

## Original Article

# Key events in the history of cardiac surgery and paediatric cardiology\*

Tom R. Karl,<sup>1,2</sup> Gerard R. Martin,<sup>3</sup> Jeffrey P. Jacobs,<sup>1,2</sup> Gil Wernovsky<sup>4</sup>

<sup>1</sup>*Division of Cardiovascular Surgery, Johns Hopkins All Children's Heart Institute, Johns Hopkins All Children's Hospital, Saint Petersburg, Florida;* <sup>2</sup>*Departments of Surgery and Pediatrics, Johns Hopkins University, Baltimore, Maryland;* <sup>3</sup>*Department of Cardiology, Children's National Health System, Washington, District of Columbia;* <sup>4</sup>*Division of Critical Care Medicine, Children's National Health System, Washington, District of Columbia, United States of America*

**Abstract** In this report, the authors prepared an opinion poll regarding the most important people, events, technologies, concepts, discoveries, and therapies in paediatric cardiology and cardiac surgery. The results were presented in continuous slide show format at the 2017 Seventh World Congress of Pediatric Cardiology & Cardiac Surgery (WCPCCS 2017), Barcelona, Spain. The presentation (under international copyright) is made available herein for educational purposes.

Keywords: Pediatric cardiology; cardiac surgery; history

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All we know is still infinitely less than all that remains unknown.

William Harvey (1578–1657)

The 2017 World Congress of Pediatric Cardiology and Cardiac Surgery (WCPCCS 2017) was held in Barcelona, Spain, from 16 to 21 July, 2017. In preparation for this congress, which itself promised to be a significant historic initiative, the authors, on invitation of the organising committee, took the initiative to nominate the most important events that have shaped our speciality. The history of paediatric cardiology is rich and fascinating. However, it is fair to say that our own era of complex diagnostic imaging, sophisticated intensive care, and neonatal open-heart surgery comprises a very small portion of the timeline (Fig 1). If one were to take the work of Galen (de Curandi, c. 162 AD) as time 12:01 AM in a single day and the WCPCCS 2017 as midnight, then

cardiopulmonary bypass would not appear until 11:26 PM. The Raskind septostomy would appear around 11:26 PM, and the Norwood operation around 11:40 PM. This brings to mind the often quoted words of Isaac Newton, who said, paraphrasing Bernard de Chartres, that “If I have seen further, it is by standing on the shoulders of giants”. This statement, to be sure, constitutes the essence of progress and discovery in any field. Yet, amidst the complexities and demands of our own careers, it is sometimes easy to overlook this fact. Our aim in undertaking this study was to document, present, and further preserve some of the key events and contributions that have brought us to the point of the 2017 World Congress. In doing so, we sought to recognise and honour the many great contributors of past and present eras, and to place our own careers in a realistic perspective. The results of the survey were tabulated and the authors prepared a presentation of the outcome in the format of a continuous “slide show”, which was displayed in various venues of the Convention Center between scientific presentations of the WCPCCS 2017.

## Method

To assess the relative importance of the many contributions that have influenced our speciality, we

\*Presented at the 2017 Seventh World Congress of Pediatric Cardiology & Cardiac Surgery (WCPCCS 2017), Barcelona, Spain, 16–21 July, 2017. Presented Friday, 21 July, 2017.

Correspondence to: Professor T. R. Karl, Johns Hopkins All Children's Heart Institute, Johns Hopkins All Children's Hospital, 601, 5th St. South, Suite 607, St. Petersburg, FL 33701, United States of America. Tel: +1 727 303 9511; E-mail: Trkarl.aus@gmail.com

conducted an opinion poll among paediatric cardiologists, cardiac surgeons, and cardiac intensivists, all of whom were currently working in these capacities in various parts of the world. The methodology involved writing to a selection of eminent practitioners who were known to the authors and perhaps more likely to respond (“convenience sample”). The question posed was, by intent, somewhat free form. Respondents were asked to nominate as many events, people, technologies, concepts, discoveries, and so on as they desired. The unifying thread was that the choices would be considered outstanding or seminal in the history of paediatric cardiology and cardiac surgery. No time constraints were imposed, allowing nominations from any period, including the present. No justification for the choices was required, and the responses represent personal expert opinions, which, by design, were not necessarily evidence based.

## Results

In all, 86 individuals were invited to offer an opinion. From this group, there were 48 respondents (56%) for whom a breakdown is given in Figure 1. There were 28 cardiologists and intensivists – 58% of respondents – and 20 surgeons – 42% of respondents – representing 16 countries in Australasia, North America, Africa, Europe, and the Middle East. The authors collated the responses and grouped them by the number of nominations for each category. Some of the responses could have been assigned to multiple categories, but were counted only once. Nominations were grouped according to the number of times each was submitted. Ultimately, the 50 highest scoring nominations were included in the WCPCCS presentation. They were grouped as follows, and presented in alphabetical order:

Group 1 included items receiving 24 or more votes, including the following:

- Arterial switch operation
- Blalock–Taussig shunt (Blalock, Taussig, and Thomas)
- Cardiopulmonary bypass
- Echocardiographic imaging (including foetal echocardiography)
- Fontan/Kreutzer procedure and subsequent modifications
- Dr William Norwood and the Norwood Procedure
- Rashkind atrial septostomy
- Prostaglandin

Group 2 included items receiving 15–21 votes, including the following:

- Dr Robert Anderson (nomenclature and anatomic concepts)

- Dr Philipp Bonhoeffer and transcatheter pulmonary valve replacement (over all other interventional catheter procedures)
- Cardiac critical care as a discipline
- Computer technology
- Databases (STS, PHYS, PC4, IMPACT)
- Digitisation of cardiac images
- Electronic health records
- Foetal echocardiography
- Interventional catheterisation, including atrial septal defect closure, persistent ductus arteriosus closure, balloon valvotomy, all types of balloon dilations, and all types of stents
- Mustard and Senning procedures
- Persistent ductus arteriosus ligation
- Dr Richard and Dr Stella Van Praagh (nomenclature and anatomic concepts)

Group 3 included items receiving 10–14 votes, including the following:

- Ablation of accessory pathways
- Cardiac catheterisation for haemodynamics and angiography
- Cardiac MRI and CT
- Cardiac transplantation
- Coarctation repair (Dr Clarence Crafoord)
- Cross-circulation for support in cardiac surgery
- Dr Aldo Castaneda
- Dr C. Walton Lillehei’s multiple contributions
- Extracorporeal membrane oxygenation
- Implantable cardiac pacemakers and defibrillators
- Genetics and genomics and the secondary heart field
- Nitric oxide
- Surgery for the neonate (early correction of CHD)
- Ventricular assist devices, especially Berlin Heart

Group 4 included items receiving five to nine votes, including the following:

- Adult CHD as a discipline
- Dr Kurt Amplatz
- Dr Leonard Bailey
- Cardioplegia
- Channelopathies
- Deep hypothermic circulatory arrest
- Dr Marc de Leval
- Electrocardiography
- Dr Paul Gillette
- Heparin
- Implementation of clinical trials in CHD (various)
- Dr James Lock
- Mechanical and biological prosthetic heart valves
- Dr Alexander Nadas
- “Natural History Study” of CHD
- Neurodevelopmental outcome analysis
- Paediatric cardiac nursing as a discipline
- Pulmonary hypertension management

- Dr Giancarlo Rastelli (the Rastelli operation and right ventricle to pulmonary artery conduits)
- Sir Donald Ross and the pulmonary autograft procedure
- Sir William Harvey
- Stem cells in heart disease
- Transoesophageal echocardiography

An additional 215 items received at least one vote. The categories of nomination, speaking broadly, can be grouped as follows: individuals (9), operations (8), specific types of interventional cardiologic procedures (7), medications (4), technology (7), imaging (6), organisation of care (4), nomenclature (1), support systems for surgery (4), concepts (3), basic science (4), and clinical outcome research (2).

Finally, during the 2017 WCPCCS, the organisers – including Jeffrey P. Jacobs, Gil Wernovsky, Mitchell Cohen, and David Cooper – of the 2021 WCPCCS to be held from September 19 to 24, 2021, in Washington, DC, United States of America ([www.WCPCCS2021.org](http://www.WCPCCS2021.org)), presented a timeline of important events in the history of congenital and paediatric cardiac care, which can be found as Figure 1. A color version of the timeline is available at [WCPCCS2021.org](http://WCPCCS2021.org)

## Discussion

Many of the attendees of the Congress have expressed an interest in obtaining a copy of the presentation, so

the authors, in conjunction with Cardiology in the Young, have decided to make the entire work available (Fig 2). The presentation is protected by international copyright but can be freely used for academic and educational purposes. Permission to reproduce any of the material in the presentation can be requested from the authors. The slide show is reproduced here in the exact format presented at the WCPCCS in Barcelona.

## Conclusion

There appears to be considerable interest in our heritage, as evidenced by the number of recent requests for this presentation, as well as the interest expressed during the WCPCCS for both access to the presentation and copies of the timeline. The task of ordering events by their importance is clearly subjective and probably impossible to complete in a simple survey of this type. We clearly recognise the importance of many other people, technologies, procedures, disciplines, and much more. These contributions constitute the “shoulders of giants” on which we currently stand. Nonetheless, it is particularly interesting to note the diversity of responses from what could be considered a rather homogeneous group of paediatric cardiac practitioners. The authors hope, however, that the responses will be thought provoking, and a tribute to those who have contributed in ways that we will continue to recognise and honour.

Timeline created for the 2021 WCPCCS exhibit in Barcelona

### 1600s

De Motu Cordis (Harvey)  
Rheumatic fever described (Sydenham)

### 1800s

Stethoscope (Laennec)  
Anesthesia  
Measured cardiac output (Fick)  
Tetralogy described (Fallot)  
Transposition described (Baille)  
The Principles & Practices of Medicine (Osler)  
X-Ray imaging discovered (Roentgen)  
Cardiac surgery for stab wounds  
Discovery of protamine  
Artificial ventilation described  
First children's hospital (Hôpital des Enfants Malades, Paris))

### 1900s – 1950s

Electrocardiography (Einthoven)  
Atlas of Congenital Heart Disease (Abbott)  
Discovery of heparin  
Endotracheal intubation and mechanical ventilation  
Cardiac catheterization  
Persistent ductus arteriosus ligation  
Isolation of digoxin from foxglove  
Mechanisms of pulmonary hypertension described  
Hypoplastic left heart syndrome described  
Preventative cardiology  
Wolff-Parkinson-White arrhythmia  
Coarctation repair (Crafoord)  
Blalock-Taussig shunt (Blalock, Taussig, Thomas)  
Battery operated Pacemaker (Bakken)  
AC defibrillation (Zoll)  
First implantable pacemaker (Senning)  
Atrial septectomy (Blalock and Hanlon)  
Waterston shunt  
Potts Shunt  
Pulmonary valvotomy (Brock)  
Pulmonary arterial band  
Cross-circulation (Lillehei)  
Open heart surgery with cardiopulmonary bypass (Dennis and others)  
Senning operation  
Glenn shunt  
Pulse oximetry  
Clinical use of coumadin (warfarin)  
Sudden cardiac death described  
Penicillin for rheumatic fever

#### Figure 1.

*Timeline of Pediatric and Congenital Cardiac Care, prepared by the organisers – including Jeffrey P. Jacobs, MD, Gil Wernowsky, Mitchell Coben, and David Cooper – of the 2021 WCPCCS to be held from 19 to 24 September, 2021, in Washington, DC, United States of America (www.WCPCCS2021.org).*



**1960s**

Transvenous pacemakers  
Dedicated cardiac ICU (adult)  
Cardiopulmonary resuscitation described  
Description of fetal circulation  
Mustard operation  
Morphologic descriptions of congenital heart disease  
Natural History Study 1  
Long QT syndrome described  
Rashkind procedure  
Transcatheter closure of ductus arteriosus (Portsmann)  
Kawasaki disease described  
Fontan and Kreutzer right heart bypass  
Di George syndrome described  
Rastelli operation  
Amiodarone introduced  
Closed mitral commissurotomy  
Ventricular assist device (DeBakey)  
Pulmonary autograft aortic valve replacement (Ross)  
Lung transplantation  
Surgical ablation of WPW  
Transvenous defibrillation  
Heart transplantation

**1970s**

Polytetrafluoroethylene (Gore-tex) for clinical use  
Transesophageal echocardiography  
Prostaglandin E1  
Transcatheter ASD closure (King)  
Extracorporeal membrane oxygenation  
Arterial switch for TGA/VSD (Jatene)  
High frequency oscillatory ventilation  
Adult congenital heart disease/Grown up congenital heart disease specialty  
Percutaneous coronary intervention  
Electrophysiologic mapping  
Expansion of clinical applications of genetics/genomics  
Total parenteral nutrition  
Gamma globulin for Kawasaki disease  
Cyclosporine introduced  
Pediatric intensive care  
Transesophageal echocardiography  
Norwood Procedure  
Neonatal arterial switch operation

**1980s**

Ablation for arrhythmia in adults  
Implantable cardiac defibrillator (trans-thoracic and trans-venous)  
Heart lung transplantation  
Natural History Study 2  
Transcatheter pulmonary valvotomy (Kan)  
Xenotransplantation (Bailey)  
Pediatric cardiac intensive care  
Pulmonary artery angioplasty  
Balloon expandable vascular stents  
Recognition and study of developmental disabilities in cardiac patients

*(continued)*

Boston Circulatory Arrest Trial  
Nitric oxide  
Total cavopulmonary connection (de Leval)  
Indomethacin for ductal closure  
Society of Thoracic Surgeons Database  
Fetal cardiac intervention  
Extracardiac Fontan (Marcelletti et al)  
Focalization of pulmonary arteries in infants  
World Congresses: London, New York, Bergamo, Bangkok

**1990s**

Ablation for arrhythmia in children  
Primacorp trial (milrinone)  
Amplatzer atrial septal defect closure  
ABO incompatible heart transplantation  
Cardiac MRI evolves  
Expansion of databases and registries  
Palivizumab trial  
Adenosine for supraventricular tachycardia  
Radiofrequency ablation for arrhythmia treatment  
Berlin Heart VAD development  
Electronic medical records  
Telemedicine  
Tissue engineering for cardiac implants  
World Congresses: Paris, Honolulu

**2000s**

Fetal cardiac catheter intervention  
Transcatheter pulmonary valve replacement (Bonhoeffer)  
Hybrid surgical strategy for hypoplastic left heart syndrome  
IMPACT Registry  
Single Ventricle Reconstruction trial  
Transcatheter aortic valve implantation  
Carvedilol Trial  
Home inter-stage monitoring following palliation for HLHS  
Robotic Surgery  
Channelopathies and sudden cardiac death  
Public reporting of surgical outcomes  
World Congresses: Buenos Aires, Cairns

**2010s**

Pediatric Critical Care Consortium  
3D printing for congenital heart imaging  
Stem cell trials in heart disease  
MAP-IT Registry  
National Pediatric Cardiology Quality Improvement Collaborative  
Fetal Cardiac Intervention Registry  
Genetic link of CHD and neurodevelopment (Pediatric Heart Network)  
World Congresses: Cape Town, Barcelona

**2020s**

8th World Congress of Pediatric Cardiology and Cardiac Surgery,  
To be held September 19-24, 2021, Washington D.C.



Important Events in Pediatric Cardiology and Congenital Heart Surgery

Thanks to the Survey Respondents Who Chose The Events, People, Technologies and Therapies Shown In These Slides

**Surgery (n = 20)**

Leonard Bailey	Viktor Hraska
Emre Belli	Hajime Ichikawa
Ed Bove	Krishna Iyer
Sertaç Çiçek	Jeff Jacobs
Joe Dearani	Richard Jonas
Yves D'Udekem	Tom Karl
Roberto DiDonato	Rick Ohye
Tjark Ebels	Giovanni Stellin
Martin Elliott	Jim Tweddell
Jose Fragata	Bill Williams

**Cardiology + Intensive Care (n = 28)**

Robert Beekman	Jan Marek
Felix Berger	Gerard Martin
Stuart Berger	Ornella Milanesi
Damien Bonnet	Douglas Moodie
Robert Campbell	Jane Newburger
John Cheatham	Daniel Penny
Mitchell Cohen	Carlos Ruiz
Ziyad Hijazi	Shak Qureshi
Chris Hugo-Hamman	Robert Shaddy
Pavarthi Iyer	Gary Sholler
Jan Janousek	Norman Silverman
Krishna Kumar	Ed Walsh
Peter Laussen	Gary Webb
Michael Landzberg	Gil Wernovsky

Respondents From:

- |           |                |
|-----------|----------------|
| Australia | Namibia        |
| Canada    | Netherlands    |
| Dubai     | Portugal       |
| France    | Qatar          |
| Germany   | South Africa   |
| India     | Turkey         |
| Italy     | United Kingdom |
| Japan     | USA            |

Figure 2. Slide show presentation displayed at the 2017 Seventh World Congress of Pediatric Cardiology & Cardiac Surgery (WCPCCS 2017), Barcelona, Spain.



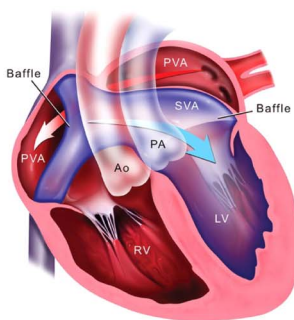
**Physiologic Repair of Transposition of the Great Arteries**

**William T. Mustard**  
Hospital for Sick Kids, Toronto

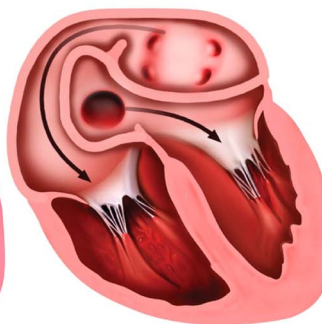


(Began His Career as an Orthopedic Surgeon)

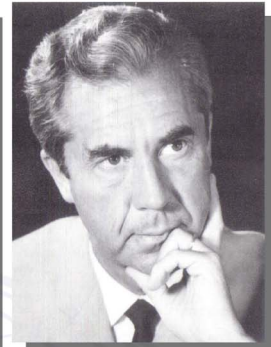
JTCVS, Dec 1964



Surgery, June 1959



**Åke Senning**  
Karolinska Institute, Stockholm



(Also Implanted First Pacemaker in a Human)

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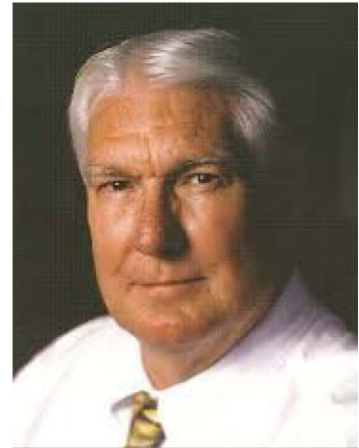


Norwood WI, Kirklin JK, Sanders SP.  
 Hypoplastic left heart syndrome: experience  
 with palliative surgery. Am J Cardiol 1980;45:87-91.

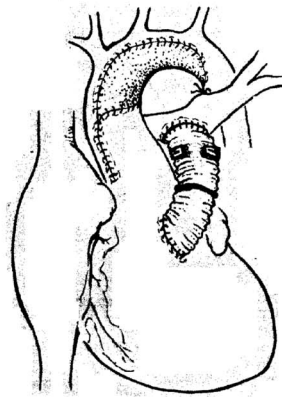
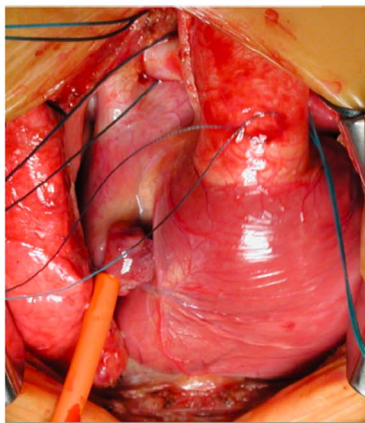


*This is a report of a new palliative procedure for HLHS that has resulted in early ongoing survival of two infants with aortic atresia. On the basis of experience with a third patient, an operation for future physiologic correction is proposed.*

**Dr. William I. Norwood**  
 Boston-Philadelphia-Genolier-Wilmington



Surgery for HLHS



- Increasing Use in:
  - Peripheral pulmonary arteries
  - Systemic and pulmonary veins
  - Aorta and branches
  - Conduits
  - Arterial duct
  - Aortopulmonary shunts
  - Intracardiac communications.

## Implantable Stents



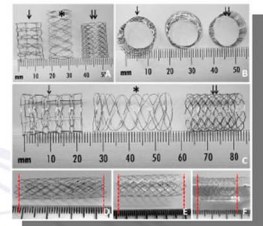
Julio Palmaz



John Cheatham



Charles Mullins



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7<sup>th</sup> WORLD CONGRESS OF PEDIATRIC CARDIOLOGY & CARDIAC SURGERY  
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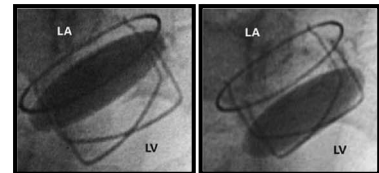


Dr. Dwight Harken (1910-1983)

Dr. Albert Starr

**First Prosthetic Heart Valve Implants, 1960**  
(Boston and Portland)

Harken mitral valve (29 year implant!)



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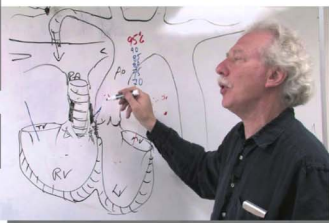
**Evolution and Specialization of Cardiac Nursing and Pediatric Cardiac Intensive Care**

Developed synergistically with technology and neonatal surgery for complex congenital cardiac disease  
First physically and administratively separate unit in Boston in late 1970's  
Originally staffed by cardiologists and catheterization specialists  
Pediatric Cardiac Intensive Care Society developed in 1990's  
Currently one of many different models of care



The Pediatric Cardiac Intensive Care Society

**SPCN**  
The Society of Pediatric Cardiovascular Nurses



Peter Lang



Patricia Hickey



David Wessel



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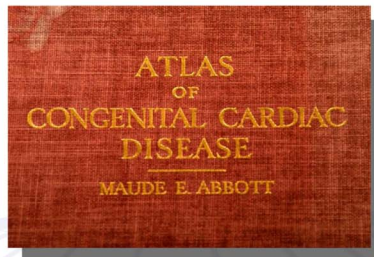
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### Detailed Morphology of Congenital Cardiac Disease



Robert Anderson



Richard and Stella Van Praagh

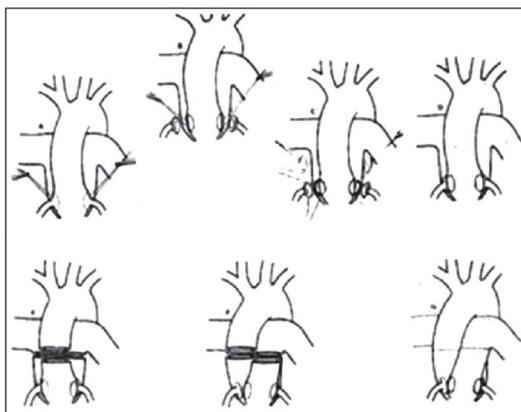
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### Dr. Adib Jatene (1929-2014)

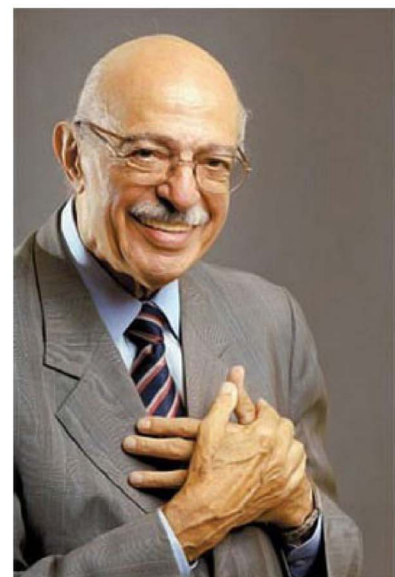
São Paulo, Brasil



#### Arterial Switch Operation 1975



Jatene AD, Fontes VF, Paulista PP, de Souza LC, Neger F, Galantier M, Souza JE. Successful anatomic correction of transposition of the great vessels. A preliminary report. Arq Bras Cardiol 1975;28:461-64.



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**Nitric Oxide**  
Selective Pulmonary Vasodilator  
Eliminated need for Hyperventilation After CHD Surgery  
Drug Testing During Cardiac Catheterization  
LMolecule of the Year” - 1992  
Nobel Prize in Medicine & Physiology - 1998

**Use of Inhaled Nitric Oxide and Acetylcholine in the Evaluation of Pulmonary Hypertension and Endothelial Function After Cardiopulmonary Bypass**

David L. Wessel, MD; Ian Adatia, MB; Therese M. Giglia, MD;  
John E. Thompson, RRT; Thomas J. Kulik, MD

*Circulation* 1993

Inhaled nitric oxide as a therapy for pulmonary hypertension after operations for congenital heart defects

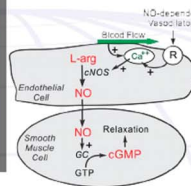
Didier Journois, MD,<sup>1</sup> Philippe Pouard, MD,<sup>2</sup> Philippe Mauriat, MD,<sup>3</sup> Thierry Malhère, MD,<sup>4</sup> Pascal Vouché, MD,<sup>5</sup> and Denis Safran, MD,<sup>6</sup> Paris, France

*J Thorac Cardiovasc Surg* 1993

Very-low-dose inhaled nitric oxide: A selective pulmonary vasodilator after operations for congenital heart disease

*JTCVS* 1994

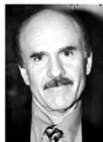
O. I. Miller, FRACP, D. S. Celermajer, FRACP, J. E. Deanfield, FRCP, and D. J. Macrae, FRCA, London, United Kingdom



**The Nobel Prize in Physiology or Medicine 1998**



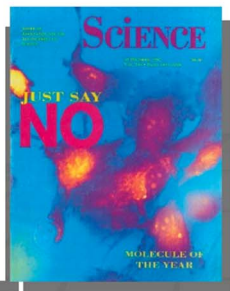
Robert F. Furchgott  
Prize share: 1/3



Louis J. Ignarro  
Prize share: 1/3



Ferid Murad  
Prize share: 1/3



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**Life Magazine May 27, 1966**  
**A standby repair until surgery**

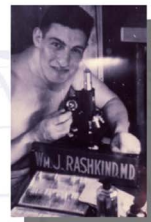
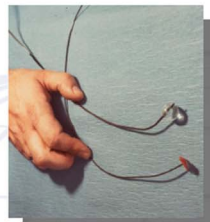
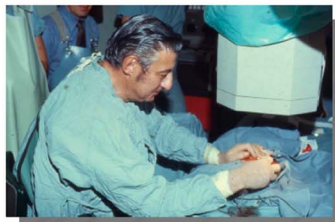
To keep Bobby alive it was absolutely essential, as a temporary measure, to break through the tissue membrane separating the two upper chambers of the heart (see diagram). The only other way to accomplish this would be by full-scale surgery—an operation that Bobby probably could not have survived. Rashkind's new balloon technique accomplished the same thing, effecting a stopgap but workable repair that will tide Bobby over for a few years. When his heart has grown large enough, doctors will be able to perform the complicated surgery needed to reconstruct the interior of the upper heart chambers so that Bobby's circulation will have full efficiency. Rashkind's treatment was carried out with only a local anesthetic at the groin. It caused so little fuss that Bobby peacefully sucked his pacifier throughout the procedure (left). When the doctor bent down (below) to coo at his little patient immediately after he had withdrawn the deflated balloon from the heart, Bobby cooed right back.



**William J. Rashkind**

Reported 1<sup>st</sup> Balloon Atrial Septostomy in a neonate (“Bobby”) in *Life Magazine* (and then in *JAMA* 1 month later)

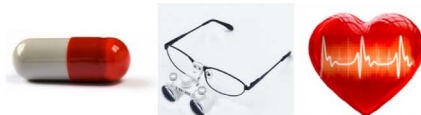
“Father of Interventional Cardiology”



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**Creation & Progressive Improvement in Implantable Pacemakers and Defibrillators**



C. Walton Lillehei and 1<sup>st</sup> External Pacemaker



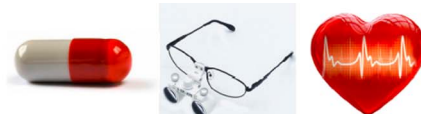
SIEMENS-ELEMA 1958



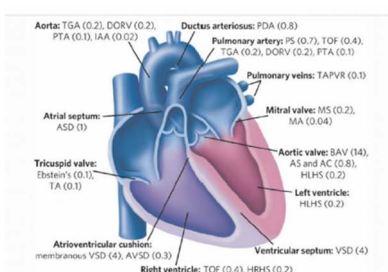
Early Implantable Defibrillator



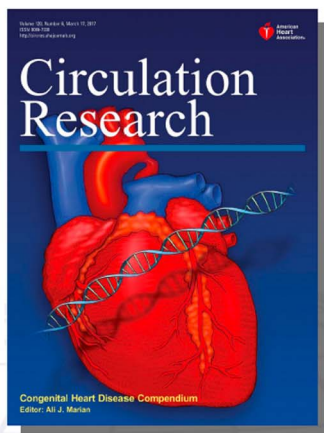
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**The Rise of Genetics and Genomics in Understanding Congenital Heart Disease**



**The developmental genetics of congenital heart disease**  
 Benoit G. Bruneau  
*Nature* 451, 943-948 (21 February 2008)  
 doi:10.1038/nature06801



Distinct genetic architectures for syndromic and nonsyndromic congenital heart defects identified by exome sequencing

Alejandra Sifim, Marc-Philip Hitz, Anna Willison, Jason Brockport, Sead H Al Turki, Bernard Theyspoet, Jeremy McRae, Tomas W Fitzgerald, Tarjinder Singh, Ganesh Jawahar Swaminathan, Elena Prigmore, Diana Rajar, Hashim Abdul-Khalik, Sidharth Banka, Ulrike M M Bauer, Jamie Benham, Felix Berger, Shoumo Bhattacharya, Frances Bu'Lock, Natalie Canham, Inna-Gabriela Colgus, Catherine Cosgrove, Helen Cox, Ingo Daehner, Allan Daly et al.

*Nature Genetics* 48, 1060-1065 (2016) | doi:10.1038/ng.3627



**Genetics and Genomics of Congenital Heart Disease**

Samir Zaidi, Martina Brueckner

**Abstract:** Congenital heart disease is the most common birth defect, and because of major advances in medical and surgical management, there are now more adults living with congenital heart disease (CHD) than children. Until recently, the cause of the majority of CHD was unknown. Advances in genomic technologies have discovered the genetic causes of a significant fraction of CHD, while at the same time pointing to remarkable complexity in CHD genetics. This review will focus on the evidence for genetic causes underlying CHD and discuss data supporting both monogenic and complex genetic mechanisms underlying CHD. The discoveries from CHD genetic studies draw attention to biological pathways that simultaneously open the door to a better understanding of cardiac development and affect clinical care of patients with CHD. Finally, we address clinical genetic evaluation of patients and families affected by CHD. (*Circ Res.* 2017;120:923-948. DOI: 10.1161/CIRCRESAHA.116.309146.)

Key Words: genetics ■ genome ■ human ■ life ■ technology

(continued)

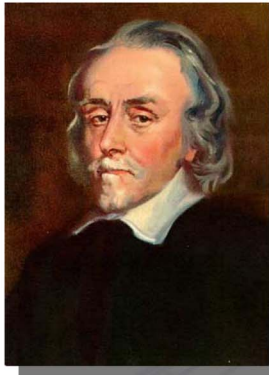




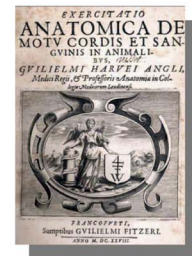
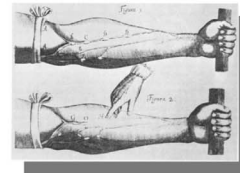
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## William Harvey and the Discovery of the Circulation



- Medical Degree - University of Padua 1602
- "Exercitatio Anatomica de Motu Cordis et Sanguinis in Animalibus" (de Motu Cordis) published in Latin in 1628



"In truth, when, from a variety of investigations through dissection of the living ...from the symmetry and magnitude of the ventricles of the heart and of the vessels entering and leaving ... I began privately to think that it might rather have a certain movement, as it were, in a circle..."



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## Paul C. Gillette 1943-2013



- Pediatric Residency and Cardiology Fellowship at Texas Children's Hospital and Baylor College of Medicine
- American Academy of Pediatrics
  - 1975 - Young Investigator Award
  - 1982-83- Chair of Section on Cardiology
  - 2009 Founder's Award
- 1998 - Pioneer in Pacing and Electrophysiology Award from the Heart Rhythm Society
- 2013 - Lifetime Achievement Award from The Pediatric and Congenital Electrophysiology Society
- Over 300 Peer-Reviewed publications
- Huge NASCAI Texas Motor Speedway



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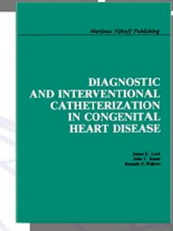
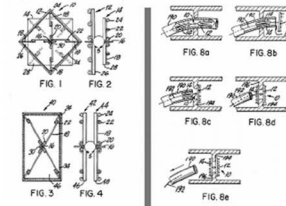


**James E. Lock**



- Medical School at **Stanford University**
- Pediatric Residency and Cardiology Fellowship at **University of Minnesota**
- Fellowship in Cardiovascular Physiology - University of Toronto, **Hospital for Sick Children**
- **Pioneering Interventional Cardiologist** who has trained numerous academic physicians in cardiopulmonary physiology, interventional cardiology, many of whom are now Division Chiefs, and Cath Lab and ICU Directors
- 1<sup>st</sup> **Textbook** on Pediatric Interventional Catheterization
- 1999 - Designed first **ASD occlusion device** approved by USA Food and Drug Administration
- 2000-2009 Director of NMT Medical
- Long time Chairman of the Department of Cardiology, Alexander S. Nadas Professor of Pediatric Cardiology and Physician-in-Chief at **Boston Children's Hospital**
- Over **300 Peer-reviewed manuscripts**

Occluder and method for repair of cardiac and vascular defects  
US Patent: 5451235 A



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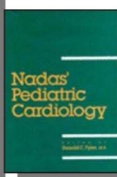
**Alexander S. Nadas**  
1913-2000



Receiving Gifted Teacher Award of American College of Cardiology from Dan McNamara



Shucking Corn with Donald Fyler at Cardiology Department Clambake 1985



- Born in Budapest, Hungary
- Graduated Medical School Semmelweis University
- Second Medical Degree from Wayne State, Detroit, USA
- Dismissed from Catholic Hospital for Advising Contraception
- Arrived Boston Children's Hospital at Invitation of Charles Janeway
- Initial Work:
  - Cardiac Manifestations of Cystic Fibrosis
  - ECG findings in Congenital Heart Disease
- First textbook in Pediatric Cardiology
- Began Training Program in Pediatric Cardiology in 1950s and long-term professional relationship with **Dr. Donald Fyler**
- Charter Member of American Academy of Pediatrics Section of Pediatric Cardiology
- American Heart Association established the Alexander S. Nadas Lectureship in 1986
- Born with Bicuspid Aortic Valve, had two bouts of Endocarditis, and died of Congestive Heart Failure
- Over 230 Peer-reviewed publications between 1951 and 1990

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Randomized Clinical Trials Begin in Pediatric Cardiac Disease

Comparison of Shunt Types in the Norwood Procedure for Single-Venticle Lesions

Richard G. Ohye, M.D., Lynn A. Steyer, Sc.D., Lynn Mahoney, M.D., Jane W. Newburger, M.D., M.P.H., Carl D. Rose, M.D., Sc.D., Minmin Lu, M.S., Karen S. Goldberg, M.D., Sarah Tabbal, M.D., Ph.D., Peter C. Fromme, M.D., Nancy S. Glassberg, M.D., Peter C. Laussen, M.B., B.S., John F. Rhodes, M.D., Alan B. Lewis, M.D., Sonoma Mittal, M.D., Chira Kumbhani, M.D., James A. Williams, M.D., Carolyn Dunbar-Matthews, B.S.N., R.N., Andrew M. Aziz, M.D., Steven Cohen, M.D., L. Lukasz Miodini, M.D., Christian Ripstein, M.D., Kirk E. Kantler, M.D., James Jagers, M.D., Jeffrey P. Jacobs, M.D., Catherine Dent-Krauss, M.D., Nancy P. Rhee, R.N., Ph.D., Brian W. McCrindle, M.D., M.P.H., Lisa Vigi, R.N., M.S., M.B.A., and William Gaynor, M.D., for the Pediatric Heart Network Investigators

Levodopa infusion in newborns after corrective surgery for congenital heart disease: randomized controlled trial

Authors and Affiliations: Deborah Kroll, Christine Gentes, Sushila Frey, Vanessa Wink, Luca Di Chiara, Paolo E. Cogo

A randomized, placebo-controlled trial of amlodipine in children with hypertension

Jonathan T. Flynn, MD, MSc, FRCPC, Jane W. Newburger, MD, MPH, PhD, Stephen P. Sanders, MD, Ronald J. Poonan, MD, Ronald J. Hogg, MD, J. Philip Sassi, MD, for the PATH-1 Investigators

Nitric oxide administration during paediatric cardiopulmonary bypass: a randomised controlled trial

Authors and Affiliations: Christopher James, Jeffrey Miller, Stephen Harter, Christian Boud, Charles Hosenberry, Howard Bick

A Comparison of the Perioperative Neurologic Effects of Hypothermic Circulatory Arrest versus Low-Flow Cardiopulmonary Arrest in Infant Heart Surgery

Jane W. Newburger, Richard A. Jonas, Gil Wernovsky, David Wypij, Paul R. Hickey, Karl Kuban, David M. Farrell, Gregory L. Holmes, Barbara S. Hoffman, Anne Corbett-Gibson, Enrique Carreras, John K. Burke, Jerry J. Walsh, Kristin C. Lusk, Jane C. Shone, David L. Wessell, Frank J. Hanley, John E. Hepler, Jr., Alan R. Castaneda, and James H. Wain

Atenolol versus Losartan in Children and Young Adults with Marfan's Syndrome

R.V. Lacro, H.C. Olier, L.A. Shapiro, A.T. Tirmas, T.J. Bradley, S.B. Colac, C.D. Pearson, E.S. Salamat-Termy, J.C. Levine, A.M. Az, D.W. Benson, A.C. Braverman, S. Chen, J. De Backer, D.D. Goff, P.D. Grossfeld, G.L. Klein, W.W. Liu, A.L. Liu, B.L. Long, L.W. Mackintosh, A.R. Olson, S.M. Paradise, Y.L. Penabazco, M.E. Pappas, R.E. Pyritz, E. Radzowski, M.J. Roman, A.M. Shalvey, M.P. Sjalama, S. Burns Wechsler, L.T. Young, and L. Mahony, for the Pediatric Heart Network Investigators

PALIVIZUMAB PROPHYLAXIS REDUCES HOSPITALIZATION DUE TO RESPIRATORY SYNCYTIAL VIRUS IN YOUNG CHILDREN WITH HEMODYNAMICALLY SIGNIFICANT CONGENITAL HEART DISEASE

Trevor F. Rutledge, MD, Alok K. Chakka, MD, H. Coor Prasad, MD, Franco M. Pagan, MD, MPH, David A. Cox, MD, Rowan H. Top, MD, PhD, Edward H. Coxson, MD, and Helen H. Sokolow, MD, for the Congenital Heart Disease Study Group

Randomized Trial of Pulsed Corticosteroid Therapy for Primary Treatment of Kawasaki Disease

Jane W. Newburger, M.D., M.P.H., Lynn A. Steyer, Sc.D., Brian W. McCrindle, M.D., M.P.H., L. Lukasz Miodini, M.D., William Gaynor, M.D., Victoria L. Wilson, M.D., Andrew M. Aziz, M.D., Jennifer E. S. M.D., Masato Takahashi, M.D., Annelle L. Baker, M.S.N., P.A.P., Steven D. Colan, M.D., Paul D. Mitchell, M.S., Gloria L. Klein, M.S., R.D., and Robert F. Surick, M.D., for the Pediatric Heart Network Investigators

A Multicenter, Randomized Trial Comparing Heparin/Warfarin and Acetylsalicylic Acid as Primary Thromboprophylaxis for 2 Years After the Fontan Procedure in Children

Presented at the 2008 Scientific Sessions of the American Heart Association, November 8-12, 2008, New Orleans, Louisiana. Paul Mangano, MD, MSc, MBBS, Andrew Cochran, MD - Robin Roberts, MD, Cedric Marchand BSc, Robert Weintraub MBBS, Barbara Sanchamman BA, Marina Hughes DPhil, Maureen Andrew MD, Brian W. McCrindle MD, MPH F.A.B., Fontan Anticoagulation Study Group

Fontan Procedure Improves Clinical Outcome of the Fontan Procedure - A Prospective, Randomized Study

Matthew S. Leiner, MD, William A. Soum, MD, Steven R. Leonard, MD, David Sternberg, MD, Claudio Ramazzini, MD

The Treatment of Kawasaki Syndrome with Intravenous Gamma Globulin

Jane W. Newburger, M.D., M.P.H., Masato Takahashi, M.D., Jere G. Burns, M.D., Aneka S. Bester, Ph.D., Kyung Ja Chang, MD, G. Elise Duffy, M.D., Mary P. Gilks, M.D., Wilbert H. Heason, M.D., Venkatesh Reddy, M.D., Stephen P. Sanders, M.D., Stanford T. Shuman, M.D., James W. Wiggins, M.D., Raquel V. Hicks, M.D., David R. Fulton, M.D., Alan B. Lewis, M.D., Donald T.M. Leung, M.D., Ph.D., Theodore Colton, B.S.D., Fred S. Rosen, M.D., and Marlan E. Malach, M.D.

Nitric oxide precursors and congenital heart surgery: A randomized controlled trial of oral citrulline

Heidi A.B. Smith, MD, MScL, Jeffrey A. Carter, MD, MPH, Karla G. Christian, MD, David C. Driekwater, MD, Frank G. Schol, MD, Brian W. Christian, MD, Geraldine D. Rice, RN, BSN, Frederick E. Bar, MD, MScL, and Marshall L. Summer, MD

A randomized clinical trial of regional cerebral perfusion versus deep hypothermic circulatory arrest: Outcomes for infants with functional single ventricle

Karen S. Goldberg, MD, Edward L. Boon, MD, Eric J. Ravussin, MD, Ellen Mallon, PhD, Edward Schwartz, PhD, Shreya Tinkal, PhD, Cheryl Nowak, RN, John Chapin, MD, Marlan E. Brown, PhD, Tom J. Kulk, MD, and Richard E. Ohye, MD

Inhaled nitric oxide and prevention of pulmonary hypertension after congenital heart surgery: a randomised double-blind study

Owen J. Miller, Steve Fang Tang, Anthony Heech, Nicholas B. Pigitt, Elaine Debar, David S. Celermajer

Efficacy and Safety of Milrinone in Preventing Low Cardiac Output Syndrome in Infants and Children After Corrective Surgery for Congenital Heart Disease

Timothy M. Hoffman, MD, Gil Wernovsky, MD, Andrew M. Atz, MD, Thomas J. Kulk, MD, David P. Nelson, MD, PhD, Anthony C. Chang, MD, MBA, James M. Bailey, MD, Akbar Akhary, MD, John F. Kocisz, PhD, Raymond Kuczmarsk, RN, BSN, Thomas L. Spray, MD, David L. Wessell, MD

Levosimendan in Congenital Cardiac Surgery: A Randomized, Double-Blind Clinical Trial

Mona Momen MD, A.R., Jean Ruby MD, PhD, T. Anne Matsuda MD, Marie-Thérèse Ravelet MD, Francis Veycoffs MD, Alain Jean Perceval MD, Christian Clement de Clay MD, Christian Aniot MD, Ruyad Joanny MD, Thierry Deslats MD

Clopidogrel in Infants with Systemic-to-Pulmonary-Artery Shunts

David L. Wessell, M.D., Felix Berger, M.D., Jennifer S. Li, M.D., M.H.S., Jigal Dahnert, M.D., Amit Rakhil, M.D., Sylvie Fontevicq, M.D., and Jane W. Newburger, M.D., M.P.H., for the CLARINET Investigators

Impact of Empiric Nesiritide or Milrinone Infusion on Early Postoperative Recovery After Fontan Surgery - A Randomized, Double-Blind, Placebo-Controlled Trial

John M. Cusack, MD, MPH, Carolyn Dunbar-Matthews, BSN, RN, Catherine K. Allan, MD, Kimberley Gavrilov, ScD, Jane W. Newburger, MD, MPH, Frank X. McConnoe, Jr, MD, David L. Wessell, MD, John E. Mayer, Jr, MD, Joshua W. Sahlin, MD, MPH, Roger E. D'Amico, PharmD, Peter C. Laussen, MBBS

Randomized comparison of atenolol and fludrocortisone acetate in the treatment of pediatric neurally mediated syncope

William A. Scott MD, Giacomo Evangelista MD, Bartolomeo M. Michael S. Schaffer MD, Barbara J. Deal MD, Frank A. Fish MD, Marcantonio DiCorleto MD

Risk factors for hospital morbidity and mortality after the Norwood procedure: A report from the Pediatric Heart Network Single Ventricle Reconstruction trial

Sarah Tabata, MD, PhD, Nancy Chavers, MD, Chira Kumbhani, MD, Lynn A. Steyer, ScD, David S. Cooper, MD, MPH, Deborah V. Frank, MD, PhD, M. Denise Lee, RN, Christian Boud, MD, Peter Fromme, MD, Karen S. Goldberg, MD, Eric M. Graham, MD, Catherine Don Kozarski, MD, Wynne W. Lal, MD, Alan Levin, MD, Neil A. Kohn, MD, Lynn Mahoney, MD, Richard G. Ohye, MD, Janet Simms, MD, Andrew J. Lotze, MD, Ellen Spertus, MD, Maria Stylianou, PhD, and Peter Laussen, MD for the Pediatric Heart Network Investigators



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Recognition of Neurodevelopmental Challenges in Patients with Congenital Cardiac Disease

A Comparison of the Perioperative Neurologic Effects of Hypothermic Circulatory Arrest versus Low-Flow Cardiopulmonary Bypass in Infant Heart Surgery

Jane W. Newburger, Richard A. Jonas, Gil Wernovsky, David Wypij, Paul R. Hickey, Karl Kuban, David M. Farrell, Gregory L. Holmes, Barbara S. Hoffman, Anne Corbett-Gibson, Enrique Carreras, John K. Burke, Jerry J. Walsh, Kristin C. Lusk, Jane C. Shone, David L. Wessell, Frank J. Hanley, John E. Hepler, Jr., Alan R. Castaneda, and James H. Wain

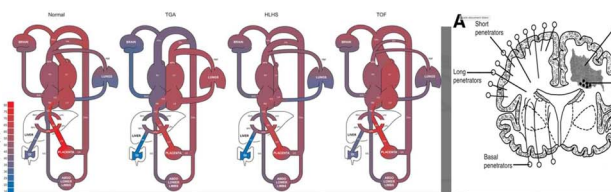
Randomized trial of hematocrit 25% versus 35% during hypothermic cardiopulmonary bypass in infant heart surgery

Jane W. Newburger, MD, MPH, Richard A. Jonas, MD, MSc, Barry D. Kusumam, MBBS, David C. Bellinger, PhD, MSc, Peter C. Laussen, MD, Richard Robertson, MD, James E. Meyer, Jr, MD, Peter J. del Negro, MD, Enola A. Barlow, MD, Joseph M. Forstner, MD, Frank Pignatelli, MD, Stephen J. Bell, MD, MPH, Karen J. Wessell, PhD, Sara J. de Perrot, MBBS, MPH, David M. Farrell, M.A., CCP, Ellen McIninch, RN, Leonard A. Rappaport, MD, and David Wypij, PhD



Jane Newburger, Richard Jonas, David Bellinger and many others

- ~40-60% of Children With Complex CHD Have Some Disability In: Motor Function, Attention, Learning, Executive Function, Anxiety, Depression, Frequency Decreased with Less Severe Disease, Multifactorial, Few Preventative Treatments Available As Yet, Guidelines Recently Developed



Oxygen and Substrate Delivery is Reduced to the Fetal Brain (courtesy Dr. Michael Seed)

AHA Scientific Statement

Neurodevelopmental Outcomes in Children With Congenital Heart Disease: Evaluation and Management

A Scientific Statement From the American Heart Association. This statement has been approved by the American Heart Association.

Bridley S. Marino, MD, MPH, MScE, FAHA, Co-Chair, Paul H. Lipkin, MD, Jane W. Newburger, MD, MPH, FAHA, Georgia Pearson, MD, MPH, Marlene Gossel, PhD, J. William Gaynor, MD, Kathleen A. Monson, PhD, RN, Karen Usark, PhD, CNP, FAHA, Karen S. Goldberg, MD, MS, Walter H. Johnson, Jr, MD, Jennifer L. M.D., Sabrina E. Smith, MD, PhD, David C. Bellinger, PhD, William T. Mahle, MD, FAHA, Co-Chair on Behalf of the American Heart Association Congenital Heart Disease Committee of the Council on Cardiovascular Disease in the Young, Council on Cardiovascular Nursing, and Stroke Council



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## Diagnosis and Management of Pediatric Pulmonary Hypertension

**1958**

**The Pathology of Hypertensive Pulmonary Vascular Disease**  
A Description of Six Grades of Structural Changes in the Pulmonary Arteries with Special Reference to Congenital Cardiac Septal Defects  
By DONALD HEATH, M.D., AND JESSE E. EDWARDS, M.D.

**1999**

**Vasodilator Therapy for Primary Pulmonary Hypertension in Children**  
Robyn J. Barst, MD; Greg Maislin, MS, MA; Alfred P. Fishman, MD

**2015 guidelines**

**AHA/ATS Guideline**

**Pediatric Pulmonary Hypertension**  
Guidelines From the American Heart Association and American Thoracic Society

**2015 ESC/ERS Guidelines for the diagnosis and treatment of pulmonary hypertension**  
The Joint Task Force for the Diagnosis and Treatment of Pulmonary Hypertension of the European Society of Cardiology (ESC) and the European Respiratory Society (ERS)

**2015 guidelines**

**Potts Shunt and Pediatric Pulmonary Hypertension: What We Have Learned**  
R. Mark Grady, MD, and Pirooz Eghtesady, MD, PhD

Humbert M et al. Circulation. 2014;130:2189-2208



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## Aldo Castañeda

C. Walton Lillehei, MD

Richard Varco, MD

C. Walton Lillehei, MD

Por suerte, no tuvo éxito. Había otro grupo de jóvenes cirujanos de University of Minnesota (y por lo tanto, aquí es donde entra Minnesota), dirigido por Walt Lillehei y el Dr. Richard Varco, que tuvo una idea diferente que fue interesante: ellos desarrollaron en el laboratorio lo que llamaron

- University of Guatemala Medical School
- Surgical and cardiothoracic residencies at the University of Minnesota (which at the time [1950s] was performing the world's first open heart surgeries)
- 1972: Recruited to Boston Children's Hospital in 1972
- Chief of Cardiovascular surgery and Surgeon-in-Chief at Boston Children's Hospital for 24 years
- Pioneer of neonatal cardiac surgery
- 1983: Helped pioneer the arterial switch operation for transposition of the great arteries
- Trained a generation of pediatric cardiac surgeons

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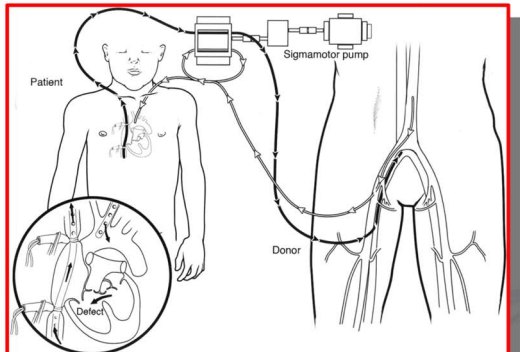




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### Cross Circulation



March 26, 1954: C. Walton Lillehei and his associates — Morley Cohen, Herb Warden, and Richard Varco — used controlled cross-circulation to correct a ventricular septal defect in an 11-year-old boy. The boy's anesthetized father served as the oxygenator.



3/26/54-7/19/55

	NO.	MORT.	<2Y	MORT.
✦ VSD	28	8(28%)	16	6(37%)
✦ TOF	11	4(36%)	5	3(60%)
✦ CAVC	4	3(75%)	3	2(67%)
✦ IPS	2	0		
✦	45	15(33%)	24	11(49%)



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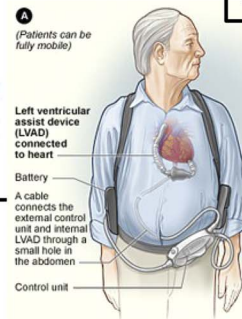


### Ventricular Assist Devices (VAD)

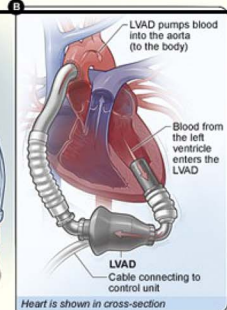


#### Berlin Heart

- 1996: The EXCOR Stationary Driving Unit Ikus received CE approval.
- 1999: The EXCOR mobile driving unit received CE approval.
- 2000: The first child in the USA is supported by EXCOR Pediatric.
- 2003: INCOR received CE approval after successfully completing the Multi-Center Study.
- 2008: The INCOR patient Jean-Pierre Offe celebrated his five-year anniversary while on the system and therefore setting an INCOR world record.
- 2008: EXCOR Pediatric received unrestricted IDE Approval in the USA.
- 2009: The 500th patient received INCOR VAD at the German Heart Institute.
- 2011: EXCOR Pediatric received FDA approval for the U.S. market. The number of children who had been on EXCOR Pediatric reached over 1,000.
- 2012: The longest support time of a toddler on EXCOR Pediatric reached 2.5 years.
- 2013: The EXCOR Pediatric 15 ml blood pump received CE approval.
- 2014: The 1,500th pediatric patient was supported by EXCOR Pediatric.



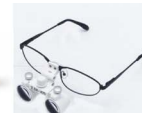
#### HeartMate



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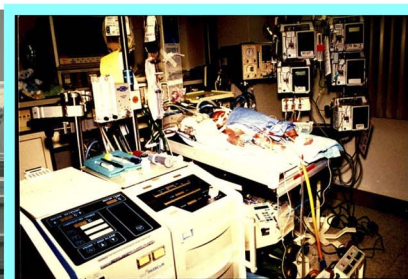


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## ExtraCorporeal Membrane Oxygenation (ECMO)

- Developed during the 1960s and 1970s
- Robert Bartlett, MD (a surgeon at the University of Michigan) and his colleagues pioneered the clinical use of ECMO in newborns with respiratory failure
- Bartlett reported the first neonatal survivor of ECMO, referred to as Baby Esperanza, in 1976. Baby Esperanza suffered lung damage from meconium aspiration syndrome. ECMO was applied as a last-ditch effort to save her life. The baby spent three days on Bartlett's machine and survived.

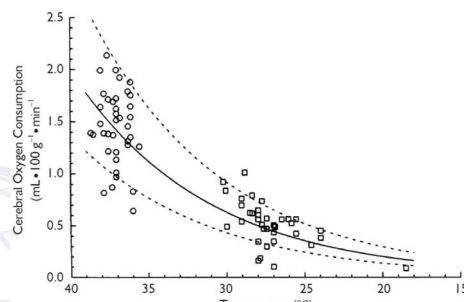
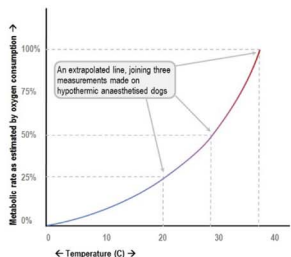


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## Deep Hypothermic Circulatory Arrest

Deep hypothermic circulatory arrest is a surgical technique that involves cooling the body to temperatures below 20°C (68°F), stopping the circulation and greatly reducing brain metabolism



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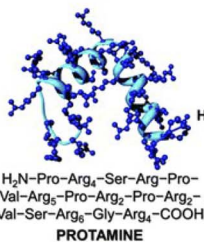
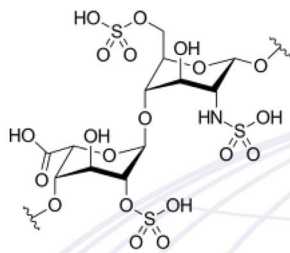
## Heparin (and Protamine)



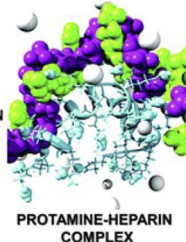
Heparin was first discovered by **Jay McLean** and **William Henry Howell**. **McLean** was a second-year medical student at **Johns Hopkins University** who was assisting Howell in the investigation of pro-coagulant preparations. **McLean** isolated a fat-soluble anticoagulant in canine liver tissue in 1916.



*Johannes Friedrich Miescher (1844-1895). A Swiss biologist who discovered a protamine in the sperms of salmon in 1870s. He also isolated nucleic acids from the nuclei of white blood cells in 1869 at the University of Tübingen in Germany, paving the way for the identification of DNA.*



HEPARIN



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## Cardioplegia

THE LANCET] [JULY 2, 1955

### CONCLUSIONS

Cardiac arrest in diastole inevitably results from an injection of potassium citrate into the root of the aorta so that the bulk of it enters the coronary arteries.

D. G. MELROSE  
M.A., B.M. Oxf

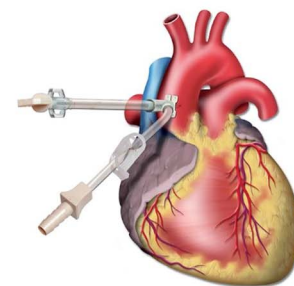
B. DREYER  
M.D. Cape Town, F.R.C.S.

H. H. BENTALL  
M.B. Lond., F.R.C.S.

J. B. E. BAKER  
M.A., B.Sc., B.M. Oxf

Department of Surgery,  
Postgraduate Medical School  
of London

Department of Physiology,  
Charing Cross Hospital Medical  
School, London



(continued)



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## Computing, Digitization of Data, & The Internet



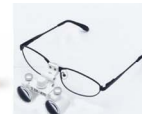
Big Data – Advanced Statistical Analyses – Database Linkage  
Transfer of Images and Data Sets to Remote Locations  
Rapid Dissemination and Availability of Information  
Collaboration of Best Practices Across Centers  
Development of Telemedicine



STS National Database  
Using data to drive quality

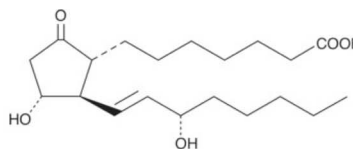


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## Aprostadi (PGE1)

Naturally occurring prostaglandin approved by the Food and Drug Administration (FDA) in 1981



[European Journal of Clinical Pharmacology](#)  
January 1980, Volume 18, [Issue 1](#), pp 75–81

Prostaglandins, ductus arteriosus, pulmonary circulation:  
Current concepts and clinical potential

[Can J Physiol Pharmacol](#), 1973 Mar;51(3):220-5.

The response of the ductus arteriosus to prostaglandins.

[Coceani F, Olley PM.](#)

Dilatation of the Ductus Arteriosus  
by Prostaglandin E<sub>1</sub> in Aortic Arch Abnormalities

MICHAEL A. HEYMANN, M.D., WILLIAM BERMAN, JR., M.D.,  
ABRAHAM M. RUDOLPH, M.D., AND VICTOR WHITMAN, M.D.

(continued)



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## Transesophageal Echocardiography

- Rapid transition from early experiences in children in 1989

*Am J Cardiol.* 1989 Mar 1;63(9):594-8.

**Efficacy of intraoperative transesophageal echocardiography in children with congenital heart disease.**

Cyran SE<sup>1</sup>, Kimball TR, Meyer RA, Bailey WW, Lowe E, Balisteri WF, Kaplan S.



- To guidelines in 2005

### AMERICAN SOCIETY OF ECHOCARDIOGRAPHY REPORT

Indications and Guidelines for Performance of Transesophageal Echocardiography in the Patient with Pediatric Acquired or Congenital Heart Disease

*A Report from the Task Force of the Pediatric Council of the American Society of Echocardiography*

Writing Committee: Nancy A. Ayres, MD, Wanda Miller-Hance, MD, Derek A. Pyke, MD, PhD, FASE, J. Geoffrey Stevenson, MD, FASE, David J. Sahn, MD, FASE, Luciana T. Young, MD, FASE, L. Luan-Minh, MD, Thomas R. Kimball, MD, FASE, Tal Geva, MD, FASE, Frank C. Smith, MD, FASE, and Jack Rychik, MD

### OR and Catheterization Lab

- Improving diagnosis
- Guide and evaluate interventions



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### First aortic coarctation repair

19<sup>th</sup> October, 1944, Stockholm

(11 y.o. boy, XCI = 2 hr)

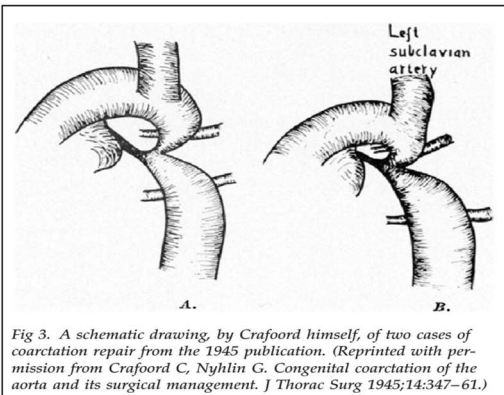
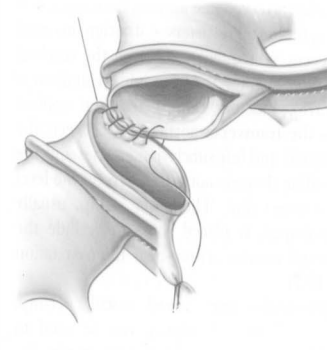


Fig 3. A schematic drawing, by Crafoord himself, of two cases of coarctation repair from the 1945 publication. (Reprinted with permission from Crafoord C, Nyhlin G, Congenital coarctation of the aorta and its surgical management. *J Thorac Surg* 1945;14:347-61.)

### Crafoord end-end anastomosis



Dr. Clarence Crafoord  
1899-1984



FROM SURGICAL CLINIC II OF THE SABBATSBERG HOSPITAL, STOCKHOLM  
(SURGEON IN CHIEF: K. H. GIERTZ, M. D.)

### ON THE TECHNIQUE OF PNEUMONECTOMY IN MAN

A CRITICAL SURVEY OF THE EXPERIMENTAL AND CLINICAL DEVELOPMENT AND A REPORT OF THE AUTHOR'S MATERIAL AND TECHNIQUE

BY CLARENCE CRAFOORD

(continued)





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## PDA Ligation



Dr. Robert E. Gross in 1938  
Boston Children's Hospital  
Lorraine Sweeney 7 year old



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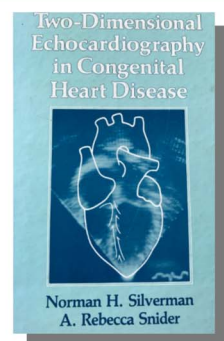
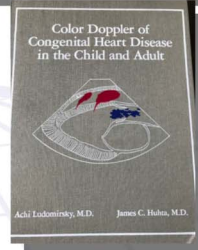
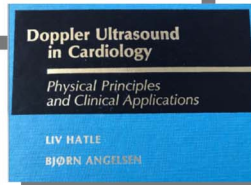
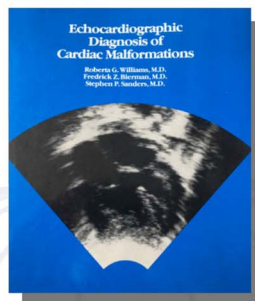
*Clin Physiol Funct Imaging*, 2004 May;24(3):118-36.

**The use of ultrasonic reflectoscope for the continuous recording of the movements of heart walls.**  
1954.

Edler I, Hertz CH.

## Echocardiography

- M-mode echocardiography
- 2 Dimensional echocardiography
- Doppler echocardiography
- Fetal Echocardiography
- Color Flow Imaging
- Transesophageal Imaging
- 3 Dimensional Echocardiography



(continued)



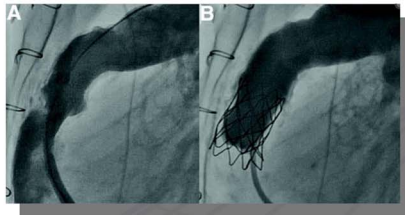
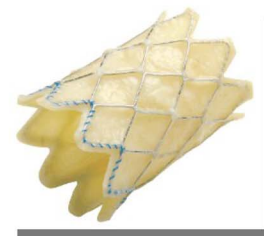


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## Transcatheter PVR

Dr. Phillip Bonhoeffer, 2000



[Circulation. 2010 Aug 3; 122\(5\): 507-516.](#)  
Published online 2010 Jul 19. doi: [10.1161/CIRCULATIONAHA.109.921692](#)

### Short- and Medium-Term Outcomes After Transcatheter Pulmonary Valve Placement in the Expanded Multicenter US Melody Valve Trial

[Doff B. McElhinney, MD](#), [William E. Hellenbrand, MD](#), [Evan M. Zahn, MD](#), [Thomas K. Jones, MD](#), [John P. Cheatham, MD](#), [James E. Lock, MD](#), and [Julie A. Vincent, MD](#)



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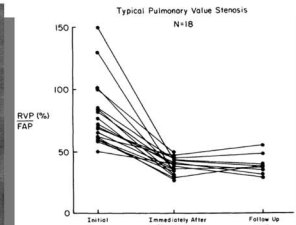
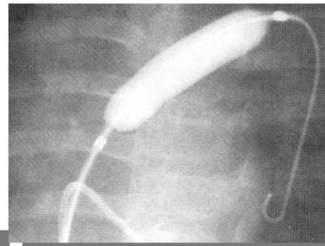
## Balloon Pulmonary Valvuloplasty

Kan, NEJM 1982  
Lababidi, Am J Cardiol 1983

### Percutaneous transluminal balloon valvuloplasty for pulmonary valve stenosis

[JEAN S. KAN, M.D.](#), [ROBERT I. WHITE, JR., M.D.](#), [SALLY E. MITCHELL, M.D.](#),  
[JAMES H. ANDERSON, PH.D.](#), and [TIMOTHY J. GARDNER, M.D.](#)

**ABSTRACT** Transluminal balloon valvuloplasty was used to treat congenital pulmonary valve stenosis in 20 patients. Follow-up cardiac catheterization was performed in 11 patients at intervals of from 2 to 12 months after the procedure. Peak systolic pressure gradient across the pulmonic valve decreased from  $68 \pm 27$  to  $23 \pm 5$  mm Hg ( $p < .001$ ) after valvuloplasty. There were no complications. Follow-up catheterization demonstrated persistent relief of right ventricular hypertension in the patients with typical pulmonary valve stenosis.  
*Circulation* 69, No. 3, 554-560, 1984.



### Balloon pulmonary valvuloplasty: Results of the Valvuloplasty and Angioplasty of Congenital Anomalies Registry

[Paul Stanger MD<sup>a,b,c,d,e</sup>](#), [Steven C. Cassidy MD<sup>a,b,c,d,e</sup>](#), [Donald A. Girod MD<sup>a,b,c,d,e</sup>](#), [Jean S. Kan MD<sup>a,b,c,d,e</sup>](#), [Zuhdi Lababidi MD<sup>a,b,c,d,e</sup>](#), [Stephen R. Shapiro MD<sup>a,b,c,d,e</sup>](#)

(continued)



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### Device Closure of ASD

King & Mills procedure in dogs, *Surgery* 1972  
King-Mills Umbrella, in 17 year old girl, *JAMA* 1975  
Rashkind Single Umbrella Device, *Circulation* 1983  
Double Disc Approach: Lock, Mullins, Hellenbrand, 1989

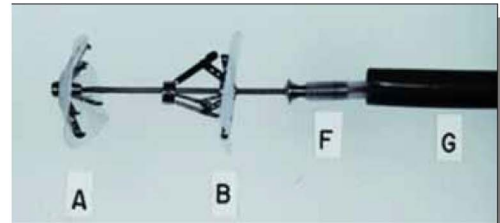


Figure 1. Cardiac umbrella used for the first experimental ASD closure: left atrial umbrella (A), right atrial umbrella (B), locking catheter and cone (F), and an outer catheter (G).

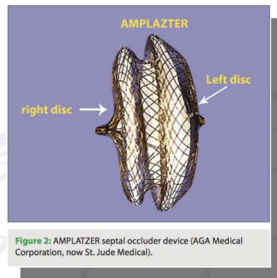
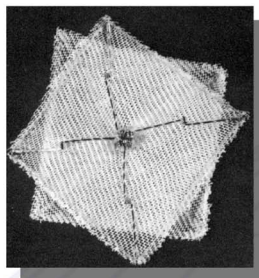


Figure 2: AMPLAZER septal occluder device (AGA Medical Corporation, now St. Jude Medical).

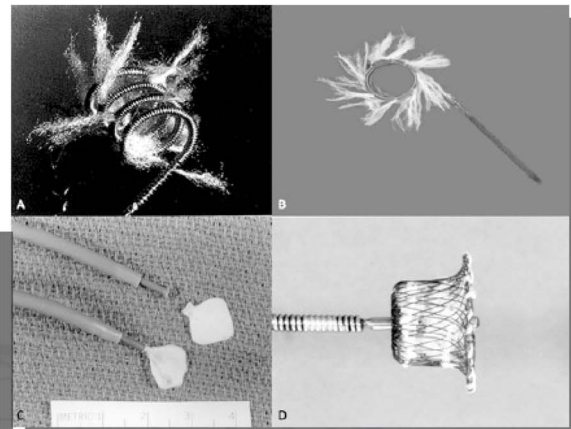
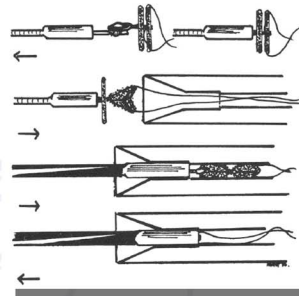
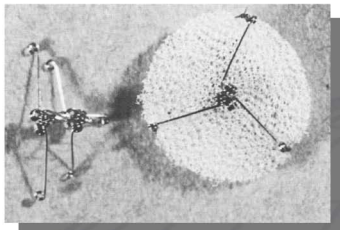


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### Device Closure of PDA

First report by Portsman 1967  
Rashkind Double Disc 1979  
Hellenbrand 2004 (Multi-center Trial)



Yarrabolu and Syamasundar Rao, *Pediat Therapeut* 2012, S5

(continued)



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## Outcome Registries for CHD



PEDIATRIC  
CARDIAC  
CRITICAL  
CARE  
CONSORTIUM  
PC<sup>3</sup> Improving outcomes and  
quality through collaboration

IMPACT Registry



Improving Pediatric and Adult Congenital Treatment  
Improving Pediatric and Adult Congenital Treatment

European Association for  
Cardio-Thoracic Surgery



Adult Congenital & Pediatric Cardiology Quality  
Network



NATIONAL PEDIATRIC CARDIOLOGY  
Quality Improvement Collaborative



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PEDIATRIC CARDIOLOGY & CARDIAC SURGERY  
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## Fetal Echocardiography

First articles.....1969

**Ann Obstet Gynecol Med Perinat.** 1969 Jul;**91**(7):491-6.

- The fetal echo-cardiogram
- Kratochwil A, Sassi D.

**Invest Radiol.** 1972 May-Jun;**7**(3):152-8.

- Echocardiography of the fetal and newborn heart.
- Winsberg F.

**J Clin Ultrasound.** 1975 Jun;**3**(2):95-105.

- Ultrasonic identification and examination of fetal heart structures.
- Egeblad H, Bang J, Northeved A.

### Major Early Investigators

- Charles Kleinman
- Liv Hatle
- David Sahn
- Norman Silverman

### Diagnosis and Treatment of Fetal Cardiac Disease: A Scientific Statement From the American Heart Association

Mary T. Donofrio, Anita J. Moon-Grady, Lisa K. Hornberger, Joshua A. Copel, Mark S. Sklansky, Alfred Abuhamad, Bettina F. Cuneo, James C. Huhta, Richard A. Jonas, Anita Krishnan, Stephanie Lacey, Wesley Lee, Erik C. Michelfelder, Sr, Gwen R. Rempel, Norman H. Silverman, Thomas L. Spray, Janette F. Strasburger, Wayne Tworetzky and Jack Rychik on behalf of the American Heart Association Adults With Congenital Heart Disease Joint Committee of the Council on Cardiovascular Disease in the Young and Council on Clinical Cardiology, Council on Cardiovascular Surgery and Anesthesia, and Council on Cardiovascular and Stroke Nursing



(continued)





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## Cardiac Catheterization

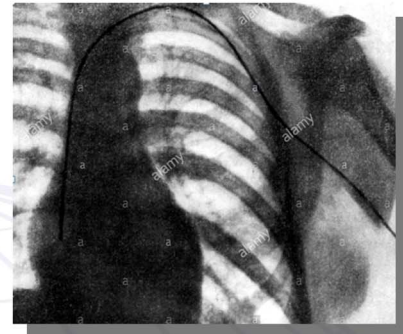
Werner Forssman 1904-1979

First Right Heart Catheterization 1929

Shared *Nobel Prize* in 1956 with Cournaud/Richards



FIGURE 4. The Nobel Laureates Forssmann, Richards, and Cournaud chattering with Professor Sten Friberg of the Karolinska Institute, Stockholm, Sweden (from left to right).



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## Electrocardiography

Willem Einthoven (1860-1927)

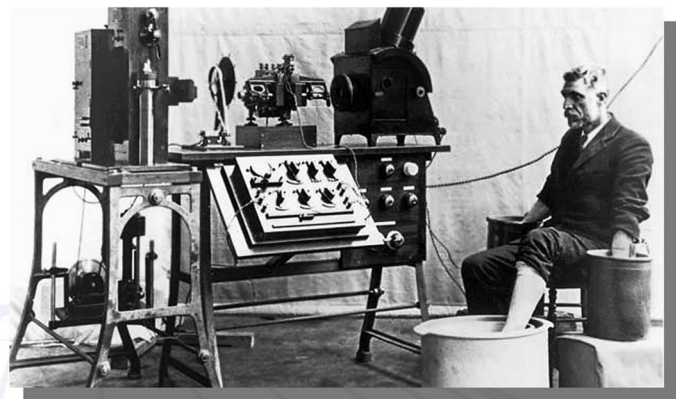
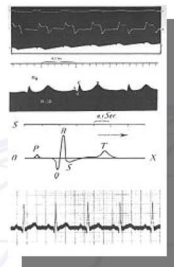
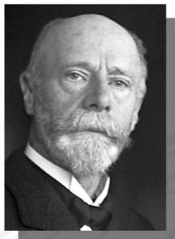
MD from University of Utrecht

String galvanometer to record ECG

ECG without direct leads on heart **1903**

Described P,Q,R,S,T waves

**Nobel Prize in 1924**



(continued)



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## Natural History / Surveillance Studies

Pediatrics  
February 1980, VOLUME 65 / ISSUE 2

Report of the New England Regional Infant Cardiac Program

Metropolitan Atlanta Congenital Defects Program (MACDP)



Baltimore-Washington Infant Study



### Circulation

AUGUST 1977  
VOL. 56 NO. 2  
SUPPLEMENT NO. 1

AN OFFICIAL JOURNAL of the AMERICAN HEART ASSOCIATION

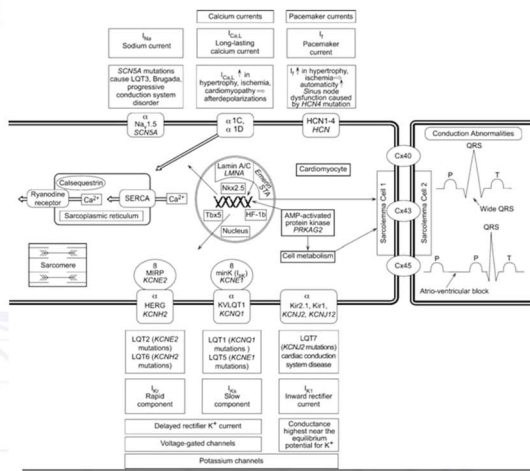
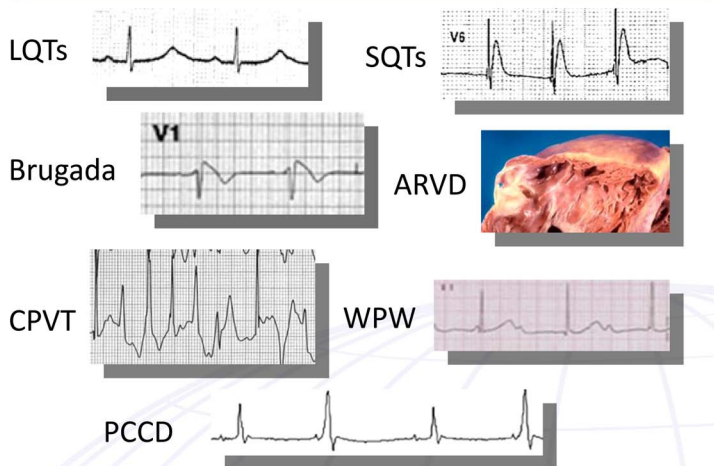
The Joint Study on the Natural History of Congenital Heart Defects



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## Discovery of Inherited Arrhythmias



(continued)



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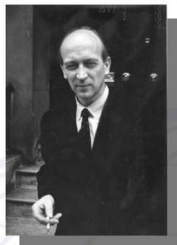
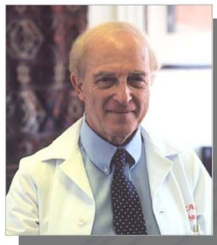
## Adult Congenital/Grown-up Heart Disease (ACHD/GUCH)

### Original Founders

Joe Perloff (UCLA)

Jane Somerville (Brompton)

Paul Wood (Brompton)



### SPECIAL ARTICLE

#### Pediatric Congenital Cardiac becomes a Postoperative Adult

The Changing Population of Congenital Heart Disease

By JOSEPH K. PERLOFF, M.D.

*Circulation* 1973

#### Near misses and disasters in the treatment of grown-up congenital heart patients

Jane Somerville MD FRCP

*J R Soc Med* 1997

### ORIGINAL RESEARCH ARTICLE

*Circulation* 2016

#### Congenital Heart Defects in the United States

Estimating the Magnitude of the Affected Population in 2010

Suzanne M. Gilboa, Owen J. Devine, James E. Kucik, Matthew E. Oster, Tiffany Riehle-Colarusso, Wendy N. Nembhard, Ping Xu, Adolfo Correa, Kathy Jenkins, Ariane J. Marelli

*Living in USA with CHD: 1.4M Adults, 1M Children*

### Major Contributors

- Roberta Williams
- David Sahn
- David Skorton
- John Child



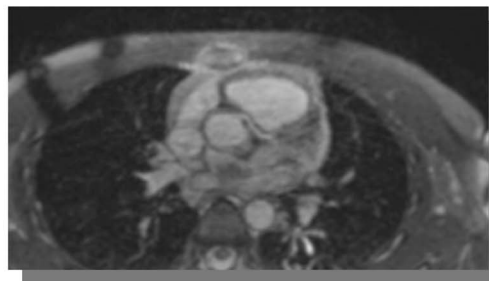
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## Cardiac MRI/CT

CT studies began in 1971

MRI studies began in 1977



CT anomalous RCA

Complex CHD  
MRI Reconstructions



Fetal MRI

(continued)





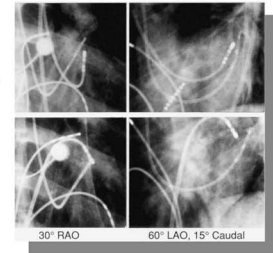
7<sup>th</sup> WORLD CONGRESS OF PEDIATRIC CARDIOLOGY & CARDIAC SURGERY  
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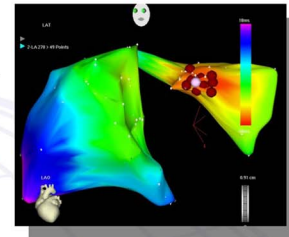
## Radiofrequency Ablation

- Intra-cardiac catheters record electrical activity 1940-50
- Recording His ECG/programed electrical stimulation (PES) 1960
- Dual pathways in WPW documented in 1967
- Initiation/Termination of atrial rhythms (PES)1960-70
- Arrhythmia Surgery for WPW 1968 Cobb
- High energy shocks ablate pathways Scheinman/Gallagher 1980-81
- Radiofrequency current Budde 1987

Past →

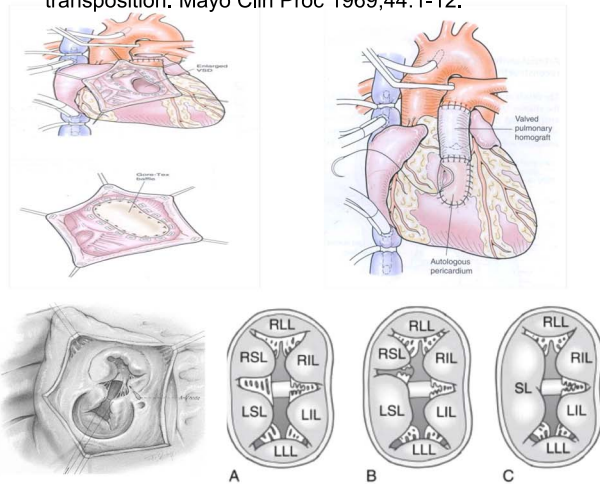


Present →



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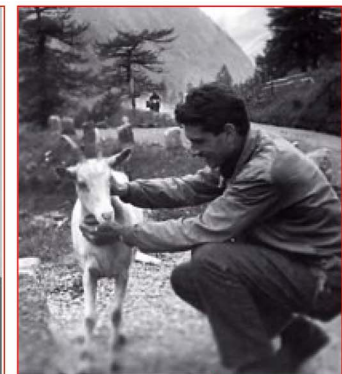
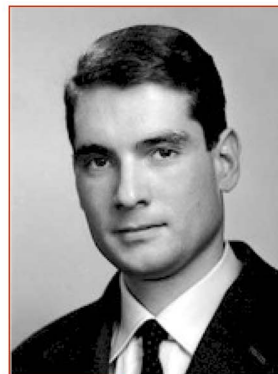
Rastelli, G.C. A new approach to "anatomic" repair of transposition. Mayo Clin Proc 1969;44:1-12.



Rastelli GC, Kirklin JW, Titus JL: Anatomic observations on complete form of persistent common AV with special reference to AV valves. Mayo Clin Proc 1966;41:296.

## Giancarlo Rastelli

1933-1970 (Parma, Italy and Rochester, USA)



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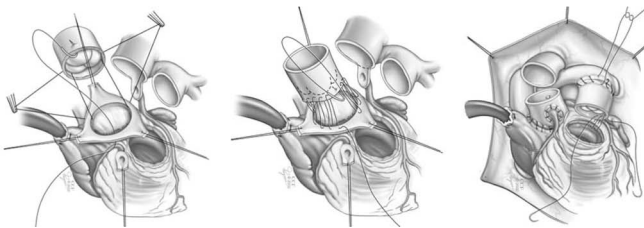


## Donald N. Ross

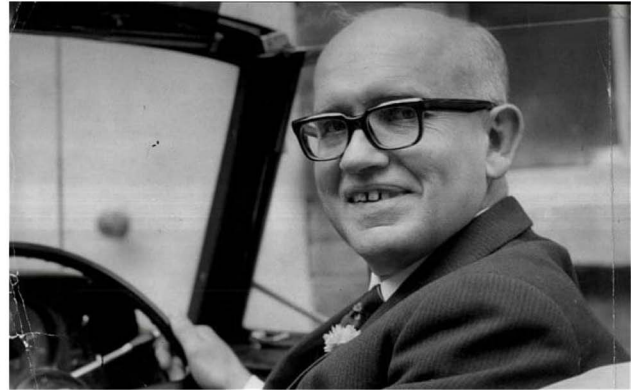
GUY'S HOSPITAL AND NATIONAL HEART HOSPITAL, LONDON

### REPLACEMENT OF AORTIC AND MITRAL VALVES WITH A PULMONARY AUTOGRAFT

*The finding of late degenerative changes in a proportion of aortic homografts prompted the use of the patient's own pulmonary valve as a replacement. As a living autograft, the transplanted pulmonary valve has the prospect of long-term or permanent survival, whilst retaining the advantages of an aortic homograft. Similarly it can be used to replace the mitral valve. The excised pulmonary valve is replaced with a homograft.*



## Ross Operation 1967

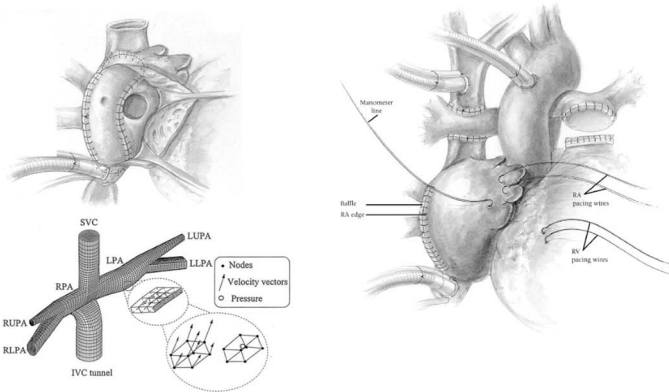


Sir Donald Ross  
1922-2014 (London)

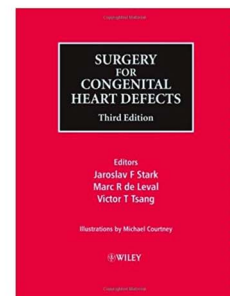
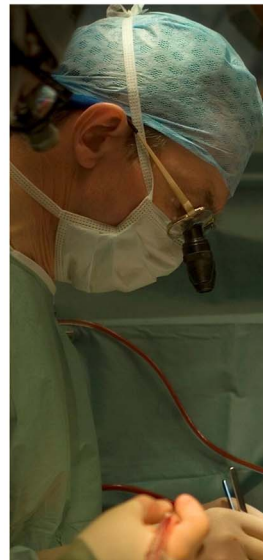


"There are limits to our knowledge, but no limits to our ignorance."

- VSD closure technique in ccTGA
- Fontan technical modifications (TCPC)
- Computational fluid dynamics of Fontan circuit
- Role of the lymphatic system in Fontan physiology
- Analysis of human error in cardiac surgery
- Extraordinary mentor and humanist



## Dr. Marc R. de Leval London, UK



Marc R. de Leval Fellowship

(continued)



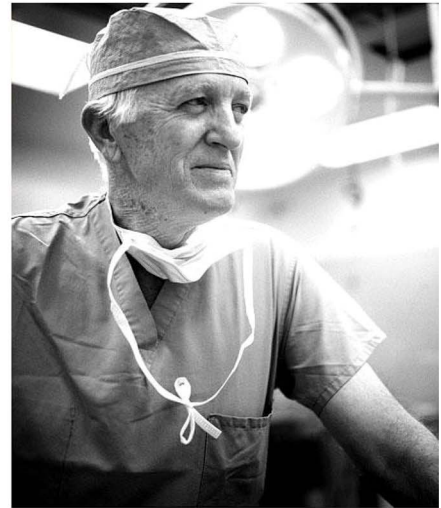
7<sup>th</sup> WORLD CONGRESS OF PEDIATRIC CARDIOLOGY & CARDIAC SURGERY 16-21 JULY, 2017 • BARCELONA



Teresa and Stephanie Fae Beauclair

**Dr. Leonard Bailey**

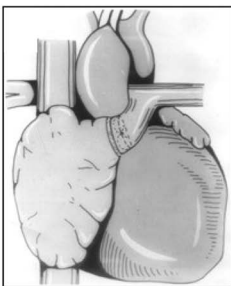
Loma Linda, USA



Neonatal cardiac xenotransplant 26<sup>th</sup> October 1984



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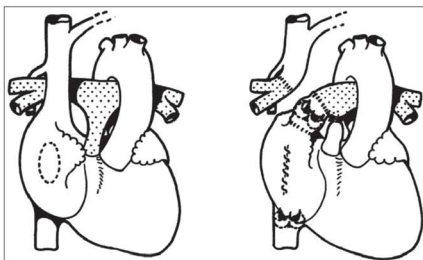


Kreutzer G, Galíndez E, Bono H, De Palma C, Laura JP. An operation for the correction of tricuspid atresia. JTCVS 1973;66:613-21.

**Dr. Guillermo Kreutzer**  
Buenos Aires



**Dr. Francis Fontan**  
Bordeaux



Fontan F, Baudet P. Surgical repair of tricuspid atresia. Thorax 1971;26: 240-248.



**Fontan-Kreutzer operation**  
Right heart bypass for tricuspid atresia

(continued)





### Blalock-Taussig-Thomas Operation

Johns Hopkins Hospital, Baltimore  
 A gender and racially integrated team employs a complex novel procedure to palliate a desperately unwell child.



Eileen Saxon Nov 29, 1944

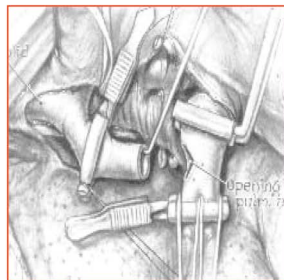
**Dr. Helen Taussig**  
 1898-1986



**Dr. Alfred Blalock**  
 1899-1964

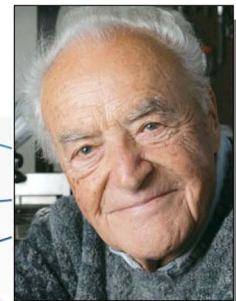
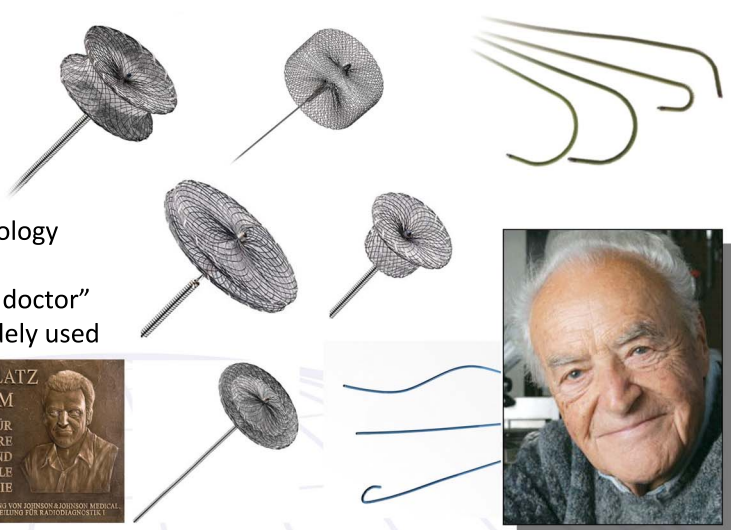


**Mr. Vivian Thomas**  
 1910-1985



### Kurt Amplatz 1924-

Born in Austria; emigrated to US 1953  
 40 year Career at University of Minnesota  
 1983 Malcolm P. Hansen Professor of Radiology  
 Co-founded AGA Medical Corporation  
 Frequently described as "a simple country doctor"  
 Designed and created multiple devices widely used  
 in interventional procedures

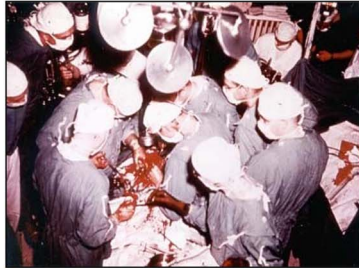
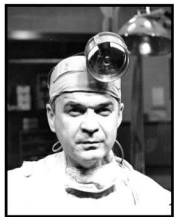


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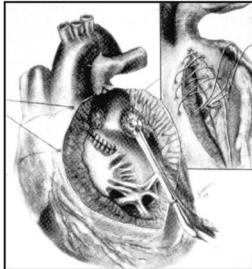
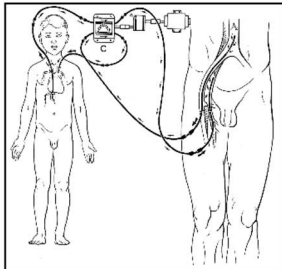
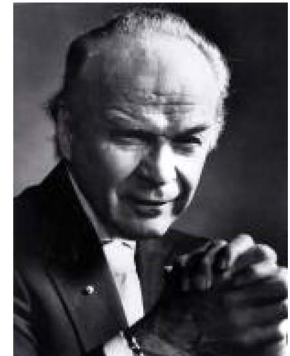


## Cross circulation 1954-1955

University of Minnesota



**Dr. C. Walton Lillehei**  
(1918-1999)



45 patients with major cardiac malformations underwent open repair utilizing cross-circulation (VSD, TOF, AVSD)

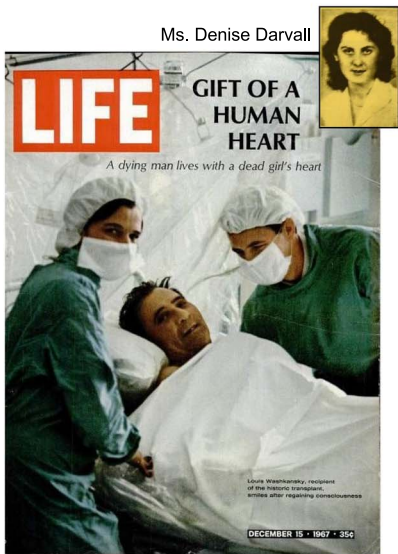
Twenty-seven patients (>50% infants), had VSD closure

Eight hospital deaths, 2 late deaths @ 30 year f/u, with seventeen 30 year survivors in NYHA Class I

At least 820 cardiothoracic surgeons in 36 countries can trace their surgical lineage to Lillehei



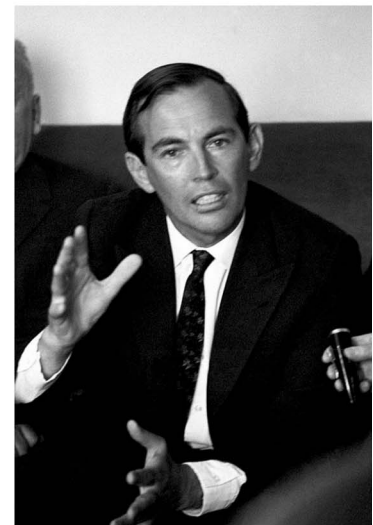
**Dr. Christian N. Barnard**  
1922 - 2001



Mr. Louis Washkansky



**First Human Heart Transplant**  
3rd December 1967  
Capetown, South Africa



*(continued)*



7<sup>th</sup> WORLD CONGRESS OF PEDIATRIC CARDIOLOGY & CARDIAC SURGERY  
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## Neonatal Surgery/Early Correction

