Recent Advance in Interventional Treatment of Congenital & Structural heart Disease

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최근 들어 급속히 발달하기 시작한‘치료적 심도자술’ 은 일부 선천성 심질환의 치료 양태를 혁신적으로 바꾸기 시작하였으며, 태아 심장병 진단, 성인 선천성 심장병클리닉 등 그간 있어온 몇 가지 중요한 소아 심장학 분야의 발달과 함께 통상적인 소아심장 전문의의 역할을 크게 바꾸는 계기가 되었고, 이러한 변화는 필연적으로 새로운 형태의 전문가 양성을 필요로 하는 시점에 이르게 되었다

H J Lee. Korean Circulation J 2002;32:15

Introduction

- **Diagnostic cardiac catheterization**

  measure Qp/Qs, pressure of chamber or vessel

  angiography

→ **Changing indications of cardiac catheterization**

  - Improved diagnostic accuracy by echocardiography

  - Advancement of imaging modalities :

  offers morphologic, hemodynamic, functional information

Introduction

- **Changing paradigm in the treatment of CHD**
  - **Expectations of patients**
    less dangerous, less painful, less limitations of activity, less scar
  - **Expectations of Doctors**
    less invasive, less complication

→ **Interventional Cardiac Catheterization**

Historical Background of the IC in CHD

Operator	Procedure	Year
Rubio-Alvarez *et al.*	Pulmonary valvotomy with ureteral catheter	1953
Dotter & Judkins	Dilatation of stenotic peripheral arteries	1964
Rashkind & Miller	Balloon atrial septostomy	1966
Porstmann *et al.*	Closure of PDA with Ivalon foam plug	1967
King *et al.*	ASD closure with umbrella device	1976
Park *et al.*	Blade atrial septostomy	1978
Kan *et al.*	Balloon dilatation of PS	1982

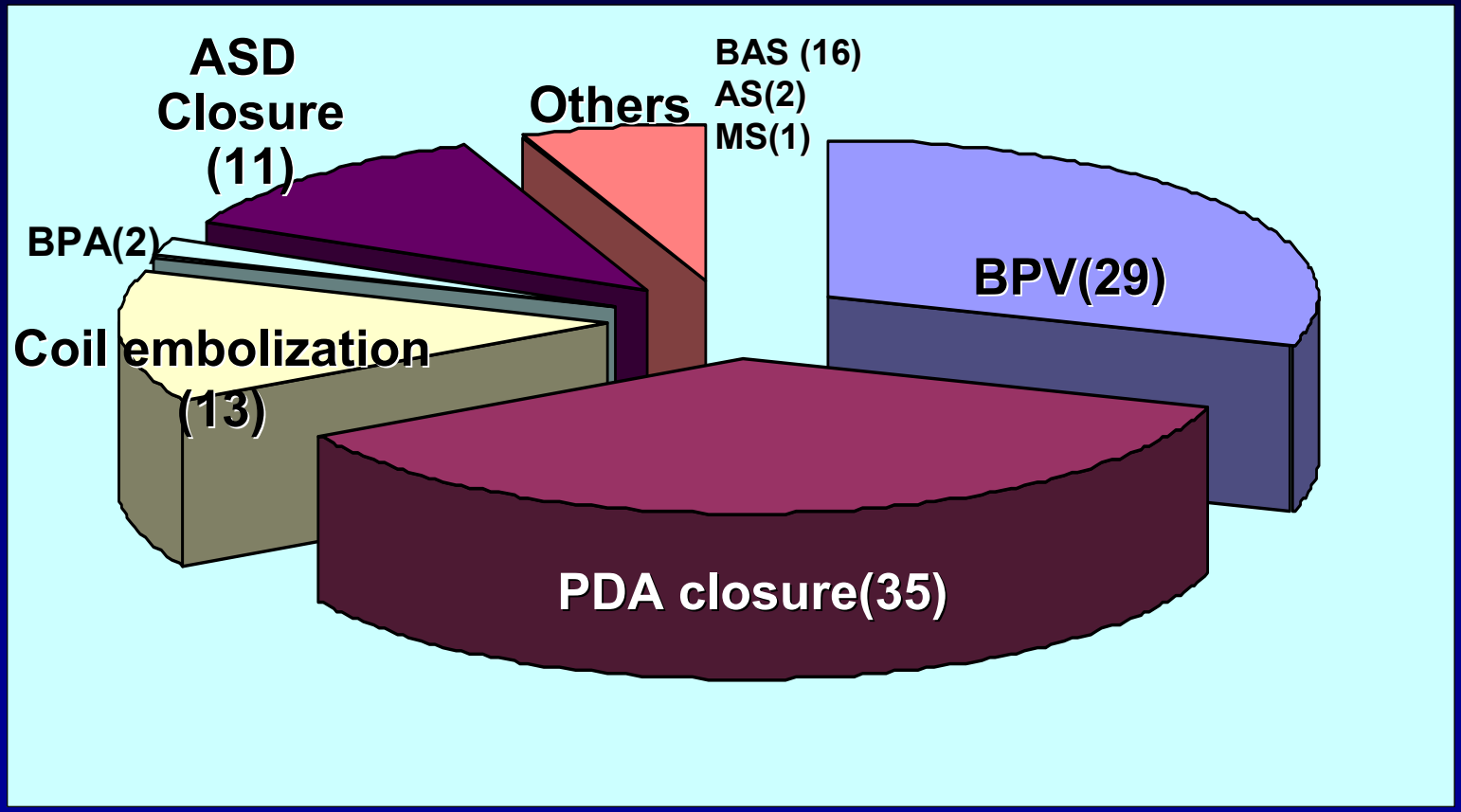
1st attempt to treat CHD via a catheter

1st intracardiac therapeutic procedure

The Changes No. of intervention

Total No. of cardiac cath.=469 cases (1994-1999)

- Division of Pediatric cardiology (Gil heart center) -

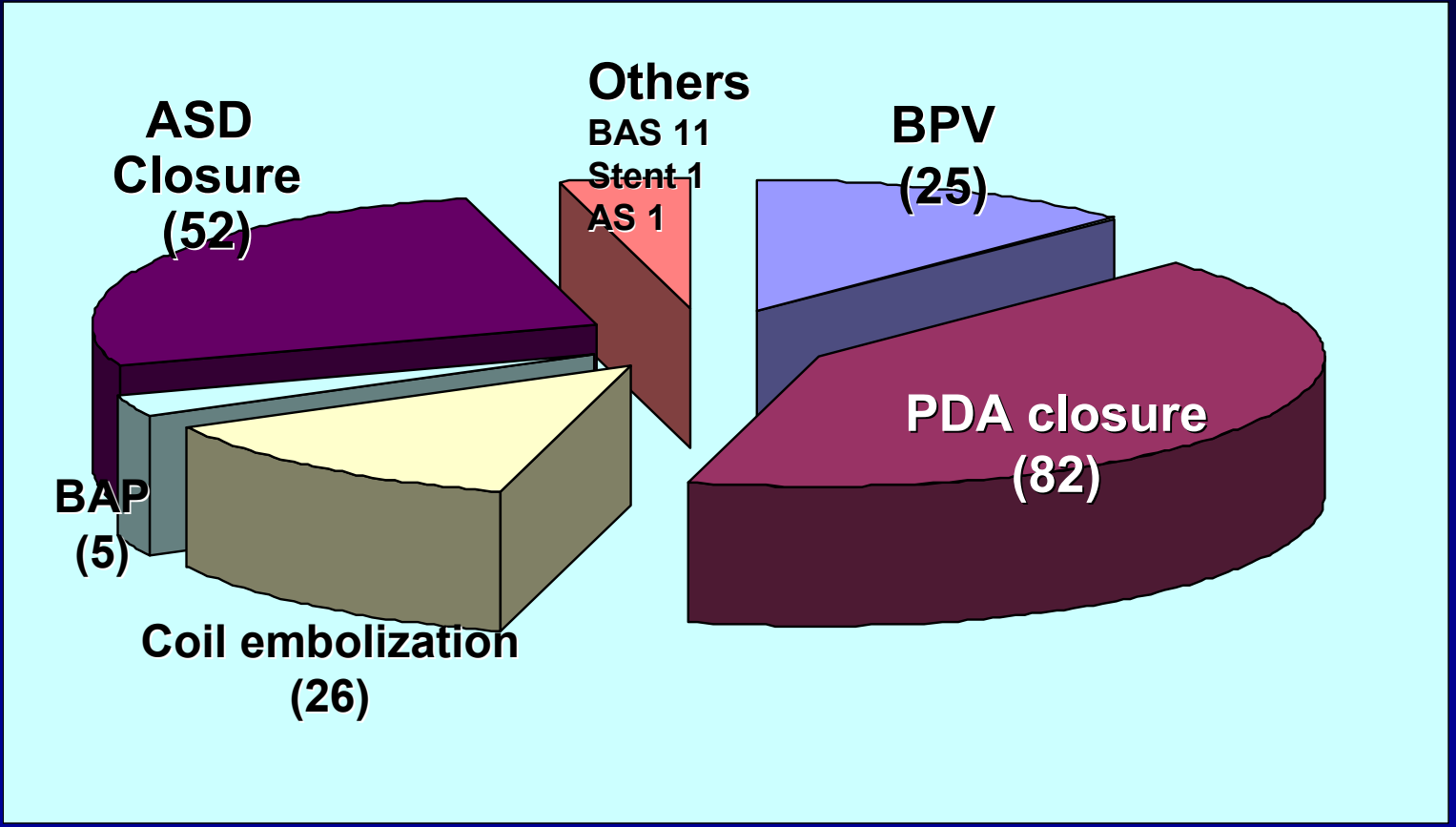


No. of IC=112 (23.9%)

The Changes No. of intervention

Total No. of cardiac cath.=482 cases (2000-2006)

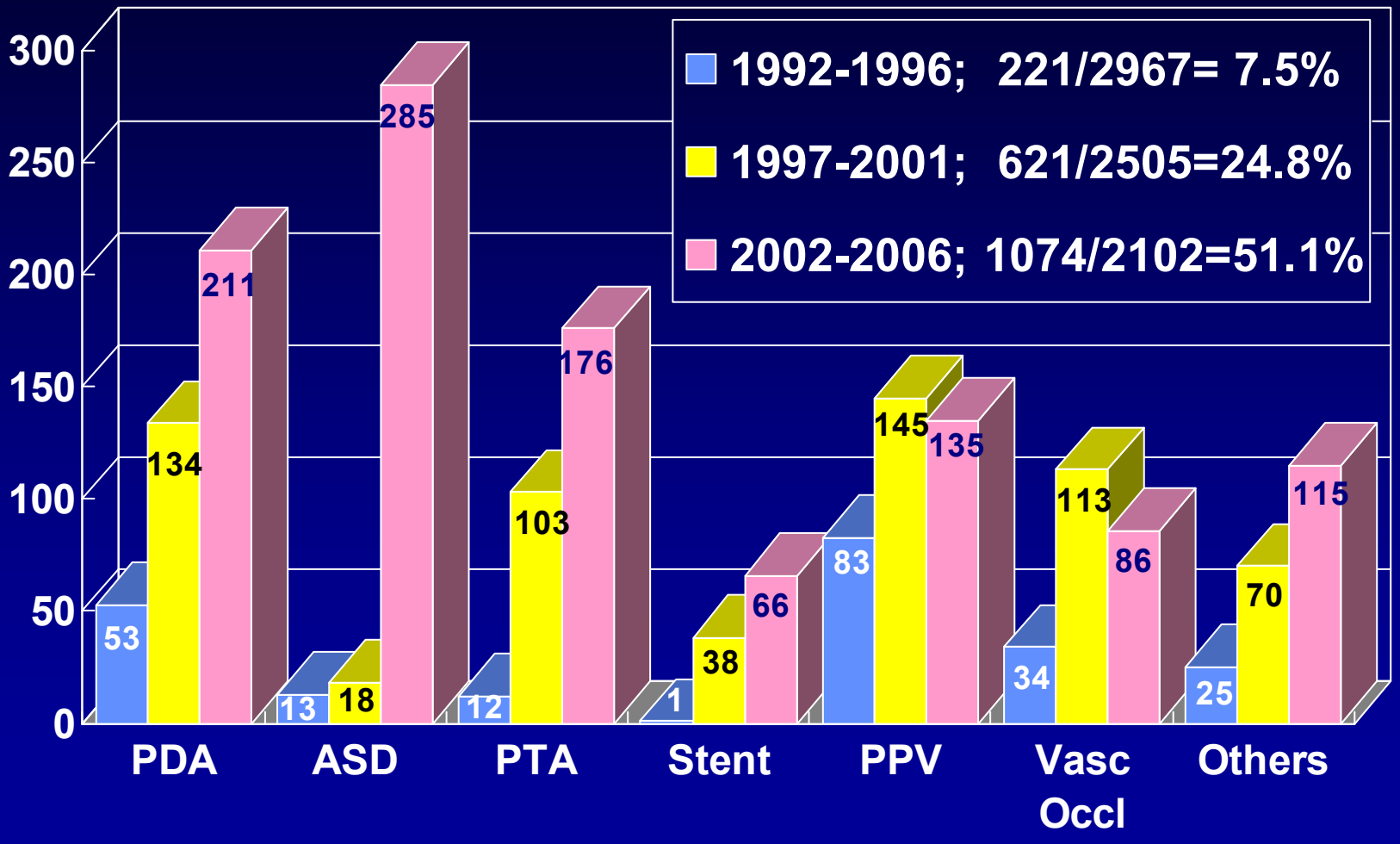
- Division of Pediatric cardiology (Gil heart center) -



No. of IC=200 (41.5%)

Increasing Numbers of Interventions

- Division of Pediatric Cardiology, YUHS -



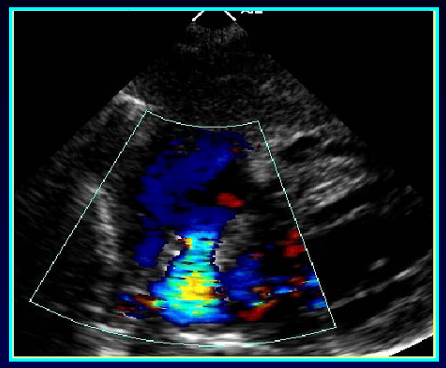
Choi JY. SCHCHOP sympo. 2007

Interventional Procedures for Cardiac Disease

- **Dilations**
  - Septostomy
  - Balloon dilatation
  - Stent implantation
- **Occlusions**
  - PDA, ASD, PFO, VSD, AV fistulae, APCAs, Shunts, Fenestrations
- **Valve insertion or repairs**
  - Percutaneous valve insertion / valve repair / annuloplasty
- **Hybrid procedures**
  - Intraop stent insertion, Intraop VSD closure, Perventricular VSD closure, Transapical Aortic valve insertion, Hybrid stage 1 repair for HLHS, Transcatheter Fontan completion from hemi-Fontan

- **Atrial septostomy**

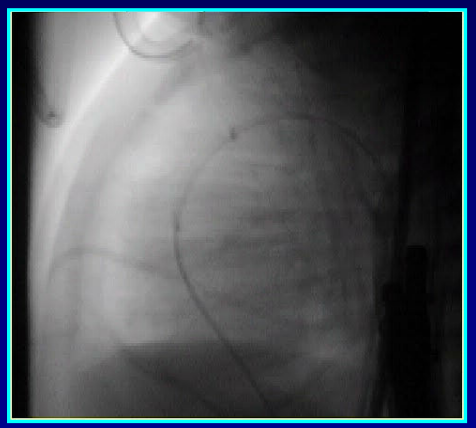
  IAS stenting



- **BPV**

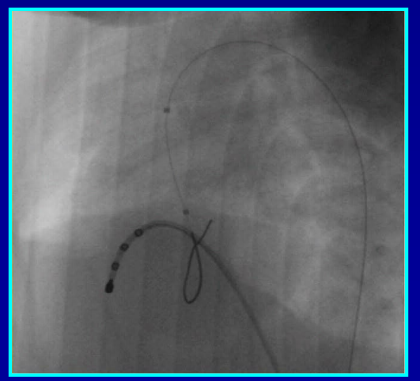
  for valvular PS

  RF perforation and BPV for PA c IVS ± PDA stent



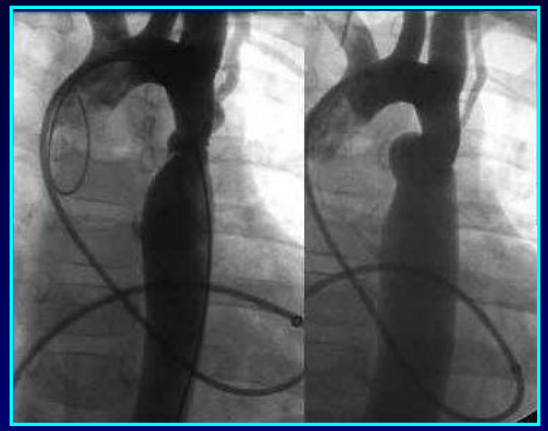
- **BAV**

  Rapid RV pacing for stable balloon position



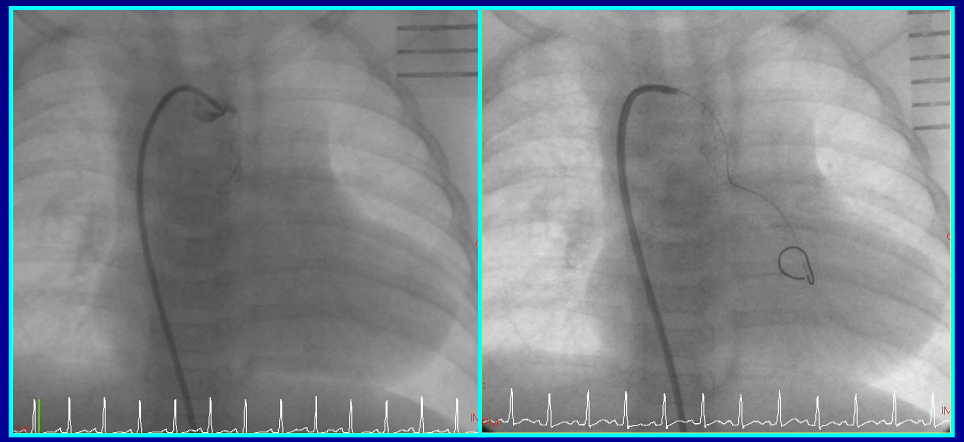
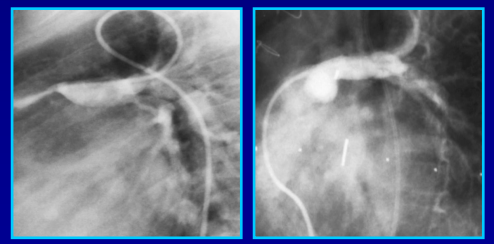
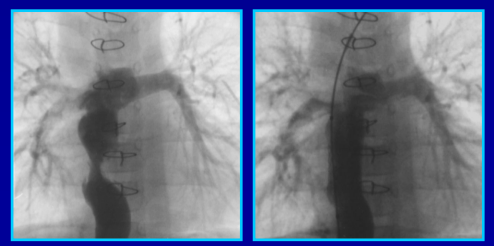
- **CoA**

Native CoA in infants / Stent for older children or adults
Covered stent – prevention of aneurysm, Ass c PDA


- **Stents**

Versatile tool for failed balloon dilation – recoil, kinking

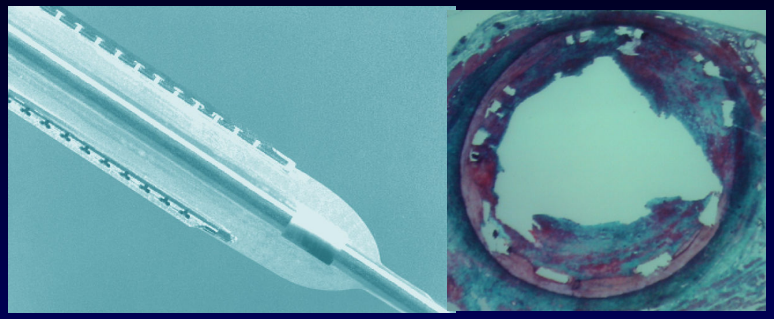
PA junction

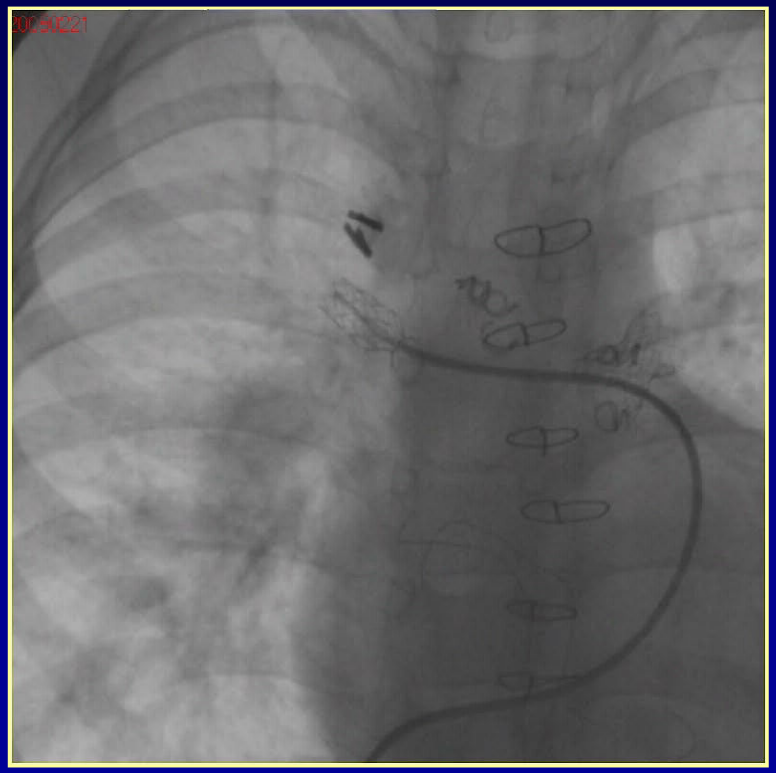
Fontan circuit

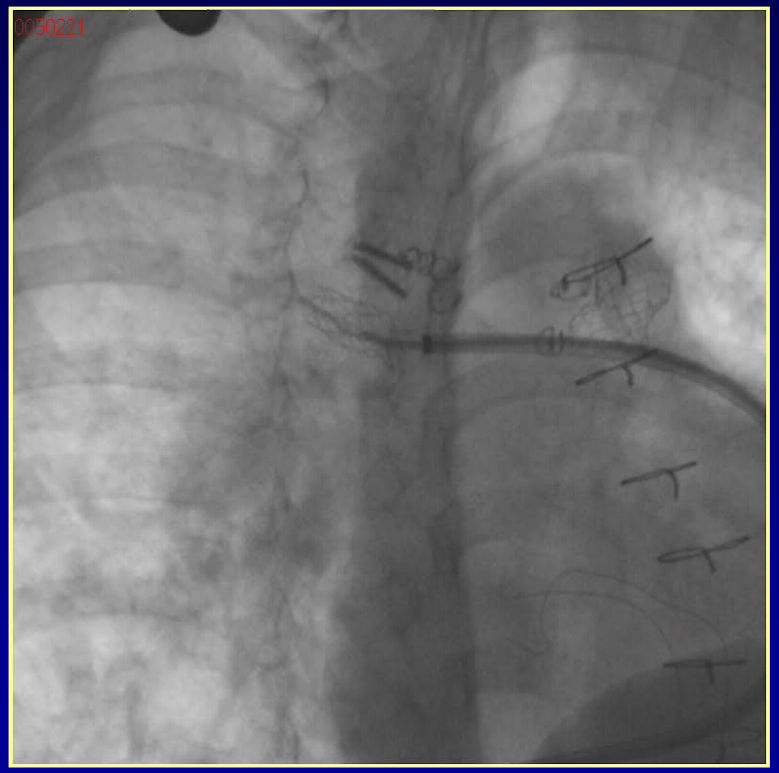
Cutting Balloons for Pediatric and Congenital Heart Disease

First application to CHD - 1999

Schneider et al. Cathet Cardiovasc Intervent 1999;48:378





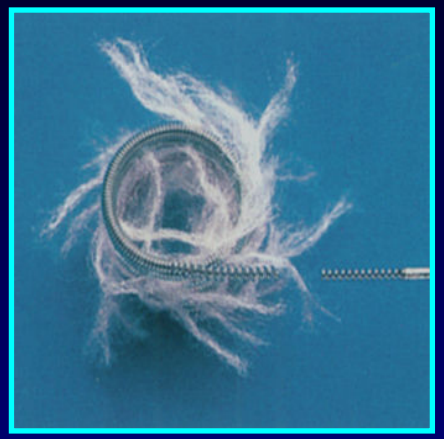


Occlusion Techniques

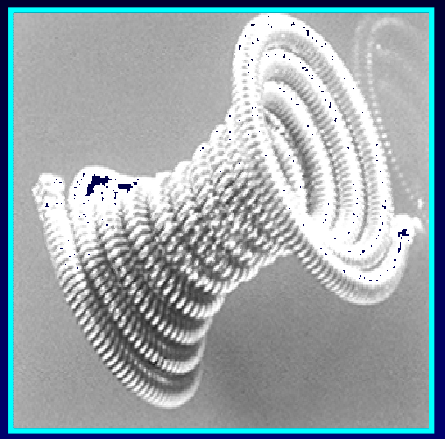
- **PDA occlusion**
  Variety of recent generation devices
- **ASD occlusion**
  Shifting from alternative to standard
- **VSD occlusion**
  Promising but need more verification for routine use
- **PFO occlusion**
  Various device
- **Others**
  Fenestration in post-Fontan, abnormal vessel occlusion etc.

The evolution and Commonly Used Devices for PDA Occlusion

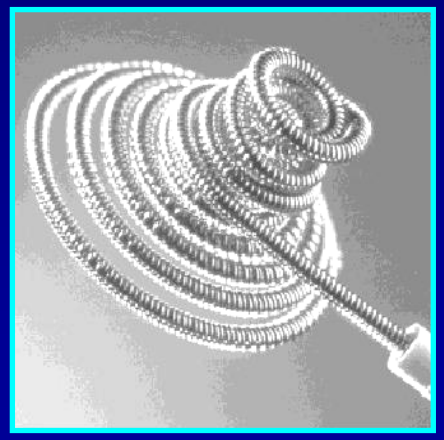
Gianturco coil



Cook detachable coil



Duct-Occlud

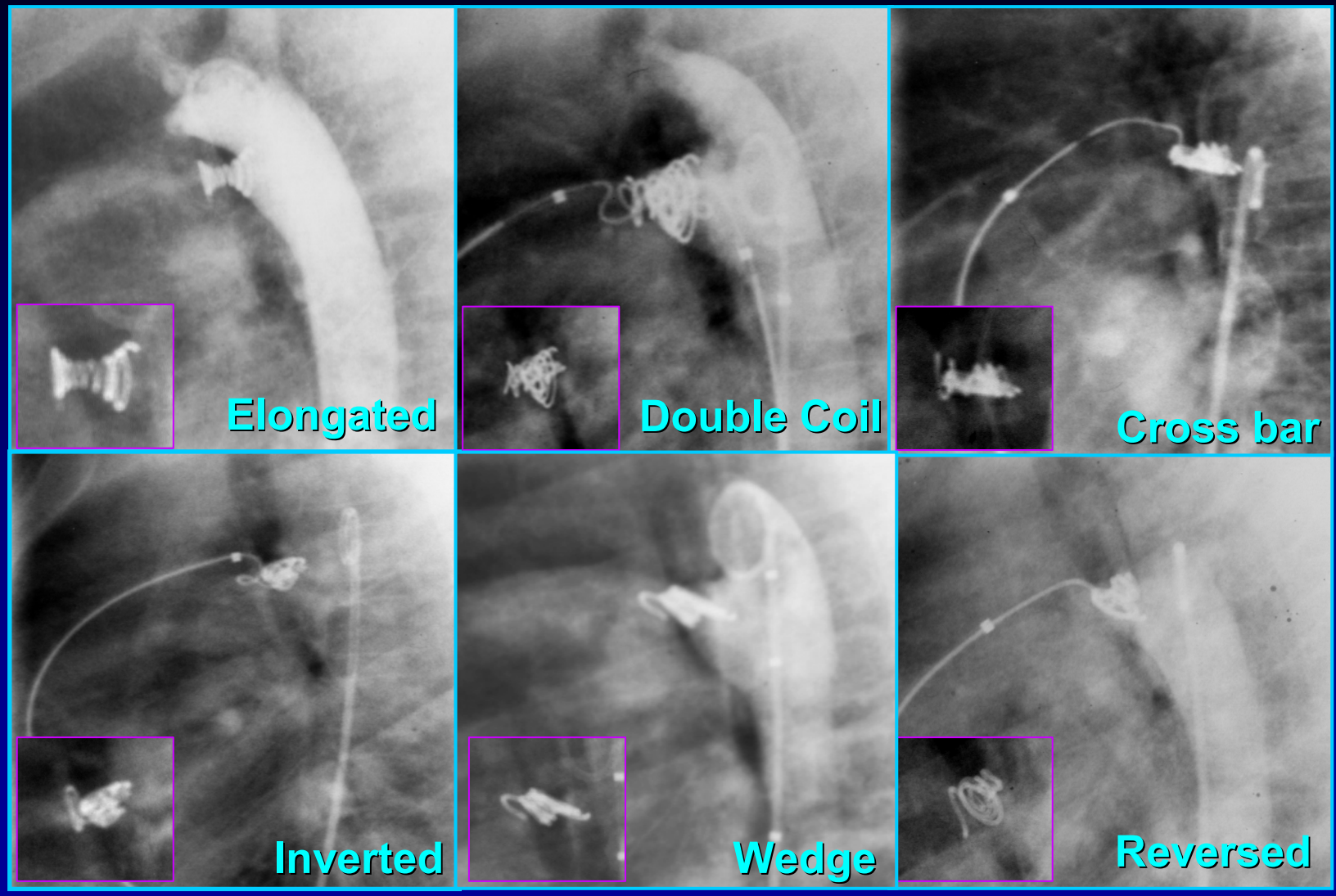


Reinforced Duct-Occlud

PFM Nit-Occlud

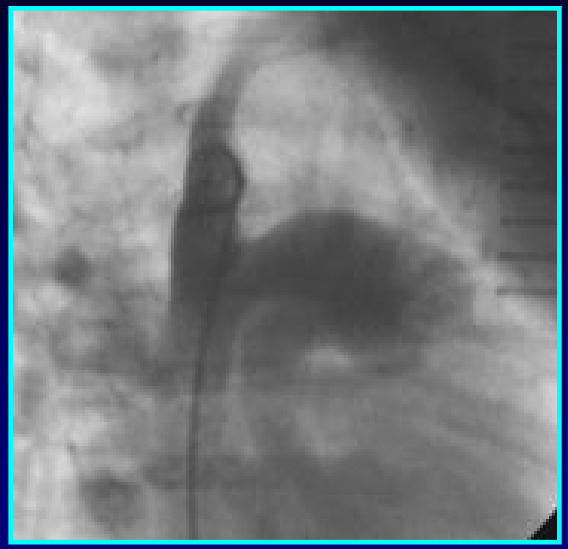
Amplatzer Duct Occluder

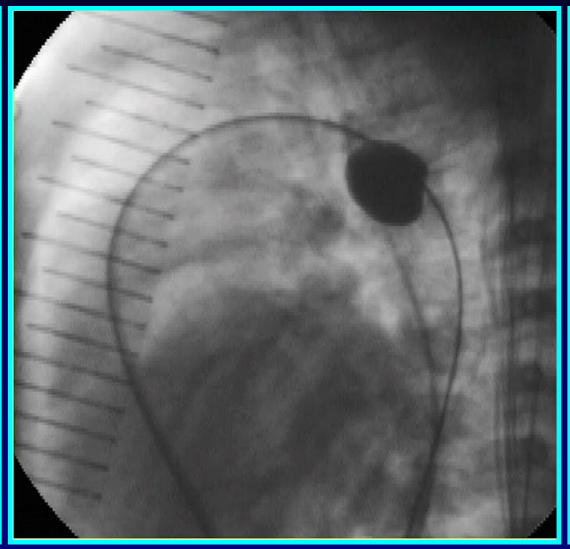
Modified Techniques of Coil Occlusion of PDA

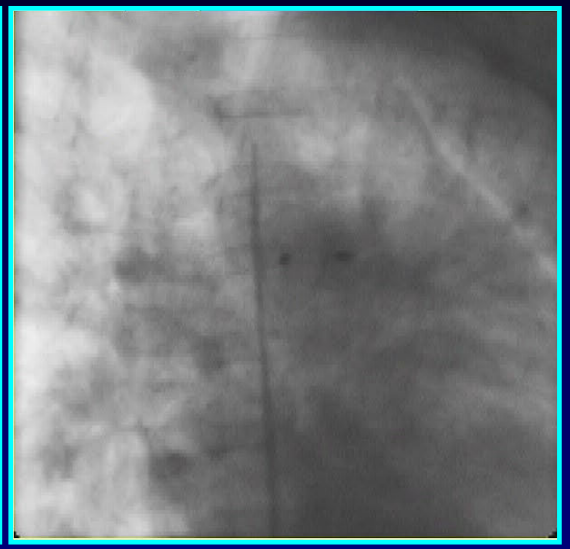


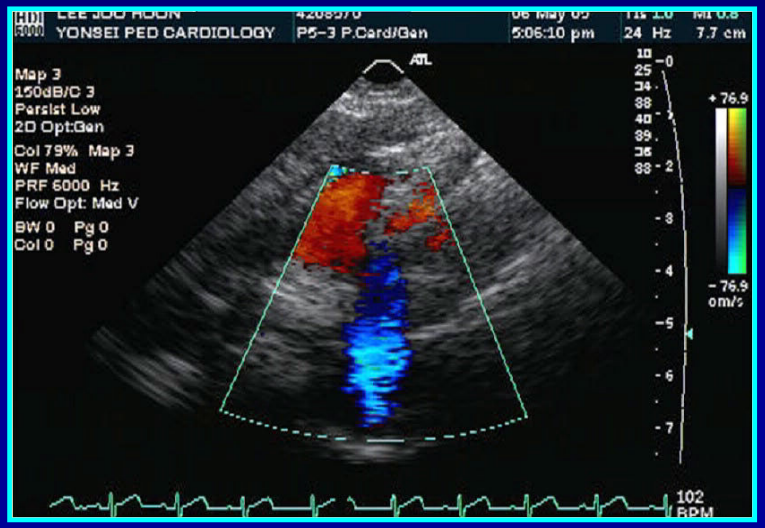
Lee JK et al. PICS 2002

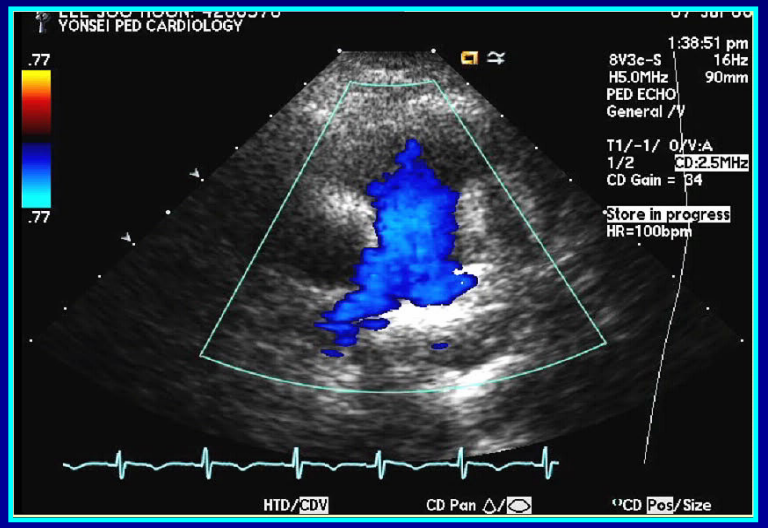
Occlusion of Large PDA with ADO



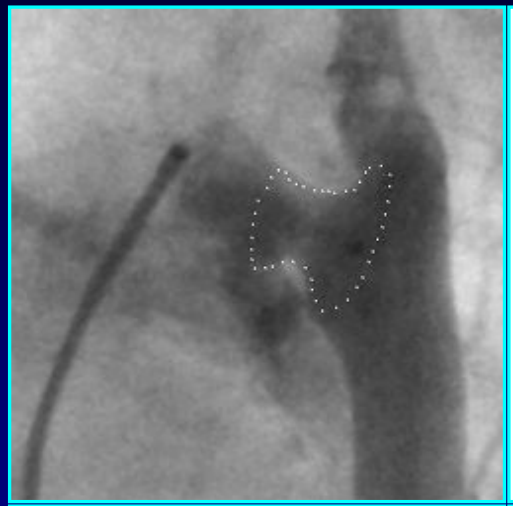
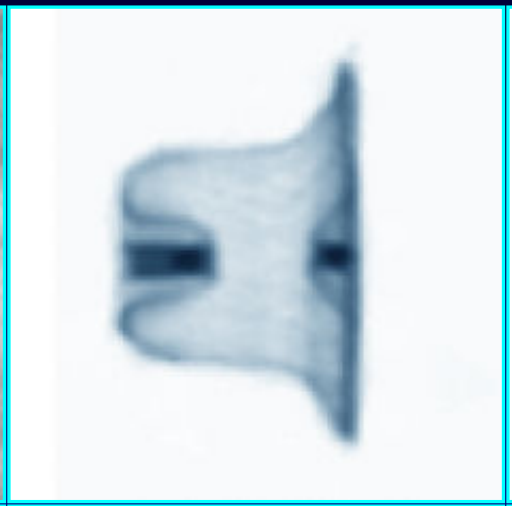
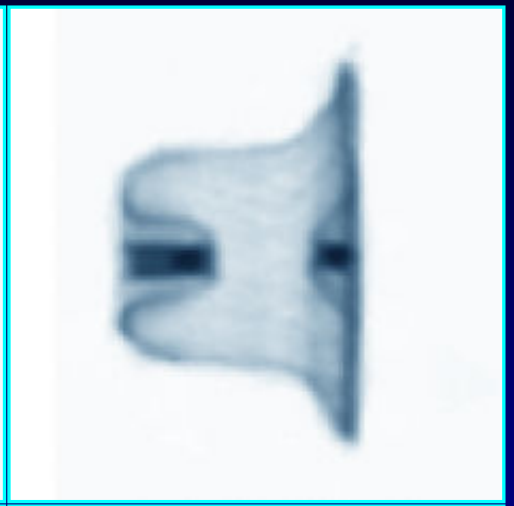
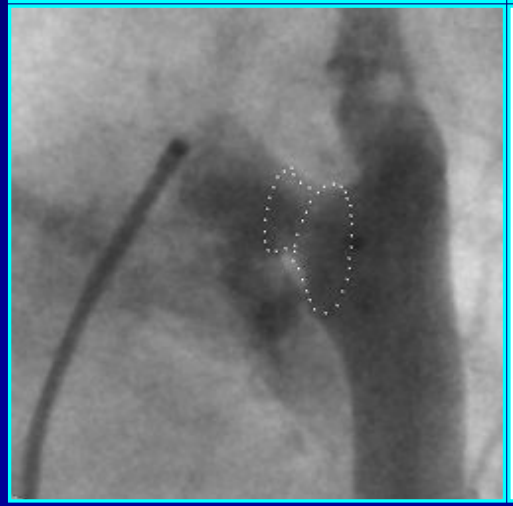








Angled ADO for Newborns and Small Infants

	Angio	View from side	View from top
Convent. ADO			
Angled ADO			

ASD Occlusion

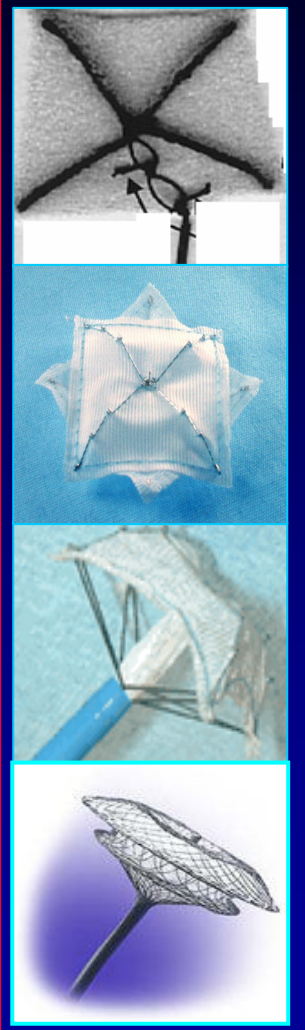
- **First human experience since 1976**
  - Various devices emerged during 1990s
  - US FDA approval of Amplatzer septal occluder in 2001

Indications – expanded by

- Accumulation of experiences
- Evolutions of device
  - *availability of larger devices*
  - *refinement of the device and delivery system*
- Development of modified implantation techniques

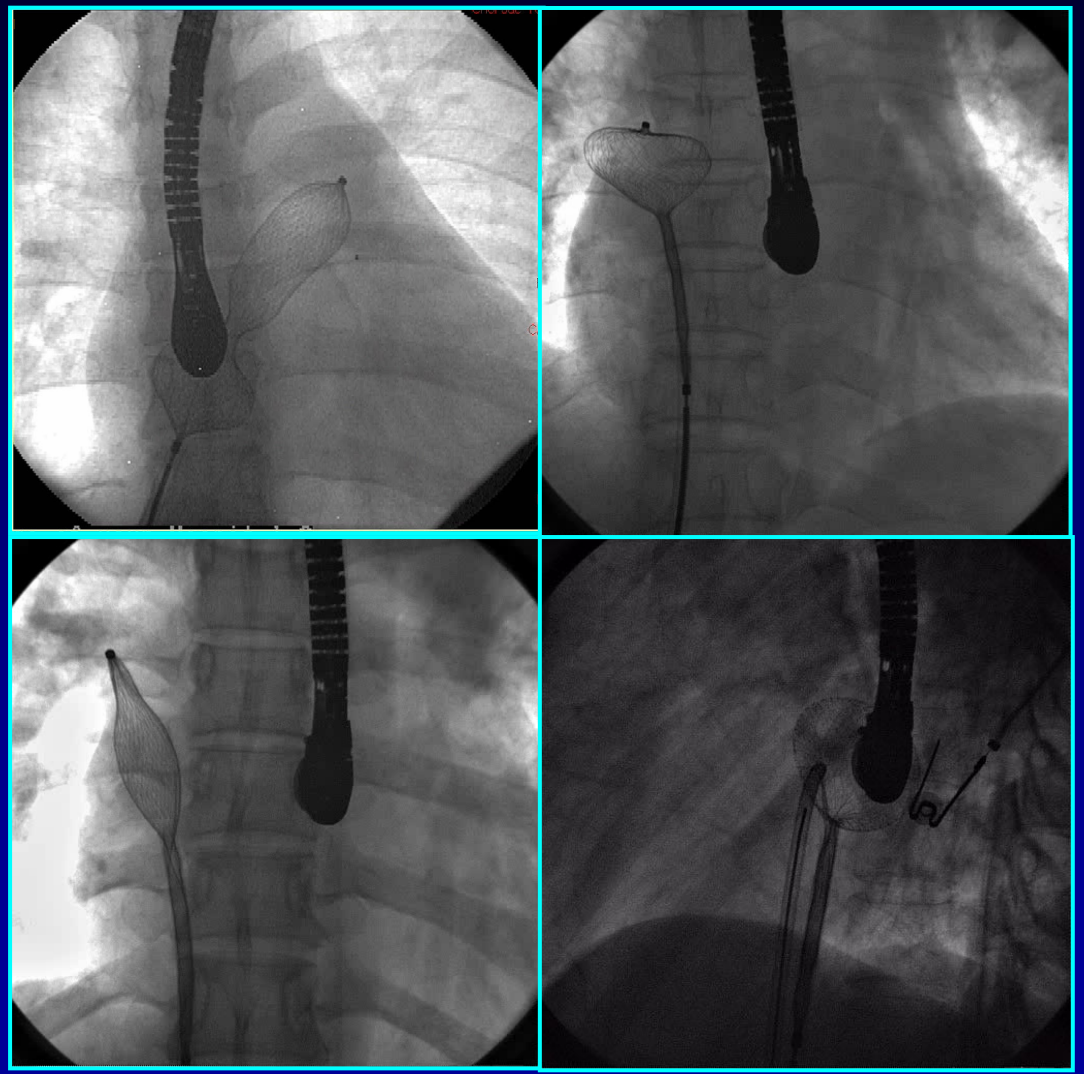
Advantages & Outcomes

- **Excellent efficacy comparable to surgery**
- **Smaller risk : about 1/3 morbidity**
- **Shorter hospitalization, less pain, early recovery, no scar, etc.**



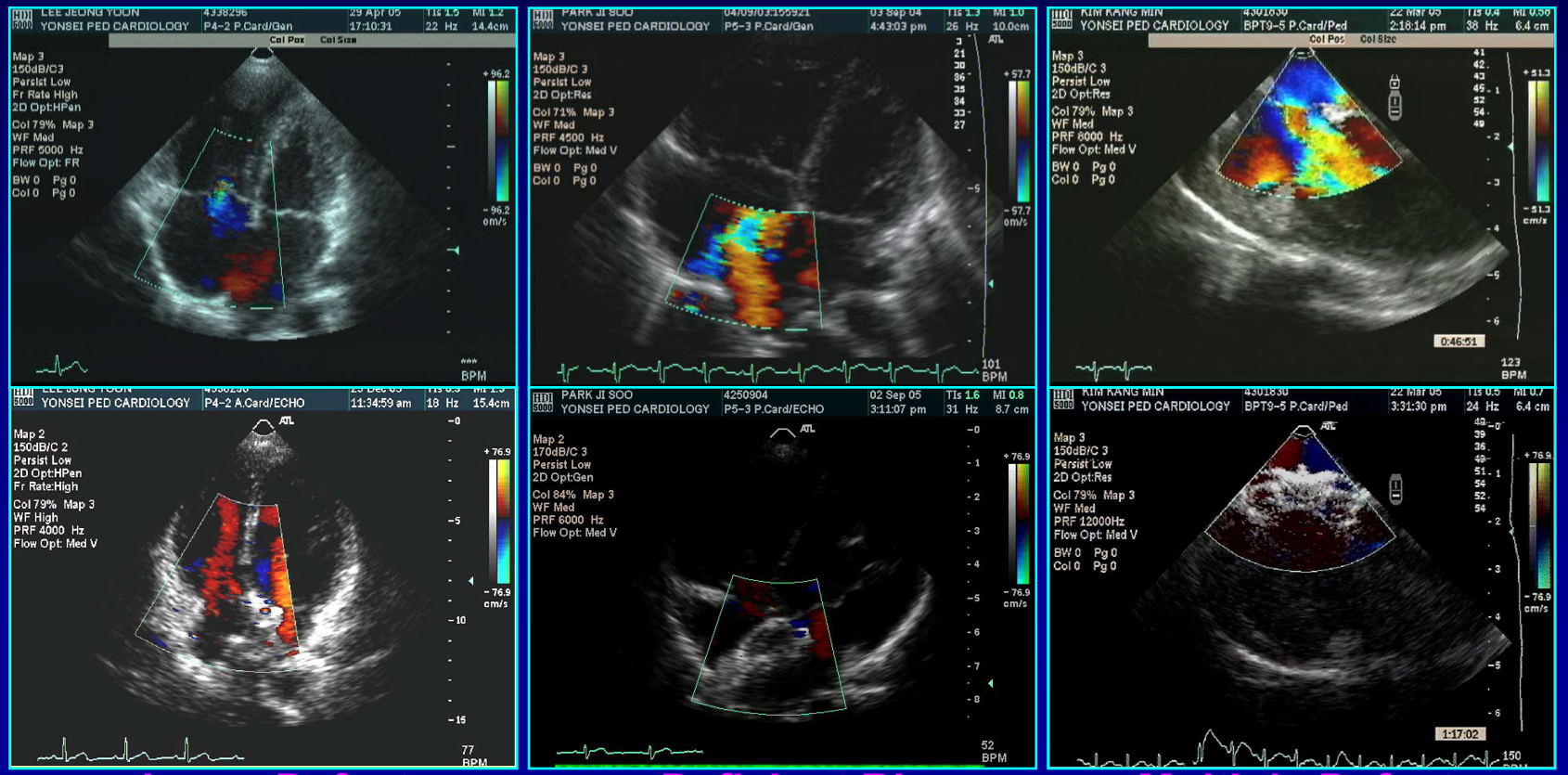
Modified Implantation Techniques of ASO

1. Clockwise rotation
2. Bending of the sheath
3. RUPV technique
   (Hypomochlion,
   LA roof technique)
4. LUPV technique
5. Stiff sheath technique
6. Balloon support
7. Hausdorf sheath
8. Boosfeld tip



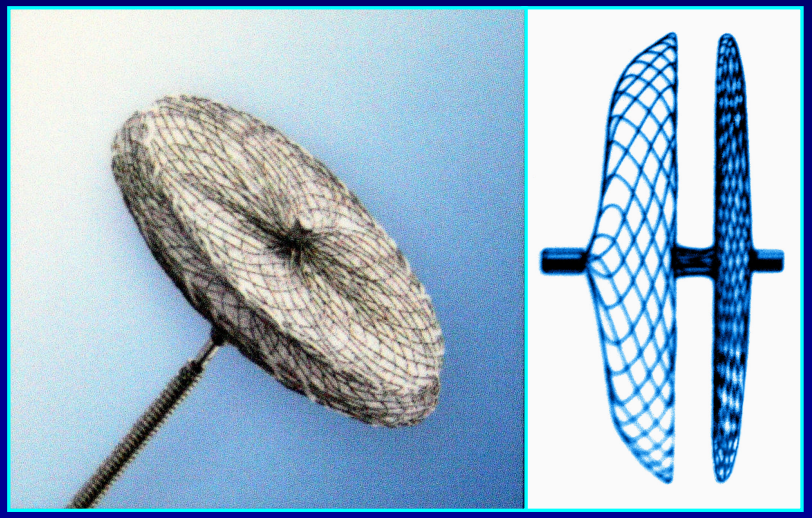
ASD occlusion with ASO – present Indications

- Large defects
- Small children
- Presence of pulmonary hypertension
- Presence of additional anomaly which can be treated by intervention
- Deficient rim(s)
- Complex anatomy

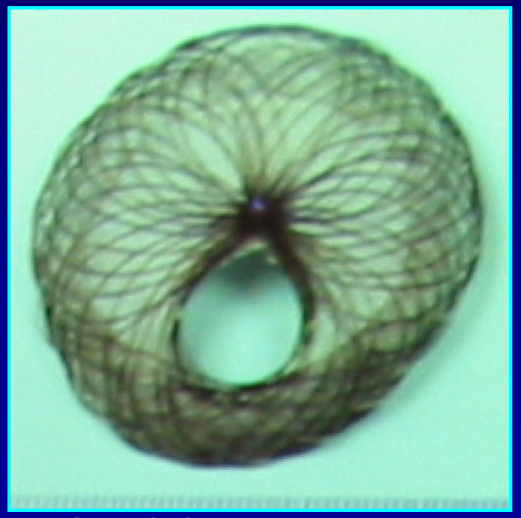


Modifications of ASO

- ✓ Multi-fenestrated ASD
  - → Cribriform device : manufactured, not FDA approved
- ✓ Severe pulmonary hypertension and potential post-occlusion LV dysfunction (esp. in elderly)
  - → Fenestrated device : not manufactured



Cribriform ASO



'Self-fabricated' Fenestrated ASO

VSD Closure

First human experience – muscular VSD, double umbrella

Lock JE et al. Circulation 1988;78:361

Few reports in 1990s mostly muscular VSD

(double umbrella, Buttoned device)

Trials with Amplatzer VSD occluder family rushed in since 2000s -

PFM Nit-occlud, VSD patch device have also been reported

Recently PM VSD has also included in the candidates for TC closure *(Amplatzer membranous VSD occluder)*

Challenging than other cardiac defects

- Conduction tissues
- Valves and valve apparatus
- Septal aneurysm
- Anatomical characteristics
- More complex catheter course

VSD Occlusion (Perimembranous)

The Complication of Transcatheter VSD occlusion

Major Cx ; device embolization, cardiac perforation, air embolization – very rare in the hand of experienced operator.
AR, MR, TR – rare
Arrhythmia (c-AV block) – major issue
; appears immediately to months after procedure, incidence 0-7%

- **International Registry**

Apr 2002 ~ Aug 2004, 24 center
2/100 PmVSD cAVB (acute) →permanent pacemaker
Holzer R et al. Catheter Cardiovasc interv. 2006;68:20

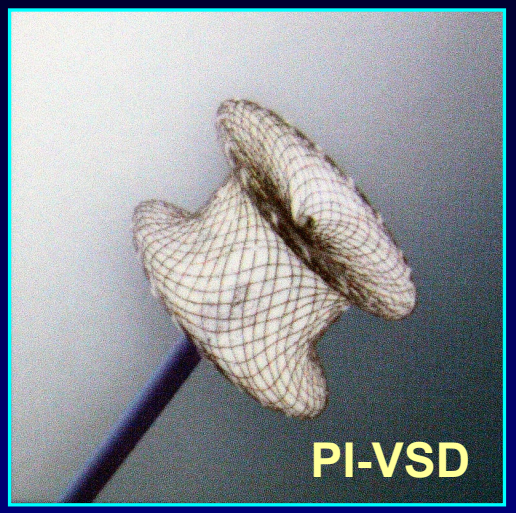
- **Italy study**

Jan 1999 ~ june 2006, 104 pm VSD
100 pts success(96.2%), cAVB 6(5.7%, 2 acute 4 late) (p-pacemaker)
Butera G et al. J Am Coll Cardiol 2007;50:1189

- European VSD Registry

23 tertiary European center
Until July 2005 430pts of VSD(pm=250)
12 of 250 pmVSD(5%), 1 of 119 mVSD (0.8%) cAVB
Carmiti M et al. Eur Heart J 2007;28:2361

Amplatzer Perimembranous / Muscular VSD Occluder



PM, m-VSD : 4~18mm

PI – VSD : 16~24mm

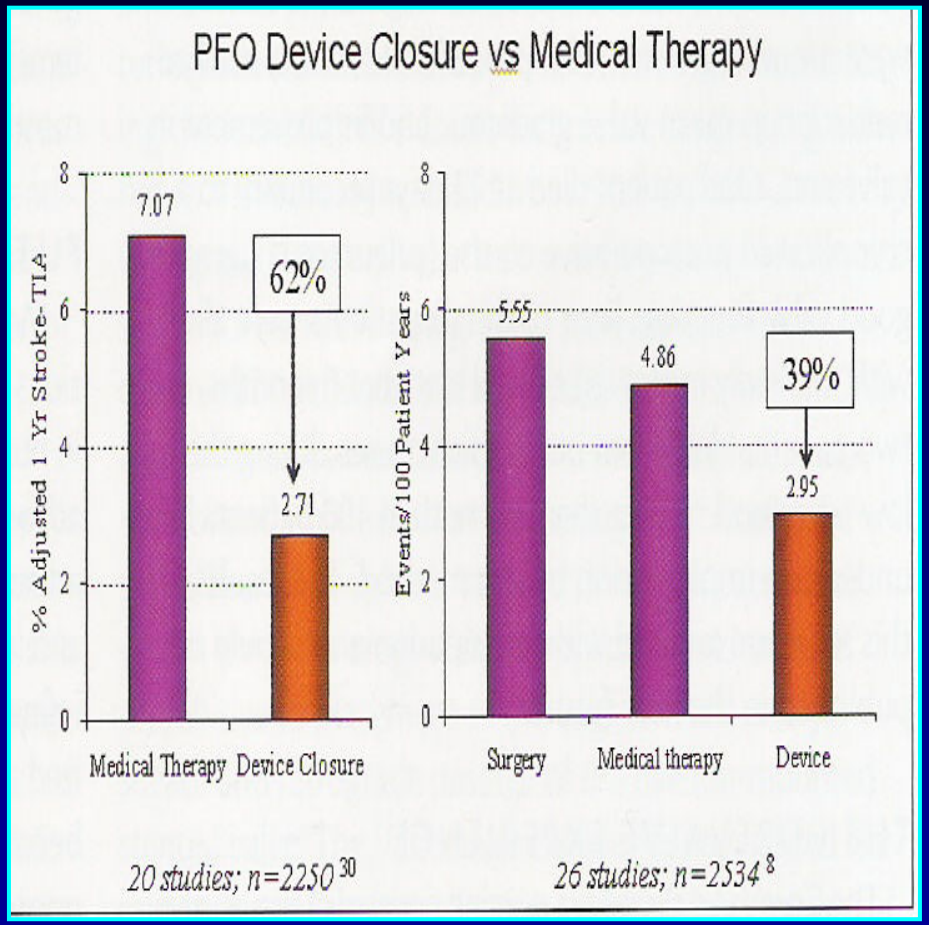
PFO closure

- **PFO and cryptogenic stroke, migrane**

  Overell JR et al.
  Neurology 2000;55:1172
  Dalla VG et al.
  J headache Pain 2005;6:328

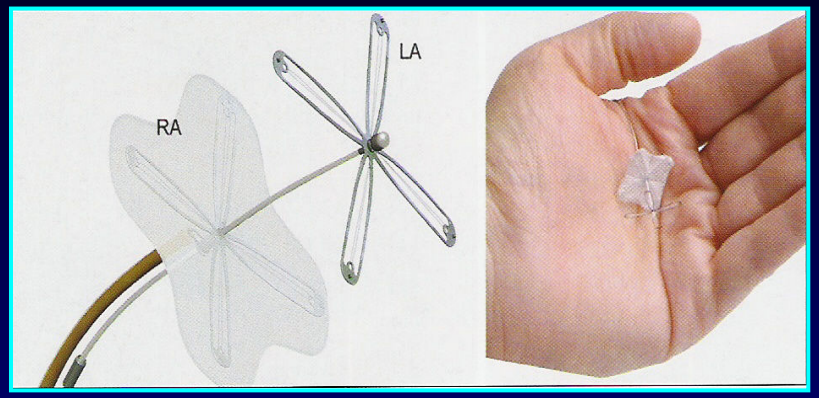
- **Incidence of PFO – large autopsy study**

  27% (17~35)
  Hagen PT et al.
  Mayo Clin Proc. 1984;59:17



Circulation 2005;112:1063
Ann Intern Med. 2003;139:753

PFO closure – the devices

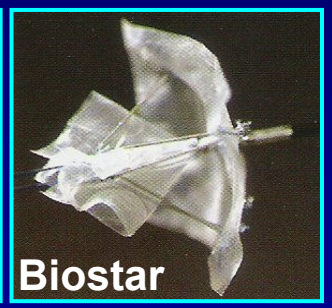


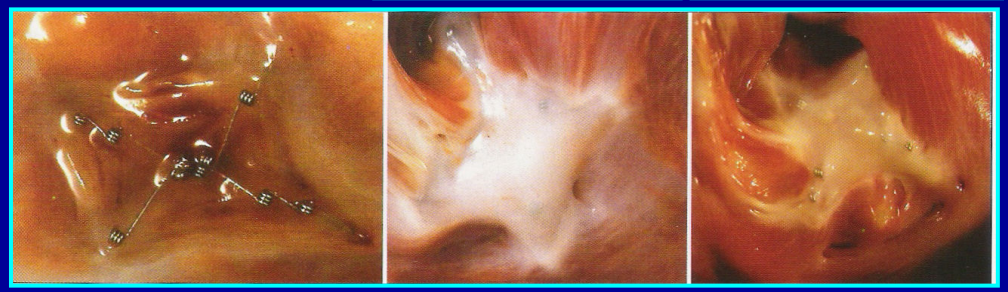
Premier device

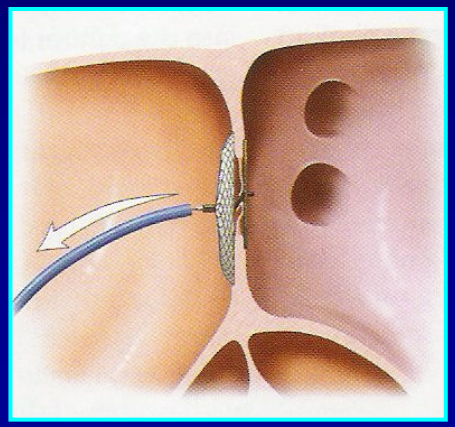
Helix device

CardioSeal

StarFlex

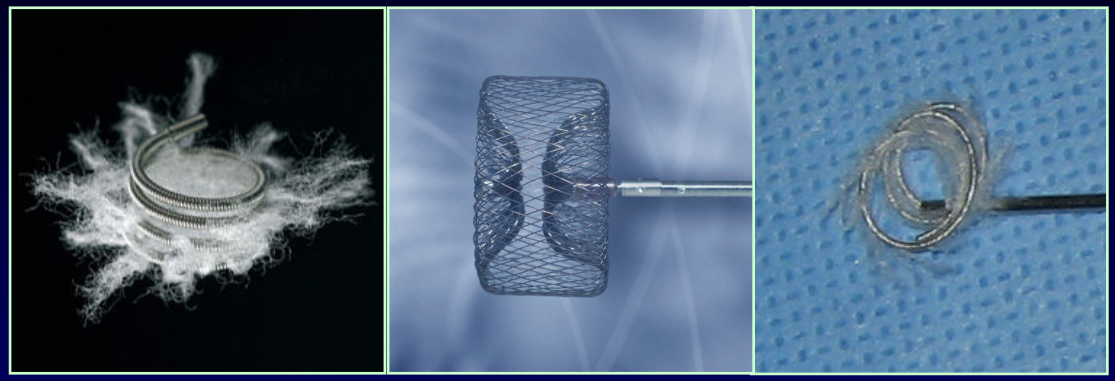


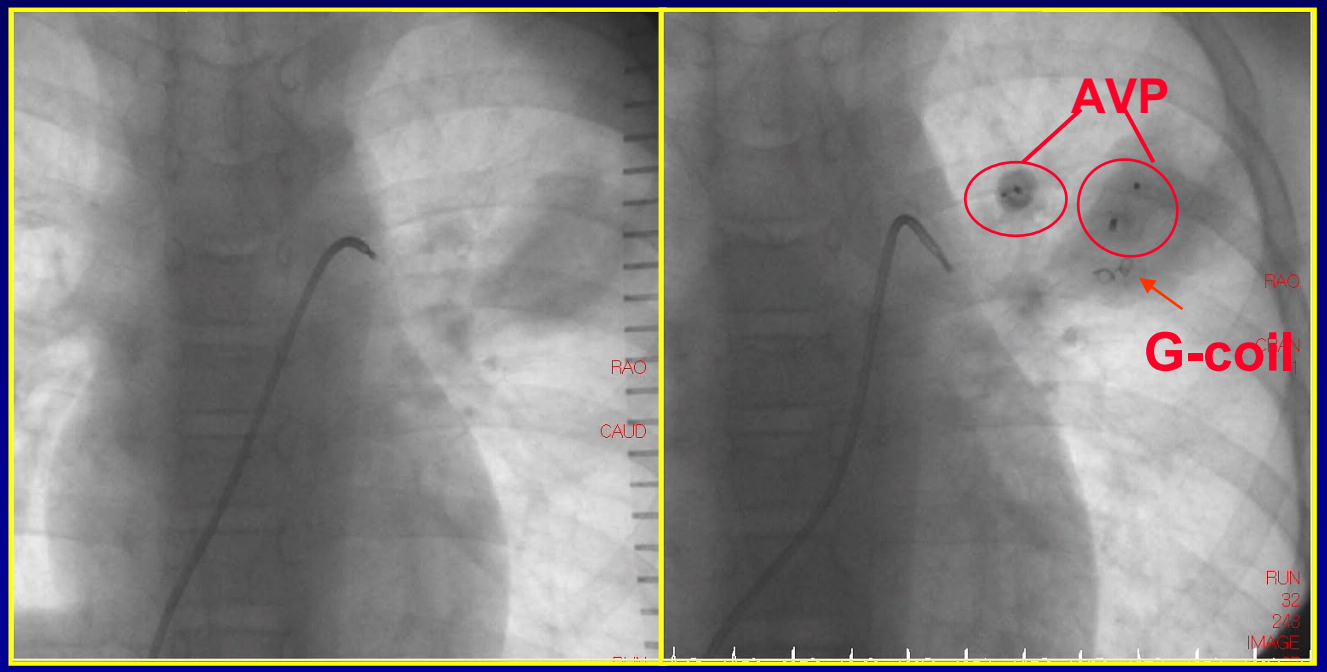




Amplatzer PFO occluder

Vascular Occlusion





Occlusion of Pulmonary A-V Malformation with Amplatzer Vascular Plug

Recently Evolved Procedures

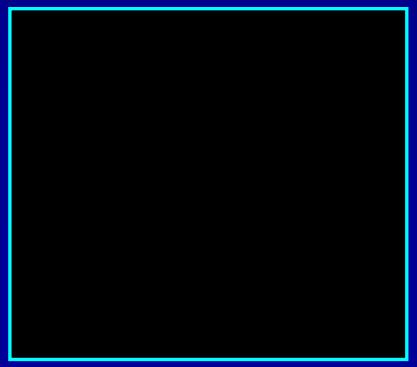
- **Percutaneous Valve Insertion**
  - Pulmonary valve / Aortic valve
- **Percutaneous Valve Repair**
  - Percutaneous MV repair / Mitral annuloplasty
- **Perventicular VSD Closure**
  - *Collaboration between surgeon and interventionist without CP bypass*
- **Transapical Valve Insertion**
  - Aortic valve
- **Hybrid Stage 1 Repair for HLHS**
  - PDA stenting, Bilateral PA banding
  - IAS stenting as needed
- **Transcatheter Fontan Completion**
  - Can be applied as a 3rd stage procedure of integrated hybrid Tx of HLHS

Percutaneous Pulmonary Valve Implantation



Bovine Jugular valve

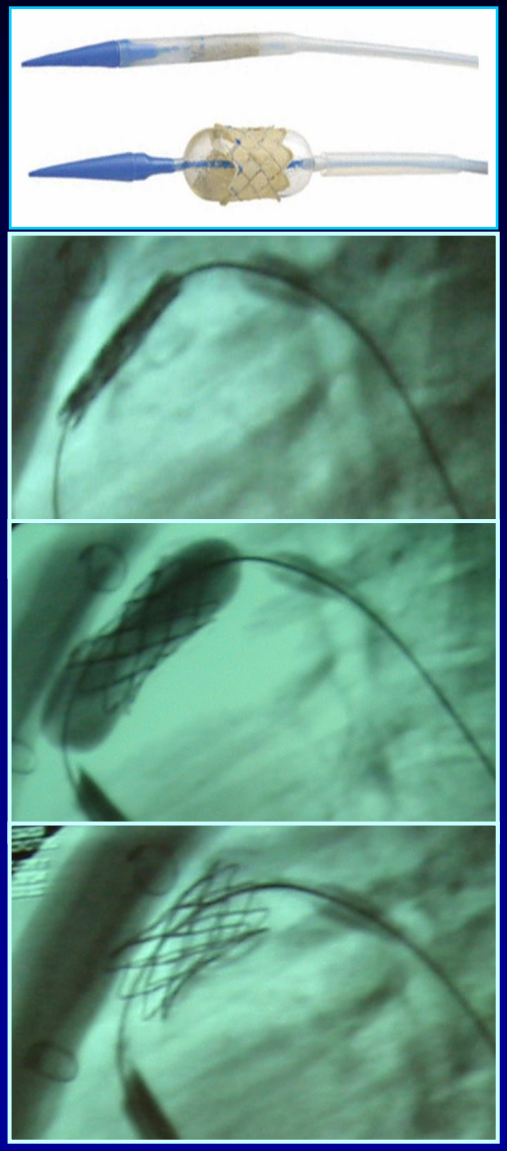


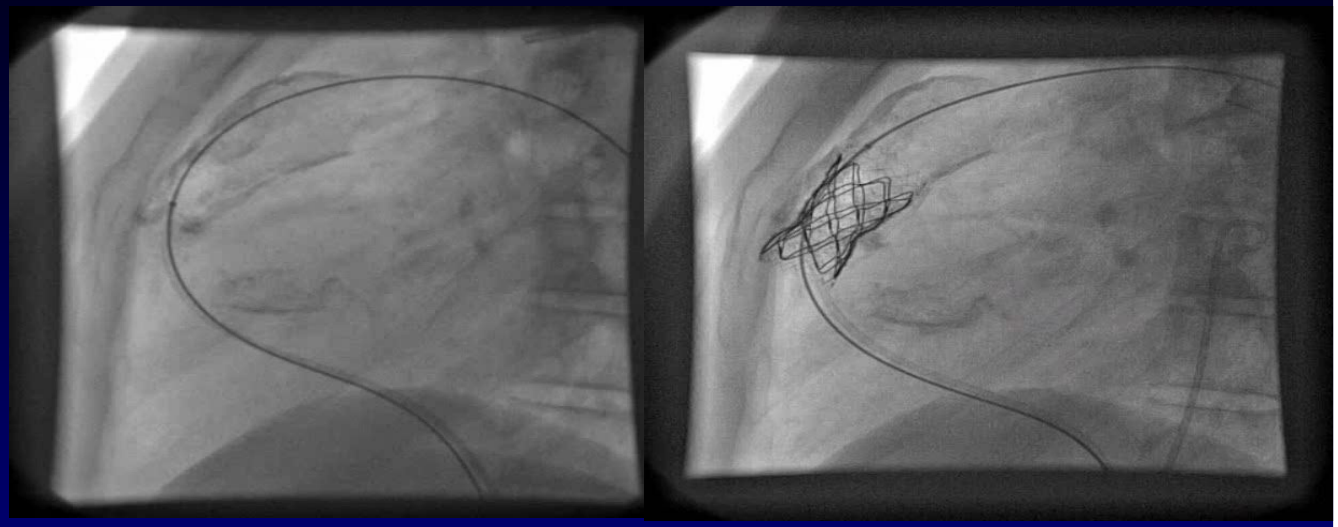



- **First human experience**
  Bonhoeffer P et al. Lancet 2000;356:1403

Figure and movie from Philipp Bonhoeffer

Percutaneous Pulmonary Valve Implantation





- **Initial results from 59 pts**

  Good functioning PV, improved RV function / exercise capacity

  Complications

  Procedural : 5% major, 12% minor

  Device-related

  : 12% restenosis by hammock effect (now solved)

  12% stent fract., clinical problem in 2

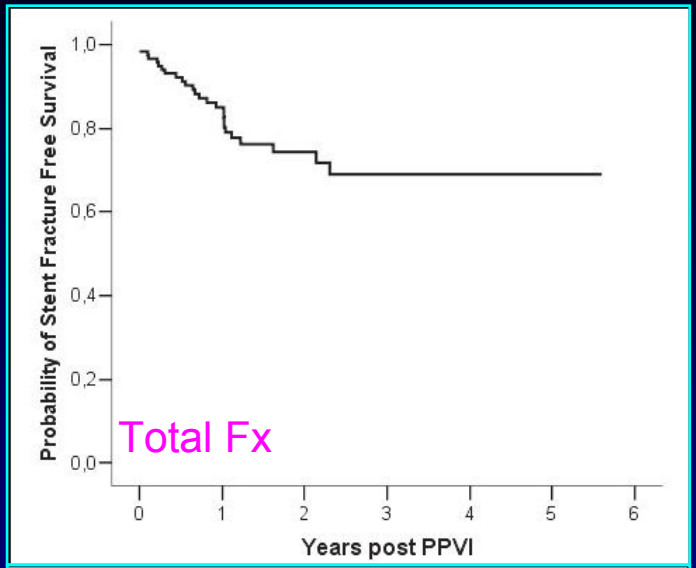
Khambadkone S et al. Circulation 2005;112:1189

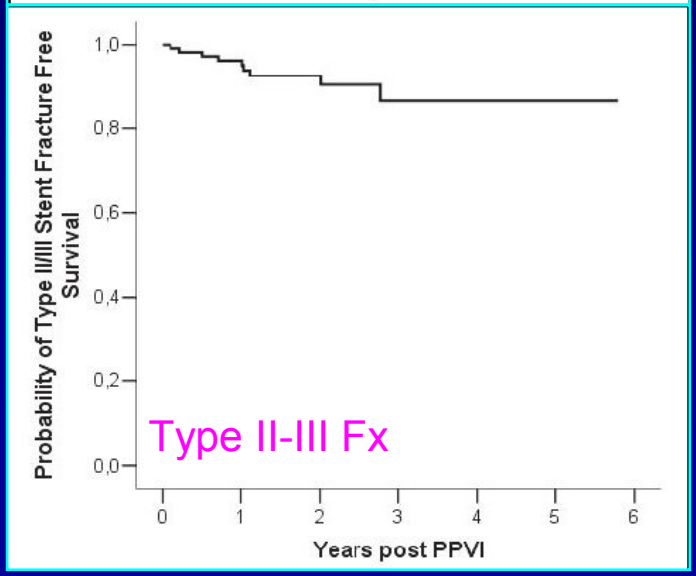
Figure and movie from Philipp Bonhoeffer

Mid-term Results of Bonhoeffer Valve

- **123 pts (Sep 2000~May 2006)**
  mean F/U duration ; 13±1 mo.
- **Complications (stent Fx)**
  26 pts(21.1%)
  mild increased RVOT, TR jet vel.(NS)
  Type I : 17(F/U), Type II :
  8(reimplantation), Type III : 1(op)
- **Fx free survival**
  1yr – 85.1%, 2yr – 74.5%, 3yr – 69.2%

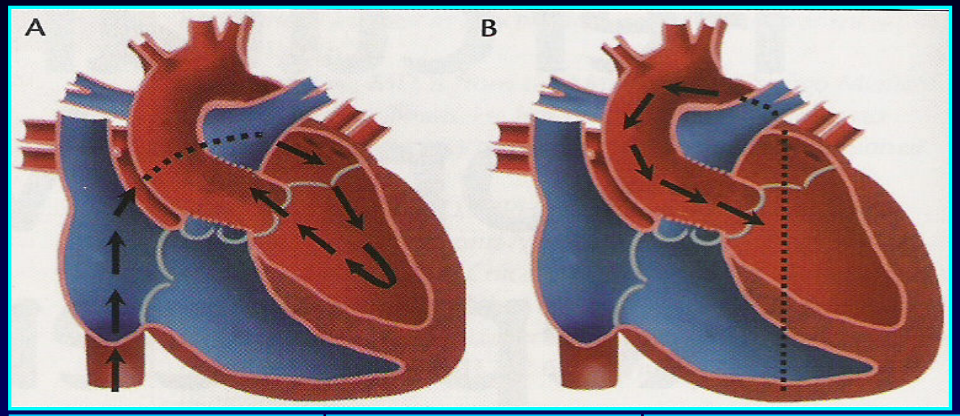
  Type II/III Fx free survival
  1yr – 96.3%, 2yr – 92.5%, 3yr – 86.5%





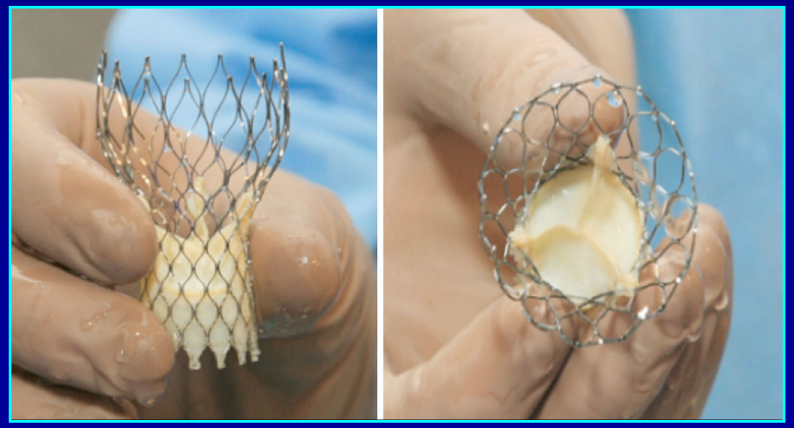
Nordmeyer J et al. Circulation 2007;115:1392

Percutaneous Aortic Valve Implantation



- **First human experience**
  Cribier A et al. Circulation 2002;106:3006
  High risk patients (elderly, LV dysfunction – inoperable)

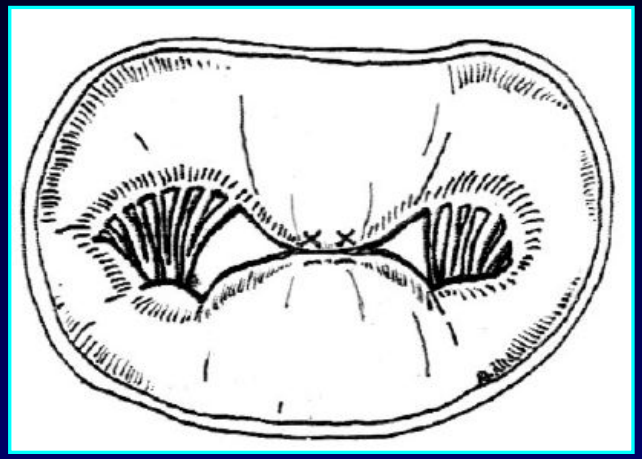
- **Mid-term results c 36 pts**
  Age : 69~91
  27 pts – success
  Area, ΔP, LV function ; improve
  Device migration(2)
  Paravalvular leak(5 ; G3/4)
  Cribier A et al. J Am Coll Cardiol. 2006;47:1214

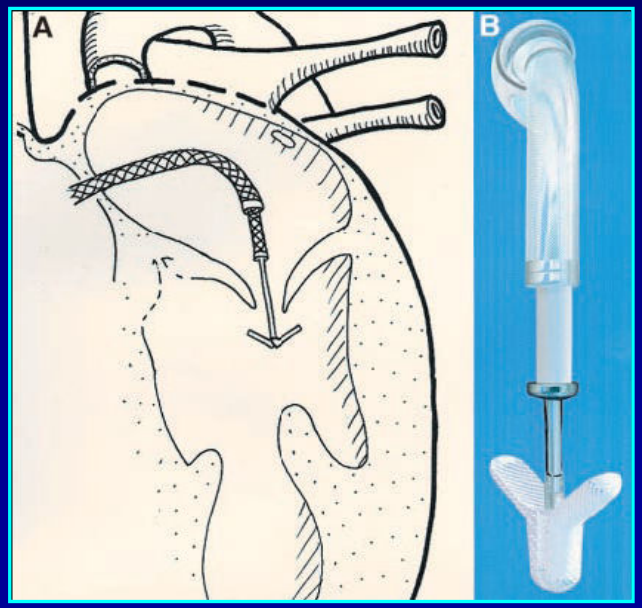


- **86 pts study c CoreValve device**

(self expanding nitinol stent, 2nd(21F), 3rd(18F) generation device)
  less paravalvular leak
  less migration(d/t self position)
76 pts(88%) success and good results
Grube E et al. J Am Coll Cardiol. 2007;50:69

Percutaneous Mitral Valve Repair

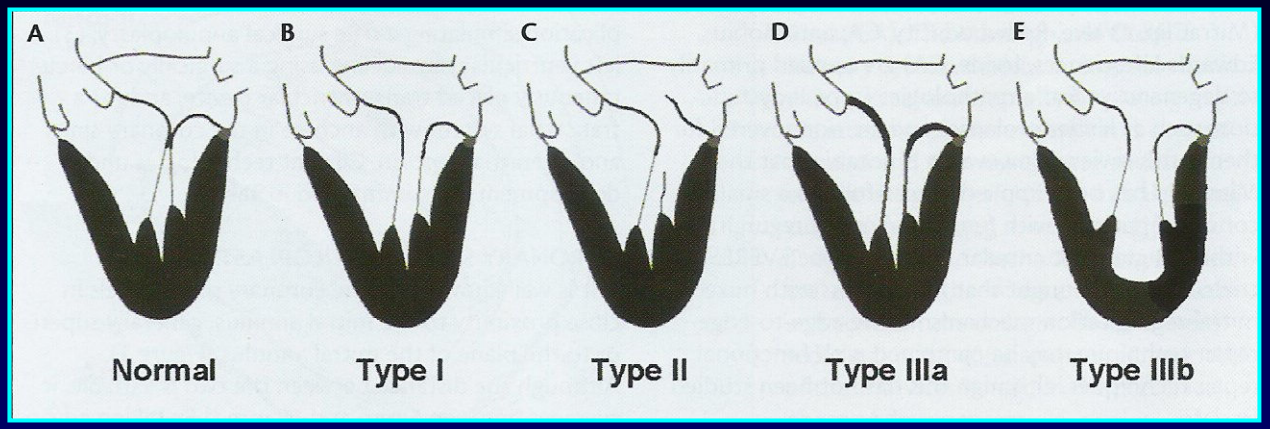




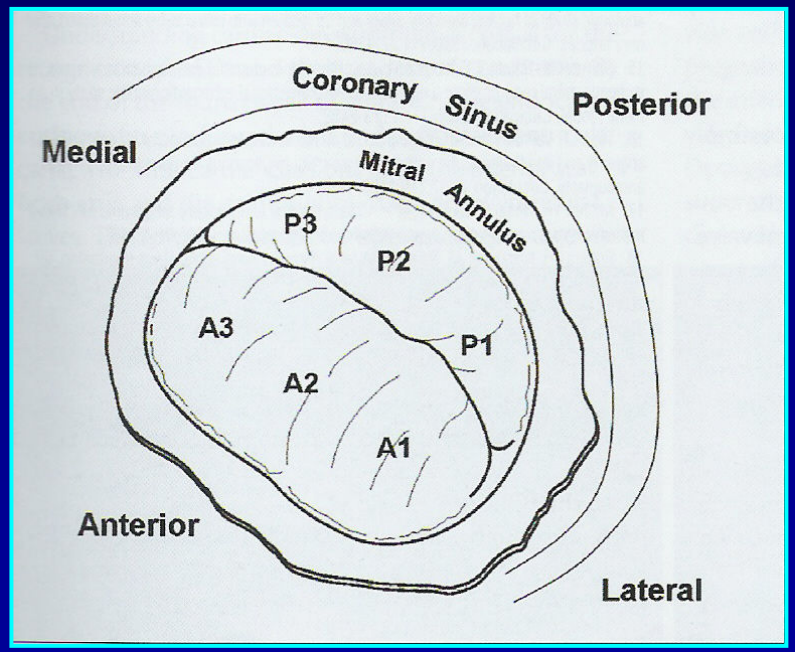
❖ **Edge to Edge Technique for Percutaneous Mitral Valve Repair**

- **Animal study**
  St Goar FG et al. Circulation 2003;108:1990
- **EVEREST Registry I**
  US multicenter phase I study
  47 pts c MR(G3-4) → 34(74%) c MR(G2↓at discharge)
  Silvestry FE et al. J Am Soc Echocardiogr 2007;20:1134
- **Report at the American College of Cardiology 2007 Scientific Session**
  104 pts c MR(G3-4), median age 71
  success 93(89%) – 1or 2 clip.
  20 pts c clip implantation & 8 pts c no clip ->op
  improved NYHA class, LV dimension

Current Catheter-Based Tx of Mitral regurgitation



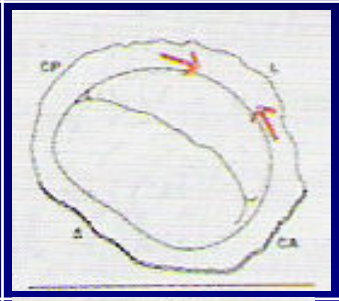
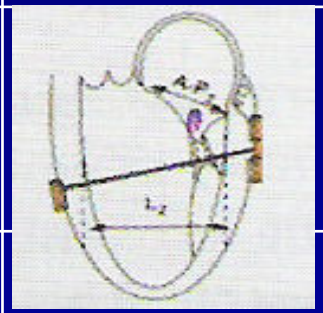
The Capentier classification of mitral valve regurgitation : new era of percutaneous mitral valve repair



Relationship of the mitral valve to the coronary sinus

Southard JA et al. Cardiac interventions today 2007;1:41

The summary of percutaneous approaches to mitral regurgitation currently under investigation

Device	Mechanism	Schematic
Coronary sinus Annuloplasty •Edwards Lifesciences: Monarch •Cardiac Dimensions: Carillon •Viacor: PTMA •St. Jude Medical	**Coronary sinus reshaping**	
Direct Annulus Plication *Mitralign *Guided Delivery systems: AccuCinch *QuantumCor: Q-Care	**Posterior annular reshaping**	
Left Ventricular shape change *Myocor: Coapsys/i-Coapsys	**LV anteroposterior reshaping**	
Trans-Atrial Shape change * Ample Medical: PS^3 system	**Coronary sinus-left atrial reshaping**	

Southard JA et al. Cardiac interventions today 2007;1:41

Hybrid Treatment of Congenital & Structural Heart Disease

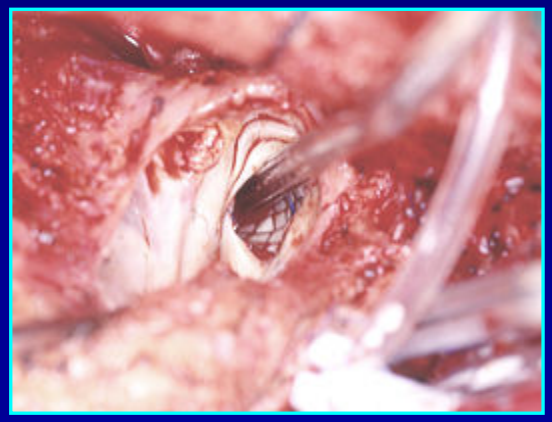
- Defined as combined catheter-based and surgical interventions in either one setting or in a planned sequential fashion within 24hrs

- Simplifies procedure

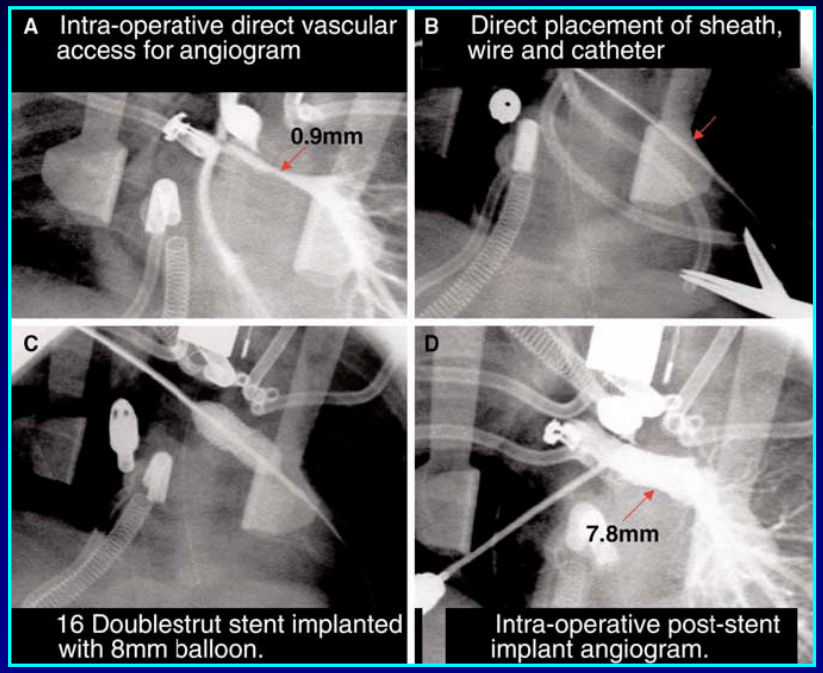
- Shortens procedure time

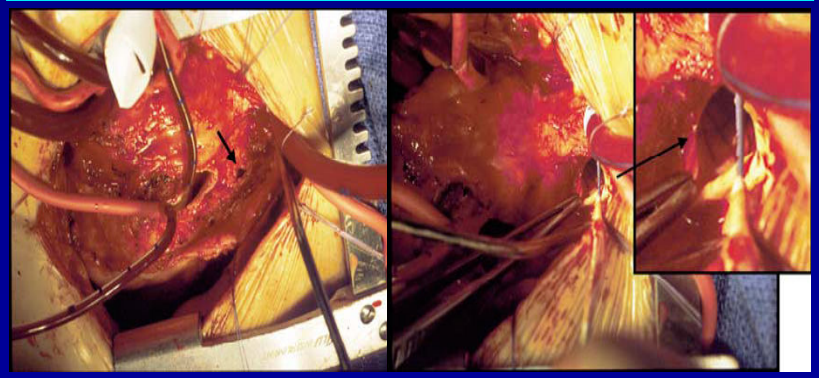
- Avoid risky manipulation / C-P bypass

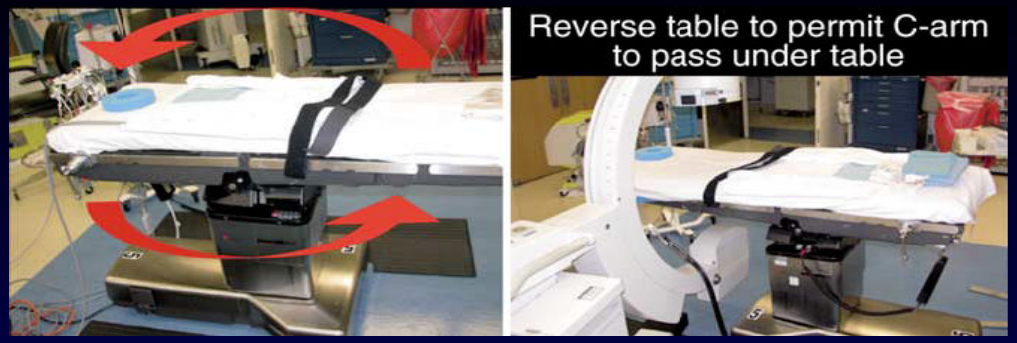
- Can be applied to smaller and high-risk patients



Intraoperative Stent Implantation







2 Techniques
- **Direct visualization c open heart bypass**
- **Direct vascular puncture s bypass**

More easy implantation, no need stiff wire and large delivery system-benefit to infant

Avoid the Cx (hemodynamic instability, balloon rupture, stent malposition, vascular tear)

Stents can be shaped and folded

Absolute Ix - early postop stenotic lesion (6-8wks) d/t high risk of rupture

Ing FF. Pediatr Cardiol 2005;26:260

Perventricular VSD Closure without Bypass

* **First human experience since 1998**

- Sternotomy s bypass c guidance of TEE ± fluoroscopy
- Puncture on RV and pass glide wire through VSD
- Introduce a short sheath through the wire and deploy occluder
- Can be applied to small neonates
- Avoid bypass, ventricular incision, RV muscle transection
  → reduces risk, improves results

Amin Z et al. J Thorac Cardiovasc Surg 1998;115:1374

* **PM-VSD closure c perventricular technique** (animal study)

- Eight Yucatan miniature pigs
- all success, no residual leak(6mo F/U), no heart block

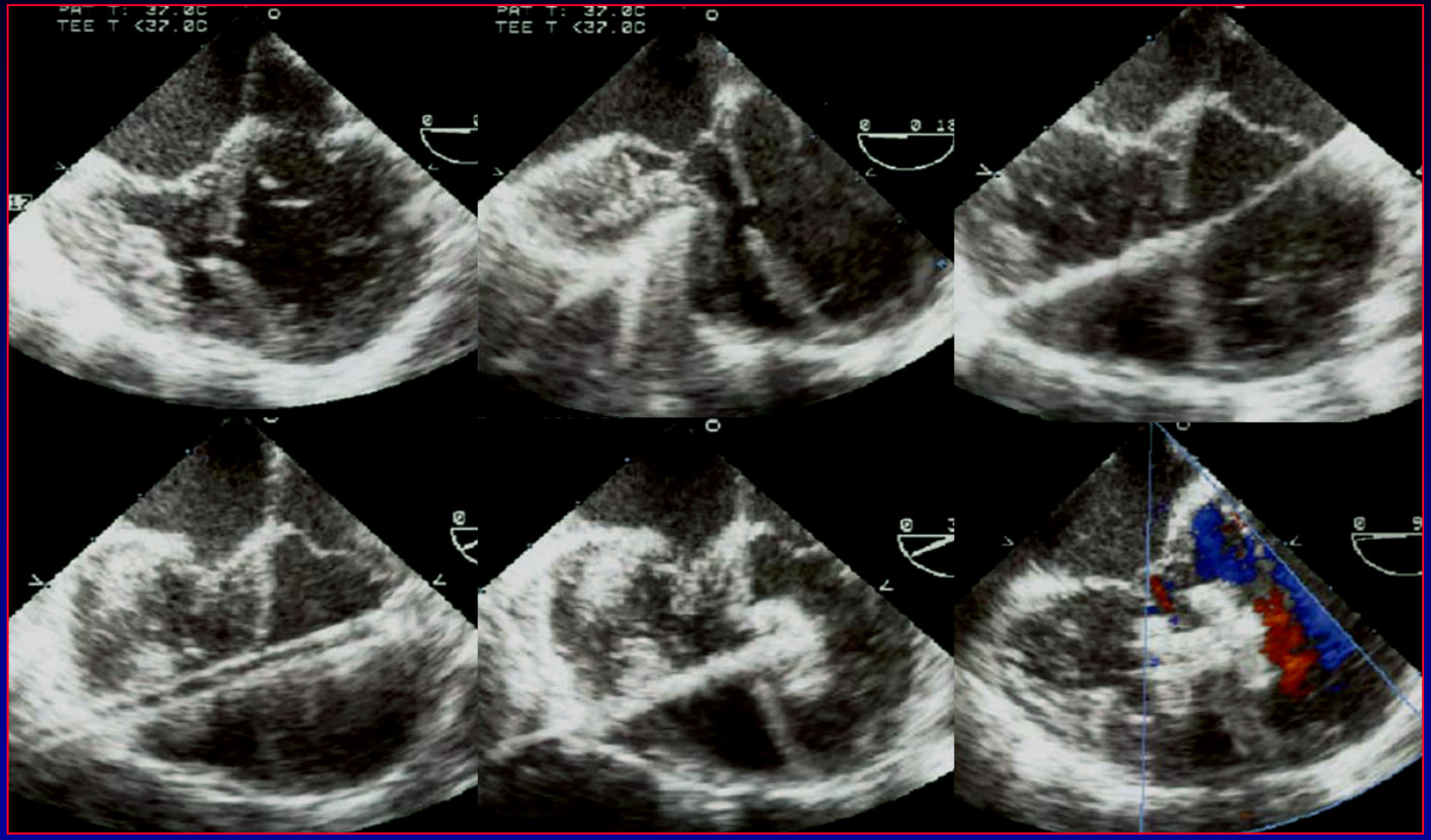
Amin Z et al. J Thorac Cardiovasc Surg 2004;127:234

* **Multicenter study**

-13 pts : iso-mVSD 2, c CoA -3, c DORV-2, s/p PA band-5
-12 pts successful implantation of device
-F/U (3~23mo) mild to mod. leak -1, trivial leak - 1

Bacha EA et al. Pediatr Cardiol 2005;25:169

Perventricular VSD Closure without Bypass



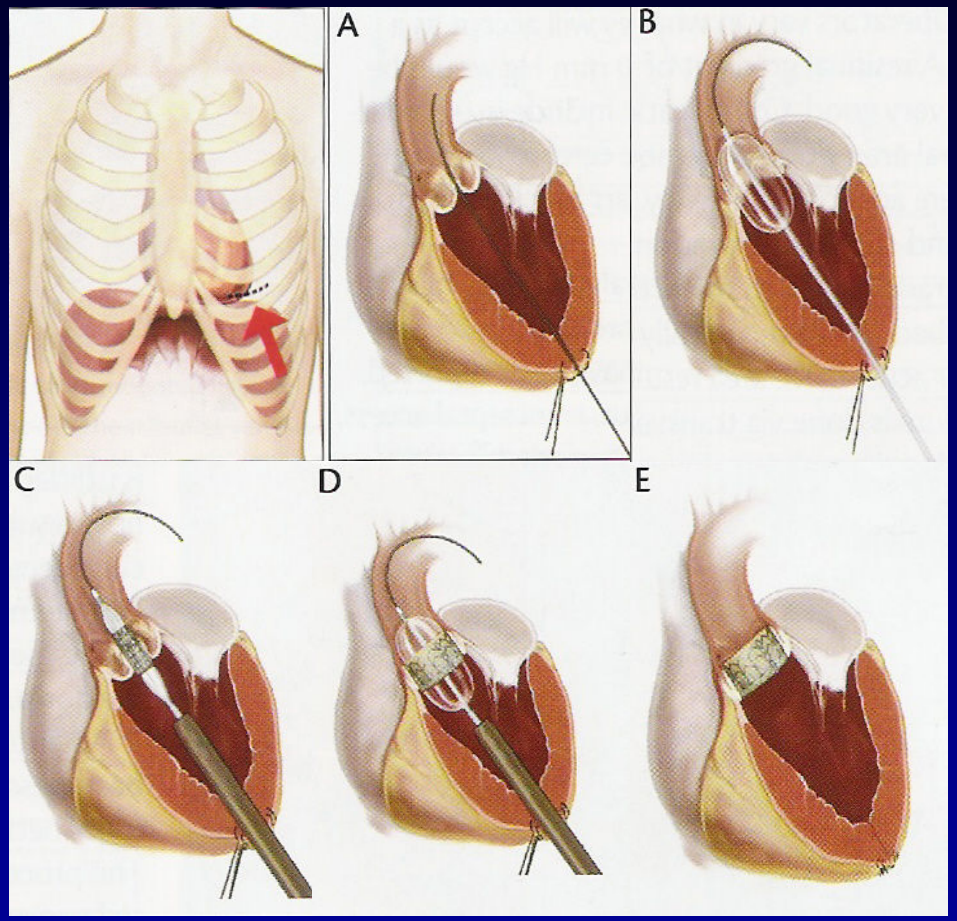
Bacha EA et al. Pediatr Cardiol 2005;25:169

Transapical Aortic valve implantation without Bypass

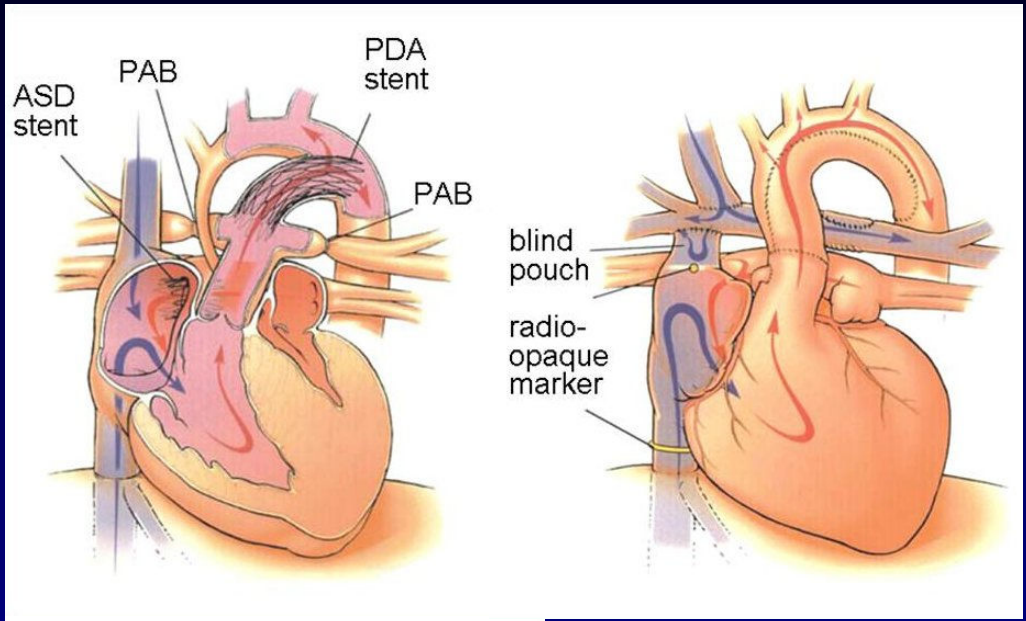
- **First human experience (2006)**
  - 7 pts c high risk AS
  - Minimal throacotomy
  - Beating heart
  - Under TEE and Fluoroscopy
  - *Lichtenstein SV et al Circulation 2006;114:591*

- **6mo F/U report**
  - 3 pts died(non-cardiogenic)
  - 4 pts live c improved state
  - *Ye J et al. Eur J Cardiothorac Surg. 2007;31:16*

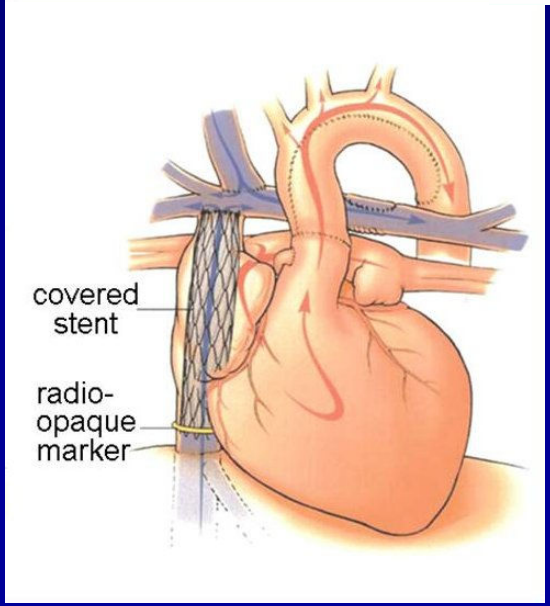
- **30 consecutive pts study**
  - Feb ~ Sep 2006, 82±5.1 yrs age
  - 29 pts success, 3 pts died (no valve relate)
  - Paravalvular leak 14pts (moderate1)
  - Good hemodynamic results
  - *Walther T et al. Eur J Cardiothorac Surg. 2007;31:9*



Hybrid Stage 1 Palliation for HLHS,Comprehensive Stage 2 Operation & Transcatheter Completion of Fontan



Galantowicz M et al. Pediatr Cardiol 2005;26:190



- **Fontan completion through transcatheter**

Sallehuddin A et al. Eur J Cardiothorac Surg 2007;32:195

Konstantinov IE et al. Scand Cardiovasc J 2006;40:75

Conclusion

- 과거에는 단지 상상만으로 가능하던 일들이 임상에 적용되고 있으며 더 새로운 전망을 가능케 한다. 새로운 술기의 개발과 적용, 충분한 검증이 중요. 중재술로부터 발전된 술기들은 수술과 함께 치료 효과와 안전성을 극대화 할 수 있다.

JY Choi. Korean J Pediatr 2006;49:917

- 무엇보다도 임상의의 가장 중요한 임무는 개개 환자에게 가장 합리적인 치료법이 무엇인지 결정하는것. 어떠한 경우에도 우리가 선택할 수 있는 진단방법과 치료방법이 늘어난다는 것은 의사나 환자 모두에게 매우 유쾌한 일이다.

HJ Lee. Korean Circulation J 2002;32:15