

The History of the Field of Pediatric Electrophysiology (a somewhat personal perspective with stories)

George Van Hare MD

Division Chief, Pediatric Cardiology

Co-Director, Heart Center



Presenter disclosures

- Financial (Relationships with industry)
 - None
- Off-label, experimental or investigational use of drugs or devices:
 - Historical only

What defines a clinical specialty?

- Distinct body of knowledge
 - Distinct from both pediatric cardiology and adult EP
- Fellowship training guidelines
 - Published 2015
- Board certification
 - IBHRE Peds EP Exam
- Laboratory and practitioner credentialing
 - Intersocietal Accreditation Commission (IAC)

Sentinel events in pediatric EP

- Early arrhythmologists
- Texas Children's Hospital as ground zero
- Founding of the Peds EP Society
- RF ablation, ablation registry, PAPCA
- Flutter ablation – EP and surgical
- Current and future trends

Early pediatric arrhythmologists

- Henry Gelband and Grace Wolff, Miami
- Jerome Liebman, MD, Cleveland
- Welton Gersony and Allan Hordoff, NY
- Madison Spach, MD Duke
- David Southall, MD London
- Arthur Pickoff, MD New Orleans



Philippe Coumel, MD, 1935–2004

Drs. Guy Fontaine & Gerard Guiraudon



Epicardial Mapping in a Variant of Type A Wolff-Parkinson-White Syndrome

By JOHN M. NEUTZE, M.D., F.R.A.C.P., ALAN R. KERR, M.B., F.R.A.C.S.,
AND RALPH M. L. WHITLOCK, M.B., D.I.C. (Lond)

SUMMARY

Electrocardiographic and epicardial mapping studies are reported in a child with an atrial septal defect and a variant of type A Wolff-Parkinson-White (WPW) syndrome. The vectorcardiogram suggested a posterior area of early activation and this was confirmed by epicardial mapping studies. Premature activation apparently occurred from a site near the endocardium of the basal region of the left ventricle and surgical interruption could not be planned on the basis of data provided by epicardial mapping.

The role of vectorcardiography in assessing patients with the WPW syndrome is discussed.

- 13 month old with ASD and WPW, left sided AP at Greenlane Hospital, Auckland
- Surgical ASD closure, mapping in 1973

Pediatric EP at Texas Children's Hospital



Paul Gillette from 1971- 1986

Tim Garson from 1979 - 1992

1974-5

ELECTROPHYSIOLOGIC STUDIES OF SURGICAL COMPLETE ATRIOVENTRICULAR BLOCK

Paul C. Gillette, M.D.

British Heart Journal, 1974, 36, 186-191.

Electrophysiological abnormalities after Mustard's operation for transposition of the great arteries¹

Paul C. Gillette, Galal M. El-Said, N. Sivarajan, Charles E. Mullins, Robert L. Williams,
and Dan G. McNamara

*From The Section of Cardiology, Department of Pediatrics, Baylor College of Medicine, and
Texas Children's Hospital, Houston, Texas, U.S.A.*

British Heart Journal, 1974, 36, 971-980.

Electrophysiology of ventricular inversion¹

Paul C. Gillette, Milton J. Reitman, Charles E. Mullins, Robert L. Williams,
John T. Dawson, Jr., and Dan G. McNamara

*From The Section of Cardiology, Department of Pediatrics, Baylor College of Medicine, and Texas Children's
Hospital, Houston, Texas, U.S.A.*

Am J Dis Child. 1974 Nov;128(5):622-6.

Electrophysiological mechanism of the short PR interval in Pompe disease.

Gillette PC, Nihill MR, Singer DB.

Am Heart J. 1975 Jan;89(1):36-44.

Intracardiac electrography in children and young adults.

Gillette PC, Reitman MJ, Gutgesell HP, Vargo TA, Mullins CE, McNamara DG.

The Mechanisms of Supraventricular Tachycardia in Children

PAUL C. GILLETTE, M.D.

SUMMARY The mechanisms of supraventricular tachycardia were investigated in 35 children. Intracardiac electrograms including His bundle potentials were recorded. Atrial pacing and single premature atrial stimuli were performed in the right atrium. Tachycardia was observed and the mechanism elucidated in 33 patients. The atrial activation sequence during tachycardia, including high right atrium, low lateral right atrium, low septal right atrium, and left atrium, together with the ability to initiate or terminate the tachy-

cardia with premature stimuli, were keys to defining the mechanisms. The observed mechanisms included atrioventricular (A-V) node re-entry (8), sino-atrial node re-entry (5), re-entry through manifest or concealed lateral anomalous pathway (8), re-entry through A-V node bypasses (3), and atrial (7) and junctional (2) ectopic foci. The frequency of the various mechanisms of SVT is more varied in children than adults, with ectopic mechanisms being more common in children.

Themes that brought patients to Houston: Tetralogy

Sudden Death after Repair of Tetralogy of Fallot

Electrocardiographic and Electrophysiologic Abnormalities

PAUL C. GILLETTE, M.D., MARK A. YEOMAN, M.D.,
CHARLES E. MULLINS, M.D., AND DAN G. McNAMARA, M.D.

SUMMARY In order to try to determine the mechanism of sudden death in patients after surgical repair of tetralogy of Fallot, electrocardiographic, intracardiac electrophysiologic, and clinical data of 51 children who had postoperative intracardiac electrophysiologic studies were reviewed. Ninety-four percent had developed right bundle branch block (RBBB) and 16 percent had additional left anterior hemiblock (LAH). Two had had transient complete A-V block (CAVB) and one had permanent CAVB. Six had a first degree A-V block and nine had premature ventricular contractions (PVC).

Nine patients were found to have prolonged intra-atrial conduction times, four prolonged A-V nodal conduction, four prolonged His-Purkinje conduction, and five prolonged corrected sinus node

recovery times. Patients with first degree A-V block or LAH did not have an increased incidence of abnormalities on electrophysiologic study.

No patient with RBBB and LAH developed complete A-V block or died. Three of the nine patients with PVCs died, one of intractable ventricular fibrillation and two suddenly, presumably of dysrhythmia. All three had significant congestive heart failure.

Although late complete A-V block occurs and should be watched for, ventricular dysrhythmias in patients with PVCs may be the cause of most sudden deaths after tetralogy repair. We currently are treating all of our postoperative tetralogy patients who have PVCs with quinidine or propranolol.

Themes that brought patients to Houston: Arrhythmia surgery

J Am Coll Cardiol. 1985 Jan;5(1):124-9.

Surgical management of refractory supraventricular tachycardia in infants and children.

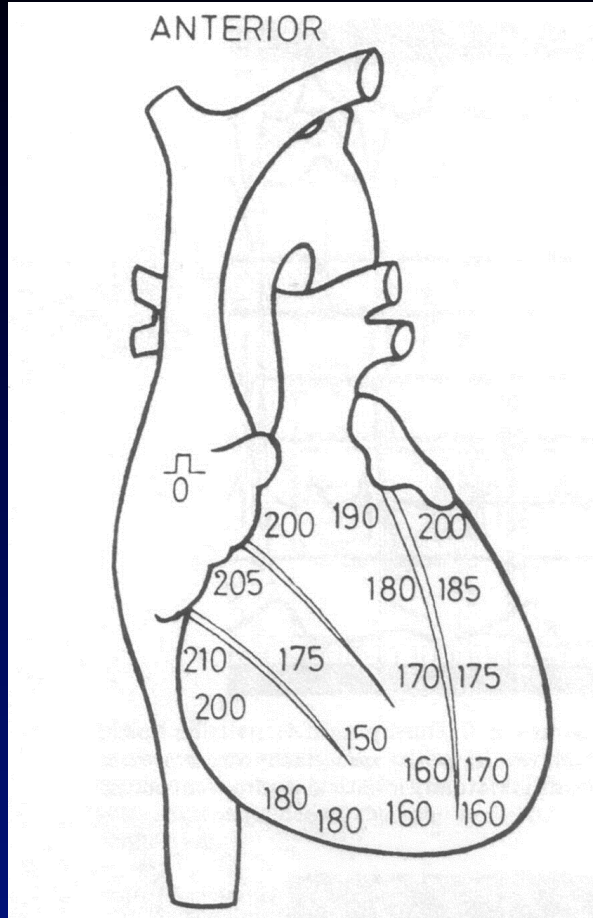
Ott DA, Gillette PC, Garson A Jr, Cooley DA, Reul GJ, McNamara DG.

Surgical Treatment of Ventricular Tachycardia in Infants

Arthur Garson, Jr., M.D., Paul C. Gillette, M.D., Jack L. Titus, M.D., Edith Hawkins, M.D., Debra Kearney, M.D., David Ott, M.D., Denton A. Cooley, M.D., and Dan G. McNamara, M.D.

N Engl J Med 1984; 310:1443-1445 | [May 31, 1984](#) | DOI: 10.1056/NEJM198405313102207

First demonstration of atriofascicular pathway



- Epicardial map
- Atrial pacing to achieve full preexcitation (i.e. 100% down pathway)
- Earliest activation RV free wall, NOT the AV groove
- AV groove dissection cured patient anyway

“Gillette and Garson Course”

Heart House, Bethesda MD 1980 - 2001



The Palm, Washington DC



...Paul got there first

Am Heart J. 1983 Oct;106(4 Pt 1):619-23.

Junctional automatic ectopic tachycardia: new proposed treatment by transcatheter His bundle ablation.

Gillette PC, Garson A Jr, Porter CJ, Ott D, McVey P, Zinner A, Blair H.

DC ablation successful in 2/2 infants with pacemaker

J Am Coll Cardiol. 1985 Apr;5(4):999-1001.

Transvenous catheter ablation of a right atrial automatic ectopic tachycardia.

Silka MJ, Gillette PC, Garson A Jr, Zinner A.

Abstract

A 10 year old patient with right atrial automatic ectopic tachycardia underwent successful transvenous catheter ablation after endocardial mapping. Tachycardia had been present for 7 years before ablation and associated with development of dilated cardiomyopathy. A single 50 J discharge at the point of earliest atrial activation was followed by the establishment of sinus rhythm that remains at 10 months' follow-up. This case represents the first reported successful catheter ablation of an atrial automatic ectopic tachycardia. Specific anatomic factors favoring successful ablation and improvement in technique are discussed.

DC ablation successful in 2/4

J Am Coll Cardiol. 1985 Aug;6(2):405-9.

Treatment of atrial automatic tachycardia by ablation procedures.

Gillette PC, Wampler DG, Garson A Jr, Zinner A, Ott D, Cooley D.

Texas Children's Hospital trainees

- Margreet Bink-Boelkens
- John Kugler
- Co-burn Porter
- Peter Hesslein
- Stan Beder
- Peter Karpawich
- Elizabeth Villain
- Jeff Moak
- William Pinsky
- Richard Smith
- Mike Silka
- Bert Ross
- Rich Friedman
- Jim Perry
- Bob Hamilton
- Thomas Paul

Pediatric EP Society

Founded 2/12/83

- Tim Garson
- Paul Gillette
- Grace Wolff
- Vicki Vetter



Earliest PACES paper

Cardiac Rhythm after the Mustard Operation for Complete Transposition of the Great Arteries

Celia J. Flinn, M.D., Grace S. Wolff, M.D., Macdonald Dick, II, M.D., Robert M. Campbell, M.D., Gordon Borkat, M.D., Alfonso Casta, M.D., Alan Hordof, M.D., Thomas J. Hougen, M., Rae-Ellen Kavey, M.D., John Kugler, M.D., Jerome Liebman, M.D., Joel Greenhouse, Ph.D., and Paul Hees, B.S.

N Engl J Med 1984; 310:1635-1638 | [June 21, 1984](#) | DOI: 10.1056/NEJM198406213102504

- 372 TGA patients who survived Mustard
- Only 57% in sinus rhythm by 8 years
- 9 sudden deaths during follow-up
- 71% survival at 15 years

PACES Milestones

- Founding: Washington DC February 1983
 - (NASPE 1979)
- Informal arrangements: 1983 – 1990 (Led by Grace Wolff)
- Yearly meeting, coincident with AHA
- Adoption of bylaws, allowing for election of a president and other officers, November 10, 1990
- Pediatric RF Ablation Registry, 1991 (John Kugler)
- Incorporation in State of Michigan as 501 (c)(3) non-profit, 1994

PACES Milestones (2)

- Pediatric representative to NASPE Program Committee, ca. 1995 (Vicki Vetter)
- Semi-annual meeting format AHA/NASPE 1998
- Website launched ca. 2000 (Bert Ross)
- Pediatric representative on HRS Board of Trustees: 2005
- Logo and name change 2006
- 1st Strategic planning conference 2008
- 2nd Strategic planning conference 2014



PACES Strategic Goals

- PACES is the inclusive, credible, global representation of the subspecialty of pediatric electrophysiology
- PACES defines pediatric EP subspecialty training.
- PACES functions as the expert society and official resource for pediatric EP and the electrophysiology of CHD.
- PACES is the resource for clinical trials, advocacy, new product development, and the improvement of quality and safety.

PACES Accomplishments

- Numerous collaborative clinical studies published, 1981-present
- 17 guideline documents published with PACES leadership or partnership
- Yearly satellite symposium prior to HRS meeting
- Young investigator awards
- International members
- Allied Professional membership and leadership
- Defined relationship with HRS as partner society

PACES-led documents

- RF ablation in children 2001 (Friedman)
- Catheter ablation in children/CHD 2016 (Saul/Kanter)
- Advanced training (Walsh)
- Arrhythmias in ACHD (Khairy)
- Asymptomatic WPW (Cohen)
- Ventricular arrhythmias (Crossen)

Presidents of PACES

1988 Woody Benson	2005 John Triedman
1989 Grace Wolff	2007 George Van Hare
1990 John Kugler	2009 Rich Friedman
1991 Mac Dick	2010 Phil Saul
1992 Ann Dunnigan	2011 Pete Fischbach
1993 Barbara Deal	2012 Susan Etheridge
1995 Jeff Moak	2013 Charlie Berul
1997 Bert Ross	2014 Ian Law
1999 Mike Silka	2015 Kathy Collins
2001 Ed Walsh	2016 Shu Sanatani
2003 Jim Perry	

Status of catheter ablation in 1988

- DC ablation used for posteroseptal pathways and for AVJ ablation in adults
- Most children with WPW cured by surgery
- RF recently available, used for AVJ ablation, not highly effective
 - Advantage: no need for general anesthesia
- Whispers of what was going on in Oklahoma City

Pediatric Reports of DC ablation

J Am Coll Cardiol. 1985 Apr;5(4):999-1001.

Transvenous catheter ablation of a right atrial automatic ectopic tachycardia.

Silka MJ, Gillette PC, Garson A Jr, Zinner A.

Pacing Clin Electrophysiol. 1989 Nov;12(11):1787-96.

Transcatheter electrical ablation of accessory pathways in children.

Bromberg BJ, Dick M 2nd, Scott WA, Morady F.

Division of Pediatric Cardiology, C.S. Mott Children's Hospital, Ann Arbor, Michigan.

Abstract

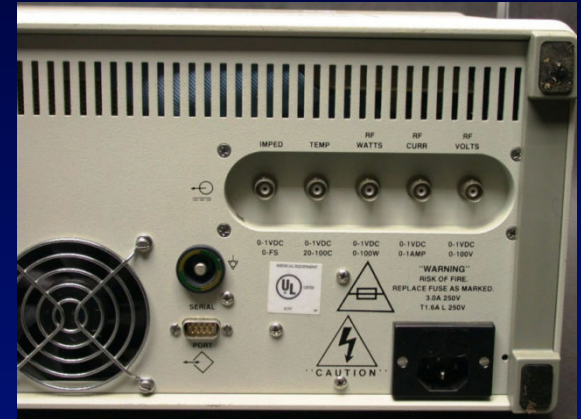
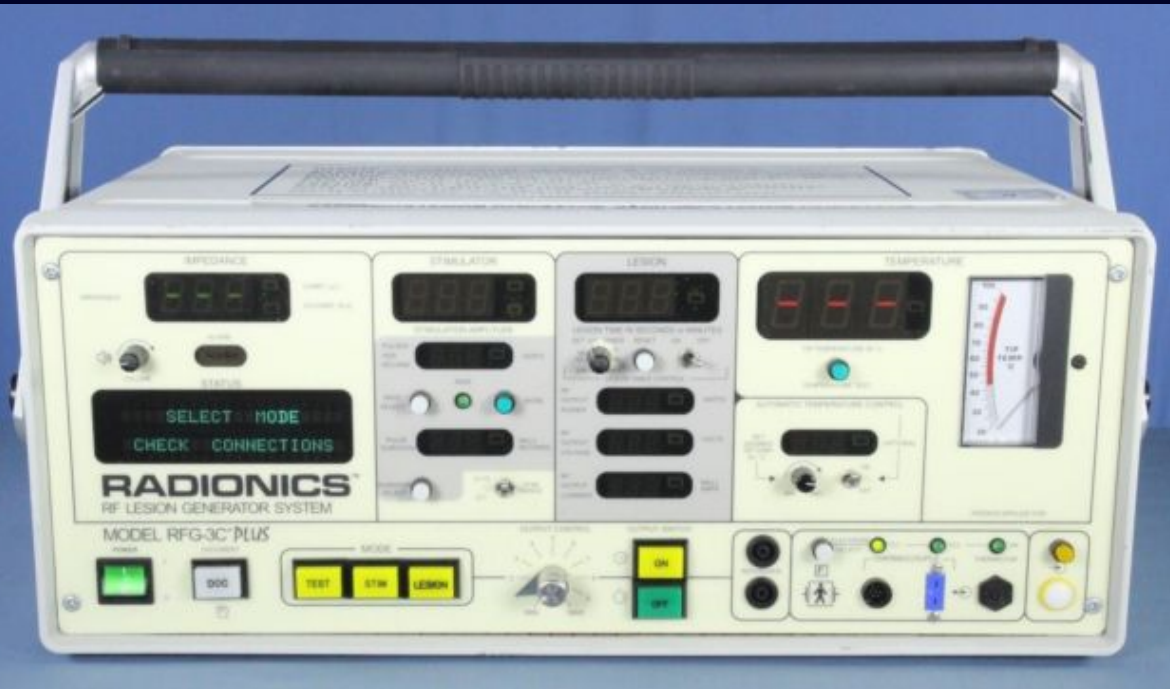
Supraventricular tachycardia (SVT), the most common sustained symptomatic arrhythmia of childhood, is often supported by a manifest or concealed accessory pathway. Permanent interruption of the accessory pathway usually requires surgical division. Recent experience with electrical ablation of posterior septal pathways in adults prompted us to apply the technique to children. Six children, ages 8 to 15 years, underwent a complete electrophysiological study followed by transcatheter electrical ablation. Five of the 6 children, 3 with a right posterior septal and 2 with a left posterior septal pathway, were approached with the ablation catheter at the os of the coronary sinus. In the remaining patient, a left lateral pathway was mapped with an electrode catheter in the coronary sinus and then approached with the ablation catheter through the patent foramen into the left atrium. Two patients are asymptomatic 18-24 months postablation; one patient had return of anomalous conduction between 7 and 21 days after ablation. Two patients had transient interruption of anomalous conduction, whereas one patient experienced no effect. We conclude that in carefully selected patients, transcatheter electrical ablation offers an alternative to surgery for permanent interruption of an accessory pathway.

1st UCSF RF generator

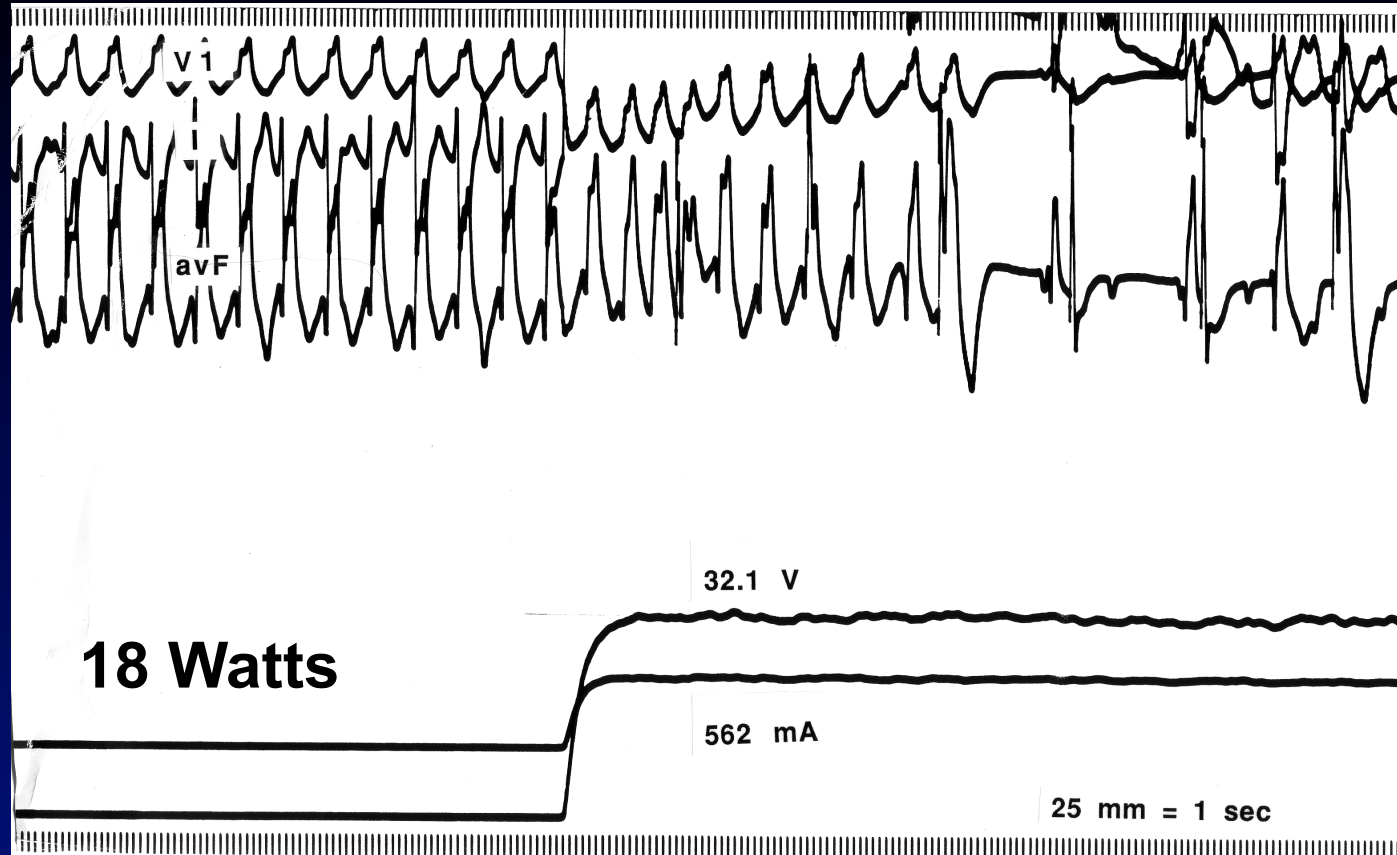


- Microvasive Bicap 4005 neurosurgical unit producing up to 18 W
- Hand-wound transformer to allow voltages of ~ 30 V
- Non-deflectable 6-F catheter with 3 mm tip
- Telemetered voltage and current, solve for power ($W = I \times V$)

Radionics RFG-3C electrosurgical unit



Successful RF ablation of JET in 10-m old



Wednesday, March 6, 1991

4:00PM-5:00PM, Room 364, West Concourse

Pediatric Arrhythmias: Diagnosis and Management

4:15

**PERCUTANEOUS RADIOFREQUENCY CATHETER ABLATION
FOR SUPRAVENTRICULAR ARRHYTHMIAS IN CHILDREN**

George F. Van Hare, Michael D. Lesh, Jonathan J. Langberg.
University of California San Francisco, San Francisco, CA.

8/10

4:30

**RADIOFREQUENCY ENERGY IS A SAFE
INITIAL TREATMENT IN CHILDREN WITH
THE WOLFF-PARKINSON-WHITE SYNDROME**

Brian K. O'Connor, Macdonald Dick, Gerald A. Serwer, Sarah
Leroy, Brian Armstrong, Michael Perlestein. C.S. Mott Children's
Hospital, The University of Michigan, Ann Arbor, MI

2/6

4:45

**RADIOFREQUENCY CURRENT CATHETER ABLATION OF
ACCESSORY PATHWAYS IN CHILDREN**

Karl H. Kuck, Manfred Geiger, Michael Schlüter, Wolfgang Duckeck,
Jürgen Siebels. University Hospital Eppendorf, Hamburg, F. R. Ger-
many

10/10

Percutaneous Radiofrequency Catheter Ablation for Supraventricular Arrhythmias in Children

GEORGE F. VAN HARE, MD, FACC, MICHAEL D. LESH, MD, FACC,
MELVIN SCHEINMAN, MD, FACC, JONATHAN J. LANGBERG, MD, FACC

San Francisco, California

JACC 17; 1991(June): 1613-20.

Transcatheter ablation for pediatric tachyarrhythmias using radiofrequency electrical energy.

Walsh EP, Saul JP.

Department of Cardiology, Children's Hospital, Harvard Medical School, Boston, MA 02115.

Pediatr Ann. 1991(Jul);20:386, 388-92.

Use of Radiofrequency Current to Ablate Accessory Connections in Children

Macdonald Dick II, MD; Brian K. O'Connor, MD; Gerald A. Serwer, MD;
Sarah LeRoy, RN, MS; and Brian Armstrong

Circulation 1991(Dec):84:2318-24.

Founding of the Pediatric RF Ablation Registry



University
of Nebraska
Medical Center

John P. Cheatham, M.D.
David A. Danford, M.D.
Carl H. Gumbiner, M.D.
Philip J. Hofschire, M.D.
John D. Kugler, M.D.
Larry A. Latson, M.D.

January 15, 1991

George F. Van Hare, M.D.
Box 0632
University of California at San Francisco
San Francisco, CA 94143-0632

RE: CATHETER RADIOFREQUENCY ABLATION REGISTRY

Dear ^{George} Dr. Van Hare:

Thank you for your interest in participating in the Catheter Radiofrequency Ablation Registry. Enclosed are the registry forms and the list of registry institutions.

The official starting date of the registry is January 1, 1991. However, if you want to include patients from 1990, we will accept them into the registry as well.

Section of Pediatric Cardiology
600 South 42nd Street
Omaha, NE 68198-2166



UNMC Office (402) 559-5341
UNMC FAX (402) 559-6737
UNMC Clinic (402) 559-7233
CMH Office/Clinic (402) 390-5612
CMH FAX (402) 390-5693
24 Hour On Call (402) 559-4000

First Registry Report

PEDIATRIC RADIOFREQUENCY CATHETER ABLATION REGISTRY

MAY 23, 1991
CONTRIBUTORS

Boston Children's Hospital
Chicago Children's Memorial Hospital
University of Nebraska Medical Center
Oregon Health Science University
San Francisco - University of CA

Procedures: 98
Age: n=95; mean=14.0±6.2
Weight n=97; mean 49.8±22.6
Normal Heart: 69

98 procedures in 95 patients
Success in 73/98 (74%)

Mean procedure time 301.2 min
Mean fluoro time 61.5 min

Pediatric RF Ablation Registry

RADIOFREQUENCY CATHETER ABLATION FOR TACHYARRHYTHMIAS IN CHILDREN AND ADOLESCENTS

JOHN D. KUGLER, M.D., DAVID A. DANFORD, M.D., BARBARA J. DEAL, M.D., PAUL C. GILLETTE, M.D.,
JAMES C. PERRY, M.D., MICHAEL J. SILKA, M.D., GEORGE F. VAN HARE, M.D.,
AND EDWARD P. WALSH, M.D., FOR THE PEDIATRIC ELECTROPHYSIOLOGY SOCIETY*

Reprinted from the *New England Journal of Medicine*
330:1481-1487 (May 26), 1994

- 24 centers
- Ages 20 days – 20.9 years
- 725 procedures, overall success 83%
 - Left freewall 89% success
 - Right freewall 69% success
- Complication rate 4.8% with 4 late deaths
- CLEAR NEED FOR A FUNDED STUDY

Application to NHLBI

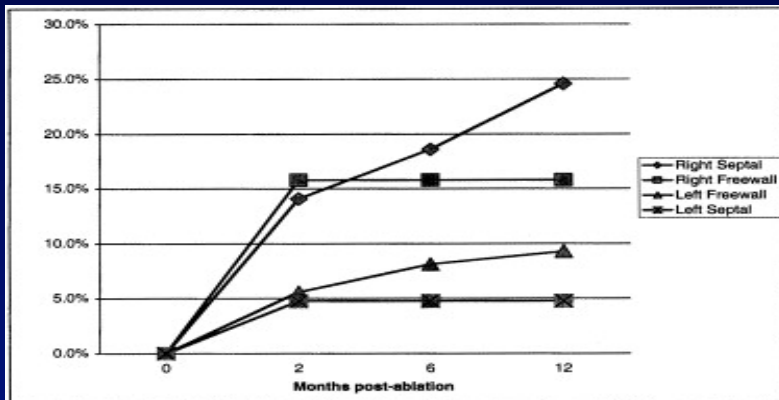
- Inspiring talk by David Bristow (CAST) regarding registries Nov 1992
- Assigned task by Peds EP Society Nov 1992
- Assistance of NIH, and unfunded RFP
- Involvement of SRI International as Data Coordinating Center
- 7/1/97 184, 17.3%ile, funded \$2.4 Million

Prospective Assessment after Pediatric Cardiac Ablation (PAPCA)

- A national, prospective observational study of children undergoing radiofrequency ablation for supraventricular tachycardia
- Clinical questions:
 - What is the true risk of radiofrequency ablation procedures, particularly in young patients and small hearts? (including echo-evident damage)
 - What is the true incidence and time course of recurrence of arrhythmias following initially successful ablation procedures in children

Ablation Results in 2756 patients

Substrate	Success rate	Substrate	Success rate
Manifest Accessory Pathway	994/1067 (93%)	AVNRT	776/800 (97%)
Concealed Accessory Pathway	702/734 (96%)	Atrial Fibrillation	4/4 (100%)
PJRT	57/68 (83%)	Atrial Flutter/intra-atrial reentry	77/91 (85%)
Pathway locations:		Ectopic atrial tachycardia	101/110 (92%)
Right Freewall	294/326 (90%)	Junctional ectopic tachycardia	9/9 (100%)
Right Septal	392/439 (89%)	Ventricular tachycardia	43/55 (78%)
Left Septal	95/108 (88%)	Other	23/31 (74%)
Left Freewall	970/991 (98%)		

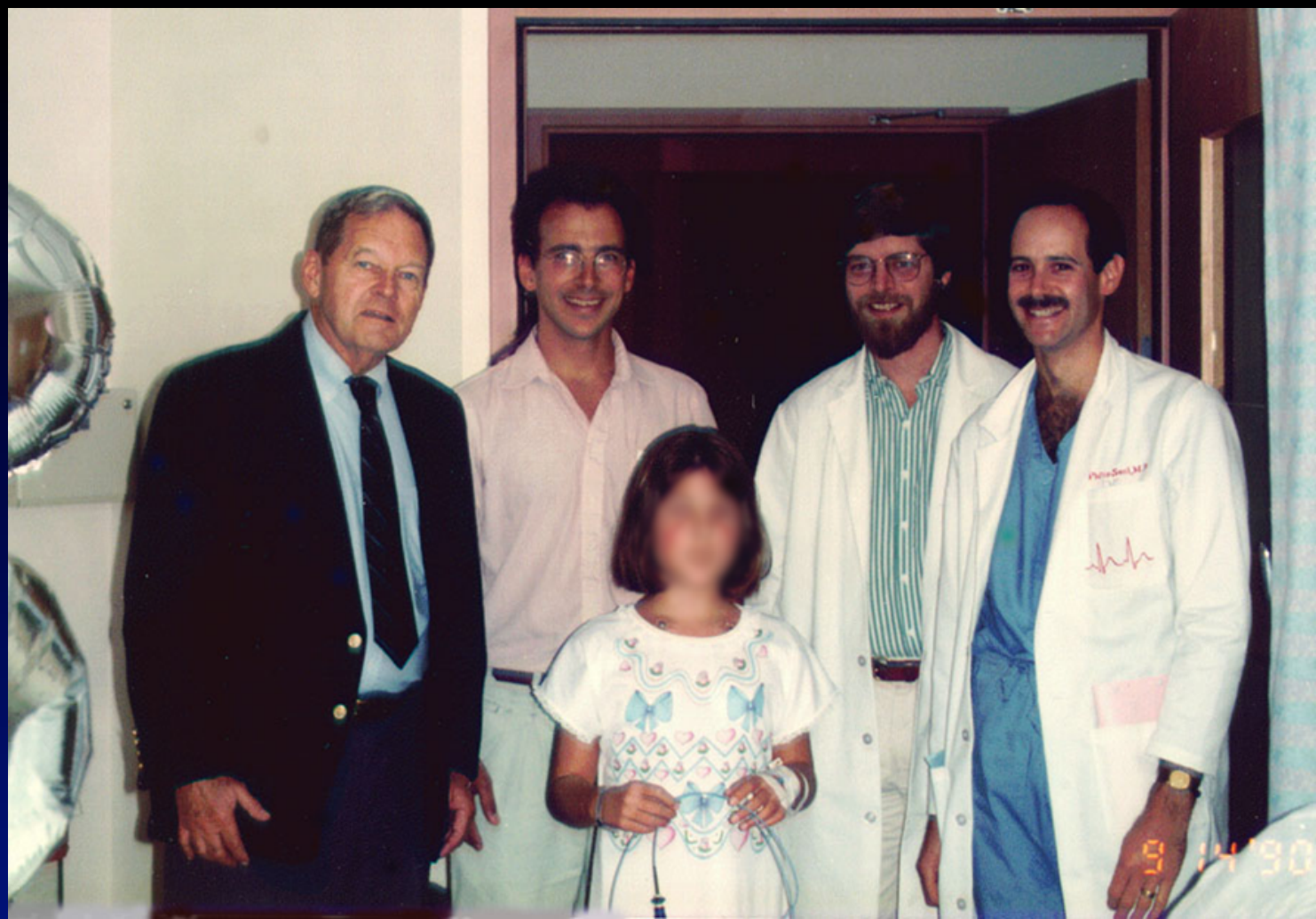


Methods: PACE 2002

Results and complications: JCE 2004

Recurrence: Heart Rhythm 2004

Echo findings: Am heart J 2007



Post-operative atrial flutter: a defining pediatric arrhythmia

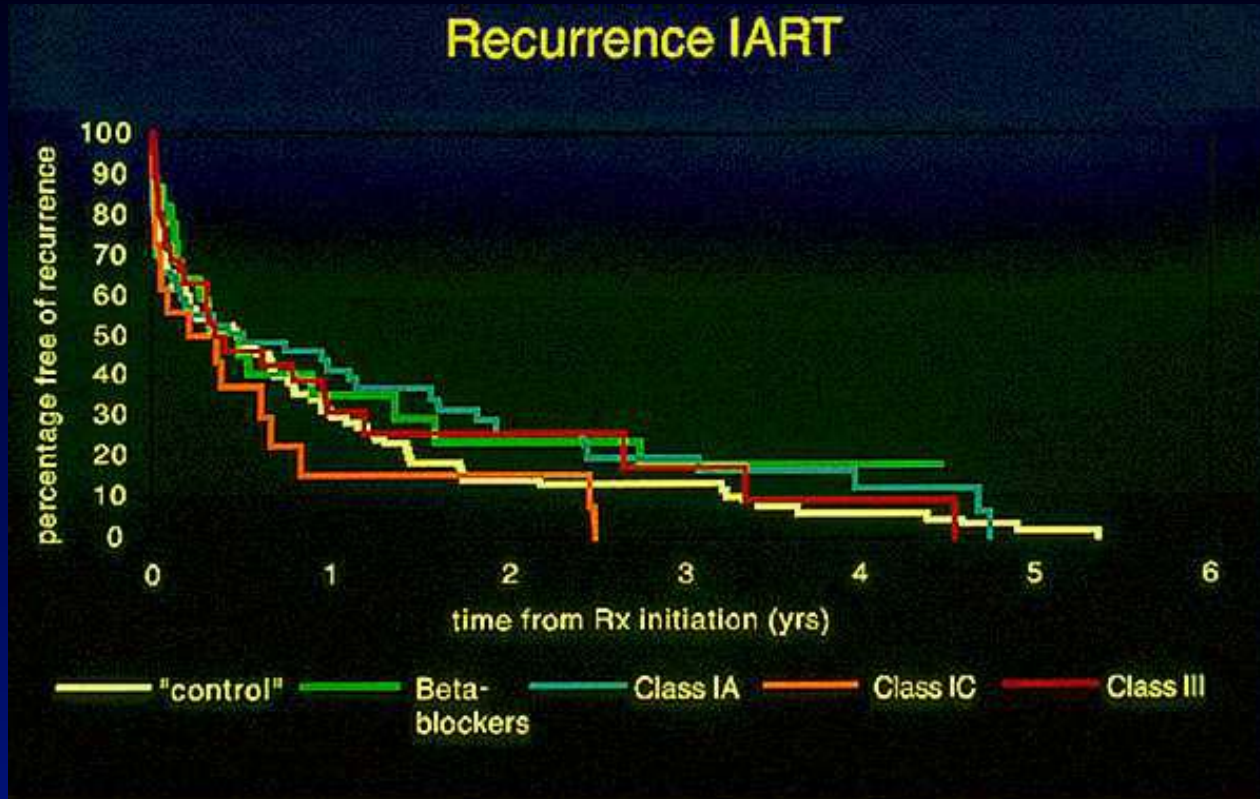
J Am Coll Cardiol. 1985 Oct;6(4):871-8.

Atrial flutter in the young: a collaborative study of 380 cases.

Garson A Jr, Bink-Boelkens M, Hesslein PS, Hordof AJ, Keane JF, Neches WH, Porter CJ.

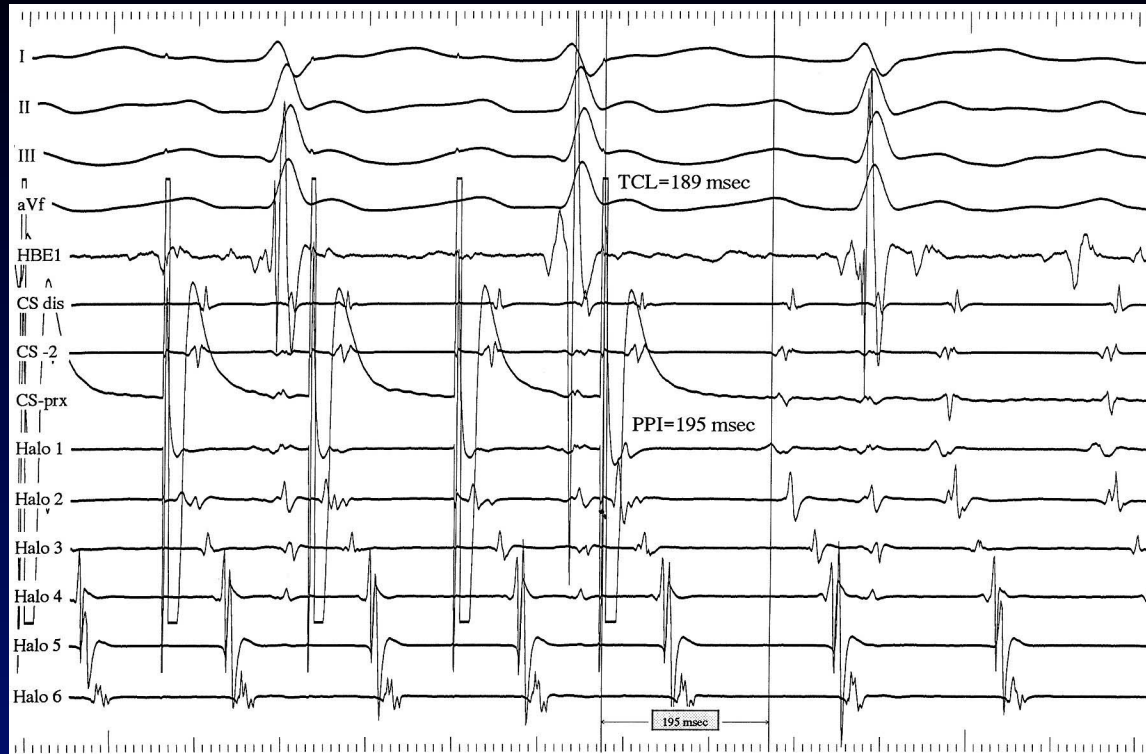
- 73% of cases were in repaired or palliated CHD
- Drugs worked 58% of the time
- 10% of patients died suddenly
- 20% died suddenly if medical did not control the flutter

Medical therapy of post-operative IART



Medications are
disappointing

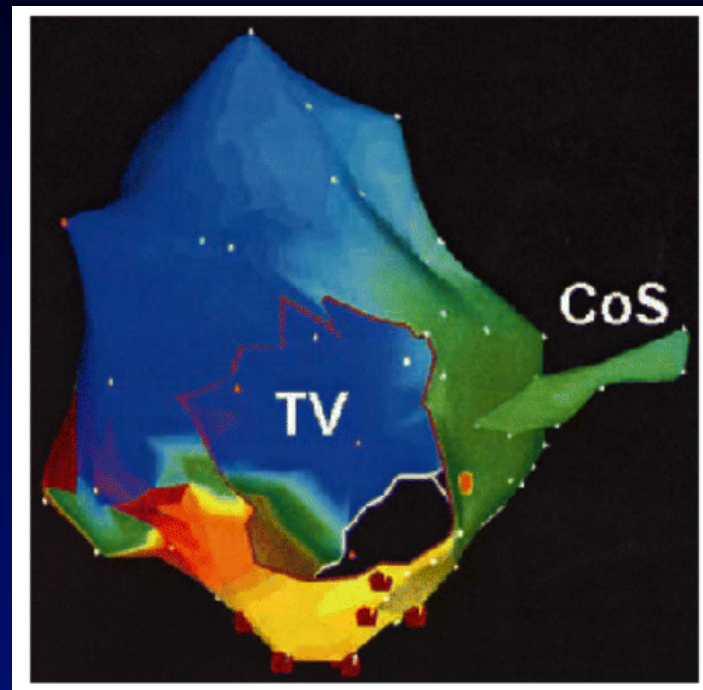
Entrainment mapping



Roving catheter used to pace during tachycardia, measuring post-pacing interval (PPI)

Electroanatomic mapping

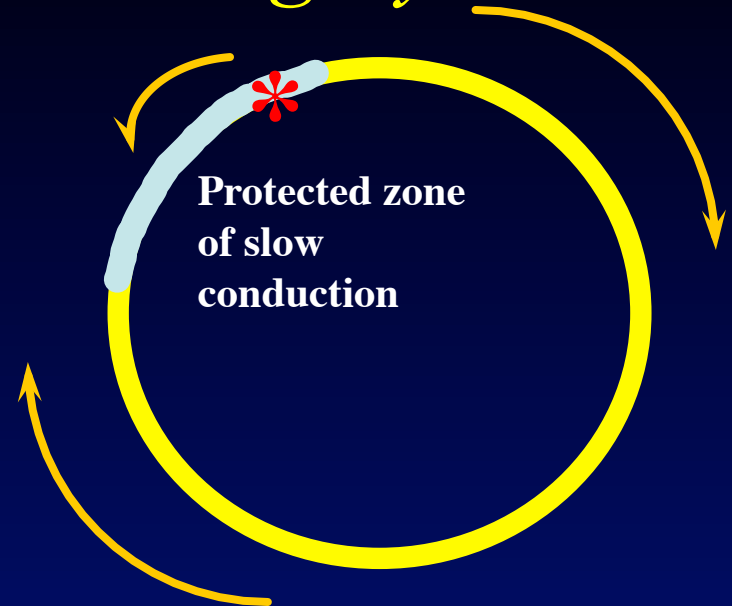
- Isochronal map
- Identifies circuit, isthmus anatomically
- Arguably, not needed for well-defined circuits
 - Typical flutter
 - WPW



Consider two atrial arrhythmias... *in a patient with atrial surgery*



Macro-reentrant



Automatic focus

Focal IART looks like macroreentry by electroanatomic mapping!

Boston Children's Program

Efficacy of Radiofrequency Ablation for Control of Intraatrial Reentrant Tachycardia in Patients With Congenital Heart Disease

JACC 1997

JOHN K. TRIEDMAN, MD, FACC, DENNIS M. BERGAU, MA, J. PHILIP SAUL, MD, FACC,
MICHAEL R. EPSTEIN, MD, EDWARD P. WALSH, MD, FACC

Estimation of Atrial Response to Entrainment Pacing Using Electrograms Recorded from Remote Sites

JCE 2000

JOHN K. TRIEDMAN, M.D., MARK E. ALEXANDER, M.D.,
CHARLES I. BERUL, M.D., LAURA M. BEVILACQUA, M.D.,
and EDWARD P. WALSH, M.D.

Update on Interventional Electrophysiology in Congenital Heart Disease Evolving Solutions for Complex Hearts

Circ A&E 2013

Elizabeth D. Sherwin, MD; John K. Triedman, MD; Edward P. Walsh, MD

Mechanism and Ablation of Arrhythmia Following Total Cavopulmonary Connection

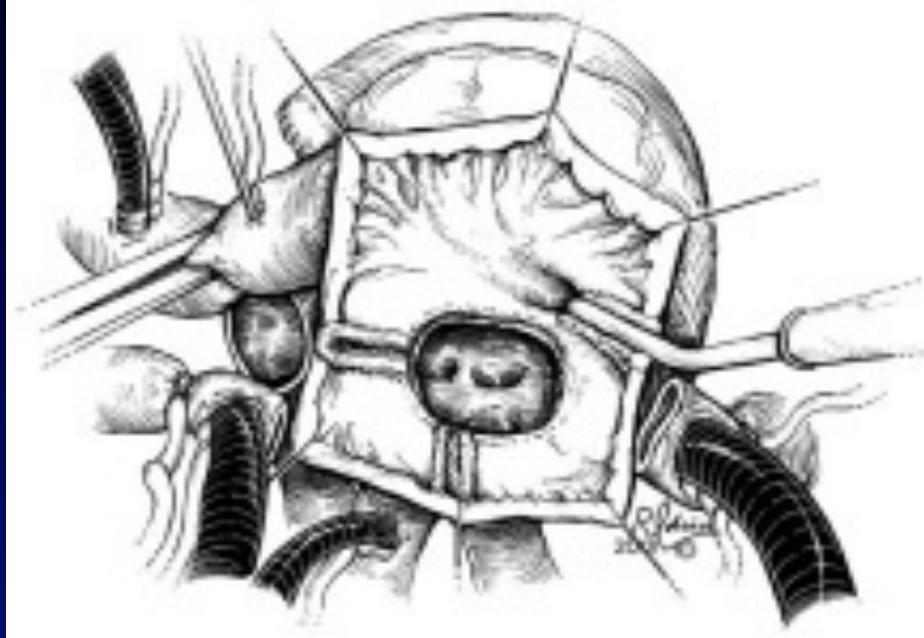
Circ A&E 2015

Rafael Correa, MD; Elizabeth D. Sherwin, MD*; Joshua Kovach, MD*; Douglas Y. Mah, MD;
Mark E. Alexander, MD; Frank Cecchin, MD; Edward P. Walsh, MD;
John K. Triedman, MD; Dominic J. Abrams, MD, MRCP

Right atrial Maze for Fontan flutter

- Arrhythmia surgery for WPW etc disappeared ~1992
- Recognition that ablation is ineffective in Fontan IART ~mid 90's
- Cox maze for atrial fibrillation ~1991
- Combination Fontan conversion and right atrial Maze, Mavroudis et al 1997

Maze at time of Fontan conversion



Mavroudis et al J Thorac Cardiovasc Surg 2001

Maze results

- 111 patients 1994-2006
- Early mortality 0.9%
- Late mortality 5.4%
- 6 patients underwent transplant
- Freedom from recurrence 86% at 5 years

Important mile-markers on the road to modern pediatric ablation practice

- 1992: Entrainment mapping
- 1994: Temperature control
- 1996: Electroanatomic mapping
- 1998: Irrigated tip ablation
- 2001: noncontact mapping
- 2004: cryoablation
--(1991 Gillette)
- 2004: Remote magnetic navigation
- 2008: Zero-fluoroscopy ablation

The future

- Shift from research to quality improvement activity
 - Research: requires consent, funding
 - QI: no consent, hospital pays for it
- Current pediatric cardiology activities
 - STS Database
 - C3PO cath lab database
 - IMPACT congenital heart disease interventions
 - PC⁴ CICU database
- Development of MAP-IT

