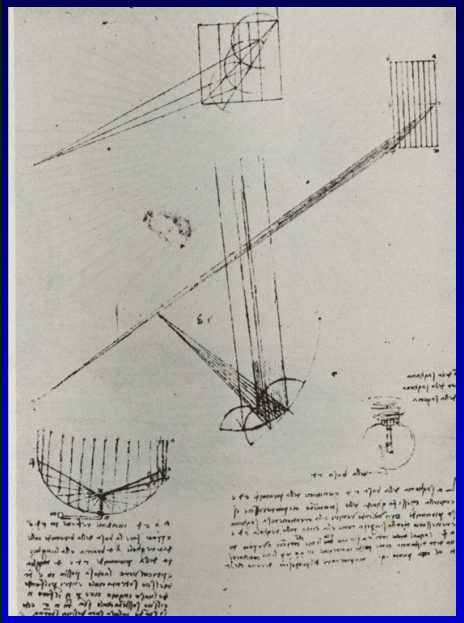
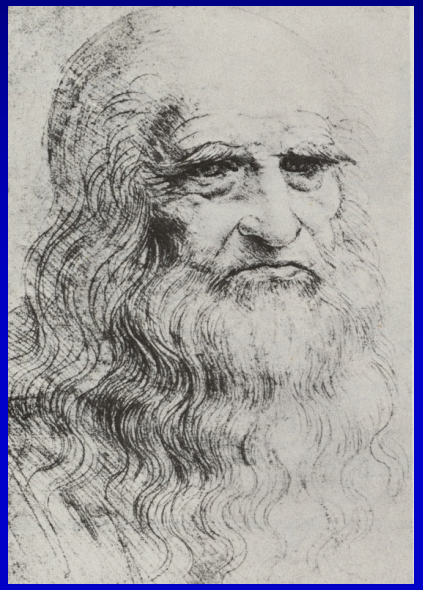
History of supraventricular arrhythmias ablation

Prof. Fiorenzo Gaita

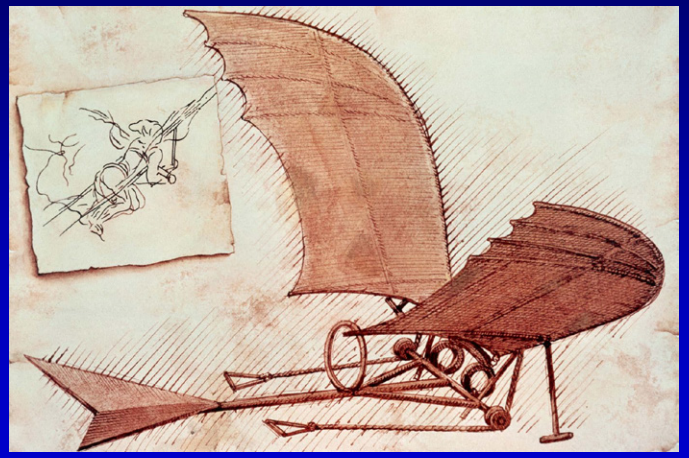
Director of the School of Cardiology, University of Turin, Italy



Knowledge



Idea



Serendipity

Technology

(right tools)

Serendipity - discovery of a new method

ARCHIVES DES MALADIES DU CŒUR ET DES VAISSEAUX

Tome 72, N° 1, janvier 1979

FAITS CLINIQUES

Arch Mal Coeur Vaiss. 1979 Jan;72(1):107-12.

Bloc auriculo-ventriculaire intra-hisien définitif induit au cours d'une exploration endoventriculaire droite

par J. VEDEL, R. FRANK, G. FONTAINE, J.F. FOURNIAL et Y. GROSGOGEAT

Permanent intra-hisian atrioventricular block induced during right intraventricular exploration.
Vedel J, Frank R, Fontaine G, Fournial JF, Grosgogeat Y.

DC shock (Fulguration) 1979-1990

- **AV node ablation**: Vedel, Frank, Fontaine 1979

  Gallagher , Sheinman 1982

(N Engl J Med. 1982; 306:194–200.)

CATHETER TECHNIQUE FOR CLOSED-CHEST ABLATION OF THE ATRIOVENTRICULAR CONDUCTION SYSTEM

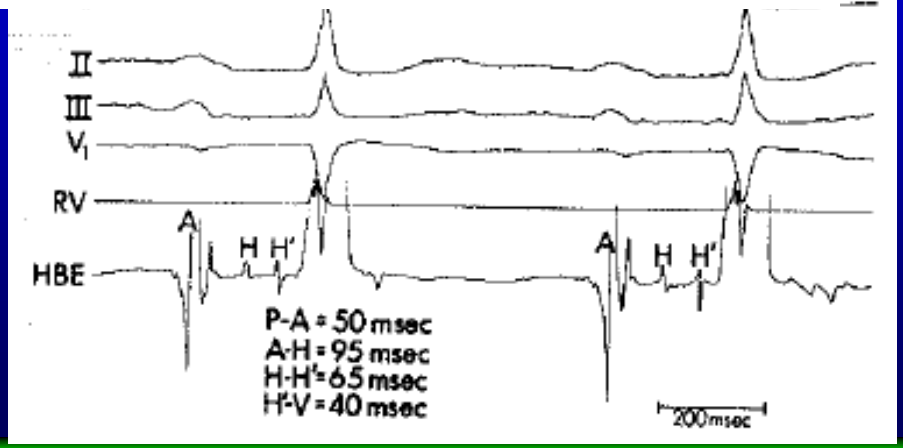
A Therapeutic Alternative for the Treatment of Refractory Supraventricular Tachycardia

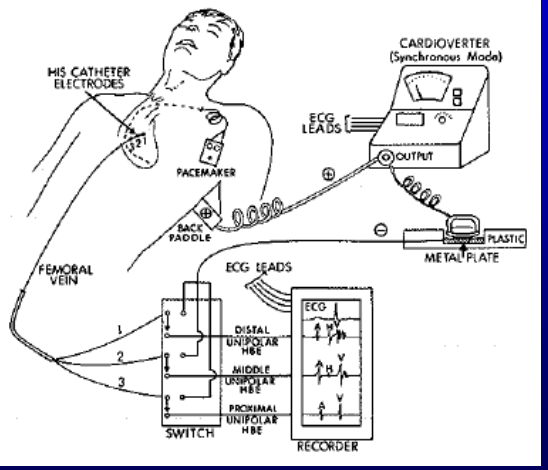
JOHN J. GALLAGHER, M.D., ROBERT H. SVENSON, M.D., JACK H. KASELL, LAWRENCE D. GERMAN, M.D., GUST H. BARDY, M.D., ARCHER BROUGHTON, M.B.B.S., AND GIUSEPPE CRITELLI, M.D.

Abstract This report describes a catheter technique for ablating the His bundle and its application in nine patients, an initial shock of 200 J was used. The His bundle was ablated by this single shock in six of these patients and by an additional shock of 300 J in one. In the remaining patient, conduction in the atrioventricular node was modified, resulting in alternating first and second-degree atrioventricular block. A stable escape rhythm was preserved in all patients. The procedure was well tolerated, without complica-

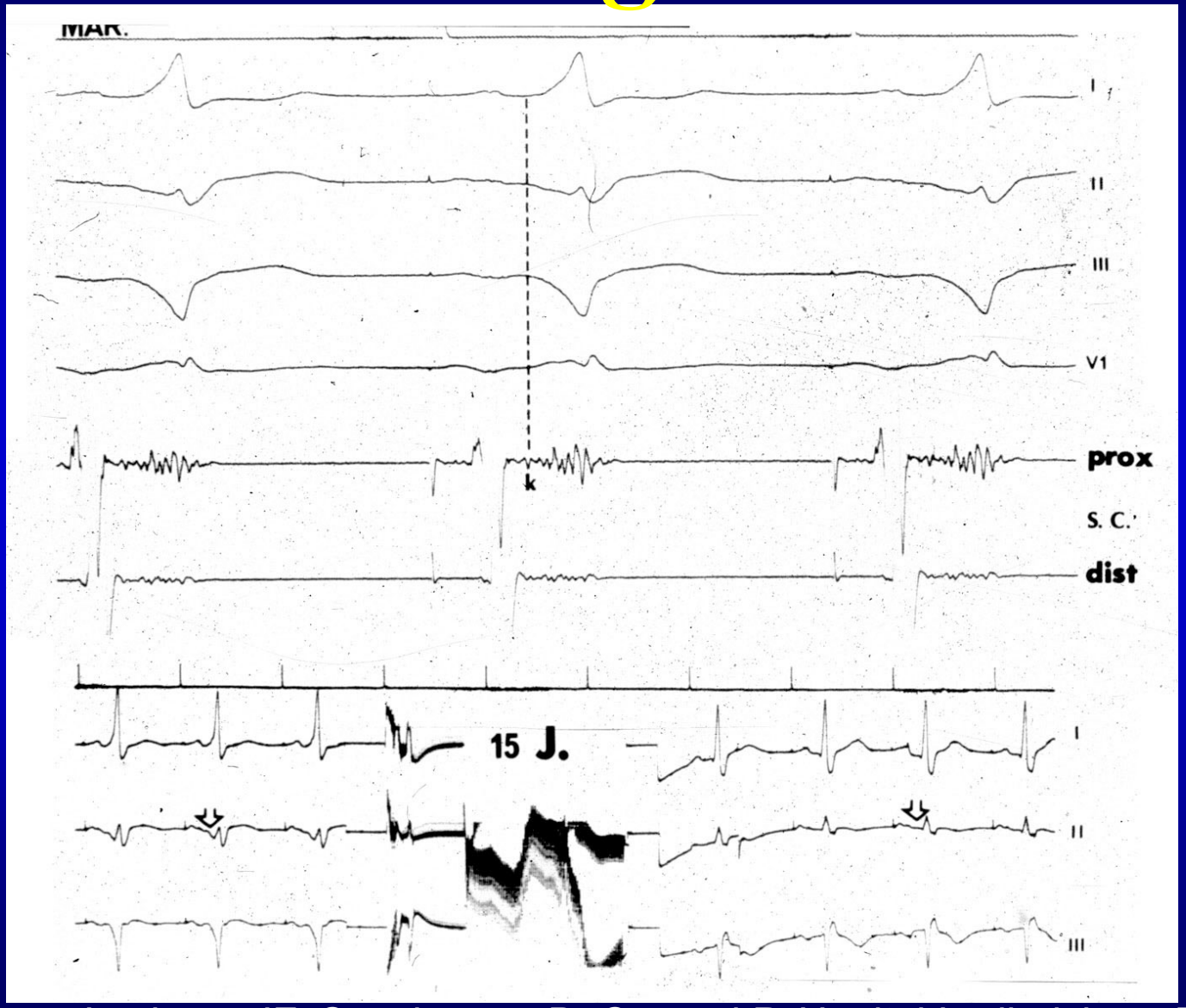
In 9 patients with recurrent supraventricular tachycardia a tripolar electrode catheter was positioned in the region of the His Bundle and the electrode recording a large unipolar His-bundle potential was identified

Delivery of 300 joule resulted in complete heart block in 8 of 9 pts





"WPW Fulguration"



Leclercq JF, Cauchemez B, Coumel P, Hopital Lariboisiere, Paris, 1983

DC shock (Fulguration) 1979-1990

- **AV node ablation**: Vedel, Frank, Fontaine 1979

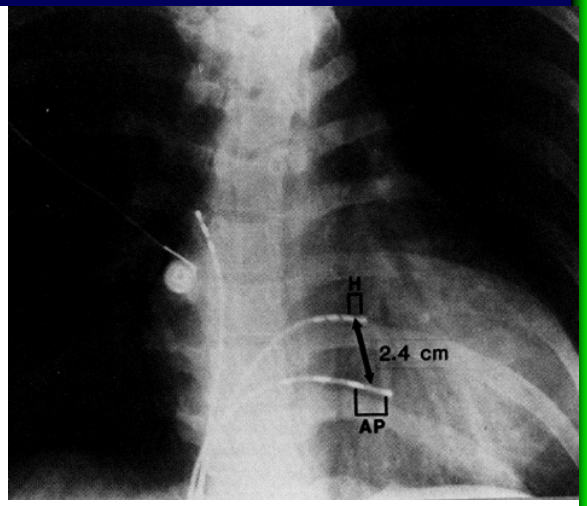
  Gallagher , Sheinman 1982

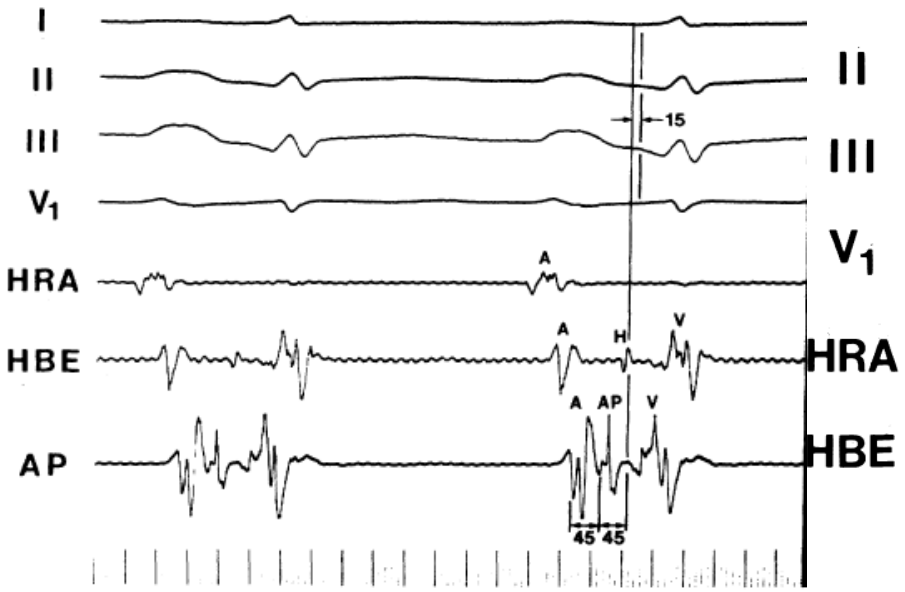
- **WPW**: Jackman 1983 (Right)

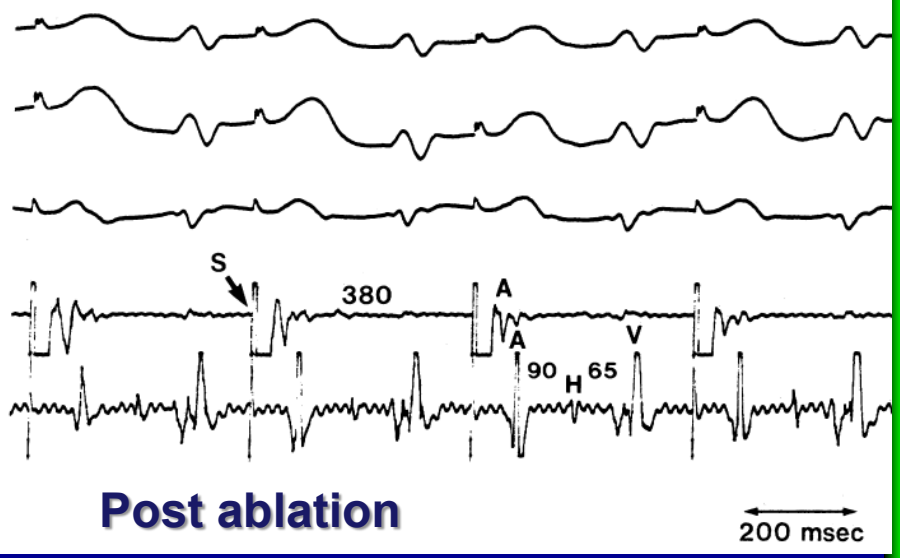
Direct endocardial recording from an accessory atrioventricular pathway: localization of the site of block, effect of antiarrhythmic drugs, and attempt at nonsurgical ablation

Warren M. Jackman, M.D., Karen J. Friday, M.D., Benjamin J. Scherlag, Ph.D., Michael M. Dehning, M.D., Eliot Schechter, M.D., Dwight W. Reynolds, M.D., Edwin G. Olson, M.D., Edward J. Berbari, Ph.D., Lura A. Harrison, Ph.D., and Ralph Lazzara, M.D.

Circulation 1983(68) 5: 906-916.







R-wave synchronous shocks of **160 and 320 W-sec** delivered between the catheter electrode recording the largest AP potential and a skin electrode

DC shock (Fulguration) 1979-1990

- **AV node ablation**: Vedel, Frank, Fontaine 1979

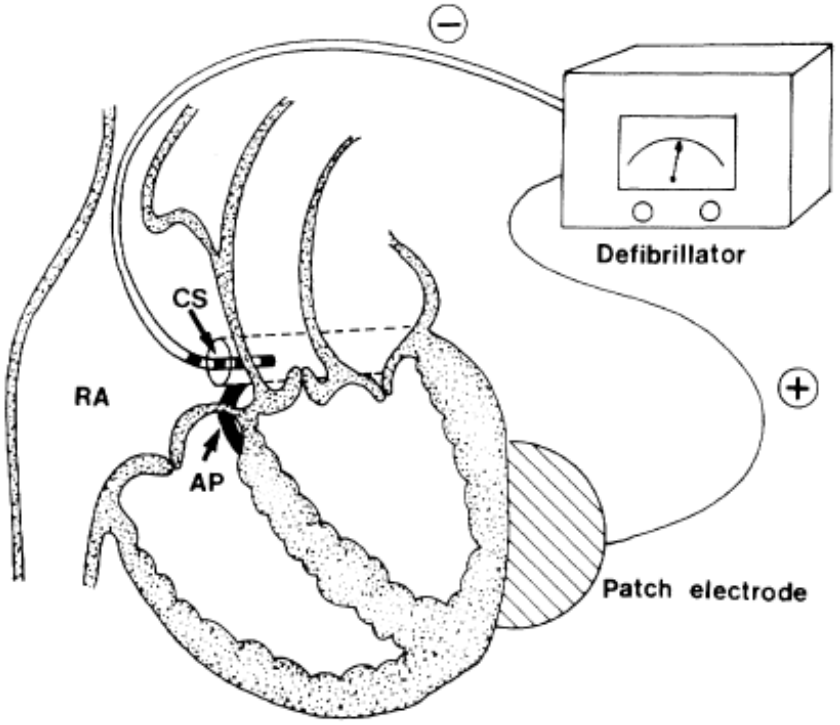
  Gallagher , Sheinman 1982

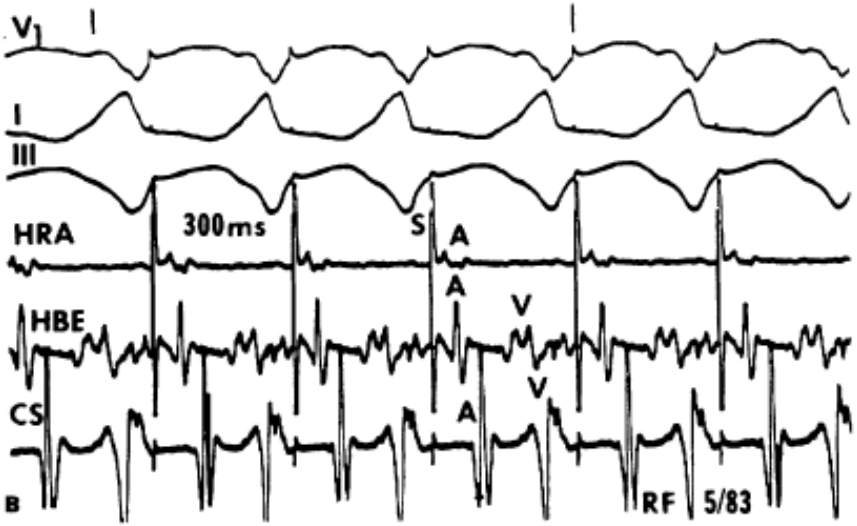
- **WPW**: Jackman 1983 (Right),
  Morady 1985 (Right anatomical),

Efficacy and safety of transcatheter ablation of posteroseptal accessory pathways

FRED MORADY, M.D., MELVIN M. SCHEINMAN, M.D., STUART A. WINSTON, M.D., LORENZO A. DiCARLO, JR., M.D., JESSIE C. DAVIS, M.D., JERRY C. GRIFFIN, M.D., MICHAEL RUDER, M.D., JOSEPH A. ABBOTT, M.D., AND MICHAEL ELDAR, M.D.

Circulation 72, No. 1, 170–177, 1985.





8 patients with a right posteroseptal accessory pathway
2-3 transcatheter shocks (200-400 J) delivered at the os of the CS.
After 4-11 months, 5 of 8 (62%) patients had no residual conduction over the AP and no effect on nodal conduction.

DC shock (Fulguration) 1979-1990

- **AV node ablation**: Vedel, Frank, Fontaine 1979

  Gallagher , Sheinman 1982

- **WPW**: Jackman 1983 (Right),
  Morady 1985 (Right anatomical),
  Warin 1988 (Right and Left approach)

First direct access to left sided accessory pathway

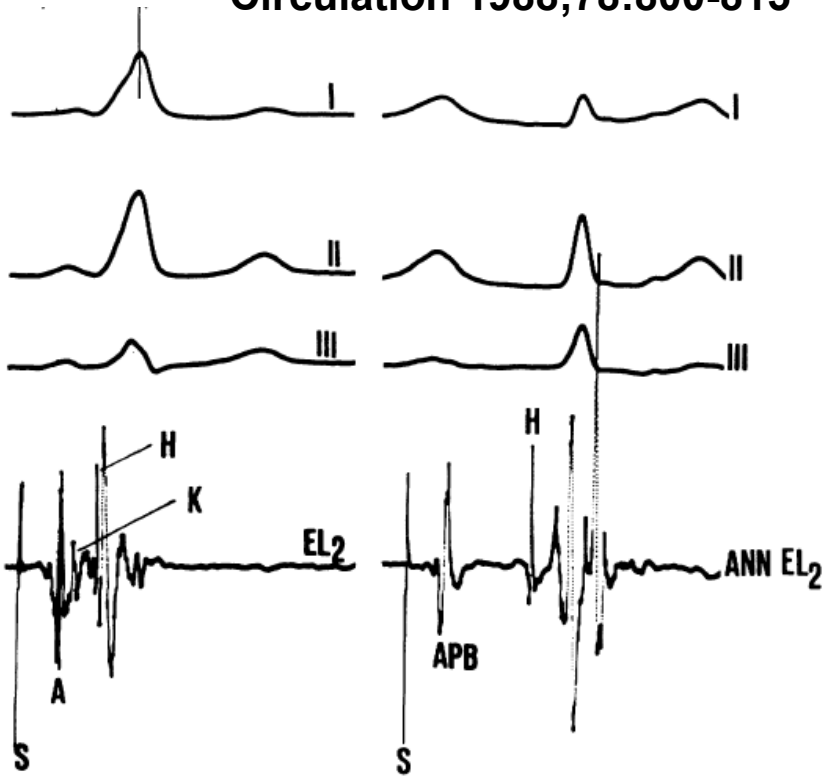
Catheter Ablation of Accessory Pathways With a Direct Approach

Results in 35 Patients

Jean-François Warin, MD, Michel Haissaguerre, MD, Philippe Lemetayer, MD, Jean-Pierre Guillem, MD, and Pierre Blanchot, MD

Circulation 1988;78:800-815

35 patients (6 left sided AP)
Left atrium was accessed through a transseptal puncture.
Ablation efficacy 32 pts (91,4%)



DC shock (Fulguration) 1979-1990

- **AV node ablation**: Vedel, Frank, Fontaine 1979

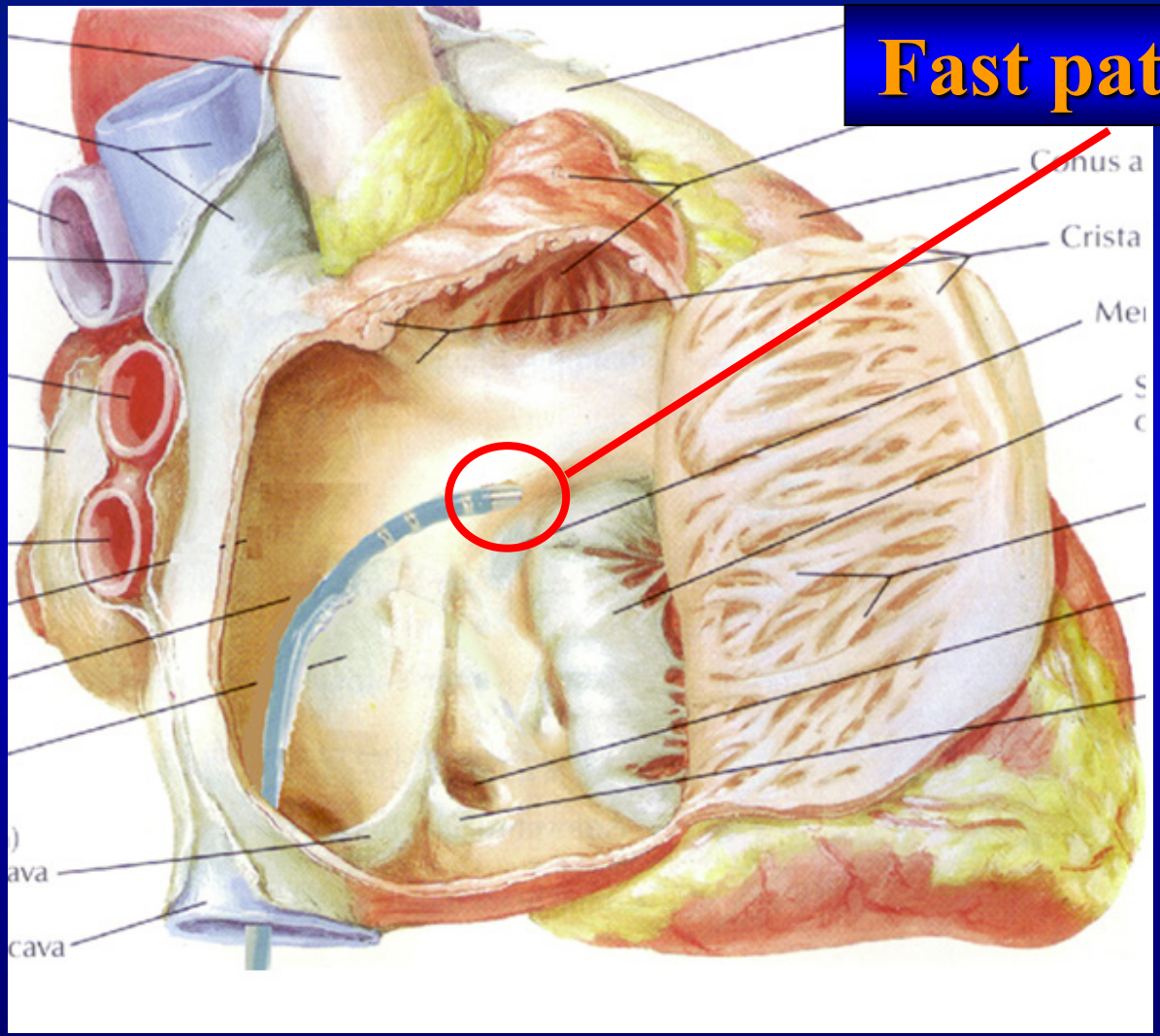
  Gallagher , Sheinman 1982

- **WPW**: Jackman 1983 (Right),
  Morady 1985 (Right anatomical),

  Warin 1988 (Right and Left approach)

- **AVNRT (fast pathway)** : Haissaguerre 1989,
  Epstein 1989

DC shock ablation technique for AVNRT



Modified from Netter, Atlas of Human Anatomy

Closed-Chest Ablation of Retrograde Conduction in Patients with Atrioventricular Nodal Reentrant Tachycardia

Michel Haissaguerre, M.D., Jean Francois Warin, M.D., Philippe Lemetayer, M.D., Nadir Saoudi, M.D., Jean Pierre Guillem, M.D., and Pierre Blanchot, M.D.

N Engl J Med 1989; 320:426-433 | February 16, 1989 | DOI: 10.1056/NEJM198902163200704

21 patients, 76% efficacy

"Complete heart block persisted in 2 patients (10%)"

Percutaneous Catheter Modification of the Atrioventricular Node

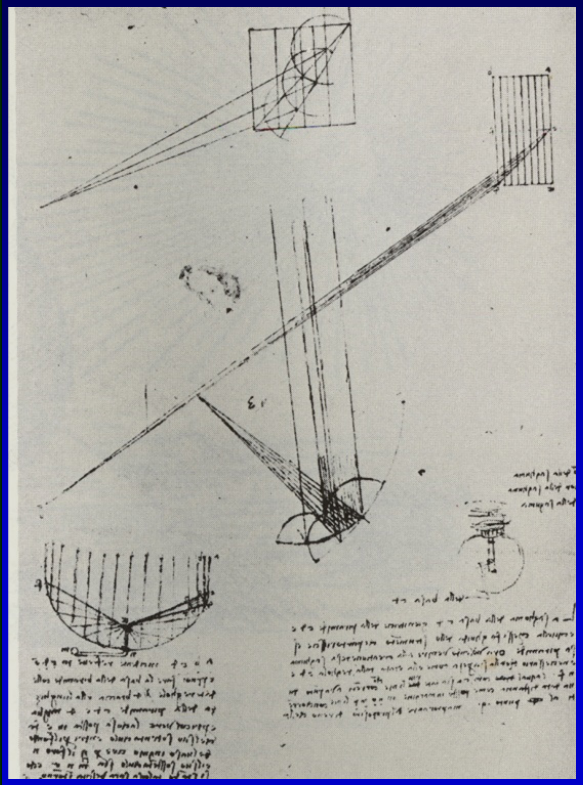
A Potential Cure for Atrioventricular Nodal Reentrant Tachycardia

(*Circulation* 1989;80:757–768)

Laurence M. Epstein, MD, Melvin M. Scheinman, MD, Jonathan J. Langberg, MD, Donald Chilson, MD, Harold R. Goldberg, MD, and Jerry C. Griffin, MD

9 patients, 67% efficacy

"Two complete ablation of the AV junction (22%)"



10 years of DC shock ablation increased our knowledge on the substrate of arrhythmia

Technology

"The right tools"

Lavergne T, Guize L, Le Heuzey JY, Carcone P, Geslin J, Cousin MT.

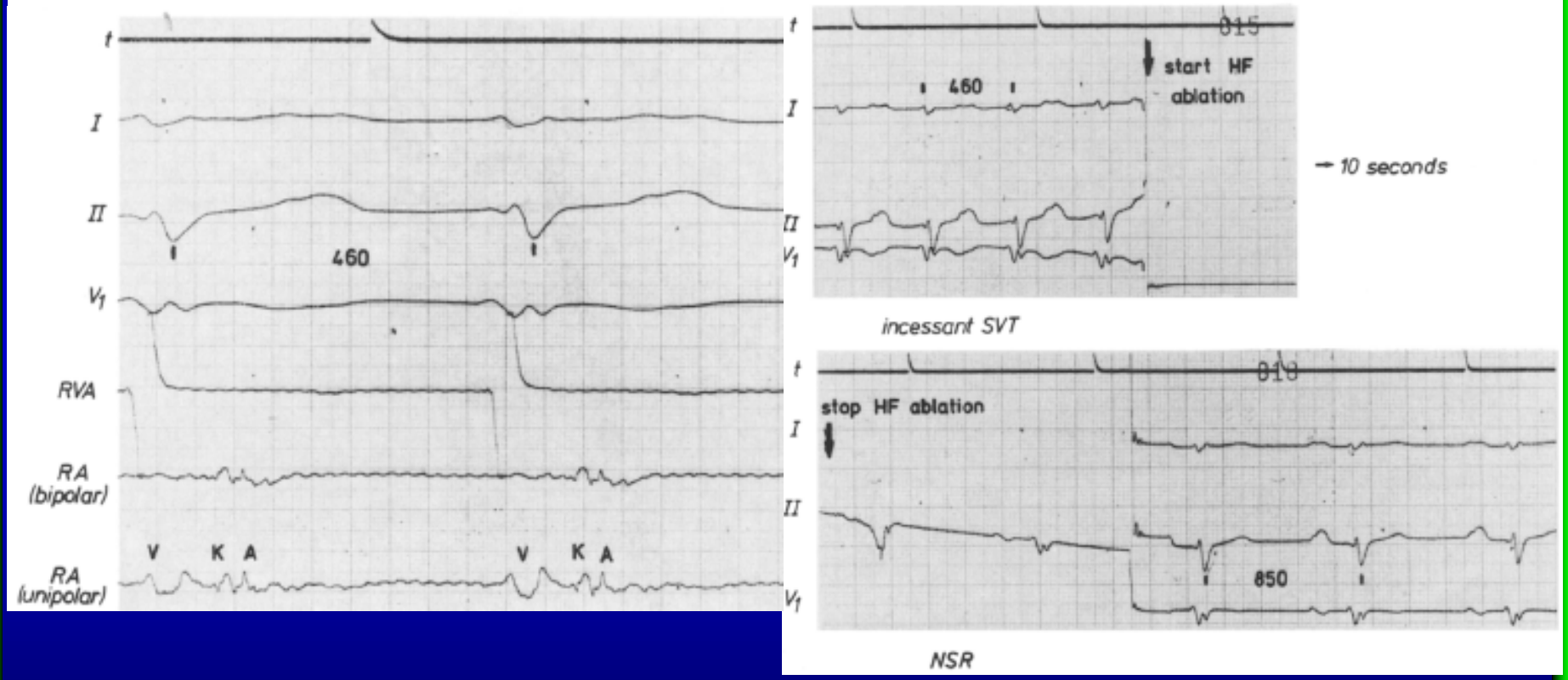
Closed-chest atrioventricular junction ablation by high-frequency energy transcatheter desiccation.

Lancet 1986; 2(8511): 858-859

High Frequency Alternating Current Ablation of an Accessory Pathway in Humans

JACC Vol. 10, No. 3
September 1987:576–82

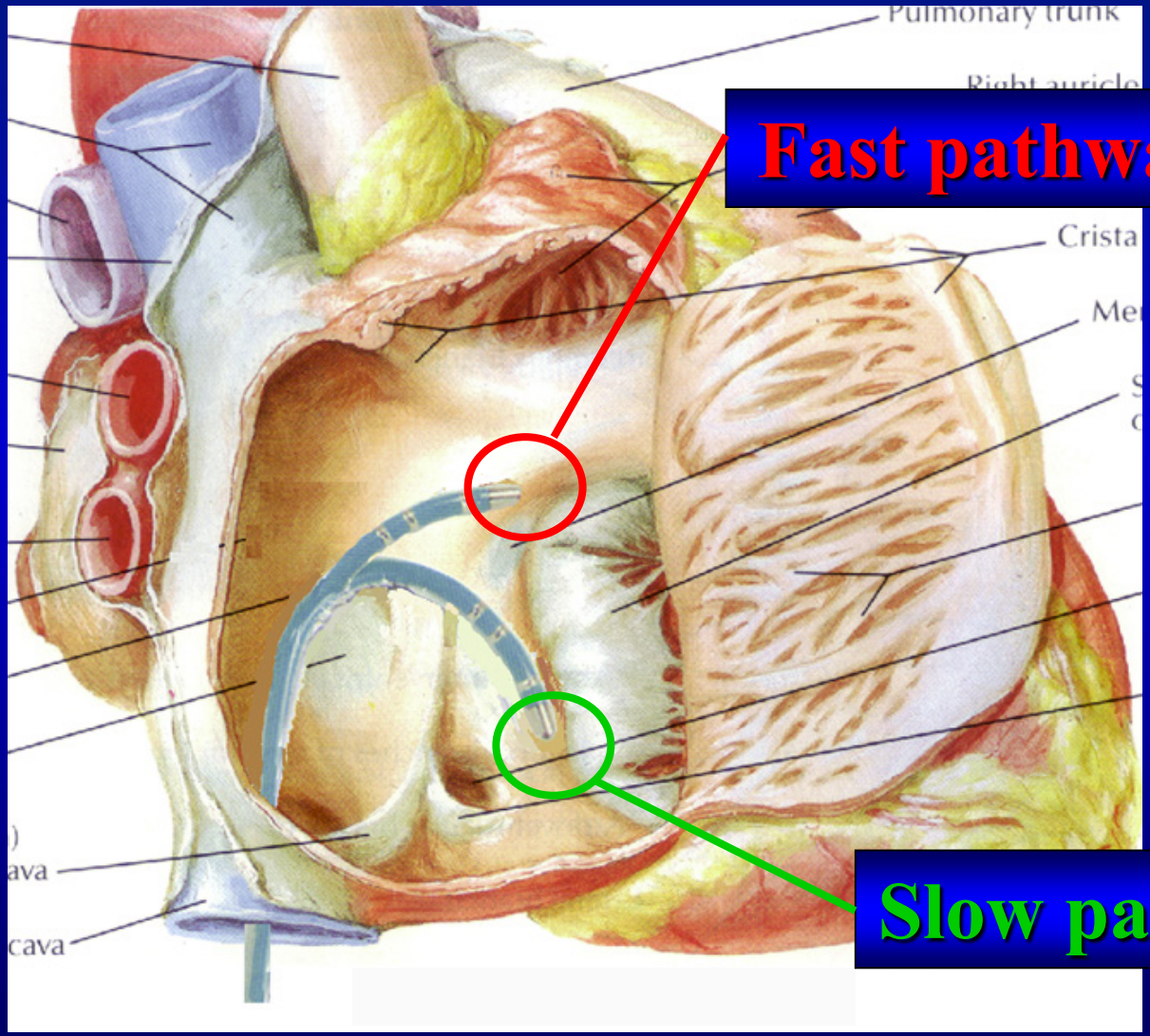
MARTIN BORGGREFE, MD, THOMAS BUDDE, MD, ANDREA PODCZECK, MD,
GÜNTER BREITHARDT, MD



1st pt. Catheter ablation using direct current shocks was ineffective. 2 alternating current high frequency impulses were delivered with an energy output of 50 W through the distal tip of the bipolar catheter

Glasgow
Belfast
Liverpool
Dublin
Amste
Birmingham
Londres
Lille
Paris
Nantes
Loire
Berne
Ljubljana
Zagreb
Lyon
Bordeaux
Asti
Milan
Mt Blanc 4 810 m
G. de Gascogne
Toulouse
Bilbao
Marseille
Corse
Sarajevo
Belgrade
Bucarest
Danube
Sofia
Rome
Skopje
Istanbul
Tirana
Madrid
Barcelone
Valence
Naples
Mt Olympe 2 917 m
Tage
Sardaigne
MER TYRRHÉNIENNE
ESPAGNE
GRÈCE
ROUMANIE
SERBIE
BULGARIE
ALBANIE
ITALIE
ANDORRE

RF ablation technique for AVNRT



Fast pathway ablation

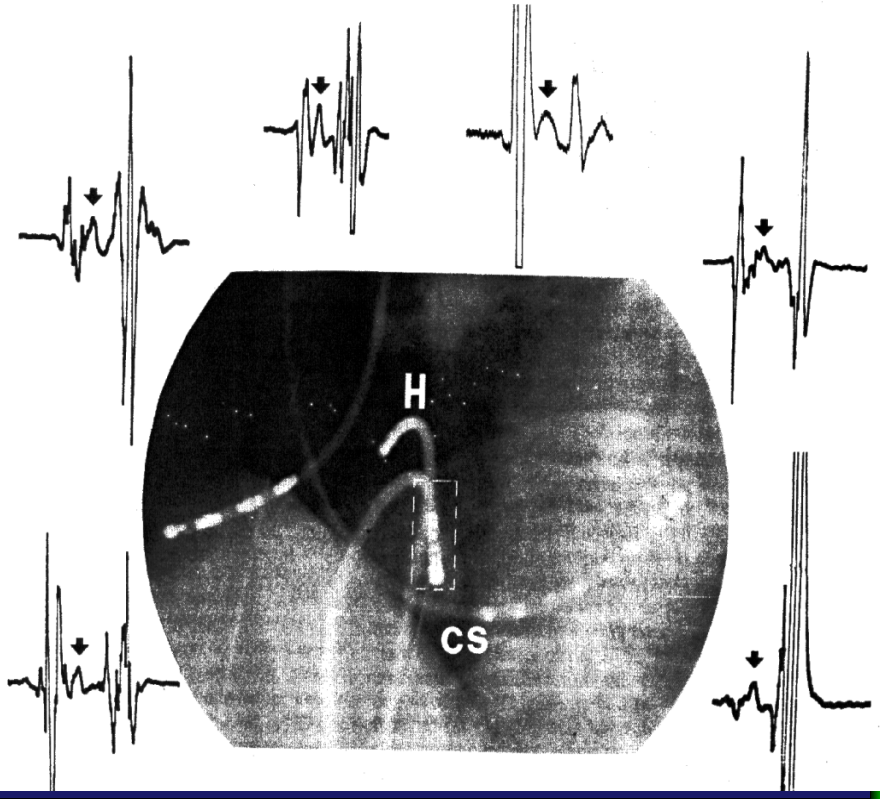
Slow pathway ablation

Elimination of Atrioventricular Nodal Reentrant Tachycardia Using Discrete Slow Potentials to Guide Application of Radiofrequency Energy

Circulation 1992;85:2162

Michel Haissaguerre, MD; Fiorenzo Gaita, MD; Bruno Fischer, MD;
Daniel Commenges, PhD; Paul Montserrat, MD; Christophe d'Ivernois, MD;
Philippe Lemetayer, MD; and Jean-François Warin, MD

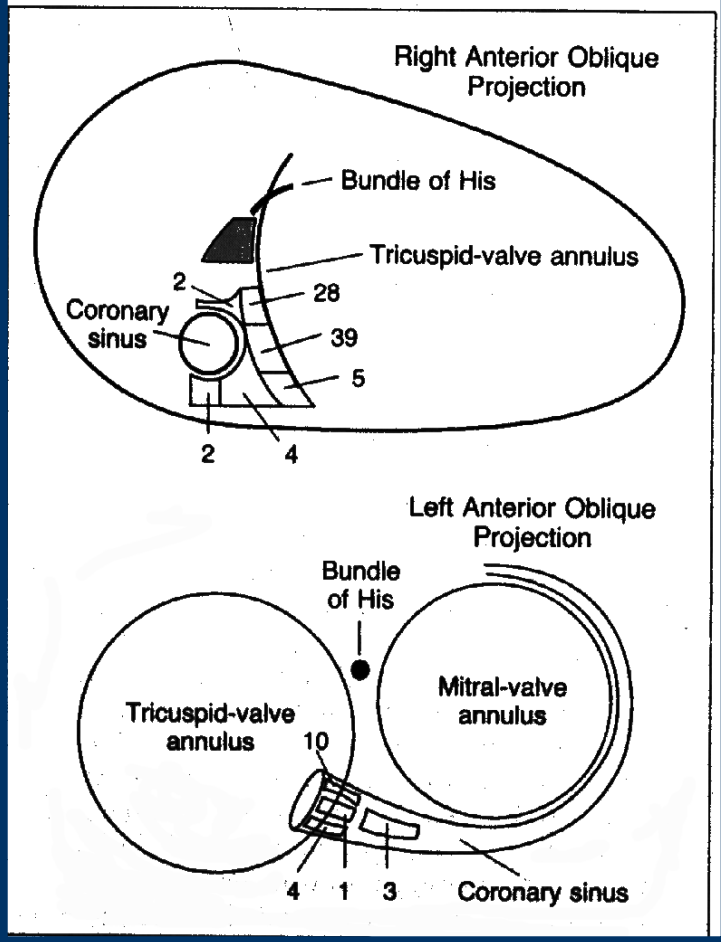
Slow potentials were recorded along a vertical band at the mid or posterior part of the septum near the tricuspid annulus. Radiofrequency energy applied at the slow potential site resulted in interruption of induced tachycardia within a few seconds and rendered tachycardia noninducible in all patients.



TREATMENT OF SUPRAVENTRICULAR TACHYCARDIA DUE TO ATRIOVENTRICULAR NODAL REENTRY BY RADIOFREQUENCY CATHETER ABLATION OF SLOW-PATHWAY CONDUCTION

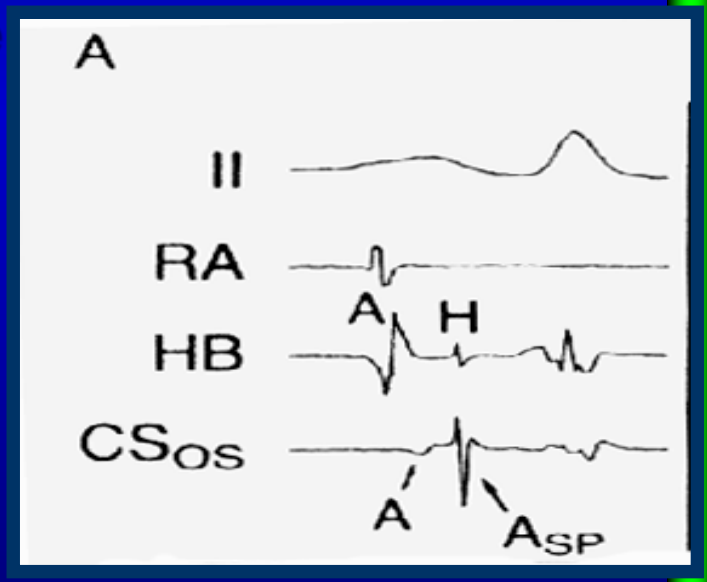
WARREN M. JACKMAN, M.D., KAREN J. BECKMAN, M.D., JAMES H. MCCLELLAND, M.D., XUNZHANG WANG, M.D., KAREN J. FRIDAY, M.D., CARLOS A. ROMAN, M.D., KRIEGH P. MOULTON, M.D., NICHOLAS TWIDALE, M.D., H. ANDREW HAZLITT, M.D., MICHAEL I. PRIOR, M.D., JESS OREN, M.D., EDWARD D. OVERHOLT, M.D., AND RALPH LAZZARA, M.D.

(N Engl J Med 1992;327:313-8.)



80 consecutive pts with AVNRT

RF delivery at the **sharp potential** resulted in elimination of AVNRT without affect anterograde AV conduction in **78 pts**.



AV block occurred in 1 case

Selective Transcatheter Ablation of the Fast and Slow Pathways Using Radiofrequency Energy in Patients With Atrioventricular Nodal Reentrant Tachycardia

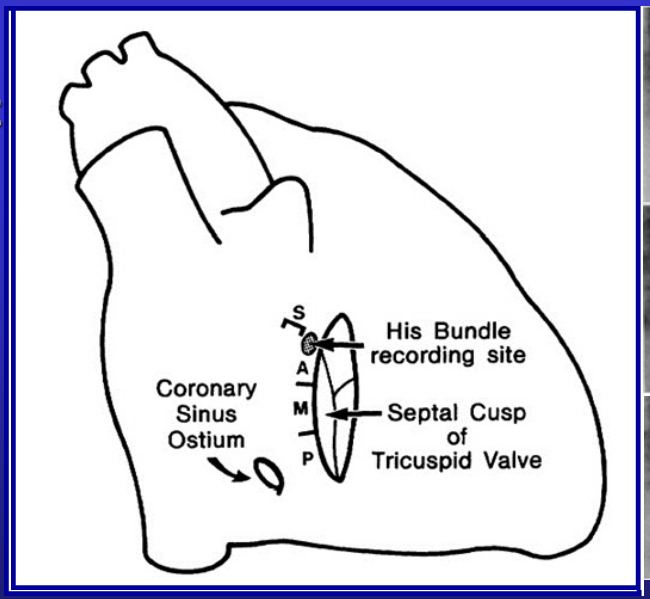
(*Circulation* 1992;85:1318–1328)

Mohammad R. Jazayeri, MD; Sandy L. Hempe, RN; Jasbir S. Sra, MD; Anwer A. Dhala, MD; Zalman Blanck, MD; Sanjay S. Deshpande, MD; Boaz Avitall, MD, PhD; David P. Krum, MS; Carol J. Gilbert, RN; and Masood Akhtar, MD

49 consecutive pts with AVNRT

The first 16 patients underwent a **fast pathway** ablation with RF (complete AV block in 4 cases)

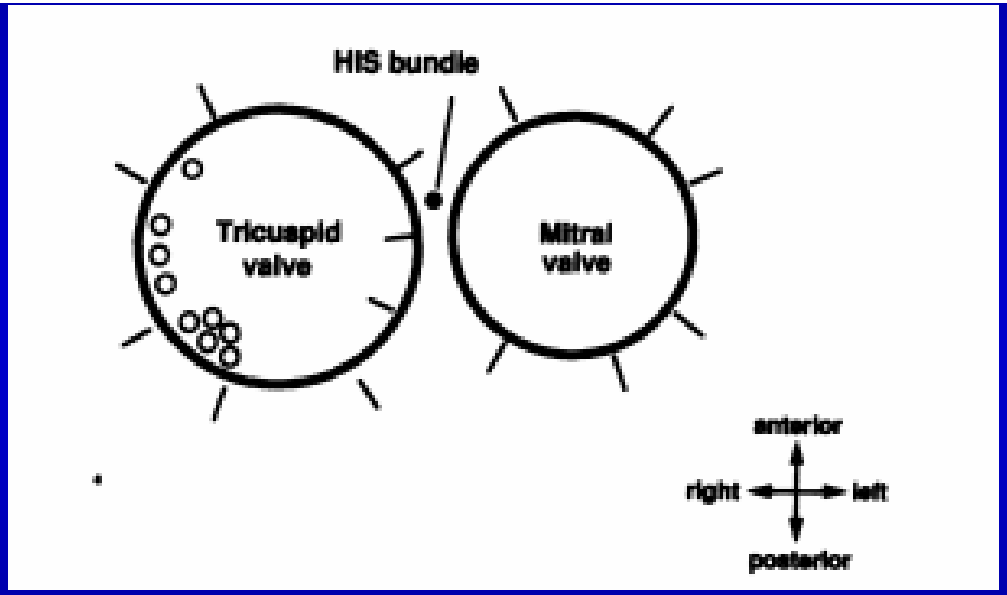
Among the last 33 patients who underwent a **slow pathway** ablation as the initial attempt and a fast pathway ablation only when the former failed, 32 (97%) had successful AVNRT abolition with intact AV conduction.

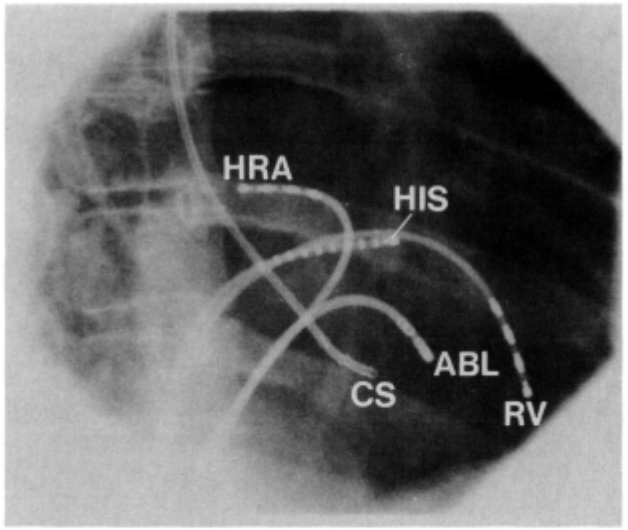


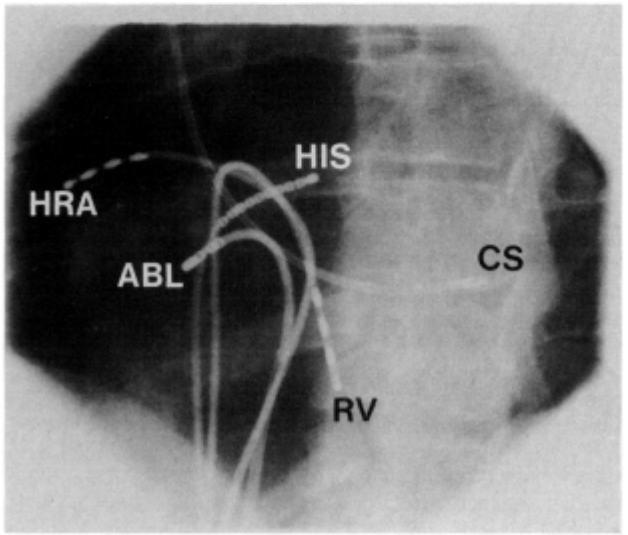
Catheter-Induced Mechanical Conduction Block of Right-Sided Accessory Fibers With Mahaim-Type Preexcitation to Guide Radiofrequency Ablation

(*Circulation*. 1994;90:282-290.)

Riccardo Cappato, MD; Michael Schlüter, PhD; Christian Weiß, MD; Jürgen Siebels, MD; Joachim Hebe, MD; Wolfgang Duckeck, MD; Ralph U. Mletzko, MD; Karl-Heinz Kuck, MD







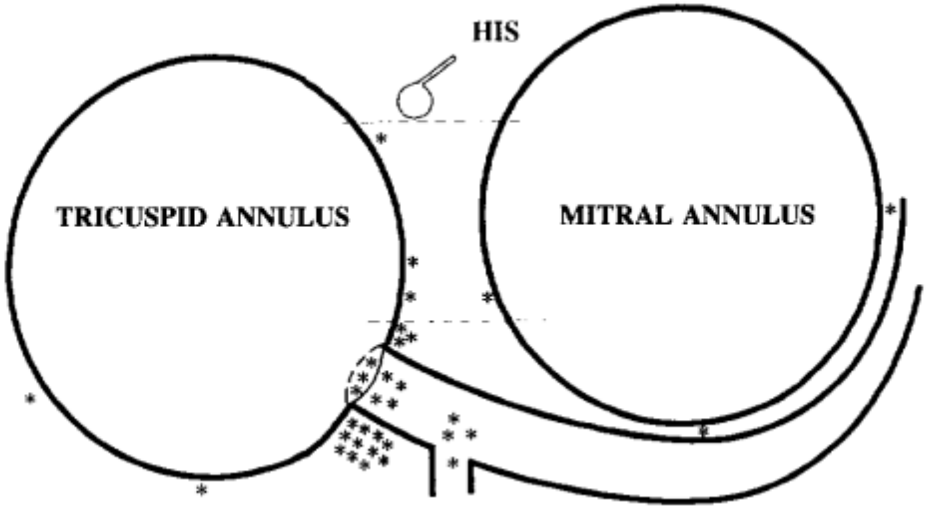
11 patients with preexcited AVRT involving a **decrementally conducting antegrade accessory pathway** underwent complete EP evaluation and subsequent **RF catheter ablation**

Catheter Ablation of Permanent Junctional Reciprocating Tachycardia With Radiofrequency Current

JACC Vol. 25, No. 3
March 1, 1995:648–54

FIORENZO GAITA, MD, MICHEL HAISSAGUERRE, MD,* CARLA GIUSTETTO, MD,†
BRUNO FISCHER, MD,* RICCARDO RICCARDI, MD, ELENA RICHIARDI, MD,†
MARCO SCAGLIONE, MD, FILIPPO LAMBERTI, MD, JEAN-FRANÇOIS WARIN, MD*

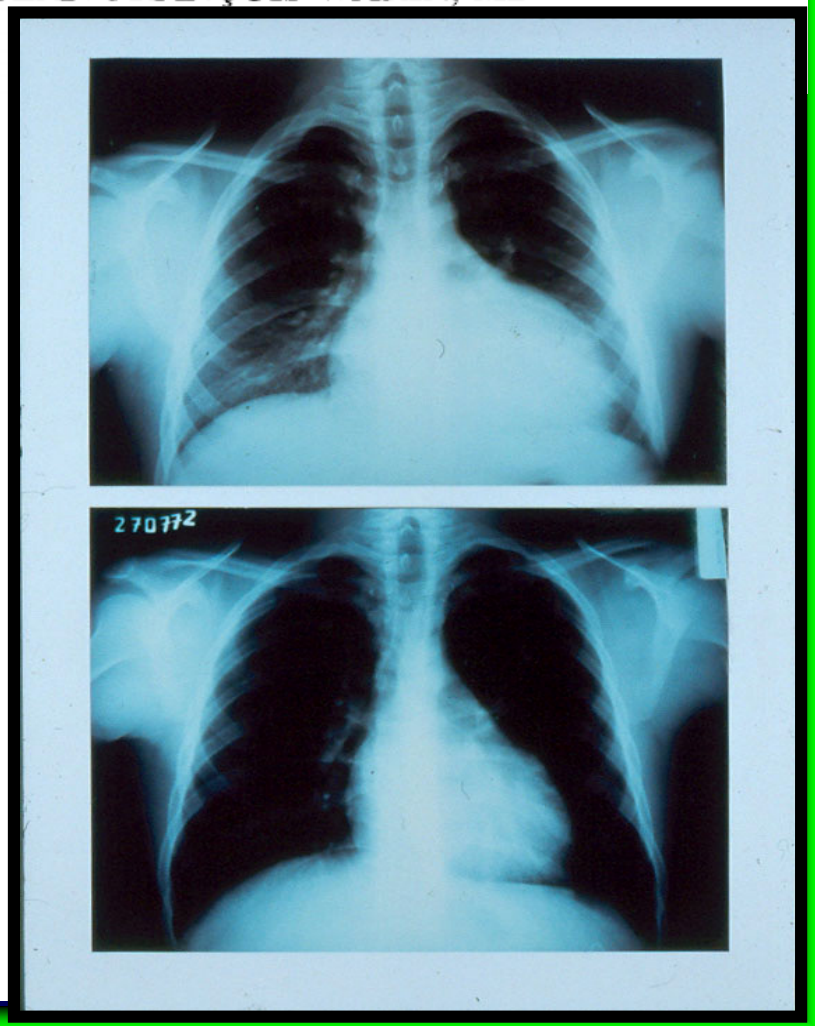
Asti and Turin, Italy and Bordeaux, France



32 patients

31 (97%) asymptomatic

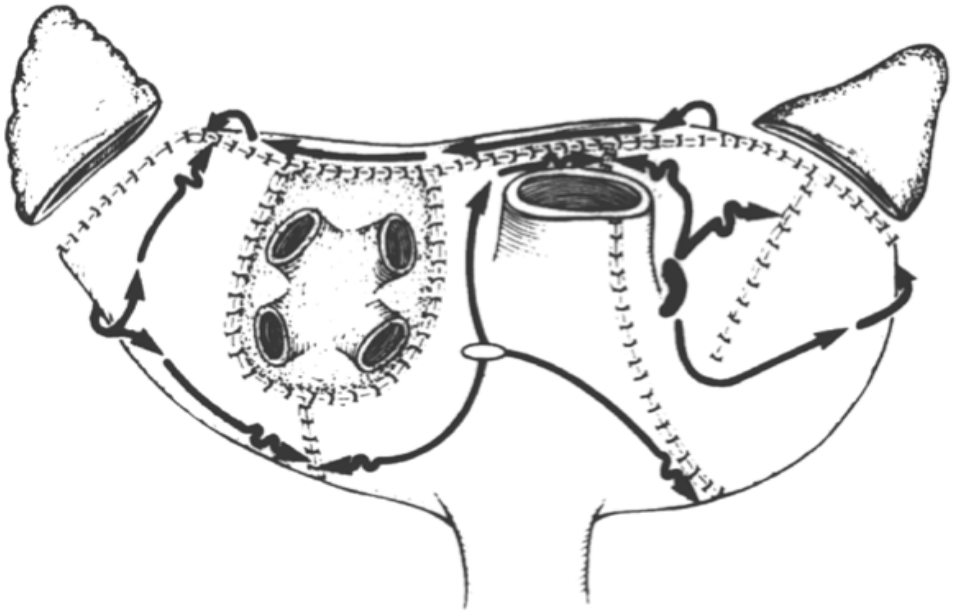
Patients with depressed LVEF showed normalization

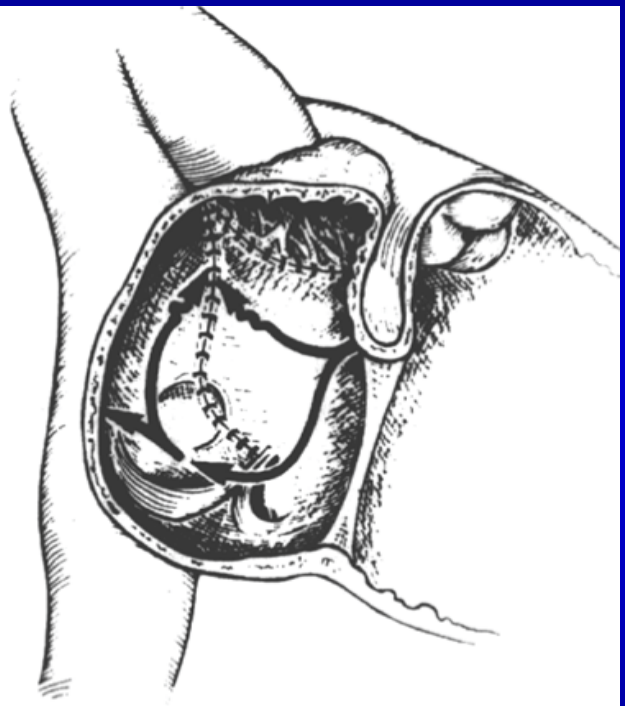


Late 90s
The last frontier of TC ablation

Atrial fibrillation

Substrate modification: linear lesions

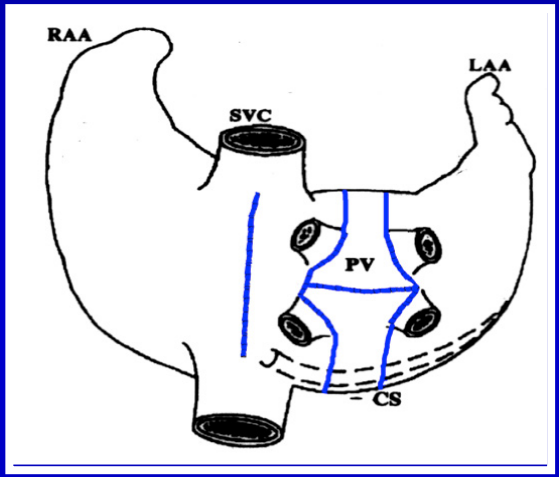




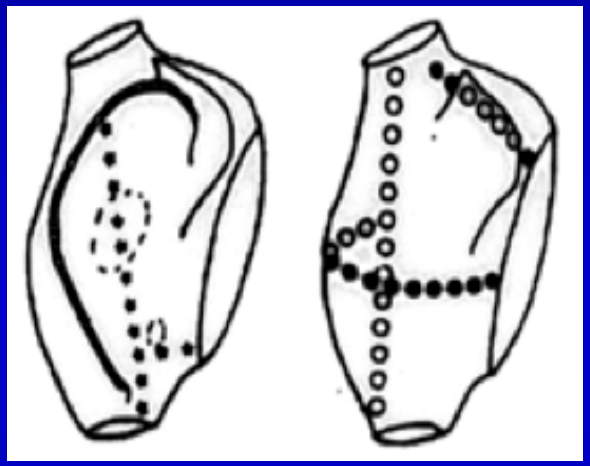
178 pts (103 paroxysmal, 75 chronic)
Follow-up : 3 - 102 months
Success rate: 93%
Complications: PM implant 30 pts, 1 stroke, 2 MI
4 deaths

Cox JL Ann Surg 1996

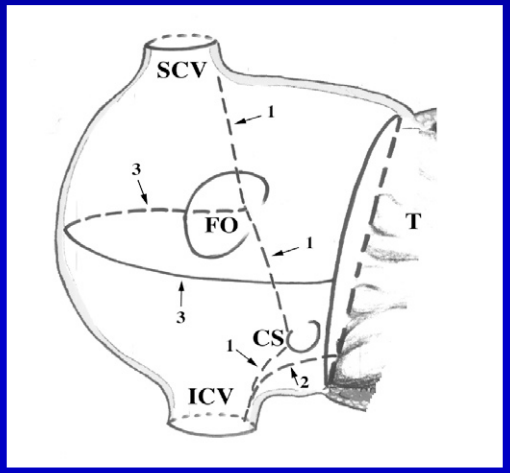
Beginning of the era of AF TC ablation



Swartz '96

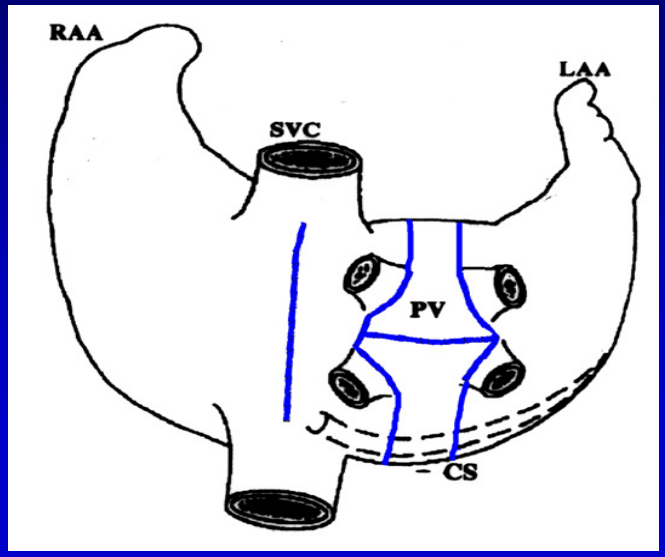


Haissaguerre '96-98



F. Gaita '96-98

Right and left ablation for atrial fibrillation



29 Pts with Chronic AF

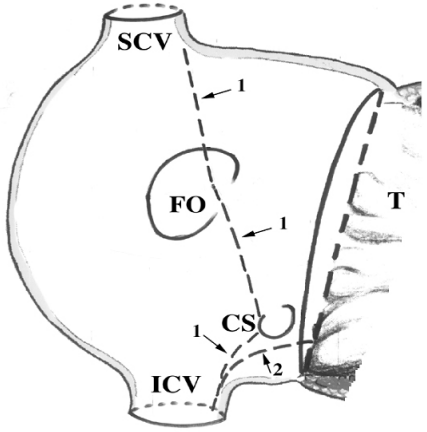
Success 79%

Complication 31% (2 cerebral vascular accidents,
1 pericardial effusion,
1 pericarditis, 1 ARDS)

Procedure duration 10.50 h

X-ray exposure 118 min

Swartz, NASPE 96 (Abstract)

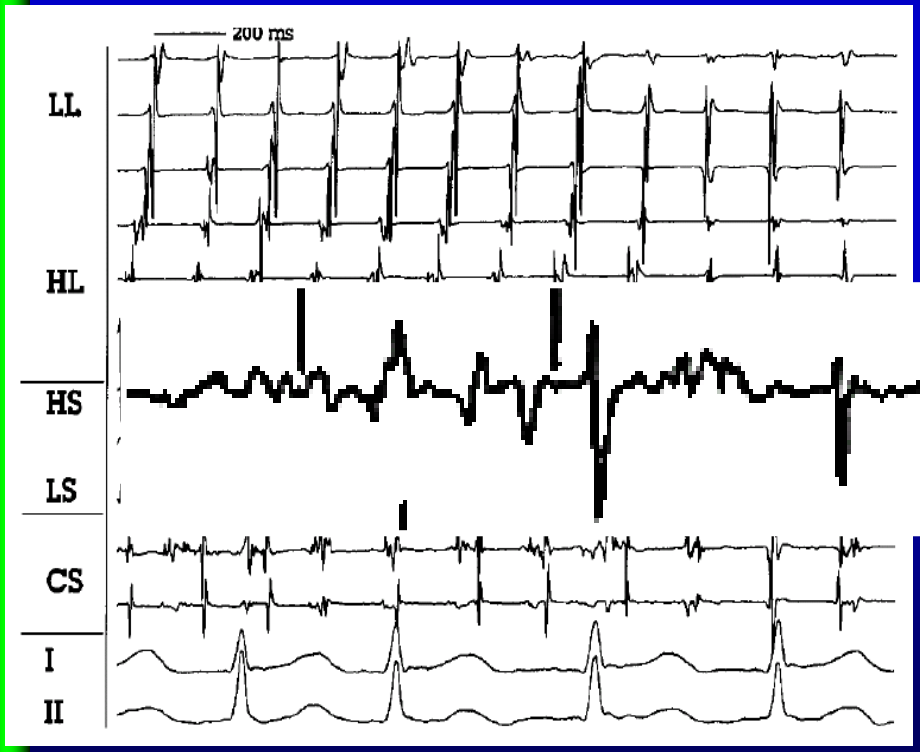


Atrial Mapping and Radiofrequency Catheter Ablation in Patients With Idiopathic Atrial Fibrillation

Electrophysiological Findings and Ablation Results

Fiorenzo Gaita, MD; Riccardo Riccardi, MD; Leonardo Calò, MD; Marco Scaglione, MD; Lucia Garberoglio, MD; Renzo Antolini, PhD; Michele Kirchner, PhD; Filippo Lamberti, MD; Elena Richiardi, MD

(*Circulation*. 1998;97:2136-2145.)



Follow-up (months)	11 ± 4	36 ± 6
Success	56%	39%
Without drugs	25%	11%
With drugs	31%	28%
Complications	none	none

Predictors of success:

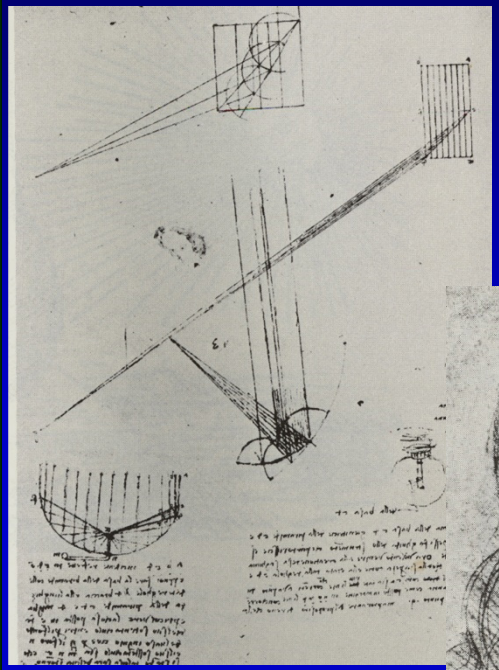
ablation in areas with

shortest FF interval,

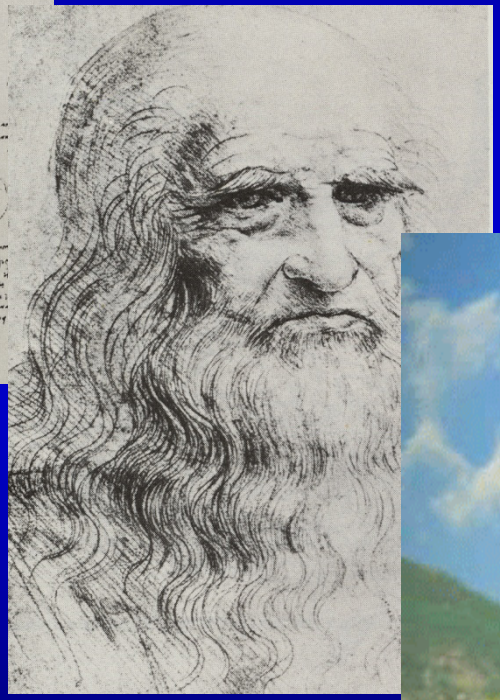
low vagal tone

demonstrated by heart rate variability

…very often the realization of an idea may take some time….



Knowledge



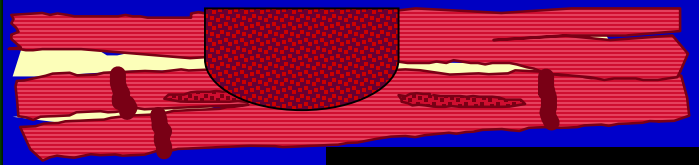
Idea

Technology

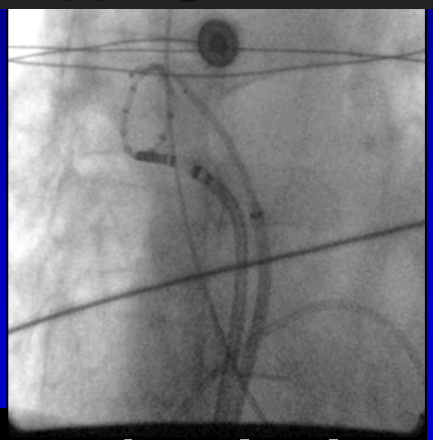
(right tools)

The right tools for ablation:

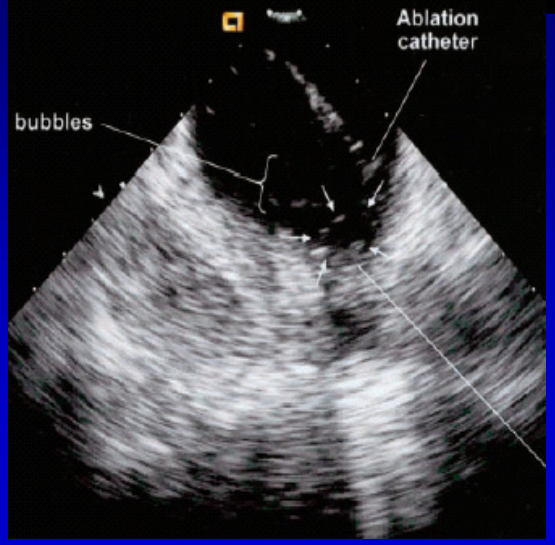
RF ablation catheter



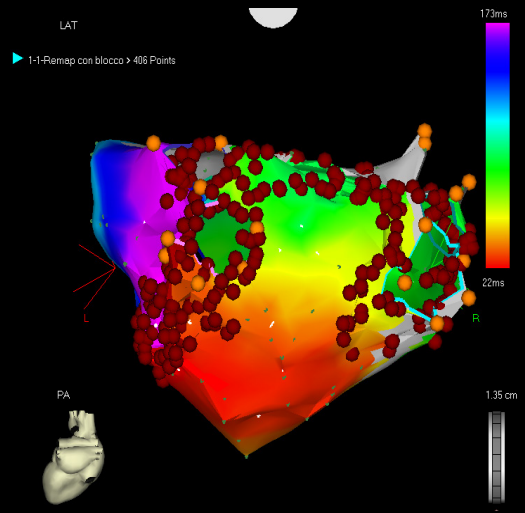
Rx Circular mapping catheter



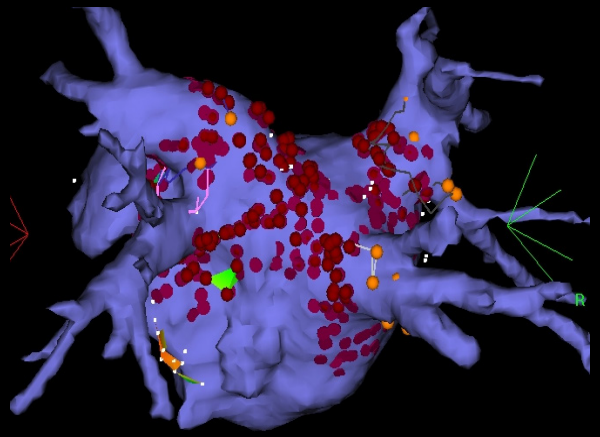
Intracardiac echo



3D electro-anatomical mapping



Integrated imaging with MRI-TC



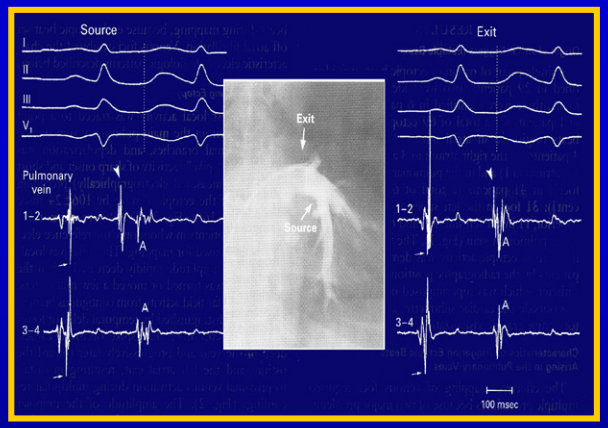
The right idea: PV ablation

Interest moves from *substrate* to *triggers*

SPONTANEOUS INITIATION OF ATRIAL FIBRILLATION BY ECTOPIC BEATS ORIGINATING IN THE PULMONARY VEINS

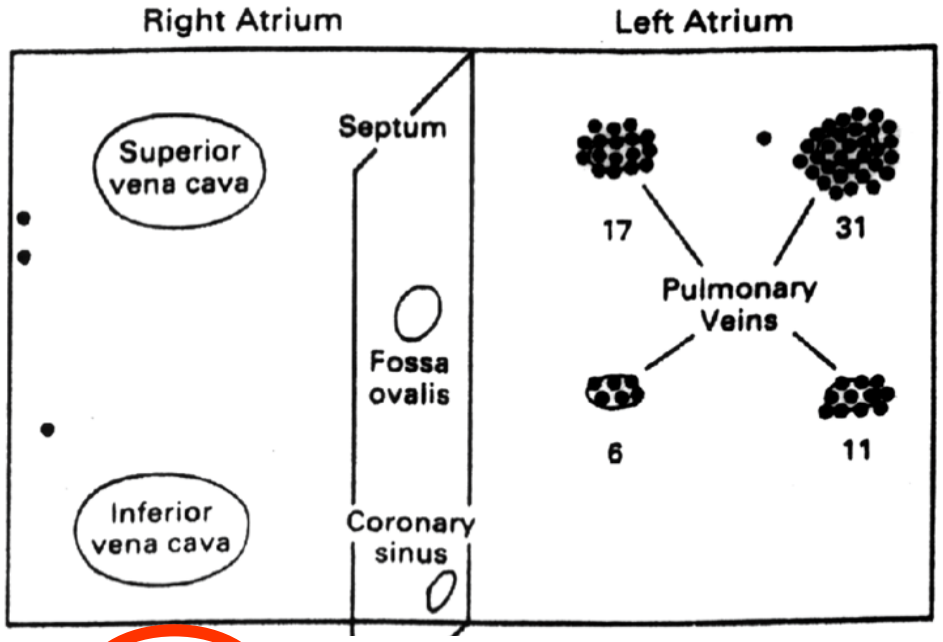
MICHEL HAÏSSAGUERRE, M.D., PIERRE JAÏS, M.D., DIPEN C. SHAH, M.D., ATSUSHI TAKAHASHI, M.D., MÉLÈZE HOCINI, M.D., GILLES QUINIOU, M.D., STÉPHANE GARRIGUE, M.D., ALAIN LE MOUROUX, M.D., PHILIPPE LE MÉTAYER, M.D., AND JACQUES CLÉMENTY, M.D.

NEJM 1998;339:659-666



45 pts with idiopathic PAF

Follow-up: 8±6 months



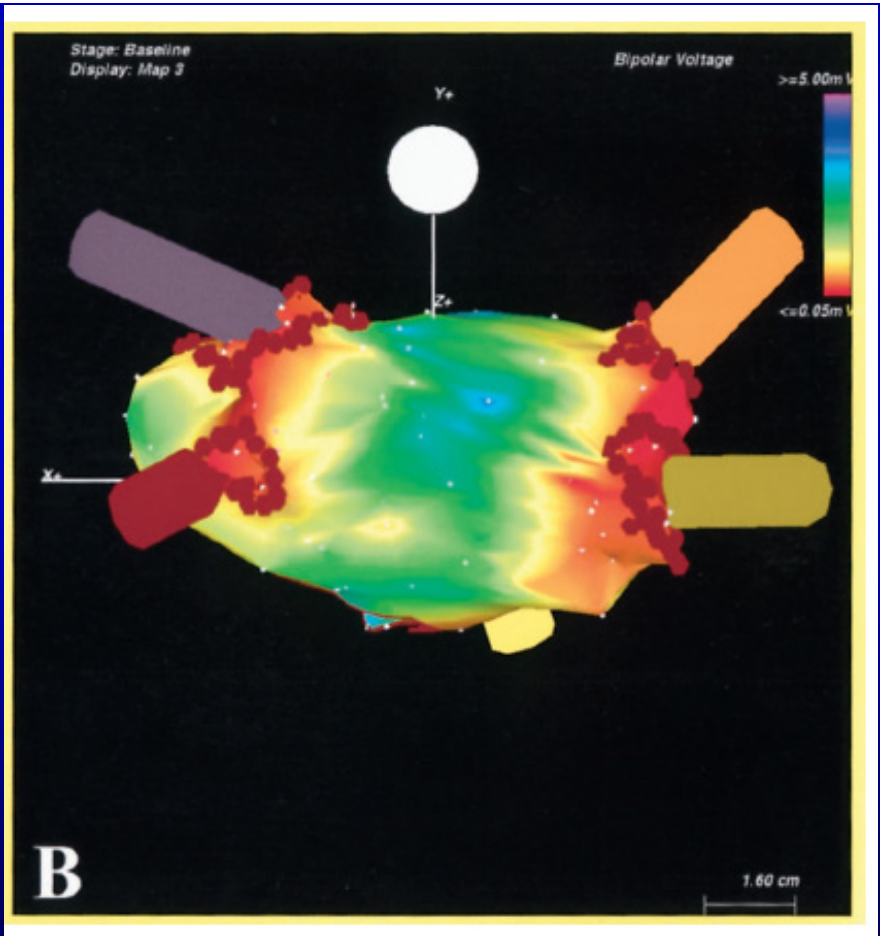
62% success rate w/oAAD

Circumferential Radiofrequency Ablation of Pulmonary Vein Ostia

A New Anatomic Approach for Curing Atrial Fibrillation

(*Circulation*. 2000;102:2619-2628.)

Carlo Pappone, MD, PhD; Salvatore Rosanio, MD, PhD; Giuseppe Oreto, MD; Monica Tocchi, MD; Filippo Gugliotta, BS; Gabriele Vicedomini, MD; Adriano Salvati, MD; Cosimo Dicandia, MD; Patrizio Mazzone, MD; Vincenzo Santinelli, MD; Simone Gulletta, MD; Sergio Chierchia, MD



The question in 2000

Can pulmonary vein isolation effectively treat also patients with persistent AF and structural heart disease?

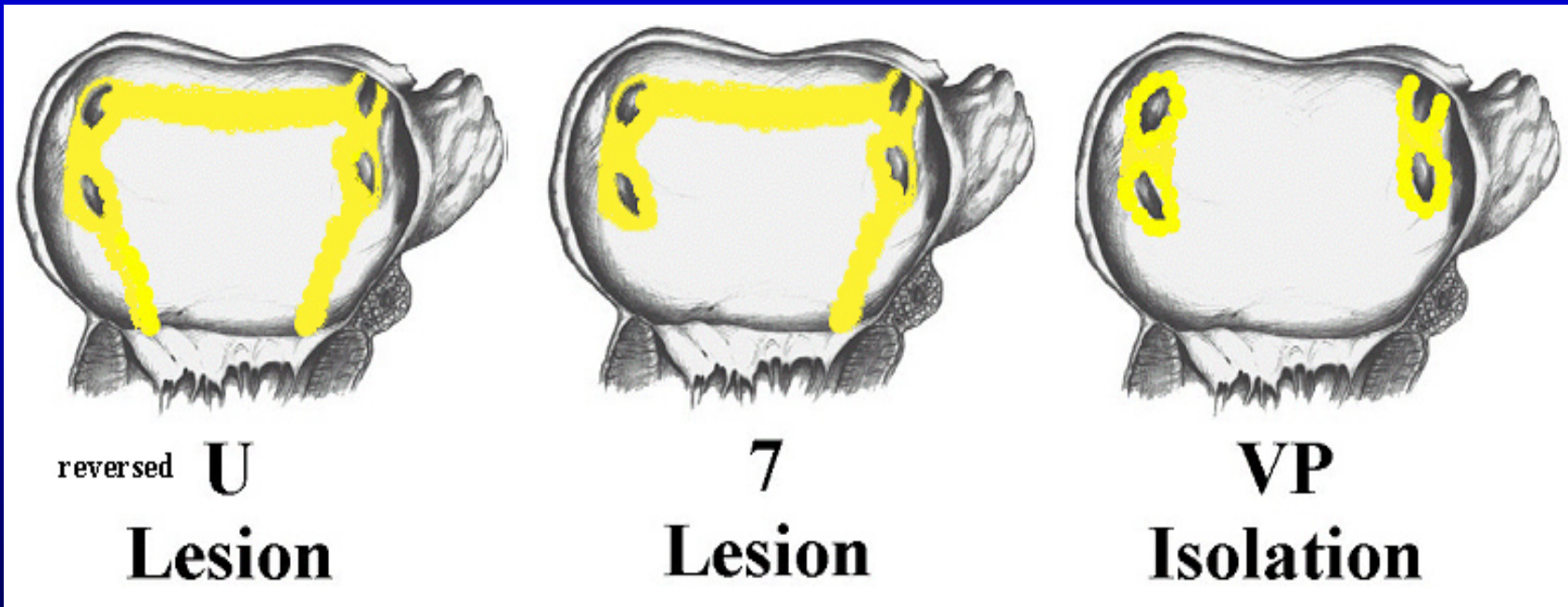
Linear Cryoablation of the Left Atrium Versus Pulmonary Vein Cryoisolation in Patients With Permanent Atrial Fibrillation and Valvular Heart Disease

Correlation of Electroanatomic Mapping and Long-Term Clinical Results

Fiorenzo Gaita, MD; Riccardo Riccardi, MD; Domenico Caponi, MD; Dipen Shah, MD; Lucia Garberoglio, MD; Laura Vivalda, MD; Alessandro Dulio, BS; Andrea Chiecchio, PhD; Eric Manasse, MD; Roberto Gallotti, MD

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION
2005;111:136-42

105 pts, Permanent AF and Valvular Heart Disease



Linear Cryoablation of the Left Atrium Versus Pulmonary Vein Cryoisolation in Patients With Permanent Atrial Fibrillation and Valvular Heart Disease

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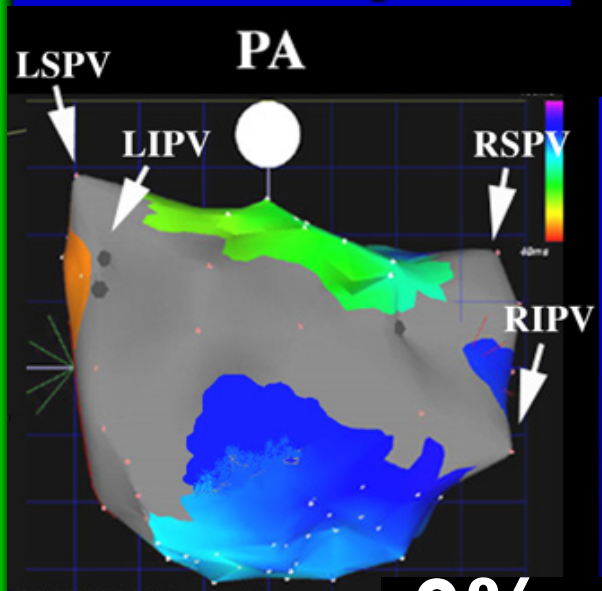
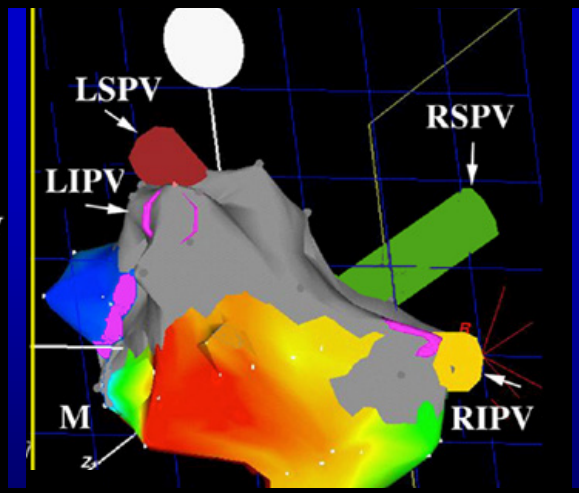
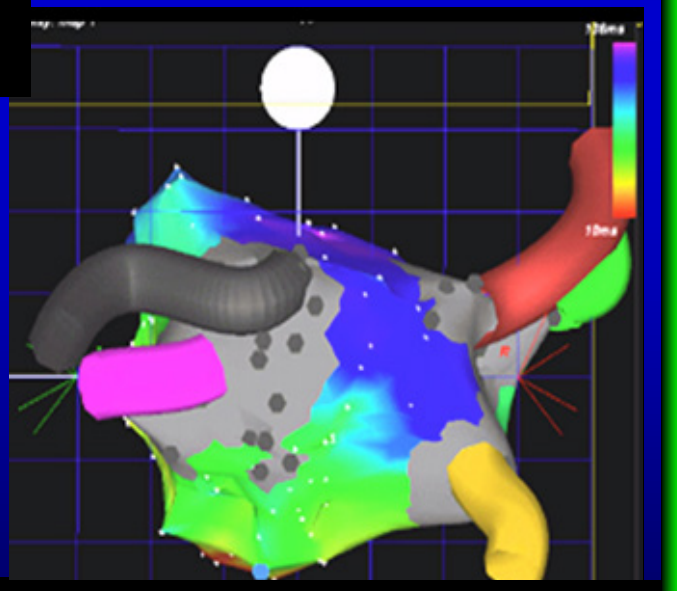
Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION
2005;111:136-42

105 pts, Permanent AF and Valvular Heart Disease

Complete Lesions

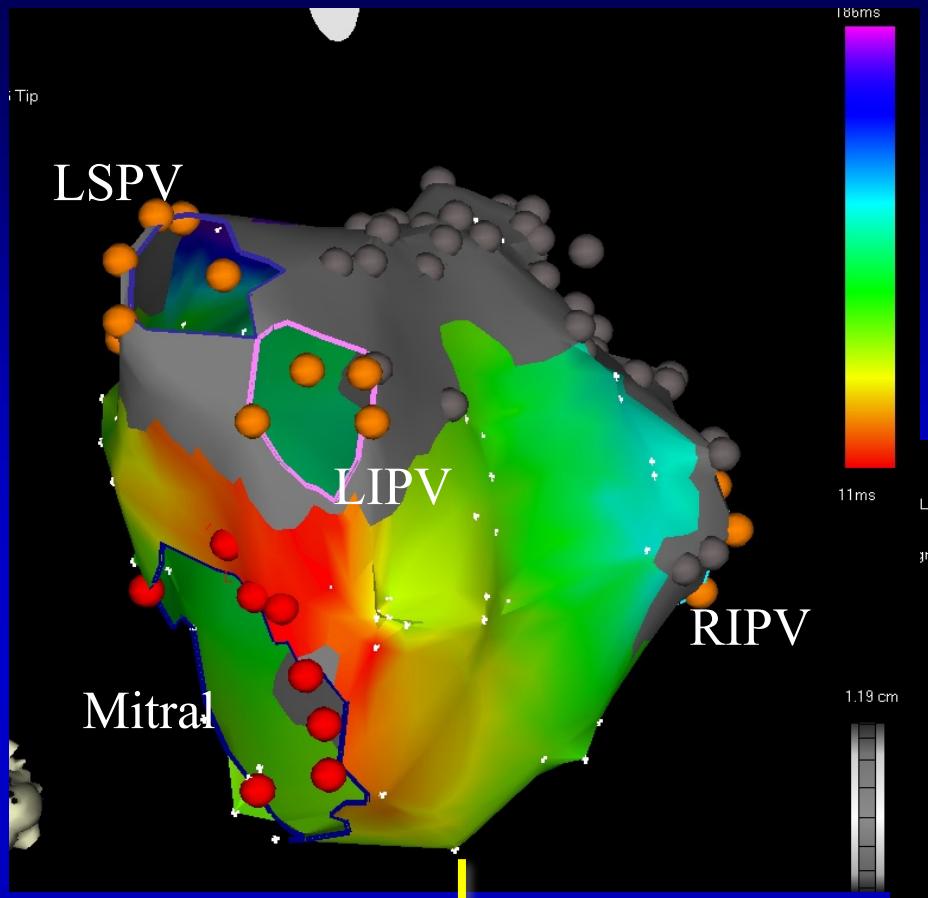


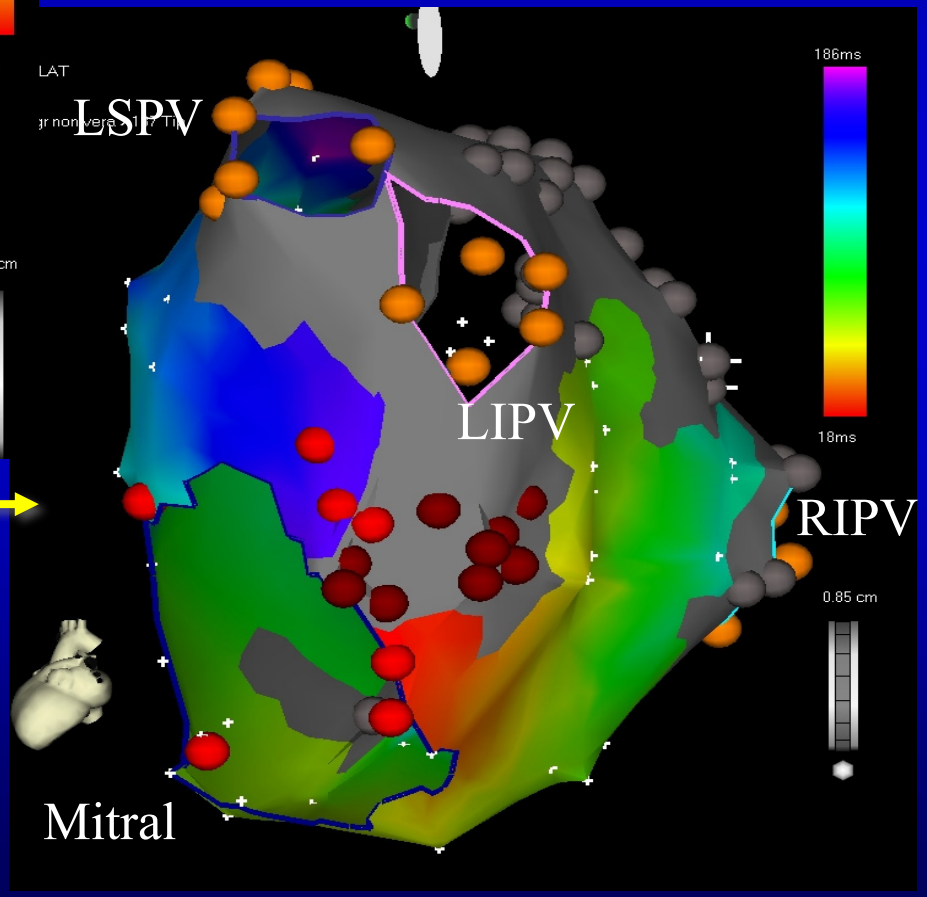




"U" lesion **0%** 7 scheme **65%** PVI isolation **81%**

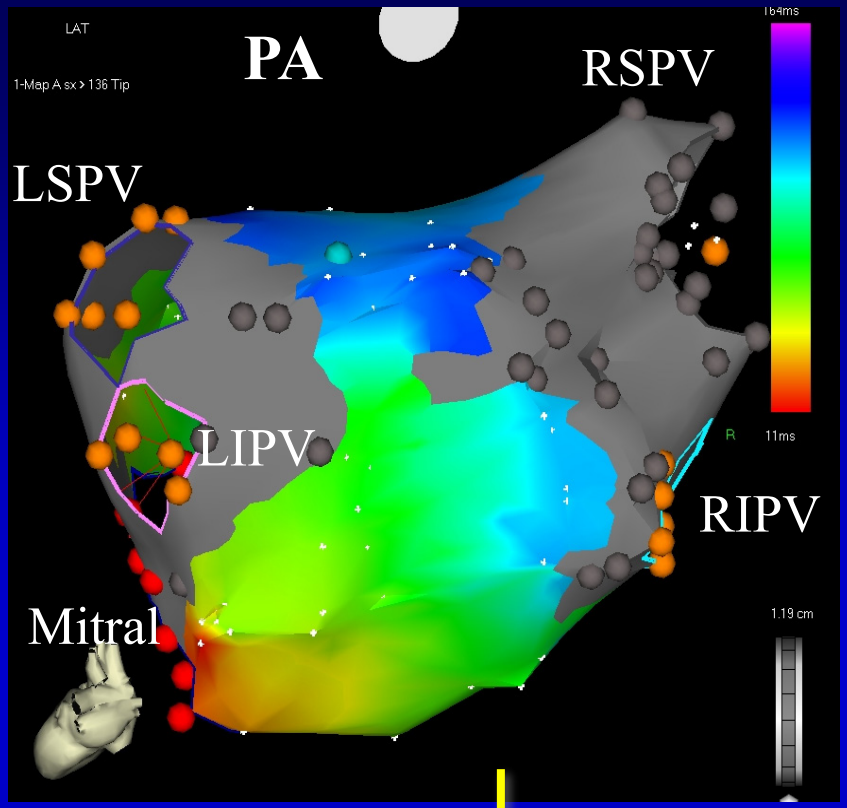
Incomplete “ 7 “ lesion

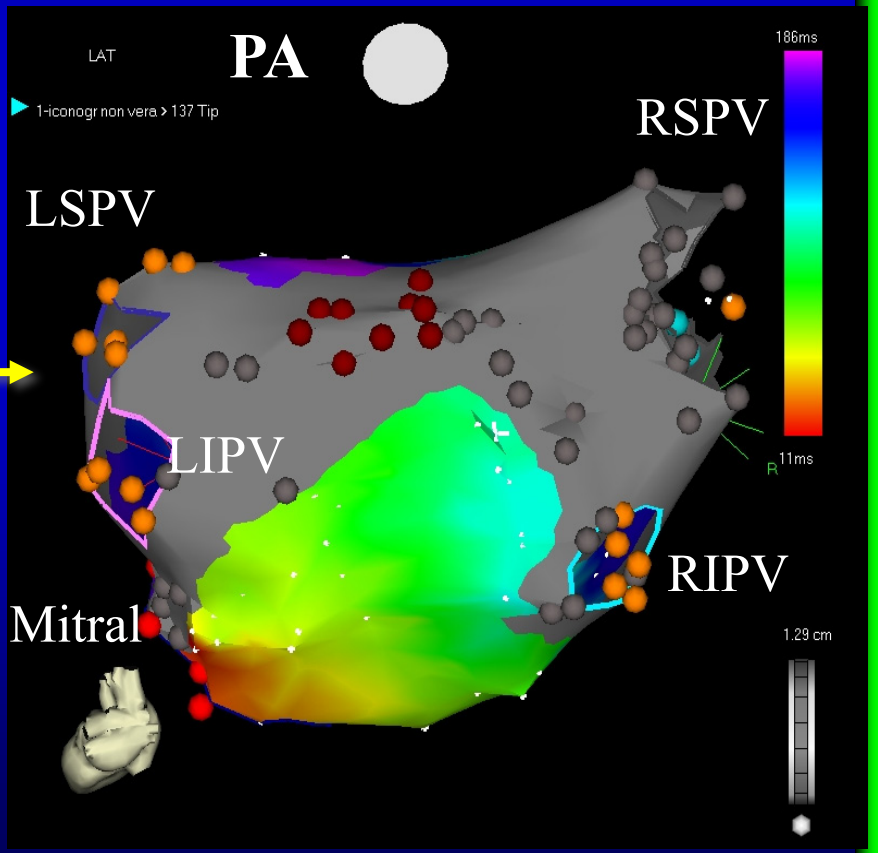




Left isthmus ablation and remap

Incomplete “ 7 “ lesion





Posterior linear ablation and remap

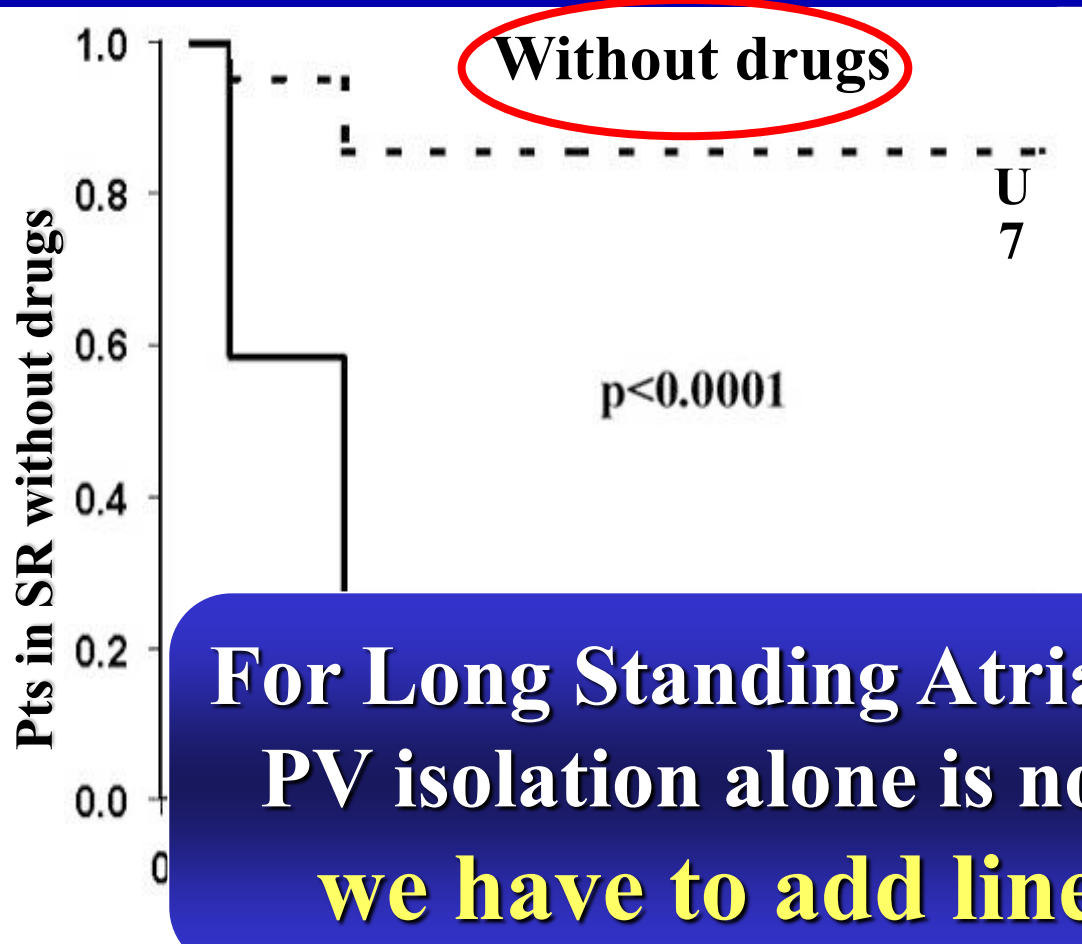
Linear Cryoablation of the Left Atrium Versus Pulmonary Vein Cryoisolation in Patients With Permanent Atrial Fibrillation and Valvular Heart Disease

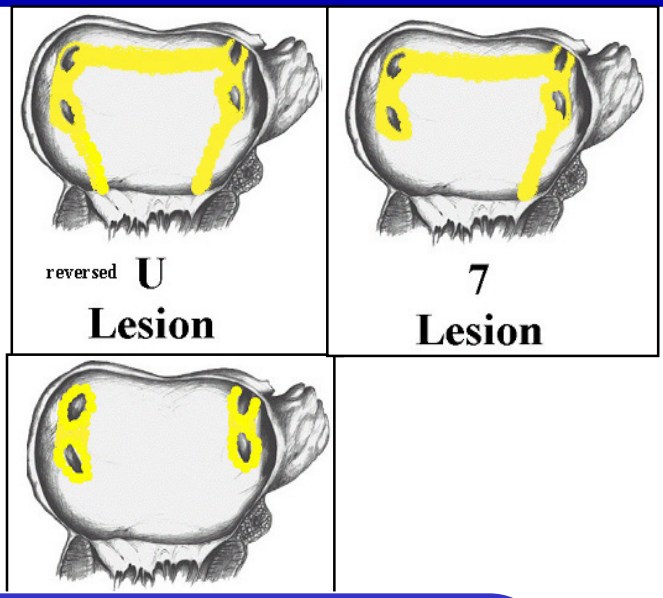
Correlation of Electroanatomic Mapping and Long-Term Clinical Results

Fiorenzo Gaita, MD; Riccardo Riccardi, MD; Domenico Caponi, MD; Dipen Shah, MD; Lucia Garberoglio, MD; Laura Vivalda, MD; Alessandro Dulio, BS; Andrea Chiecchio, PhD; Eric Manasse, MD; Roberto Gallotti, MD

Circulation
2005;111:136-42

Permanent AF and Valvular Heart Disease





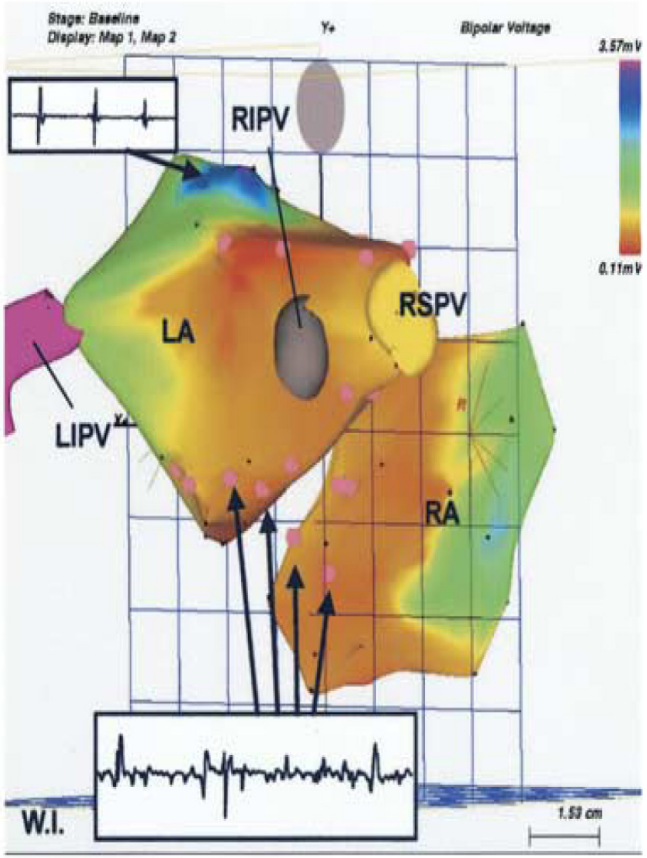
For Long Standing Atrial Fibrillation PV isolation alone is not sufficient: we have to add linear lesions

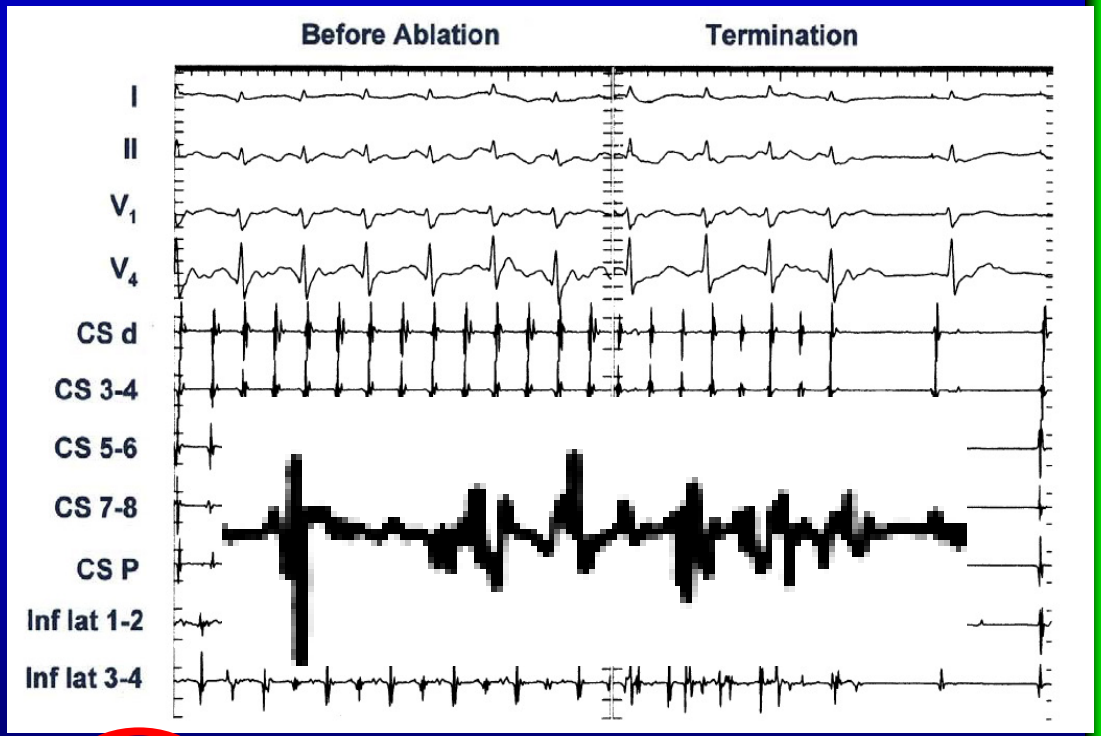
A New Approach for Catheter Ablation of Atrial Fibrillation: Mapping of the Electrophysiologic Substrate

Koonlawee Nademanee, MD, FACC,* John McKenzie, MD,* Erol Kosar, MD,* Mark Schwab, MD,* Buncha Sunsaneewitayakul, MD,† Thaveekiat Vasavakul, MD,* Chotikorn Khunnawat, MD,* Tachapong Ngarmukos, MD‡

(J Am Coll Cardiol 2004;43:2044–53)

121 pts with refractory AF (57 PAF, 64 chronic). FU: 1 y

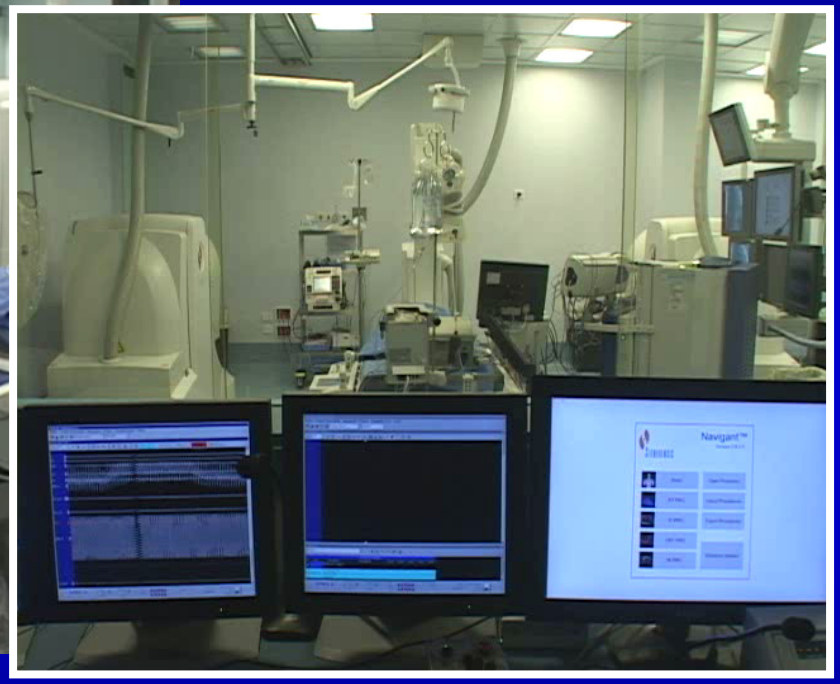




84% success rate w/out AAD (16% redo)

Stereotaxis

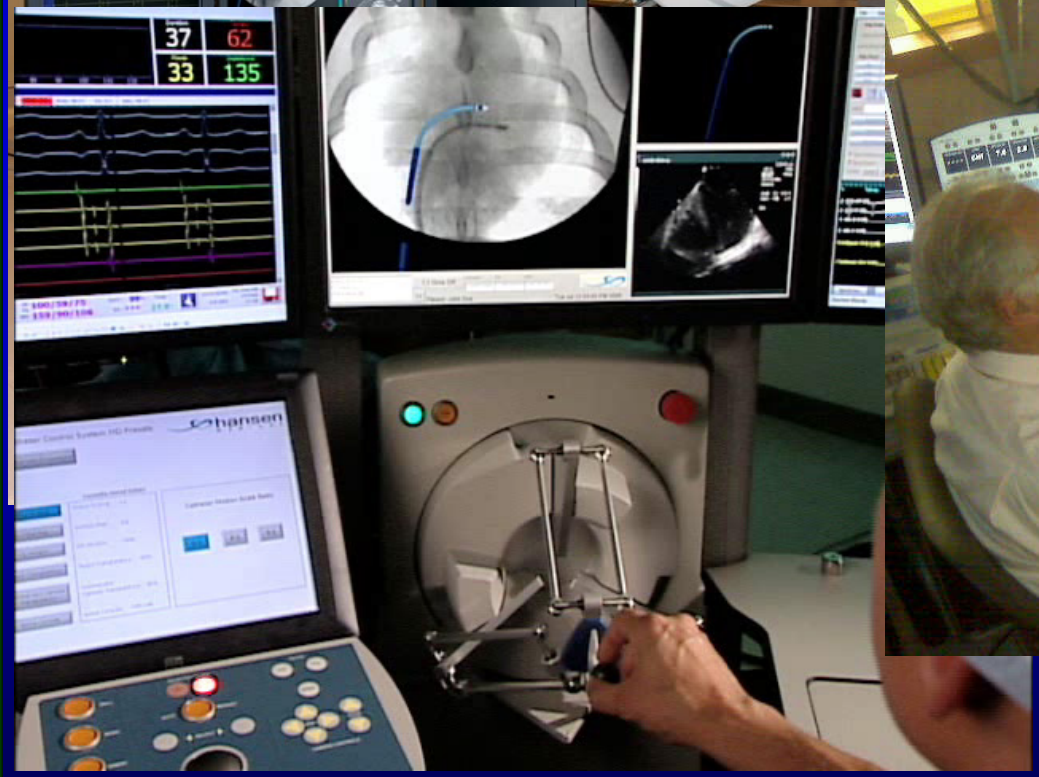
Year 2006



Integrating diagnostic data with the ability to maneuver dedicated catheters and guide wires, the Stereotaxis allows to perform interventional procedures either in the EP Lab (ablations, CRT) and in the Cath Lab (PTCA, stent).

Sensei™ system with Artisan™ introductor (Hansen Medical)

Year 2006

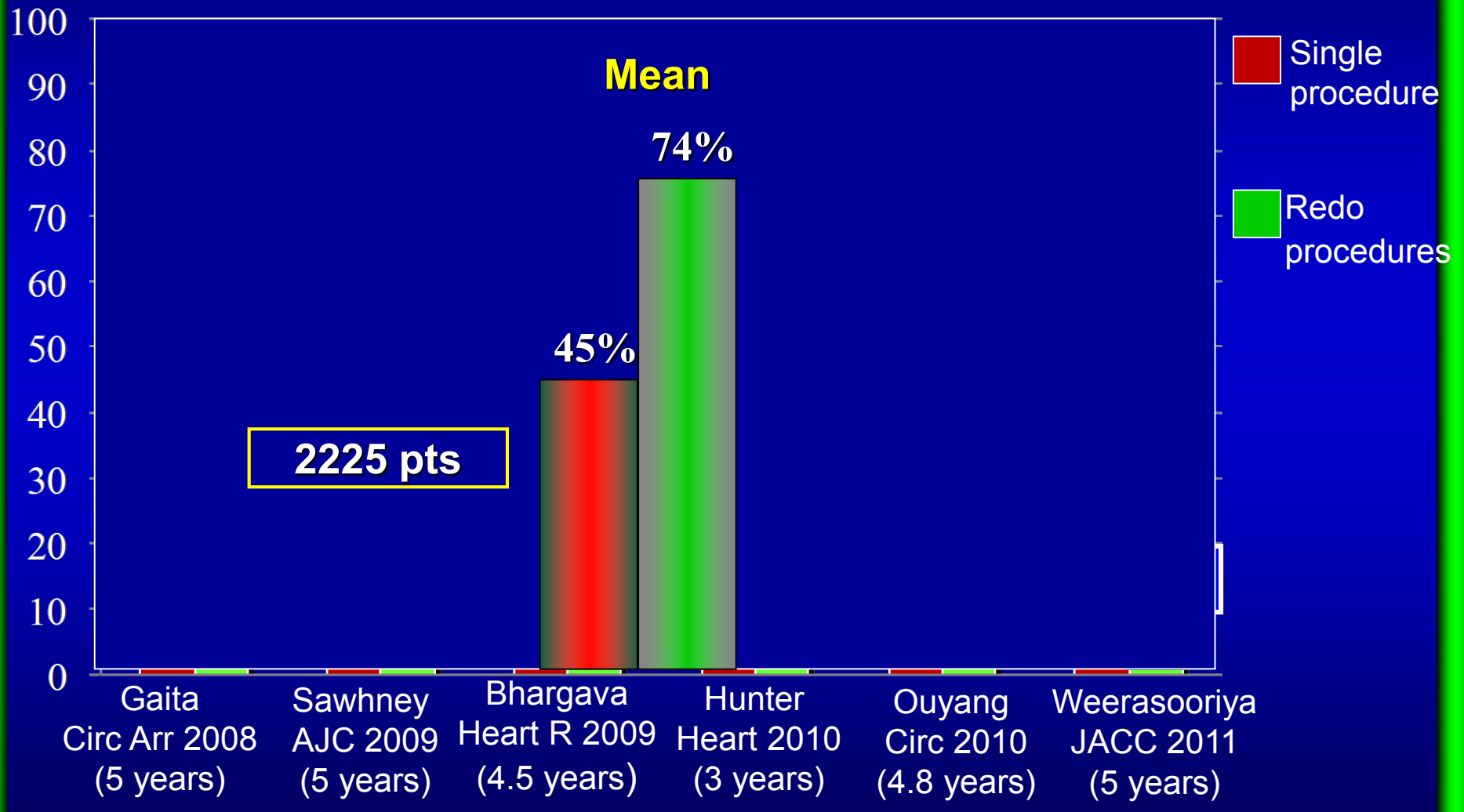


LONG-TERM EFFICACY

5 years

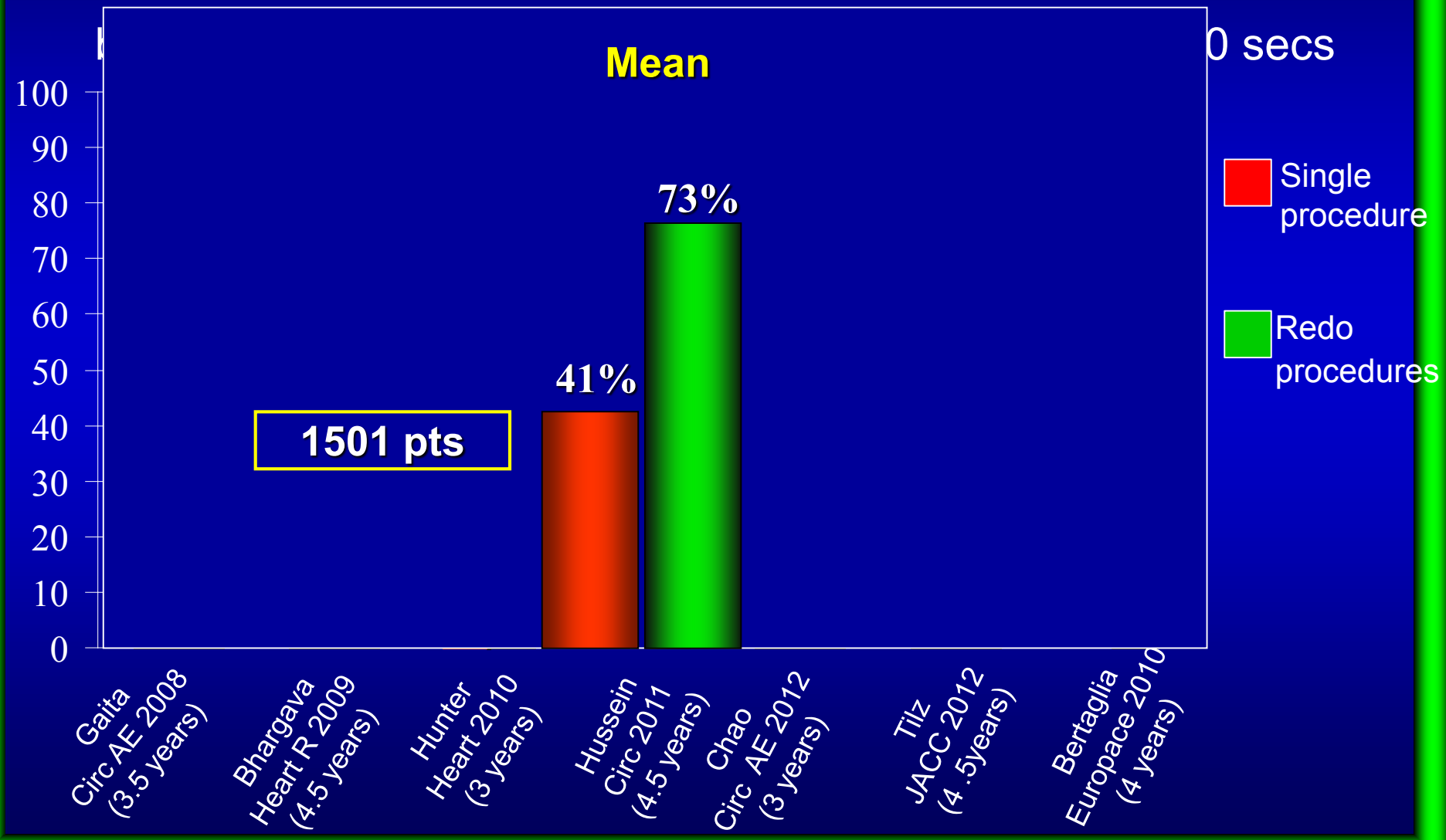
Paroxysmal AF transcatheter ablation

Long term results (5 years) from studies involving more than 50 pts



Persistent AF transcatheter ablation

Long term results (3 years) from studies involving more than 50 pts



Complications of radiofrequency AF ablation

	1033 pts Experienced centers		2049 pts Our experience		16309 pts Worldwide survey	
Complications	Pts	1.6%	Pts	1.1%	Pts	3.6%
Deaths	0	0	0	0	25	0.15
Stroke	1	0.1	4	0.2	37	0.23
TIA	4	0.4	7	0.4	115	0.71
Severe PV stenosis	3	0.3	2	0.1	48	0.29
Tamponade/Perf	5	0.5	6	0.3	213	1.31
Vascular complic	3	0.3	2	0.1	152	0.93
	Verma Circulation 2005		Gaita 2010		Cappato Circ Arr 2010	

AF ablation per year today

25.000

93% RF

6% cryo

1% other

213.000

91% RF

7% cryo

2% other

250.000

92% RF

6% cryo

2% other

800.000

92% RF

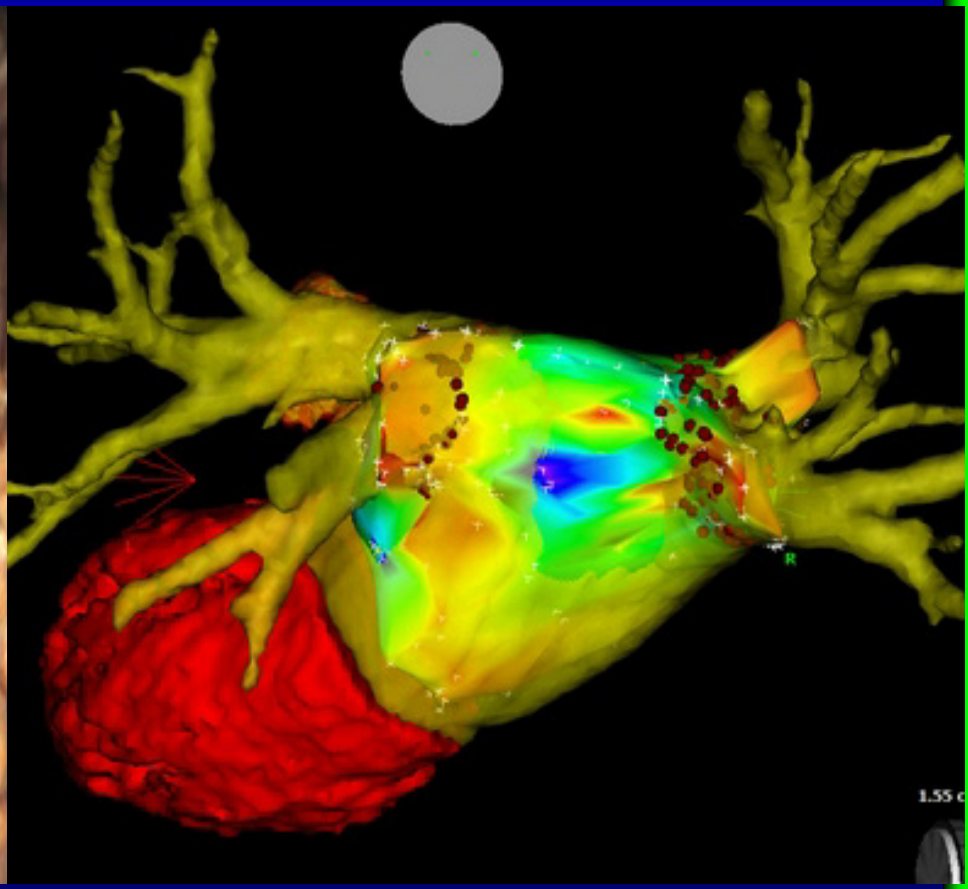
6% cryo

2% other

So what is the state of the art of Atrial Fibrillation Ablation in 2016?

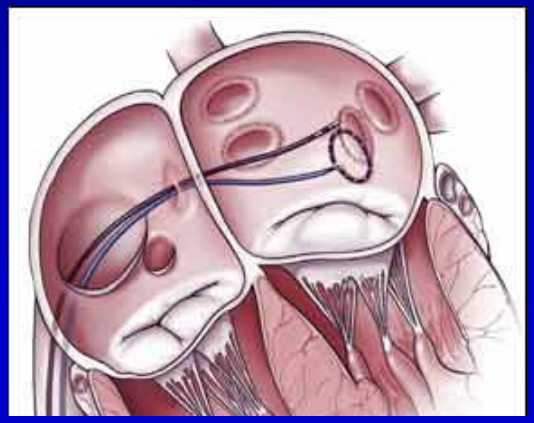
Target for Paroxysmal AF

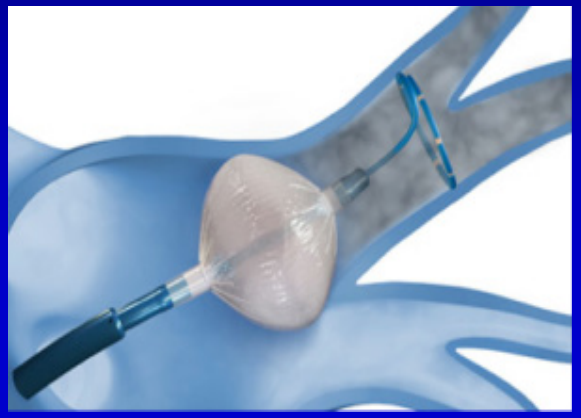
Pulmonary vein isolation

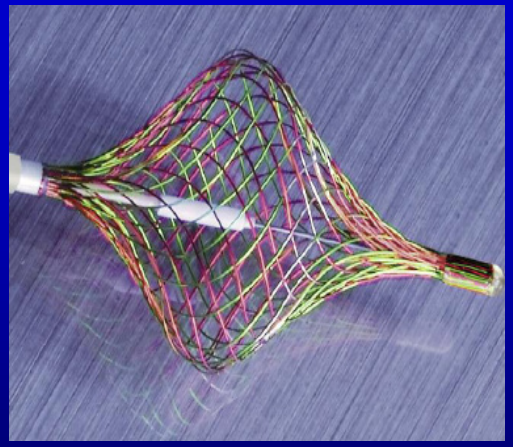


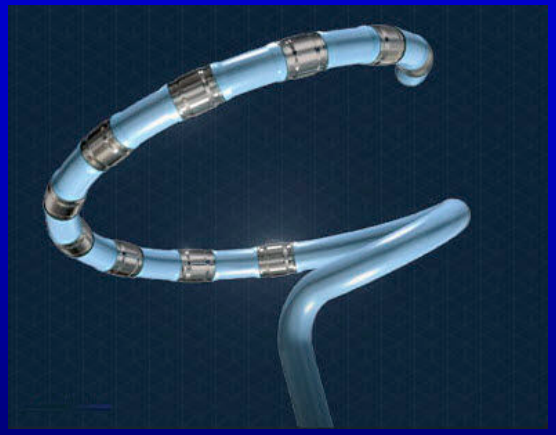
Courtesy of Dr. D Sanchez-Quintana

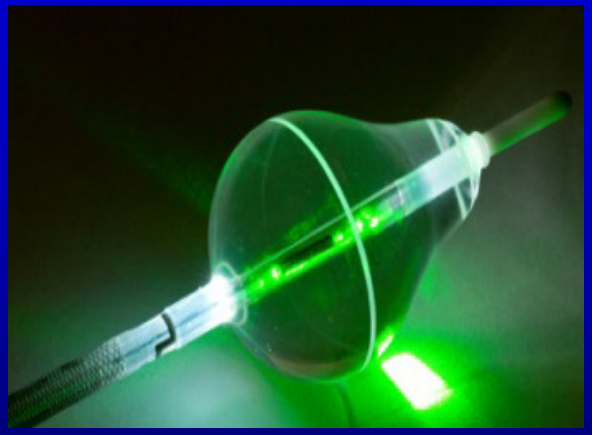
Ablation of paroxysmal AF, no doubt: PVI…but which tool?





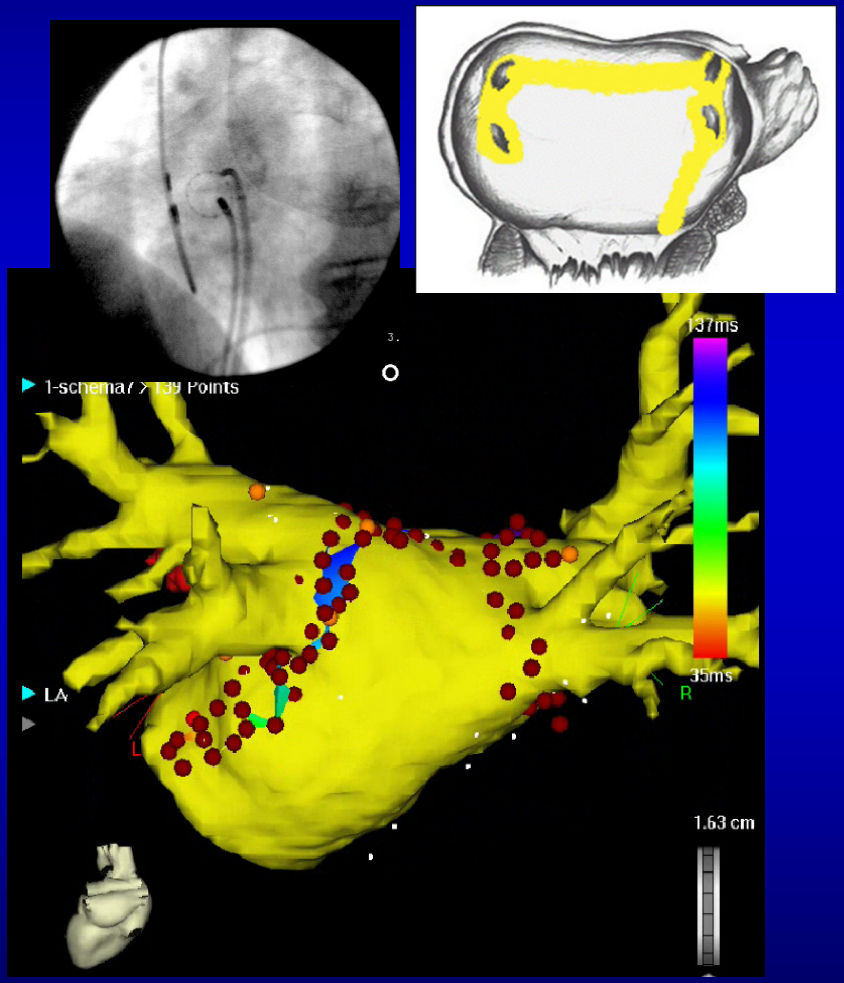


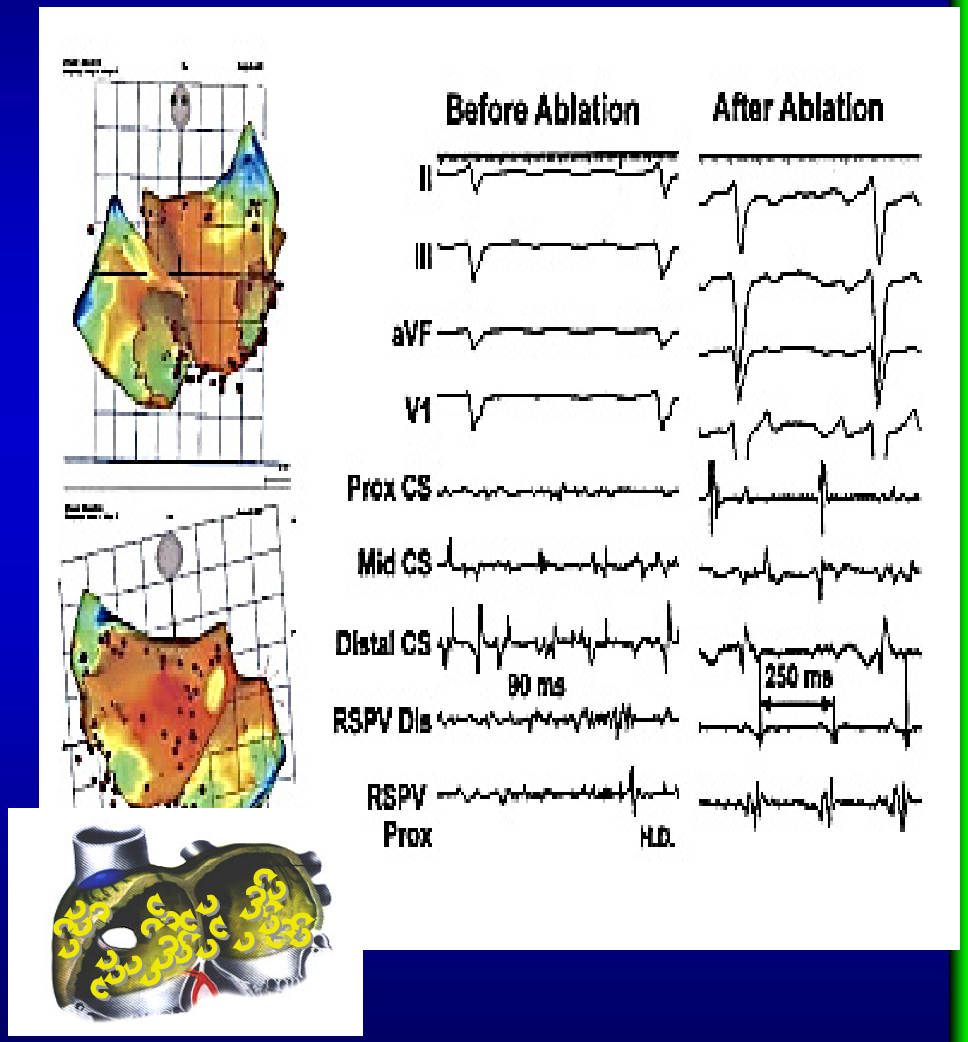




Target for Persistent AF

PVI + Linear Lesions (7 scheme) + **Complex fractioned electrogram**



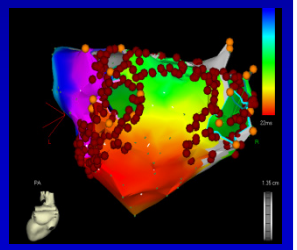
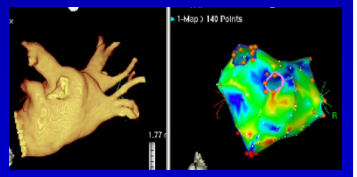
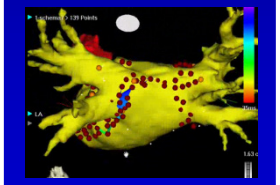
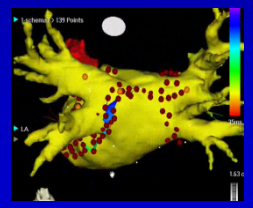
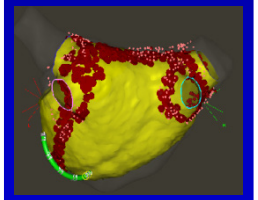
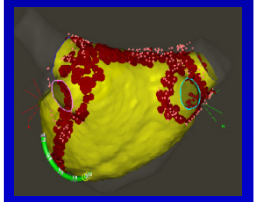


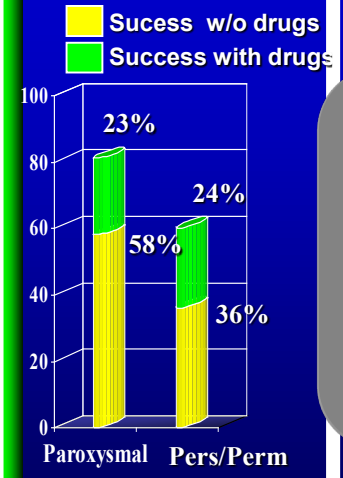
Gaita et al. Circulation 2005. 18;111:136

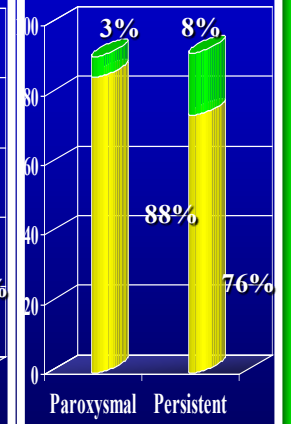
Nademanee et al. JACC 2004; 43:2044

AF Ablation, single center experience
(1999 - 2014) = 3192 pts

FU: 1 year

1999-2001	2002-2005	2006-07	2008-09	2010-11	2012-14
Pts 245	Pts 746	Pts = 500	Pts = 501	Pts =450	Pts = 810
					
Proc. Durat. 4 h.	Proc. Durat 2,30 h.	Proc. Durat. 2 h.	Dur. Proced. 2 h.	Dur. Proced 1.30 h.	Dur. Proced. 1.20 h
X-Ray:62’	X-Ray:44’	X-Ray:22’	X-Ray:9’	X-Ray:5’	X-Ray:2,5’





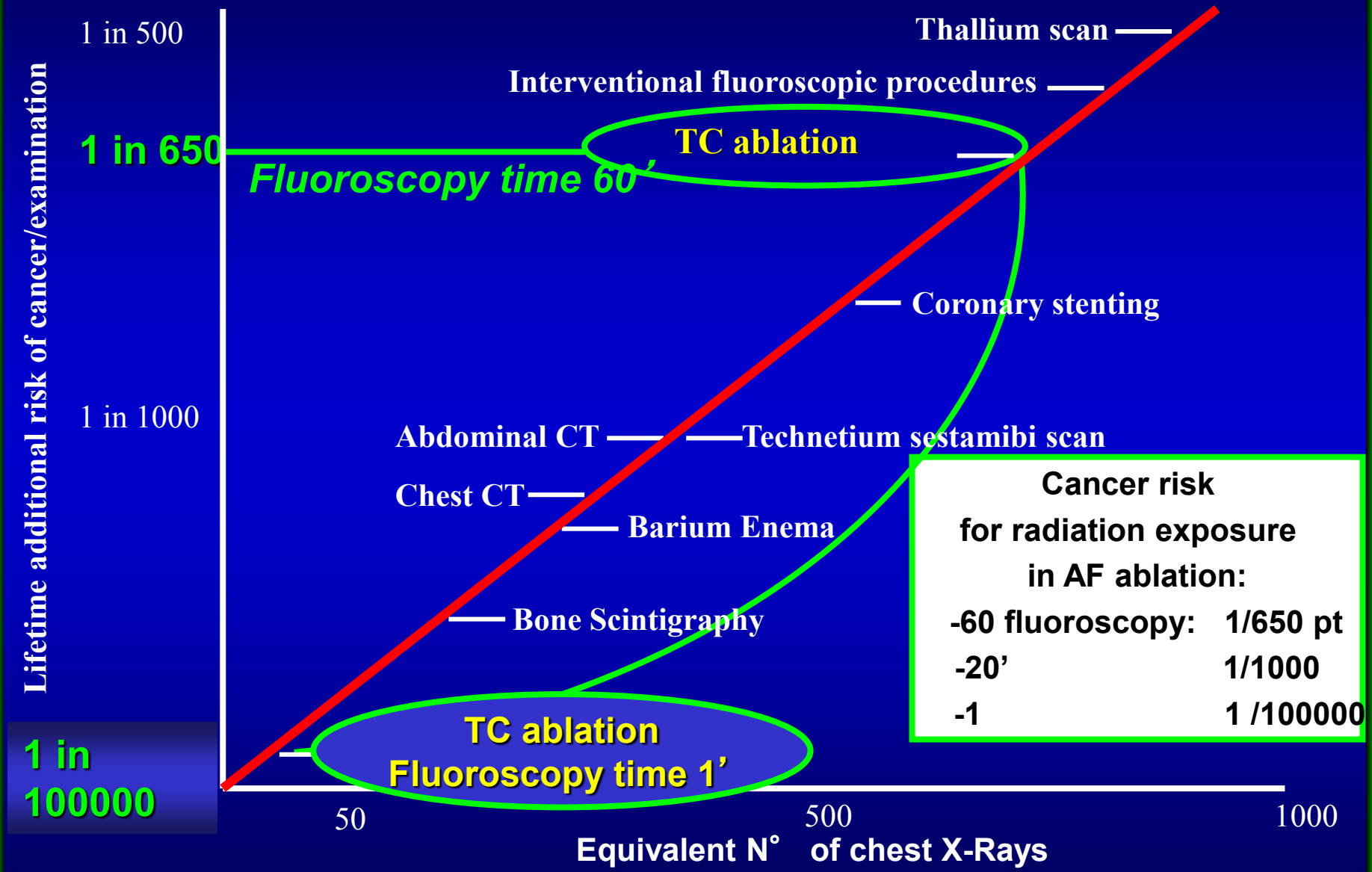
2016

Mean X-ray time: <1 min

AF transcatheter ablation

Città della Salute e della Scienza – Prof. Gaita

Radiation exposure: additional cancer risk for patients



Modified from Picano BMJ 2004

Cryoballoon or Radiofrequency Ablation for Paroxysmal Atrial Fibrillation

Karl-Heinz Kuck, M.D., Josep Brugada, M.D., Alexander Fürnkranz, M.D., Andreas Metzner, M.D., Feifan Ouyang, M.D., K.R. Julian Chun, M.D., Arif Elvan, M.D., Ph.D, Thomas Arentz, M.D., Kurt Bestehorn, M.D., Stuart J. Pocock, Ph.D., Jean-Paul Albenque, M.D., Ph.D., and Claudio Tondo, M.D., Ph.D., for the FIRE AND ICE Investigators*

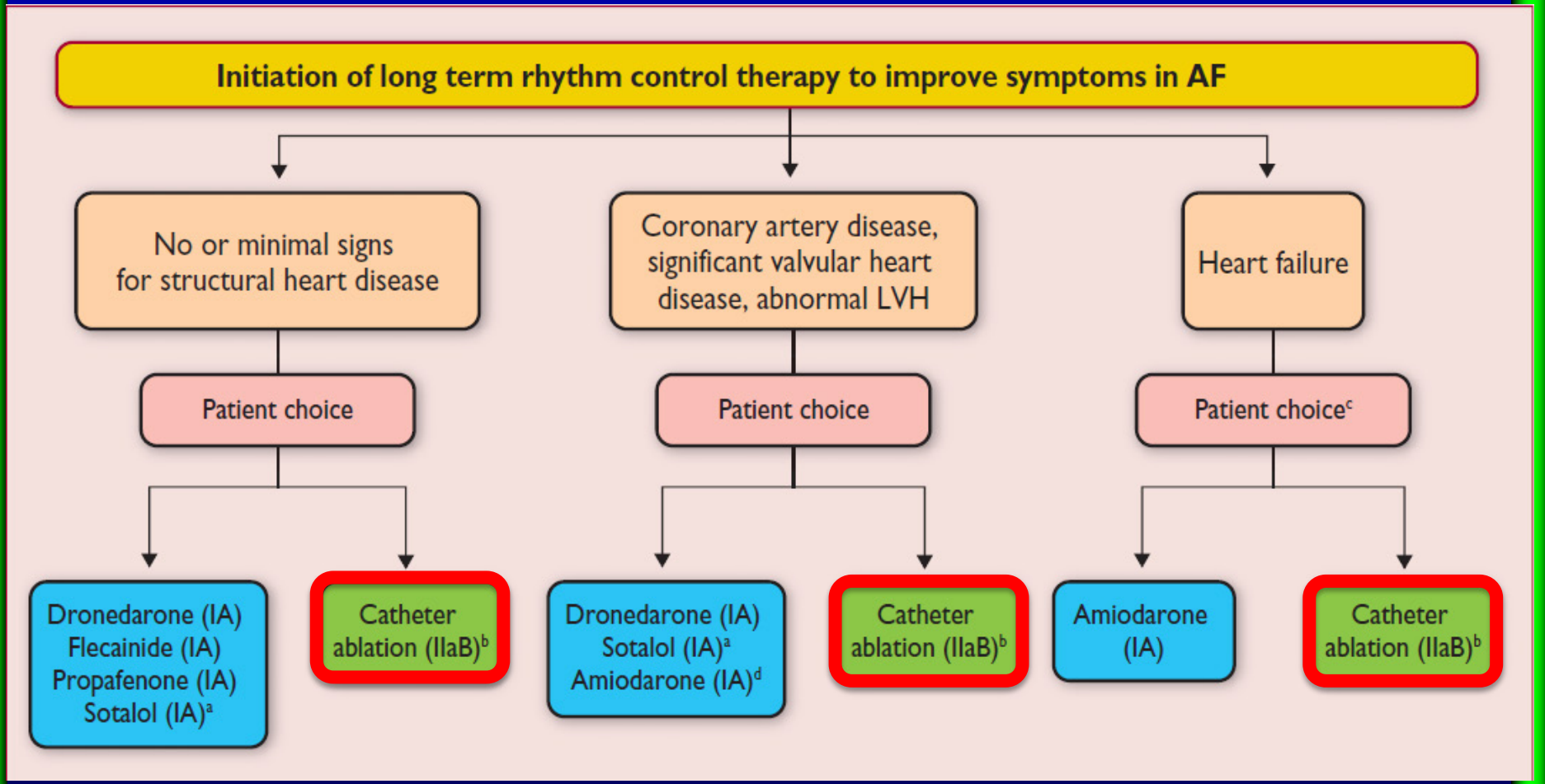
N ENGL J MED 374;23 NEJM.ORG JUNE 9, 2016

762 patients, **9 European Centers**
(4 Germany, 1 Spain, 1 Netherland, 1 France, 1 UK, 1 Italy)

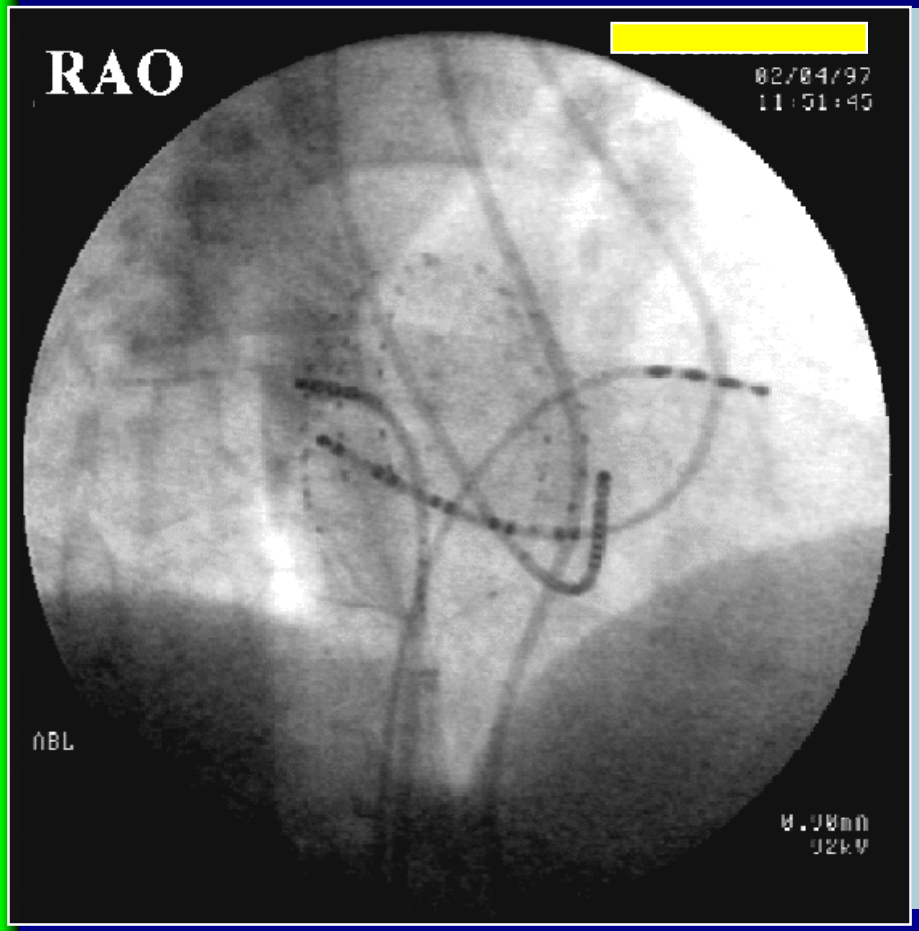
End Point	Radiofrequency Group (N=376)	Cryoballoon Group (N=374)
Secondary efficacy end points		
Death from any cause — no. of patients	0	2‖
Death from arrhythmia — no. of patients	0	0
Total fluoroscopy time — min§§	16.6±17.8	21.7±13.9
Total fluoroscopy time — min§§	16.6±17.8	21.7±13.9

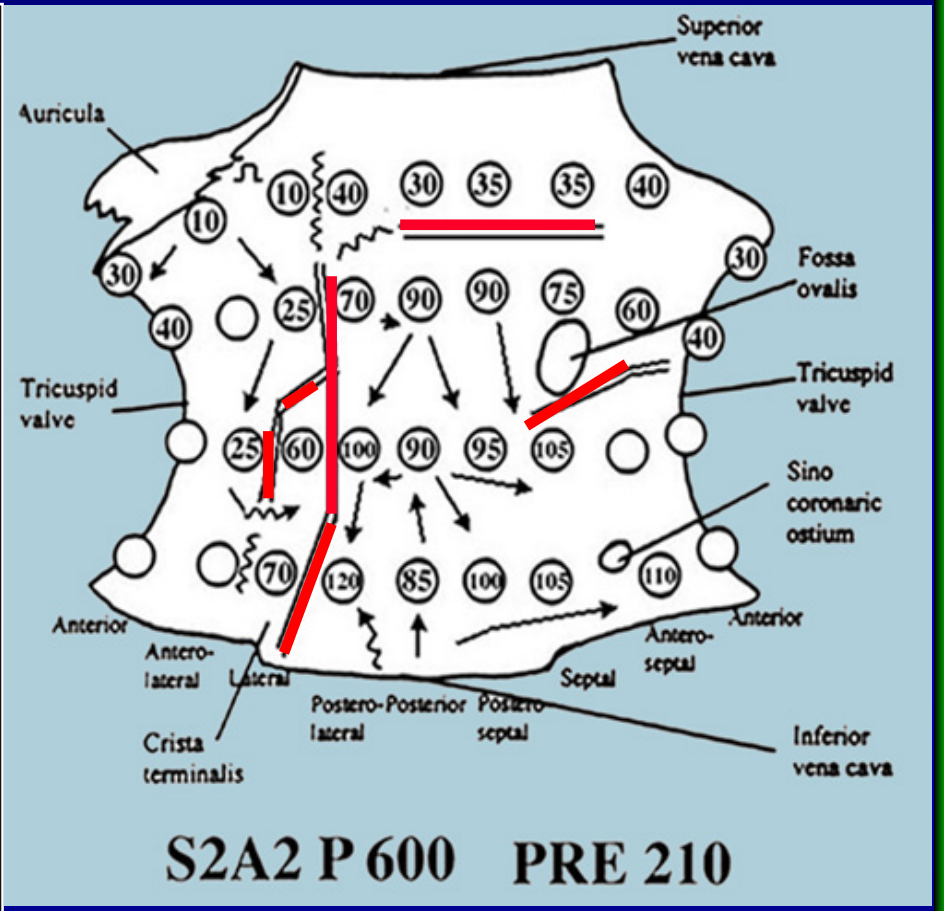
2016

AF guidelines ESC



The future perspectives…





Gaita, JACC 2001

Riccardi, G It Arit Cardiostim 2002

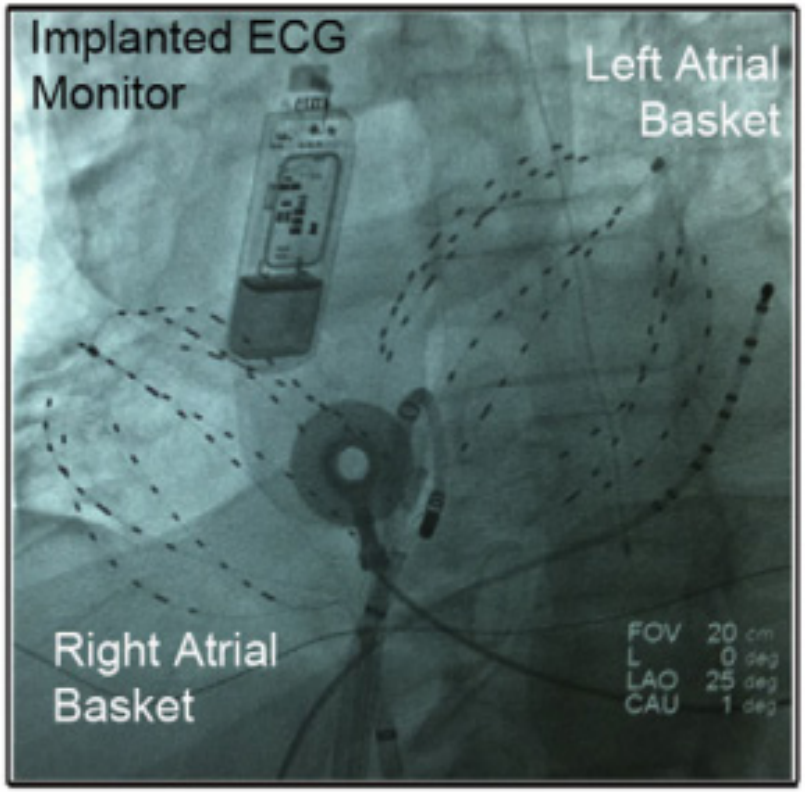
Treatment of Atrial Fibrillation by the Ablation of Localized Sources

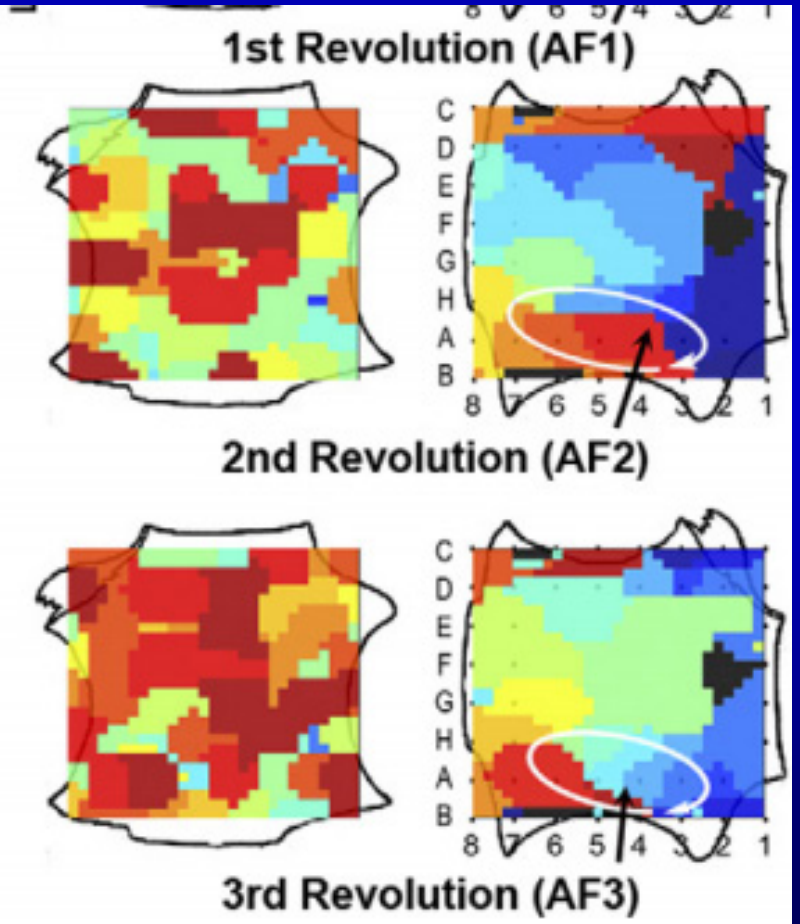
CONFIRM (Conventional Ablation for Atrial Fibrillation With or Without Focal Impulse and Rotor Modulation) Trial

Sanjiv M. Narayan, MD, PHD,*† David E. Krummen, MD,*† Kalyanam Shivkumar, MD, PHD,‡ Paul Clopton, MS,† Wouter-Jan Rappel, PHD,§ John M. Miller, MD‖

San Diego and Los Angeles, California; and Indianapolis, Indiana

B Basket Catheters in Both Atria

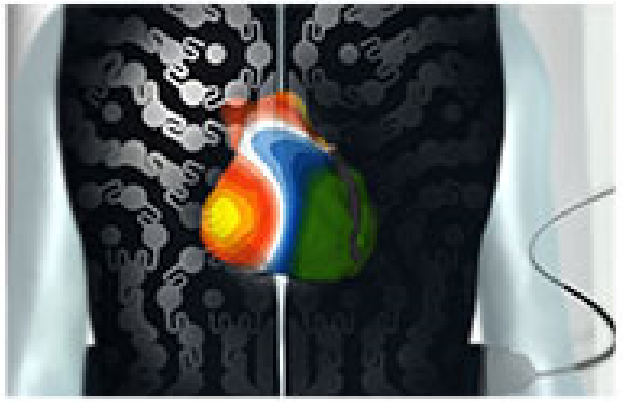




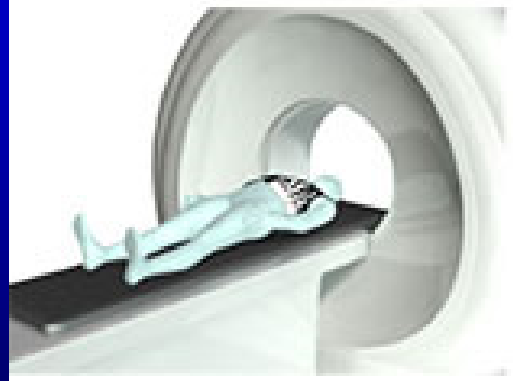
High resolution non invasive mapping

252 ELECTRODE VEST

ECM* ALGORITHMS SOLVES "INVERSE PROBLEM"



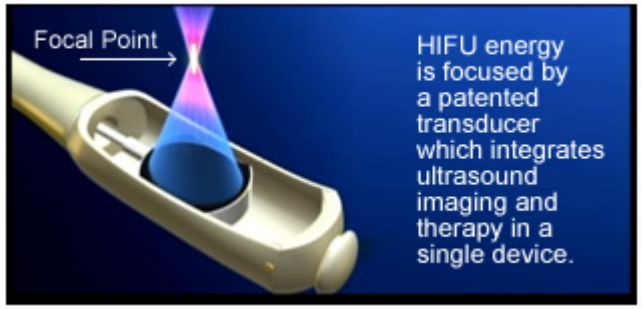
HEART-TORSO GEOMETRY (CT)

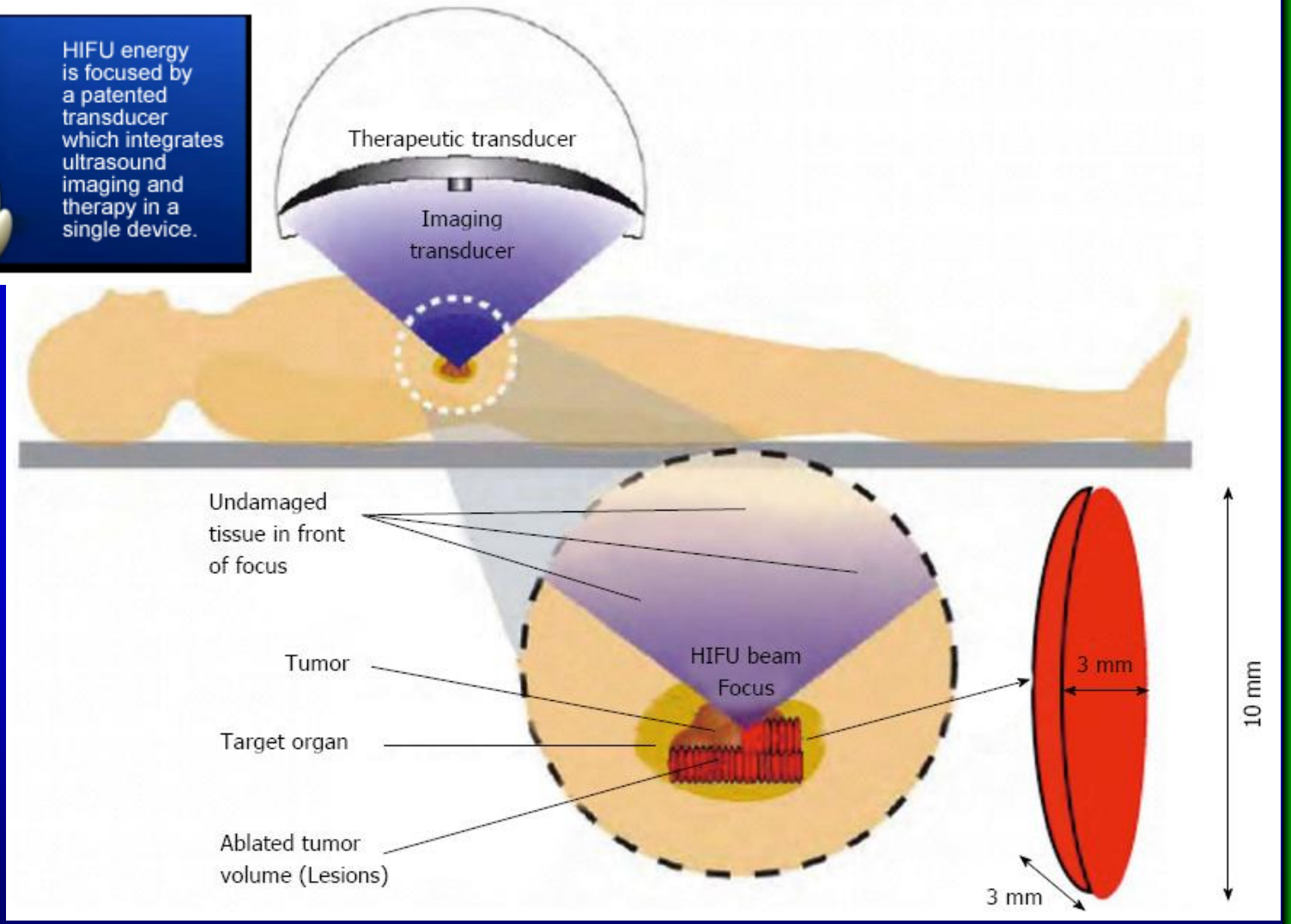


ECM MAPS

Sebastien Knecht Cardiac Rhythm News Dec 2014

Focused ultrasound therapy for AF?





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Thank you for your attention