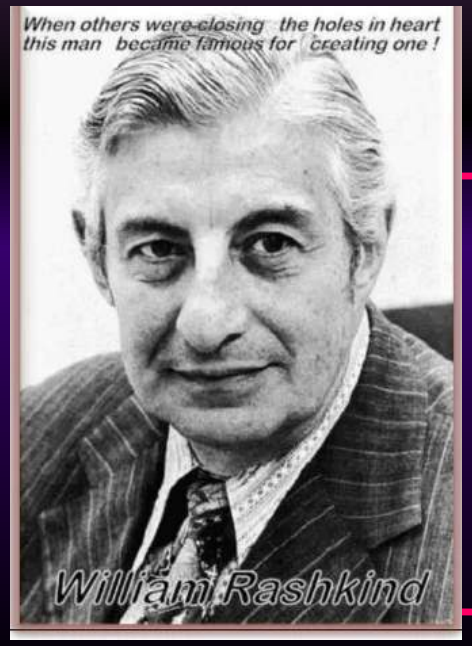


CARDIOLOGY 2023

Annual William J. Rashkind Lecture

The Changing Faces of Pediatric Interventional Cardiology

Jacqueline Kreutzer MD, FACC, FSCAI

Professor of Pediatrics - Chief, Division of Cardiology

Peter & Ada Rossin Endowed Chair in Pediatric Cardiology ,

Co-Director Heart Institute, UPMC Children's Hospital of Pittsburgh

University of Pittsburgh, School of Medicine

Faculty Member of the McGowan Institute of Regenerative Medicine

UPMC CHILDREN'S HEART INSTITUTE

University of Pittsburgh

UPMC | HEART AND VASCULAR INSTITUTE

UPMC | CHILDREN'S HOSPITAL OF PITTSBURGH

Disclosures

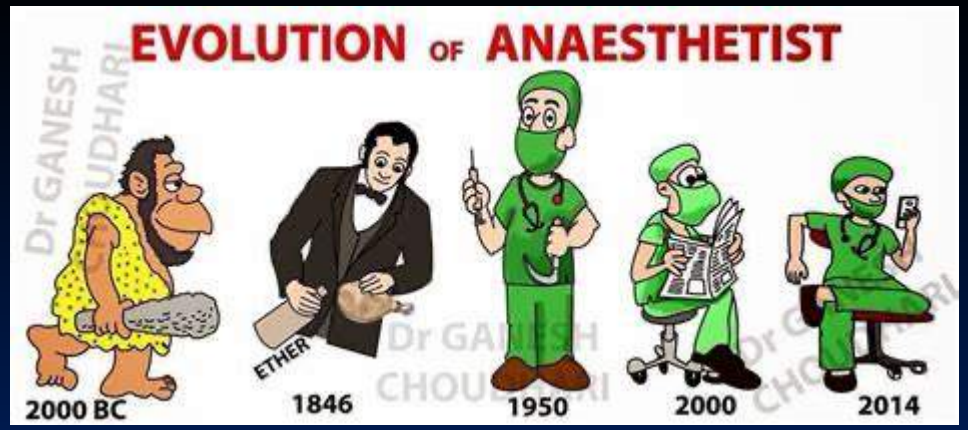
- Research support
  - Medtronic - PAS (Melody/ Harmony)
  - Edwards Lifesciences- PAS (Compassion XT & S3 PAS)
- Consultant/proctor
  - Medtronic

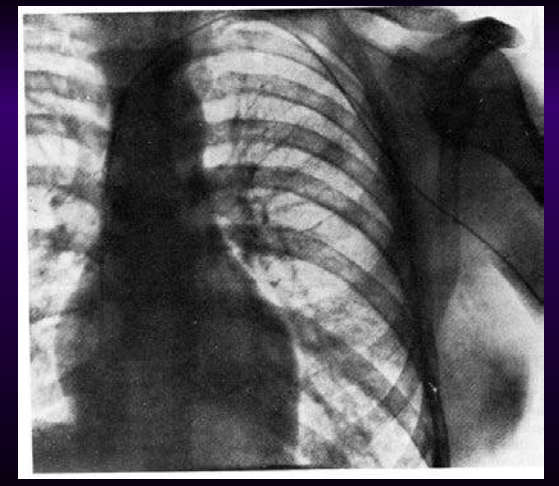
Content limited by time constraints

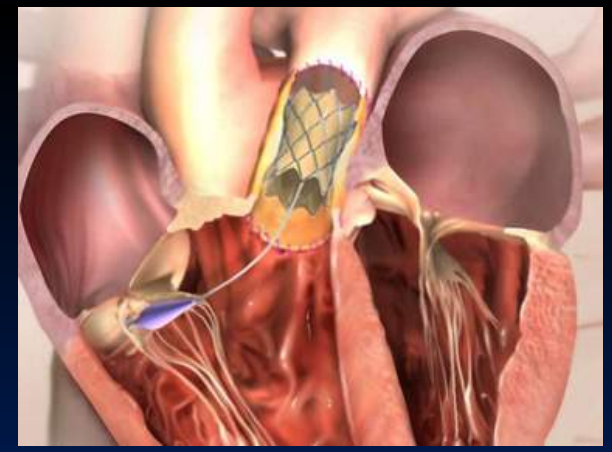
Presentation biased by personal perspectives and career experiences

Objectives

- Explore evolution of the field
- Invasive cardiology ➡ Interventional
  - Very early days
  - 80's-90's
  - Last 2 decades







Objectives


RAMIREZ INVESTOR'S BUSINESS DAILY
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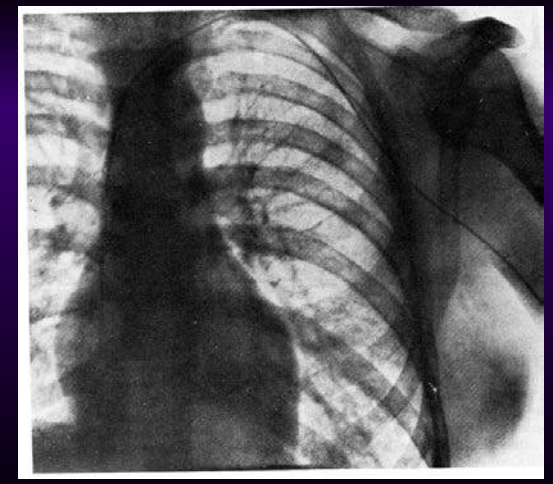
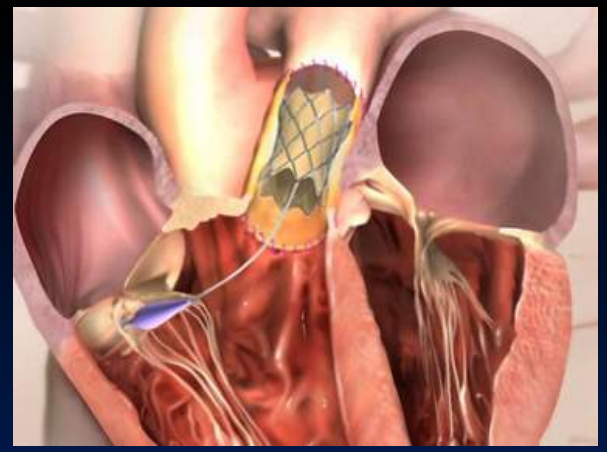
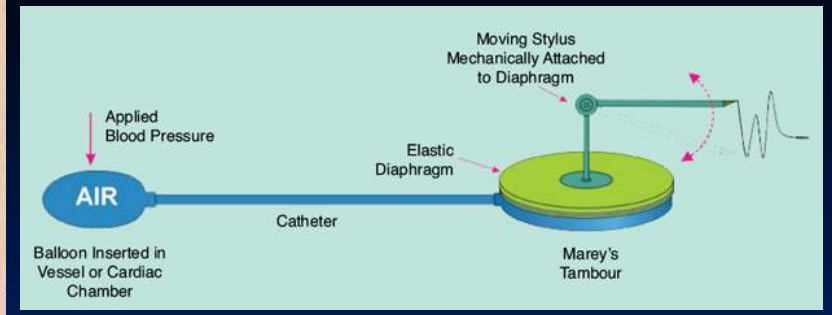




The Very Early Days of Invasive Cardiology

- Animal catheterization
  - ***Stephen Hales*** – blood pressure with brash pipes inserted in venous and arterial system of a horse
  - ***Chauveau and Marey*** – first intracardiac pressure- graphic records of atrial and ventricular pressures
  - ***Claude Bernard-*** invention of cardiac catheterization 1844

"catheterisme du coeur" Using RIJ for right heart and carotid for left heart



The Very Early Days of Invasive Cardiology

- Human catheterization
  - 1900s Fritz Bliechroder & Ernst Unger
  - 1929 – Werner Forssmann

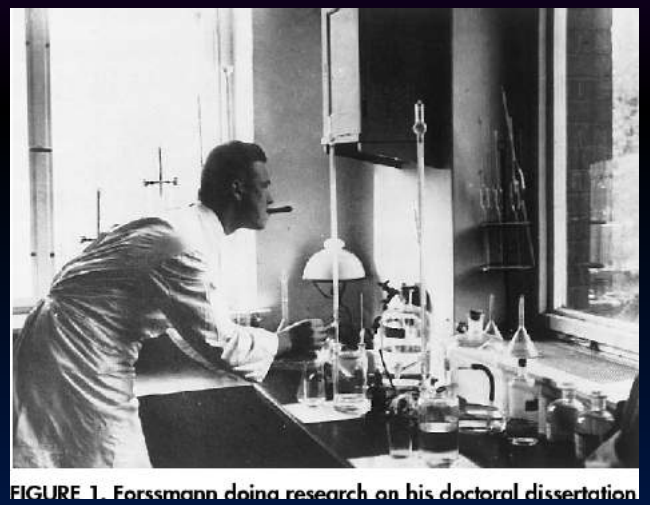
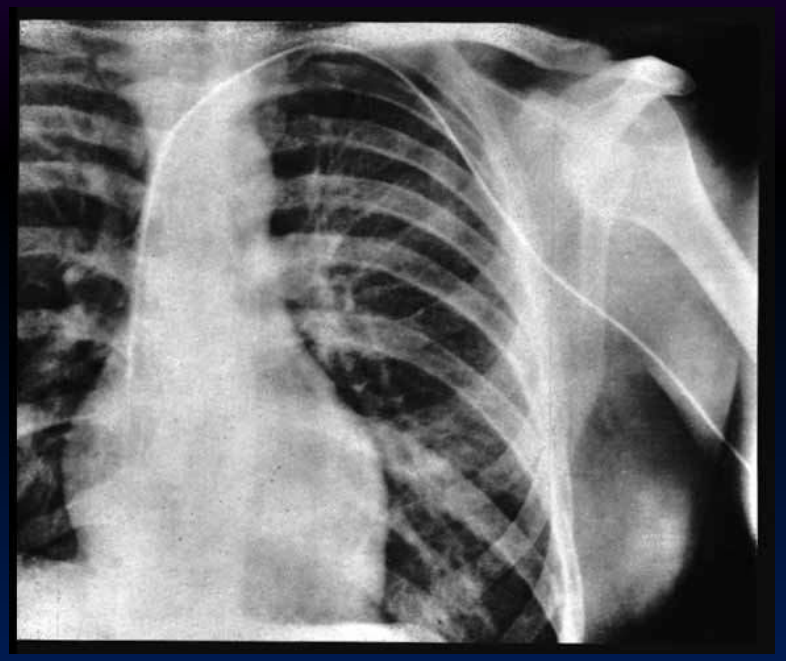


FIGURE 1. Forssmann doing research on his doctoral dissertation



The Nobel Prize in Physiology or Medicine 1956

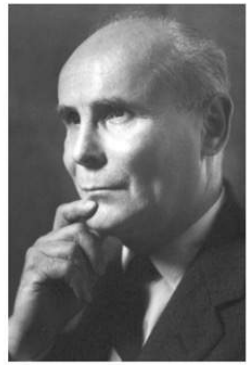


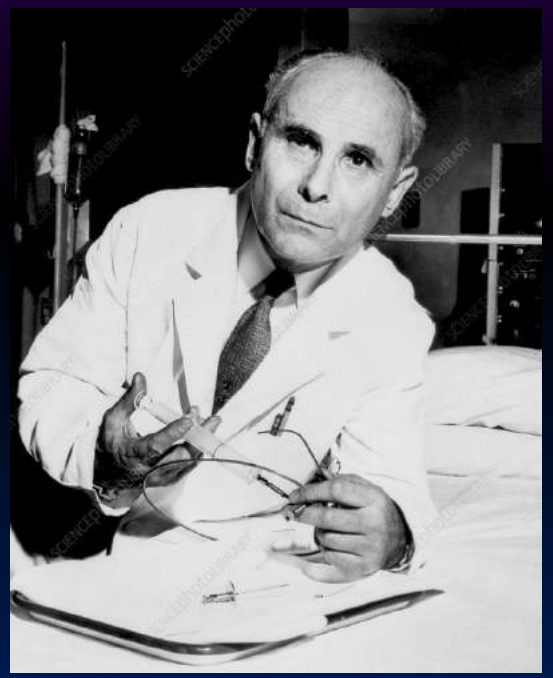
Photo from the Nobel Foundation archive.
André Frédéric Cournand
Prize share: 1/3

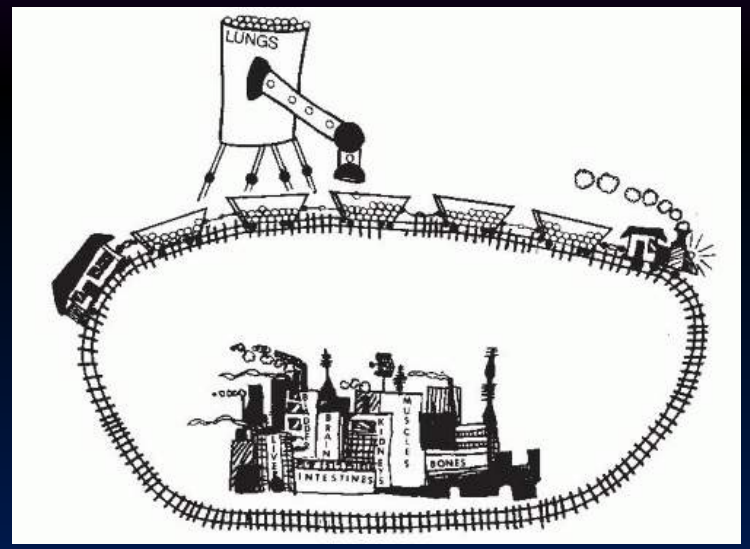
Photo from the Nobel Foundation archive.
Werner Forssmann
Prize share: 1/3

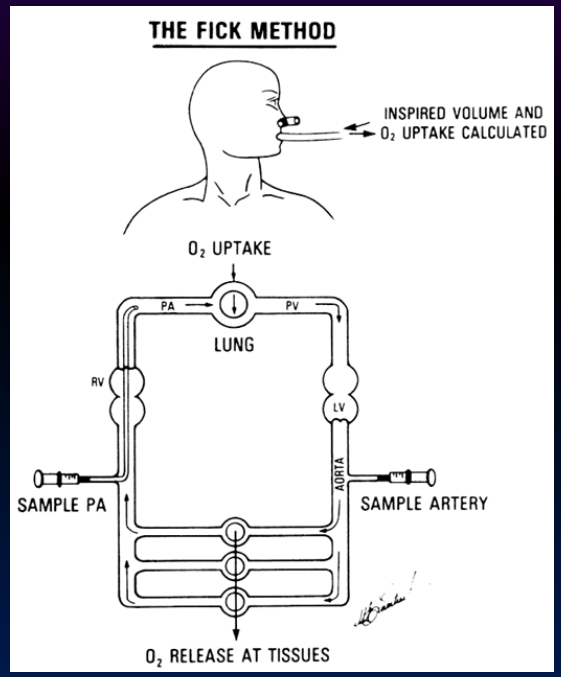
Photo from the Nobel Foundation archive.
Dickinson W. Richards
Prize share: 1/3

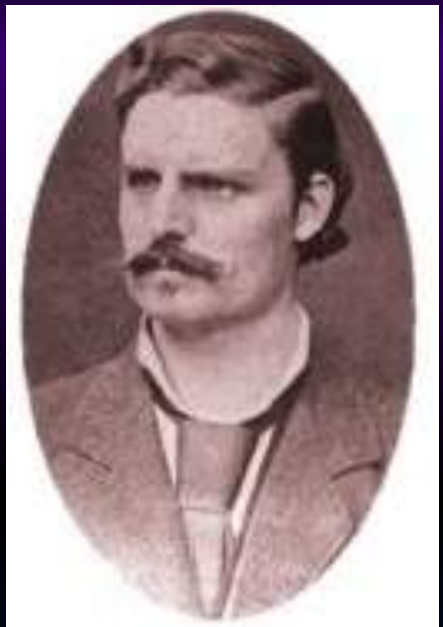
The Very Early Days of Invasive Cardiology

- Diagnostic catheterization
  - Right heart cath – Cournand & Richards
  - The Fick principle





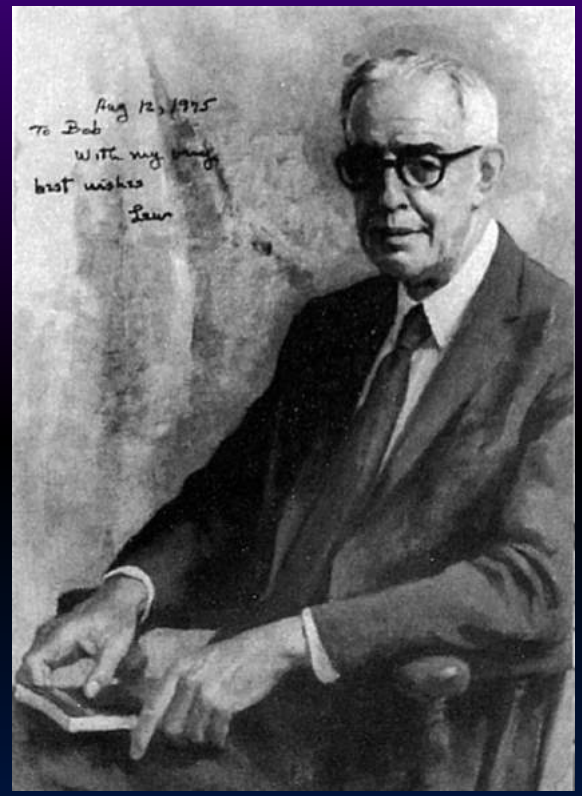




The German scientist Adolph Eugen Fick (1828-1901) was the first to devise a technique for measuring cardiac output in 1870.

The Very Early Days of Invasive Cardiology

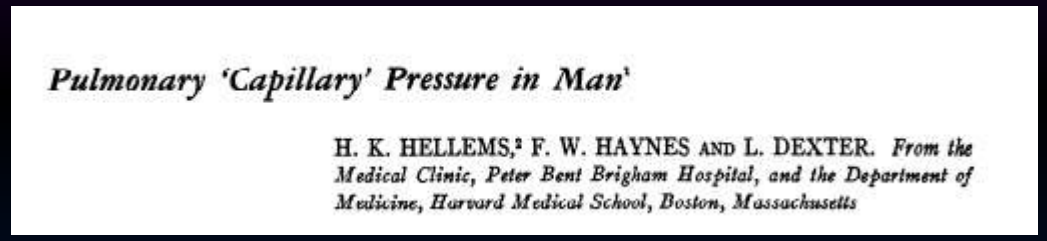
- Diagnostic catheterization
  - Right heart cath - Dexter
  - PCWedge pressure -1949
  - The balloon wedge catheter



I decided to wander around the heart which I understood was above the diaphragm somewhere. Suddenly, this catheter came clear out in the lung field and I was sure I [had] perforated the heart. I didn't have any idea of what to do and … I turned on the overhead lights and said, "Mr. S____, how are you?" He said, "I feel a hell of a lot better than you look."

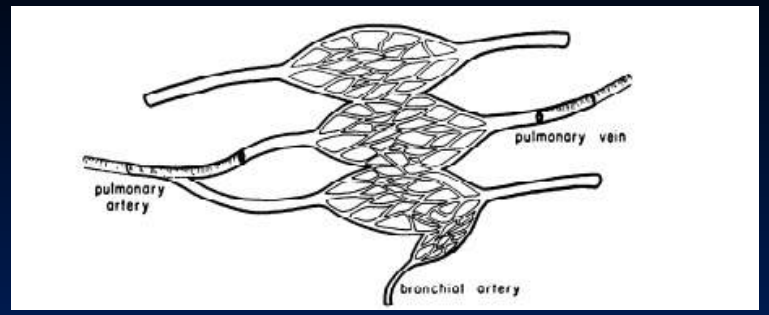
The Very Early Days of Invasive Cardiology

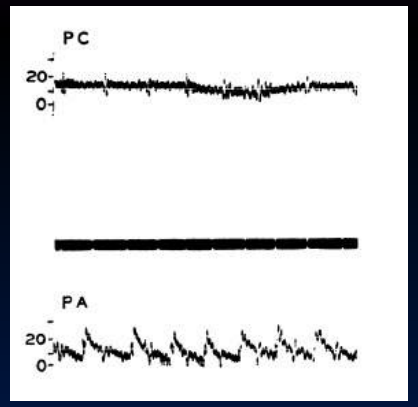
- Diagnostic catheterization
  - PCWedge pressure -1949
  - The balloon wedge catheter 1953

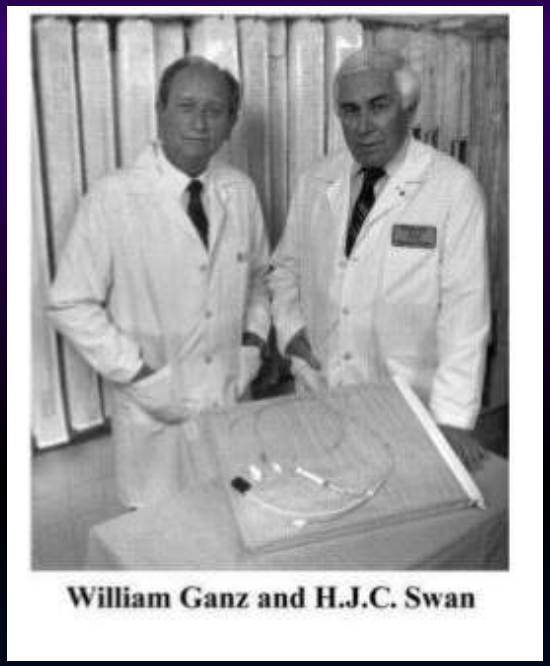


Pulmonary 'Capillary' Pressure in Man[1]

H. K. HELLEMS,[2] F. W. HAYNES AND L. DEXTER. *From the Medical Clinic, Peter Bent Brigham Hospital, and the Department of Medicine, Harvard Medical School, Boston, Massachusetts*





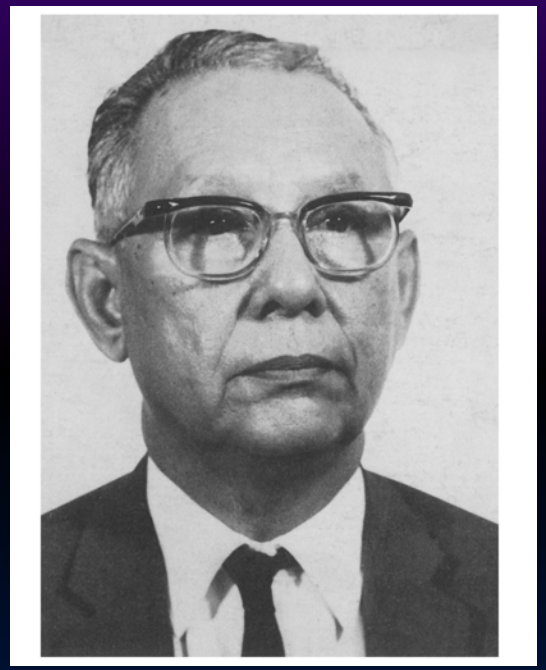


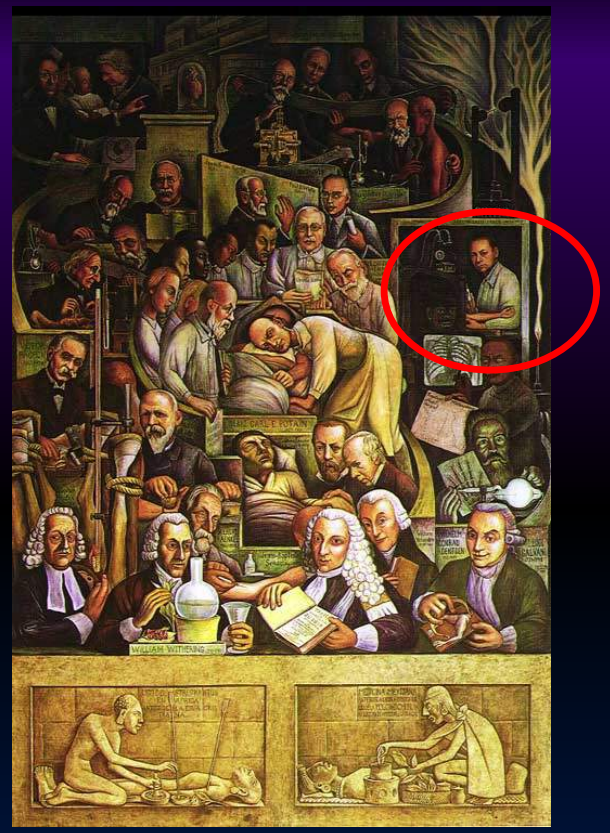
William Ganz and H.J.C. Swan

- 1970- Balloon Flotation Catheter by Doctor H.J.C Swan and William Ganz

The Very Early Days of Invasive Cardiology

- Angiography



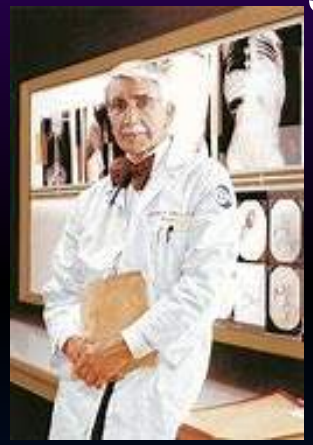


1940's - Cardiac Catheterization in Congenital Heart Disease: A Clinical and Physiological Study in Infants and Children. Andre Cournand , Janet S. Baldwin , Aaron Himmelstein

Dr Agustin Castellanos – Cuban cardiologist pioneer in angiocardiography- published in the Archivos de la Sociedad de Estudios Clinicos in 1937 (nl angiocardiography, VSD, PS)
1938 - Retrograde aortography injection in aorta 1938

The Early Days of Invasive Cardiology

- Percutaneous access (70's)
- Angled angiography (70's)



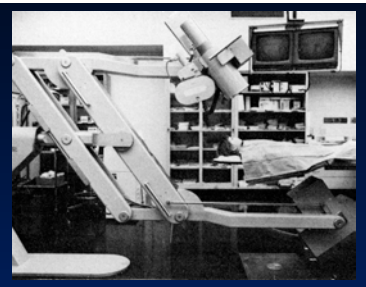
Axial Cineangiography in Congenital Heart Disease

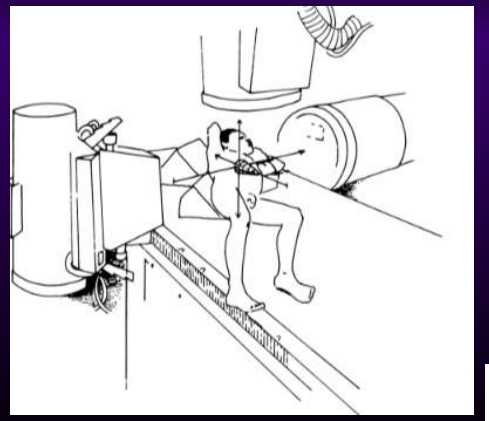
Section I. Concept, Technical and Anatomic Considerations

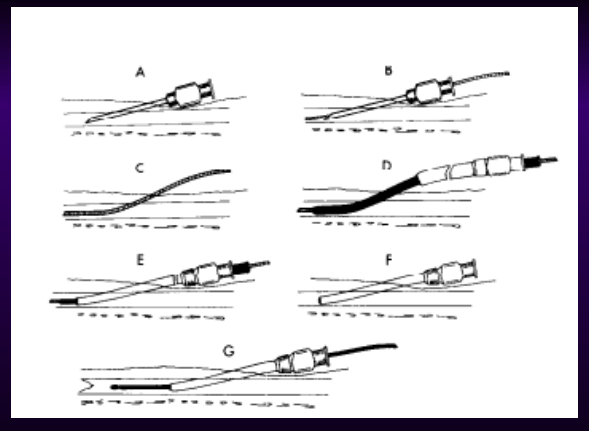
L. M. Bargeron, Jr., M.D., Larry P. Elliott, M.D., Benigno Soto, M.D., Peter R. Bream, M.D., and George C. Curry, M.D.

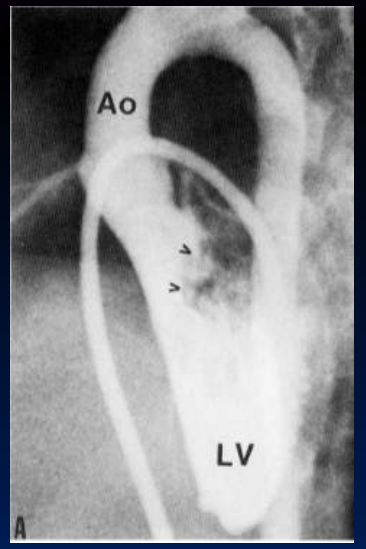
Angled Views in Cineangiocardiography of Congenital Heart Disease

Kenneth E. Fellows, M.D., John F. Keane, M.D., and Michael D. Freed, M.D.





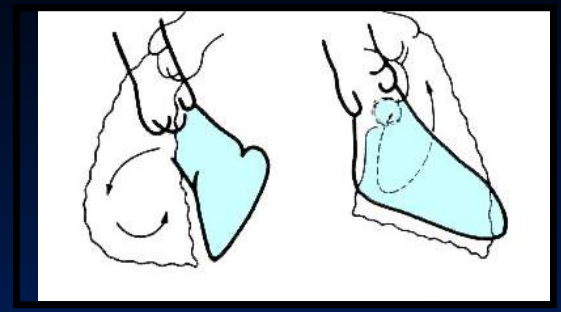




Percutaneous Sheath Cardiac Catheterization

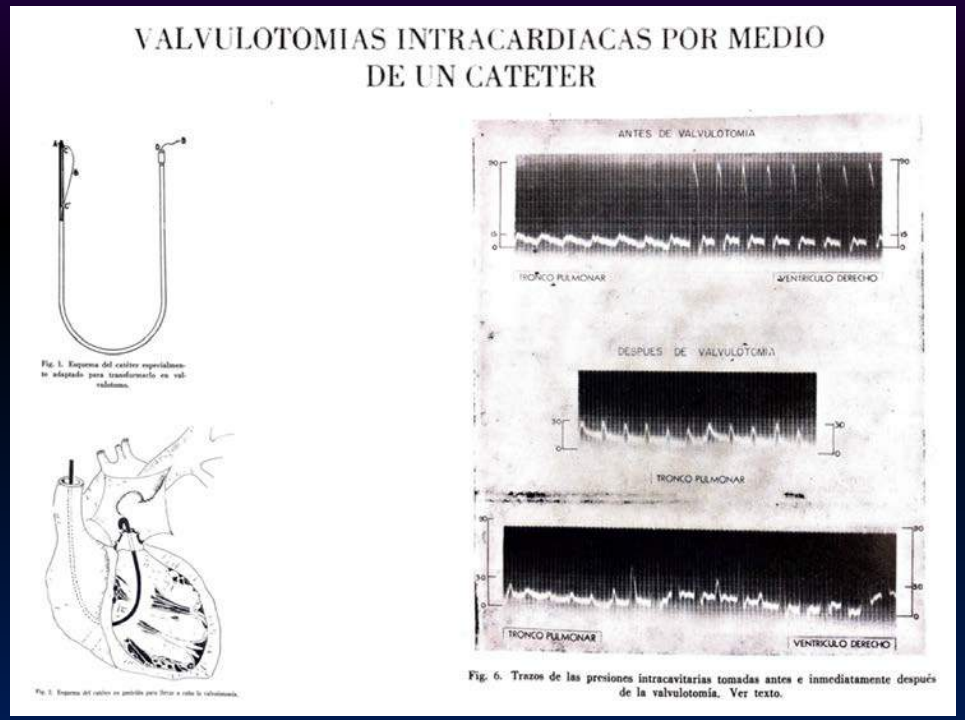
WILLIAM H. NECHES, MD*
CHARLES E. MULLINS, MD
ROBERT L. WILLIAMS, MD
THOMAS A. VARGO, MD
DAN G. McNAMARA, MD, FACC
Houston, Texas

The feasibility and safety of percutaneous
terization in infants and children was inves
July 1, 1970 to July 1, 1971. Femoral ve
an indwelling sheath was performed in 56
cedures attempted. The percutaneous tec
and a venous cutdown procedure require



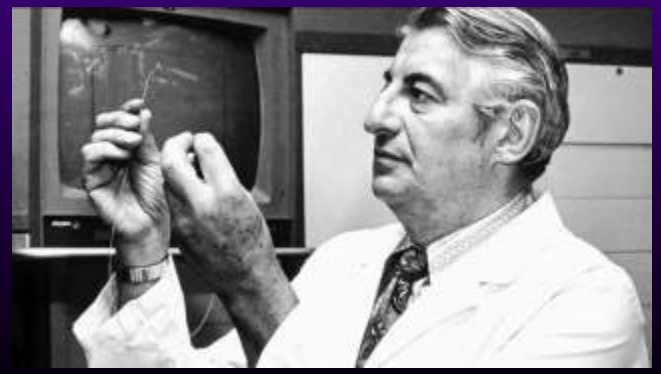
Pediatric *Interventional* Cardiology

- Rubio Alvarez & Limon 1952 ⇒ first balloon valvotomy by catheter – *pull back – dynamic technique*



Pediatric *Interventional* Cardiology

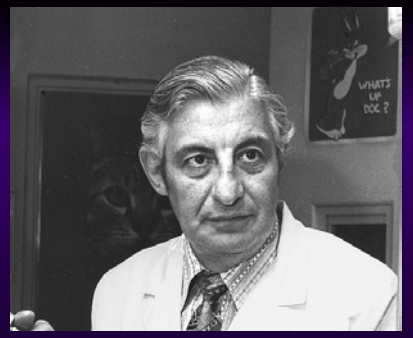
- 1966 ⇒ first balloon atrial septostomy



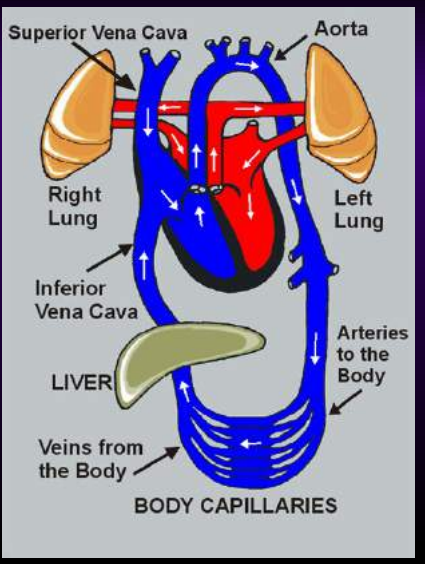
Septostomy balloon: First pediatric device to undergo a prospective FDA trial with subsequent "approval" for pediatric catheterization

Bill Rashkind

Pediatric *Interventional* Cardiology



- 1966 ⇒ first balloon atrial septostomy

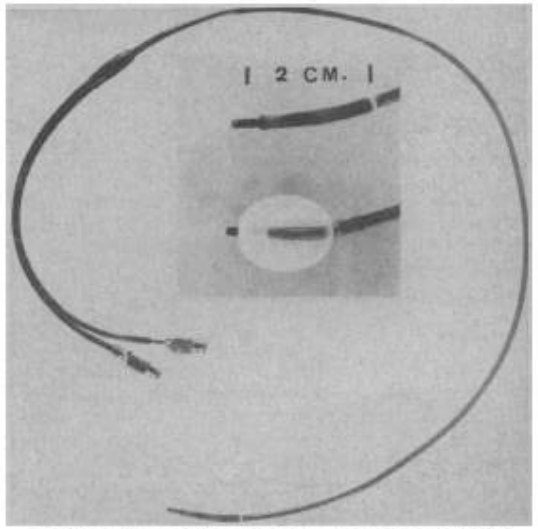


Creation of an Atrial Septal Defect Without Thoracotomy

A Palliative Approach to Complete Transposition of the Great Arteries

William J. Rashkind, MD, and William W. Miller, MD

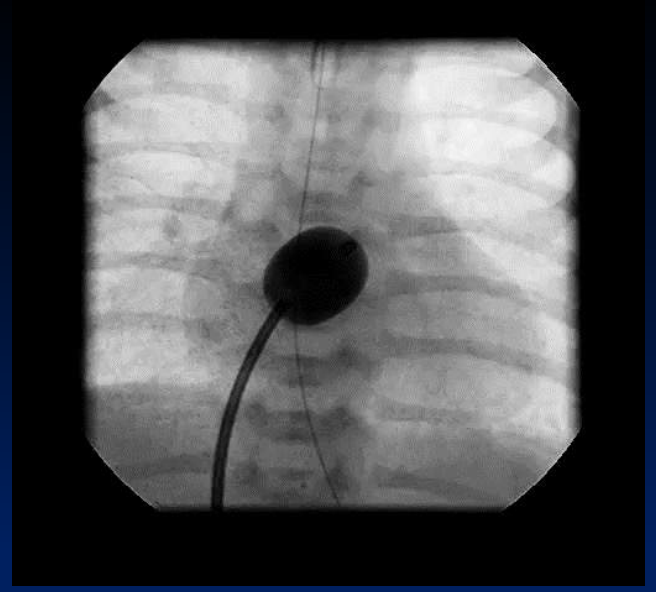
Seven littermate puppies weighing between 6 and 8 lb (2.7 to 3.6 kg) were studied. Six had atrial septal defects created by the technique described. The seventh served as a normal control. Five of the puppies have been sacrificed at intervals of one hour to two months after the procedure. The remaining puppy is being kept for one year of follow-



1. Illustration of the special balloon-tipped catheter (6.5 F). Insert shows the tip magnified in both deflated and inflated positions.

Three infants with TGV, age 15 hours, 5 weeks, and 6 weeks, have been treated successfully with this technique. None of them showed ventricular or ductal shunting on angiography. They are now

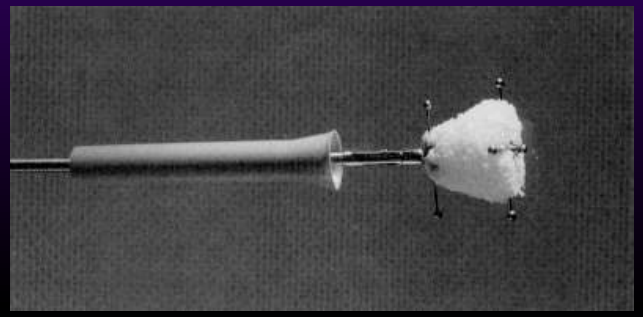
four months, seven months, and nine months post-septotomy. All are clinically well and at home.

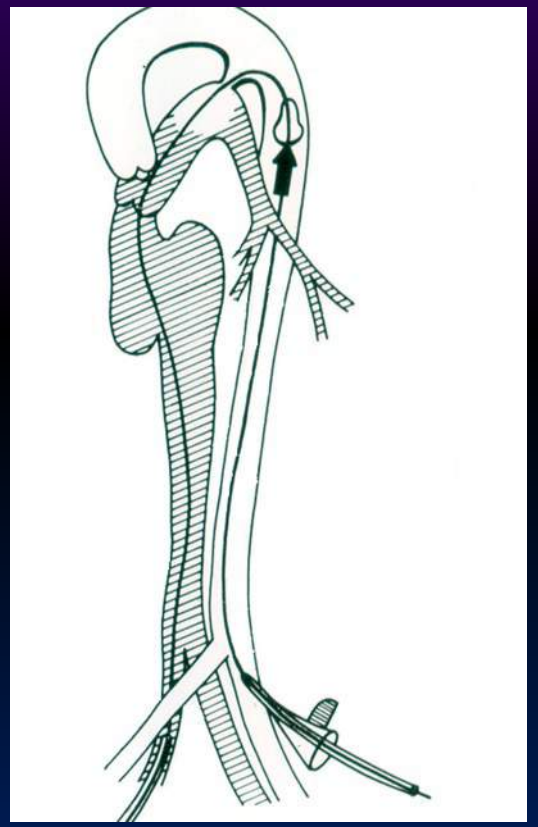


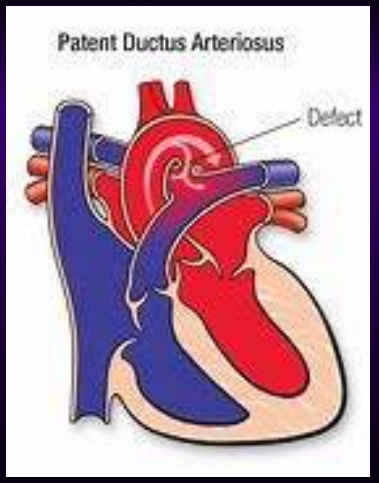
University of Pittsburgh

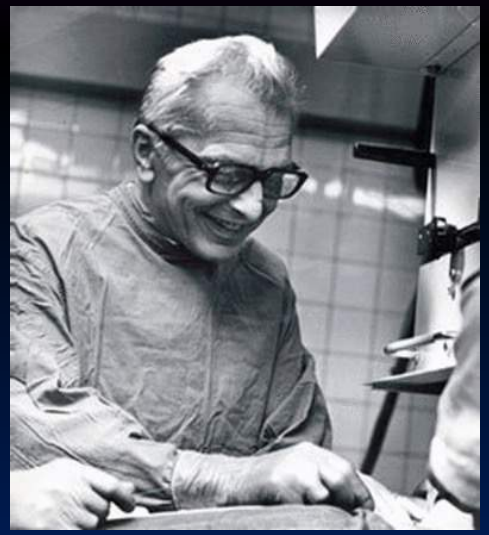
Pediatric *Interventional* Cardiology- 60s

- 1967: Portsman's PDA plug







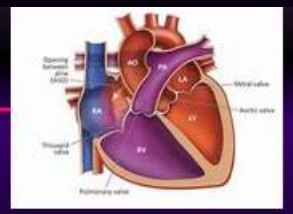


The first "correction"of a cardiac defect via a catheter technique

Pediatric *Interventional* Cardiology- 70's

Early Devices: ASD

- 1974: King and Mills: closure of atrial septal defects (ASD)



Secundum Atrial Septal Defect

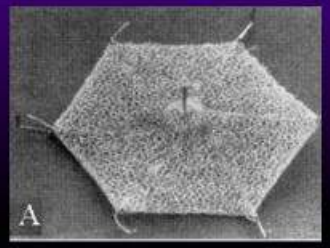
Nonoperative Closure During Cardiac Catheterization

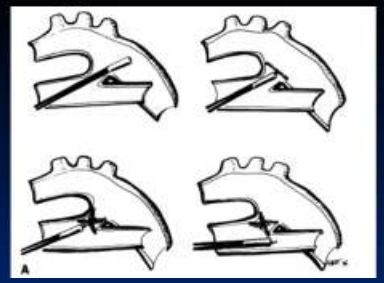
Terry D. King, MD; Sandra L. Thompson, RN; Charles Steiner, MD; Noel L. Mills, MD

First "correction" of an intracardiac defect
Their device introduced the concept of the catheter delivered "double disk" to close cardiac defects

• A 17-year-old girl had clinical and cardiac catheterization findings compatible with a secundum atrial septal defect. During cardiac catheterization, the atrial septal defect was sized and closed using a transvenous umbrella technique.
(*JAMA* 235:2506-2509, 1976)

- 1977: Rashkind transcatheter "umbrella" closure of atrial septal defect
- Shortly thereafter, Rashkind closure of a PDA

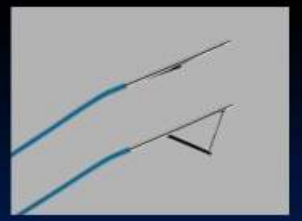




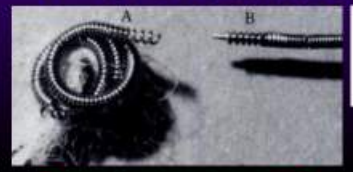
- 1975: Dr Sang Park in Pittsburgh opening atrial septum **small retractable blade**

Blade Atrial Septostomy: Collaborative Study

Sang C. Park, M.D., William H. Neches, M.D., Charles E. Mullins, M.D., Donald A. Girod, M.D., Peter M. Olley, M.D., George Falkowski, M.D., V.A. Garibjan, M.D., Robert A. Mathews, M.D., Frederick J. Fricker, M.D., Lee B. Beerman, M.D., Cora C. Lenox, M.D., and James R. Zuberbuhler, M.D.



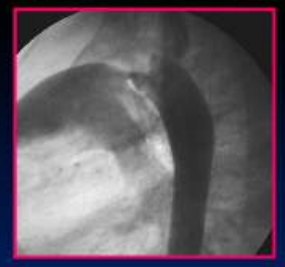
- 1975: Gianturco coils – vascular occlusion

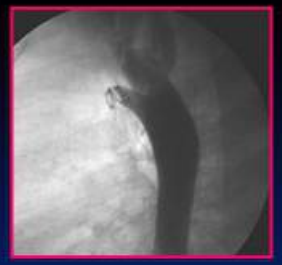


Transcatheter Intravascular Coil Occlusion of Experimental Arteriovenous Fistulas

JAMES H. ANDERSON,[1] SIDNEY WALLACE,[2] AND CESARE GIANTURCO[1]

***JAMA* 235:2506-2509, 1976**



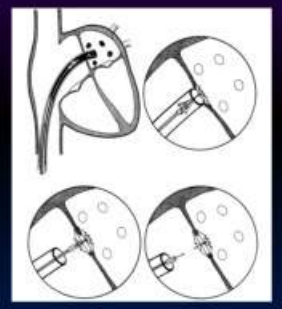


Boom of Pediatric Interventional Cardiology 80's …

- Late 80s early 90s

- 1989- closure of a ASD
Lock Clamshell






- CardioSEAL & STARFlex

Jim Lock

Transcatheter umbrella closure of congenital heart defects

JAMES E. LOCK, M.D., JOHN T. COCKERHAM, M.D., JOHN F. KEANE, M.D., JOHN P. FINLEY, M.D., PAUL E. WAKELY, JR., M.D., AND KENNETH E. FELLOWS, M.D.

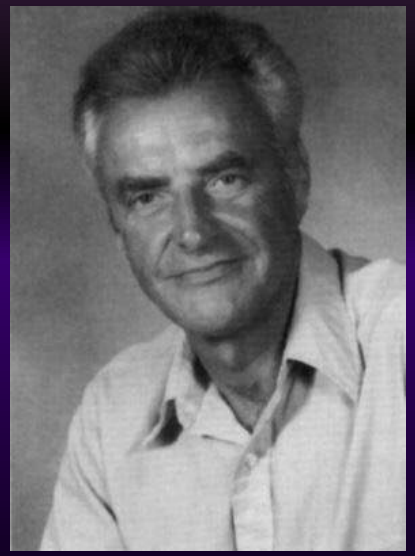
Transcatheter Closure of Ventricular Septal Defects

Double-Umbrella Closure of Atrial Defects

Initial Clinical Applications

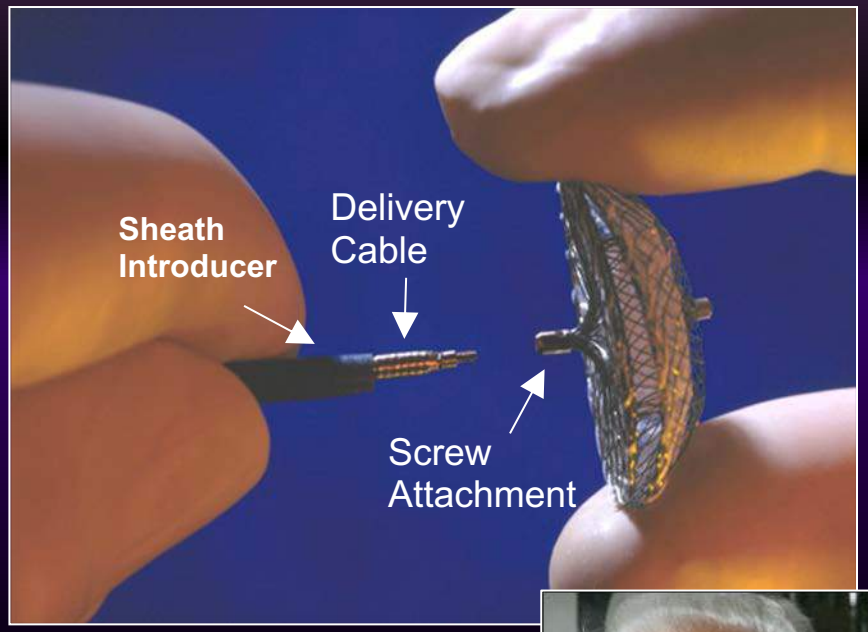
Outpatient closure of the patent ductus arteriosus

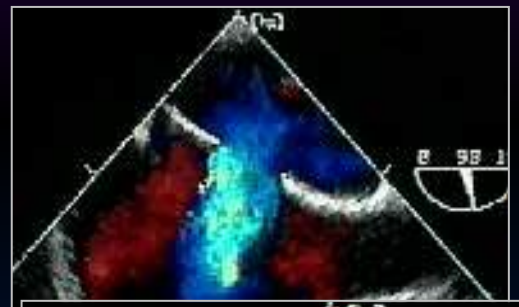
DAVID L. WESSEL, M.D., JOHN F. KEANE, M.D., IRA PARNESS, M.D., AND JAMES E. LOCK, M.D.



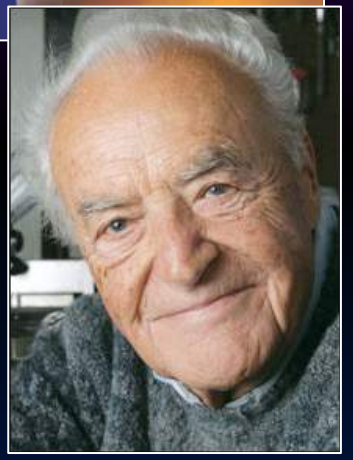
Kurt Amplatz

- Pioneer on angiography, catheter and device development

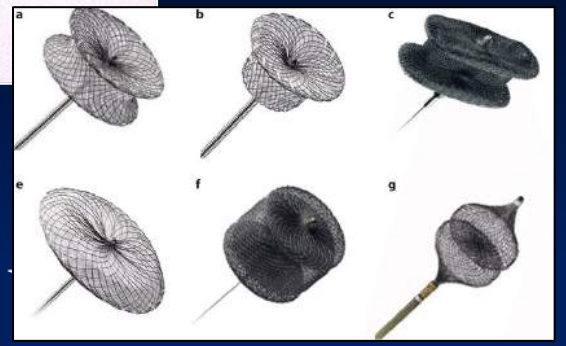




Mid 90s
Approval by FDA in 2001



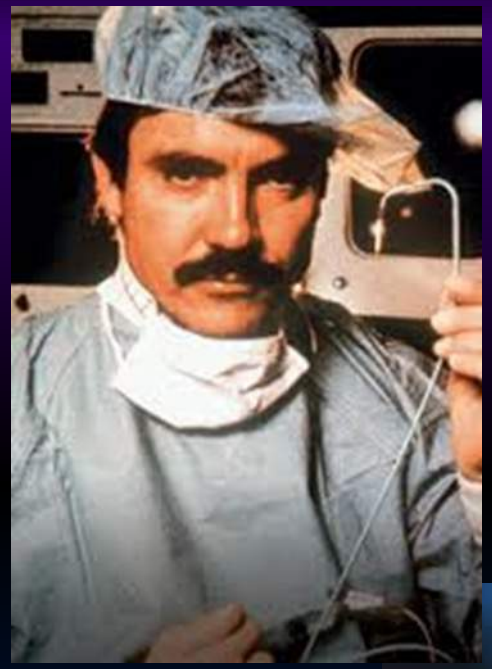
- **Self-Expandable**
- **Short-connectg Waist**
- **Nitinol Wire .004” - .008”**
- **Sizes: 4-38 mm**



Pediatric *Interventional* Cardiology- 70's

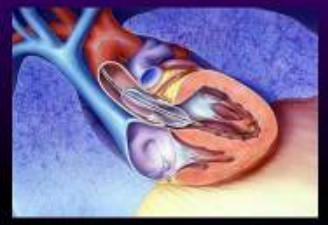
- 1974: University of Zürich, German-born physician-scientist Andreas Grüntzig first time applied a balloon-tipped catheter to re-open a severely stenosed femoral artery

"percutaneous transluminal dilatation"

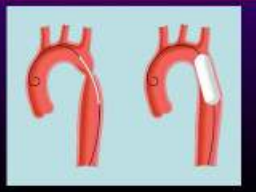


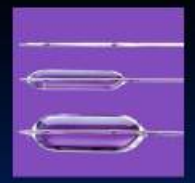
Pediatric *Interventional* Cardiology- 80's

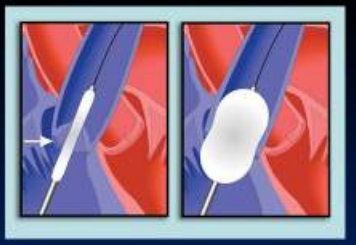
- Explosion of balloon uses
  - Lababidi 1983 balloon aortic valve & coarctation of aorta
  - Lock et al. early-mid 80s
    - branch pulmonary artery stenosis
    - aortic stenosis, coarctation of Aorta
    - systemic venous channel stenosis



- Singer et recoarctation of AO
- Driscoll et al. stenotic pulmonary veins in several critically ill patients
- Kan et al. valvar PS 1982







PEDIATRIC CARD

Early Results and Pulmonary Artery

AB
JA
Bos

Balloon Dilation of Postoperative Right Ventricular Outflow Obstructions

BENJAMIN ZEEVI, MD, JC

Balloon Dilation of Congenital Aortic Valve Stenosis

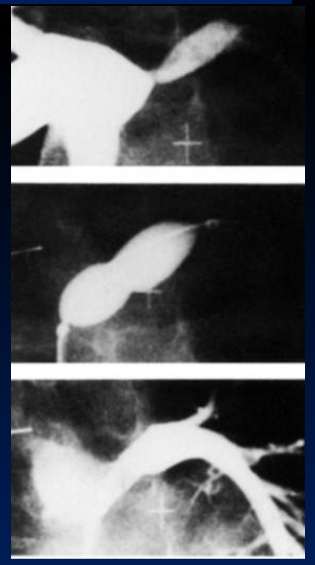
Influence of Technical and Morphological Features on Outcome

B, BS, FRACP, John F. Keane, MD, Stanton B. Perry, MD,
hen P. Sanders, MD, and James E. Lock, MD

Neonatal Critical Valvar Aortic Stenosis

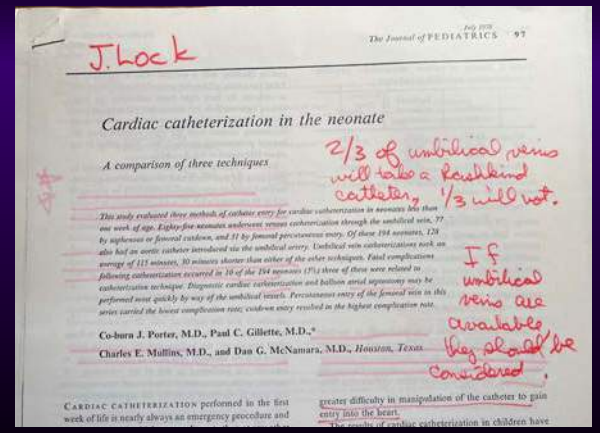
A Comparison of Surgical and Balloon Dilation Therapy

Benjamin Zeevi, MD, John F. Keane, MD, Aldo R. Castaneda, MD,
Stanton B. Perry, MD, and James E. Lock, MD, FACC



Pediatric *Interventional* Cardiology- 80's…

- The Mullins sheath
- Mullins diagrams
- Krichenko classification for PDA morphology
- Techniques newborn caths
- Stents in CHD – 1988


J. Lock

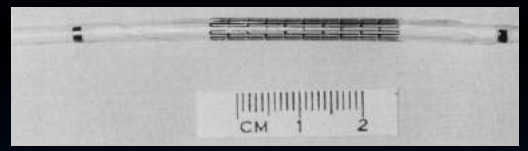
Cardiac catheterization in the neonate

A comparison of three techniques

2/3 of umbilical veins will take a Rashkind catheter, 1/3 will not.

If umbilical veins are available they should be considered.

Co-burn J. Porter, M.D., Paul C. Gillette, M.D.,*
Charles E. Mullins, M.D., and Dan G. McNamara, M.D., Houston, Texas



Double-Transseptal, Double-Balloon Valvuloplasty for Congenital Mitral Stenosis

Ronald G. Grifka, MD; Martin P. O'Laugh
Michael R. Nihill, MD, FACC; and Charles E.

Congenital Stenosis of Individu
Clinical Spectrum and Unsucc
Transvenous Balloon Dilation

DAVID J. DRISCOLL, MD, FACC*
PETER S. HESSLEIN, MD
CHARLES E. MULLINS, MD, FACC

Houston, Texas

Doub
in C

CHARLES E. MULLINS, MD, FAC
G. WESLEY VICK III, MD, PHD, A
J. TIMOTHY BRICKER, MD, FAC

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congenital cardiac defects. Two of the eig
after operative pulmonary venoplasty. In t

Implantation of balloon-expandable intravascular

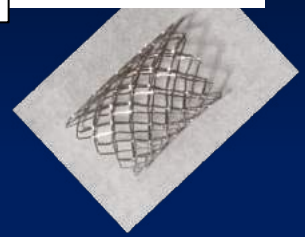
eries and

Re-expansion of Balloon-Expandable Stents After Growth

W. ROBERT MORROW, MD, FACC, JULIO C. PALMAZ, MD,* FERMIN O. TIO, MD,*
WILLIAM J. EHLER, DVM,† ADRIAN F. VANDELLEN, DVM,†
CHARLES E. MULLINS, MD, FACC‡

II, M.D., PH.D.,

May 1982 The American Journal of CARDIOLOGY



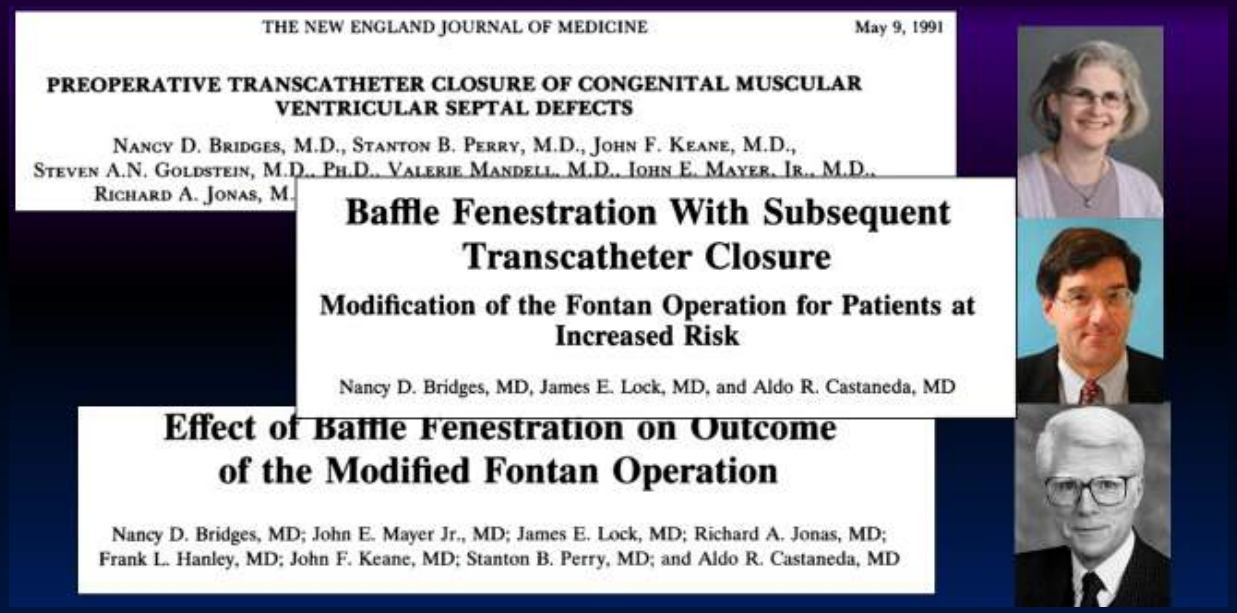
Chuck Mullins

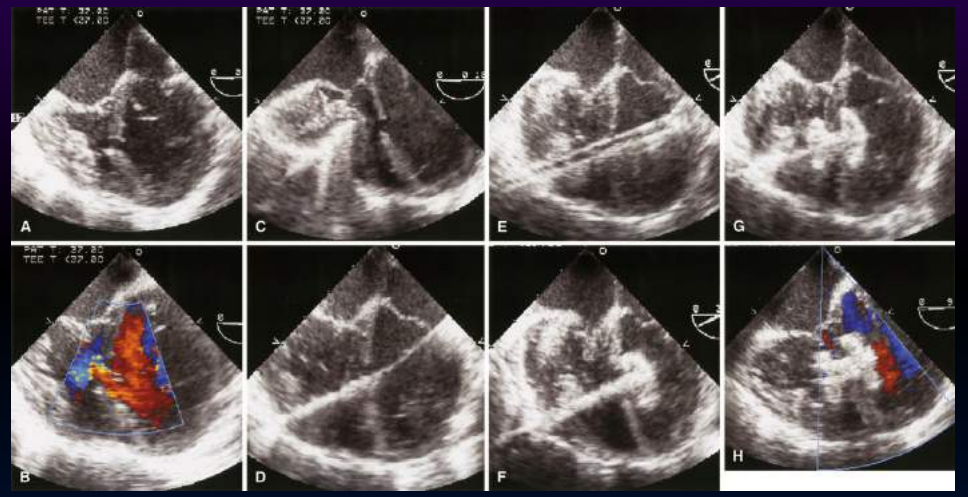
Pediatric *Interventional* Cardiology- 80's…

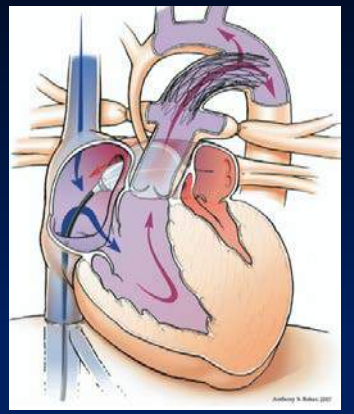
Chuck Mullins

Pediatric *Interventional* Cardiology & CT Surgery

- Since early in the development of the subspecialty CT surgery and interventional pediatric cardiology – true partnership
- Hybrid procedures





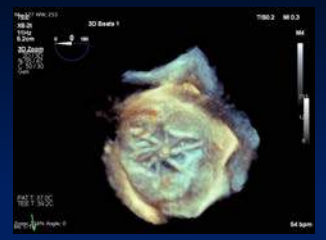


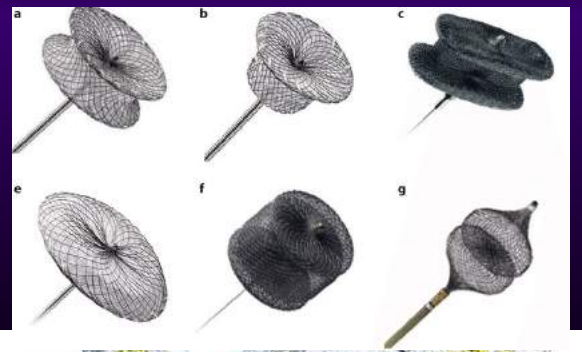
Intraoperative Device Closure of Ventricular Septal Defects

Steven B. Fishberger, MD; Nancy D. Bridges, MD; John F. Keane, MD; Frank L. Hanley, MD; Richard A. Jonas, MD; John E. Mayer, MD; Aldo R. Castaneda, MD; James E. Lock, MD

Further Improvements in Catheter Technologies

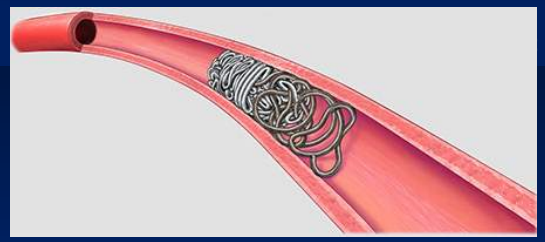
- New closure devices
  - Helex Gore
  - CARDIOFORM





- Device of choice ASD secundum

- New embolization tools

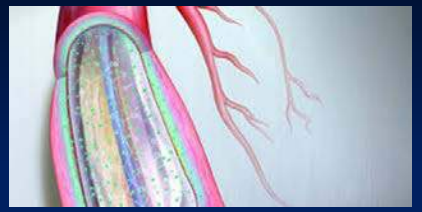


Further Improvements in Catheter Technologies

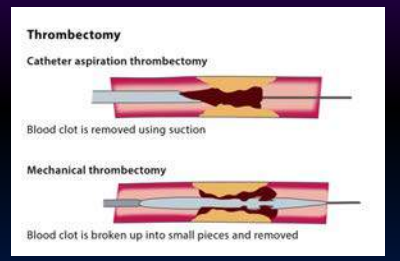
- New angioplasty tools
  - Cutting balloons
  - Angiosculp
  - Ultra high pressure balloons
  - Drug eluting balloons (paclitaxel)

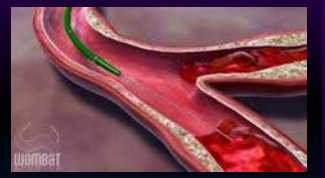




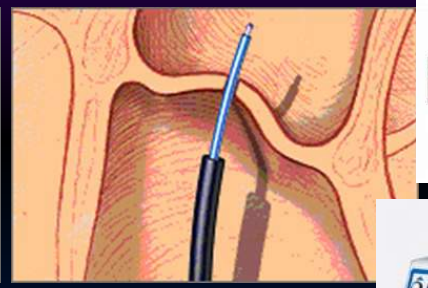
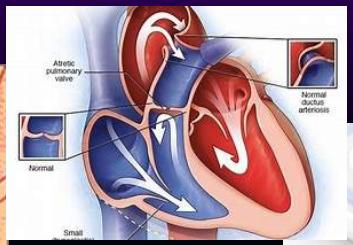



- Transcatheter perforation & recanalization tools





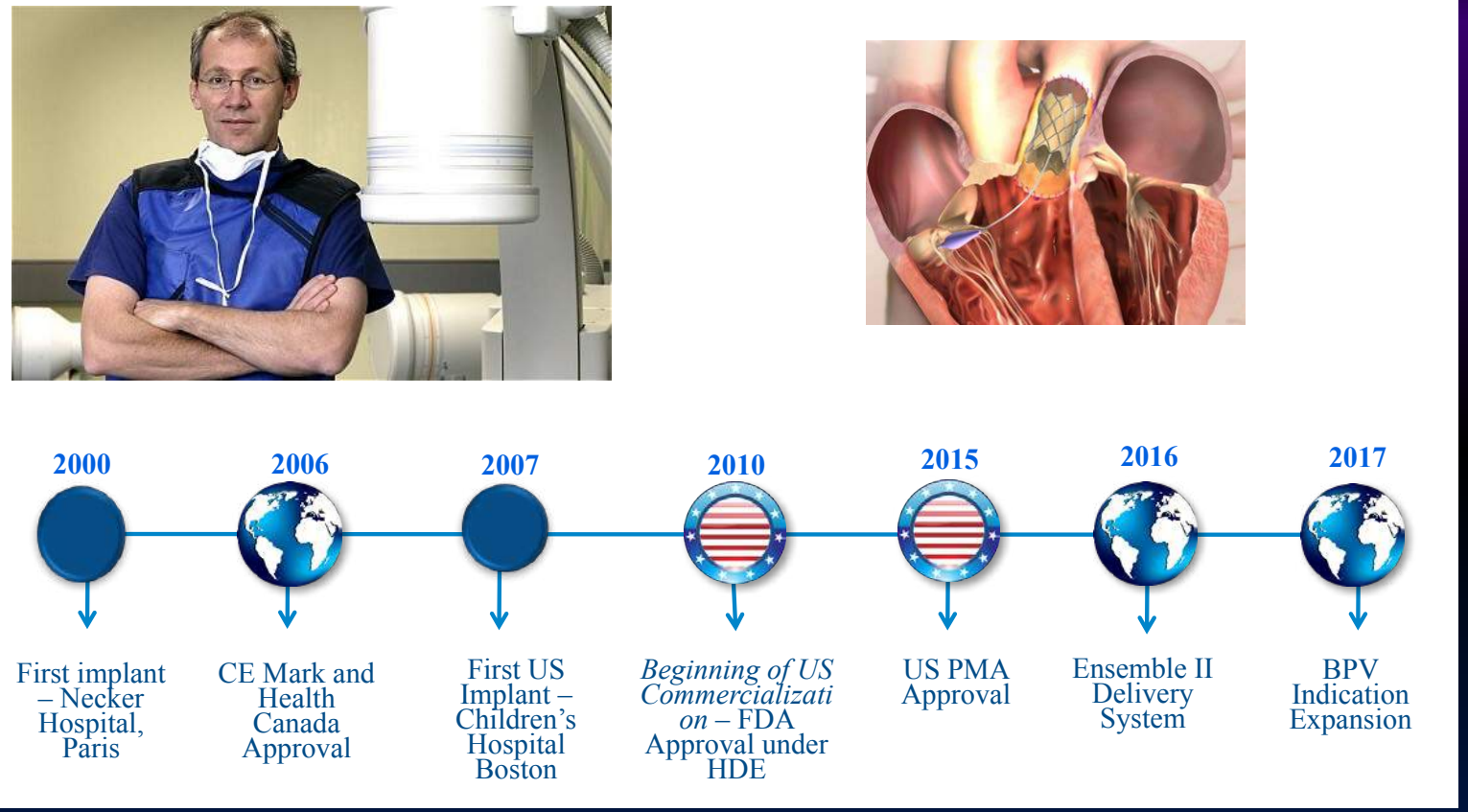

- Radiofrequency perforation


Vascular recanalization

- Nykanen RF Wire

Further Improvements in Catheter Technologies

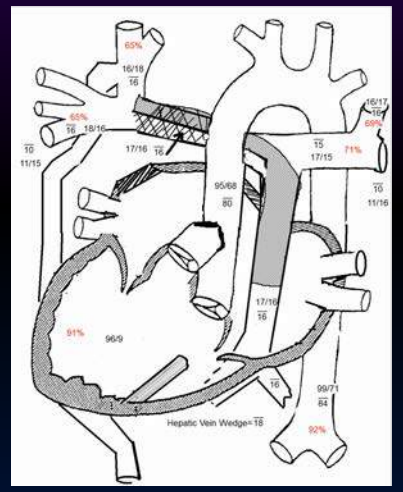


UPMC CHILDREN'S HEART INSTITUTE

Further Improvements in Catheter Technologies

- New stent technology

- Innovative use of covered stents to create anastomosis



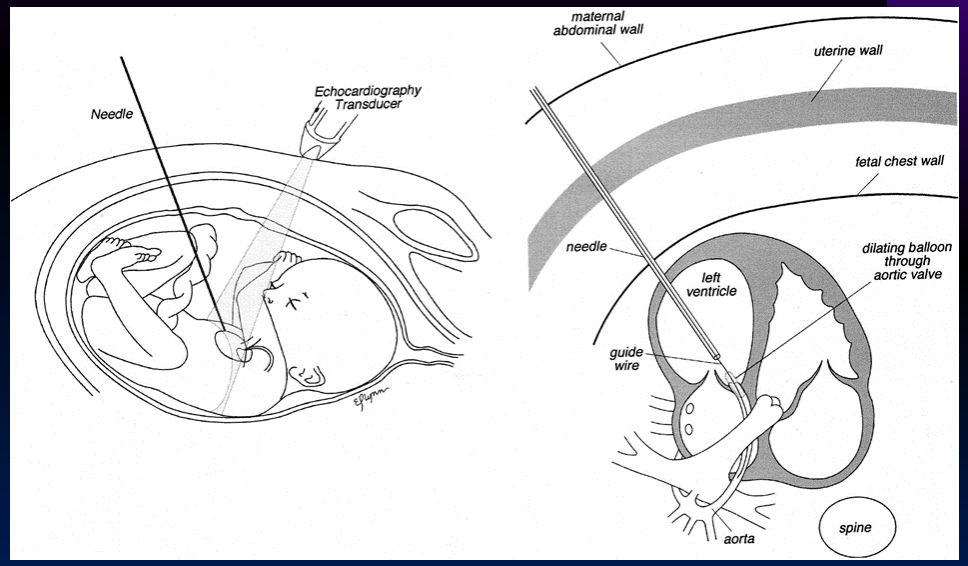
Decompression of the thoracic duct: A novel transcatheter approach

Christopher L. Smith MD, PhD[1] | Timothy M. Hoffman MD[2] | Yoav Dori MD, PhD[1] | Jonathan J. Rome MD[1]

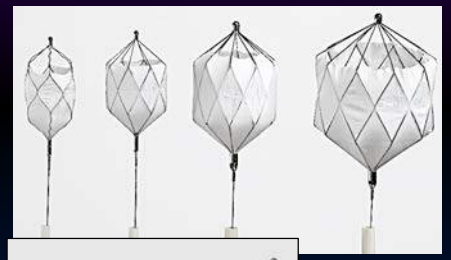
University of Pittsburgh

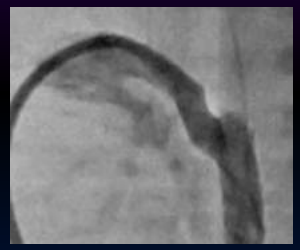
Evolution of the field: Further Changes

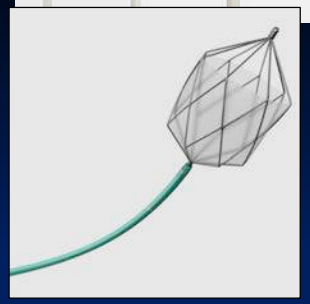
- *Prenatal catheter interventions*
- *PDA closure - premie ducts less than 1kg!*



- Piccolo Device
- Microvascular plug MVP



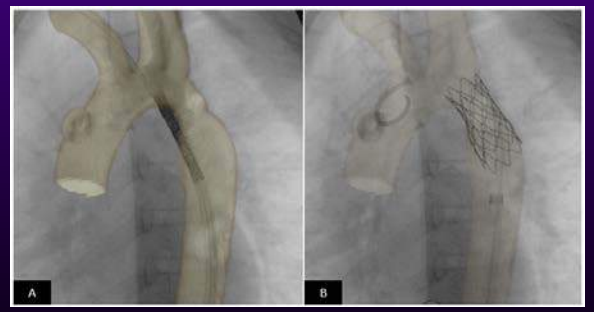


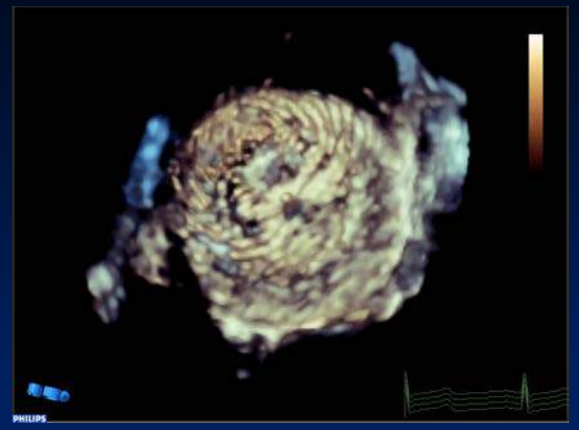


UPMC | HEART AND VASCULAR INSTITUTE

Evolution of the field – Partnership with Cardiac Imaging

- TEE guidance
- ICE
- 3D echo technologies
- Advanced imaging – Cardiac CT & Cardiac MRI
- Pre-procedure 3 D printing planning
- Fusion imaging technology
- ICMRI





Evolution of the field – Multicenter Collaboratives

- VACA Valvuloplasty Angioplasty Congenital Anomalies
- PCCC
- MAGIC
- CCISC
- C3PO
- IMPACT Registry
- CCRC

James H. Moller, MD
Catherine Borbas, MPH

The Pediatric Cardiac Care Consortium: A Physician-Managed Clinical Review Program

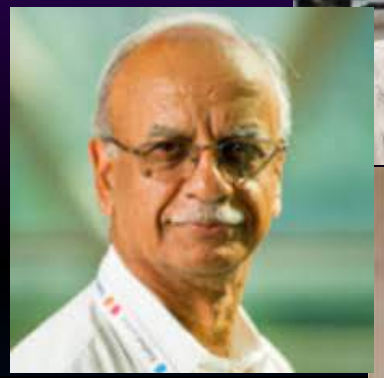
CCRC
CONGENITAL CARDIAC RESEARCH COLLABORATIVE

Adverse Event Rates in Congenital Cardiac Catheterization – A Multi-Center Experience

IMPACT Registry™

C3PO Congenital Cardiac Catheterization Outcomes Project

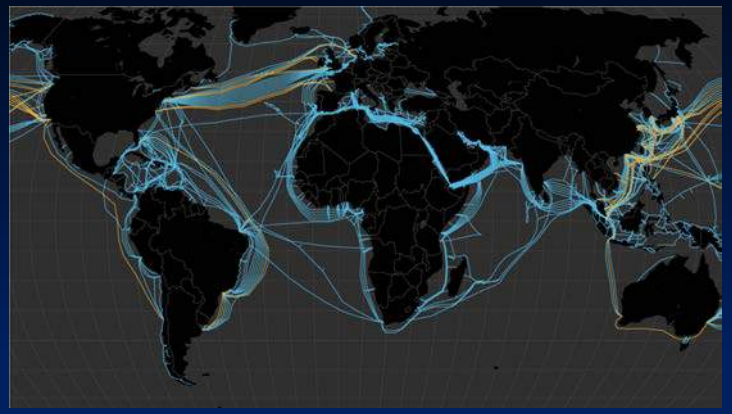
Evolution of the field: Connecting us across the world



PICS-AICS
Pediatric and Adult Interventional Cardiac Symposium

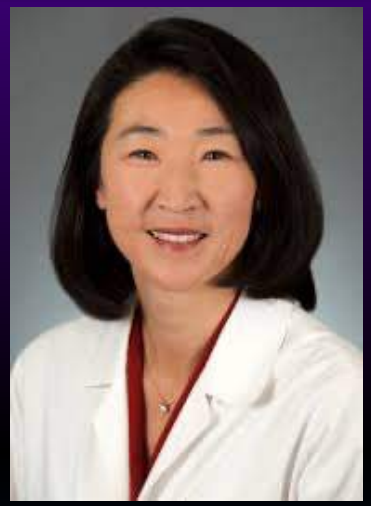
PICS Society
Pediatric and Congenital Interventional Cardiovascular Society

- Live case sessions
- Training sessions
- State of the art
- Introduction of new technologies
- More



Evolution of the field: More Diversity

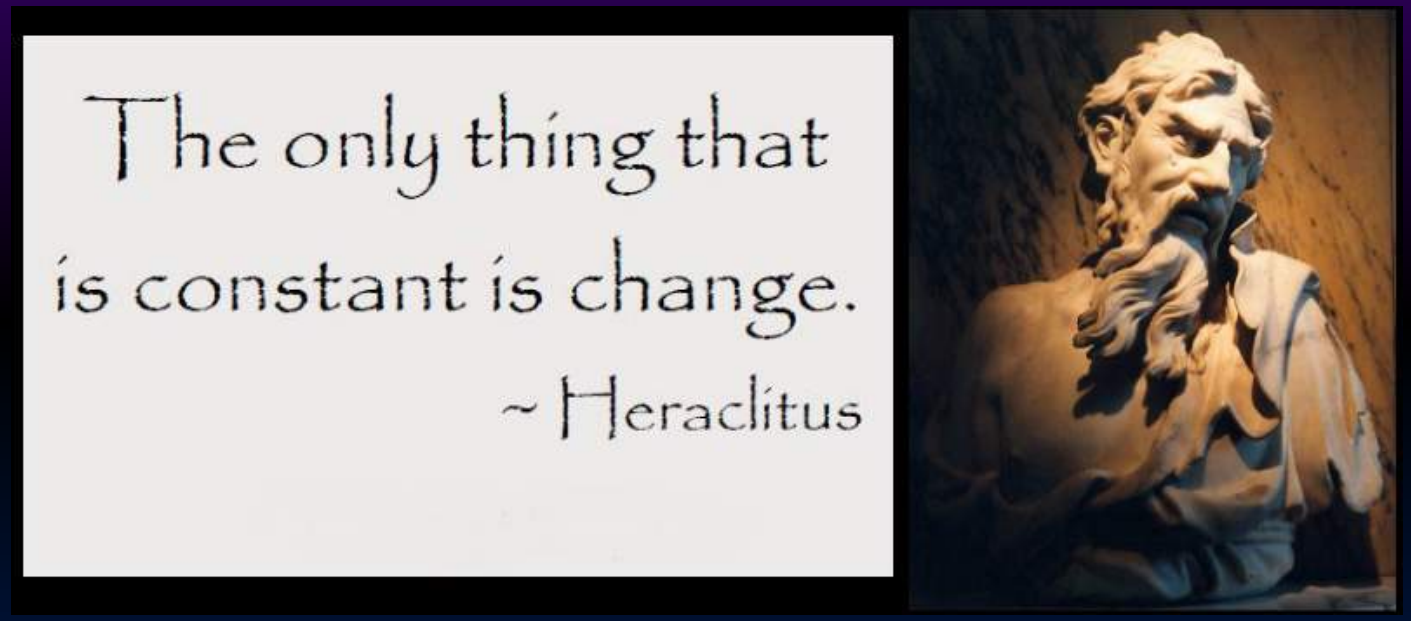




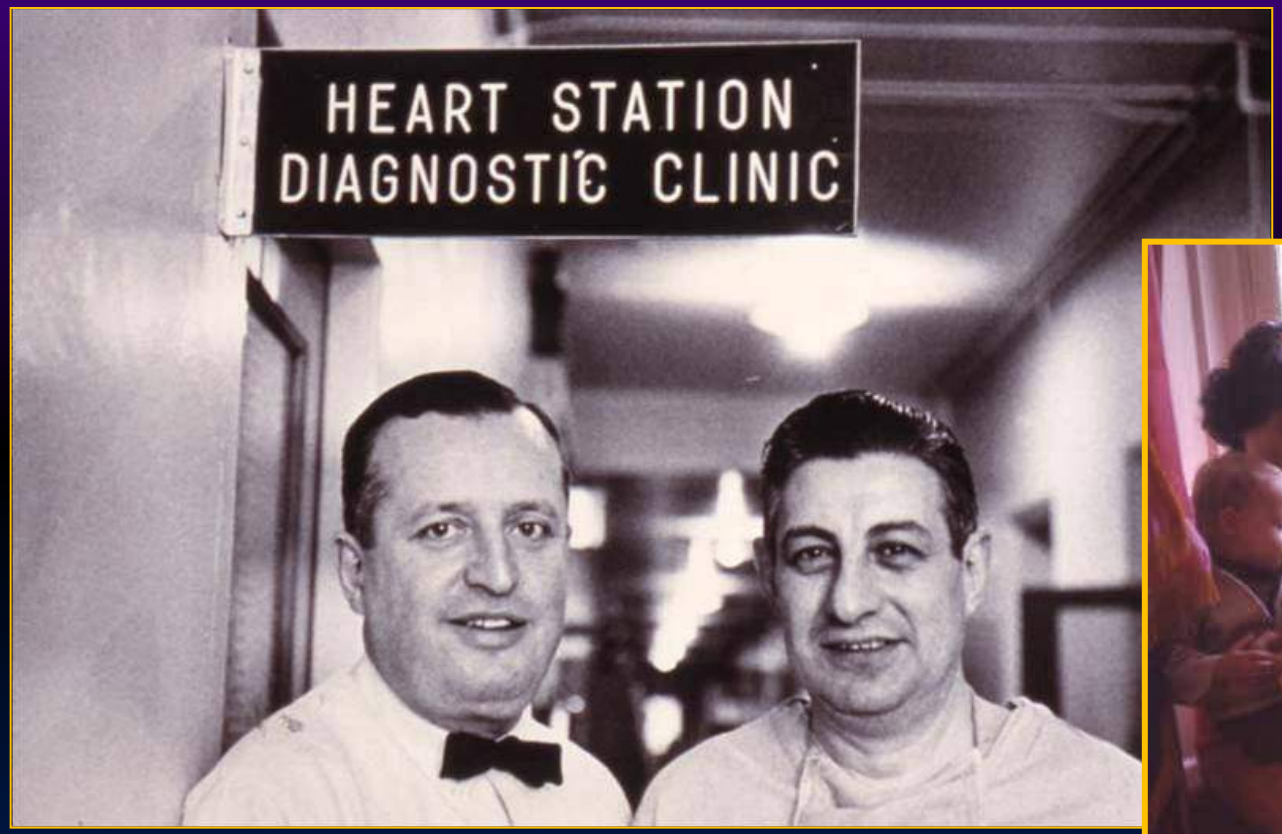





Evolution of the field- Conclusion



Remembering Bill Rashkind



Remembering Bill Rashkind

"It would be wonderful if we can do some of the simpler operations without opening the chest..
I think that is a real advance and a real look into the future."

UPMC | CHILDREN'S HOSPITAL OF PITTSBURGH

Muchas Gracias!