HISTORY OF EGM-BASED ABLATION

Dr THOMAS PAMBRUN

University of Bordeaux – LIRYC institute

C·H·U
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L'INSTITUT DE RYTHMOLOGIE
ET MODÉLISATION CARDIAQUE
BORDEAUX

DISCLOSURES: NONE

DEBATE ABOUT THE RELEVANCE OF COMPLEX SIGNALS RECORDING

EDITORIAL

Fractionated electrical activity and continuous electrical activity: fact or artifact?

MARK E. JOSEPHSON, M.D., AND ANDREW L. WIT, PH.D.

Circulation. 1984;70:529-532

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | STRATEGY REFINEMENT

Mark E. Josephson

These proposals are all based on the assumption that fractionated electrograms are caused by slow, inhomogeneous conduction, a property that can cause reentry.

These proposals are also a source of controversy. It has been suggested that fractionated electrograms and continuous activity may be artifacts, resulting from movement between the electrode and myocardium.

FRACTIONATED POTENTIALS

INITIAL DOUBTS: THE « ARTIFACTS THEORY »

Significance of Fragmented Ventricular Electrograms Observed Using Intracardiac Recording Techniques in Man

HARVEY L. WAXMAN, M.D., AND RUEY J. SUNG, M.D.

Circulation 62, No. 6, 1980.

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | STRATEGY REFINEMENT

FIGURE 3. *Fragmentation of the ventricular electrogram with beat-to-beat variation recorded in patient 2, with cardiomyopathy and a history of sustained ventricular tachycardia. Note the beat-to-beat variation in the timing of the fragmentation (arrows) recorded in an unstable catheter electrode position near the left ventricular apex (LVA). No fragmentation is apparent in the right ventricular apical (RVA) electrogram.*

SIGNAL ARTIFACTS CAUSED BY

ELECTRODE MOTION

FRACTIONATED POTENTIALS

INITIAL DOUBTS: THE « ARTIFACTS THEORY »

Techniques of Intraoperative Electrophysiologic Mapping

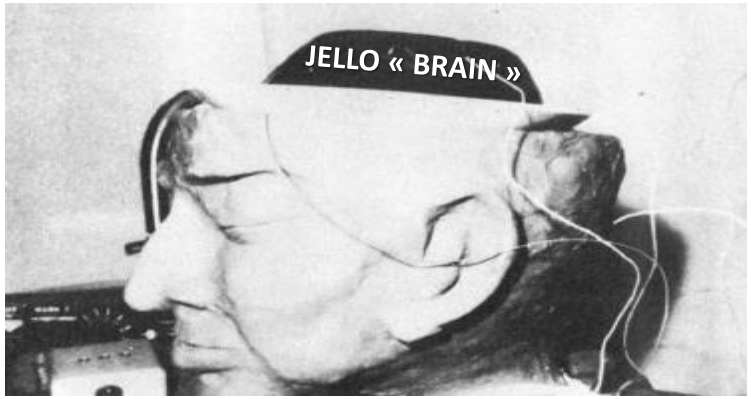
JOHN J. GALLAGHER, MD, FACC
JACK H. KASELL
JAMES L. COX, MD
WILLIAM M. SMITH, PhD
RAYMOND E. IDEKER, MD, PhD
WARREN M. SMITH, MD

Durham, North Carolina

The American Journal of CARDIOLOGY
January 1982
Volume 49 221

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | STRATEGY REFINEMENT

A



B

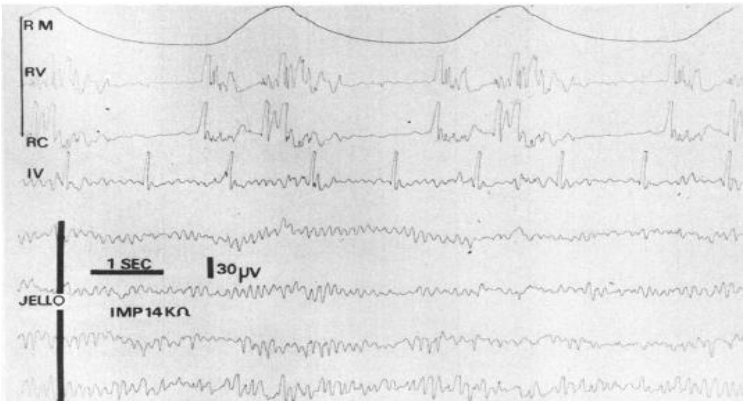


FIGURE 7. Recording of continuous activity from the jello "brain." **Panel A,** laboratory model showing electroencephalographic recording leads inserted in jello. **Panel B,** electroencephalographic tracing recorded from the jello. Recordings from **top to bottom** are from the respiration monitor (RM), the respirator/ventilator (RV), the respirator coil (RC), the intravenous line (IV) and four channels directly from the jello. The impedance of these latter recordings was 14,000 ohms. The amplitude of the recorded activity is approximately 30 μV. The artifactual electroencephalographic activity recorded from the jello probably stems from several sources. Simultaneous recordings of several devices in the laboratory environment suggest a source for some of the components of this activity. Especially striking is the activity recorded from the intravenous drip apparatus, which suggests electrocardiographic complexes. (These illustrations were kindly supplied by Dr. Adrian Upton, Chedoke-McMaster Hospital, Hamilton, Ontario, Canada.)

SIGNAL ARTIFACTS CAUSED BY

FARFIELD ACTIVITIES

FRACTIONATED POTENTIALS

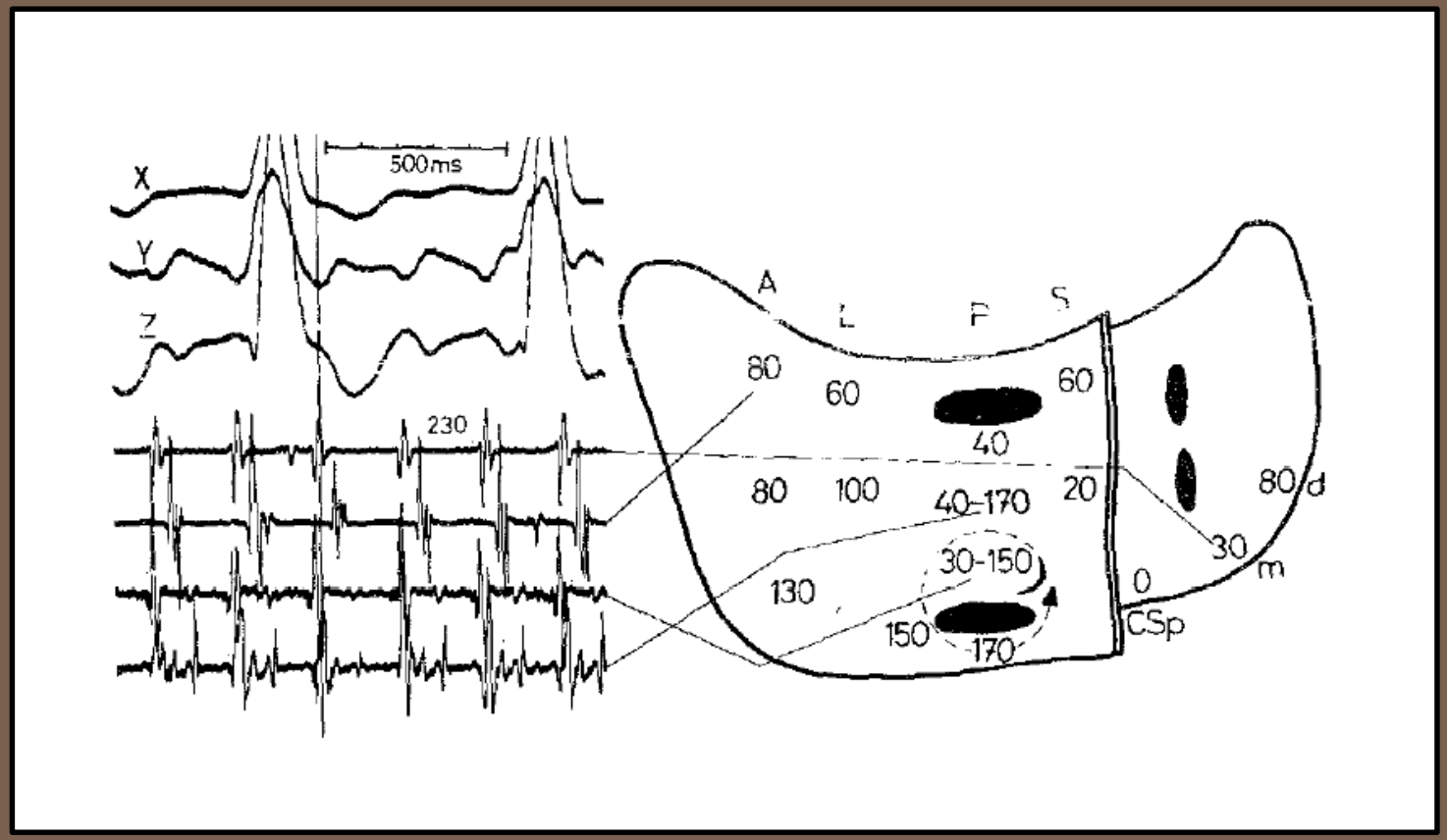
SCIENTIFIC EVIDENCES FOR « ASYNCHRONOUS SLOWING OF THE TION »

Fragmented Electrograms and Continuous Electrical Activity in Atrial Flutter

FRANCISCO G. COSIO, MD, FERNANDO ARRIBAS, MD, JOSE PALACIOS, MD, JUAN TASCON, MD, and MARIA LOPEZ-GIL, MD

Am J Cardiol 1986;57:1309–1314

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | STRATEGY REFINEMENT



FRACTIONATED POTENTIALS

EVIDENCES FOR « ASYNCHRONOUS SLOWING OF THE CONDUCTION »

L'INSTITUT DE RYTHMOLOGIE ET MODÉLISATION CARDIAQUE — BORDEAUX

Relating Extracellular Potentials and Their Derivatives to Anisotropic Propagation at a Microscopic Level in Human Cardiac Muscle

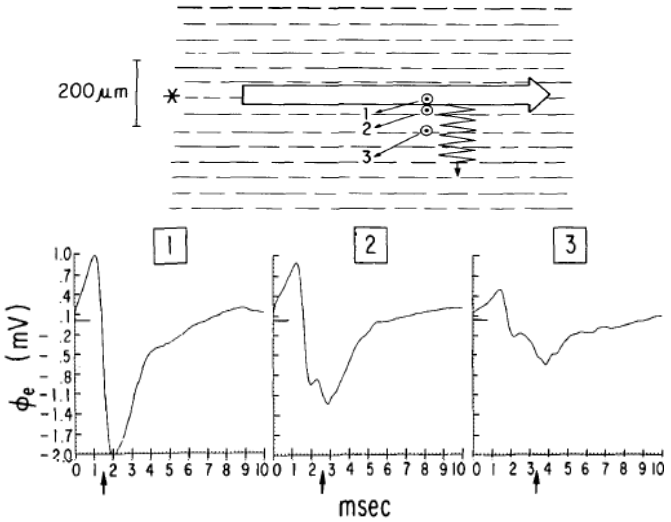
Madison S. Spach and Paul C. Dolber
From the Departments of Pediatrics and Physiology, Duke University Medical Center, Durham, North Carolina

Circulation Research/*Vol. 58, No. 3, March 1986*

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | STRATEGY REFINEMENT

ASYNCHRONOUS ACTIVATION CAUSED BY

ANISOTROPIC PROPAGATION



The above results in the older age group suggest an anisotropic propagation medium comprised of cells that are tightly coupled along the longitudinal axis of the fibers, but along the transverse axis there are recurrent areas in which side-to-side electrical coupling of adjacent groups of parallel fibers is absent. Thus, when compared to the tightly coupled medium with uniform anisotropic propagation of the young preparations, there is a progressive loss with age of side-to-side electrical coupling between groups of parallel-oriented atrial fibers. Such a medium would account for the uniform fast propagation without delays in the direction of low axial resistivity (the long axis of the fibers) in the presence of nonuniform slow propagation with delays along the axis of high axial resistivity (the transverse direction). The periodic absence of side-to-side electrical coupling between groups of fibers should also produce a zigzag course of transverse propagation. A significant zigzag component of excitation spread, in turn, should generate numerous deflections (and their varied shapes) in the extracellular waveforms.

FRACTIONATED POTENTIALS

EVIDENCES FOR « ASYNCHRONOUS SLOWING OF THE CONDUCTION »

Slow Conduction in the Infarcted Human Heart

'Zigzag' Course of Activation

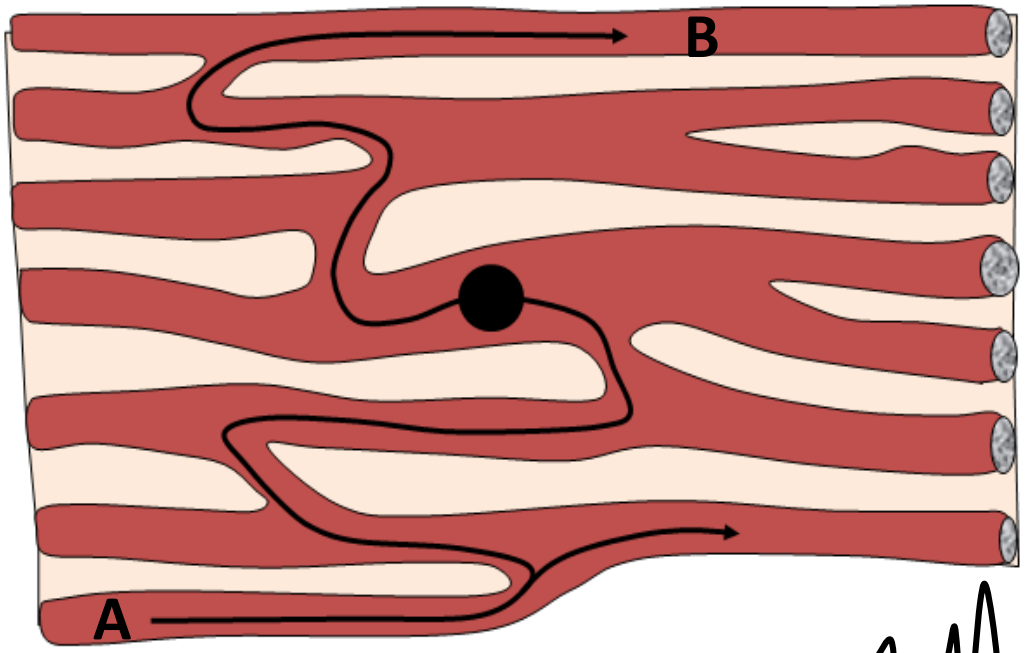
Jacques M.T. de Bakker, PhD; Frans J.L. van Capelle, PhD; Michiel J. Janse, MD;
Sara Tasseron, RT; Jessica T. Vermeulen, MD;
Nicolaas de Jonge, MD; Jaap R. Lahpor, MD

Circulation *Vol 88, No 3 September 1993*

FUNDAMENTAL BASIS → CLINICAL DESCRIPTION → PRACTICAL APPLICATION → STRATEGY REFINEMENT

ASYNCHRONOUS ACTIVATION CAUSED BY

ANATOMICAL BARRIERS



FRACTIONATED POTENTIALS

EVIDENCES FOR « ASYNCHRONOUS SLOWING OF THE CONDUCTION »

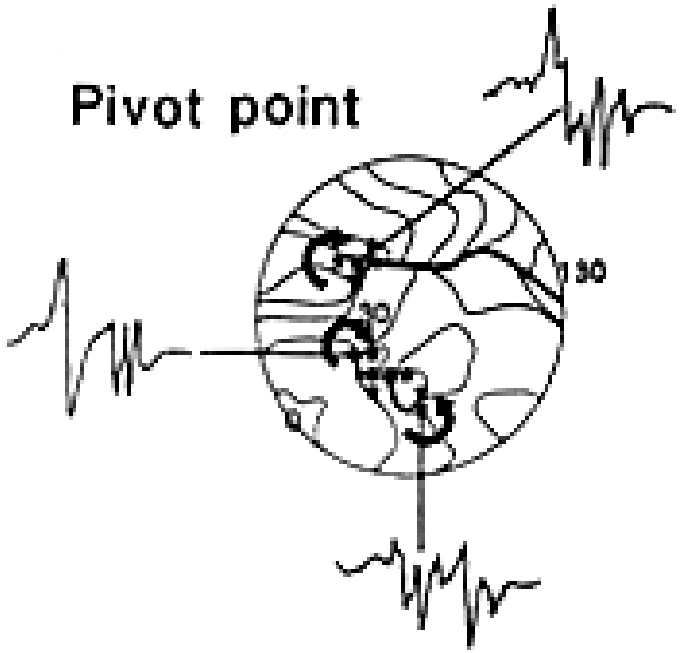
Configuration of Unipolar Atrial Electrograms During Electrically Induced Atrial Fibrillation in Humans

Karen T.S. Konings, Joep L.R.M. Smeets, Olaf C. Penn, Hein J.J. Wellens, Maurits A. Allessie

Circulation. 1997;95:1231-1241

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | STRATEGY REFINEMENT

ASYNCHRONOUS ACTIVATION CAUSED BY **WAVEFRONT CURVATURE**



Pivot points of turning wavelets seem to be important factors for perpetuation of AF.

COMPLEX SIGNALS ARE A REAL PHENOMENON

Anisotropic propagation, anatomical barriers and wavefront curvature are the mechanisms favoring the recording of complex signals.

These complex signals have subsequently proved to be key elements for atrial fibrillation.

FIRST DESCRIPTION OF ATRIAL FIBRILLATION DRIVERS AND THEIR ELECTROPHYSIOLOGICAL EXPRESSIONS

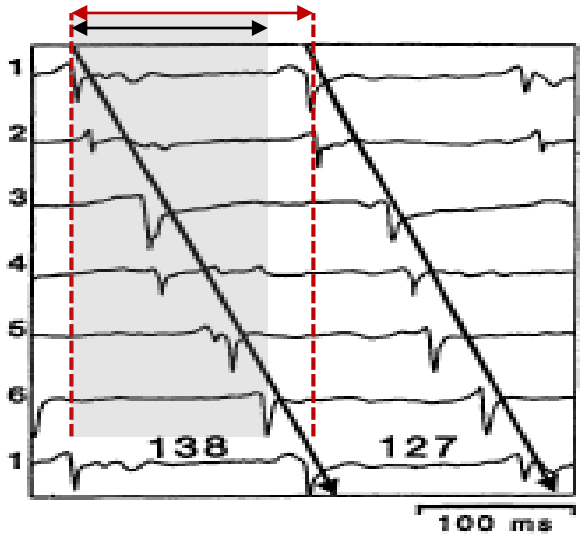
REENTRY : MULTIPLE WAVELETS THEORY

High-Density Mapping of Electrically Induced Atrial Fibrillation in Humans

Karen T.S. Konings, MD; Charles J.H.J. Kirchhof, MD, PhD; Joep R.L.M. Smeets, MD, PhD; Hein J.J. Wellens, MD, PhD; Olaf C. Penn, MD, PhD; Maurits A. Allessie, MD, PhD

(*Circulation*. 1994;89:1665-1680.)

FUNDAMENTAL BASIS | **CLINICAL DESCRIPTION** | PRACTICAL APPLICATION | STRATEGY REFINEMENT



Incidence of Reentry

more common (28±25%). In type III fibrillation, random reentry occurred in 33±10% of the beats, whereas a shifting leading circle was observed during 66±29% of the fibrillation cycles. During type III, the average persistence of a shifting leading circle in the free wall of the right atrium was 5.4±3.1 beats. The incidence of

Pivot points are crucial because no matter how many wavelets are present, if they do not turn, they will soon die out at the boundaries of the atria and fibrillation will terminate.

GRADIENT

FIRST DESCRIPTION OF ATRIAL FIBRILLATION DRIVERS AND THEIR ELECTROPHYSIOLOGICAL EXPRESSIONS

REENTRY : MULTIPLE WAVELETS THEORY

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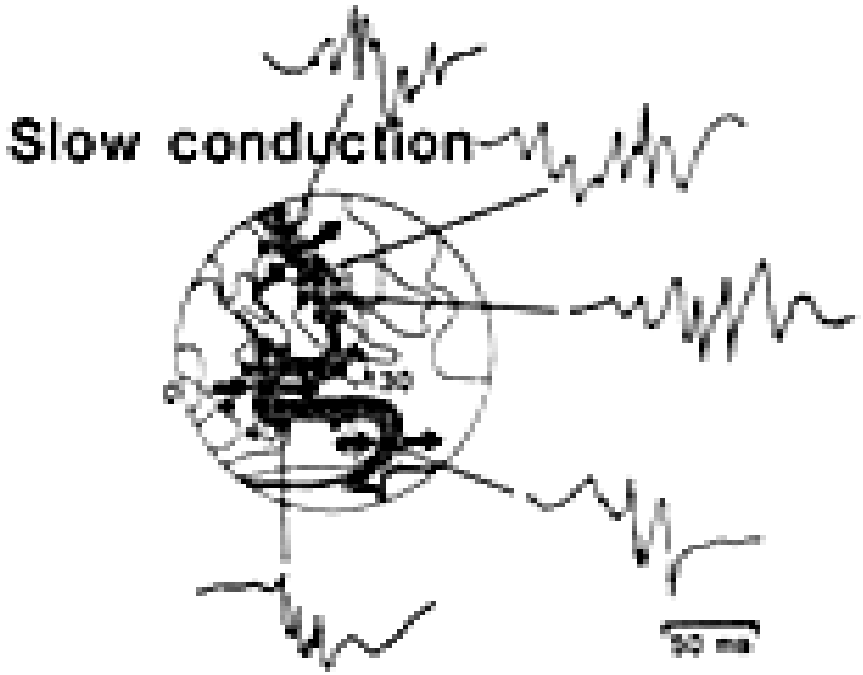
L'INSTITUT DE RYTHMOLOGIE ET MODÉLISATION CARDIAQUE BORDEAUX

Configuration of Unipolar Atrial Electrograms During Electrically Induced Atrial Fibrillation in Humans

Karen T.S. Konings, Joep L.R.M. Smeets, Olaf C. Penn, Hein J.J. Wellens, Maurits A. Allessie

Circulation. 1997;95:1231-1241

FUNDAMENTAL BASIS | **CLINICAL DESCRIPTION** | PRACTICAL APPLICATION | STRATEGY REFINEMENT



Our present study shows that abnormal conduction patterns are "translated" into fragmented potentials.

Areas of slow conduction shorten the wavelength of the wandering wavelets, thereby increasing the number that can coexist in the atria.

FRACTIONATION

FIRST DESCRIPTION OF ATRIAL FIBRILLATION DRIVERS AND THEIR ELECTROPHYSIOLOGICAL EXPRESSIONS

BURSTS: FOCAL SOURCES THEORY

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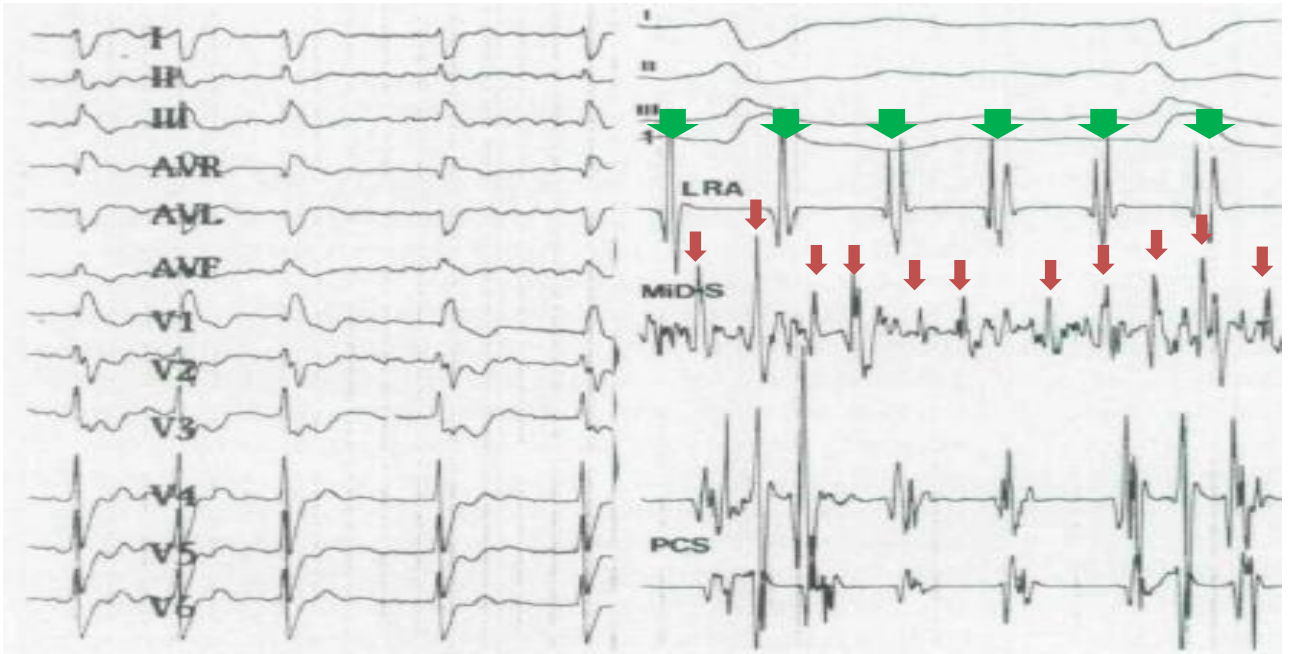
Radiofrequency Catheter Ablation in Unusual Mechanisms of Atrial Fibrillation:
Report of Three Cases

MICHEL HAÏSSAGUERRE, M.D., FRANK I. MARCUS, M.D.,*
BRUNO FISCHER, M.D., and JACQUES CLÉMENTY, M.D.

Journal of Cardiovascular Electrophysiology Vol. 5, No. 9, September 1994

FUNDAMENTAL BASIS | **CLINICAL DESCRIPTION** | PRACTICAL APPLICATION | STRATEGY REFINEMENT

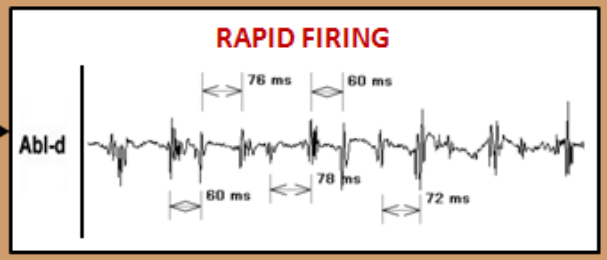


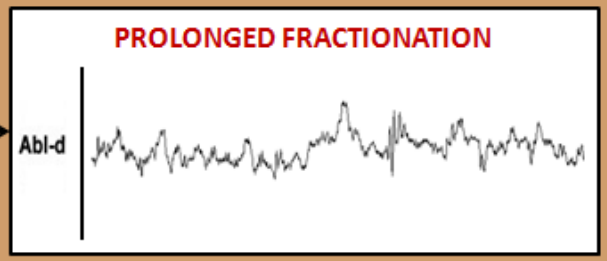
This report describes successful ablation of "focal" AF using catheter techniques. AF appeared to be due to a rapid focus

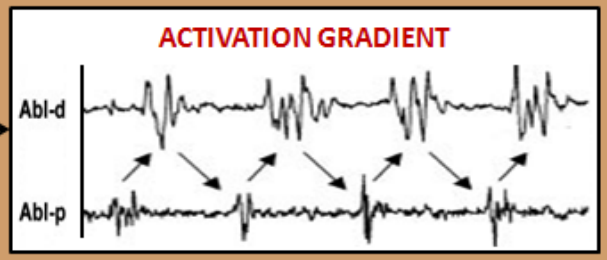
FIRING

WHICH SIGNALS MAY BE TARGETED N THE EP LAB ?

DRIVER'S CATEGORY	ELECTROPHYSIOLOGICAL MECHANISMS	TARGET SIGNALS
SOURCE	FOCAL BURSTS	RAPID FIRING
REENTRY	SLOW CONDUCTION	PROLONGED FRACTIONATION
	TRANSITORY ROTATION	ACTIVATION GRADIENT







FIRST DESCRIPTION OF THESE COMPLEX SIGNALS AS A POTENTIAL TARGET FOR AF ABLATION

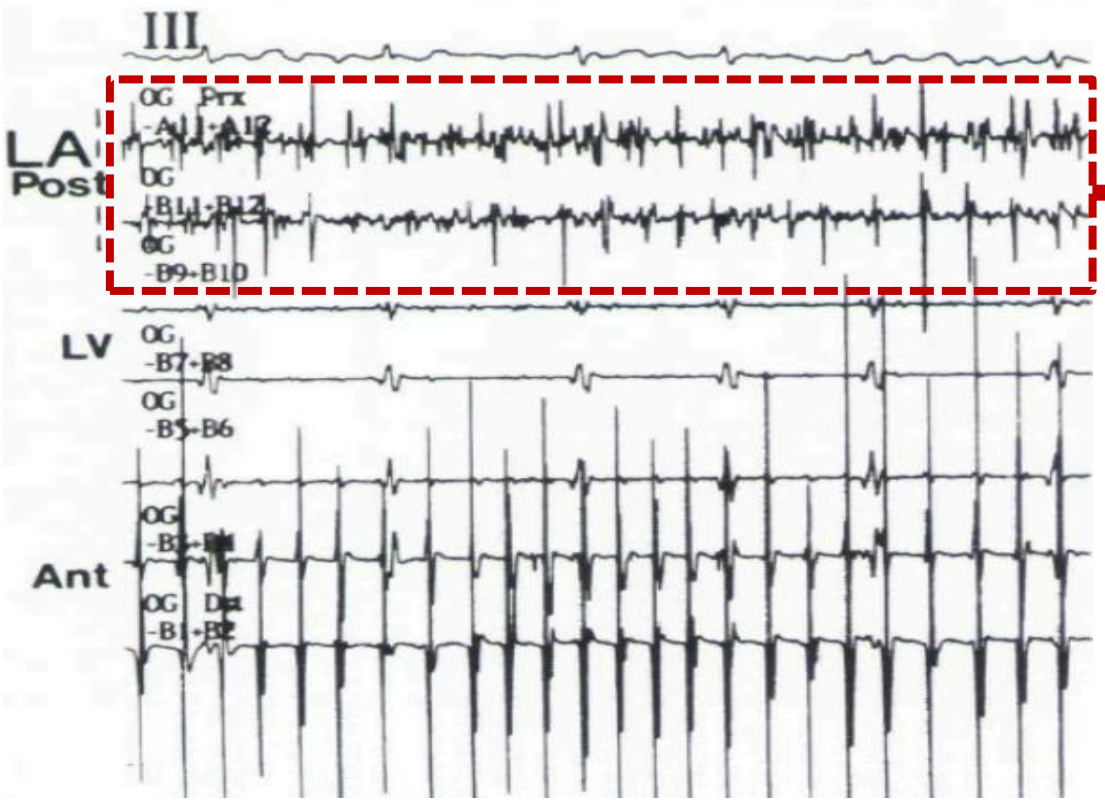
Regional Disparities of Endocardial Atrial Activation in Paroxysmal Atrial Fibrillation

PIERRE JAÏS, MICHEL HAÏSSAGUERRE, DIPEN C. SHAH, SALAH CHOUAIRI, and JACQUES CLÉMENTY

Hôpital Cardiologique du Haut-Lévêque, Bordeaux, France

(PACE 1996; 19[Pt. II]:1998–2003)

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | **PRACTICAL APPLICATION** | STRATEGY REFINEMENT



complex electrical activity (CEA)

=

continuous electrical activity

OR

FF interval < 100 ms

The areas exhibiting the most consistently disorganized electrograms could be considered preferential targets for catheter-based AFib ablation.

FIRST APPLICATION IN DAILY-LIFE PRACTICE FOR ATRIAL FIBRILLATION ABLATION

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L'INSTITUT DE RYTHMOLOGIE ET MODÉLISATION CARDIAQUE BORDEAUX

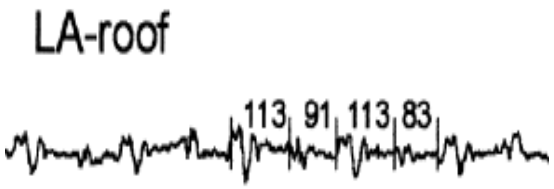
A New Approach for Catheter Ablation of Atrial Fibrillation: Mapping of the Electrophysiologic Substrate

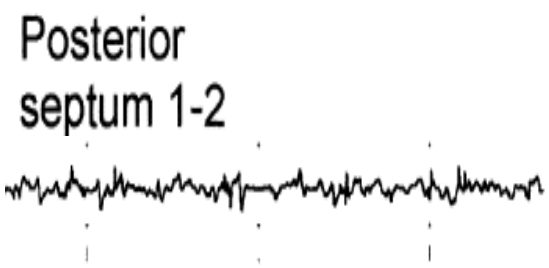
Koonlawee Nademanee, MD, FACC,* John McKenzie, MD,* Erol Kosar, MD,* Mark Schwab, MD,* Buncha Sunsaneewitayakul, MD,† Thaveekiat Vasavakul, MD,* Chotikorn Khunnawat, MD,* Tachapong Ngarmukos, MD‡

JACC Vol. 43, No. 11, 2004
June 2, 2004:2044–53

FUNDAMENTAL BASIS → CLINICAL DESCRIPTION → **PRACTICAL APPLICATION** → STRATEGY REFINEMENT

FIRING	FRACTIONATION	GRADIENT
« Atrial EGM with very short CL < 120 ms averaged over a 10-s recording period »	« Atrial EGM displaying perturbation of the baseline with continuous deflection over a 10-s recording period »	-





AF TERMINATION DURING ABLATION : 95%

SUBSEQUENT VALIDATION BY DIFFERENT TEAMS USING SIMILAR « SUBSTRATE-BASED » TARGETS

Catheter Ablation of Long-Lasting Persistent Atrial Fibrillation:
Critical Structures for Termination

MICHEL HAÏSSAGUERRE, M.D., PRASHANTHAN SANDERS, M.B.B.S., PH.D., MÉLÈZE HOCINI, M.D., YOSHIHIDE TAKAHASHI, M.D., MARTIN ROTTER, M.D., FREDERIC SACHER, M.D., THOMAS ROSTOCK, M.D., LI-FERN HSU, M.B.B.S., PIERRE BORDACHAR, M.D., SYLVAIN REUTER, M.D., RAYMOND ROUDAUT, M.D., JACQUES CLÉMENTY, M.D., and PIERRE JAÏS, M.D.

J Cardiovasc Electrophysiol. 2005 Nov;16(11):1125-37.

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | **PRACTICAL APPLICATION** | STRATEGY REFINEMENT

FIRING

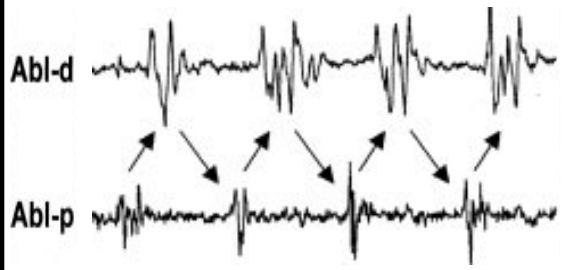
« Discrete atrial EGM with shorter CL than the mean LAA CL »

FRACTIONATION

« Atrial EGM with continuous electrical activity »

GRADIENT

« Atrial EGM with significant offset between distal and proximal bipoles of the mapping catheter »



AF TERMINATION DURING ABLATION : 87%

SUBSEQUENT VALIDATION BY DIFFERENT TEAMS USING SIMILAR « SUBSTRATE-BASED » TARGETS

Active or passive pulmonary vein in atrial fibrillation: Is pulmonary vein isolation always essential?

Julien Seitz, MD,* Jérôme Horvilleur, MD,† Laurence Curel, MSc,* Jérôme Lacotte, MD,† Alexandre Maluski, MD,* Ange Ferracci, MD,* Michel Bremondy, MD,* Arnaud Rosier, MD,† Mehran Monchi, MD,† Guillaume Penaranda, MSc,* Jacques Faure, MD,* Sylvain Beurtheret, MD,* André Pisapia, MD, FHRS*

Heart Rhythm 2014;11:579–586

FUNDAMENTAL BASIS → CLINICAL DESCRIPTION → **PRACTICAL APPLICATION** → STRATEGY REFINEMENT

FIRING | **FRACTIONATION** | **GRADIENT**

Mean procedure and fluoroscopy duration times were 210 ± 60 min (range 90–420 minutes) and 21.3 ± 14.1 minutes (range 4–77 minutes), respectively. Mean RF time was 77.7 ± 29.8 minutes (range 17.3–164.1 minutes).

AF TERMINATION DURING ABLATION : 95%

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WHICH NEW CRITERIA WOULD ENSURE EFFICIENT SELECTION OF ACTIVE SIGNALS ?

L'INSTITUT DE RYTHMOLOGIE ET MODÉLISATION CARDIAQUE BORDEAUX

ARE ALL THESE SIGNALS ACTIVE ?

MAJOR INFLUENCE OF CYCLE LENGTH

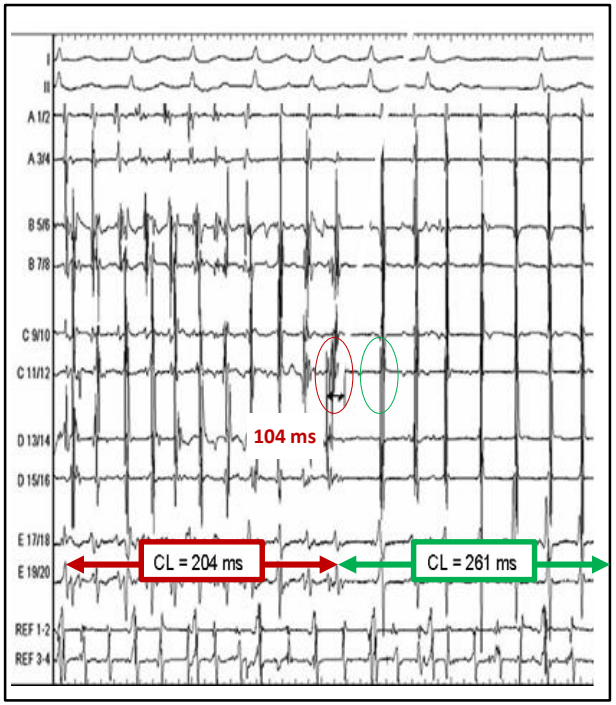
High-density activation mapping of fractionated electrograms in the atria of patients with paroxysmal atrial fibrillation

Thomas Rostock, MD,[a] Martin Rotter, MD,[a] Prashanthan Sanders, MBBS, PhD,[a] Yoshihide Takahashi, MD,[a] Pierre Jaïs, MD,[a] Mélèze Hocini, MD,[a] Li-Fern Hsu, MBBS,[a] Fréderic Sacher, MD,[a] Jacques Clémenty, MD,[a] Michel Haïssaguerre, MD[a]

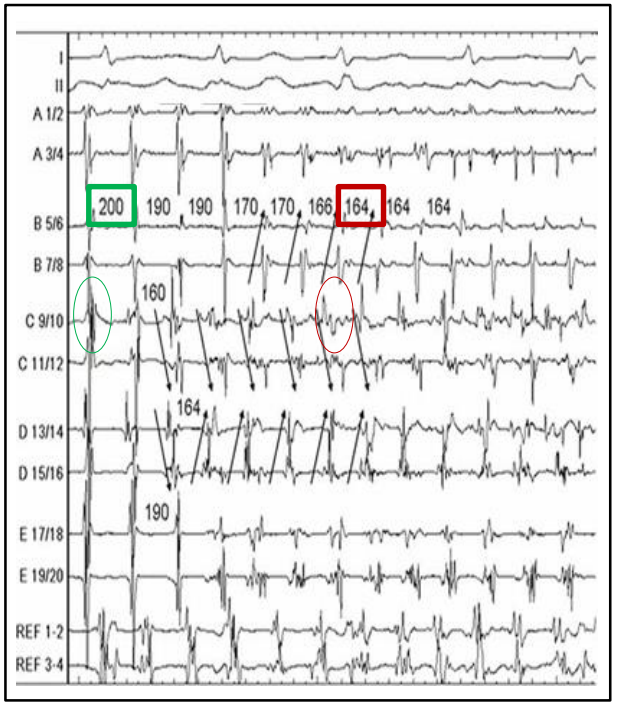
(Heart Rhythm 2006;3:27–34)

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | **STRATEGY REFINEMENT**

FRACTIONATED-EGM ARE DETERMINED BY AF-CYCLE LENGTH AND PARTLY ASSOCIATED WITH PASSIVE PHENOMENA



84% of fractionated-EGM occur nearly simultaneously in all splines, reflecting a passive activity.



16% of fractionated-EGM display a non-simultaneous activation compatible with underlying reentry

ARE ALL THESE SIGNALS ACTIVE ?

INFLUENCE OF WAVEFRONT DIRECTION

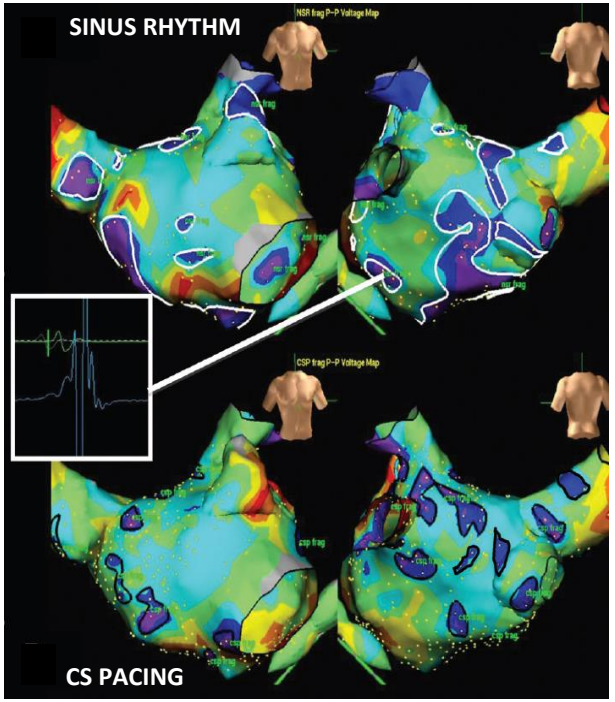
Functional Nature of Electrogram Fractionation Demonstrated by Left Atrial High-Density Mapping

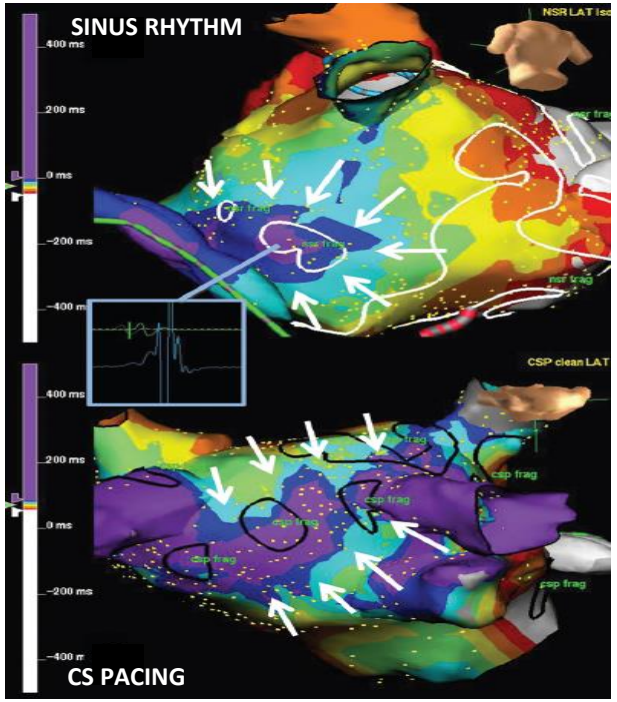
Amir S. Jadidi, MD; Edward Duncan, PhD; Shinsuke Miyazaki, MD; Nicolas Lellouche, MD; Ashok J. Shah, MD; Andrei Forclaz, MD; Isabelle Nault, MD, FRCPC; Matthew Wright, MBBS, PhD; Lena Rivard, MD; Xingpeng Liu, MD; Daniel Scherr, MD; Stephen B. Wilton, MD; Frédéric Sacher, MD; Nicolas Derval, MD; Sebastien Knecht, MD; Steven J. Kim, MSEE; Mélèze Hocini, MD; Sanjiv Narayan, MD; Michel Haïssaguerre, MD; Pierre Jaïs, MD

(*Circ Arrhythm Electrophysiol*. 2012;5:32-42.)

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | **STRATEGY REFINEMENT**

FRACTIONATED-EGM DISTRIBUTION HIGHLY DEPENDS ON WAVEFRONT DIRECTION AND MOSTLY RESULTS FROM WAVES COLLISION





Fractionated-EGM location did not match between SR and CS pacing at 70 ± 10 % of the sites

Activation maps in SR and CS pacing showed that wave collision caused 71% of fractionated-EGM

ARE ALL THESE SIGNALS ACTIVE ?

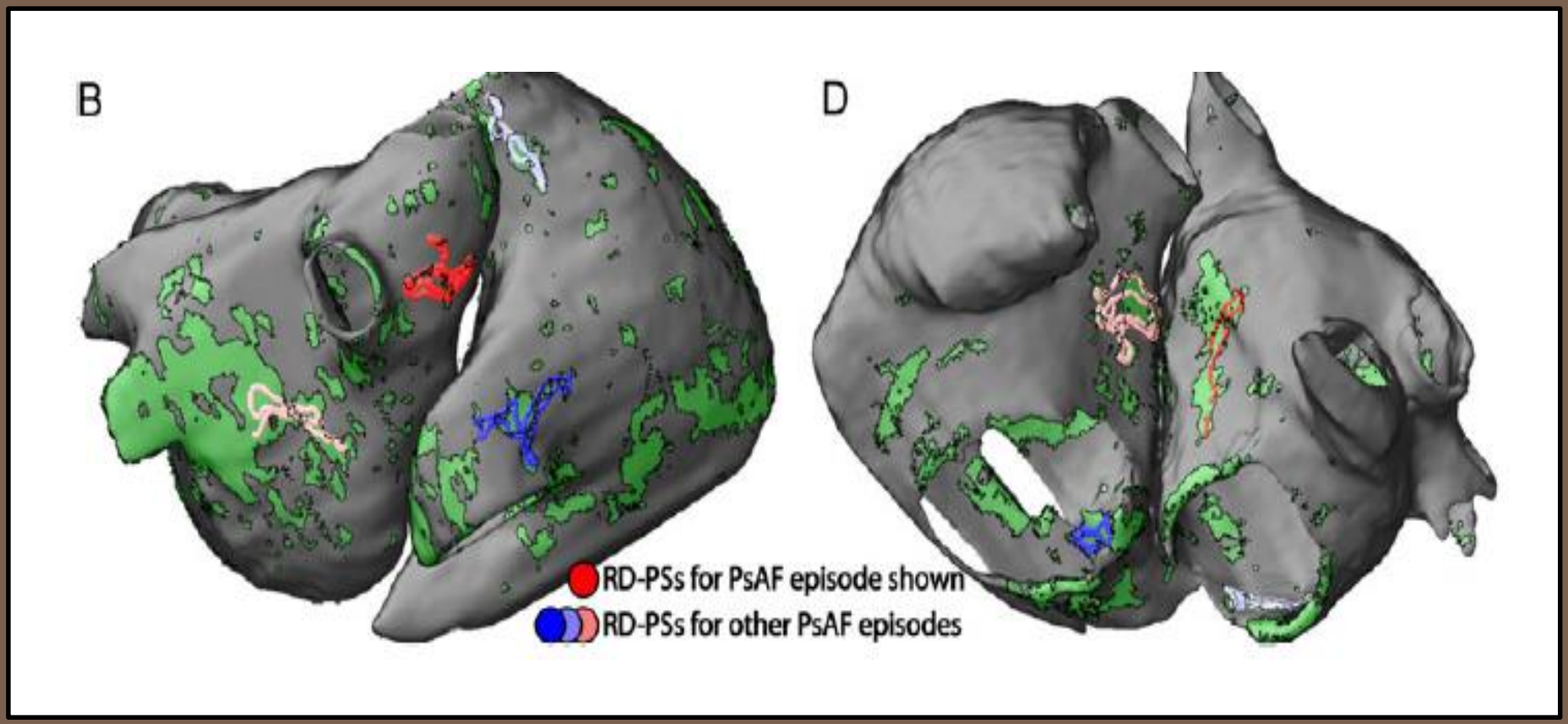
INFLUENCE OF TISSUE CHARACTERISTICS

Patient-derived models link re-entrant driver localization in atrial fibrillation to fibrosis spatial pattern

Sohail Zahid[1†], Hubert Cochet[2,3†], Patrick M. Boyle[1†], Erica L. Schwarz[1], Kaitlyn N. Whyte[1], Edward J. Vigmond[2], Rémi Dubois[2], Mélèze Hocini[2,3], Michel Haïssaguerre[2,3], Pierre Jaïs[2,3], and Natalia A. Trayanova[1,4*]

Cardiovascular Research (2016) **110**, 443–454

FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | **STRATEGY REFINEMENT**



NEW REFINED APPROACHES FOR SUBSTRATE ABLATION

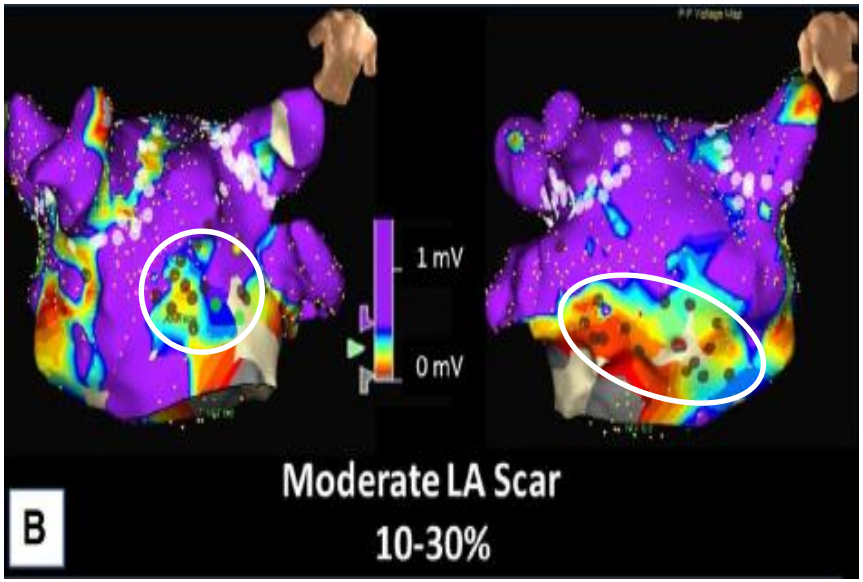
FOCUSED ON LOW-VOLTAGED AREAS

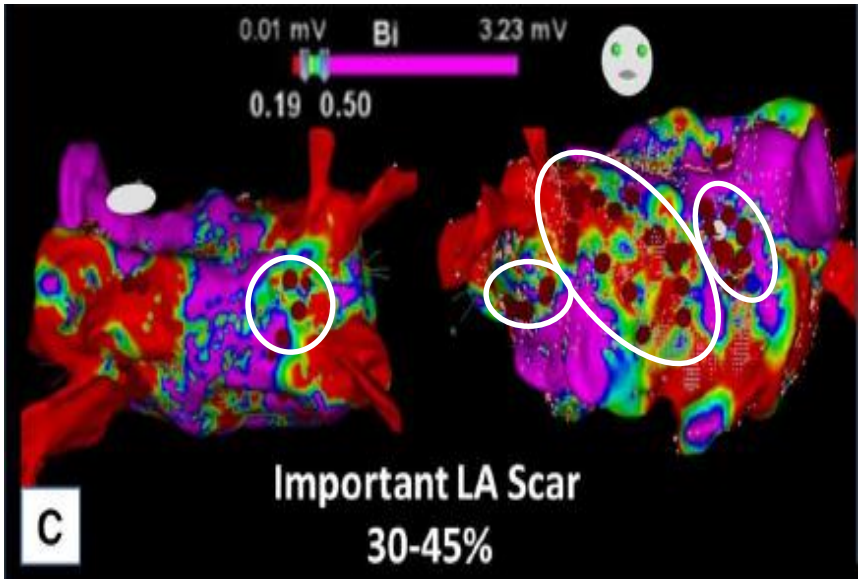
Ablation of Persistent Atrial Fibrillation Targeting Low-Voltage Areas With Selective Activation Characteristics

Amir S. Jadidi, MD; Heiko Lehrmann, MD; Cornelius Keyl, MD; Jérémie Sorrel, MD; Viktor Markstein, BSc; Jan Minners, MD; Chan-Il Park, MD; Arnaud Denis, MD; Pierre Jaïs, MD; Mélèze Hocini, MD; Clemens Potocnik, MD; Juergen Allgeier, MD; Willibald Hochholzer, MD; Claudia Herrera-Sidloky, MD; Steve Kim, MSEE; Youssef El Omri, MD; Franz-Josef Neumann, MD; Reinhold Weber, MD; Michel Haïssaguerre, MD; Thomas Arentz, MD

(*Circ Arrhythm Electrophysiol*. 2016;9:e002962. DOI: 10.1161/CIRCEP.115.002962.)

FUNDAMENTAL BASIS → CLINICAL DESCRIPTION → PRACTICAL APPLICATION → **STRATEGY REFINEMENT**





CUT-OFF VALUE < 0,5 mV

NEW REFINED APPROACHES FOR SUBSTRATE ABLATION

FOCUSED ON DISPERSION AREAS

AF Ablation Guided by Spatiotemporal Electrogram Dispersion Without Pulmonary Vein Isolation

A Wholly Patient-Tailored Approach

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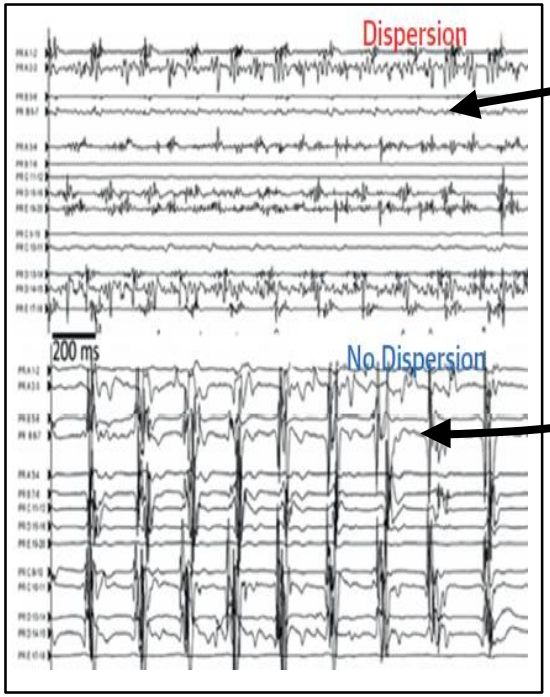
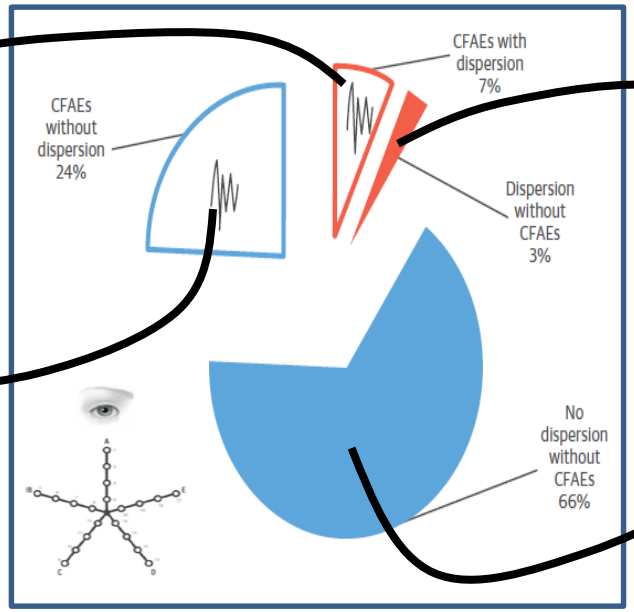
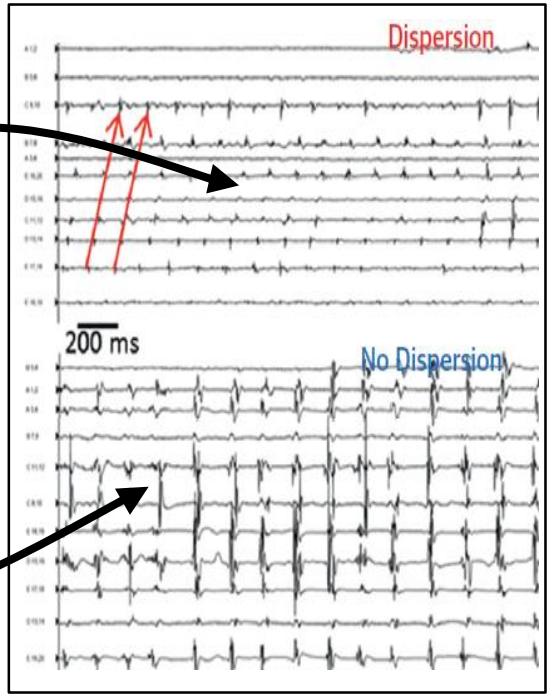
FUNDAMENTAL BASIS | CLINICAL DESCRIPTION | PRACTICAL APPLICATION | **STRATEGY REFINEMENT**







C·H·U
Hôpitaux de Bordeaux

L'INSTITUT DE RYTHMOLOGIE
ET MODÉLISATION CARDIAQUE
BORDEAUX

THANK YOU