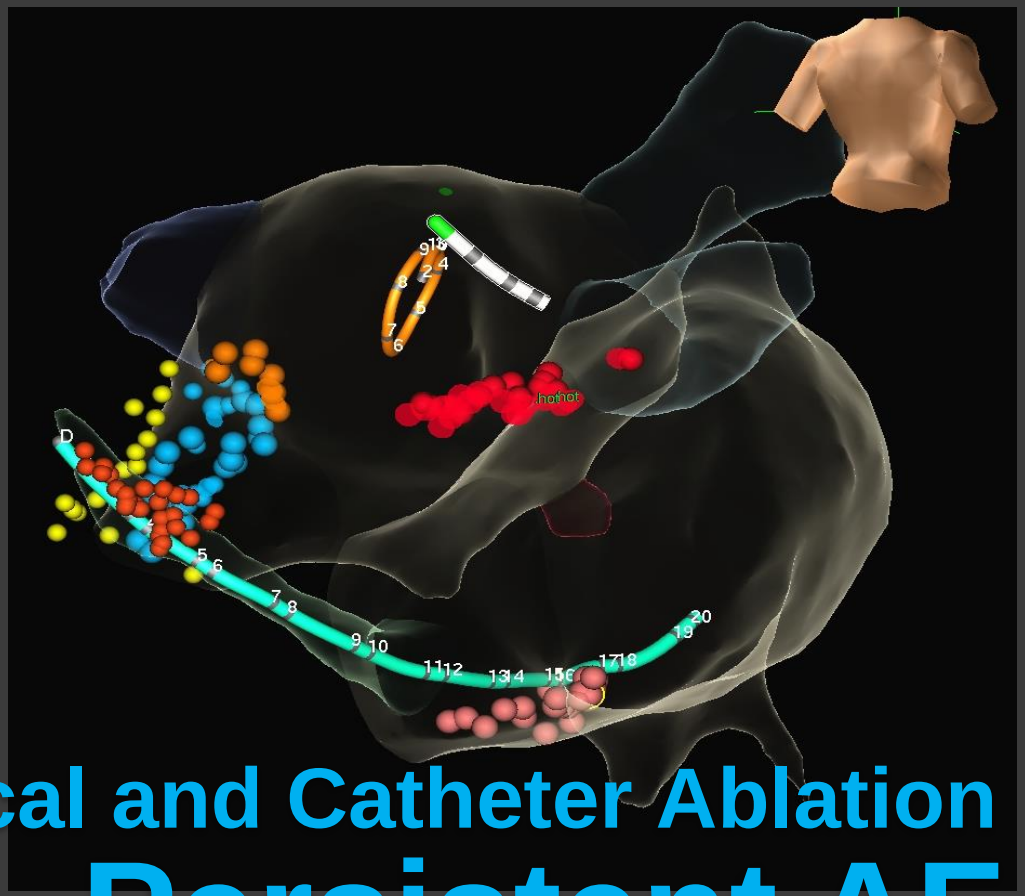


Hybrid Surgical and Catheter Ablation For Persistent AF

L. Bing Liem, DO FHRS FACC FACOI
Professor of Medicine, University of California San Francisco

Disclosure

AtriCure – consultant

TABLE 4 Definitions of AF: A Simplified Scheme

Term	Definition
Paroxysmal AF	• AF that terminates spontaneously or with intervention within 7 d of onset. • Episodes may recur with variable frequency.
Persistent AF	• Continuous AF that is sustained >7 d.
Long-standing persistent AF	• Continuous AF >12 mo in duration.
Permanent AF	• The term "permanent AF" is used when the patient and clinician make a joint decision to stop further attempts to restore and/or maintain sinus rhythm. • Acceptance of AF represents a therapeutic attitude on the part of the patient and clinician rather than an inherent pathophysiological attribute of AF. • Acceptance of AF may change as symptoms, efficacy of therapeutic interventions, and patient and clinician preferences evolve.
Nonvalvular AF	• AF in the absence of rheumatic mitral stenosis, a mechanical or bioprosthetic heart valve, or mitral valve repair.

AF indicates atrial fibrillation.

General Considerations

- Increases in prevalence with age
- Mechanisms causing and sustaining AF are multifactorial
- Symptoms are broad and non-specific
- AF causes frequent hospitalization
- AF causes hemodynamic abnormality
- AF causes stroke
- AF causes dementia
- AF is expensive

General Considerations

- Increases in prevalence with age
  - 1% of AF pts are < 60, 12% 75-84, >50% over 80 years old
  - In European descent, 26% (m) and 23% (w) have AF risk > 40 y/o
  - Less in African and Asian descent (despite higher risk factors)
- Mechanisms causing and sustaining AF are multifactorial
- Symptoms are broad and non-specific
- AF causes frequent hospitalization
- AF causes hemodynamic abnormality
- AF causes stroke
- AF causes dementia
- AF is expensive

General Considerations

- Increases in prevalence with age
- Multifactorial mechanisms causing & sustaining AF
  - Associated comorbidities
  - AF Risk factors
- Symptoms are broad and non-specific
- AF causes frequent hospitalization
- AF causes hemodynamic abnormality
- AF causes stroke
- AF causes dementia
- AF is expensive

TABLE 5 Selected Risk Factors and Biomarkers for AF

Clinical Risk Factors	References
Increasing age	(139)
Hypertension	(139)
Diabetes mellitus	(139)
MI	(139)
VHD	(139)
HF	(38,139)
Obesity	(140–142)
Obstructive sleep apnea	(142)
Cardiothoracic surgery	(137)
Smoking	(143)
Exercise	(144–146)
Alcohol use	(147–149)
Hyperthyroidism	(150–152)
Increased pulse pressure	(153)
European ancestry	(154)
Family history	(155)
Genetic variants	(156–159)
ECG	
LVH	(35)
Echocardiographic	
LA enlargement	(35,160)
Decreased LV fractional shortening	(35)
Increased LV wall thickness	(35)
Biomarkers	
Increased CRP	(86,161)
Increased BNP	(162,163)

AF indicates atrial fibrillation; BNP, B-type natriuretic peptide; CRP, C-reactive protein; ECG, electrocardiographic; HF, heart failure; LA, left atrial; LV, left ventricular; LVH, left ventricular hypertrophy; MI, myocardial infarction; and VHD, valvular heart disease.

TABLE 5 **Selected Risk Factors and Biomarkers for AF**

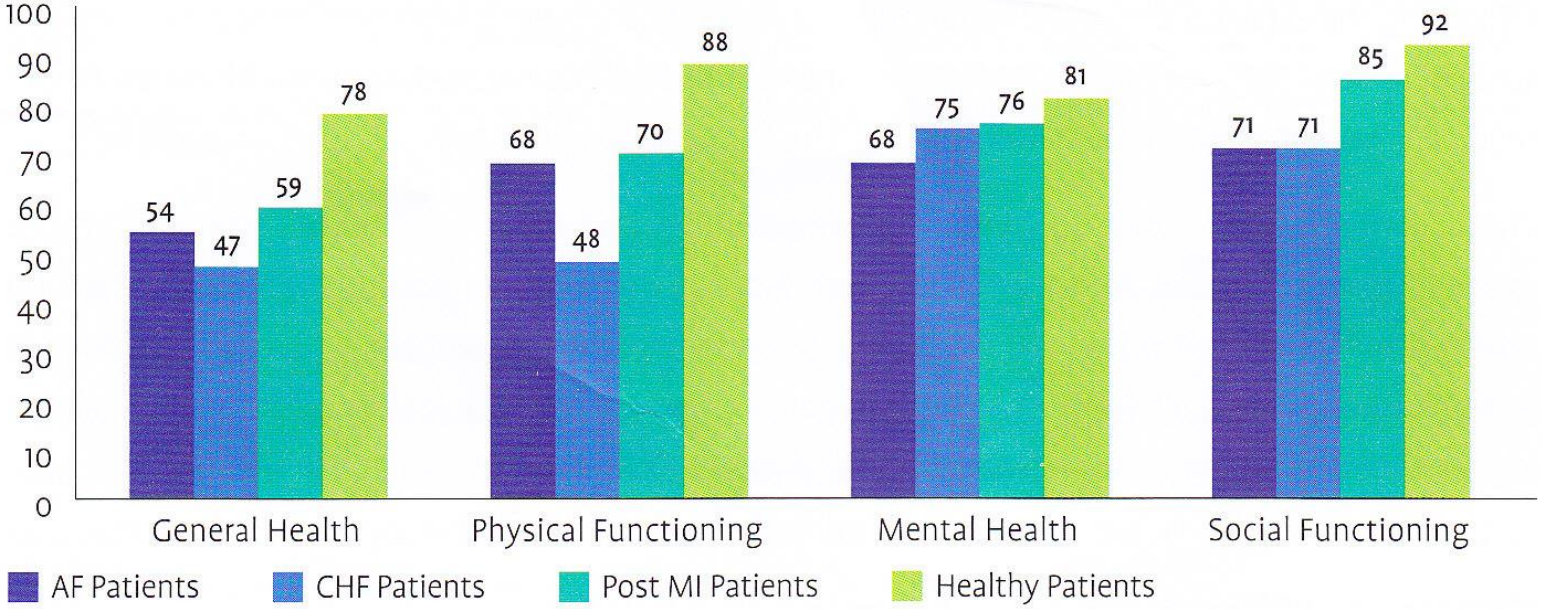
Clinical Risk Factors	References
Increasing age	(139)
Hypertension	(139)
Diabetes mellitus	(139)
MI	(139)
VHD	(139)
HF	(38,139)
Obesity	(140–142)
Obstructive sleep apnea	(142)

General Considerations

- Increases in prevalence with age
- Mechanisms causing and sustaining AF are multifactorial
- Symptoms are broad and non-specific
  - None
  - Palpitations
  - Dyspnea, DOE
  - Fatigue
  - Presyncope and syncope
- AF causes frequent hospitalization
- AF causes hemodynamic abnormality
- AF causes stroke
- AF causes dementia
- AF is expensive

FIGURE 7: AFIB REDUCES PATIENTS' QUALITY OF LIFE

Quality of Life Scores for AFib Patients Compared to Patients with Other Cardiovascular Conditions and Control Group



Dorian P, Werner J, Newman D, et al. "The impairment of health-related quality of life patients with intermittent atrial fibrillation: implications for the assessment of investigational therapy." Journal of the American College of Cardiology. 36 (2000) No. 4.
AFib = atrial fibrillation; CHF = congestive heart failure; Post MI = post myocardial infarction

General Considerations

- Increases in prevalence with age
- Mechanisms causing and sustaining AF are multifactorial
- Symptoms are broad and non-specific
- AF causes frequent hospitalization
  - 476,000 hospitalizations annually in the US
  - Patients with AF are hospitalized 2x more than those without AF
  - Patients with AF are 3x more likely to have multiple hospitalizations
  - 2.1% AF patients (compared to 0.1% without) died in the hospital
- AF causes hemodynamic abnormality
- AF causes stroke
- AF causes dementia
- AF is expensive

General Considerations

- Increases in prevalence with age
- Mechanisms causing and sustaining AF are multifactorial
- Symptoms are broad and non-specific
- AF causes frequent hospitalization
- AF causes hemodynamic abnormality
  - Uncoordinated atrial contraction and variability in ventricular filling
  - Sub-optimal ventricular rate (too slow or too fast)
  - Sympathetic activation
  - Exacerbates or causes heart failure
    - Tachycardia-induced cardiomyopathy
    - AF-induced cardiomyopathy
    - 3-fold risk increase in HF
- AF causes stroke
- AF causes dementia
- AF is expensive

General Considerations

- Increases in prevalence with age
- Mechanisms causing and sustaining AF are multifactorial
- Symptoms are broad and non-specific
- AF causes frequent hospitalization
- AF causes hemodynamic abnormality
- AF causes stroke
  - 5x increase in stroke risk
  - Stroke risk increases with age
  - AF-related stroke is more severe than non AF-related stroke
- AF causes dementia
- AF is expensive

General Considerations

- Increases in prevalence with age
- Mechanisms causing and sustaining AF are multifactorial
- Symptoms are broad and non-specific
- AF causes frequent hospitalization
- AF causes hemodynamic abnormality
- AF causes stroke
- AF causes dementia
  - 2-fold increased risk in dementia and mortality
- AF is expensive

Atrial fibrillation and cognitive decline in the Framingham Heart Study

Arvind Nishtala, MD, MPH,[*] Ryan J. Piers, MA,[†‡§] Jayandra J. Himali, PhD,[‡§‖] Alexa S. Beiser, PhD,[‡§‖] Kendra L. Davis-Plourde, MA,[§‖] Jane S. Saczynski, PhD,[¶] David D. McManus, MD,[¶] Emelia J. Benjamin, MD, ScM,[§#**] Rhoda Au, PhD[‡§**††]

*From the *Department of Medicine, University of California, San Francisco, California, †Department of Psychological and Brain Sciences, Boston University, Boston, Massachusetts, ‡Department of Neurology, Boston University School of Medicine, Boston, Massachusetts, §The Framingham Heart Study, Framingham, Massachusetts, ‖Department of Biostatistics, Boston University School of Public Health, Boston, Massachusetts, ¶Department of Medicine, University of Massachusetts, Worcester, Massachusetts, #Department of Medicine, Boston University School of Public Health, Boston, Massachusetts, **Department of Anatomy & Neurobiology, Boston University School of Public Health, Boston, Massachusetts, and ††Department of Epidemiology, Boston University School of Public Health, Boston, Massachusetts.*

BACKGROUND There is a paucity of longitudinal research investigating the relations between atrial fibrillation (AF) and domain-specific cognitive performance.

OBJECTIVE The purpose of this study was to investigate the association between AF and cognitive performance cross-sectionally and longitudinally.

METHODS Eligible participants were dementia- and stroke-free at the time of baseline neuropsychological (NP) assessment and underwent at least 1 additional NP assessment with at least 1-year inter-test interval. AF status was examined as a 2-level variable (prevalent AF, no AF) in cross-sectional analyses and then separately as a 3-level variable (prevalent AF, interim AF, no AF) in longitudinal analyses. We examined the association between AF status and cognitive performance with linear regression. We first adjusted models for age and sex and then for vascular risk factors and apolipoprotein ε4 (*APOE4*) status.

RESULTS We studied 2682 participants of the Framingham Heart Study original and offspring cohorts. At the baseline NP assessment, 112 participants (4%) had AF (mean age 72 ± 9 years; 32% women). After adjustment for vascular risk factors and *APOE4* status, prevalent AF was significantly associated with poorer attention; sex differences were also noted with men performing worse on tests of abstract reasoning and executive function, while women did better on a measure of executive function. Prevalent AF was significantly associated with longitudinal decline in executive function in the original cohort, and interim AF was significantly associated with longitudinal decline in executive function in the offspring cohort.

CONCLUSION After accounting for vascular risk factor burden and *APOE4* status, AF was associated with a vascular profile of change in cognitive function.

KEYWORDS Atrial fibrillation; Neuropsychological assessment; Cognition; Cognitive decline; Framingham Heart Study

(Heart Rhythm 2018;15:166–172)

Table 1 Description of neuropsychological tests

Test	Description	Cognitive domain
Visual Reproduction Immediate and Delayed Recall	Participants are shown a drawing for 10 s and asked to draw them from memory and then asked to draw them again after a time delay	Visual memory
Similarities	Participants are asked how a list of paired items are alike	Abstract reasoning
Hooper Visual Organization Test	Participants are asked to recognize pictures of objects that have been cut and rearranged	Visuoperceptual organization
Trail Making Test A	As quickly as possible, participants are asked to draw a line connecting numbers that are randomly placed on a page in sequence	Attention
Trail Making Test B	As quickly as possible, participants are asked to draw a line alternating between numbers and letters that are randomly placed on a page in sequence	Executive function

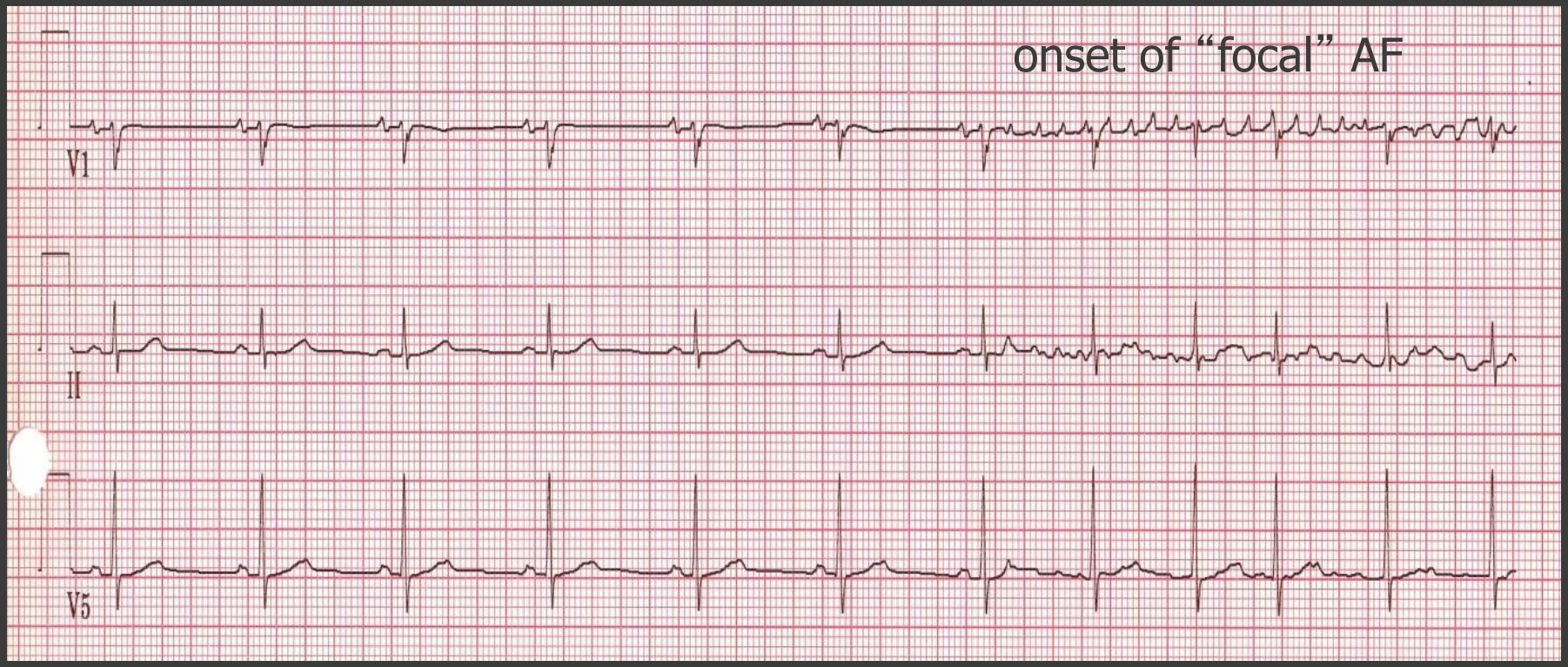
General Considerations

- Increases in prevalence with age
- Mechanisms causing and sustaining AF are multifactorial
- Symptoms are broad and non-specific
- AF causes frequent hospitalization
- AF causes hemodynamic abnormality
- AF causes stroke
- AF causes dementia
- AF is expensive
  - Additional $ 8700 per year for AF patients
  - Additional 26 billion dollars annually in the US
  - Total AF patients will double in the next 25 years

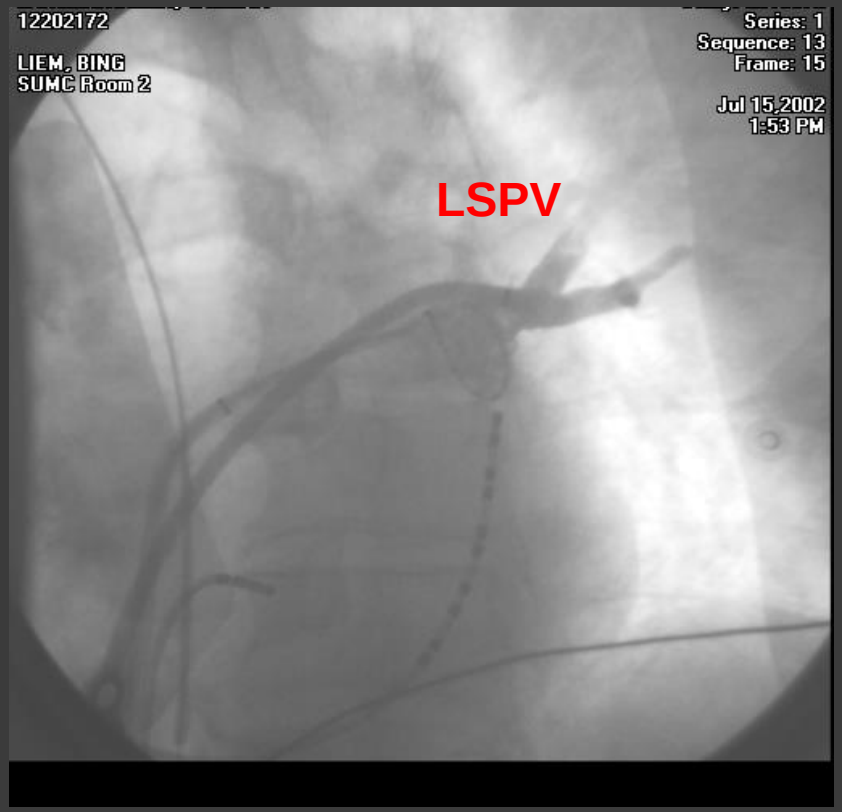
STRATEGY FOR AF ABLATION

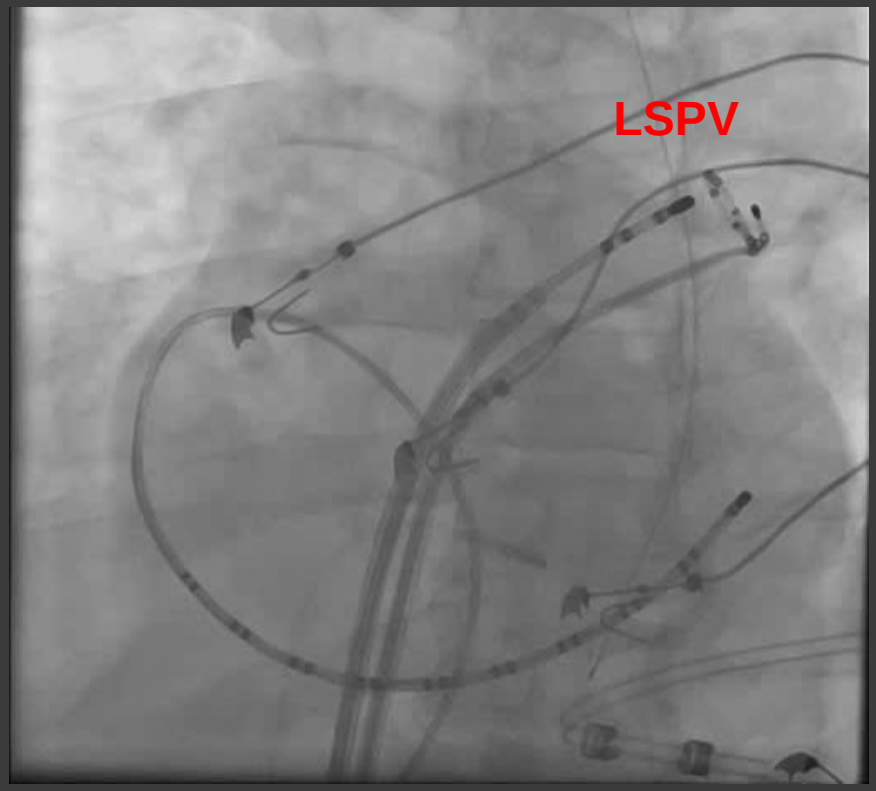
- Paroxysmal AF
  - AF can be initiated but not sustained
  - initiation of AF is 90-95% from PV
- Persistent AF
  - once AF is initiated, it will be sustained
  - AF is sustained (predominantly) by the LA posterior wall
  - AF perpetuation mechanism is re-entry but encompassing a broad area of pathological and functional block and slow conduction

- Origin of Paroxysmal AF
  - “Focal” AF

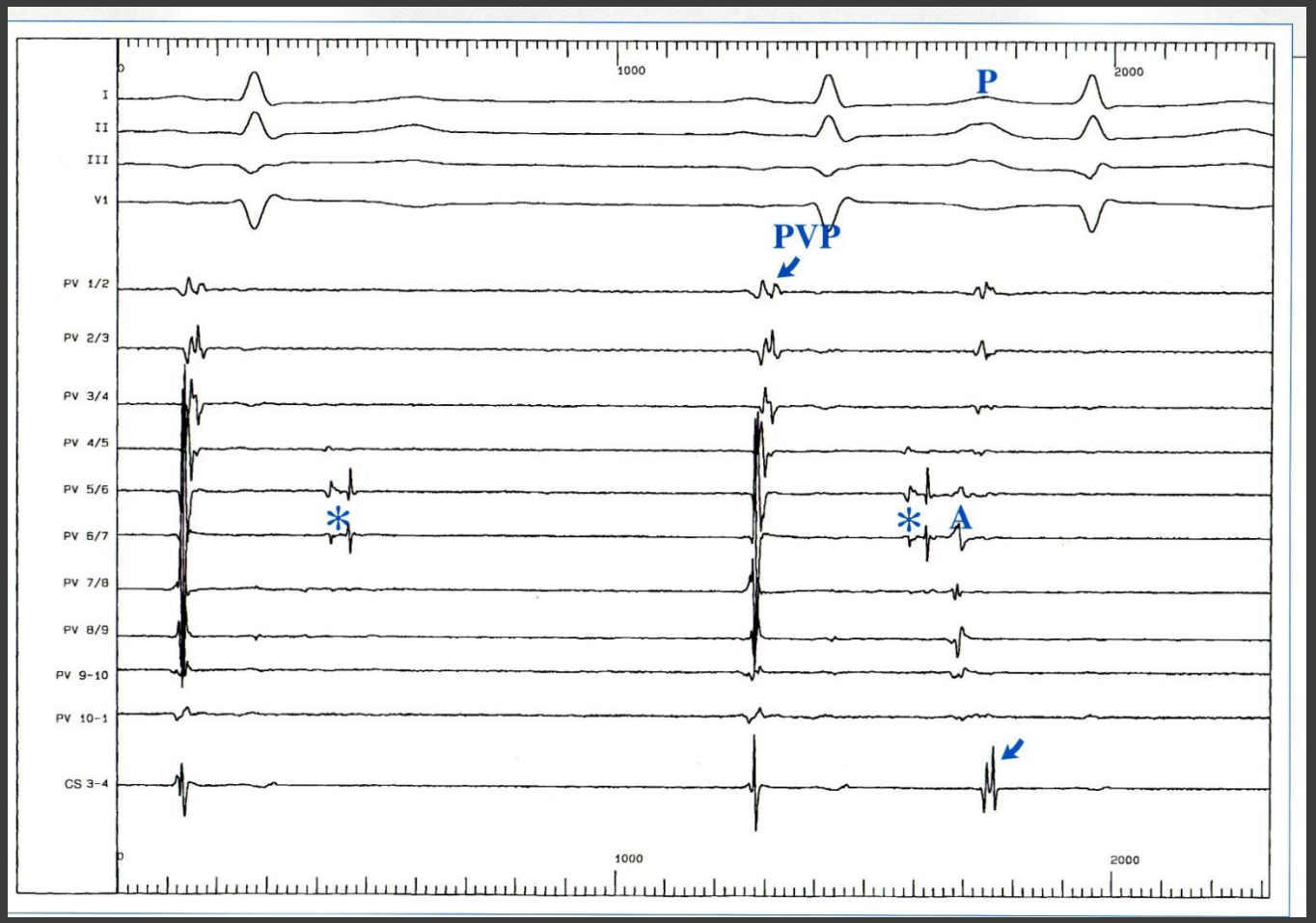


- Ablation of Paroxysmal AF
  - “Focal” AF

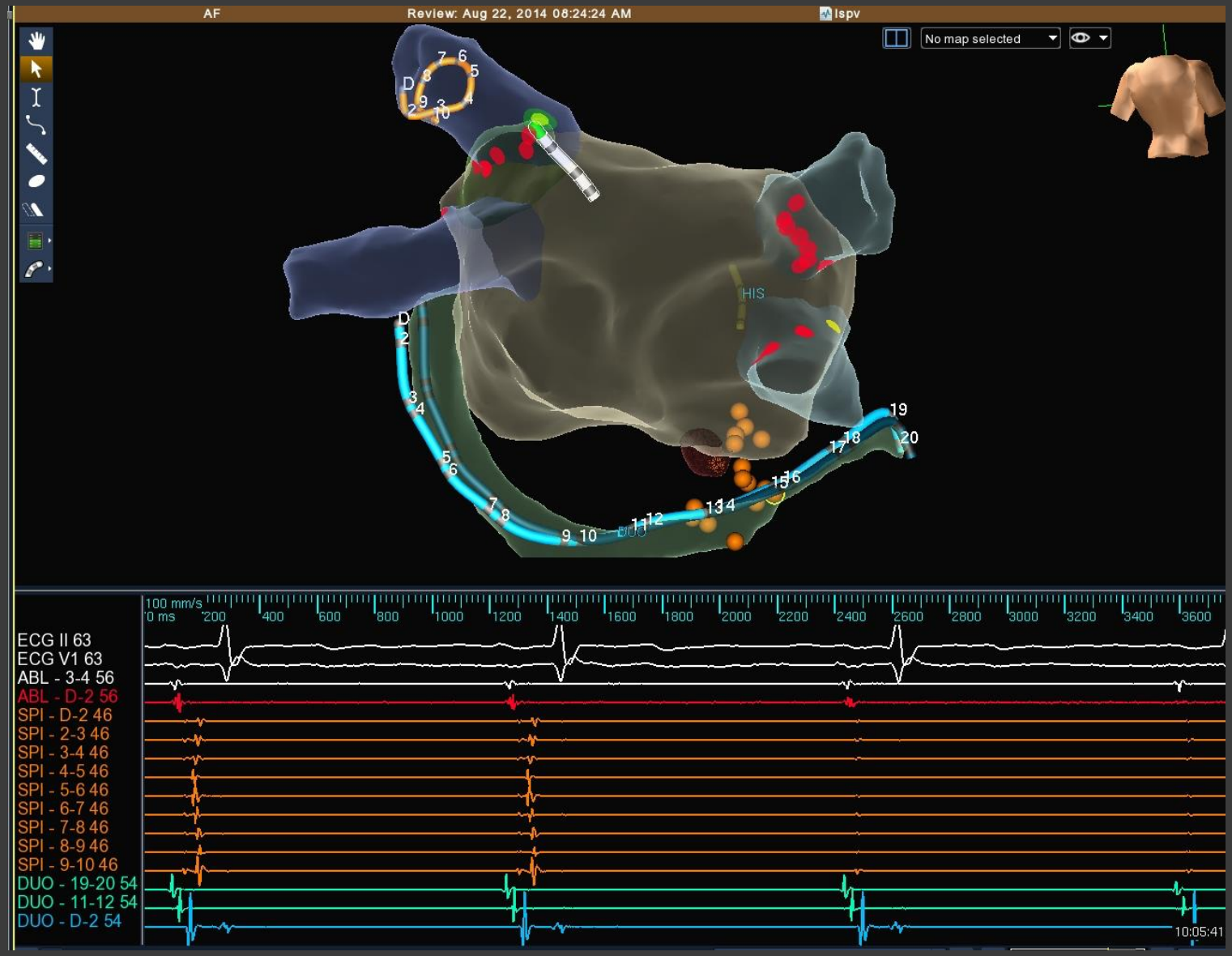




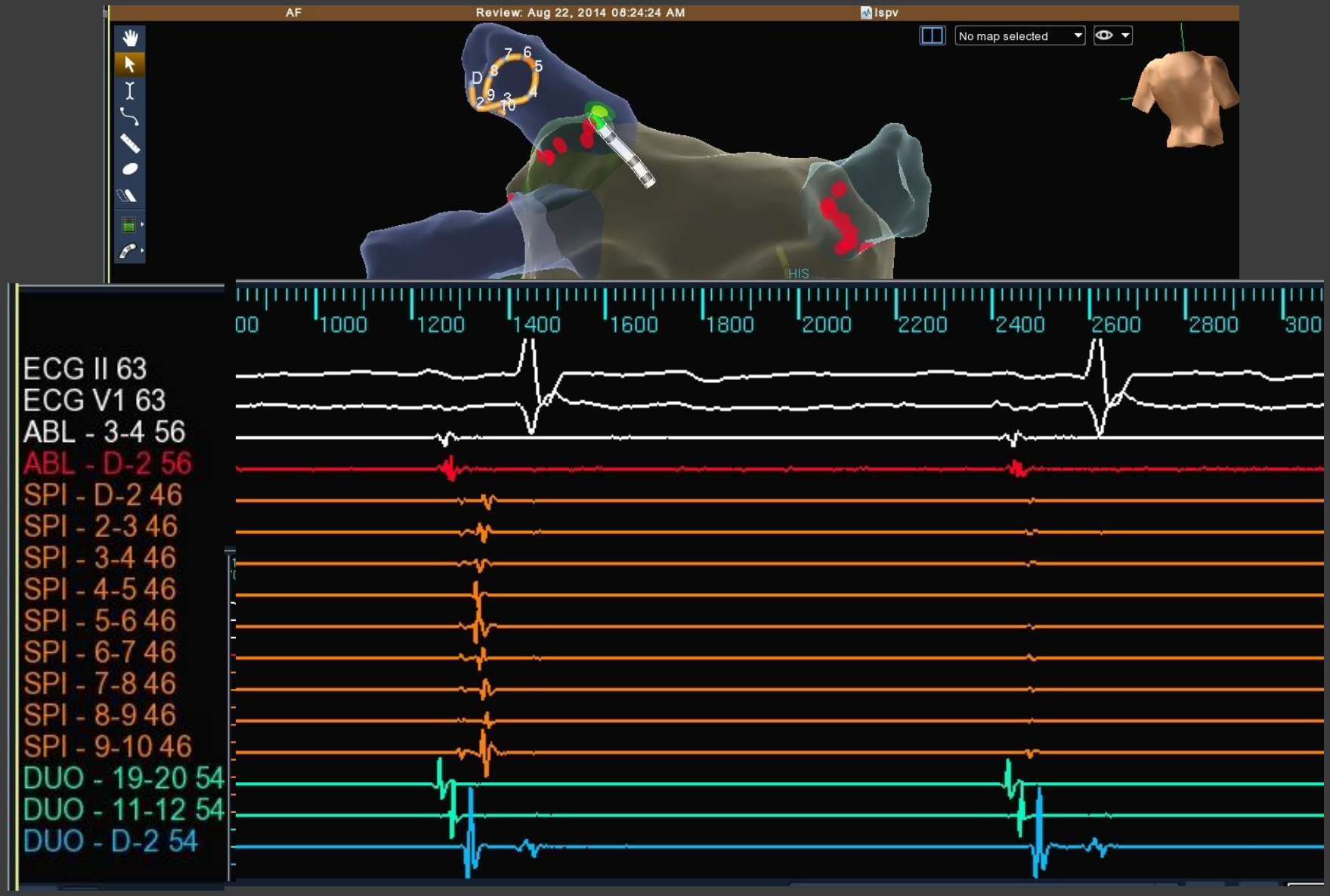
- Origin of Paroxysmal AF
  - Origin of PACs



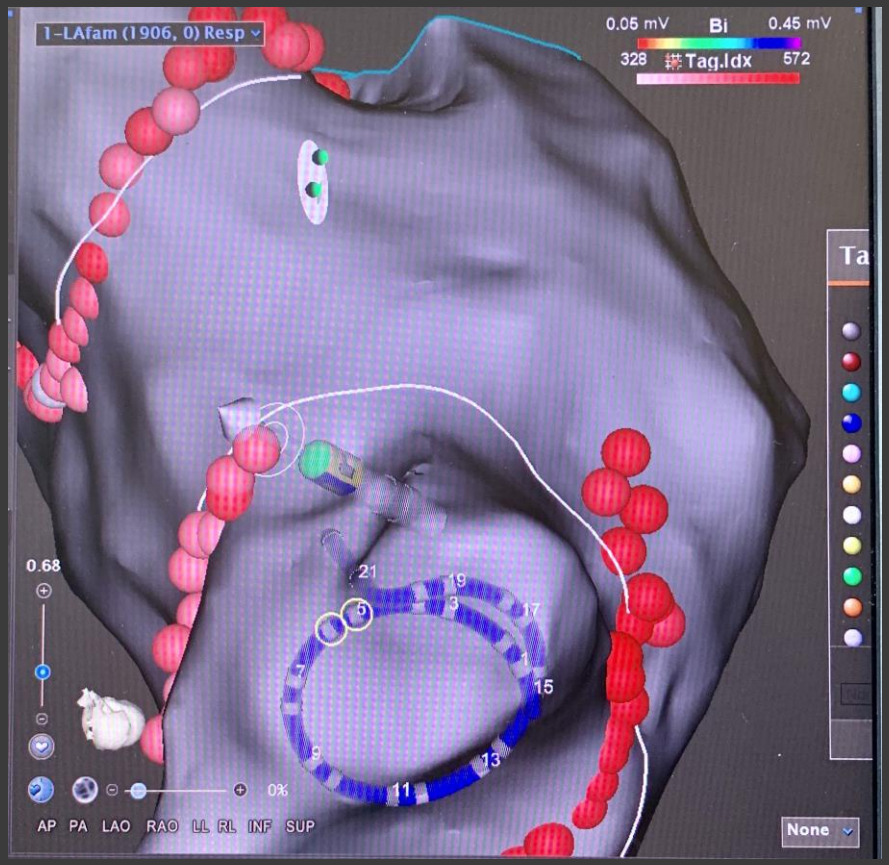
Ostial PV approach
Segmental or circumferential

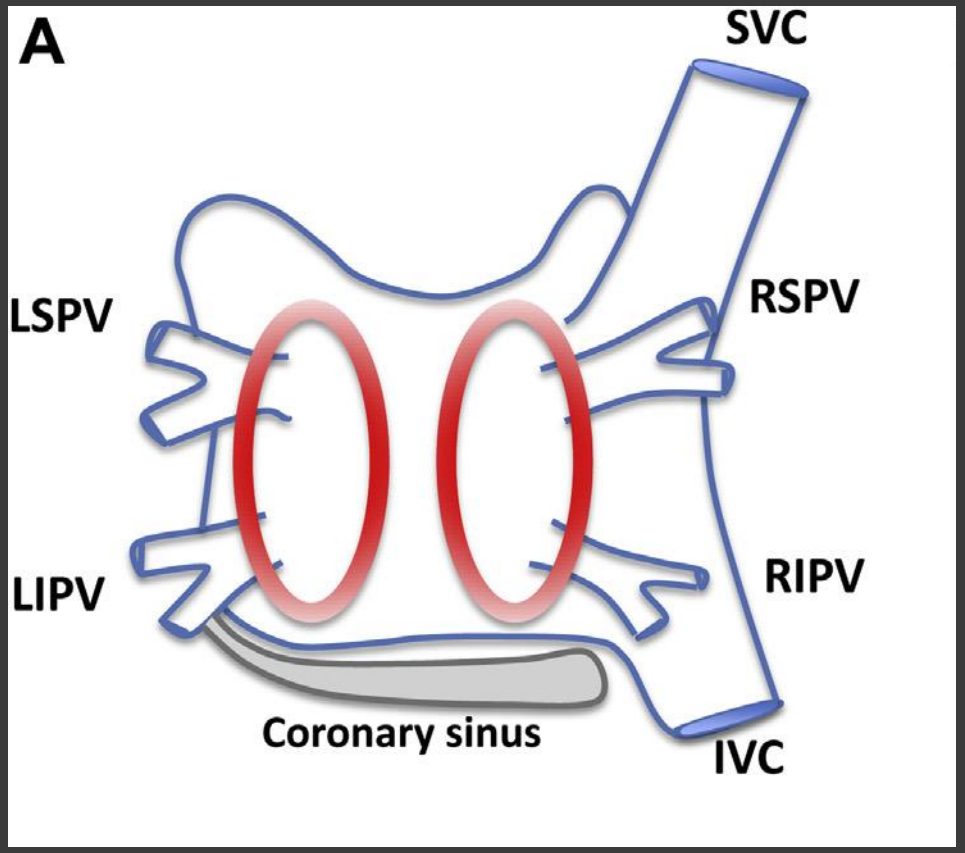


Ostial PV approach
Segmental or circumferential



WACA
Wide Antral Circumferential ablation



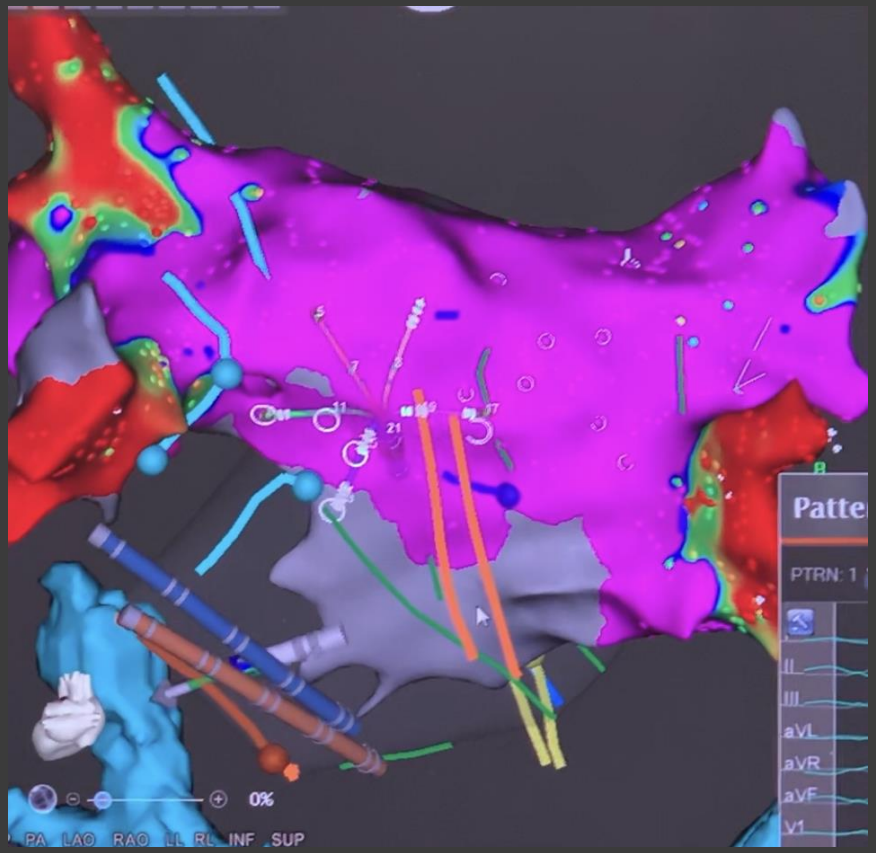


STRATEGY FOR AF ABLATION

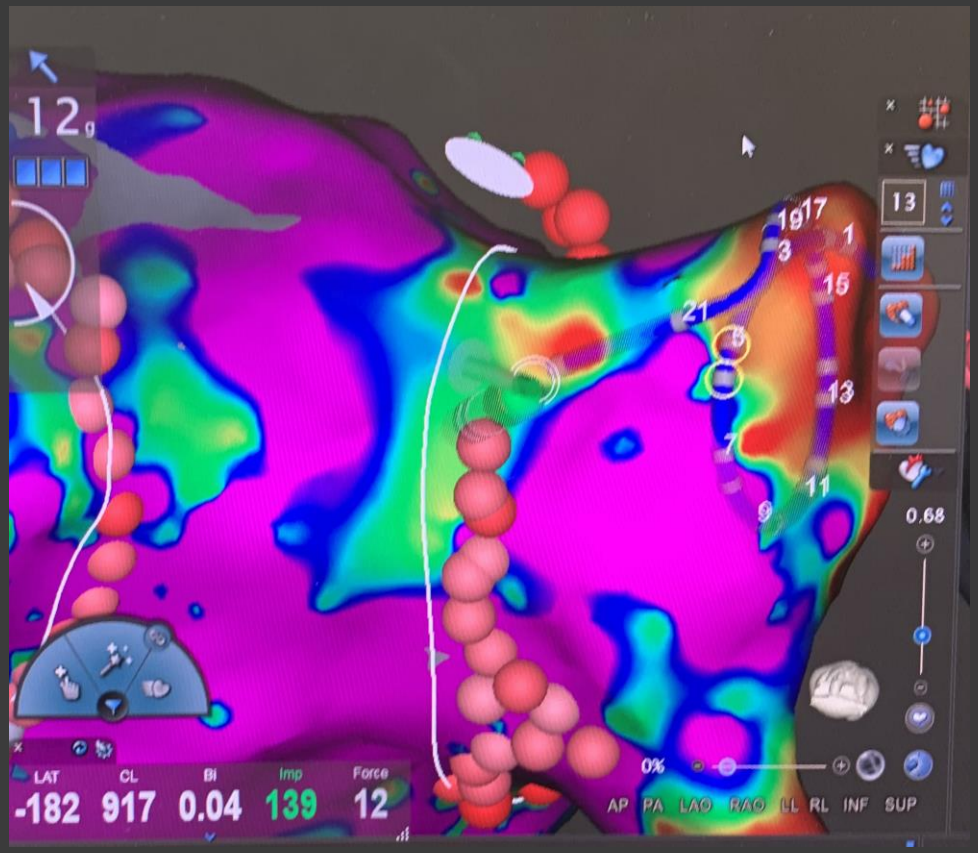
- Paroxysmal AF
  - AF can be initiated but not sustained
  - initiation of AF is 90-95% from PV
- Persistent AF
  - once AF is initiated, it will be sustained
  - AF is sustained (predominantly) by the LA posterior wall
  - AF perpetuation mechanism is re-entry but encompassing a broad area of pathological and functional block and slow conduction

STRATEGY FOR AF ABLATION

Voltage mapping



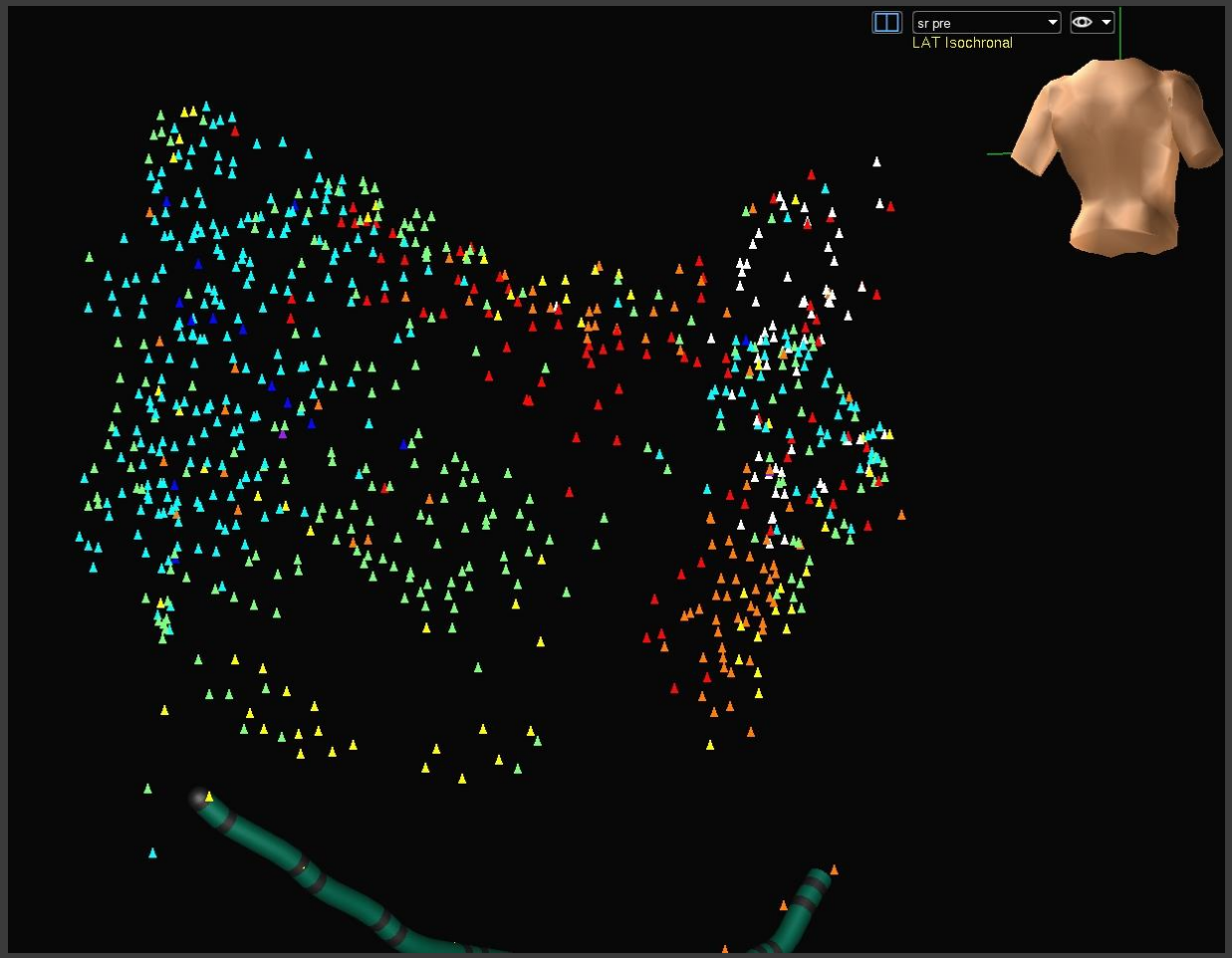
Paroxysmal AF



Early Persistent AF

STRATEGY FOR AF ABLATION

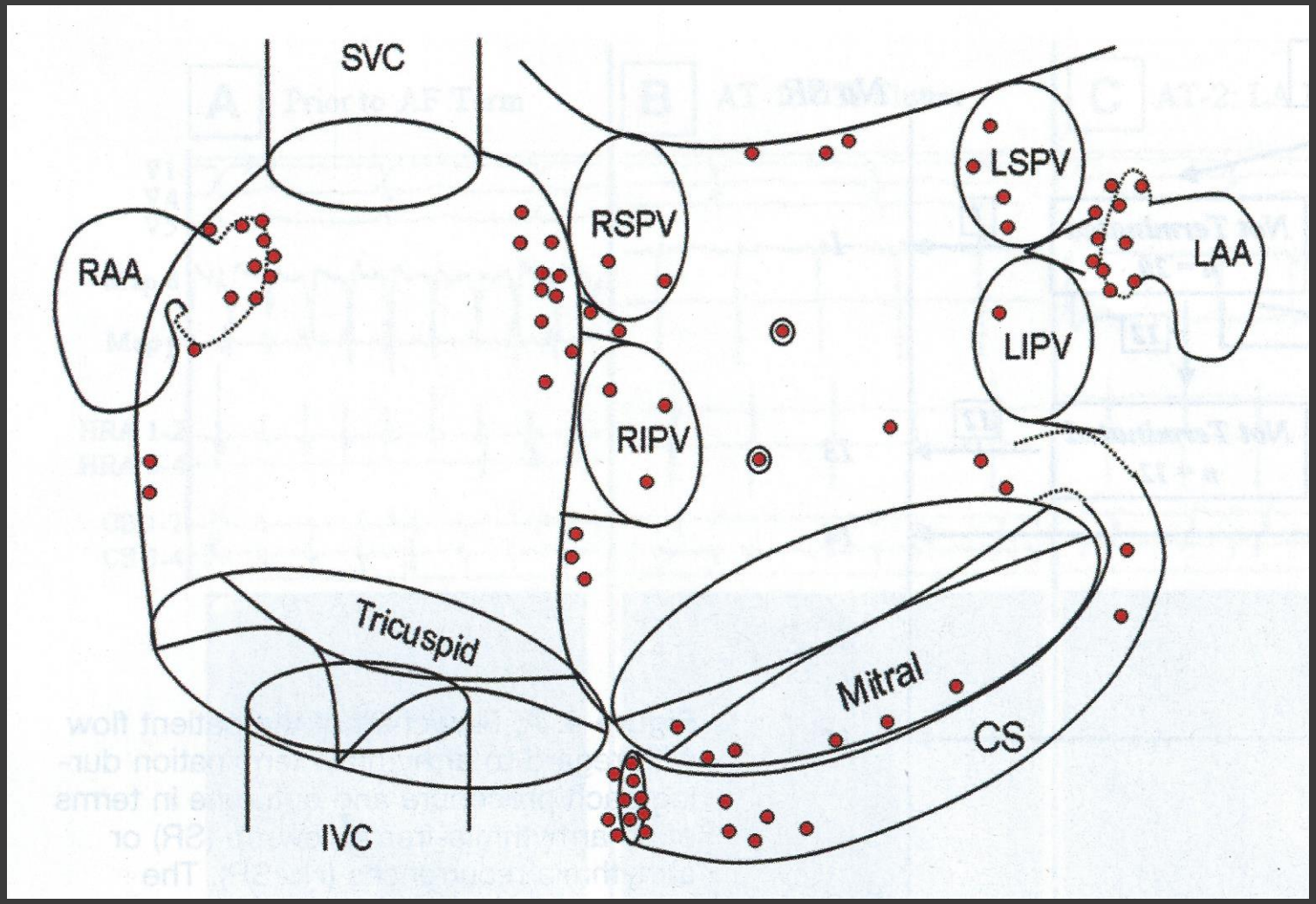
Voltage mapping



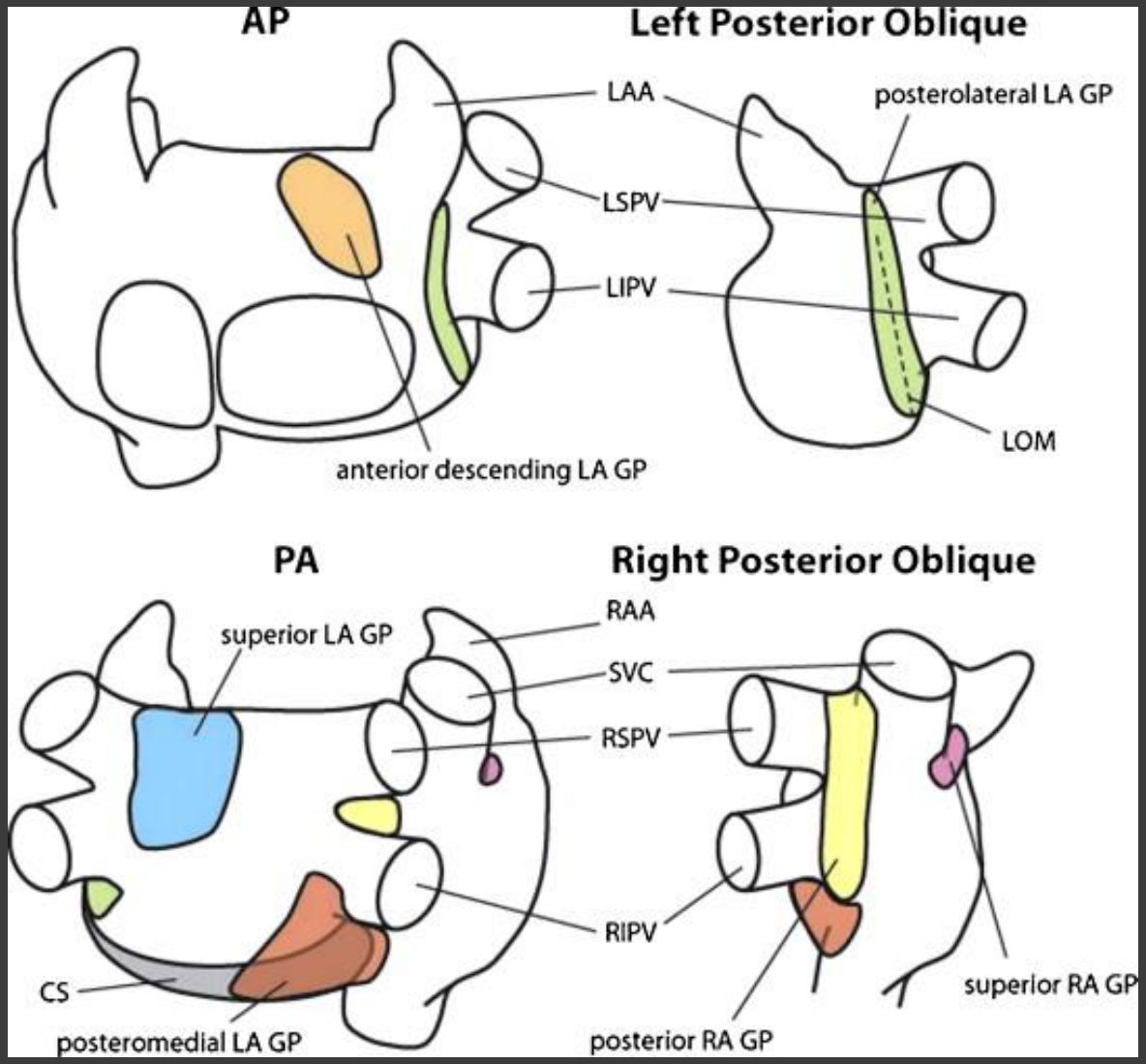
Persistent AF - Substrate Ablation - CFAE

Journal of Cardiology 2010 55, 1-12DOI: (10.1016/j.jjcc.2009.11.002)

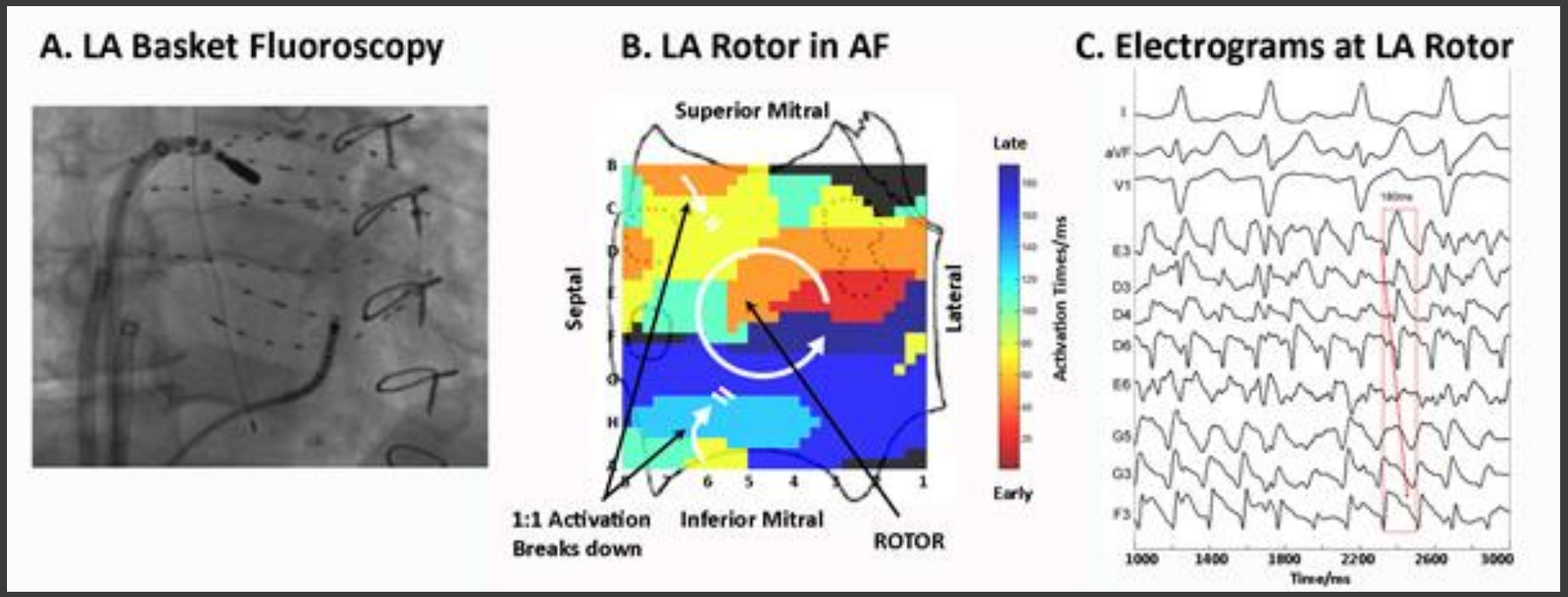
Persistent AF - Substrate Ablation - CFAE



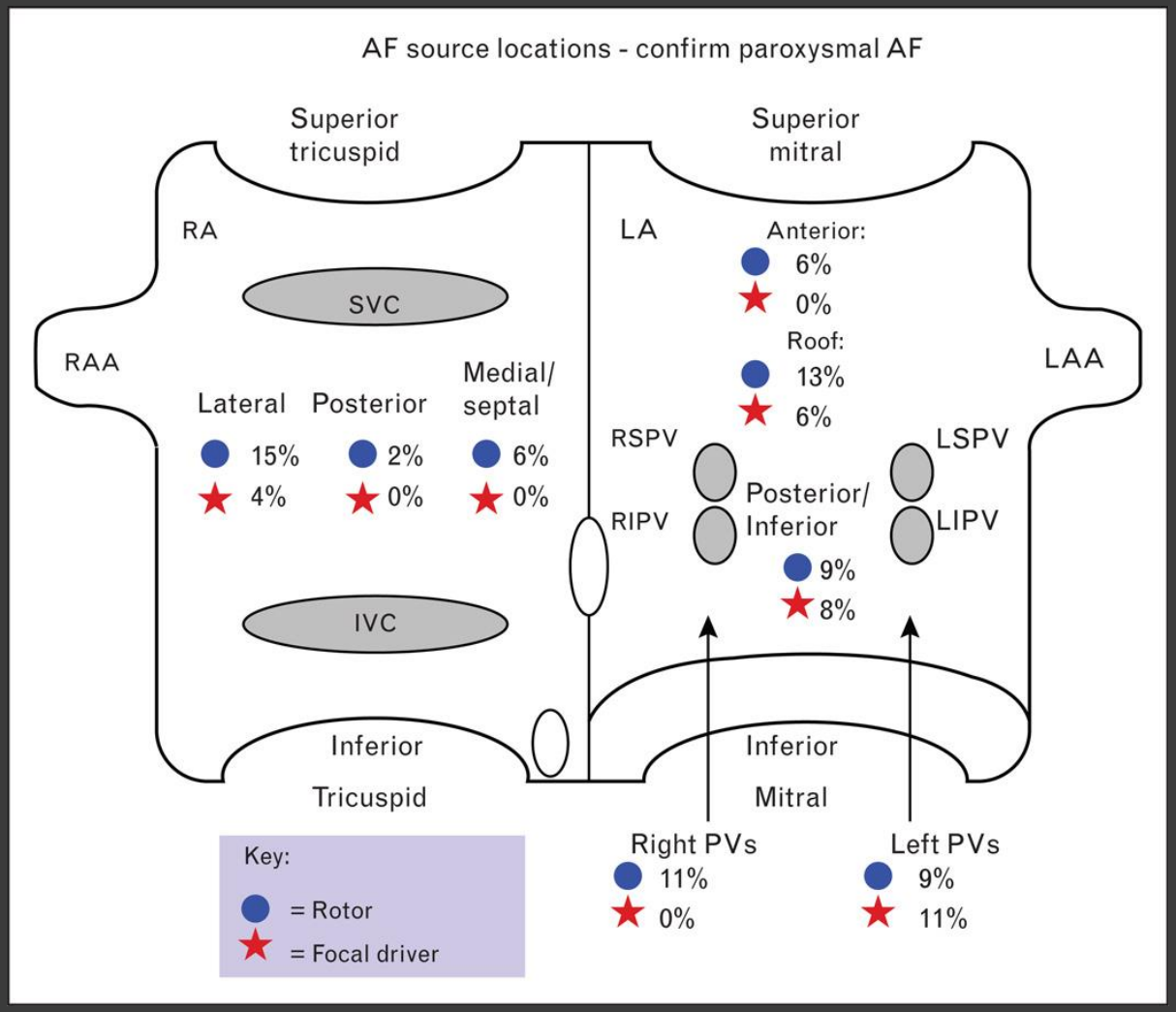
Persistent AF - Substrate Ablation - Ganglionic Plexus



Persistent AF - Substrate Ablation - Rotor



Persistent AF - Substrate Ablation - Rotor



Do additional ablations improve outcome?

ablation of non-PV triggers

CFAE ablation
HFSA ablation
GP ablation
rotors ablation
LAA isolation

substrate reduction or isolation

posterior wall de-bulking
posterior wall boxing
mitral isthmus line

Do additional ablations improve outcome?

ablation of non-PV triggers

CFAE ablation	**STAR AF**	100	PVI+CFAE > PVI > CFAE
HFSA ablation	**STAR AF II**	585	PVI+CFAE = PVI+CFAE+linear = PVI
GP ablation			PVI alone – ↓ procedure time & radiation
rotors ablation			
LAA isolation			

substrate reduction or isolation

posterior wall de-bulking

posterior wall boxing

mitral isthmus line

Do additional ablations improve outcome?

ablation of non-PV triggers

CFAE ablation

HFSA ablation

GP ablation

rotors ablation

LAA isolation

RADAR AF

232

PaAF HFSA = PVI

PeAF HFSA+PVI = PVI

↑ complications in HFSA+PVI

substrate reduction or isolation

posterior wall de-bulking

posterior wall boxing

mitral isthmus line

Do additional ablations improve outcome?

ablation of non-PV triggers

CFAE ablation

HFSA ablation

GP ablation	(all PaAF)	242	GP+PVI > PVI alone > GP alone
rotors ablation	no PeAF study		
LAA isolation			

substrate reduction or isolation

posterior wall de-bulking

posterior wall boxing

mitral isthmus line

Do additional ablations improve outcome?

ablation of non-PV triggers

CFAE ablation

HFSA ablation

GP ablation

rotors ablation

LAA isolation

CONFIRM	92	PaAF:	FIRM+WACA > WACA
		PeAF:	FIRM+WACA+roof > WACA+roof
RCT		PeAF:	FIRM < FIRM+PVI < PVI

substrate reduction or isolation

posterior wall de-bulking

posterior wall boxing

mitral isthmus line

Do additional ablations improve outcome?

ablation of non-PV triggers

CFAE ablation

HFSA ablation

GP ablation

rotors ablation

LAA isolation **BELIEF** 173 PeAF LAAI + ext LA > ext LA

substrate reduction or isolation

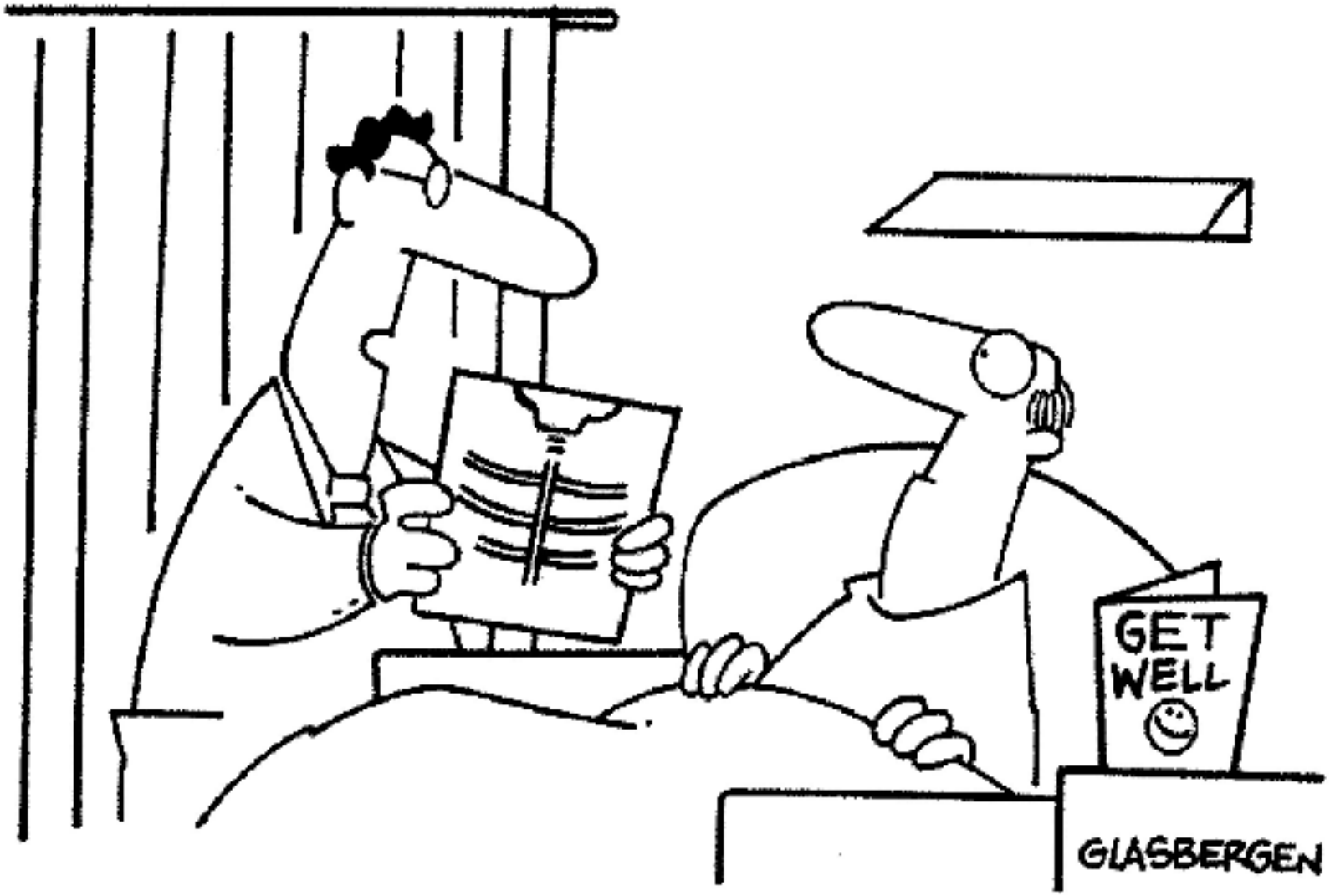
posterior wall de-bulking

posterior wall boxing

mitral isthmus line

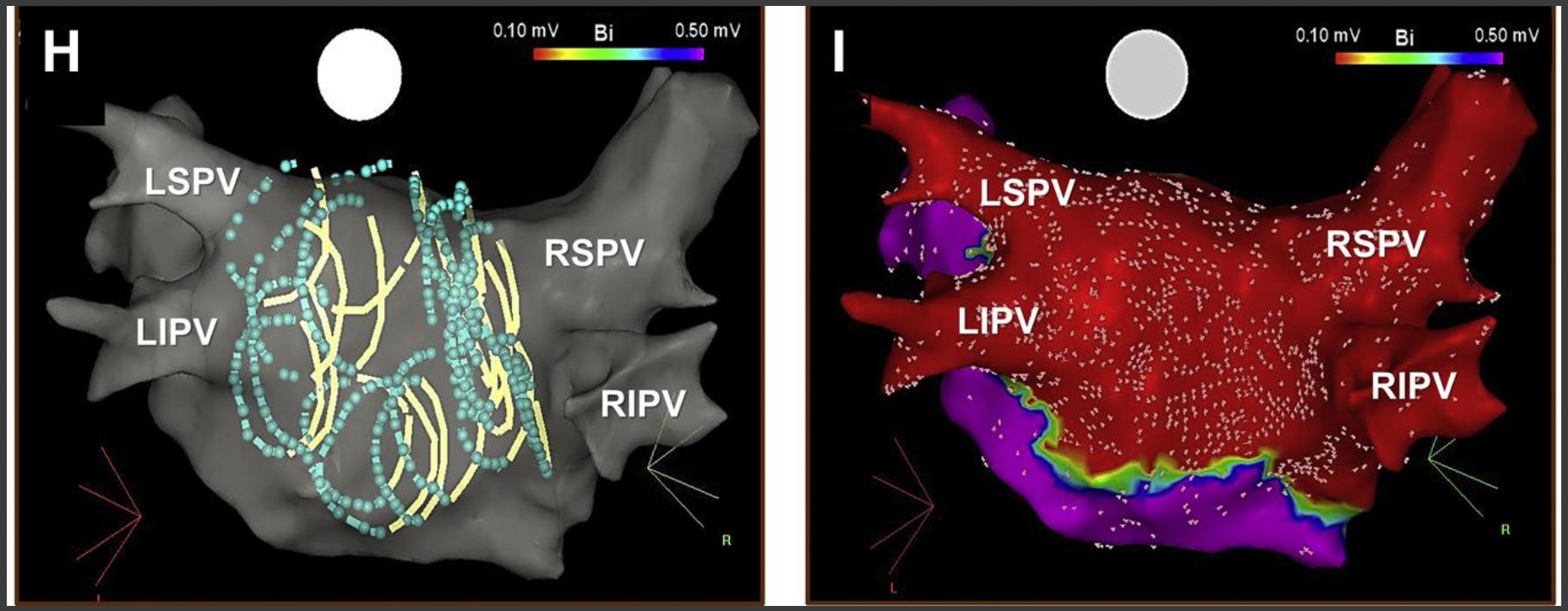
Persistent AF - Substrate Ablation – Posterior Wall Isolation

Eduardo B. Saad, MD, PhD, FHRS, Charles Slater, MD, FHRS, RCES, CCDS, CEPS. www.jafib.com Dec 2014-Jan2015



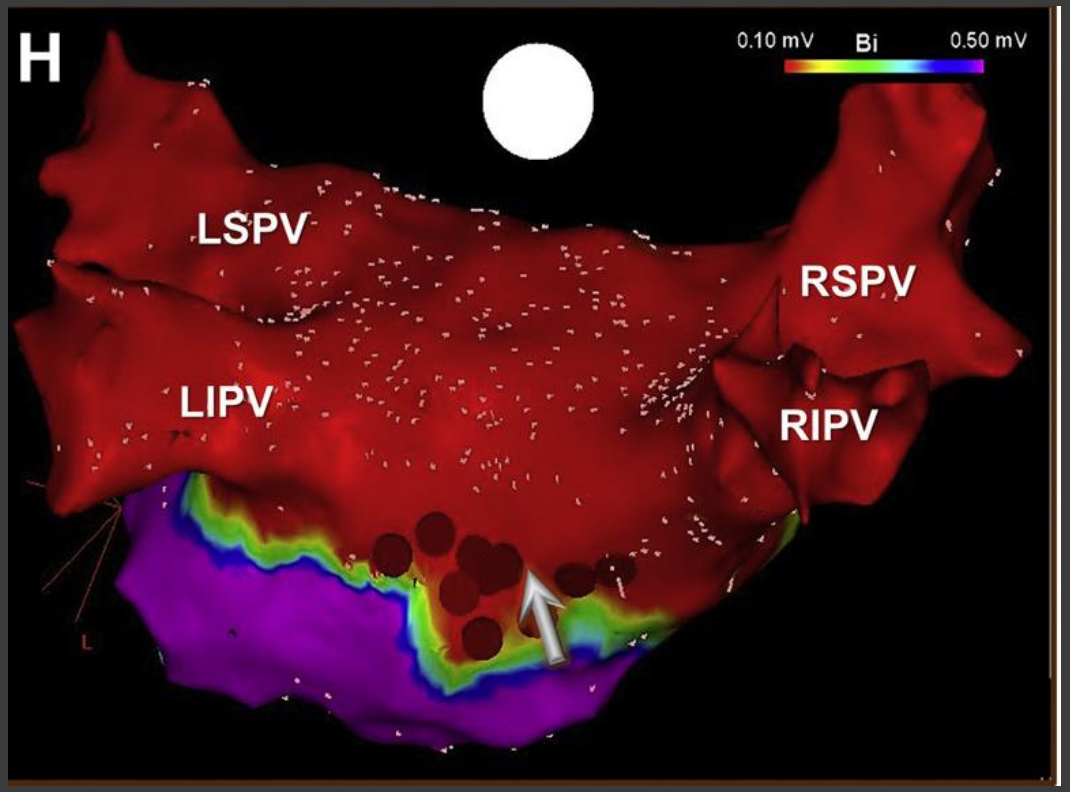
"Your x-ray showed a broken rib, but we fixed it with Photoshop."

Persistent AF - Substrate Ablation – Posterior Wall Debulking



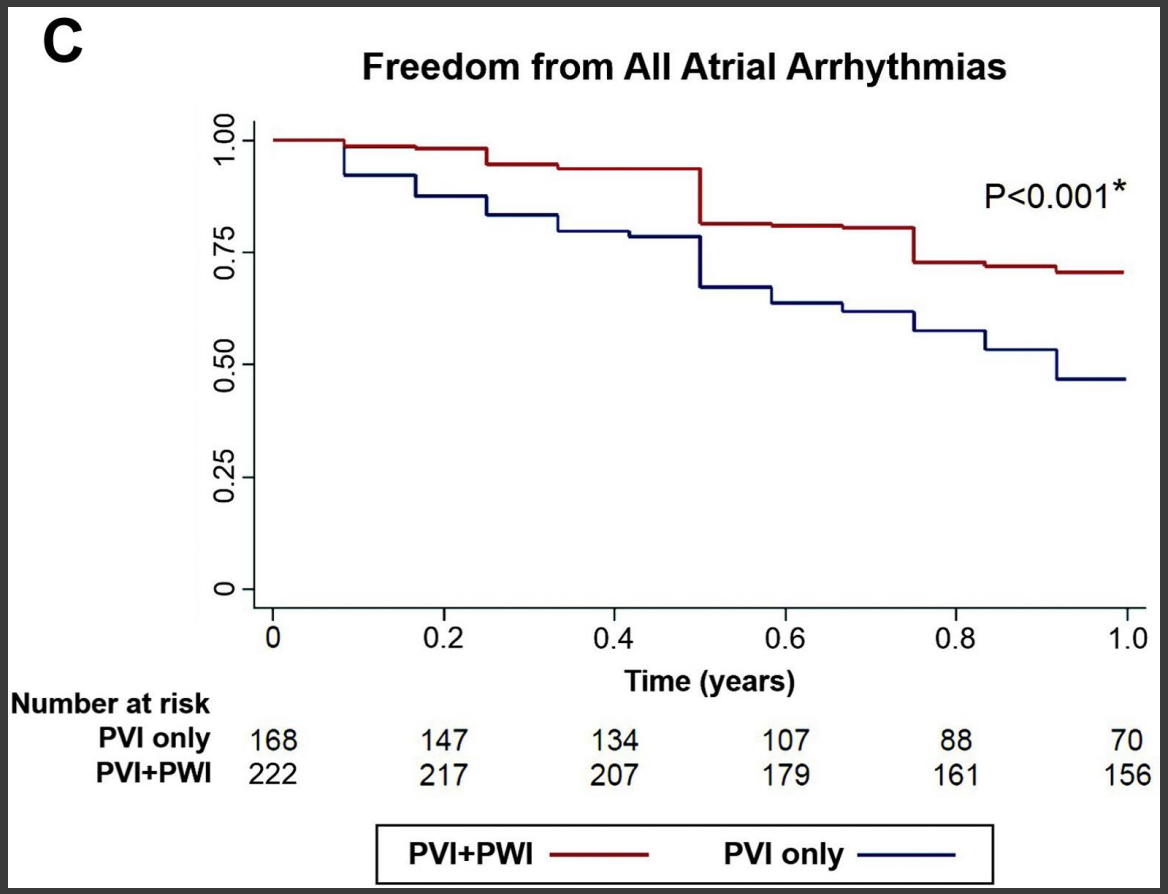
Aryana, A, Heart Rhythm 2018;15:1121-1129

Persistent AF - Substrate Ablation – Posterior Wall Debulking



Aryana, A, Heart Rhythm 2018;15:1121-1129

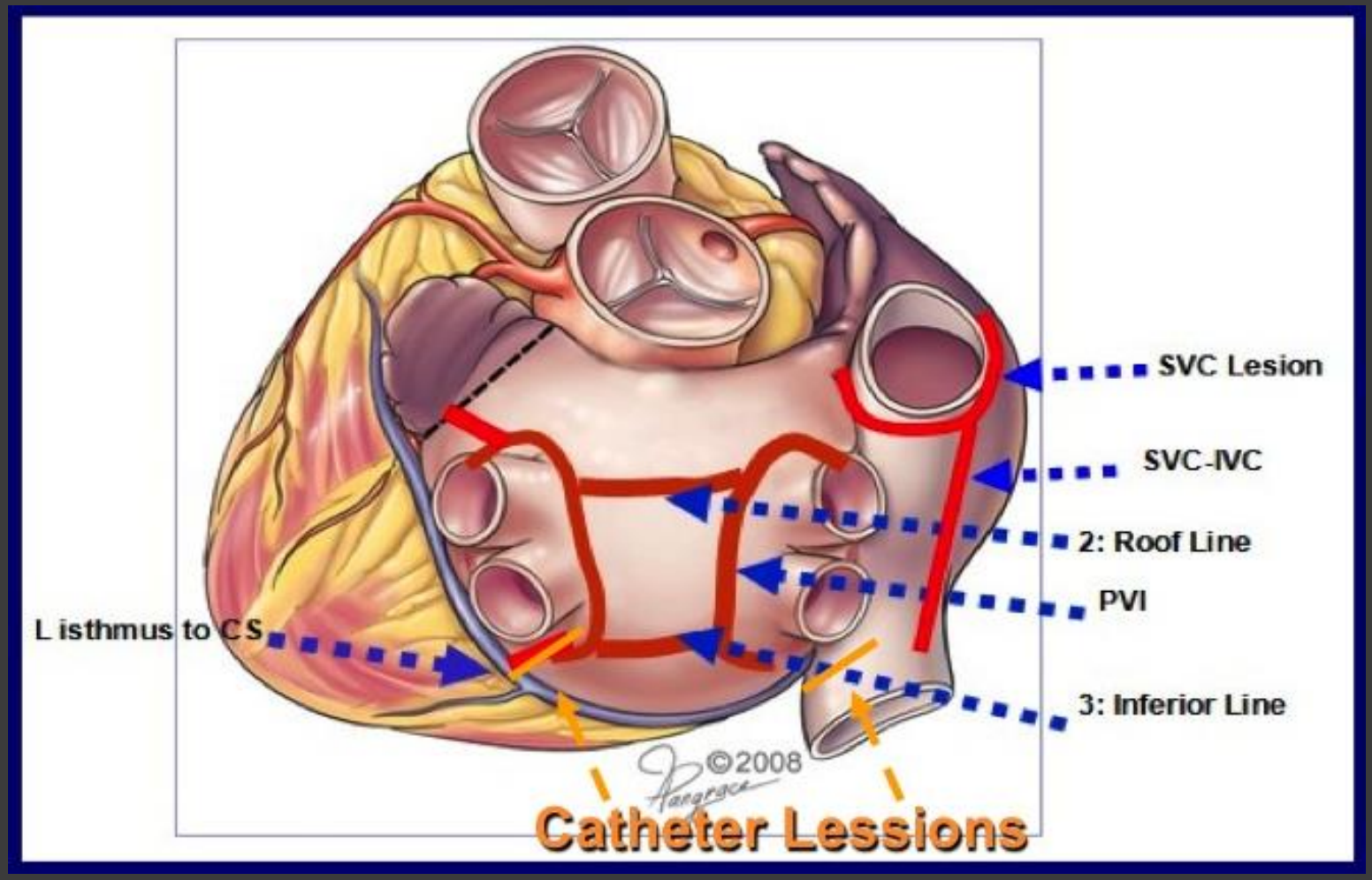
Persistent AF - Substrate Ablation – Posterior Wall Debulking



Aryana, A, Heart Rhythm 2018;15:1121-1129

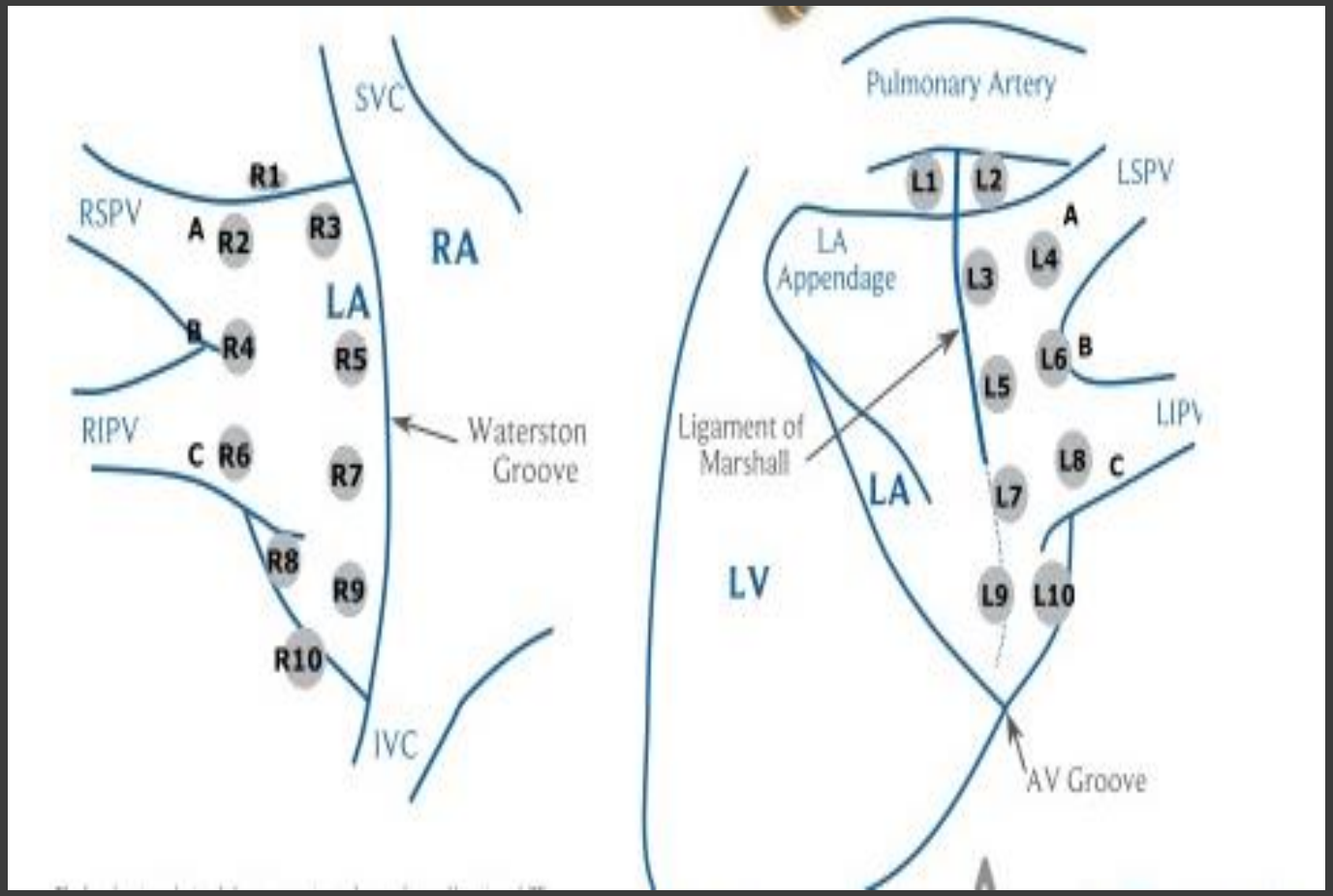
Persistent AF - Substrate Ablation – Posterior Wall Isolation

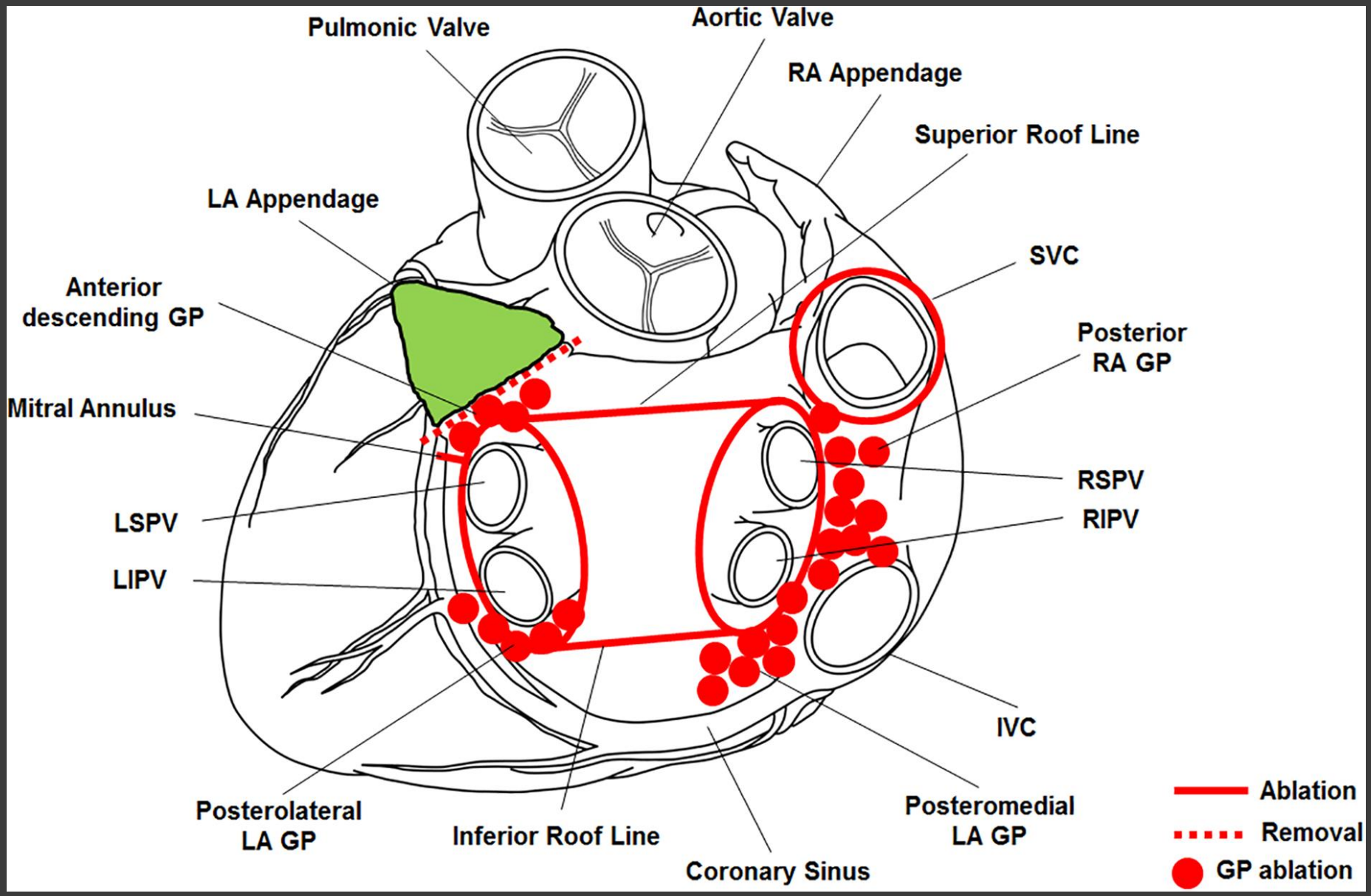
VATS Maze

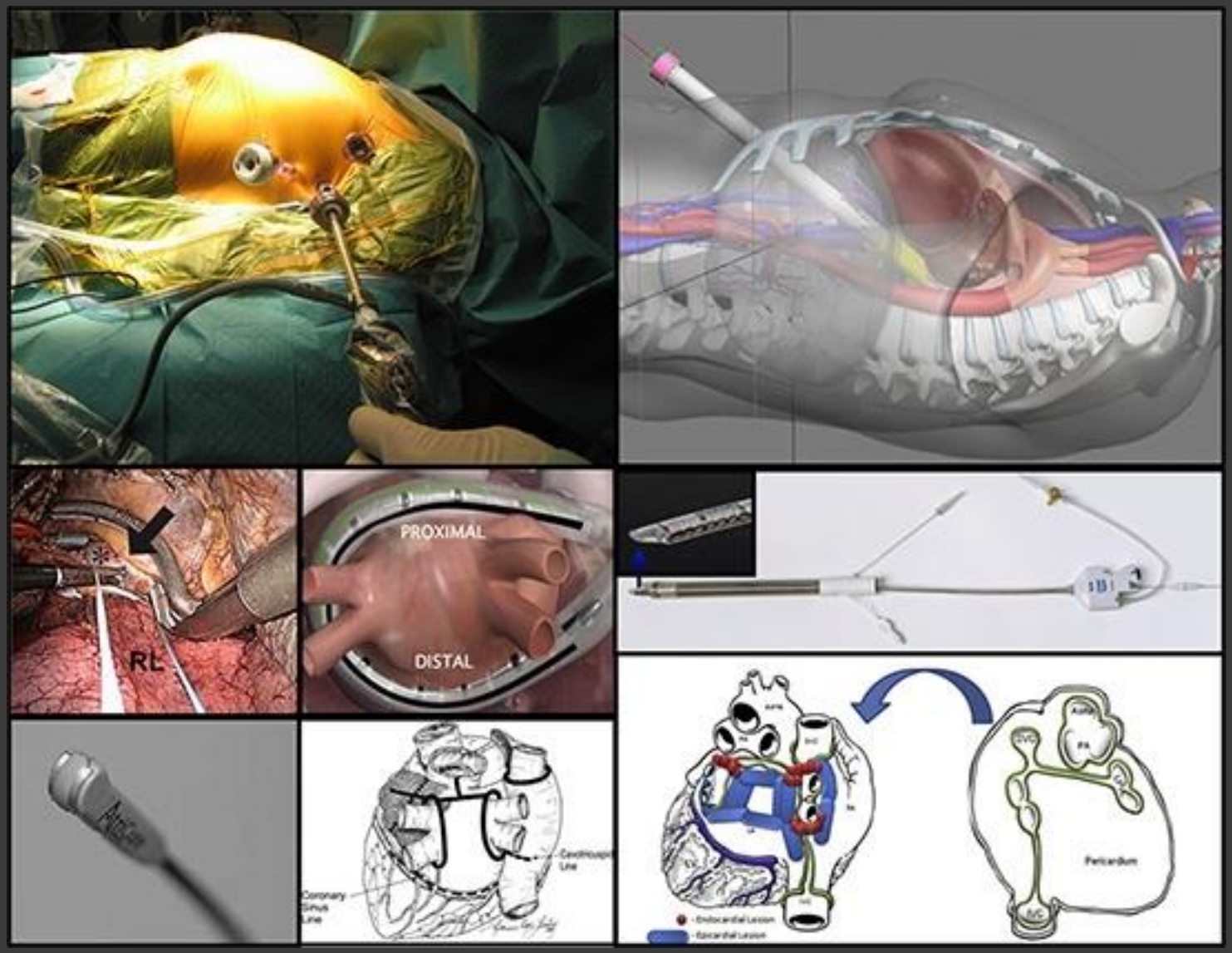


Persistent AF - Substrate Ablation – Ganglionic Plexus

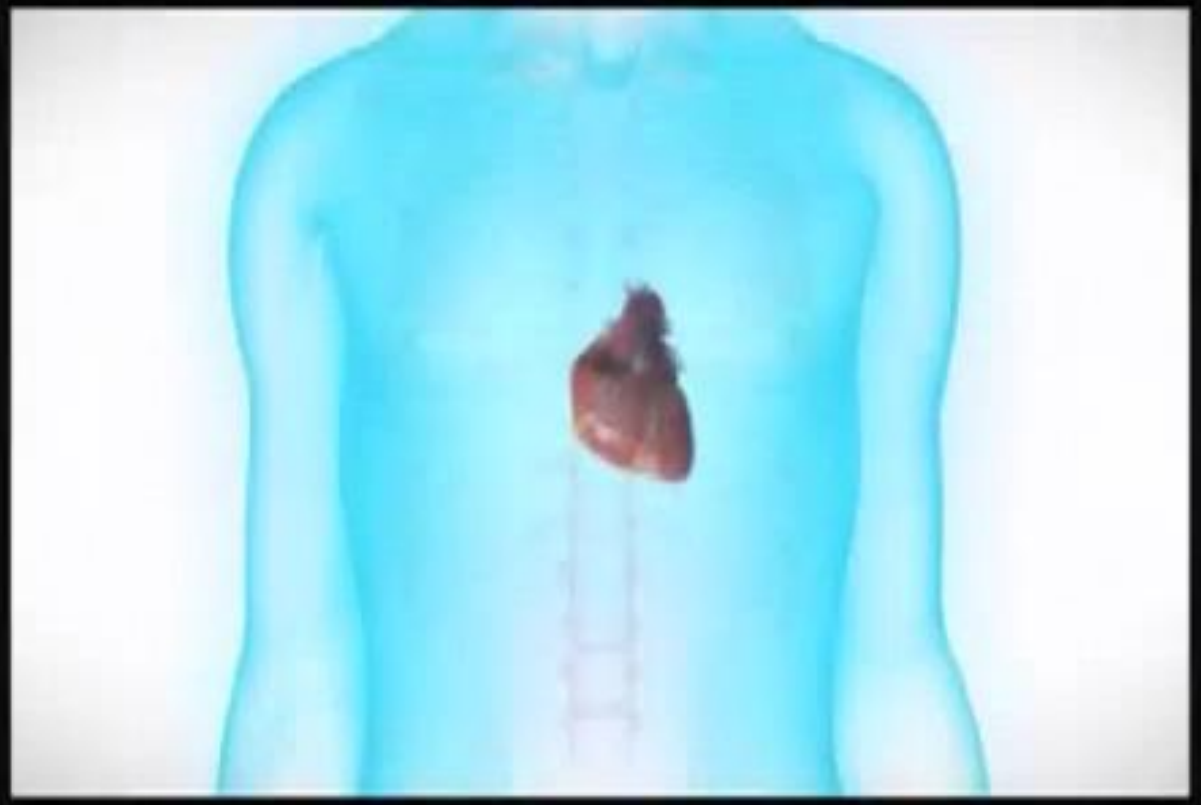
VATS GP Ablation

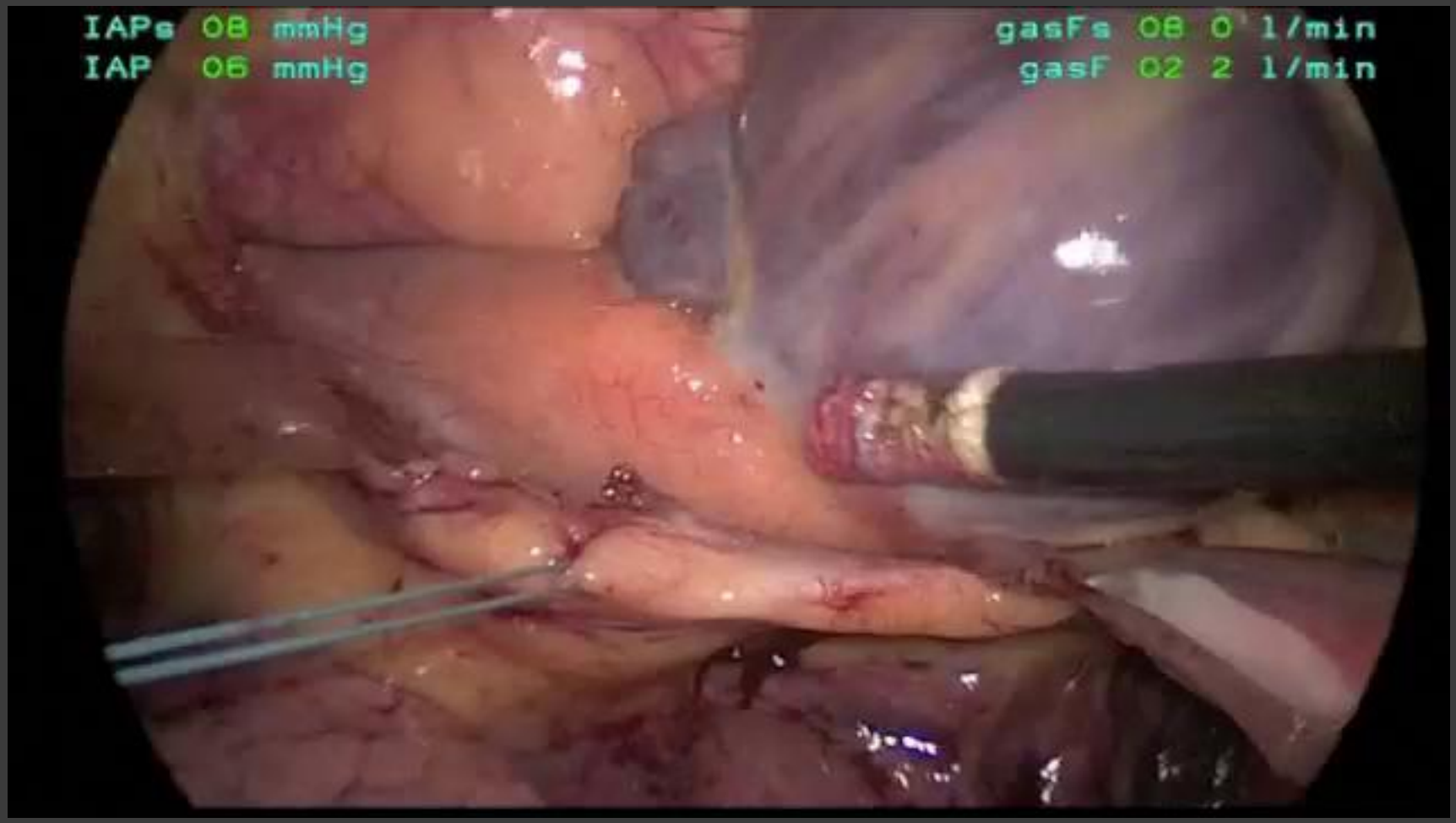



Pulmonic Valve
Aortic Valve
RA Appendage
Superior Roof Line
LA Appendage
SVC
Anterior descending GP
Posterior RA GP
Mitral Annulus
RSPV
LSPV
RIPV
LIPV
IVC
Posterolateral LA GP
Inferior Roof Line
Coronary Sinus
Posteromedial LA GP
Ablation
Removal
GP ablation


RL
PROXIMAL
DISTAL
Coronary Sinus Line
Pericardium

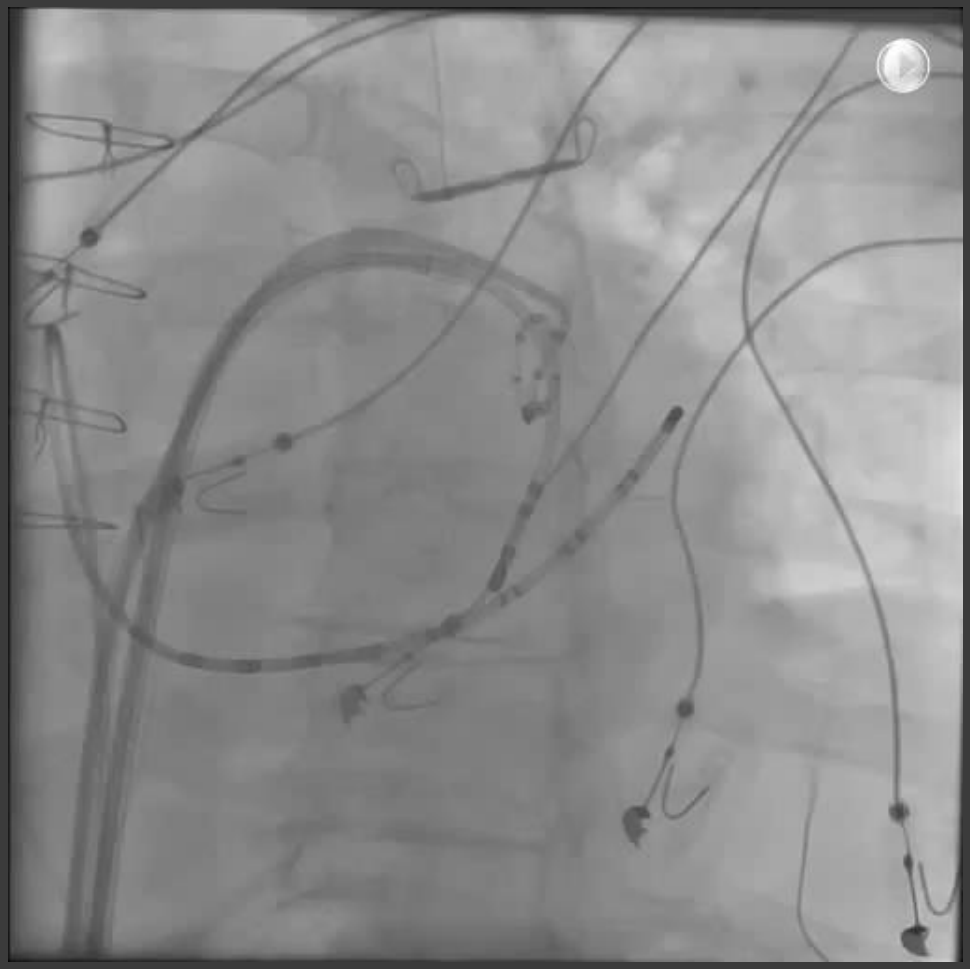
VATS MAZE

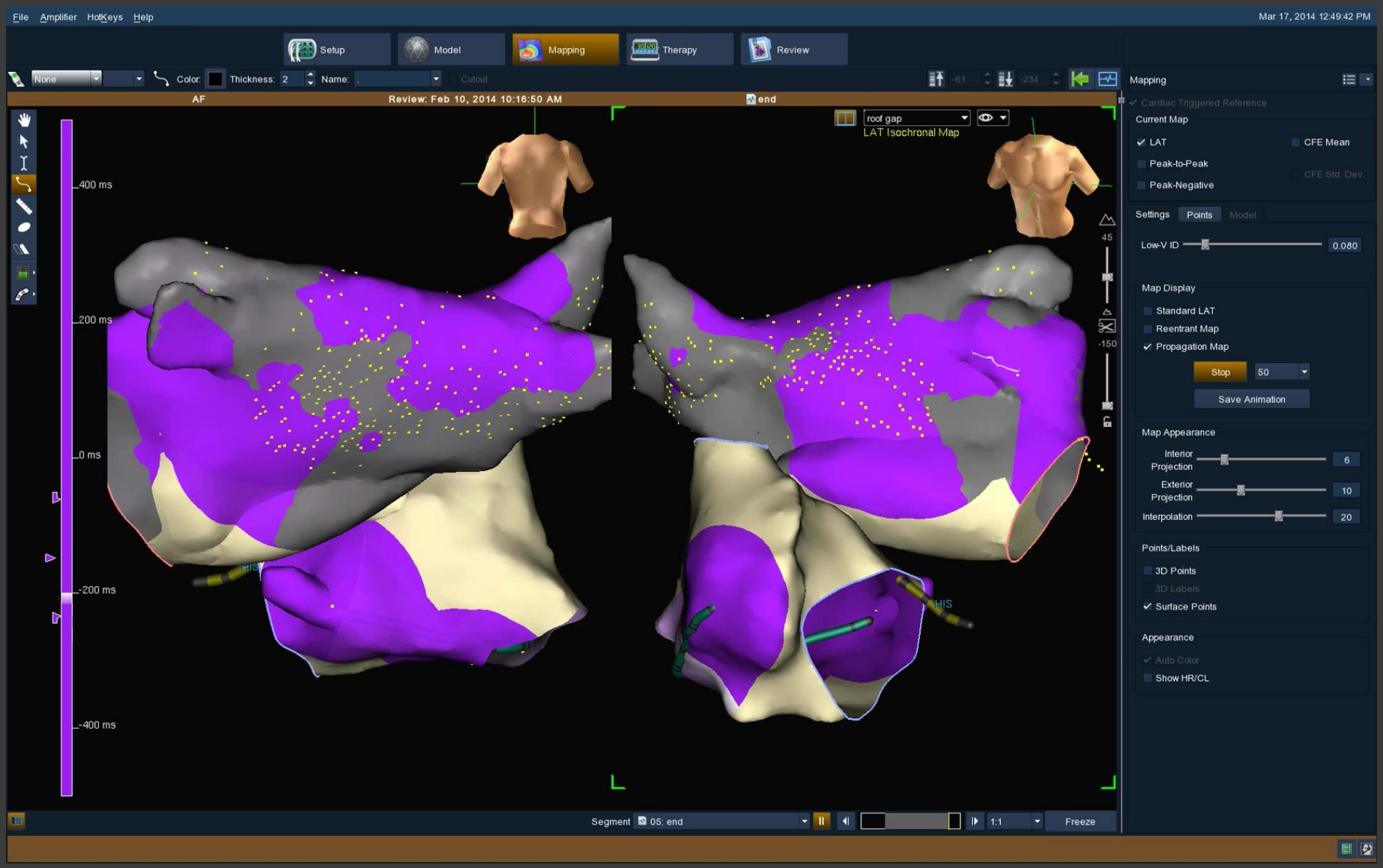



IAPs 08 mmHg
IAP 06 mmHg
gasFs 08 0 l/min
gasF 02 2 l/min

- From OR to cath lab for same day hybrid, flutter lines completed by EP
- Patient DC’d home on POD 3 on AAD, OAC for 2 months

Catheter (Second-Stage) Ablation post VATS Maze




File
Amplifier
HotKeys
Help
Mar 17, 2014 12:49:42 PM
Setup
Model
Mapping
Therapy
Review
None
Color:
Thickness:
2
Name:
Cutout
AF
Review: Feb 10, 2014 10:16:50 AM
end
roof gap
LAT Isochronal Map
400 ms
200 ms
0 ms
-200 ms
-400 ms
HIS
Mapping
Cardiac Triggered Reference
Current Map
LAT
CFE Mean
Peak-to-Peak
CFE Std. Dev.
Peak-Negative
Settings
Points
Model
Low-V ID
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Map Display
Standard LAT
Reentrant Map
Propagation Map
Stop
50
Save Animation
Map Appearance
Interior Projection
6
Exterior Projection
10
Interpolation
20
Points/Labels
3D Points
3D Labels
Surface Points
Appearance
Auto Color
Show HR/CL
Segment
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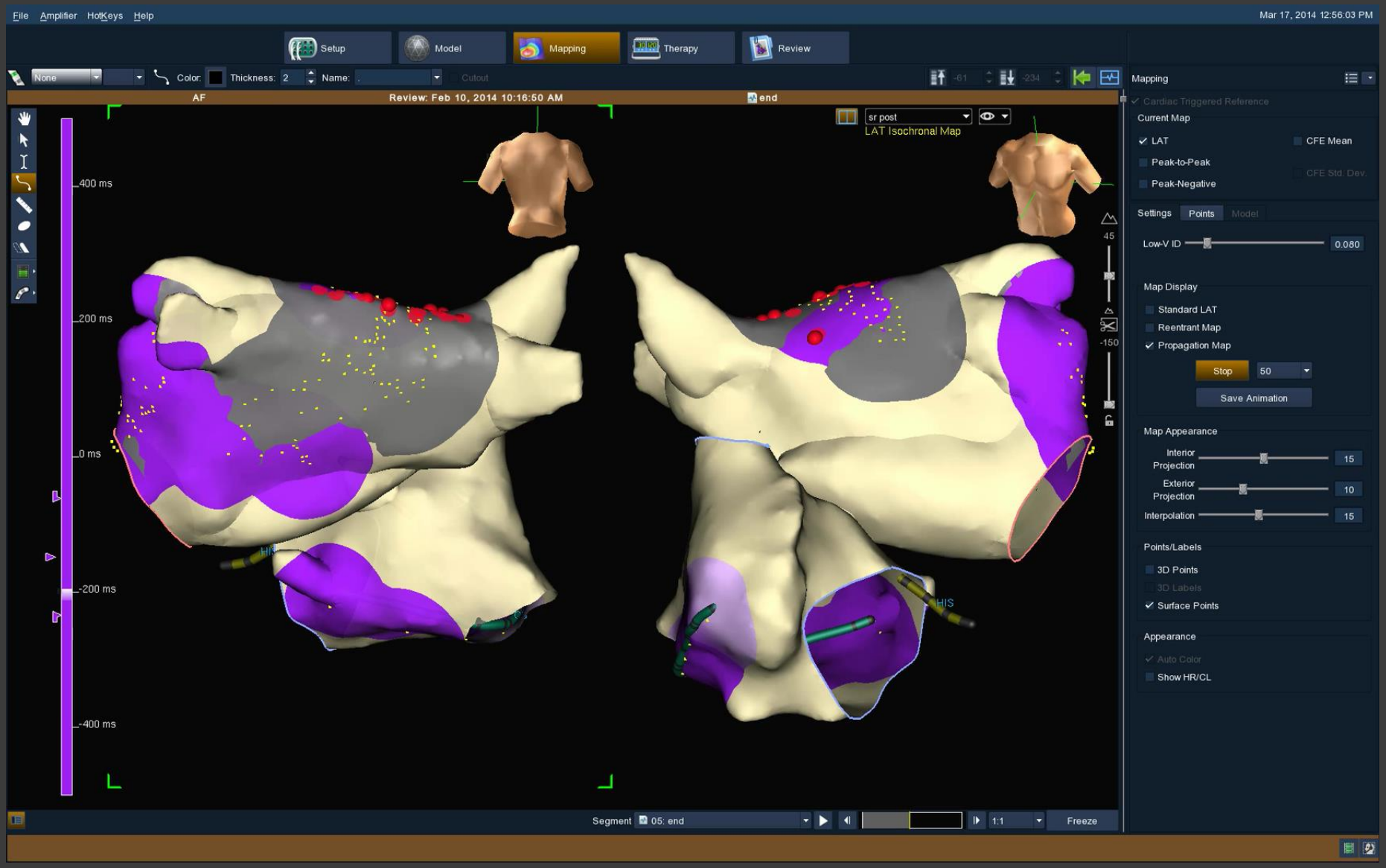
1:1
Freeze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Cardiac Triggered Reference
Current Map
LAT
CFE Mean
Peak-to-Peak
Peak-Negative
CFE Std. Dev.
Settings
Points
Model
Low-V ID
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Map Display
Standard LAT
Reentrant Map
Propagation Map
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Save Animation
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Interior Projection
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Exterior Projection
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Interpolation
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Points/Labels
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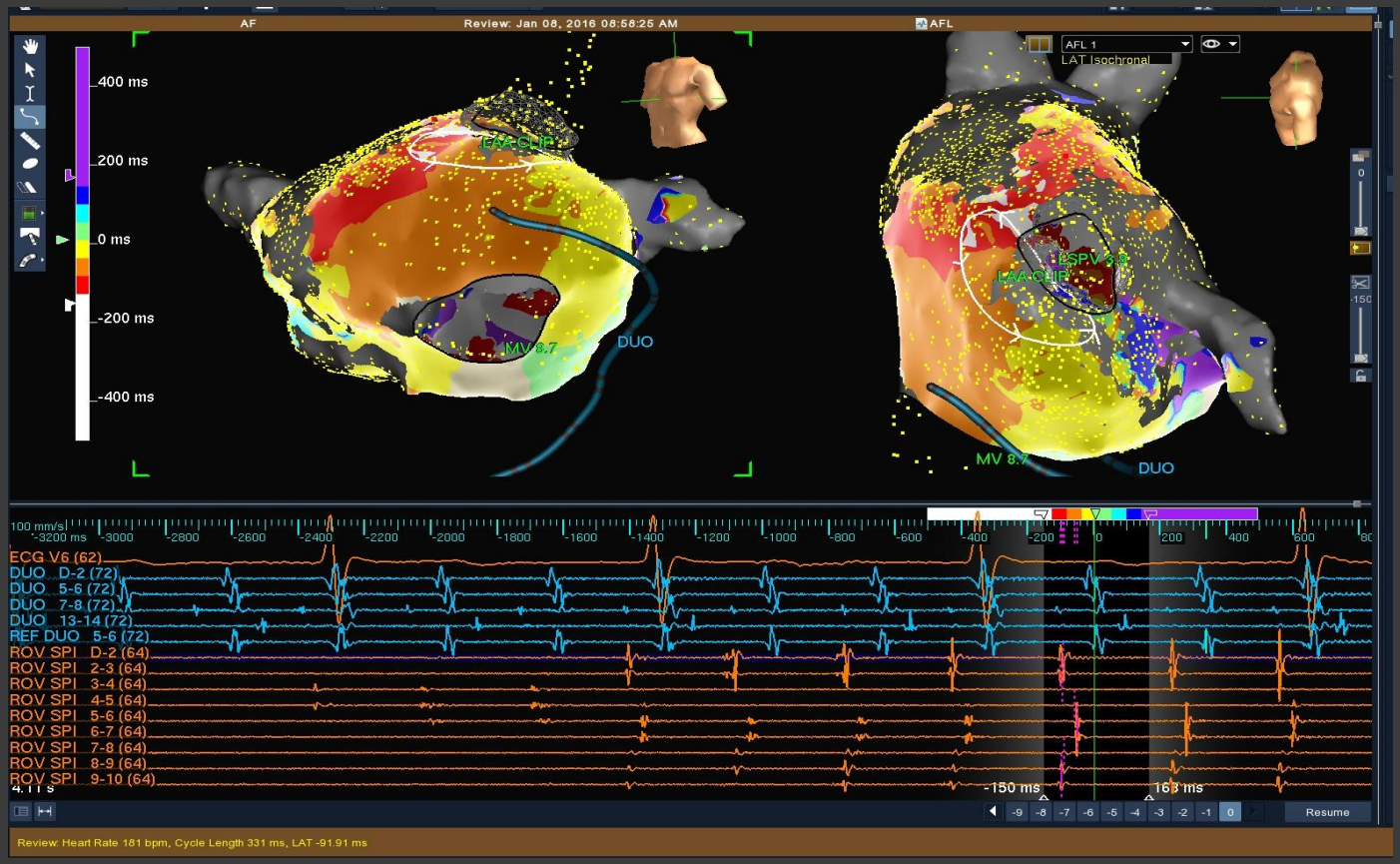
Surface Points
Appearance
Auto Color
Show HR/CL

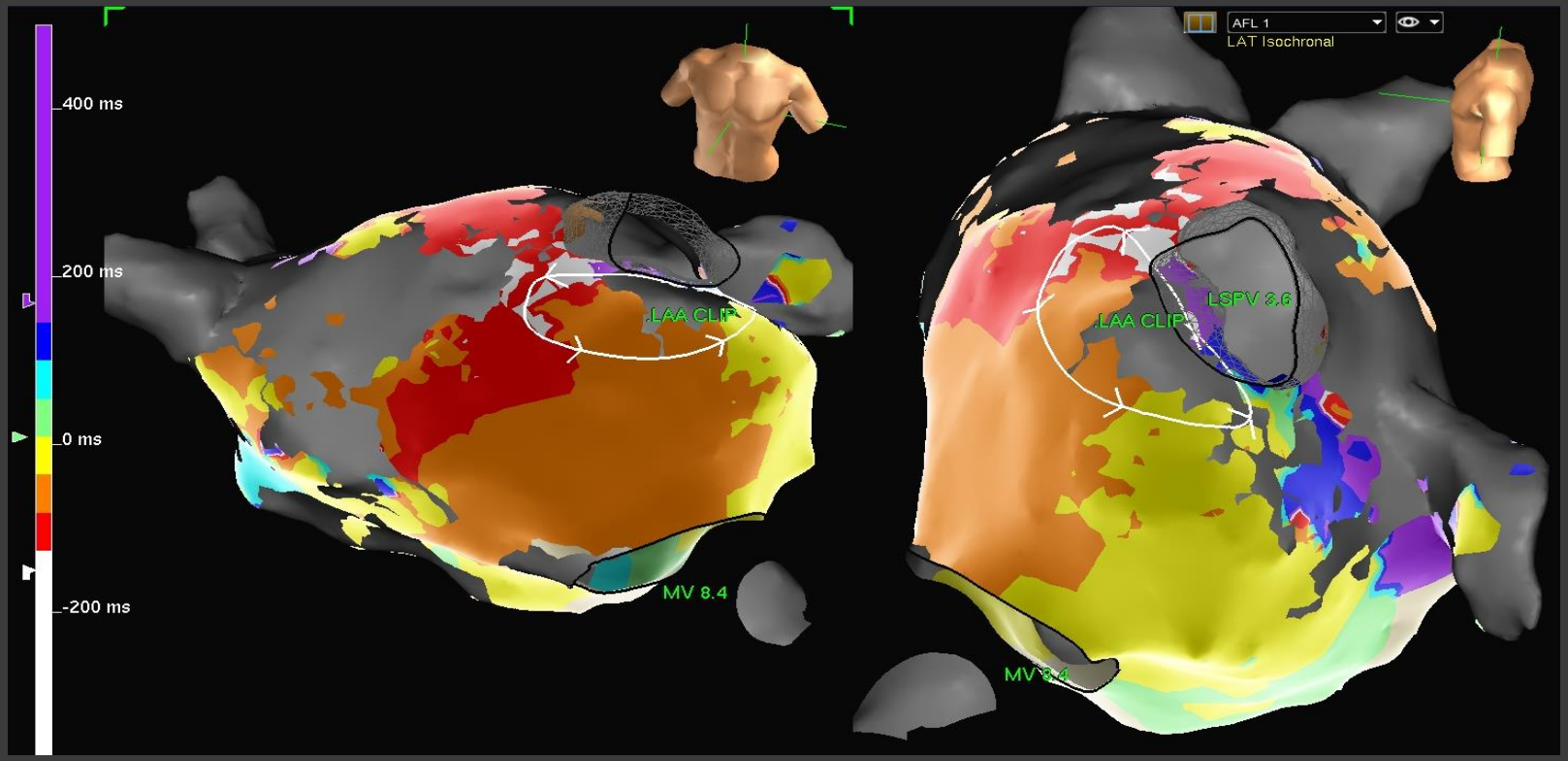
Catheter Mapping & Ablation – Post VATS Maze

Recurrent atypical atrial flutter



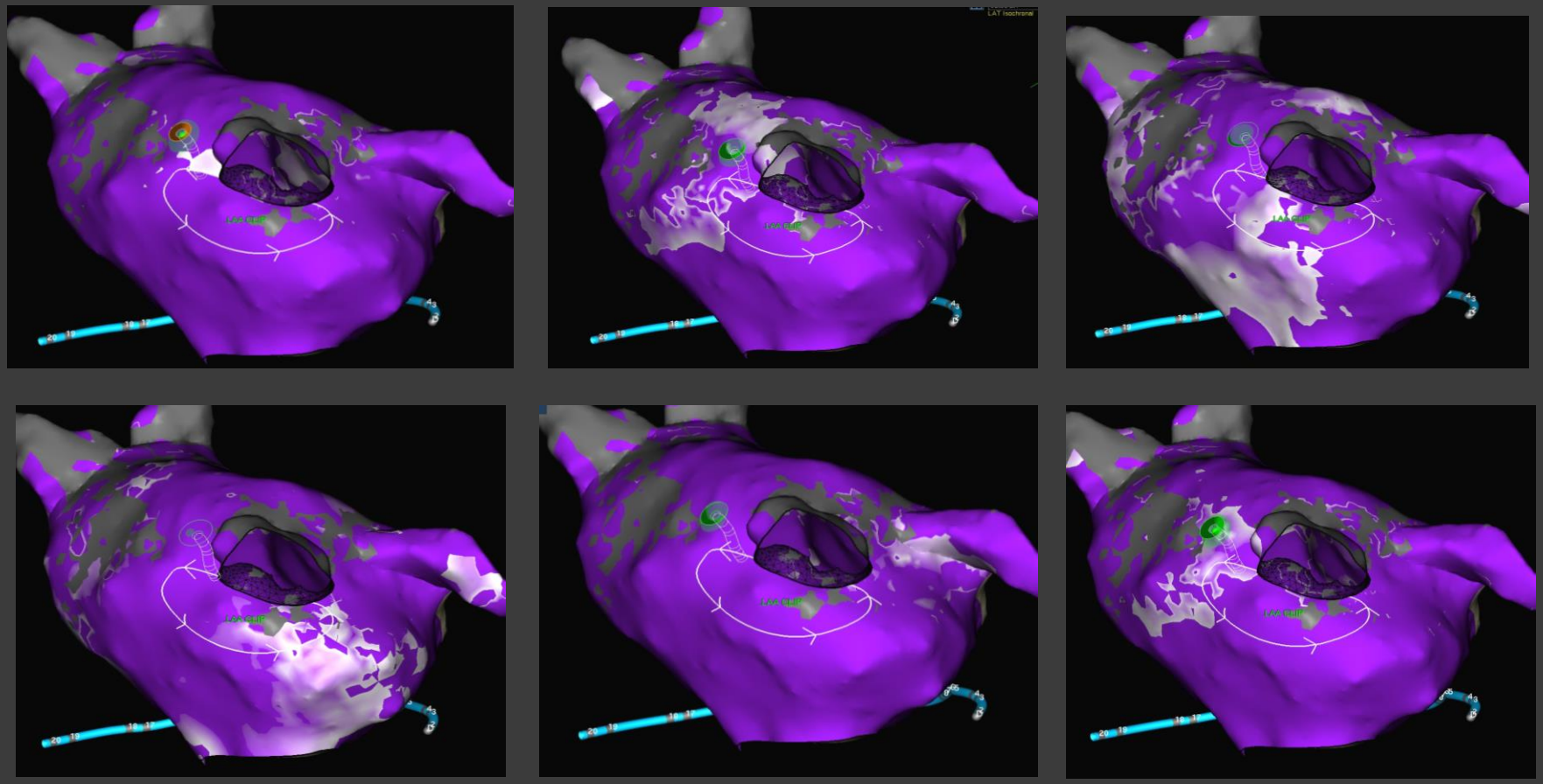
Catheter Mapping & Ablation – Post VATS Maze

Propagation Mapping



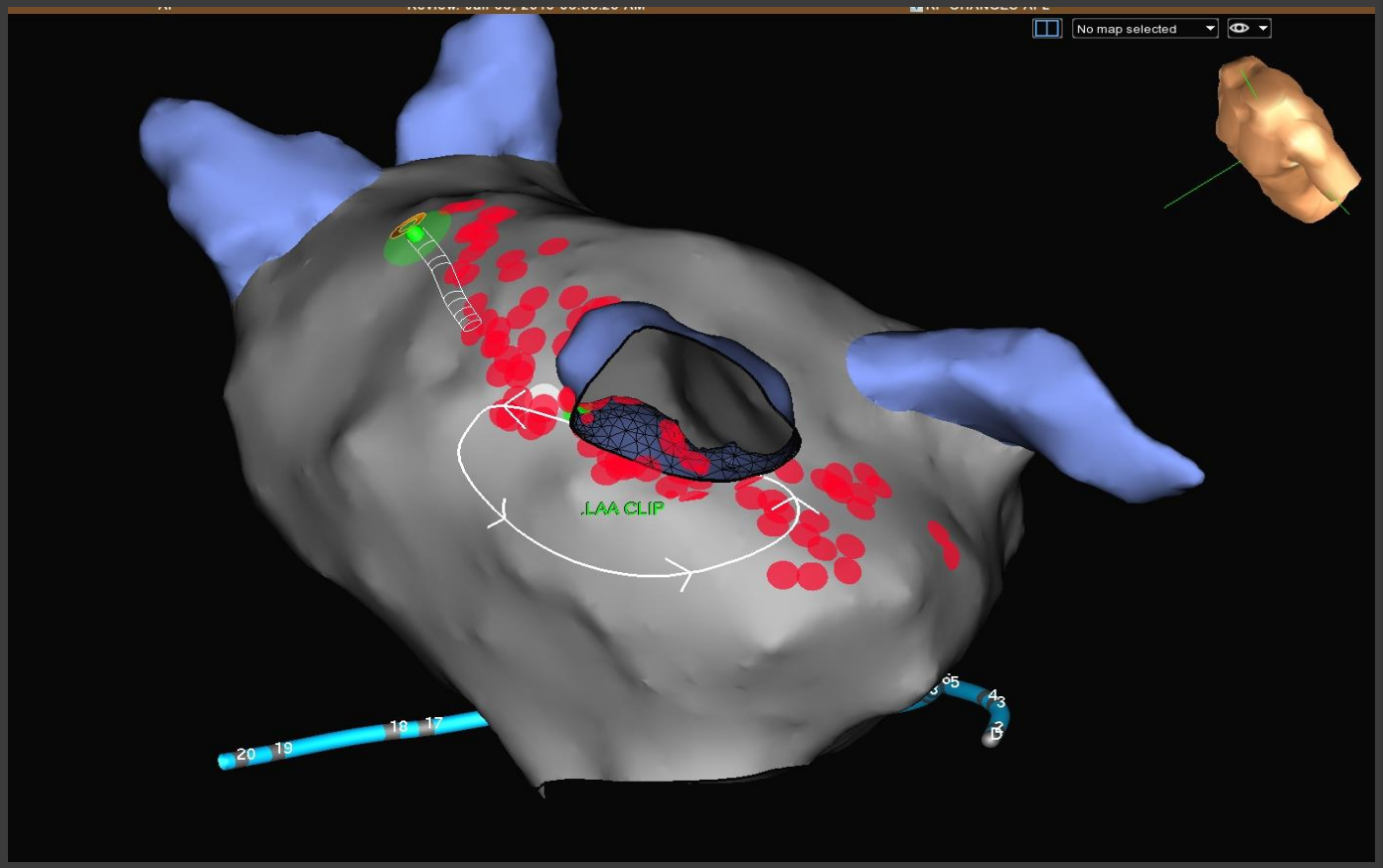
Catheter Mapping & Ablation – Post VATS Maze

Propagation Mapping



Catheter Mapping & Ablation – Post VATS Maze

Lesion set



the message:

Incomplete line(s) are worse than no-line at all

(macro re-entry source)

Cluster ablations in posterior wall also creates new re-entry

It is very difficult to create COMPLETE (and transmural) lines with endocardial catheter approach

It is very easy to (endocardially) complete an incomplete epicardial line (the final result is likely transmural)

Catheter (“second”) stage is necessary – hence “hybrid”

Evolution of the definition of hybrid

- same-setting (in OR or Hybrid CathLab Room)
  - discouraging outcome during in-experienced era (8-12 hours)
    - significant post-operative morbidity
  - also can be impractical to synchronized surgeon’s and EP’s time
  - but do-able at experienced centers
- 3-4 days apart but same hospitalization
  - very do-able and patients like it
- same day (with transport from OR to EPLab)
  - do-able with improved surgeon’s and EP’s efficiency
  - (2-hour surgical time and 45-minute EP time at SHH)
  - and patients like it more
  - but high (10%) recurrence rate and need for repeat EP stage
- > 30-day apart (typically 45-60 days)
  - allows for complete surgical lesion recovery – lower recurrence

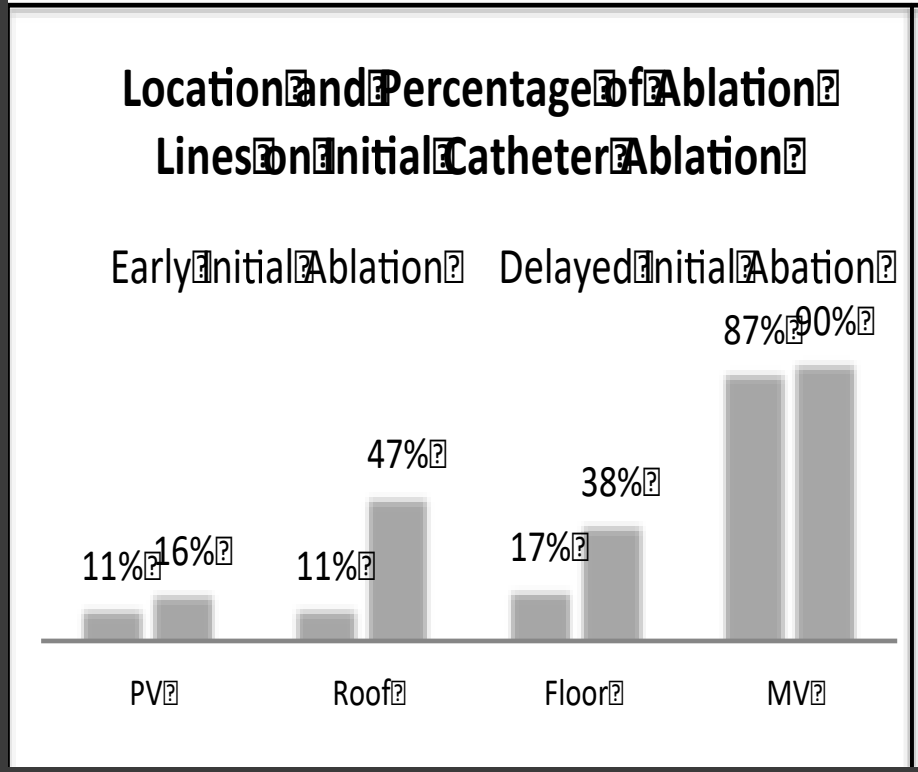
Differential Findings in Early versus Late Electrophysiology Study after Video- Assisted Thoracoscopic Surgery (VATS) Maze Procedure

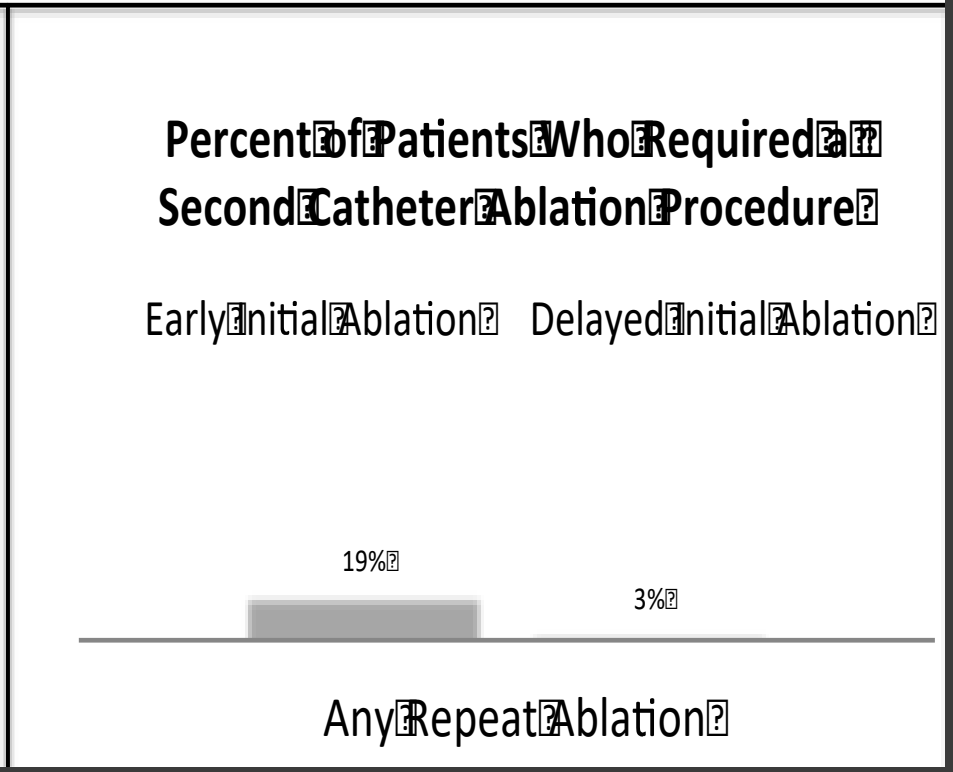
L. Bing Liem, DO FHRS, Dan W. Kaiser, MD, **Gan H. Dunnington, MD**, Peter Chang-Sing, MD FHRS

HRS 2015

EP Data from 86 patients completed VATS Maze + Catheter

- Early = within 3-4 days post VATS Maze (the same hospitalization)
- Delayed = > 30 days post VATS Maze

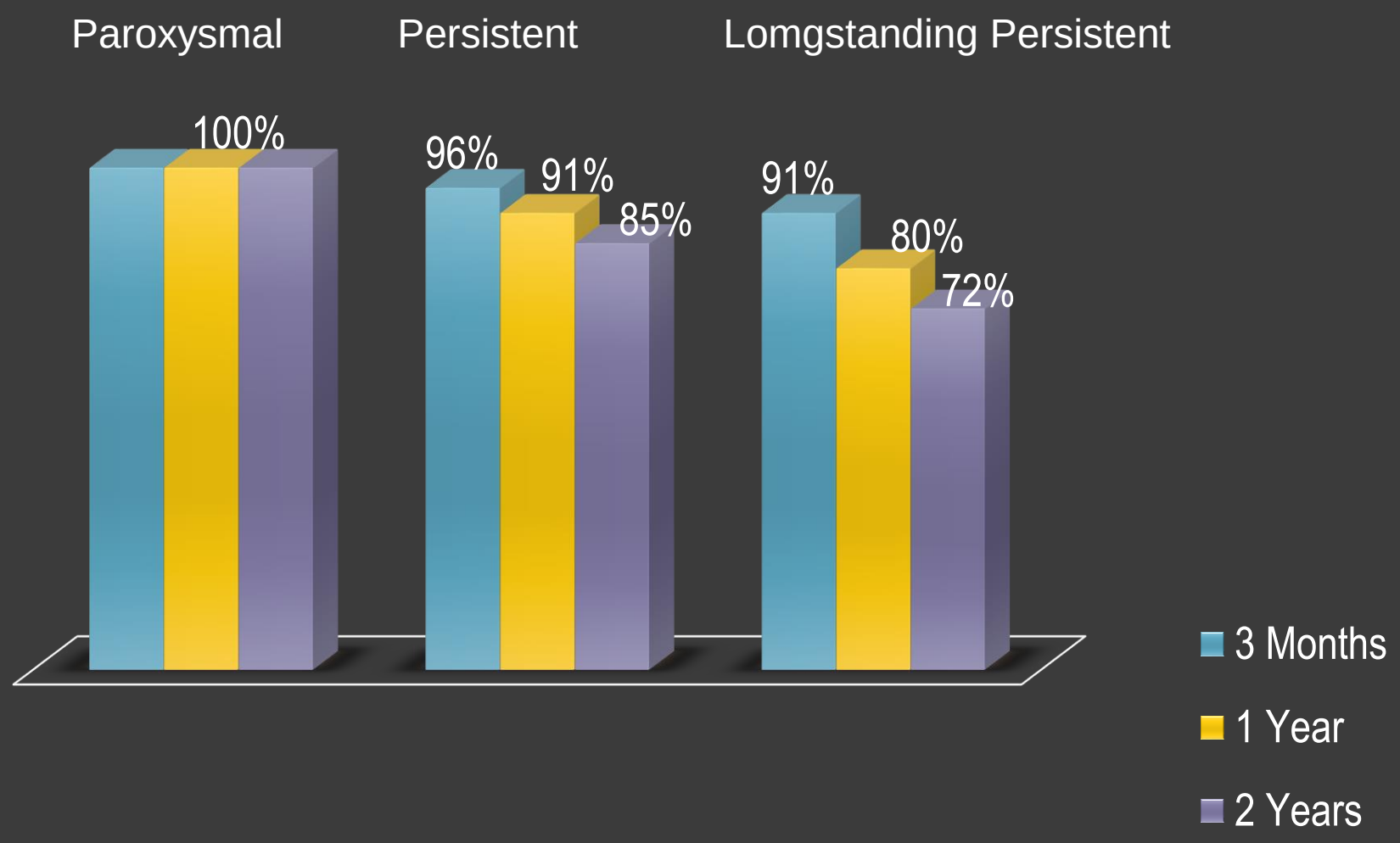




Outcomes of the Hybrid Video-Assisted Thoracoscopic Surgery (VATS) Maze Followed by Catheter Ablation in Patients with Persistent and Longstanding Persistent Atrial Fibrillation: Clinical Results from a High-Volume Center

Daniel Kaiser, Carrie Pierce, Shelby Burk, L. Bing Liem, Peter Chang Sing, Gansevoort Dunnington

ACC 2017



ECG Characteristics of Recurrence Predict Electrophysiologic Findings and Long-Term Outcome in Patients Undergoing Hybrid Procedure for Persistent AF

L. Bing Liem, DO, Gansevoort Dunnington, MD, Carolyn Pierce, RN, Daniel W. Kaiser, MD and Peter Chang-Sing, MD. St. Helena Hospital, St. Helena, CA

ACC 2017

- 268 patients who completed hybrid procedures (2013-2016)
- 20 patients with recurrence of AF or (atypical) AFL
- (ages 56-75, mean CHADSVASC 2.5, mean LA size of 5.2)

- **Results:**
- **16 had atypical AFL and 4 had AF**
- **Atypical AFL: incomplete MI line (14/16) or PVI (2/16)**
- **AF: multiple incompletion (2/4) or none (2/4)**
  - Those with multiple incompletion had the lines re-completed and have done well afterwards
  - Those with no incompletion noted, received empiric ablation (SVC isolation, multiple AT ablation) but continued to have persistent AF afterwards

ECG Characteristics of Recurrence Predict Electrophysiologic Findings and Long-Term Outcome in Patients Undergoing Hybrid Procedure for Persistent AF

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ACC 2017

- 268 patients who completed hybrid procedures (2013-2016)
- 20 patients with recurrence of AF or (atypical) AFL
- (ages 56-75, mean CHADSVASC 2.5, mean LA size of 5.2)

Conclusions:

- **Atypical AFL on ECG in patients with recurrence after completed (both stages) hybrid procedure predicts incompletion of surgical/catheter lines and completion of them results in good outcome**
- **AF predicts poor outcome**

Long-Term Outcome of Hybrid Surgical and Catheter Ablation for Persistent and Longstanding-Persistent Atrial Fibrillation

L. Bing Liem DO FHRS FACC,*#+ Gansevoort H. Dunnington MD FHRS,* Daniel W. Kaiser MD FHRS FACC,*#^ Carrie Pierce RN,* Peter Chang-Sing MD FHRS FACC*% and Susan Eisenberg MD FHRS FACC*

*St. Helena Hospital, St. Helena, California, #El Camino Hospital, Mountain View, California, %Santa Rosa Memorial Hospital, Santa Rosa, California, +University of California San Francisco, California and San Francisco VA Health Care, San Francisco, California, ^St. Thomas Heart, Nashville, Tennessee.

- 550 patients – 462 had standard VATS maze
- mean age 67.2±8.1 (25% females)
- The mean $CHADS_2$-VA_2S_c was 2.6±1.4.
- persistent : long-standing persistent AF = 40% : 60%
- FU: 2013 – 2019
- AF/AT freedom off AAD (majority of patients):
  - Persistent 81%
  - Longstanding-persistent 70%
- Major complications occurred in 3.4%) patients
  - 1.5% conversions to open thoracotomy
  - 0.8% phrenic nerve palsies
  - 0.4% stroke (0.4%)
  - 0.8% death

Hybrid versus catheter ablation in patients with persistent and longstanding persistent atrial fibrillation: a systematic review and meta-analysis†

Claudia A.J. van der Heijden[a,†], Mindy Vroomen[b,†], Justin G. Luermans[b], Rein Vos[c], Harry J.G.M. Crijns[b], Sandro Gelsomino[a], Mark La Meir[a], Laurent Pison[b,d] and Bart Maesen[a,*]

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[b] Department of Cardiology, Maastricht University Medical Centre, Maastricht, Netherlands
[c] Department of Methodology and Statistics, Maastricht University, Maastricht, Netherlands
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Key question

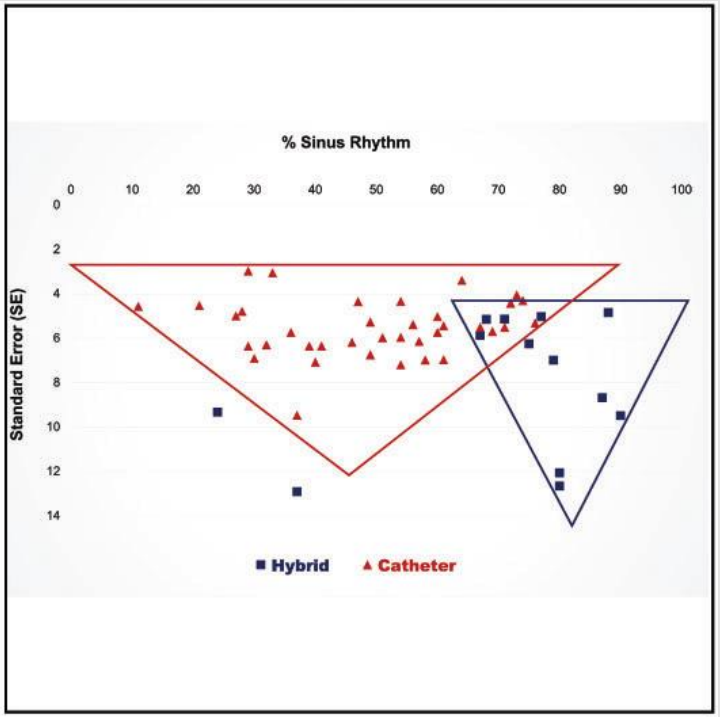
Is hybrid or catheter ablation more effective and safer in the treatment of persistent atrial fibrillation?

Key finding

More sinus rhythm (70.7% vs 49.9%, *P*<0.001) and slightly more complications after hybrid ablation were noted.

Take-home message

Hybrid ablation is more effective than catheter ablation in maintaining sinus rhythm but is associated with a slightly higher complication rate.



n = 34 publications, 574 (hybrid) and 3291 (catheter)

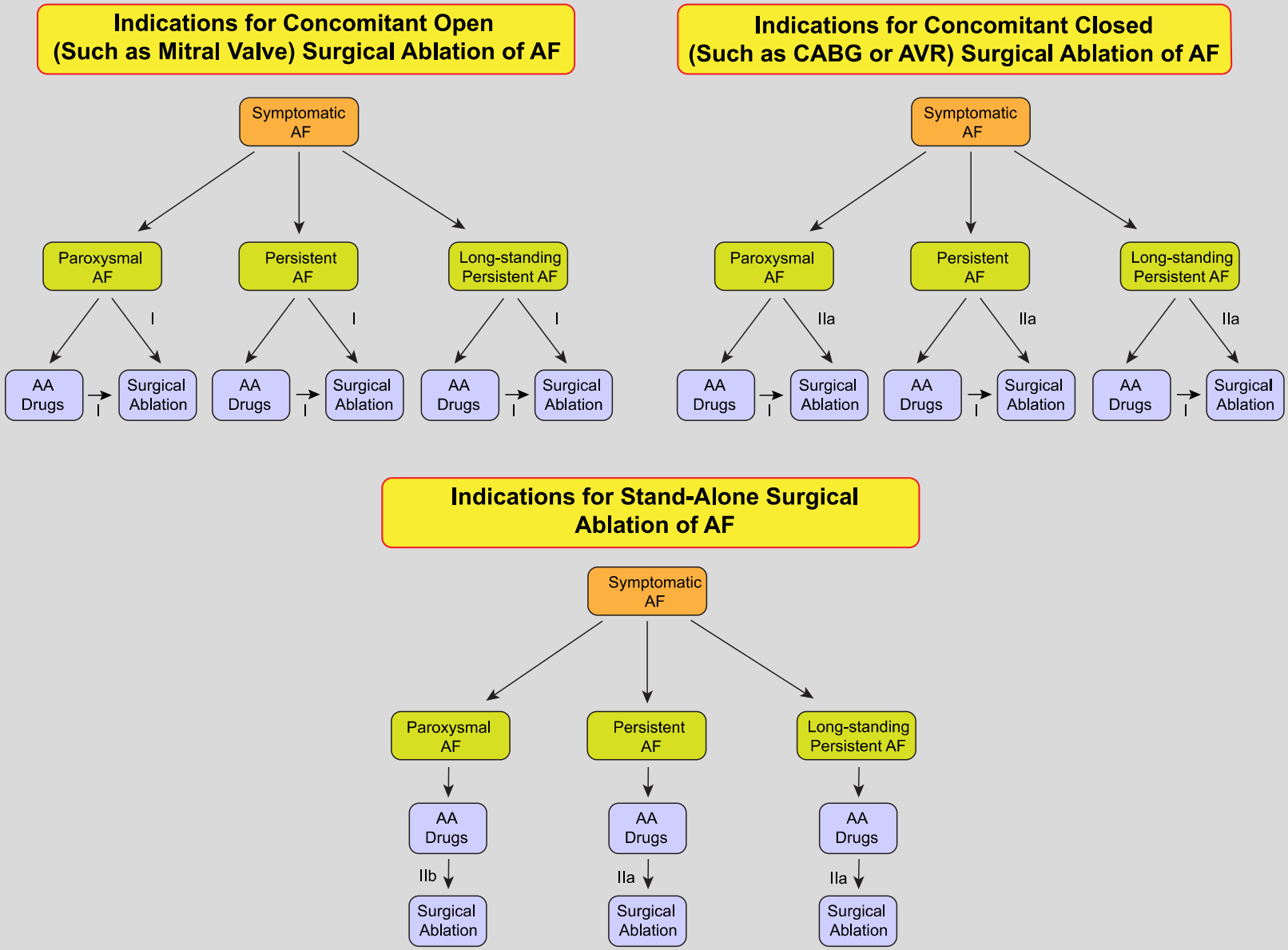


Figure 8 Indications for surgical ablation of atrial fibrillation. Shown in this figure are the indications for surgical ablation of paroxysmal, persistent, and long-standing persistent AF. The Class for each indication based on whether ablation is performed after failure of antiarrhythmic drug therapy or as first-line therapy is shown. The indications for surgical AF ablation are divided into whether the AF ablation procedure is performed concomitantly with an open surgical procedure (such as mitral valve replacement), a closed surgical procedure (such as coronary artery bypass graft surgery), or as a stand-alone surgical AF ablation procedure performed solely for treatment of atrial fibrillation.


EXIT