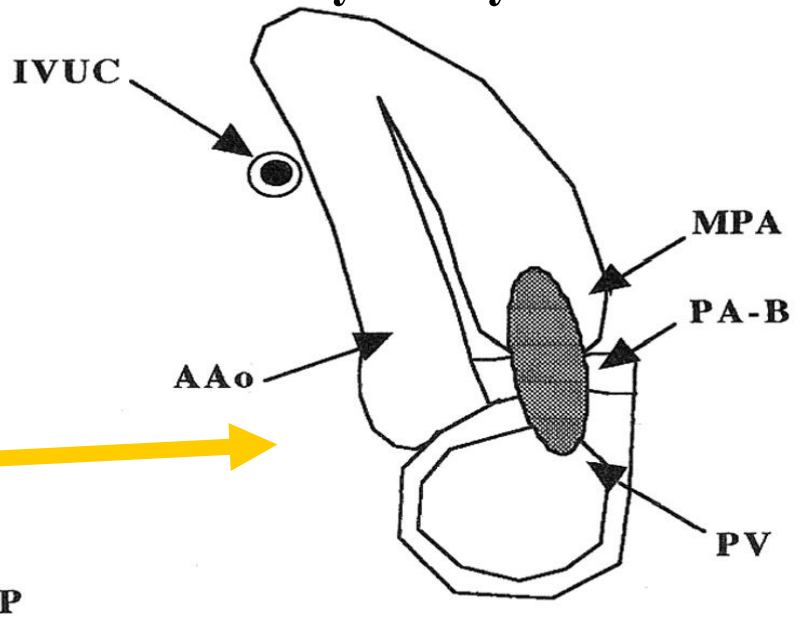

**4F catheter sheath**
**550 g fetal sheep**
**at 99 days**
**of gestation**


Kohl T. *Circulation 1997;95:1048-1053.*

# Open transumbilical arterial cardiac cathterization




**0.014 wire**
**4 mm coronary artery balloon catheter**

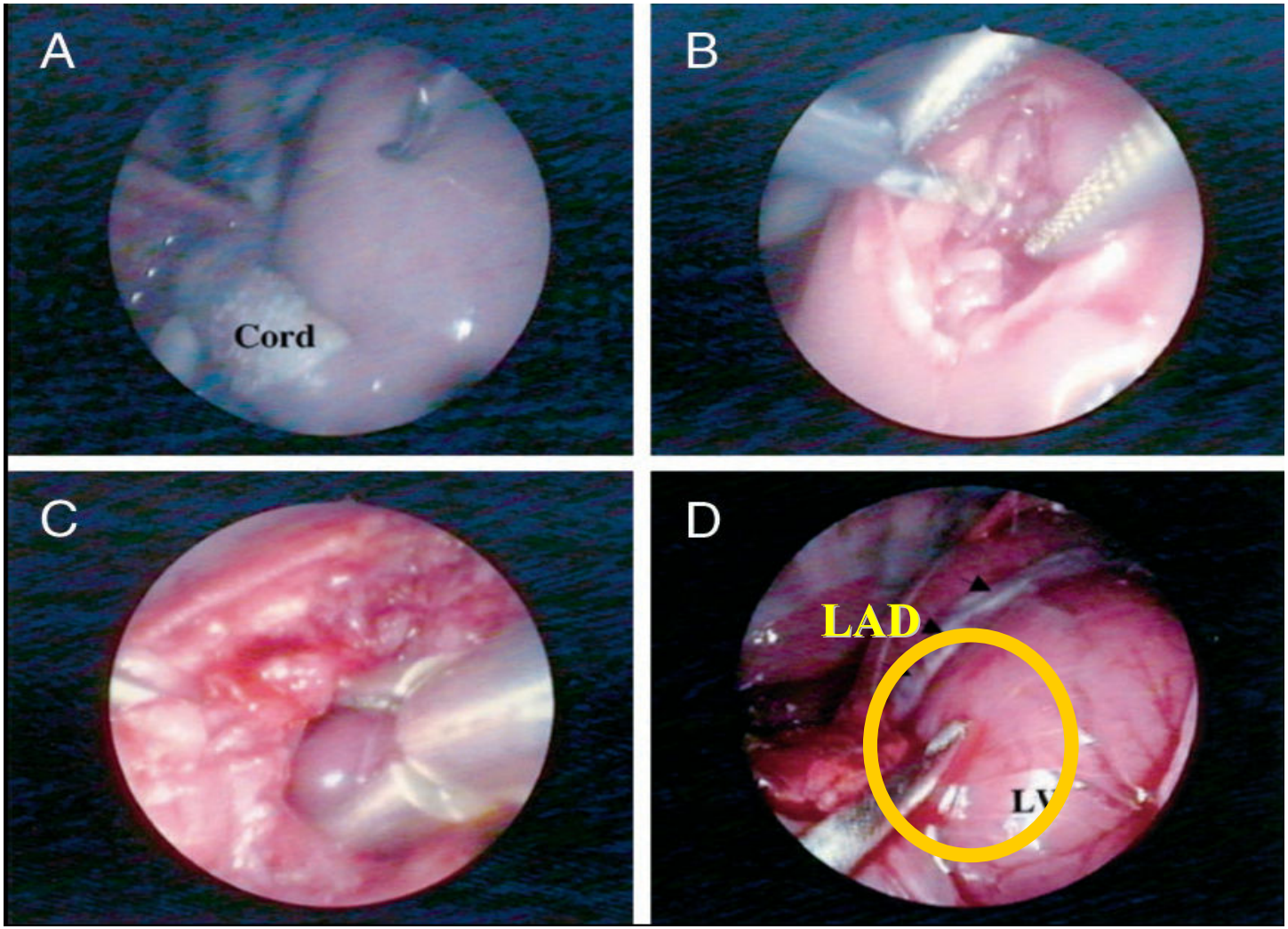



P
R + L
A

**96 days of gestation in a 750 g fetal sheep**
**Fetal TEE 10F, 10 MHz IVUS**

**Kohl T.** ***Circulation. 1997;95:1048-1053.***

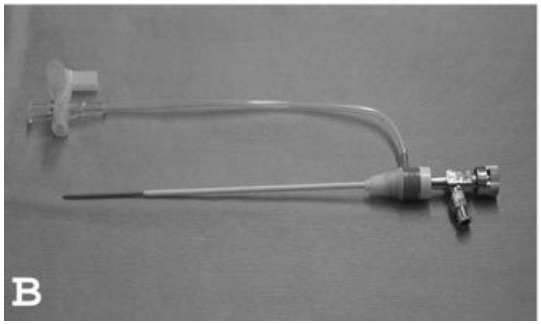
# Fetoscopic direct fetal cardiac access in sheep

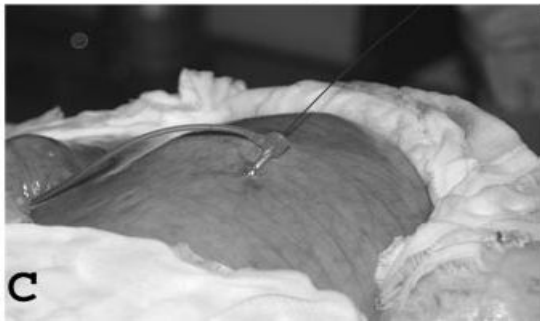



- Needle(16G)
- → LV → LVOT
- 0.014-inch guidewire and a balloon catheter across the aortic valve antegrade

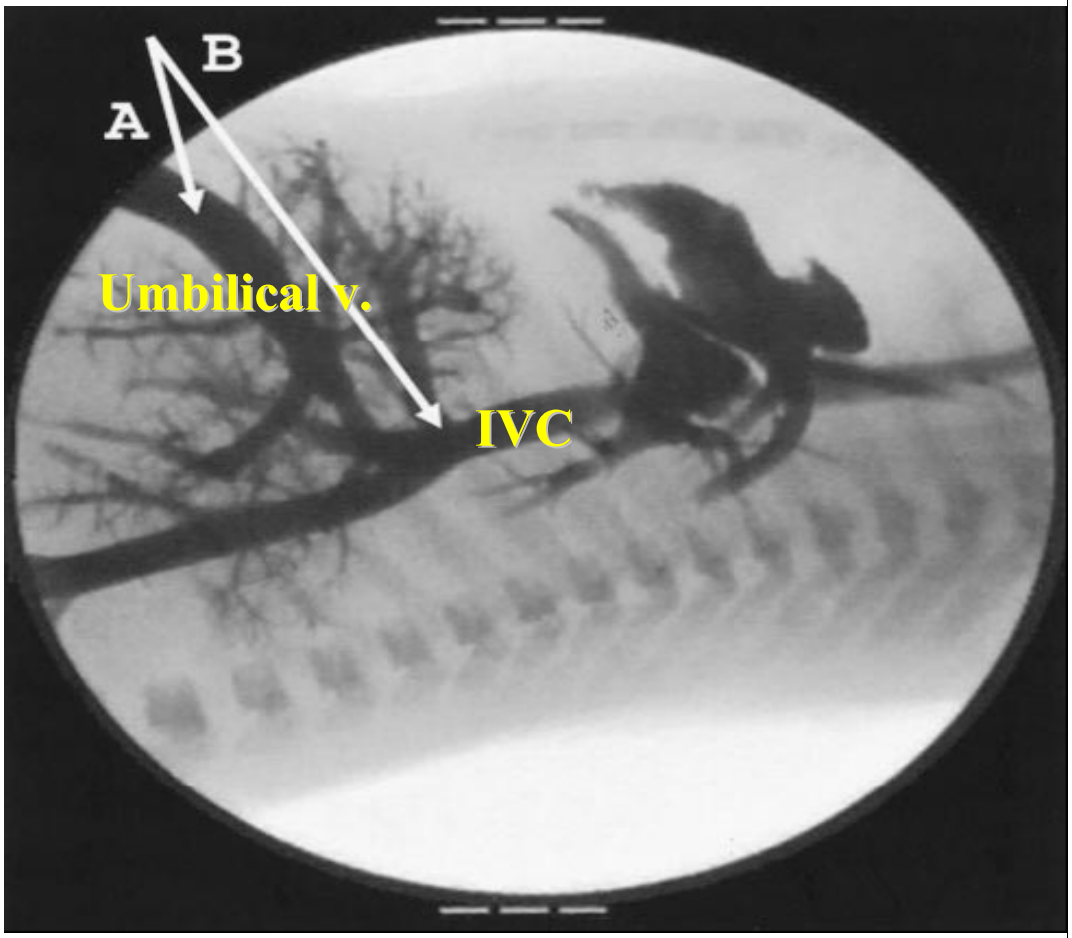
**Kohl T, et al.*Circulation 2000;102;1602-1604.***

# Transhepatic ultrasound-guided cardiac catheterization

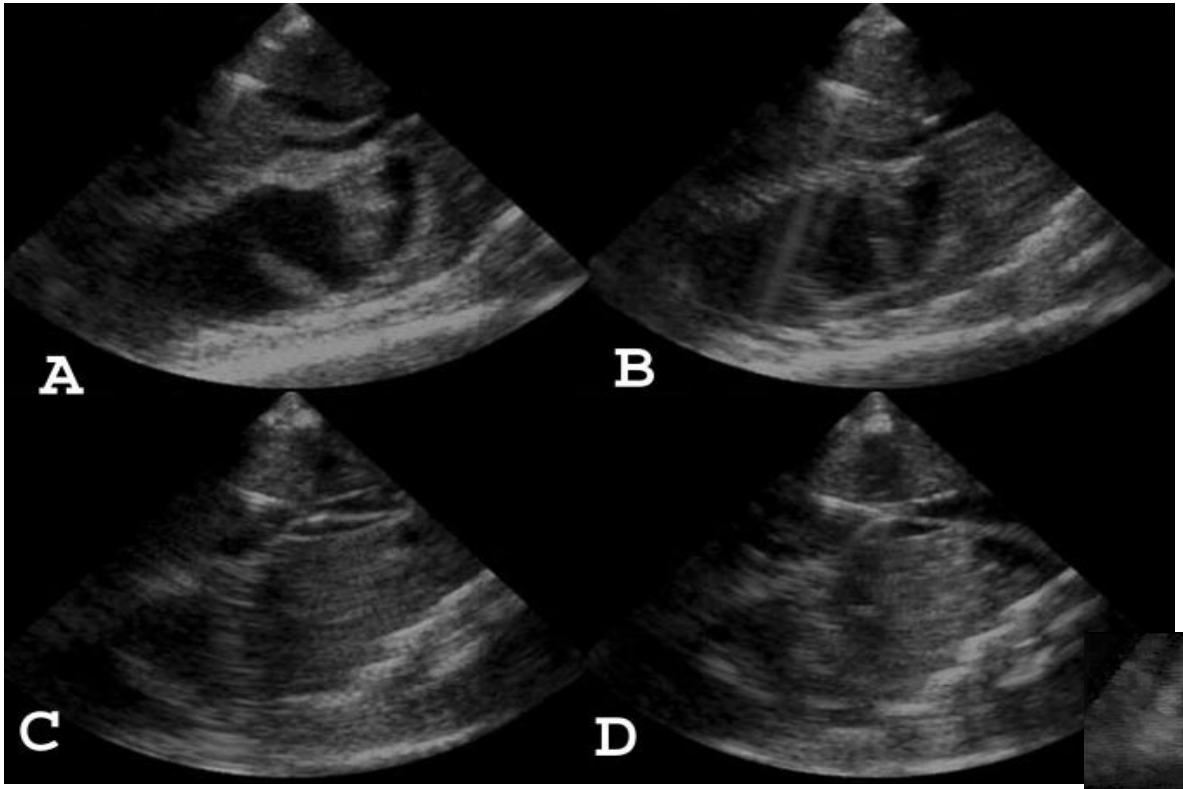




A, Exteriorization of uterus through midline laparotomy
B, 4F sheath is mounted over trocar
C, Trocar has been retrieved, and sheath is sutured on uterus to prevent migration

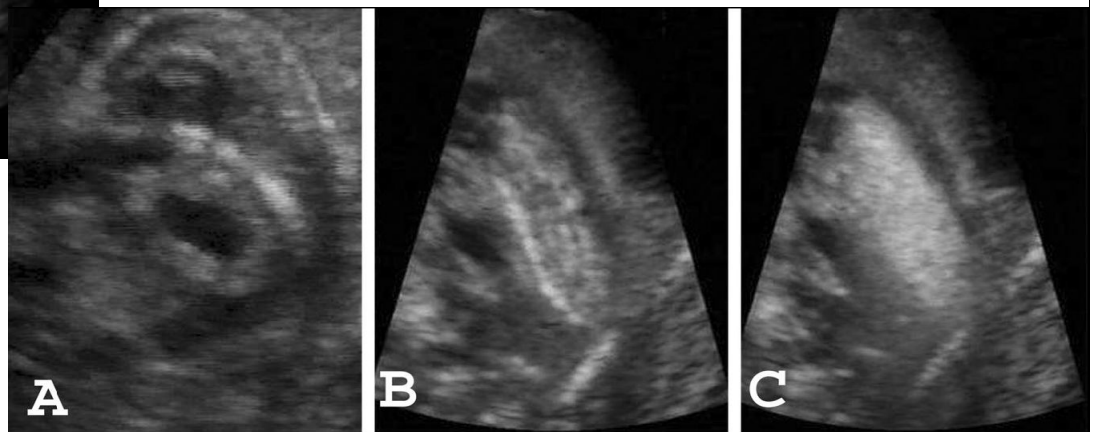



**Jouannic JM, et al. *Circulation 2005;111;736-741.***

# Transhepatic ultrasound-guided cardiac catheterization

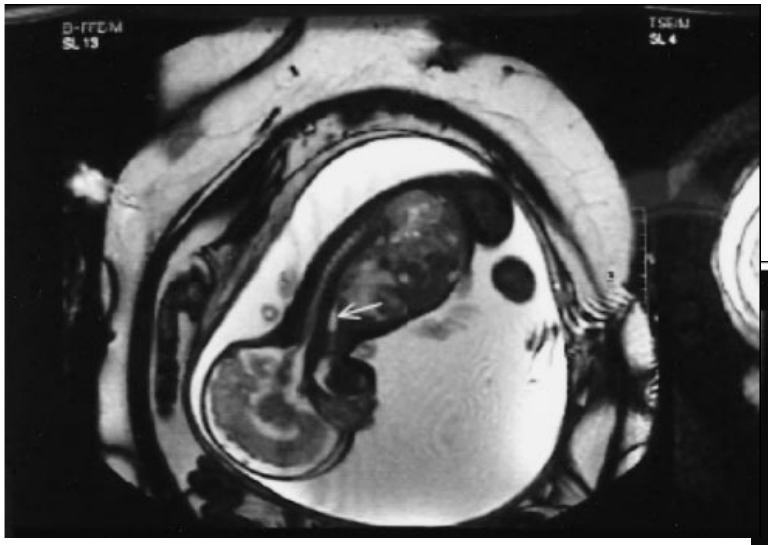



Ballooning of pulmonary valve

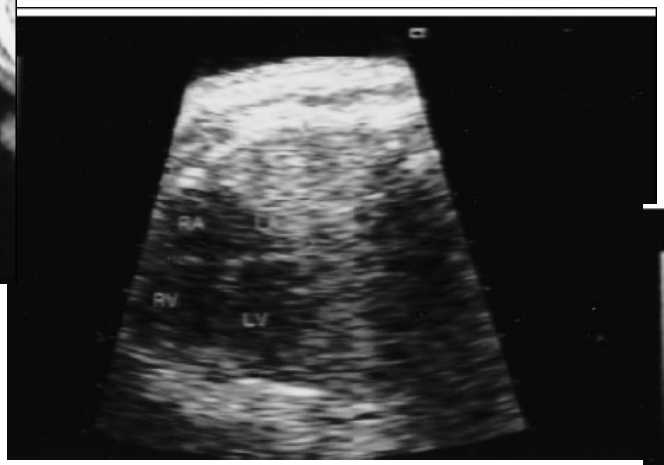



**Jouannic JM, et al.** ***Circulation 2005;111;736-741.***

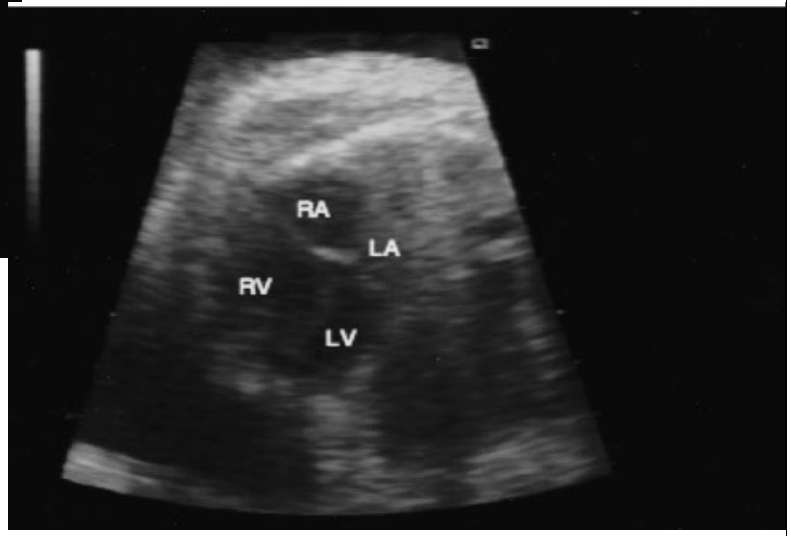
# Intraamniotic Fetal Echocardiography



adipositas
polyhydramnios



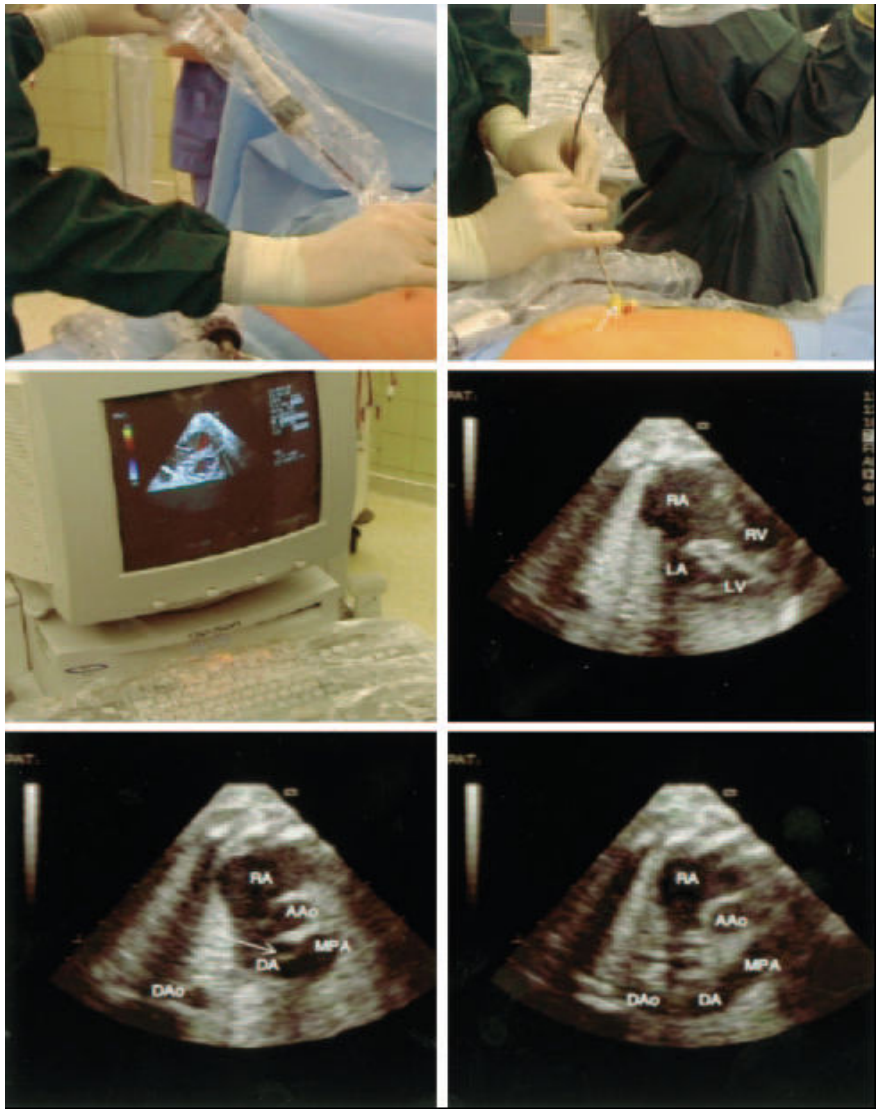

transabdominal
ultrasound imaging

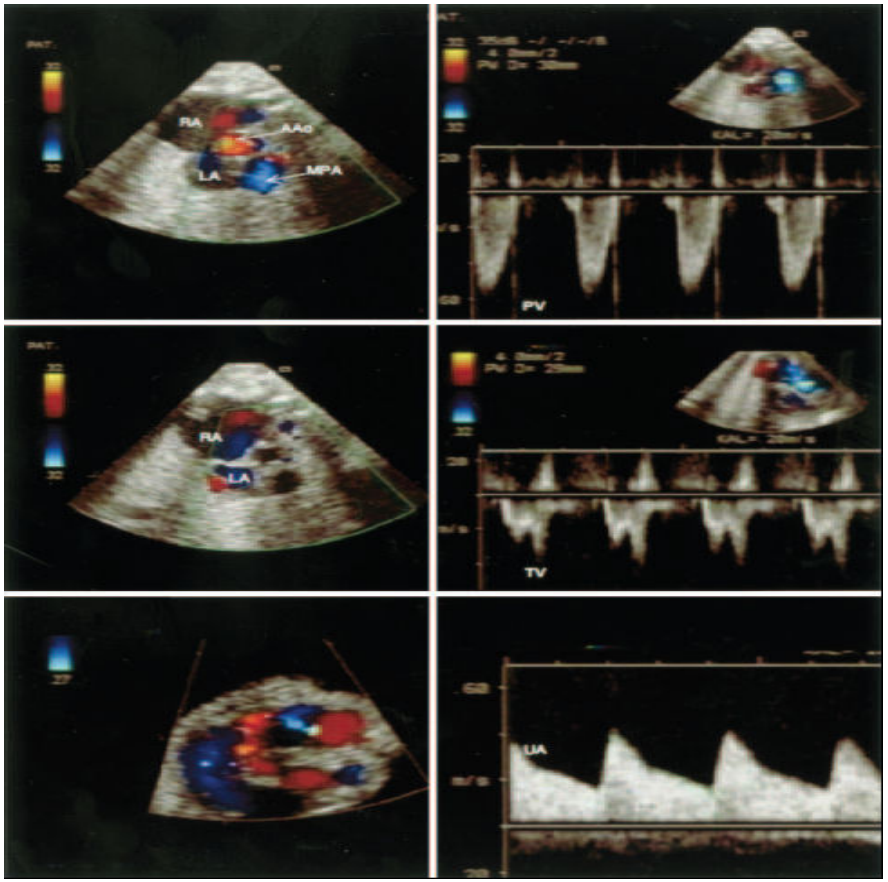



Intraamniotic Fetal Echo

**Kohl T et al.** ***Circulation. 2006;114:e594-e596.***

# Intraamniotic fetal echocardiography

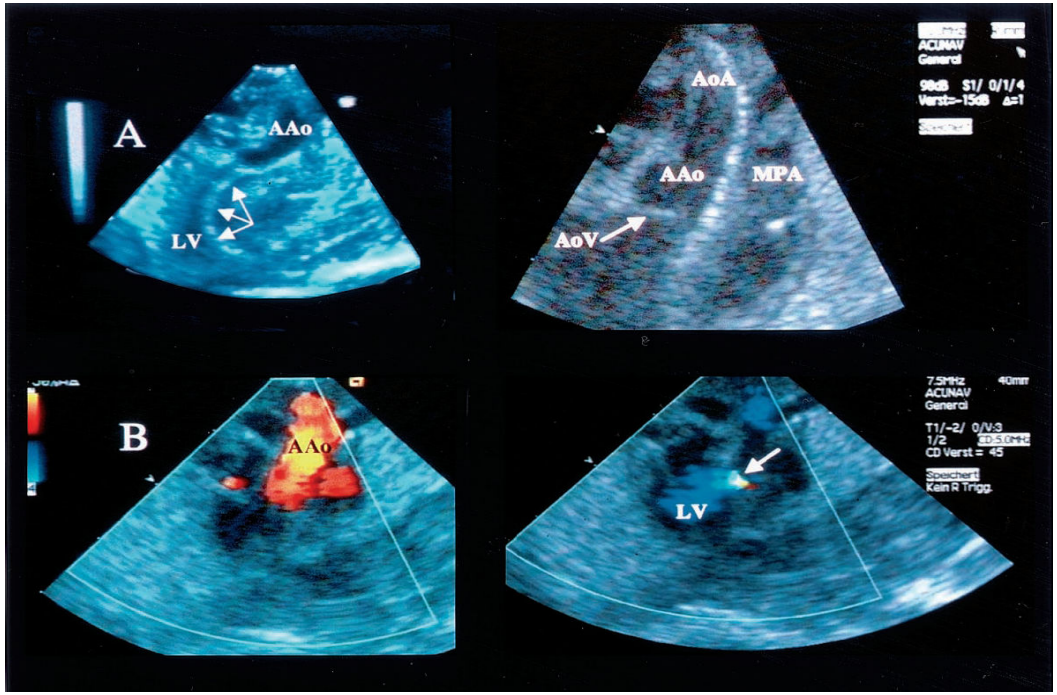


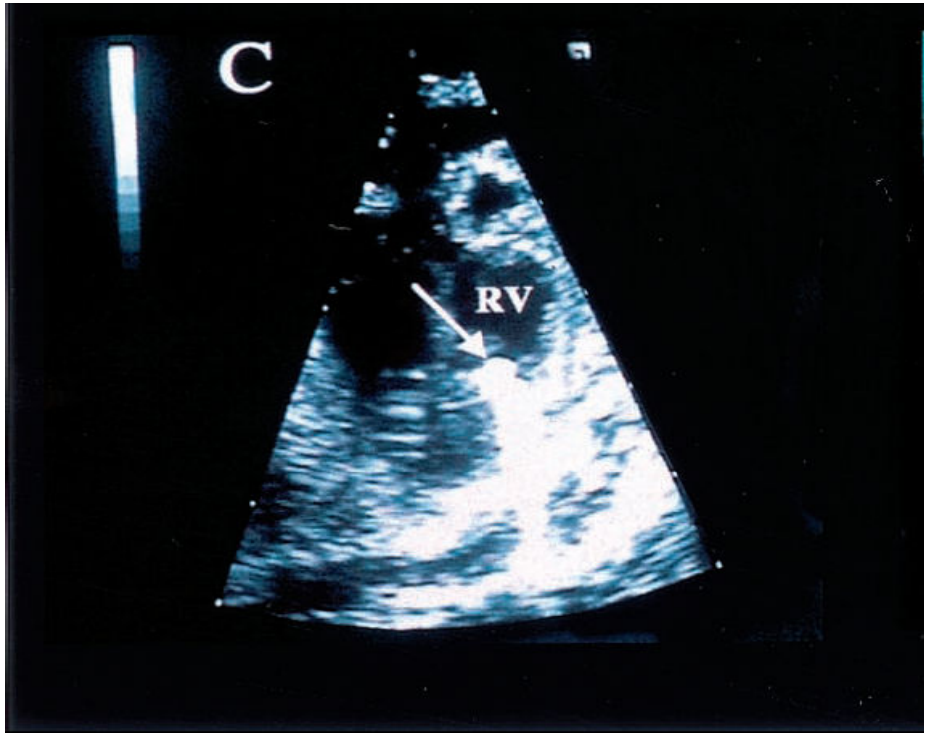

Diaphragmatic hernia
fetoscopic tracheal balloon occlusion
11-F catheter sheath

**Kohl T et al.** ***Circulation. 2006;114:e594-e596.***

# Multimodal Fetal TEE for Fetal Cardiac Intervention in Sheep



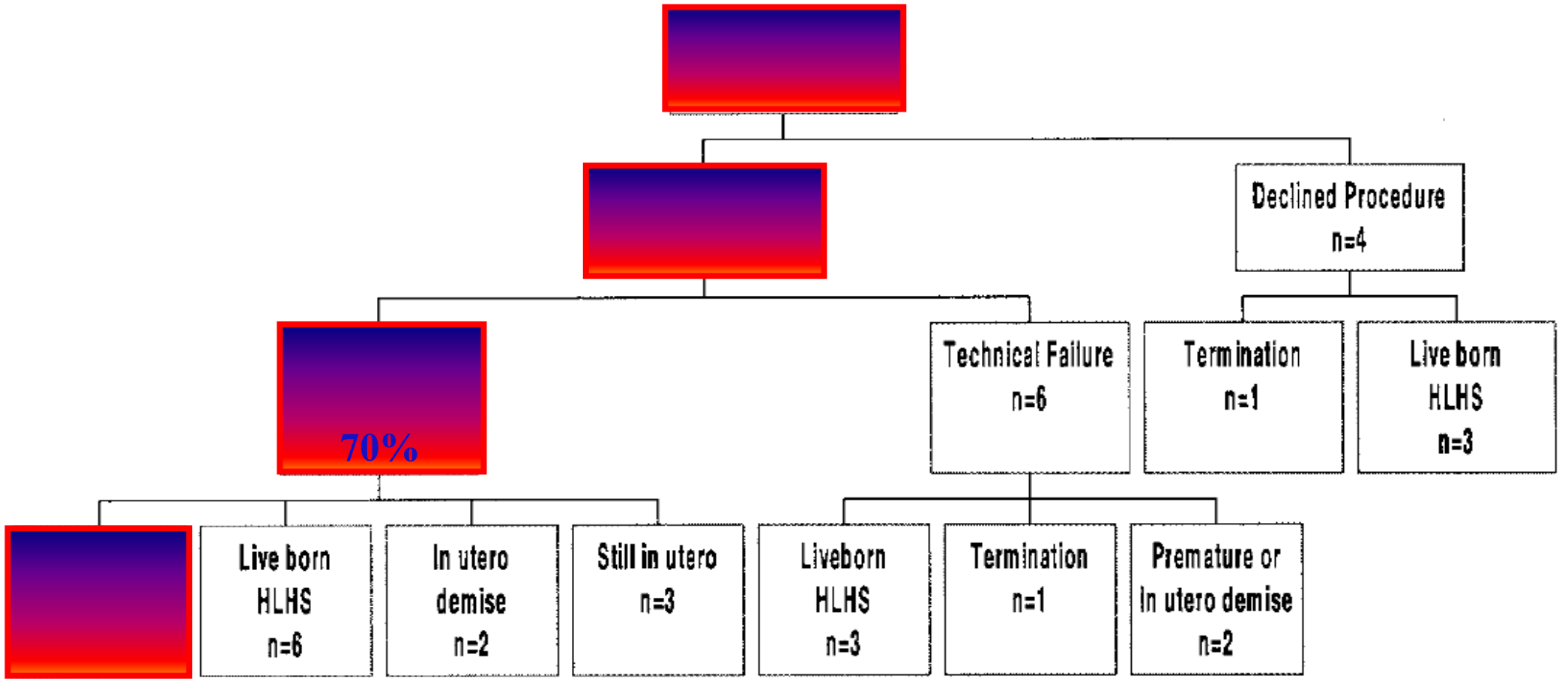

Retrograde cardiac catheterization (through the umbilical artery)




Transventricular fetal cardiac catheterization

**Kohl T et al.*Circulation 2001;104;1757-60.***

# Flow chart showing perinatal outcomes of all 24 patients initially considered candidates for in utero aortic valvuloplasty




Tworetzky W et al. *Circulation 2004;110:2125-31.*

# Future requirement

- Laser
- Echocardiography
- Small equipment size
- Percutanous ultrasound-guided intervention ⇒ Application of fetoscopic procedure with guidance of fetal TEE in human fetus

# Summary

- Intervention in the early third trimester may significantly alter the course of secondary morphogenesis, leading to improved outcomes for a variety of complex congenital heart disease
  - Team approach
  - Access route
  - Technique
  - Peri-interventional care

# Thank you for your attention

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