

# **Closing the Ductus in the Presence of Pulmonary Hypertension**

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# Definition of PHT

- **m PAP  $\geq$  25mmHg (at rest)**  
 **$\geq$  30mmHg (with exercise)**
- **PCWP  $\leq$  15mmHg**
- **PVR  $\geq$  3 Wood units**
- **sPAP  $\geq$  50% of systemic pressure (children)**
- **5-10% of all pts with CHD**

# Traditional Operable Criteria

## ■ Lung biopsy

- severe intimal fibrosis (>50% of internal vessel diameter) and/or plexiform lesions  
→ irreversible

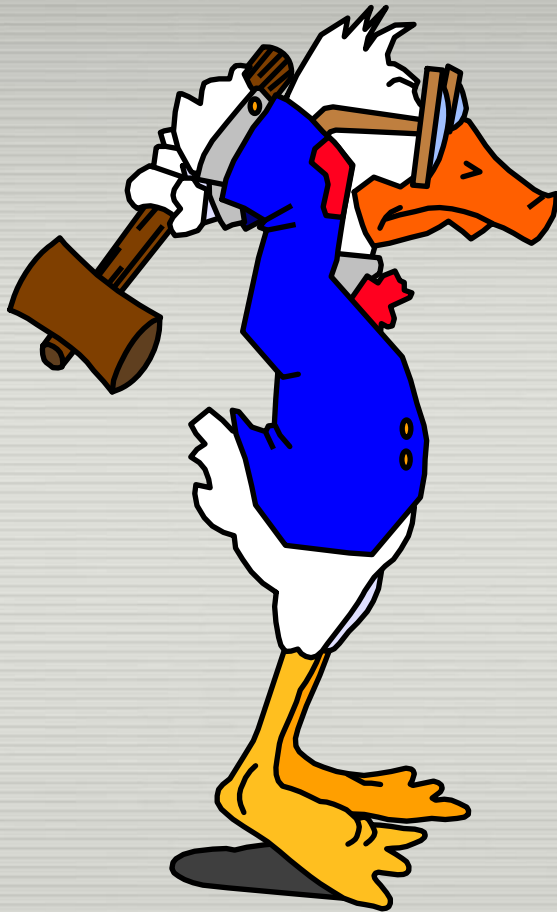
## ■ Severity of PAH

- Baseline PVR  $\leq 6$  WU, Rp/Rs  $\leq 0.3$

# Myth

**“Eisenmenger syndrome is a stable disease, not amenable to treatment”**

# Myth-busters



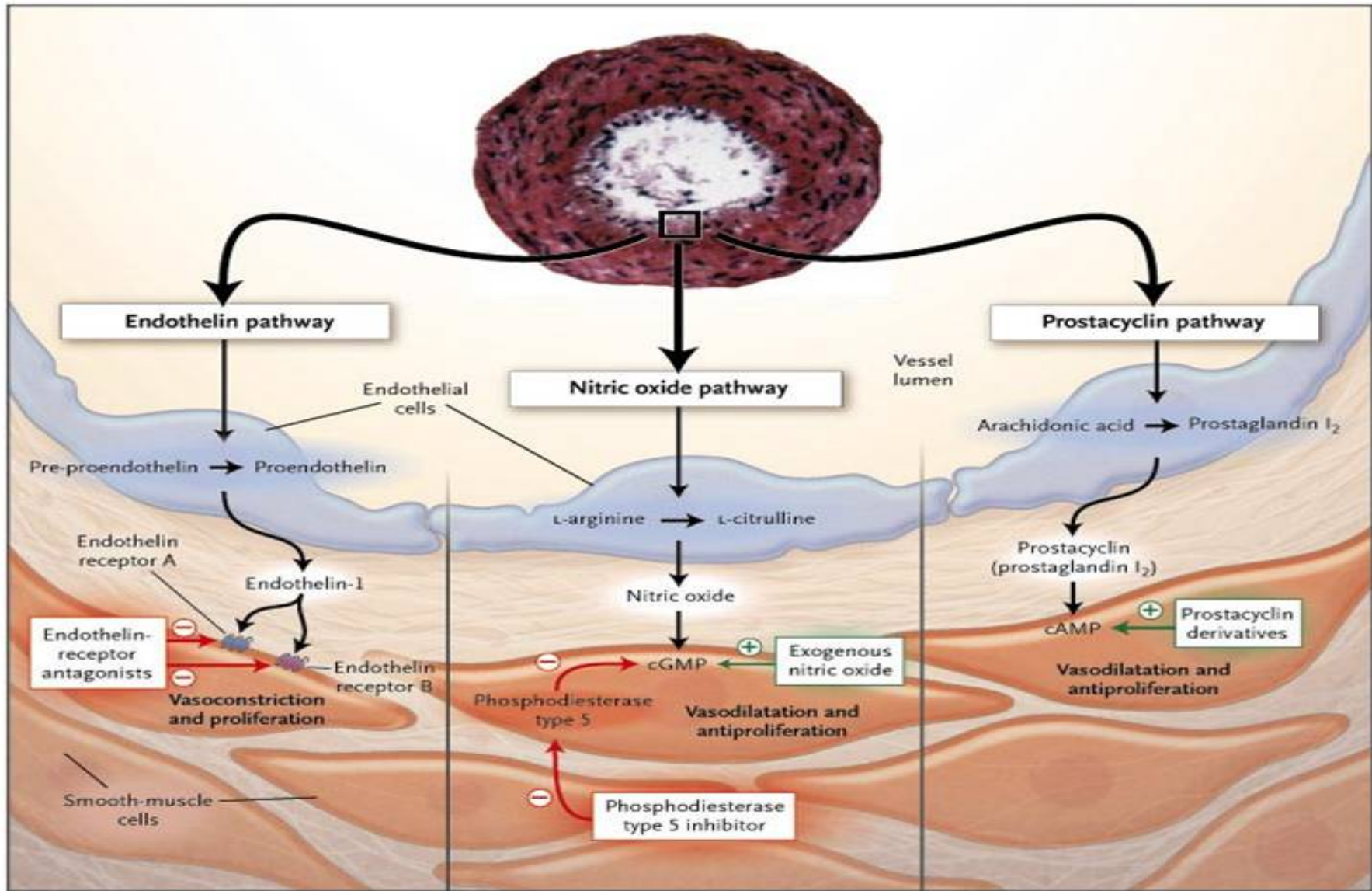
What is the cutoff value of  $R_p$  in closing ductus?

6WU?

8Wu?

10WU?





*N Engl J Med 2004;351:1425-36*

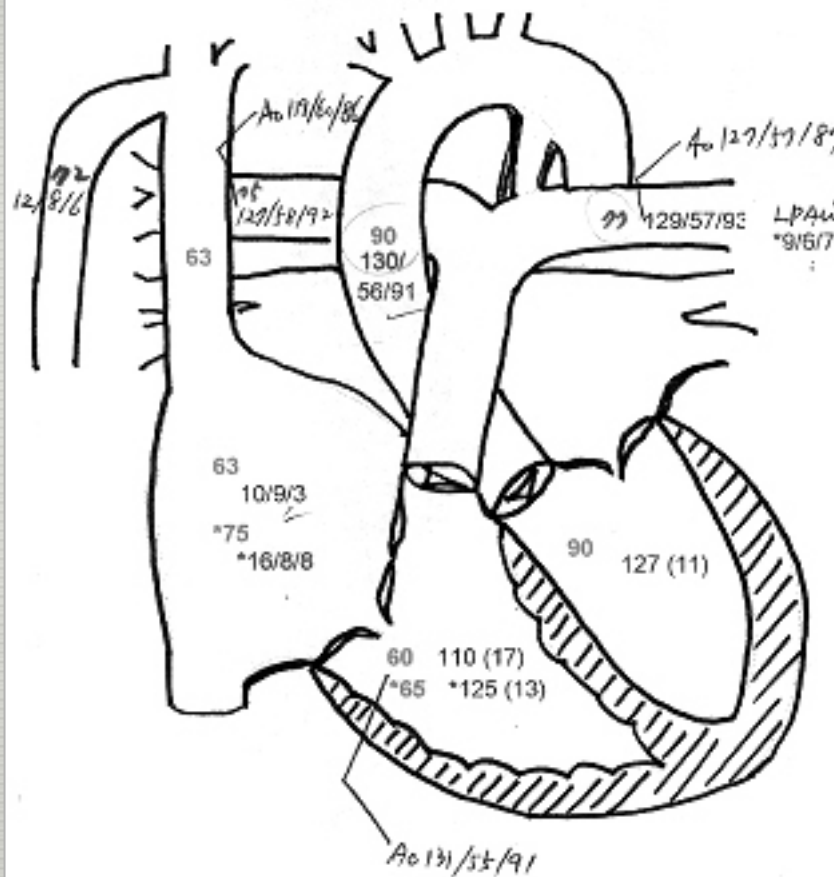
# Case

- **4Y/boy, Wt 11.5kg**
- **Mild CHF symptom**
- **Mild cardiomegaly on CXR**
- **Echo.**

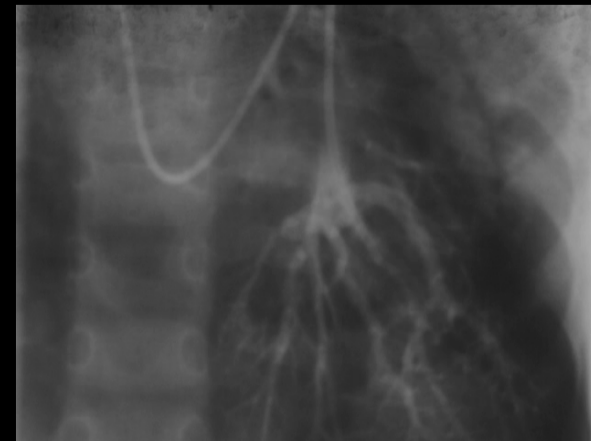
**Large PDA with severe PAH**  
**d=7.1mm, bidirectional shunt**  
**Interrupted IVC**

## Cath. (99-6-4, 4Y)

ABGA: 7.325-44-87.4- (Sat:95.9%)  
 ABGA2: 7.307-45-258.3- (Sat:99.8%)  
 \* Oxygen 5L



<b>Qp/Qs</b>	<b>1.6</b>
<b>R<sub>p</sub></b>	<b>15.1</b>
<b>R<sub>p</sub>/R<sub>s</sub></b>	<b>0.6</b>
<b>P(PA/Ao)</b>	<b>1.0</b>





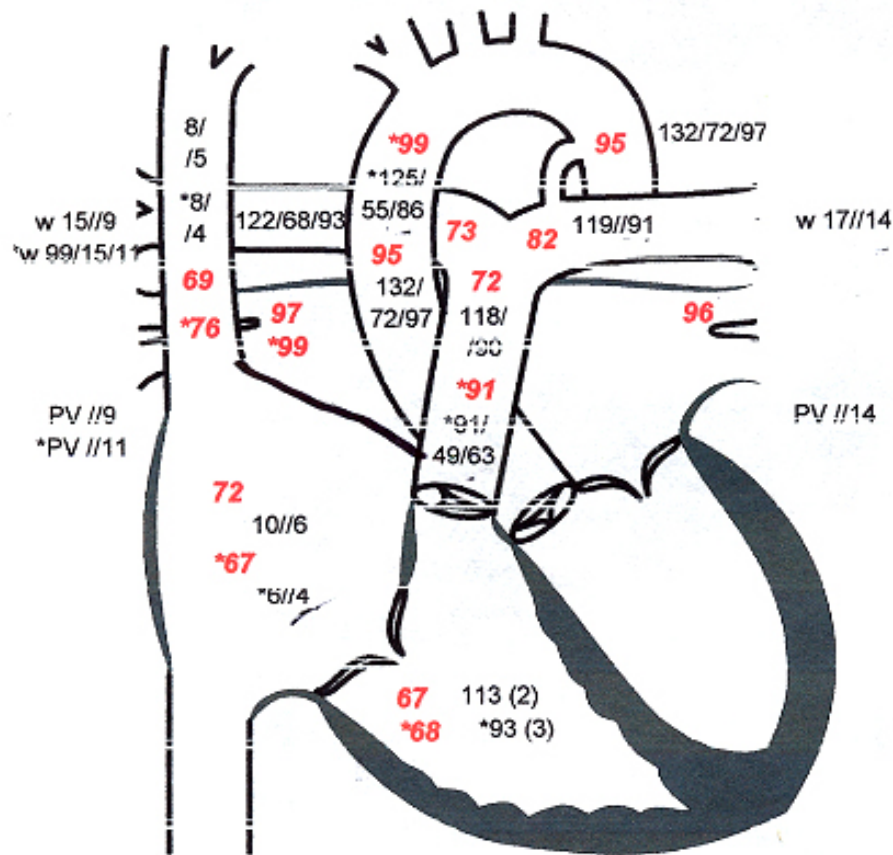
## *Management (99-6-30)*

- **No closure of PDA**
- **Beraprost PO (2ug/kg/day)**
- ***Echo. (2001-3-13, 21months later)***

**PDA PG=41mmHg (↑)  
bidirectional shunt,  
dominantly L to R shunt  
Enlarged LA and LV (↑)**

## Cath. (2001-3-16, 6Y)

ABGA: 7.359-42-84.5- (Sat:95%)  
 ABGA2: 7.352-40.7-160.4- (Sat:99%)  
 \* Oxygen+milinone

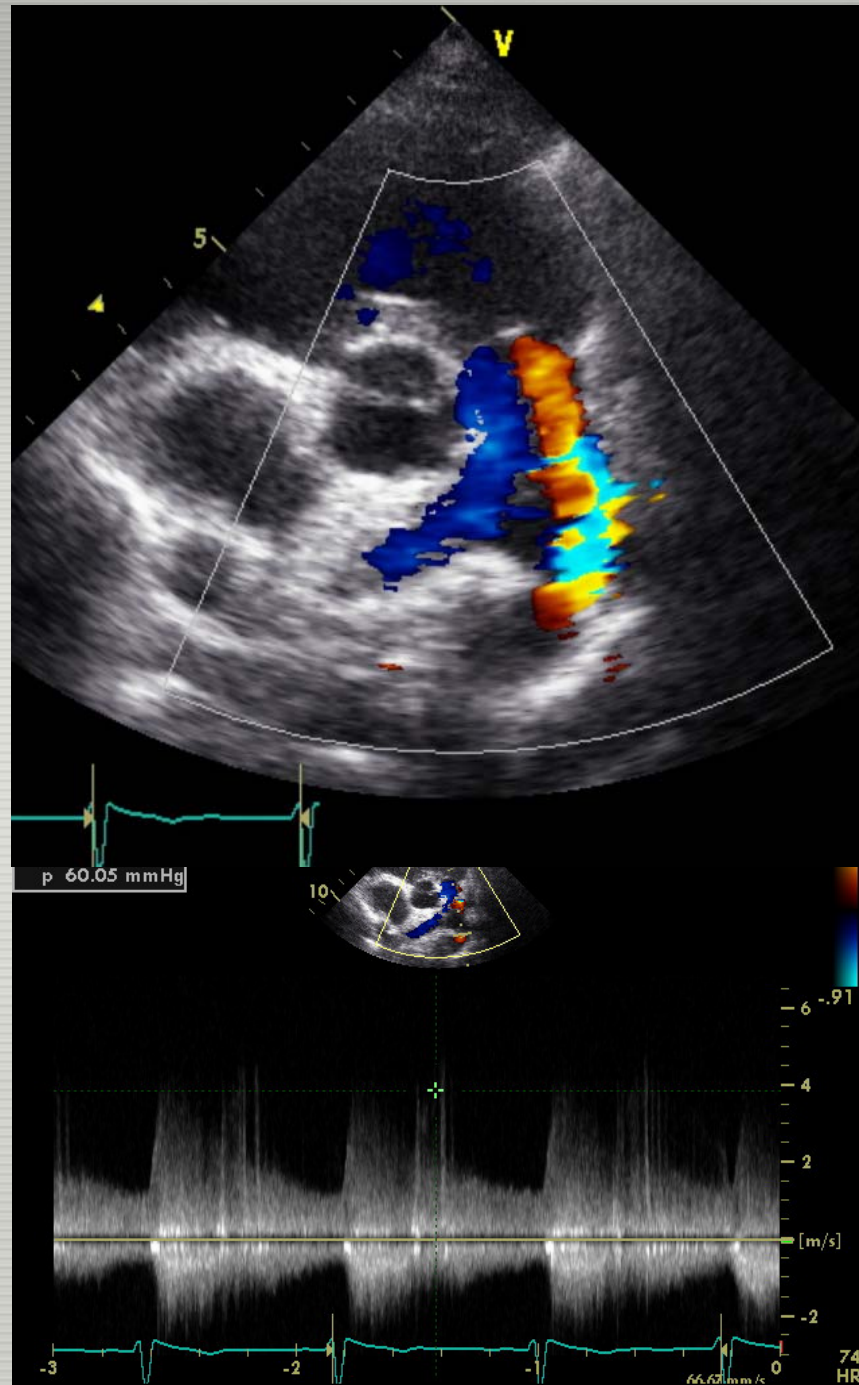


	Baseline	O2
$Q_P$	4.6	9.7
$Q_S$	3.4	3.8
$Q_P/Q_S$	1.4	2.6
$R_P$	16.5	5.3
$R_P/R_S$	0.6	0.3
$P(PA/Ao)$	0.9	0.7

*High  $R_p$ (16)  
 Vasoreactivity(+)*

*Echo. (2006-7-11, 11y)*

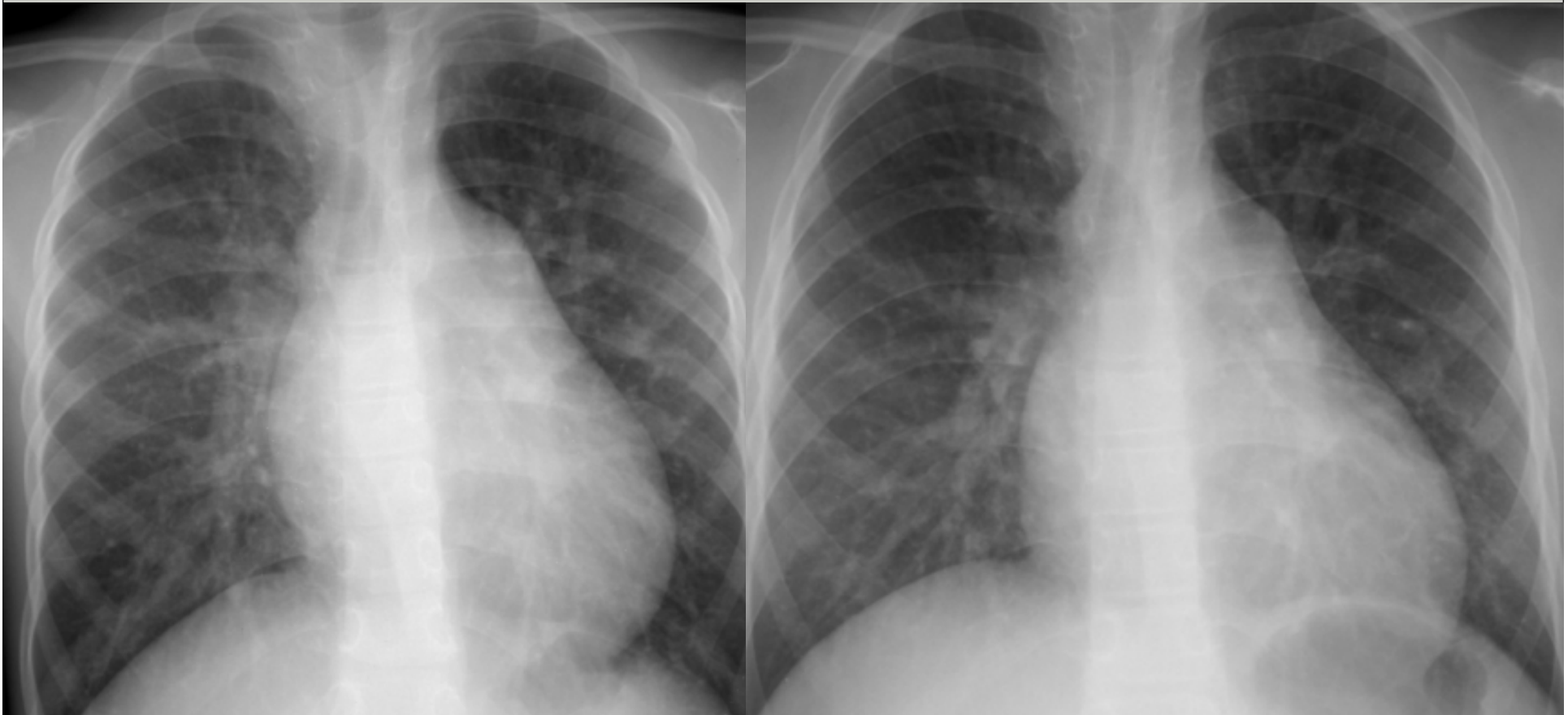
- PDA PG = 60 mmHg(↑)
- Increasing L-to-R shunt



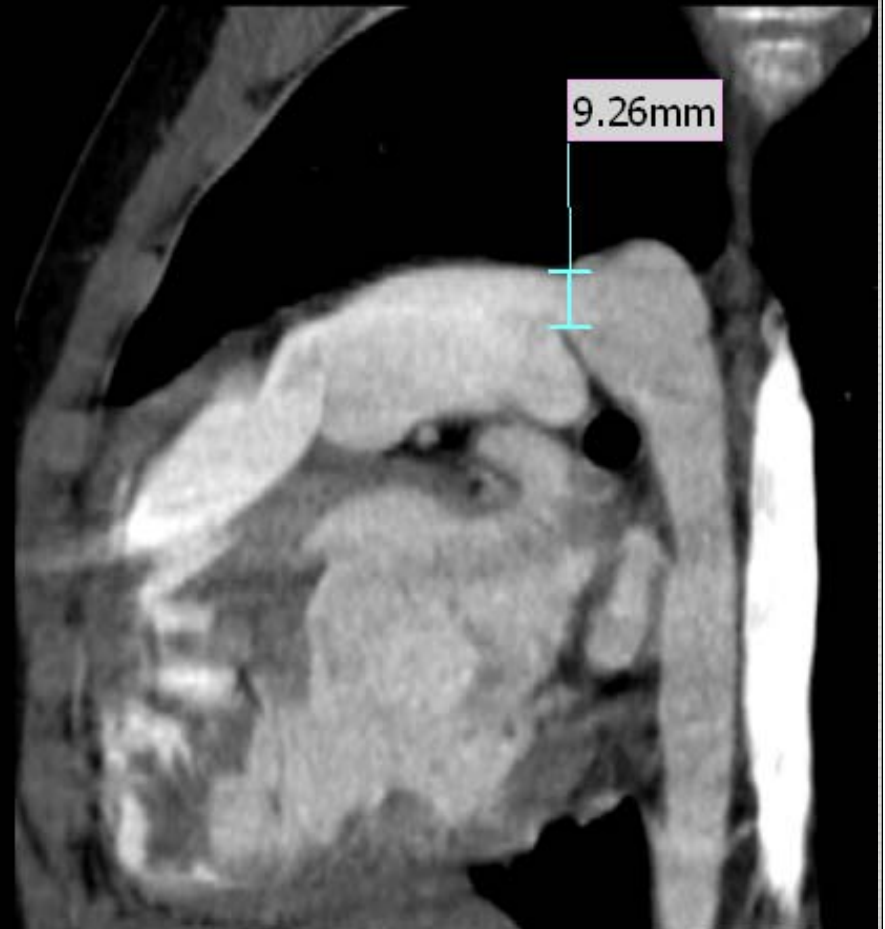
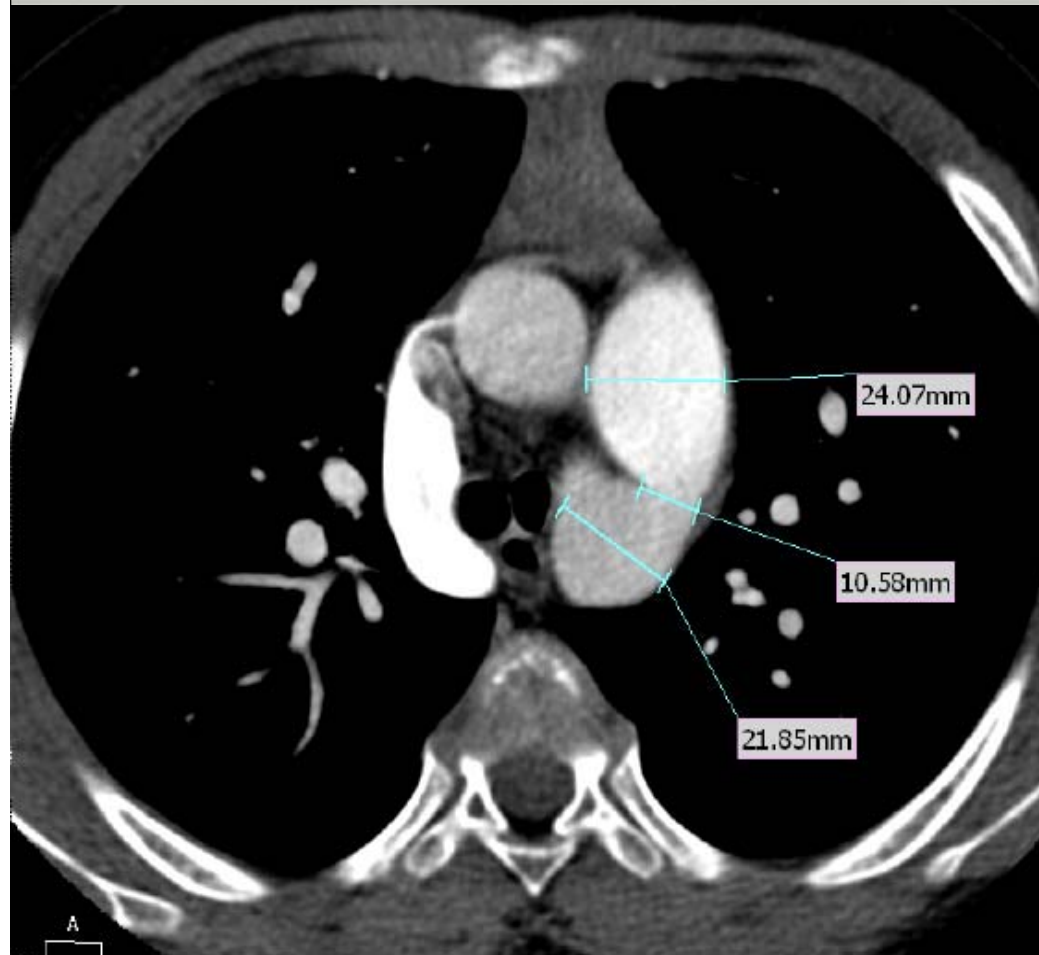
## *Change of Chest X-ray*

▪ 2003-1-30, 8y

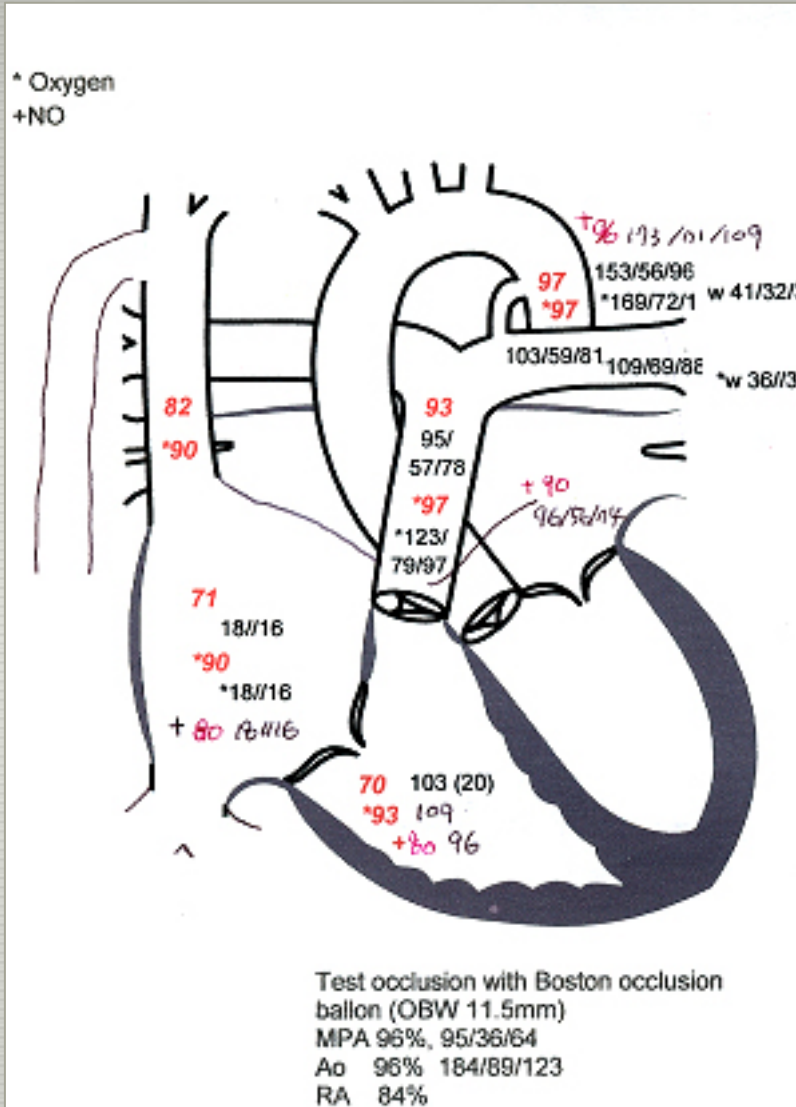
▪ 2007-1-20, 12y



## CT Angio. (2007-1-23)



# Cath. (2007-1-22, 11Y)

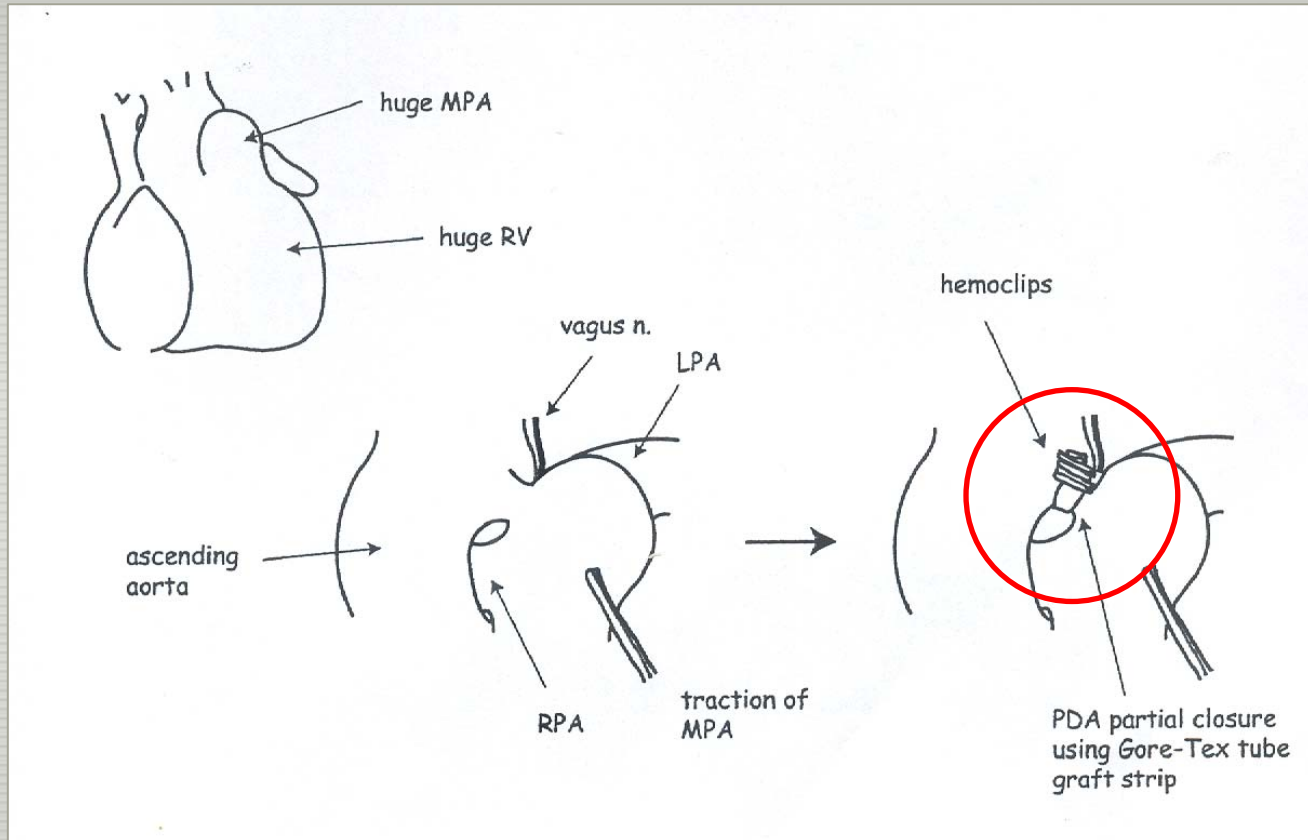


	Baseline	O2	TestOcclusion
Q <sub>P</sub>	12.3	24.7	
Q <sub>S</sub>	4.9	10.6	
Q <sub>P</sub> /Q <sub>S</sub>	2.5 ↑	2.3	
R <sub>P</sub>	3.3 ↓	2.6	
R <sub>P</sub> /R <sub>S</sub>	0.21	0.29	
P(PA/Ao)	0.92	0.72	0.51

*Low Rp(3.8), High Qp(12.3)*

## Op. (2007-4-11, 11Y)

- Partial closure of PDA

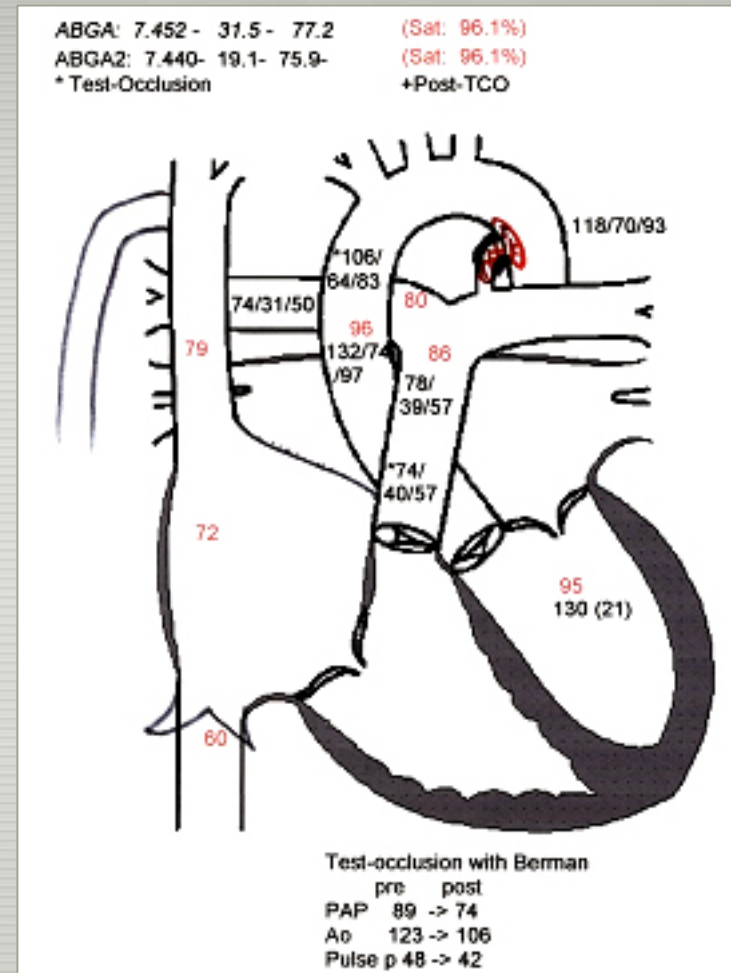


- after surgery, medication with Tracleer & Beraprost

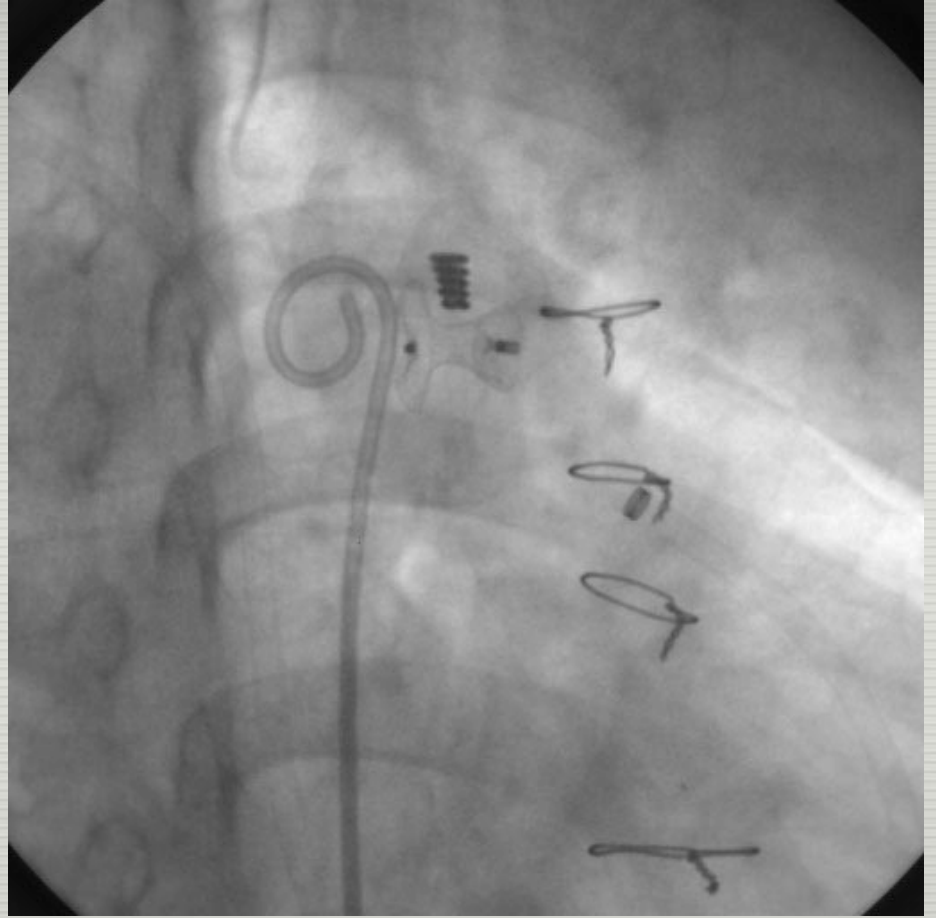
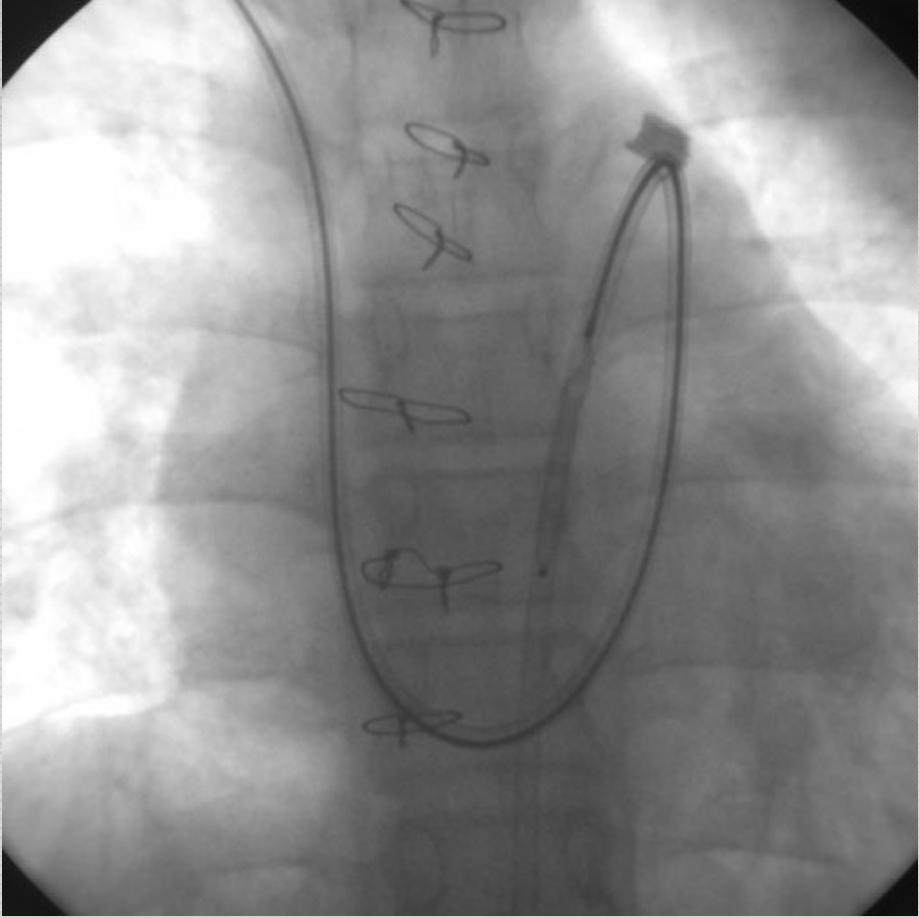
## Cath. (2010-1-06, postop. 33mo)

	Baseline
$Q_P$	5.8
$Q_S$	3.4
$Q_P/Q_S$	1.7
$R_P$	6.2
$P(PA/Ao)$	0.6 ↓

- After Test Occlusion
- Closure with Amplatzer ductal occluder 10-8mm





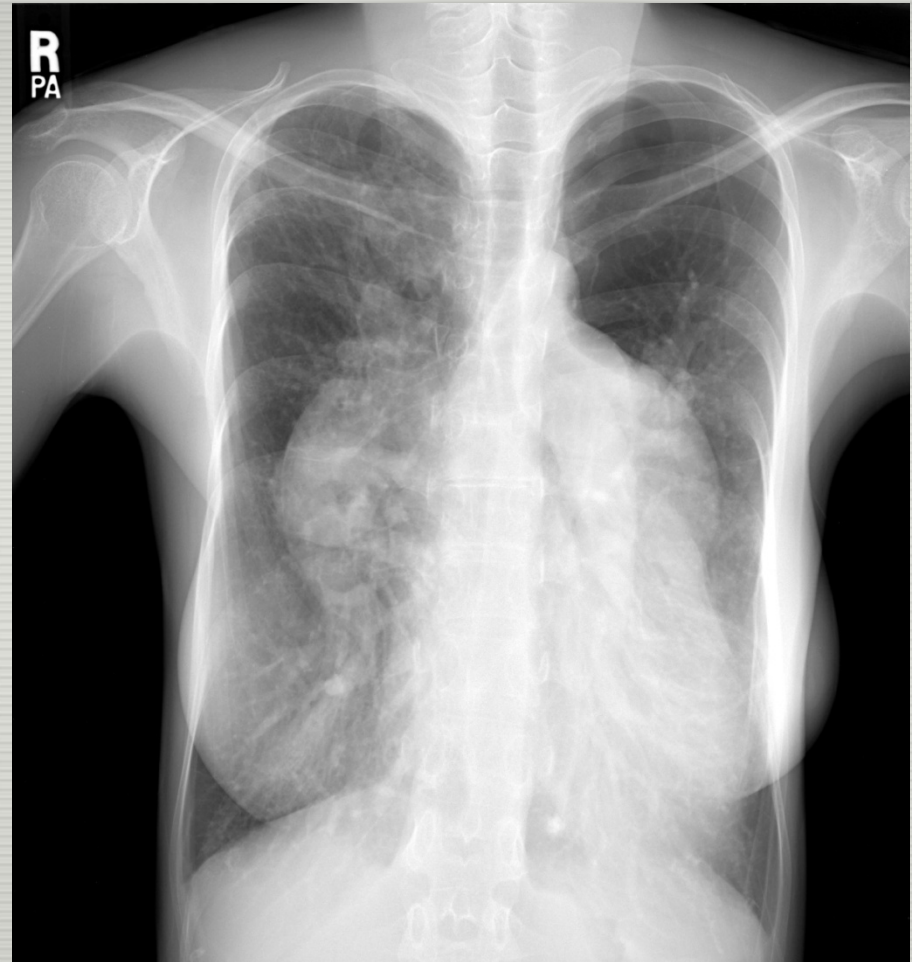


## *Follow - Up*

- **FC I**
- **Echo. (2010-1-7)**
  - **No PDA leak**
  - **Mild LVE**
  - **Trivial TR, no RVE**
- **Medication**
  - **Bosentan 250mg/day**
  - **Beraprost 0.04mg/day**

# Staged repair : SMC experience

- F/38
- NYHA Fc III
- Spo2 90% (rest), 87% (exercise), 96%(with O<sub>2</sub>)
- EchoCG
  - 1) Huge PMC-SA VSD (size 32mm) with bidirectional shunt
  - 2) Gr I MR, Gr I TR, Gr I-II PR
  - 3) Markedly dilated PA (size 60mm), LA & LV (LVDd=77.3mm)



# Staged repair : SMC experience

## ■ Cath

	Baseline	O2	NO
PAP	117/46(96)	101/33(65)	112/39(68)
A Ao	118/92(88)	117/68(88)	118/84(86)
Rp	6.8	2.3	4.0
Qp/Qs	2.5	5.7	3.1
Rp/Rs	0.31	0.11	0.22
PaO2	61	280	65mmHg

## ■ PAB

- SpO2 92% at FiO2 0.25
- Systemic BP 110mmHg, PAP 62mmHg
- Intraoperative TEE
  - PA banding state: diameter 25mm
  - Bidirectional shunt (mainly L->R) through large VSD

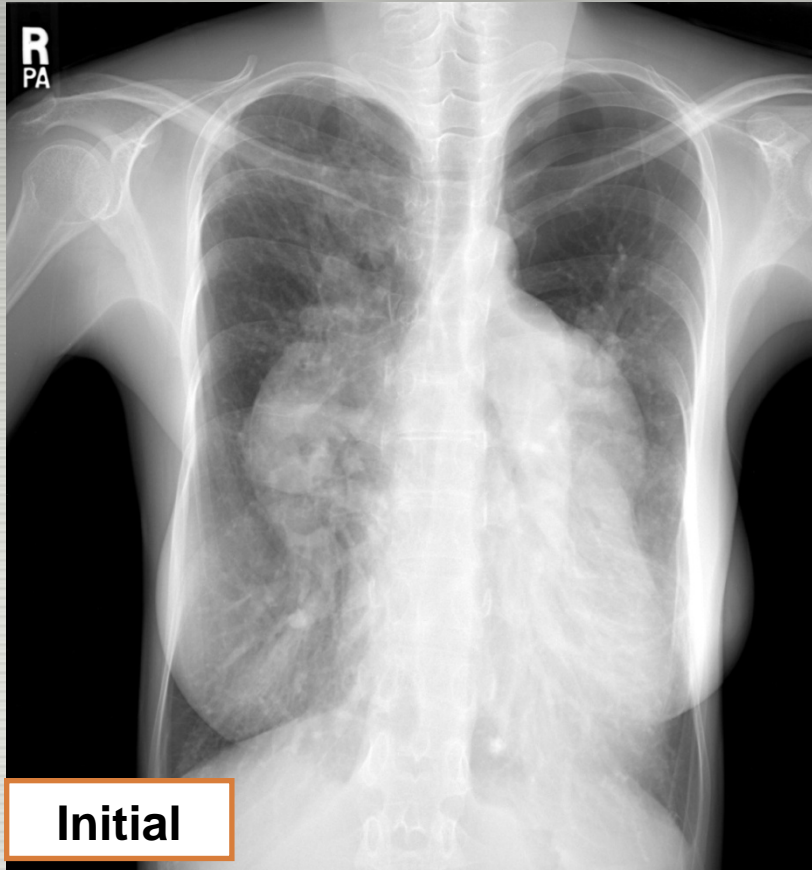
# Staged repair : SMC experience

- Cath (8Mo after PAB)

	Baseline	O2	NO
PAP	98/31(57)	83/24(48)	84/21(49)
A Ao	96/58(75)	93/57(73)	102/60(78 )
Rp	7.33	2.2	5.9
Qp/Qs	2.6	5.4	2.23
Rp/Rs	0.25	0.10	0.24
PaO2	64	225	67mmHg

# Staged repair : SMC experience

- Op.
  - VSD closure, ASD creation (6mm)
  - PA debanding, TR repair
- Immediate postop. data
  - Spo2 94~100%
  - BP: 105/43mmHg, sPAP 33mmHg
- 4 yrs after op.
  - NYHA Fc II, SpO2 94%
  - Medication : Enalapril, diuretics, Aspirin
  - EchoCG
    - 1) Small residual VSD (size 3mm) (L->R, PGmax 86mmHg)
    - 2) Neo-ASD (size 5~6mm) (bidirectional shunt, R->L during systole)
    - 3) G1 TR (PG 20mmHg), G1 MR
    - 4) hyperkinetic IAS motion: rather paradoxical, RL during systole



**Initial**



**Latest**

Cath data	Pre-PAB	After PAB	After VSD closure
Pr Ao/PA	117/118 → 117/101 (O <sub>2</sub> )	96/98 → 93/83 (O <sub>2</sub> )	138/44
mean PAP	96 → 65 mmHg	57 → 48 mmHg	44 mmHg
Rp	6.8 → 2.3	7.33 → 2.2	5.49
Qp/Qs	2.5 → 5.7	2.6 → 5.4	1.75

# Test for reversibility

- **100% oxygen inhalation**
- **NO gas**
- **Adenosine, CCB**
- **Temporary balloon test occlusion**



# Vasoreactivity Test

- **INOP test I** *Circulation 2002; 106: 176-81.*
- multicenter, retrospective
- N=124  
CHD with PHT(baseline  $R_p/R_s > 0.33$ )
- Combination of O<sub>2</sub> and inhaled NO decreases PVR more than O<sub>2</sub> alone → more candidates for operability (74/124 Op, 12/74 died, broad gray zone  $0.16 < R_p/R_s < 0.41$ )

# **Measurement, interpretation and use of hemodynamic parameters**

*Lopes , Cardiol Young 2009;19:8-12*

**“Calculation of blood flow and vascular resistance using the Fick principle requires attention to several possible sources of errors.”**

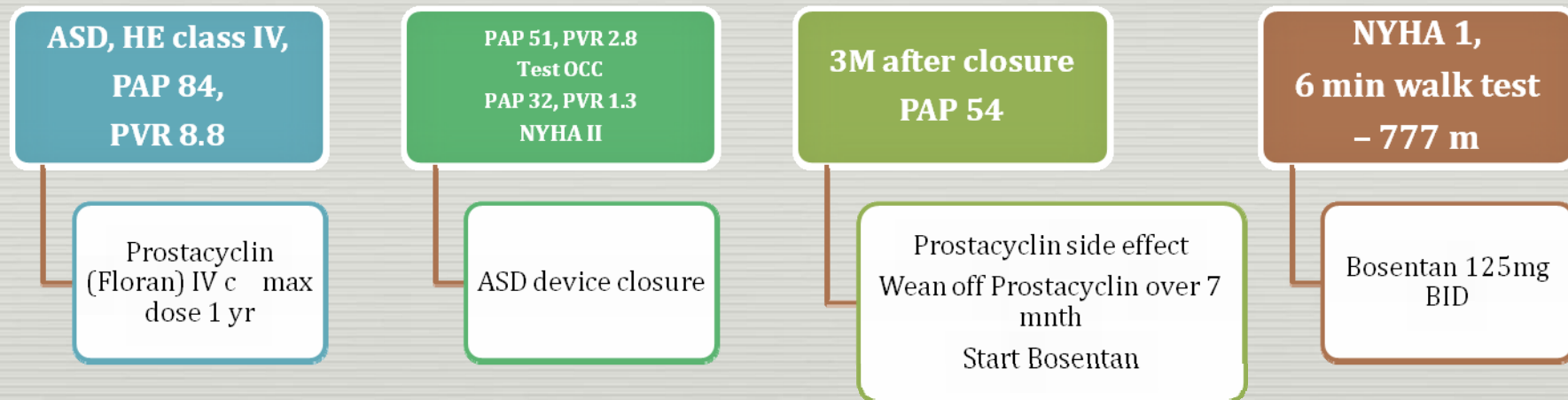
**Inappropriate hemodynamic and respiratory conditions**

**Inadequate blood sampling and processing for blood gas analysis**

**Inappropriate assumptions - mixed venous and pulmonary venous O<sub>2</sub> saturation, the value of oxygen consumption**

# Treat-and-repair

**Atrial septal defect closure in a patient with “irreversible” pulmonary hypertensive arteriopathy**  
*Schwerzmann et al. IHJ,2005*



# Treat-and-repair

- treatment and a “**conditioning**” therapy for possible late closure
  - lowering PERIoperative risks
  - widening the range of cases amenable to repair

# Treat-and-repair

- **intravenous & inhaled prostacyclin**
  - Epoprostenol (IV)
  - Iloprost (Ventavis<sup>®</sup>)
- **oral endothelin antagonists**
  - Bosentan
  - Ambrisentan
  - Sitaxsentan
- **type-5 phosphodiesterase inhibitor**
  - Sildenafil

		PAP	PVR	Reversibility	duration		
Hoetzen ecker (JTCS, 2009)	ASD (1) WHO FC IV NO (-)	54→30 mean	465 → 325		Preoop 10 mths	Bosentan	
Eicken (IHJ,2006)	PDA (1) WHO FC III	85→ 75		NO 2.2:1 → 6:1	Postop 4 mths	Bosentan	
Schwerz mann (IHJ,2005)	ASD (1) plexiform pulmonary arteriopathy	84→ 54	8.8→ 2.8	Bi→ LR	Preop 1yr Post op Several mths	IV prostacyclin Bosentan	Lung biopsy ; HE class II
Xu (Zhonghua Yi Xue Za Zhi, 2009)	LR shunt(18)	74→ 54			Preoop 3 mths	Bosentan	O2 SAT 78→ 86

		PA pr	PVR	Reversibility	duration		
Frost (JHLT, 2005)	ASD (1) WHO FC ///	86→ 50 sys		RL → 3:1	Preop 4 yrs	epoprostenol	
Yamauchi (ATS,2001 )	ASD (1)	110→ 65 sys		Oxy 1.3:1 → 2:1	Postop 2 yrs	epoprostenol (oral)	Lung biopsy ; HE class ///
Imanaka (Kyobu Geka, 1998)	ASD (1)	96→ 52 sys	14.2→ 9.9 u		Postop 2 yrs	? (immd postop NO)	

# Treat-and-repair

- Bosentan therapy in patients with Eisenmenger syndrome – a multicenter, double-blind, randomized, placebo-controlled study

*Galie, Circulation. 2006;114:48-54*

→ *Bosentan may be a new treatment option in pts with Eisenmenger syndrome*

mPAP -5.5mmHg, PVR -472 dyne.s/cm<sup>5</sup>, 6MWT +53.1m compared to placebo



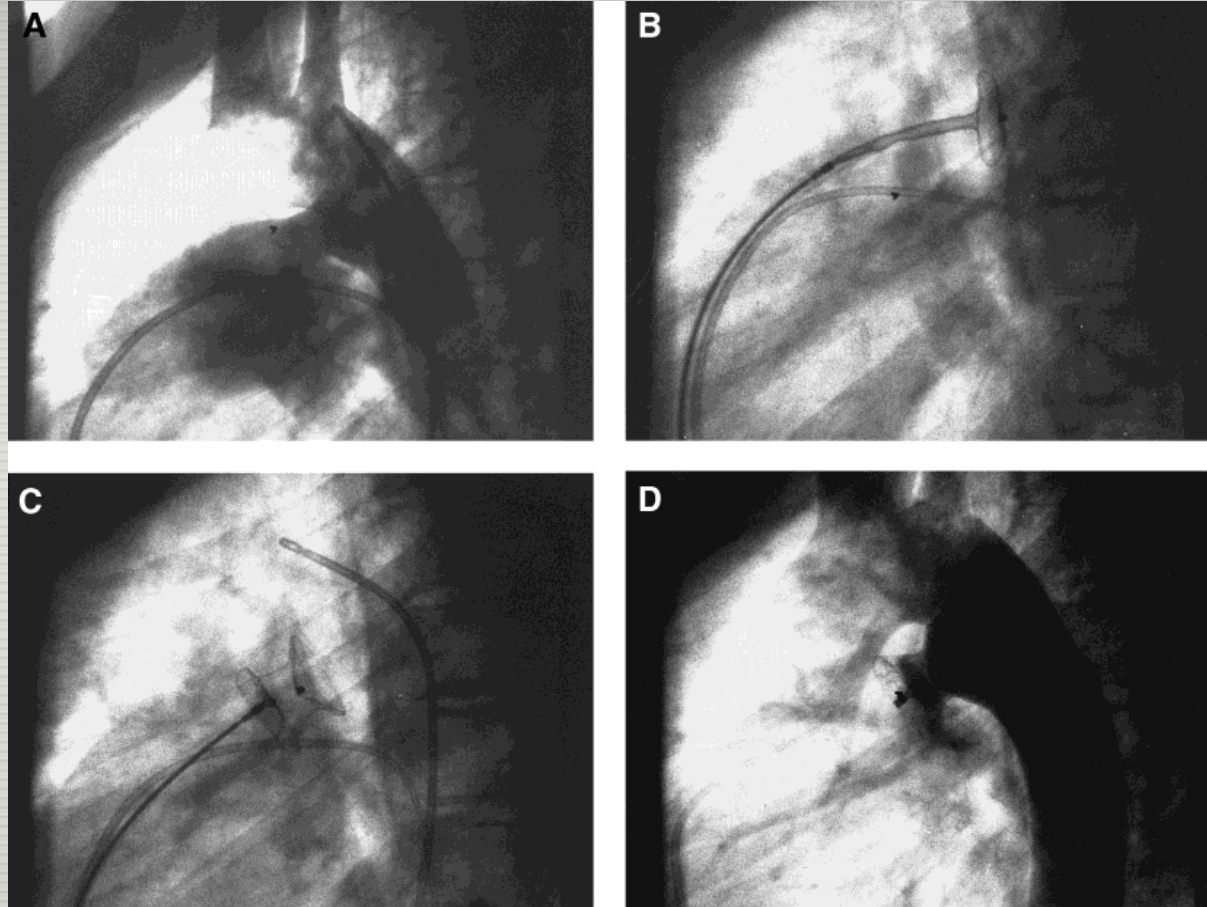
# Decision making for operability



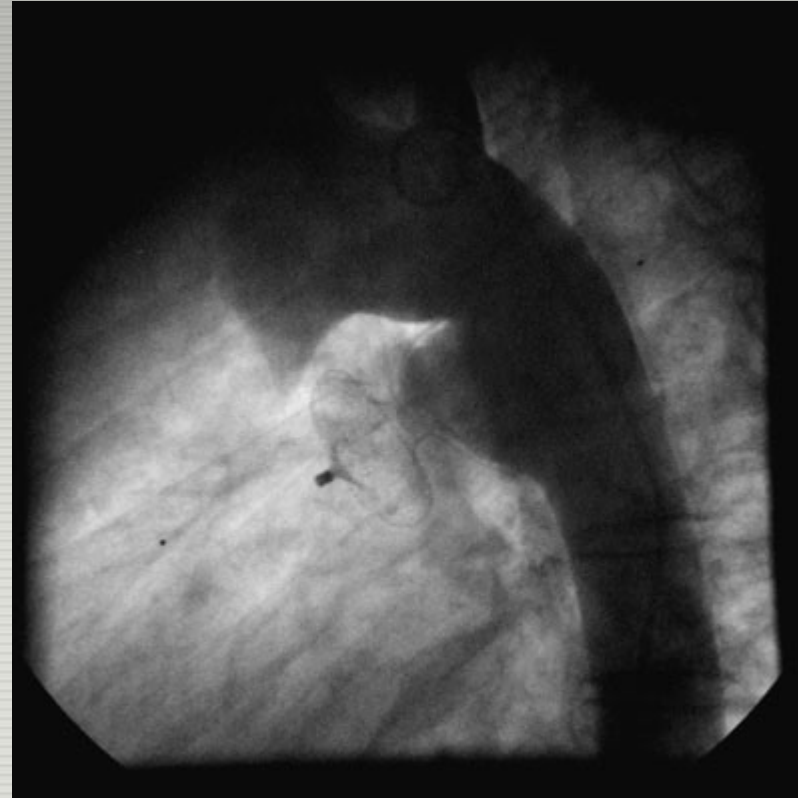
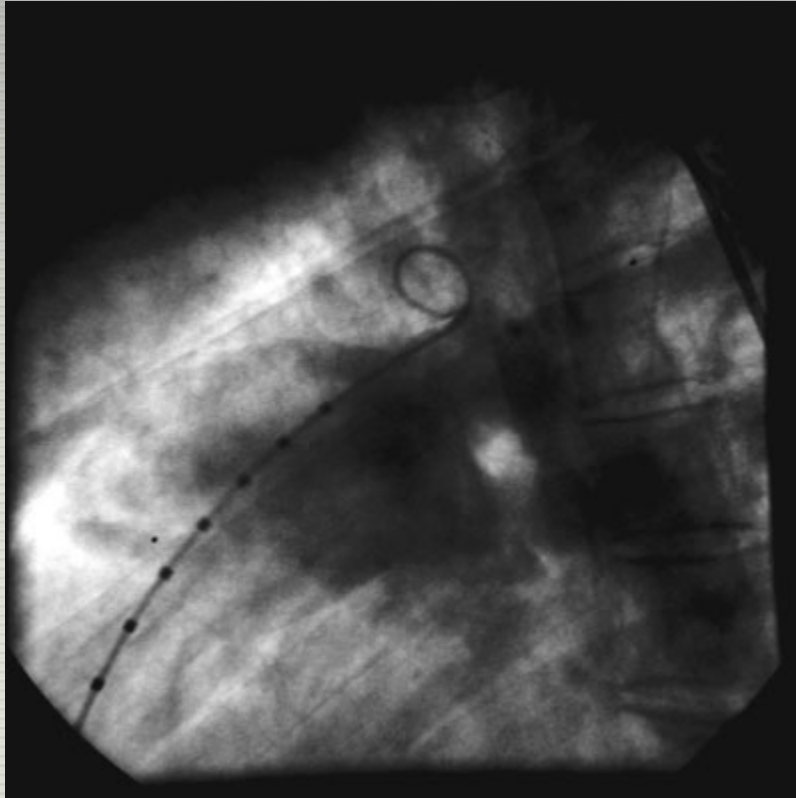
# Closing hypertensive ductus

- Amplatzer ductal occluder
  - 6\*4, 8\*6, 10\*8, 12\*10, 14\*12, 16\*14
- Amplatzer muscular VSD occluder
  - *Demkow, Cathet Cardiovasc Intervent 2001*
  - *Thanopoulos, Heart 2002*
  - *Eicken, Int J Cardiol 2007*
- Amplatzer atrial septal occluder
  - *Spies, Cathet Cardiovasc Intervent 2005*

**15 Ys old girl  
PDA d=15.5mm  
mPAP  
100→32(TO)  
Qp/Qs  
1.9→3.0(O2)  
PVR  
10.9→3.8WU(O2  
)**

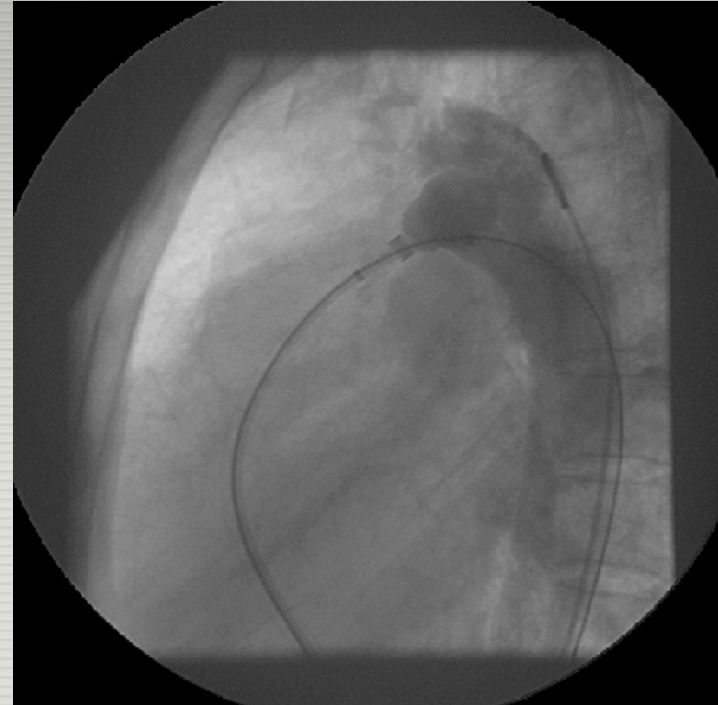
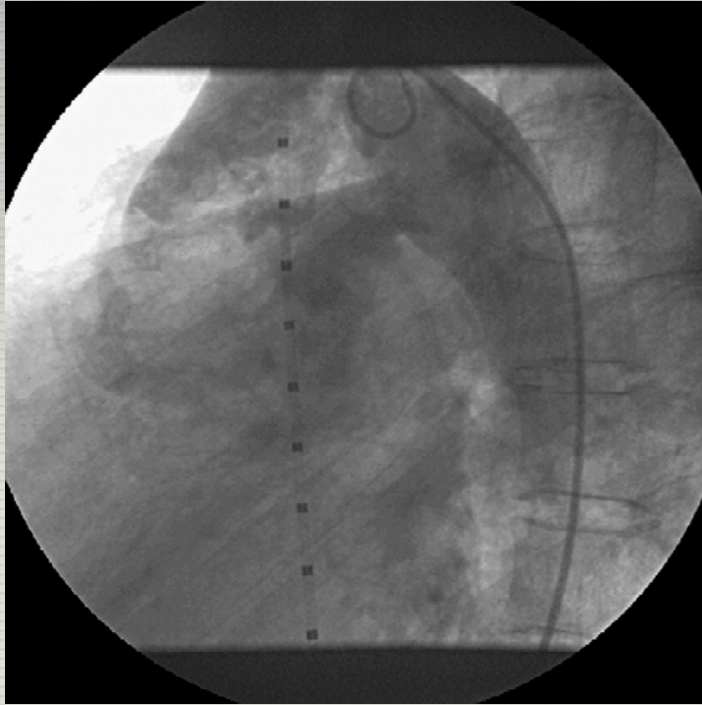


*Demkow, Cathet Cardiovasc Intervent 2001;52:359-362*



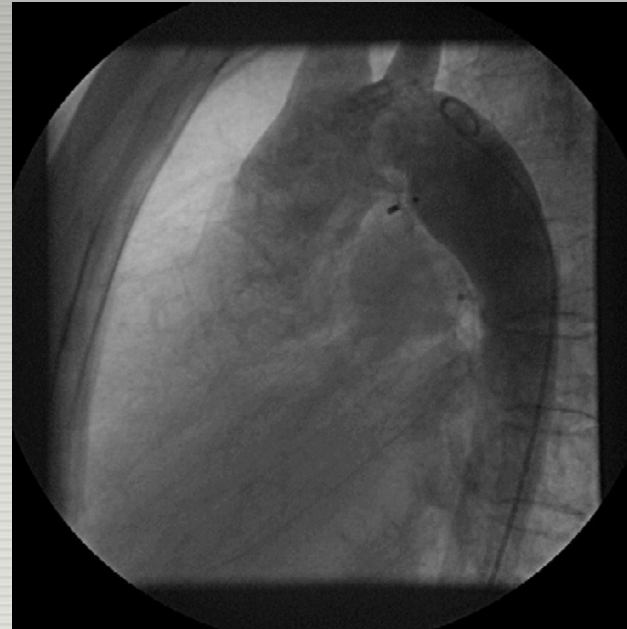
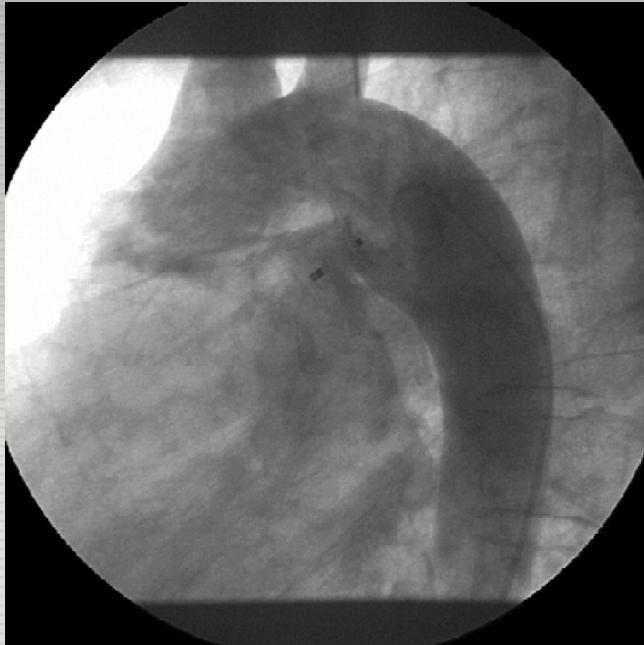
**24 ys old female  
PDA d=22mm, sPAP 68mmHg, PVR 4.1WU  
ADO 16\*14 - easily pulled through the duct  
ASO 24mm  
F/U cath (12M) sPAP 28mmHg, complete  
closure**

*Spies, Cathet Cardiovasc Intervent 2005*



**35 ys old woman  
PDA d=14mm(balloon sizing)  
Systemic PAP  
PVR 17Wu, Rp/Rs 0.46  
Positive vasoreactivity test**

*Eicken, Int J Cardiol 117 (2007) e40-e42*



	<b>Qp/Qs</b>	<b>PVR</b>	<b>Rp/Rs</b>
<b>RA</b>	<b>2.2</b>	<b>17</b>	<b>0.46</b>
<b>O2</b>	<b>4.3</b>	<b>7.5</b>	<b>0.21</b>
<b>NO</b>	<b>6.0</b>	<b>5.4</b>	<b>0.14</b>
<b>PC</b>	<b>4.0</b>	<b>3.8</b>	<b>0.21</b>

**ADO 16\*14 → passed through the ductus  
Amplatzer mVSD occluder 16mm  
F/U cath(4M) - PVR 11.6Wu, Rp/Rs 0.43  
Bosentan + nocturnal O2 Tx**

# Conclusions

- Potent pulmonary vasodilators widen the criteria of operability in patients with CHD and severe PHT.
- Treat-and-repair approach may be carefully tried in patients with CHD and severe PHT.
- Continued research and long term follow-up is needed to establish new operability criteria in patients with CHD and severe PHT.
- Amplatzer muscular VSD occluder or Amplatzer septal occluder may be used for closing large ductus with severe PHT.