Current guideline of AF catheter ablation

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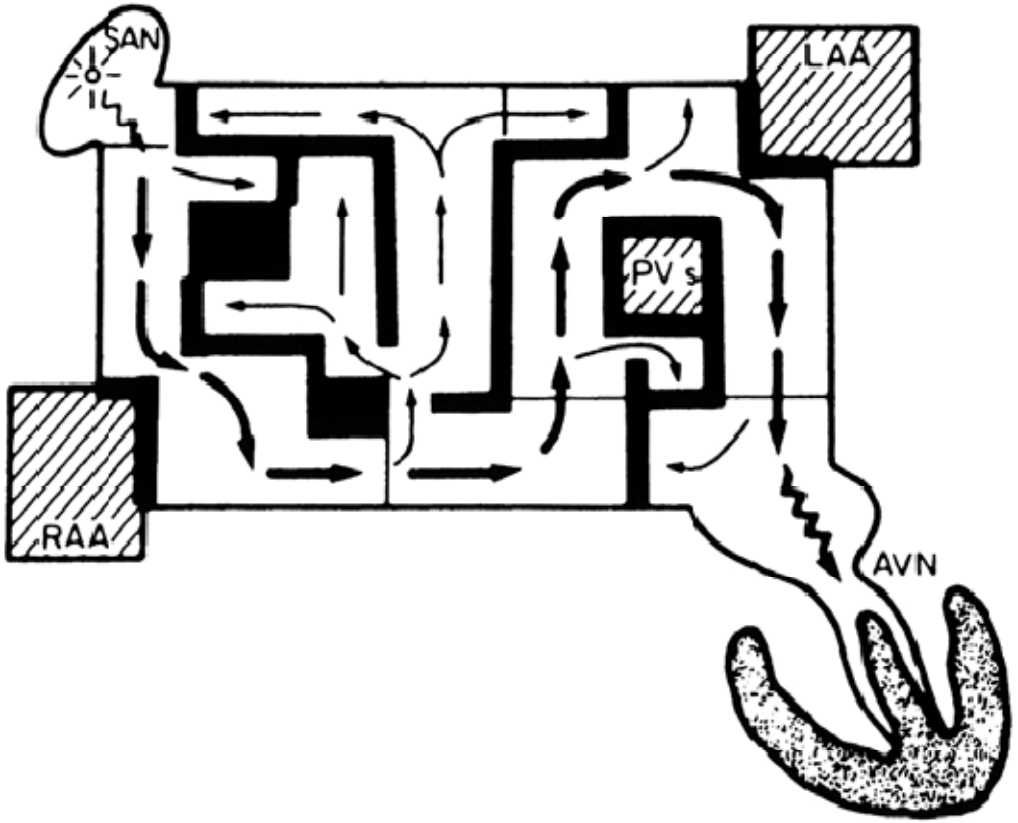
• Early efforts to treat AF with catheter ablation attempted to replicate the surgical Cox-Maze procedure with limited success.

Surgical Treatment of AF: The Maze Procedure



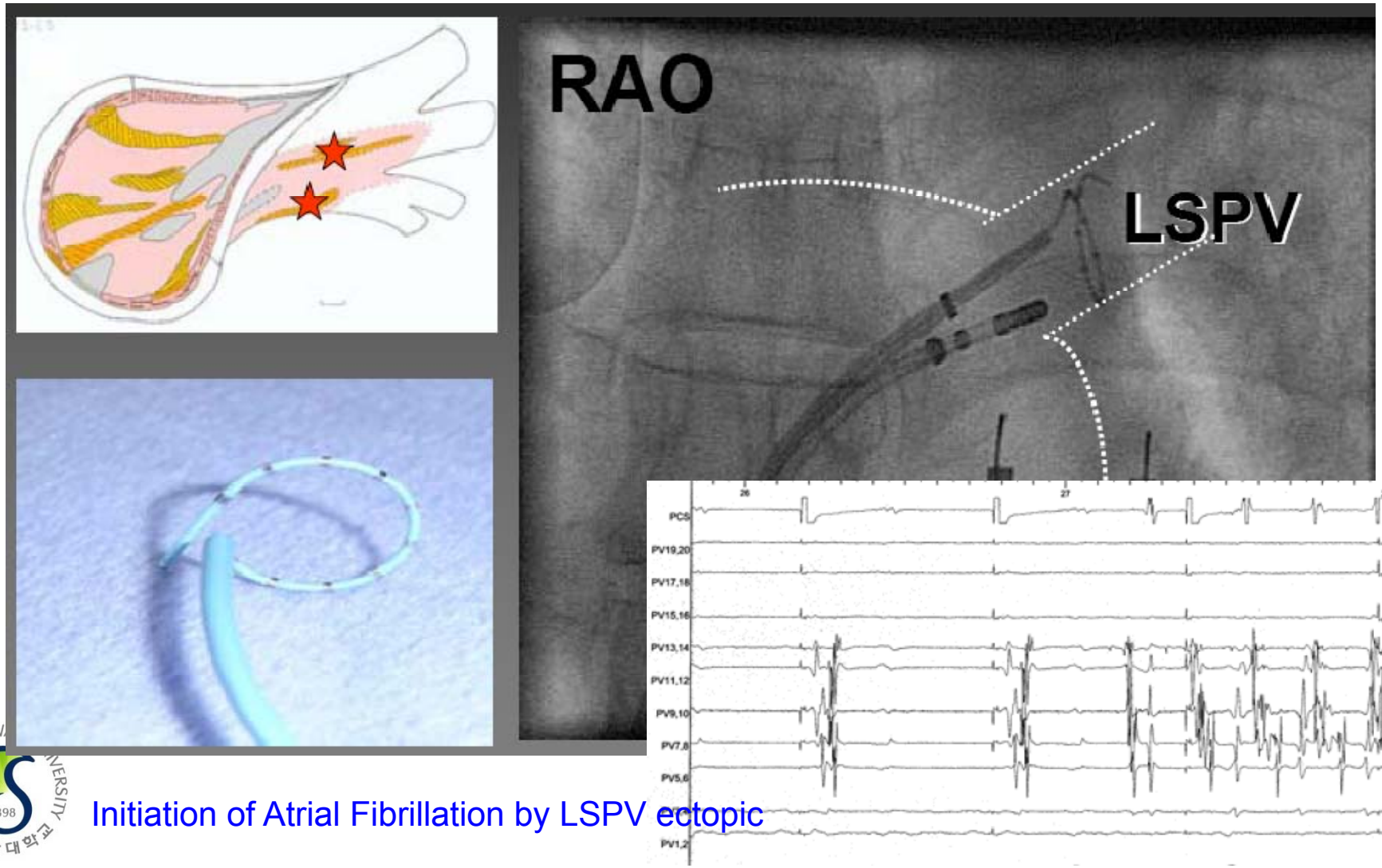
Cox JL. *J Thorac Cardiovasc Surgery 1991*

- Focal AF

Haissaguerre M. *N Engl J Med 1998*

: foci in the pulmonary veins(41 of 45 patients)

Myocardial sleeves extending from the LA into PVs.



Initiation of Atrial Fibrillation by LSPV ectopic

- With the identification of PV triggers of AF, the AF ablation was to target the site of specific PV triggers
- Inconsistent triggers and a high incidence of PV stenosis limited this approach.

  : Ablation strategy from the PV tissue itself to PV Antral isolation.
- PV Antral isolation (electrically disconnecting the PV from the LA) has become the cornerstone for ablation of AF.
- PV isolation alone may be an adequate strategy for paroxysmal AF without significant structural heart disease.
- PV isolation alone appears inadequate in other AF patients (persistent AF, AF with CHF and AF with significant underlying heart disease).
- The mechanisms of initiation and maintenance of AF may differ.

Reasons of AF catheter ablation

- Improvement in quality of life: symptomatic AF
- Decreased stroke risk
- Decreased heart failure risk
- Improved survival: on-treatment analysis of the AFFIRM study
  Corley SD. *Circulation 2004*
  DIAMOND study (retrospective study)
  Pedersen OD. *Circulation 2001*
  AF ablation long-term study
  Pappone C. *J Am Coll Cardiol 2003*

On-treatment analysis of the AFFIRM study

Increased risk of death
: increasing age, coronary artery disease, congestive heart failure, diabetes, stroke or transient ischemic attack, smoking, left ventricular dysfunction, and mitral regurgitation

Improve survival
: presence of sinus rhythm, warfarin use

			HR: 99% Confidence Limits	
Covariate	*P*	HR	Lower	Upper
Age at enrollment*	<0.0001	1.06	1.05	1.08
Coronary artery disease	<0.0001	1.56	1.20	2.04
Congestive heart failure	<0.0001	1.57	1.18	2.09
Diabetes	<0.0001	1.56	1.17	2.07
Stroke or transient ischemic attack	<0.0001	1.70	1.24	2.33
Smoking	<0.0001	1.78	1.25	2.53
Left ventricular dysfunction	0.0065	1.36	1.02	1.81
Mitral regurgitation	0.0043	1.36	1.03	1.80
Sinus rhythm	<0.0001	0.53	0.39	0.72
Warfarin use	<0.0001	0.50	0.37	0.69
Digoxin use	0.0007	1.42	1.09	1.86
Rhythm-control drug use	0.0005	1.49	1.11	2.01

*Per year of age.

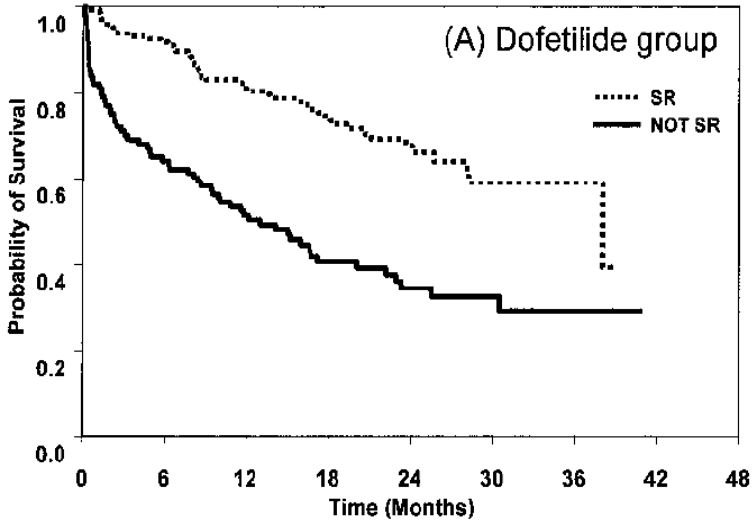
Corley SD. *Circulation 2004*

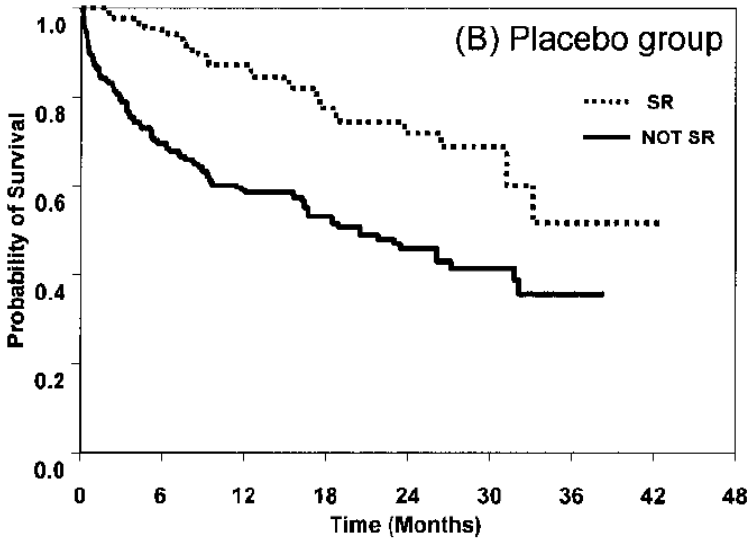
DIAMOND (The Danish Investigations of Arrhythmia and Mortality ON Dofetilide) study

Pedersen OD. *Circulation 2001*

- 506 patients with CHF or recent MI and AF-AFl at baseline .

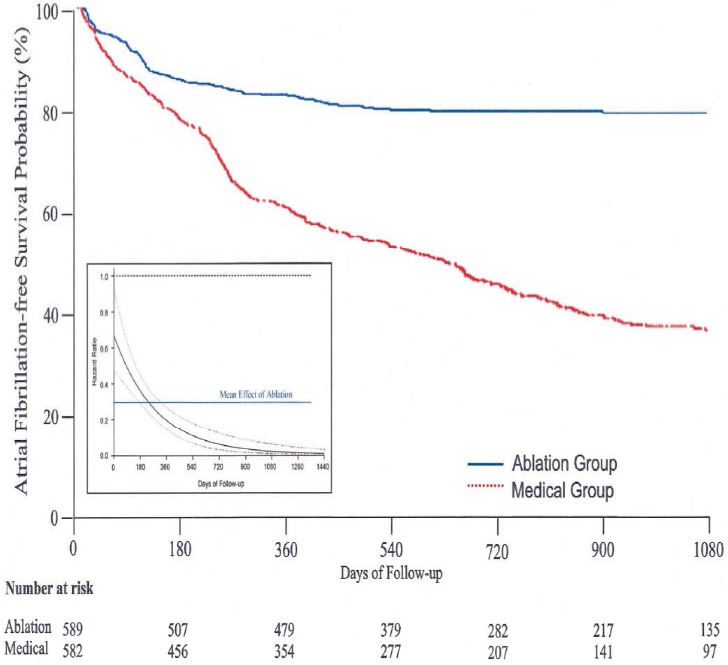
- Cardioversion including DC: 59% with dofetilide vs 34% with placebo
- Maintaining sinus rhythm:
  79% with dofetilide vs 42% with placebo (*p<0.001)*
- Dofetilide had no effect on all-cause mortality.
- Restoration and maintenance of sinus rhythm:
  reduction in mortality (RR=0.44, p<*0.0001)*
- Restoration of sinus rhythm is associated with improved survival.

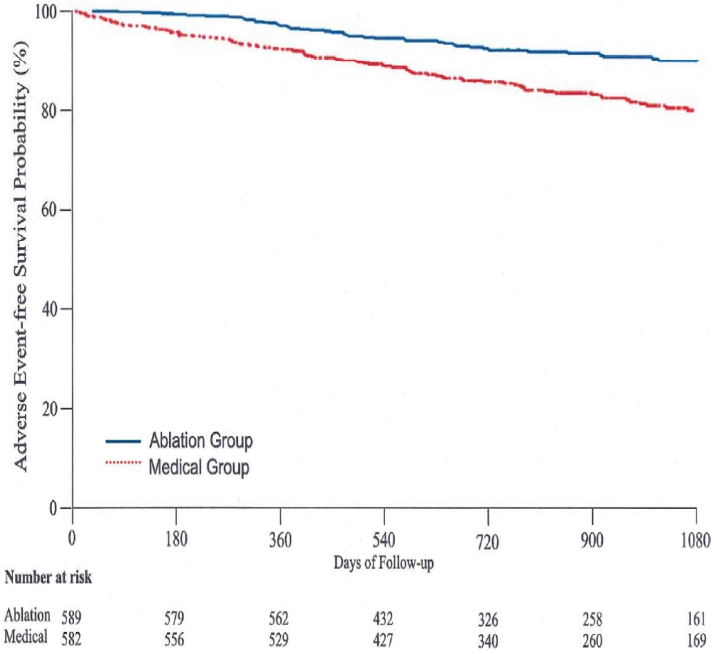




AF ablation long-term study

• To investigate the circumferential PV ablation for AF to maintain sinus rhythm, thus reducing mortality and morbidity while enhancing quality of life.
• Median FU 900 days
• Hazard ratios of 0.46 (*p< 0.001)* for all-cause mortality,
0.45 (*p< 0.001*) for morbidities mainly due to HF and ischemic cerebrovascular events,
0.30 (*p< 0.001*) for AF recurrence.





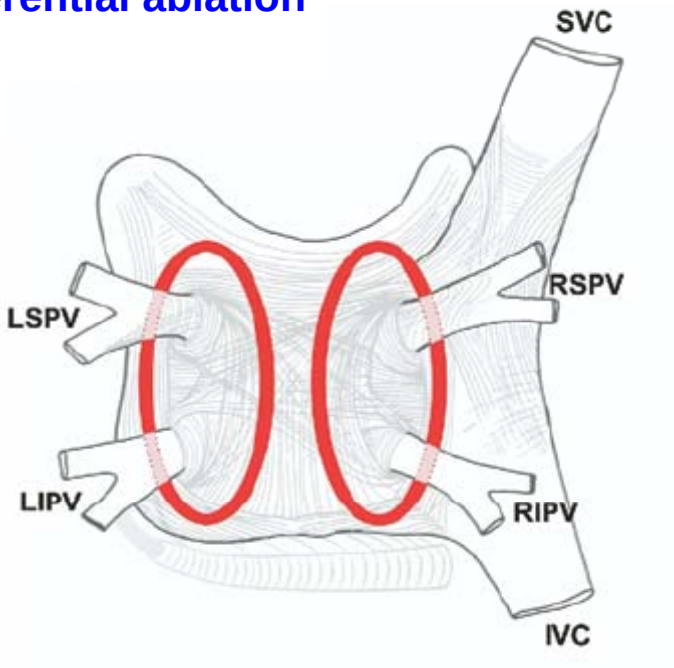
Pappone C. *J Am Coll Cardiol 2003*

The goals of AF ablation

: to prevent AF 1) by eliminating the trigger that initiates AF or

2) by altering the arrhythmogenic substrate.

Circumferential ablation (PVI)



PVs: the most common site of triggers for AF

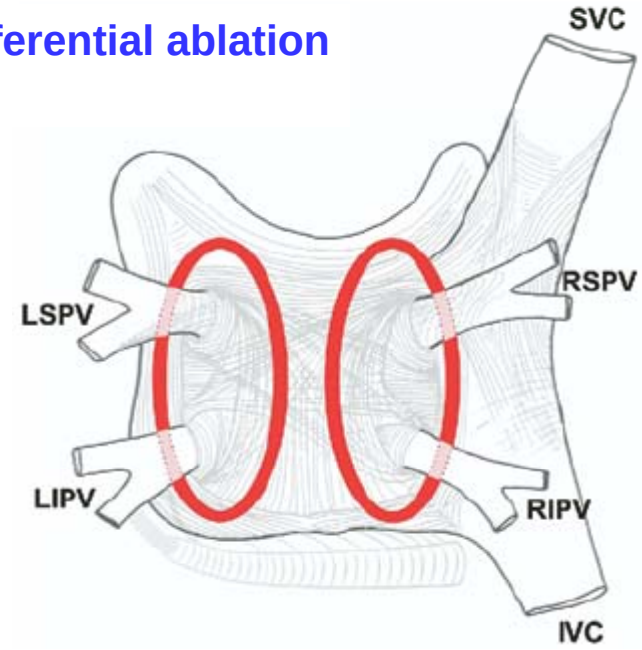
Circumferential lesions also alter the arrhythmogenic substrate

by elimination of tissue located near the atrial–PV junction

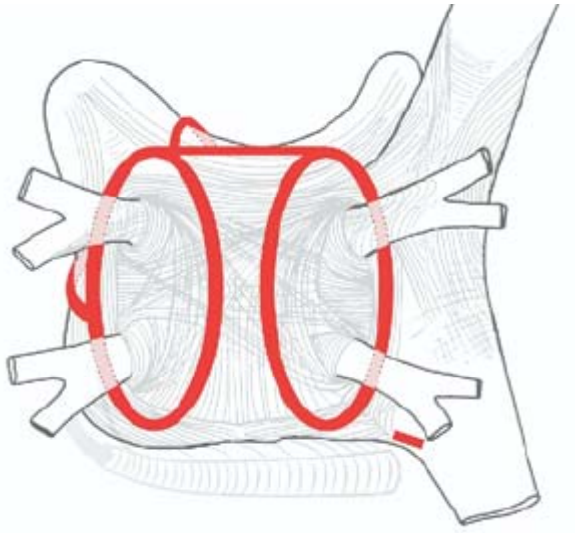
by reduction of the mass of atrial tissue needed to sustain reentry

by interrupt sympathetic and parasympathetic innervation.

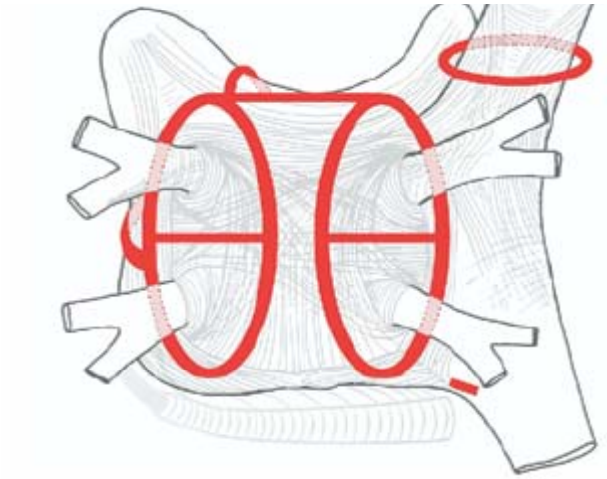
Circumferential ablation (PVI)



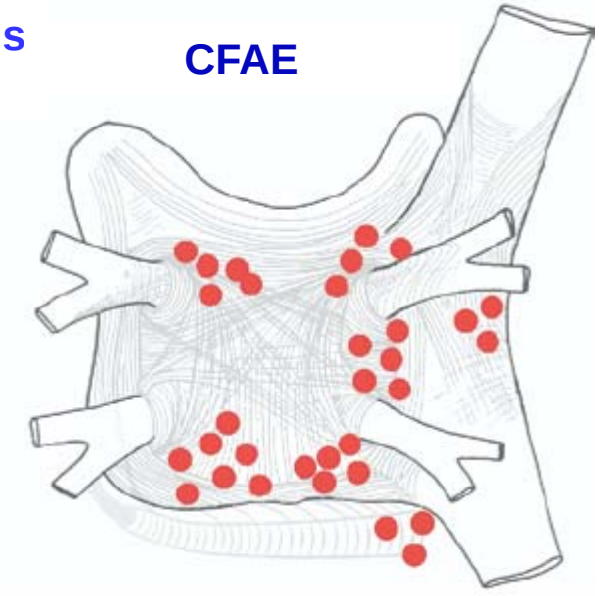
Circumferential ablation + roof line + mitral isthmus line+ cavotricuspid isthmus



Circumferential ablation + roof line + mitral isthmus line+ cavotricuspid isthmus + lines b/w sup and inf PVs + SVC isolation



CFAE



Calkins H. *Heart Rhythm 2007*

Patient selection

• Catheter ablation is a reasonable alternative to pharmacological therapy to prevent recurrent AF in symptomatic patients with little or no LA enlargement. (Class 2A recommendation, level of evidence C)

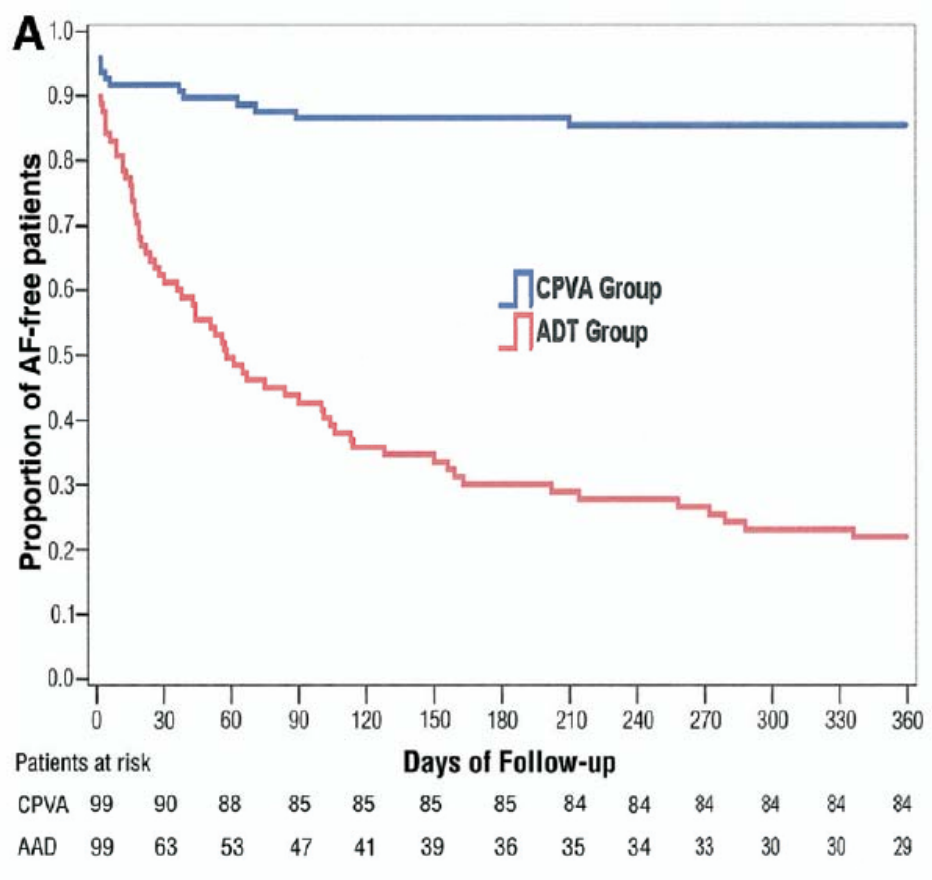
ACC/AHA/ESC 2006 guideline

• Catheter ablation should be considered after failure of antiarrhythmic medication for recurrent paroxysmal AF.

• Second-line therapy for the maintenance of sinus rhythm for AF.
• Selected symptomatic patients with heart failure and/or reduced ejection fraction.
• LA thrombus: a contraindication to catheter ablation of AF.

The APAF Study

- To assess the role of AF ablation in a long history of PAF as compared with antiarrhythmics
- 198 patients
- Age: 56 ± 10 year
- PAF of 6 ± 5 years' duration (mean AF e
antiarrhythmics
- CPVI + CTI ablation and antiarrhythmics
- 1 yr FU, 86% in CPVI vs 22% in antiarrh
tachyarrhythmias (*p<0.001*)
- a repeat ablation: 9% in the CPVA group



Pappone C. *J Am Coll Cardiol. 2006*

The A4 Study

• To compare AF ablation with AADs in patients with paroxysmal AF who failed at least 1 AAD.

• multicenter (2 in North America and 2 in Europe)

• 112 patients, Age: 51 ± 11 year

• PAF of ≥ 6 mo duration (mean AF episodes 12/month) who had failed antiarrhythmics

• CPVI and antiarrhythmics 6 wks after AF

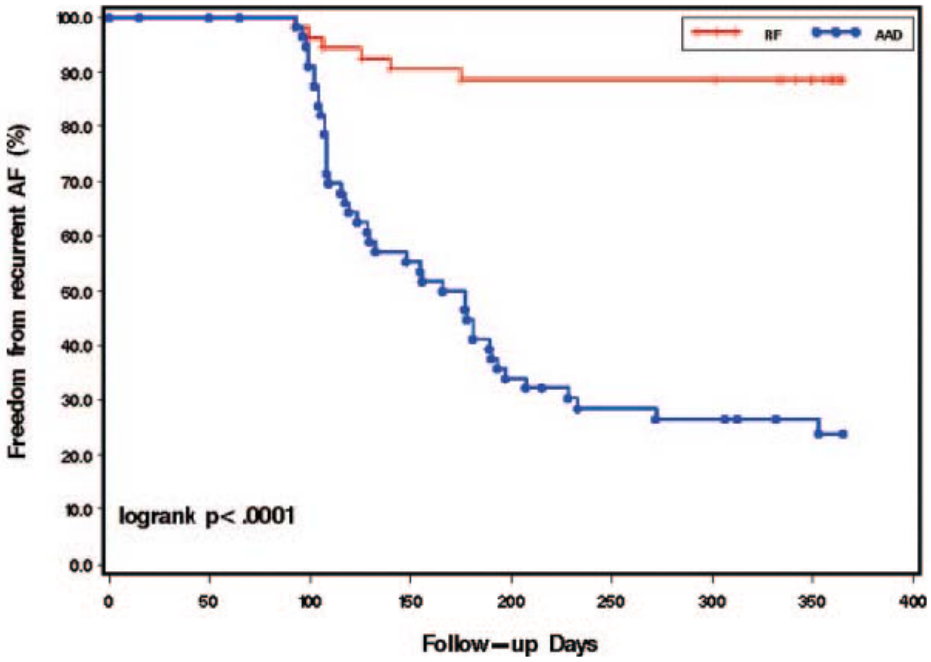
• allowed 2 repeat ablation during the 90-d

(repeat ablatior

• CTI ablation (64%), roof line (17%), mitra

• 1 yr FU, 89% in CPVI vs 23% in antiarrhy

(*p<0.001*)

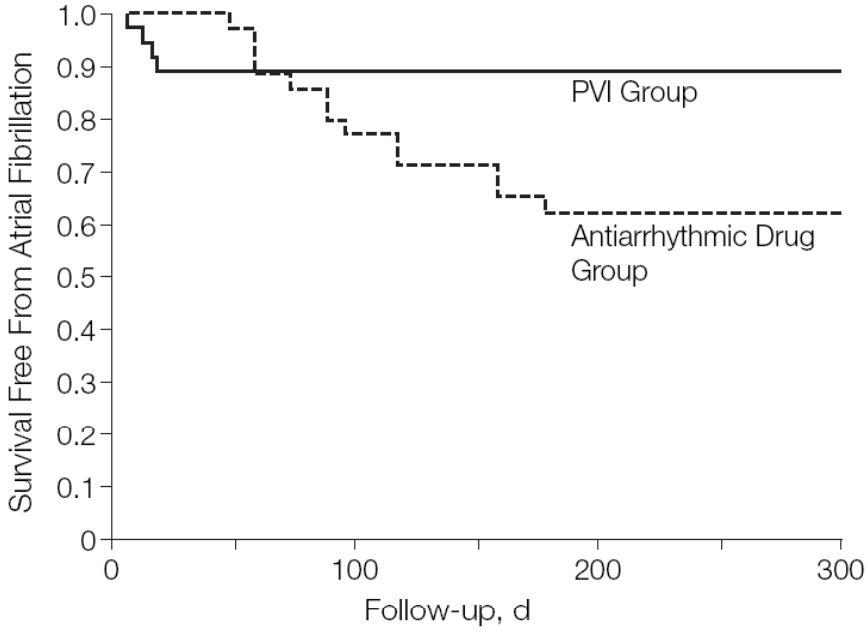


Jais P. *Circulation 2008*

AF RFCA as 1st line treatment of AF

- 70 patients aged 18~75 years who experienced monthly symptomatic AF episodes for at least 3 months
- PVI using radiofrequency ablation (n=33) or antiarrhythmic drug treatment (n=37), with a 1-year FU.
- Re-ablation: 12% in ablation
- Free from AF: 87% in RFCA vs 37% in antiarrhythmics
- Hospitalization: 9% in R

Wazni OM. *JAMA 2005*



No. at Risk							
PVI Group	32	28	28	28	28	28	28
Antiarrhythmic Drug Group	35	34	23	19	13	13	13

Catheter ablation vs AAD in paroxysmal AF

: The superiority of catheter ablation

Pt No				Duration AF	age	EF	LA	procedure	%	control	add AAD	repeat ablation	mean ablation	FU	Free Arrhy case	Free Arrhy control
198	APAF	Pappone	JACC 2006	6yr	56	61	39	CPVA+CTI	100	AAD	6wk	9%		1yr	86	22 %
112	4A	Jais	Cicul 2008	>6mo	51	64	40	PVI+CTI	64	AAD		43%	1.8	1yr	89	23 %
	2Euro 2NorAm							+MI	30							
								+Roof line	17							
70	1st line Tx	Wanzi	JAMA 2005	>3mo	54	54	42	PVI		AAD		12%		1yr	87	37 %

Persistent and long-standing persistent AF

• Recurrent persistent AF only after failure of at least 1 antiarrhythmic medication and severe symptoms despite rate control

(*ACC/AHA/ESC 2006 guideline*)

Literature Review of Catheter Ablation for Chronic AF

Study	No. of Patients	Follow-Up, mo	Technique	PVI (Confirmed)	Linear Lesions	Complex Potentials	Success in CAF Group	AAD Status	Procedure Time, min	Fluoroscopy Time, min	Serious Complications
Willems et al, 2006[45]	62	14–17	EAM, lasso	Yes	Roof, MI	No	45% (63% in linear-ablation group)	None	No data*	73±17*	CVA ×1, tamponade ×1
Haïssaguerre et al, 2005[22]	60	11±6	Lasso	Yes	Yes	Yes	95%	None	264±77	84±30	LAA isolation ×1
Oral et al, 2005[46]	80	9±4	EAM	No	Yes	Yes	68%	None	149±42*	40±11*	None
Oral et al, 2006[35]	146	12	EAM	No	PLA, roof, MI	No	74%	None	96±77	No data	None
Lim et al, 2006[47]	51	17±9	PVI	Yes	No	No	45%	17%	No data	No data	PVS ×1, CVA ×1
Ouyang et al, 2005[44]	40	8±2	Double lasso, EAM	Yes	No	No	95%	None	219±42	28±11	None
Kanagaratnam et al, 2001[43]	71	29±8	EAM, lasso	Yes (31%)	No	No	21%	None	365±77	115±49	PVS >70% in 5 patients
Calo et al, 2006[48]	80	14±5	EAM	No	MI	No	72% (85% biatrial group)	49%	228±32*	41±14*	RPH ×1, hemothorax ×1
Hsu et al, 2004[31]	106	12±7	Lasso	Yes	MI, roof	No	71%	None	232±90*	72±36*	Stroke ×1, tamponade ×2
Bertaglia et al, 2006[49]	74	20±6	EAM	No	MI	No	70%	64%	204±68	28±12	None

PVI indicates PV isolation; CAF, chronic AF; AAD, antiarrhythmic drug; EAM, electroanatomic mapping; MI, mitral isthmus; CVA, cerebrovascular accident; LAA, LA appendage; PLA, posterior LA; PVS, PV stenosis; and RPH, retroperitoneal hematoma.

Only studies in which >90% of recruited patients had persistent or permanent AF are described.

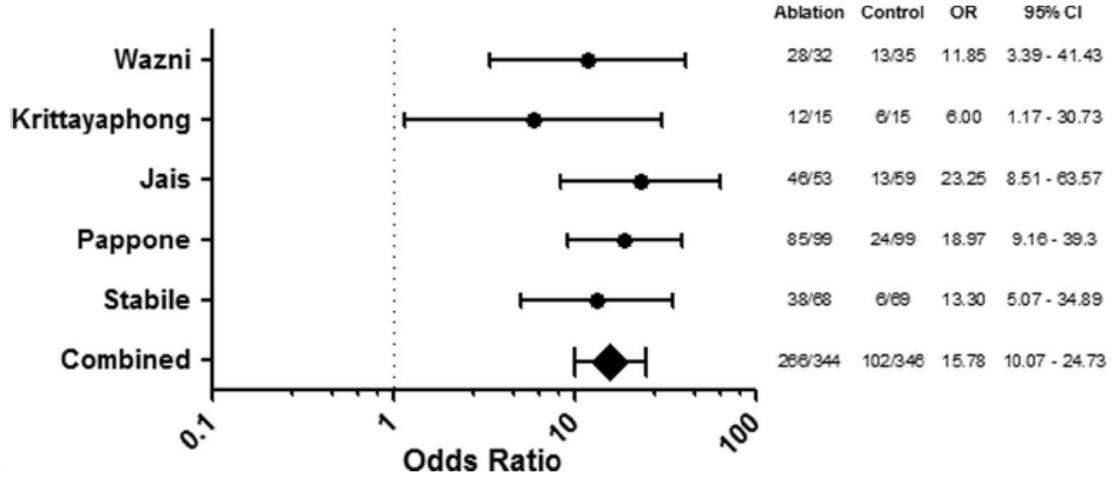
O'Neill MD. *Circulation 2007*

Meta-Analysis of Randomized, Controlled Trials : PVI for the maintenance of sinus rhythm in AF

paroxysmal AF (70%), 55 years old, and EF of 60%.

Trial	Mean Age, y	Female, %	Paroxysmal AF, %	Persistent AF, %	Mean EF, %	Mean LA Diameter, mm	Mean No. of Prior Ineffective AADs	β-Blockers, %
Krittayaphong et al[10]	52	37	67	33	63	39	NR	NR
Wazni et al[14]	54	NR	96	4	54	42	0	60
Stabile et al[13]	62	41	67	33	59	46	NR	10
Oral et al[11]	57	12	0	100	56	45	2	NR
Pappone et al[12]	56	33	100	0	61	39	2	NR
Jais et al[15]	51	16	100	0	64	40	≥1	NR

ORs (ablation versus control) for freedom from AF at 12 mo



17% needed reablation.

Piccini JP. *Circ Arrhythm Electrophysiol 2009*

Meta-Analyses of AADs or Ablation for Treatment of AF

- 63 RF Ablation and 34 AAD studies were included.
- Mean age (55 vs 62 years), duration of AF (6.0 vs 3.1 years)
- Type of AF

  Ablation: PAF/PeAF/Long-standing (70%/15%/14%)

  AAD: PAF/PeAF/Long-standing (56%/35%/8%)
- The success rate of ablation (mean FU: 14 mo)

  single-procedure success rate of ablation off AAD: 57%

  multiple procedure success rate off AAD: 71%

  multiple procedure success rate on AAD or with unknown AAD usage : 77%.
- The success rate for AAD therapy (mean FU: 12 mo) : 52%.
- Major complication of catheter ablation in 4.9%

  Side effects of AAD therapy: approximately 30%

Calkins H. *Circ Arrhythm Electrophysiol 2009*

Preinterventional Diagnostic Modalities

ECG: for diagnosis and quantification of AF

Transthoracic echocardiography

to assess cardiac structure and function.

TEE

to exclude the presence of intra-atrial thrombus before transseptal puncture and catheter manipulation within the LA.

Preinterventional Diagnostic Modalities

ECG: for diagnosis and quantification of AF

Transthoracic echocardiography

to assess cardiac structure and function.

TEE

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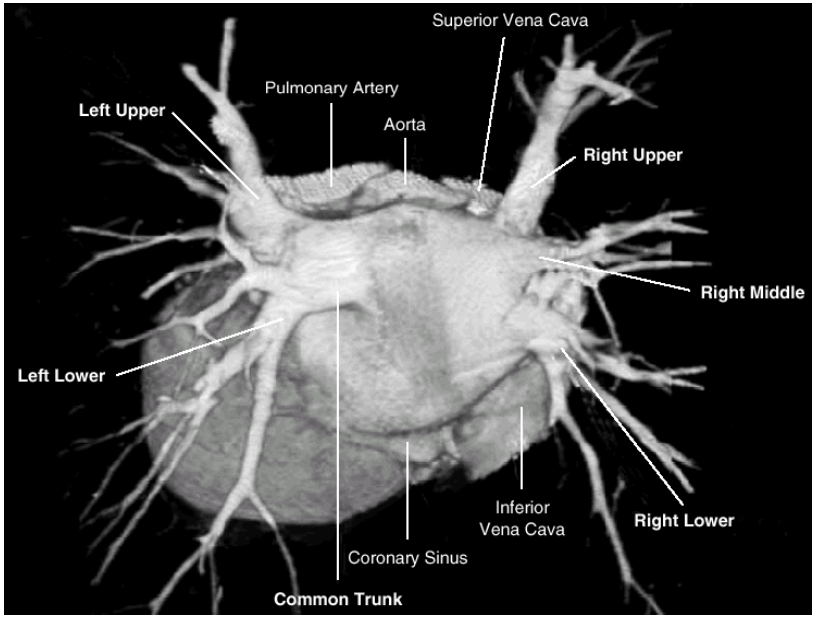
MRI or CT cardiac images

to give detailed anatomic information.

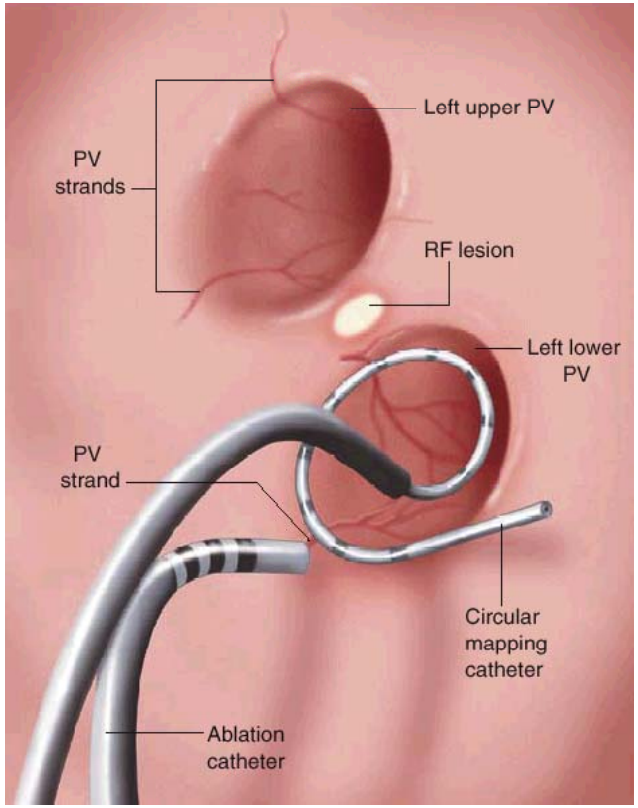


Tools

Radiofrequency energy: for production of myocardial lesions

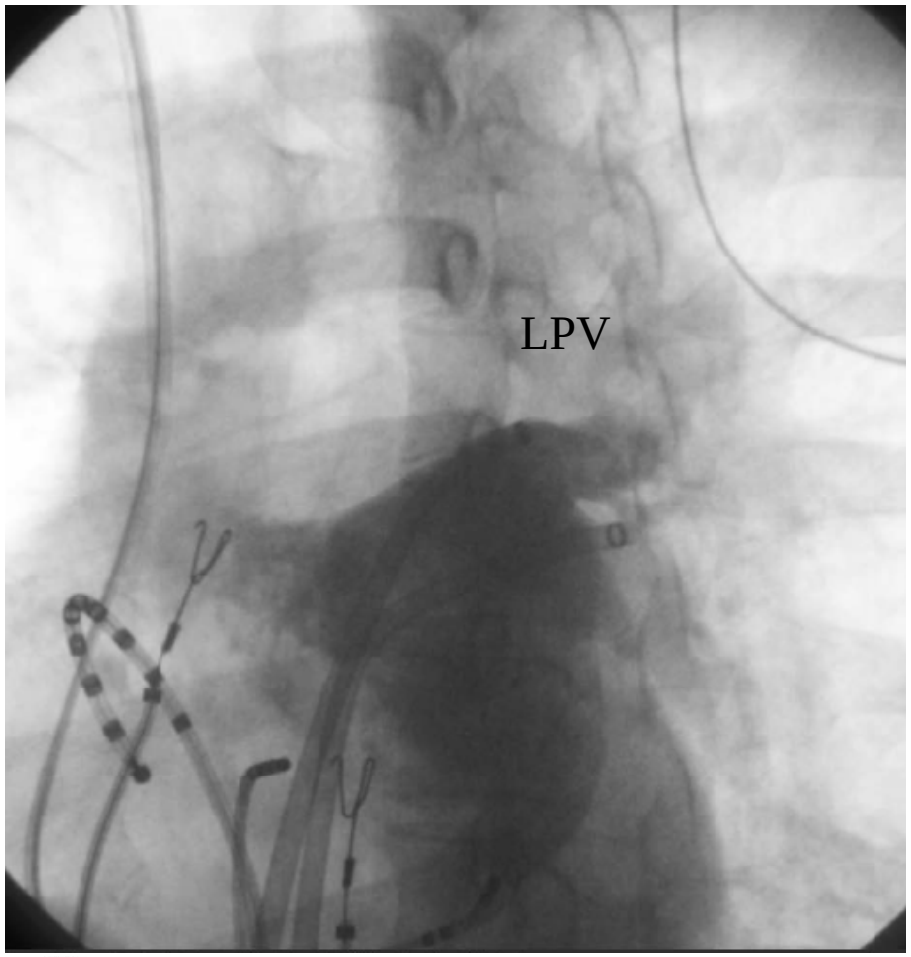
Multielectrode circumferenital mapping catheter

to assess the isolation of PV potentials.

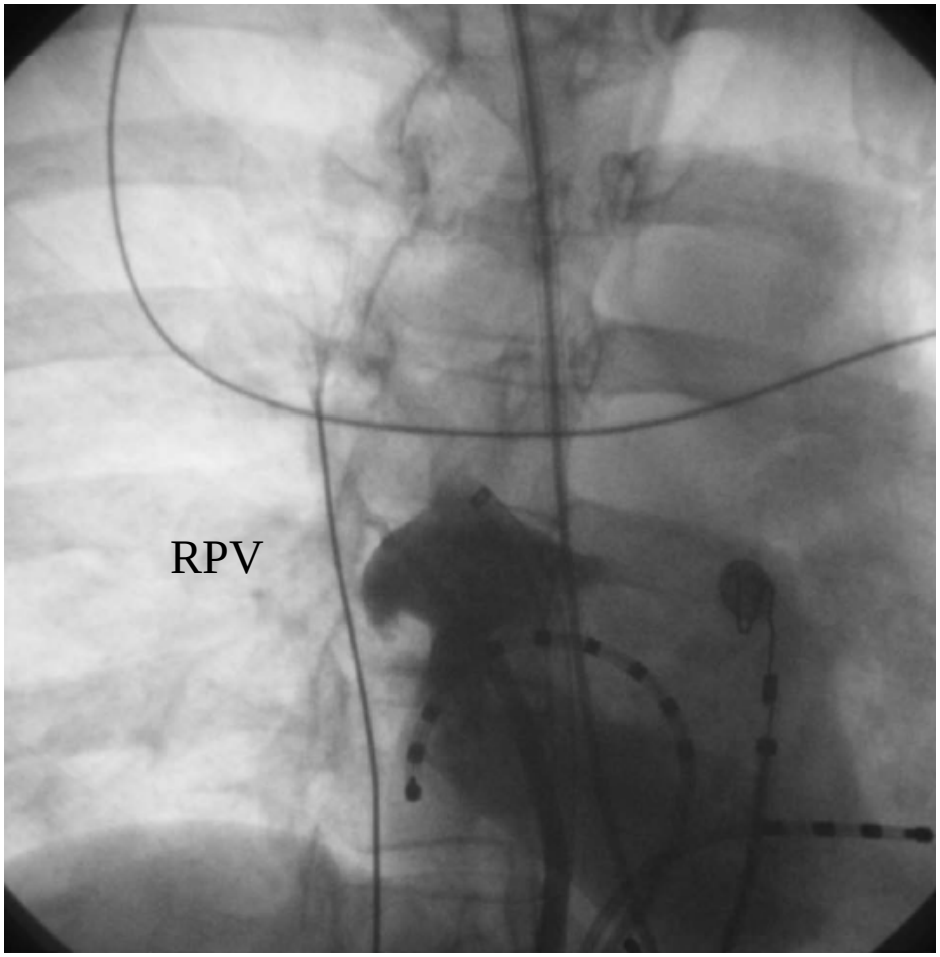


Pulmonary vein venography

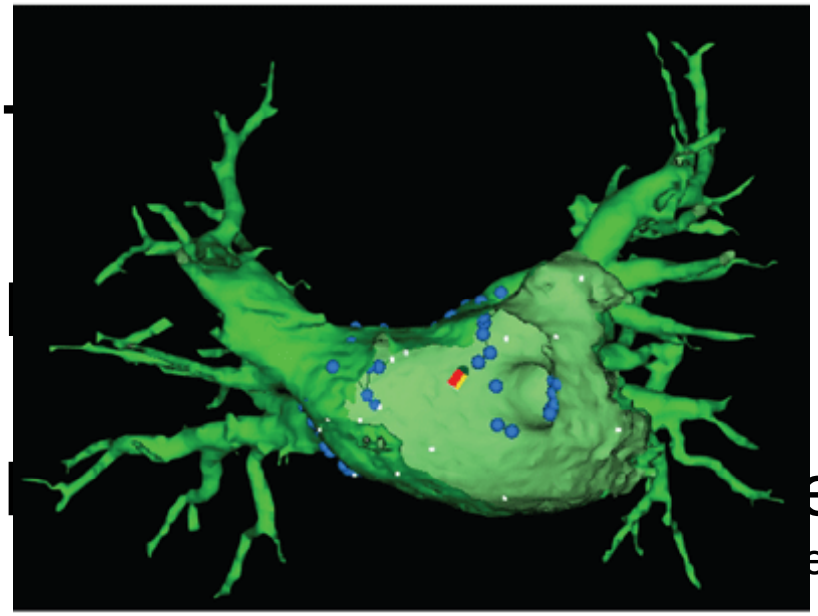
to guide catheter manipulation and determine the size and location of the PV ostia.



LAO 40



RAO 30



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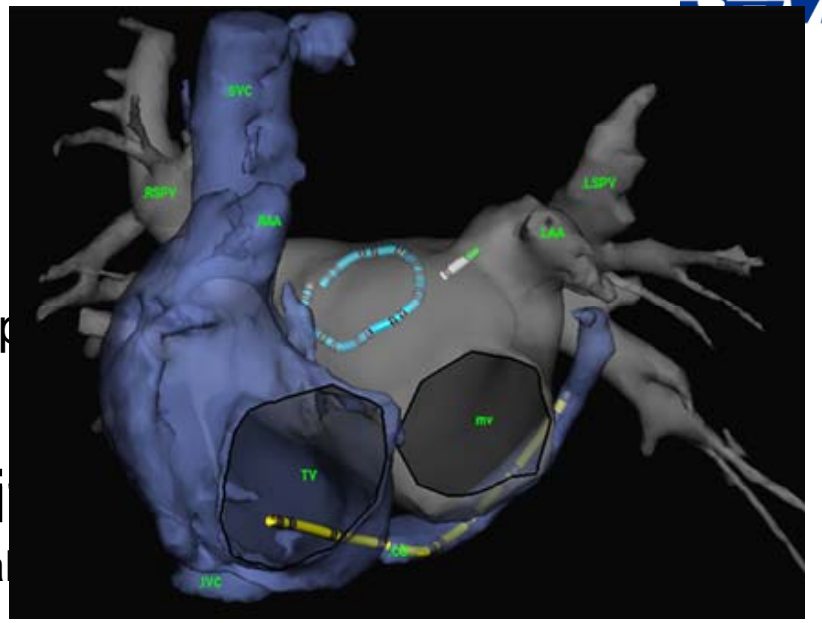
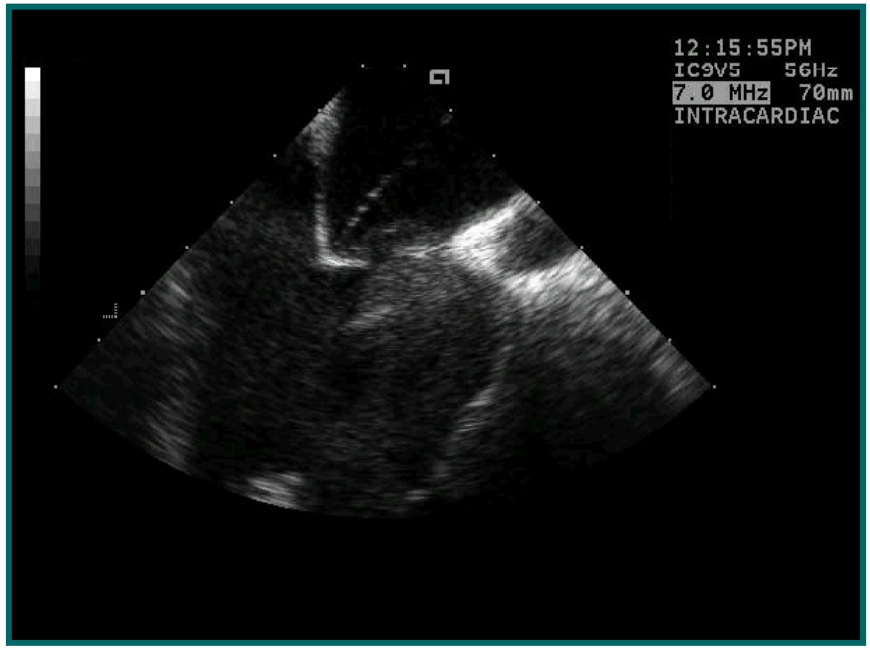


Electroanatomic mapping (CARTO, NavX)

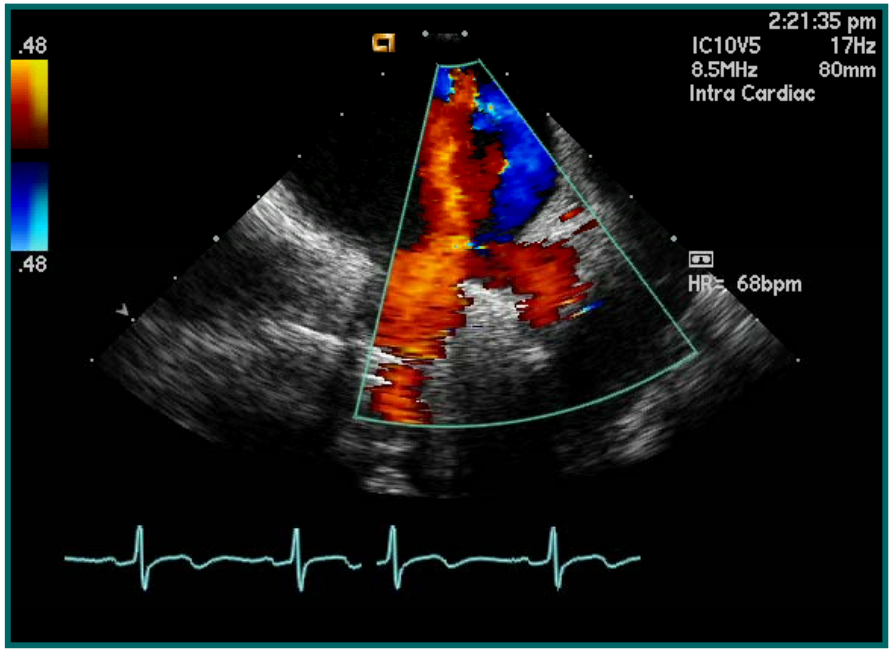
to localize a given electrode position in 3D space and thereby enable the construction of atrial anatomy.

Intracardiac echocardiography

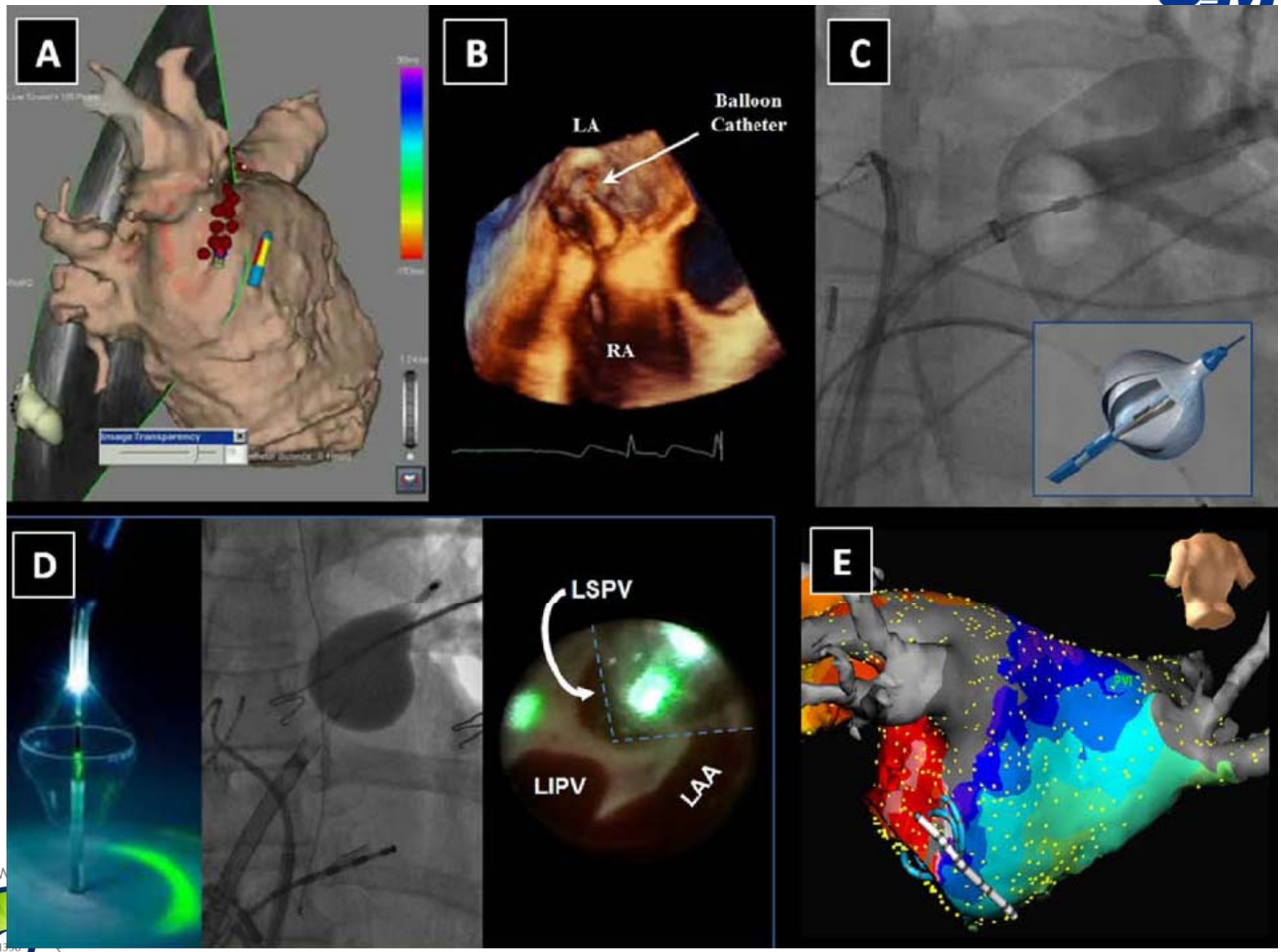
to provide real time anatomic information and facilitate the transseptal puncture.



Transseptal Puncture of the Intra-atrial Septum



Left Inferior and Superior Pulmonary Vein Blood Flow



Ahmed H. *Heart Rhythm 2009*

Catheter with force-sensing technology

lateral force, axial force, and contact force
angle that the ablation catheter applies to the tissue

Remote catheter navigation

Magnetic navigation system designed by Stereotaxis

Robotic controlled catheter system by Hansen Medical.

Techniques for AF ablation

- PAF: a trigger-dependent phenomenon
- Persistent AF and chronic AF: complex and diffuse abnormality of the atrial substrate.

- Modification of the triggers and/or substrate of AF.

- 3 principal techniques for catheter ablation of AF:

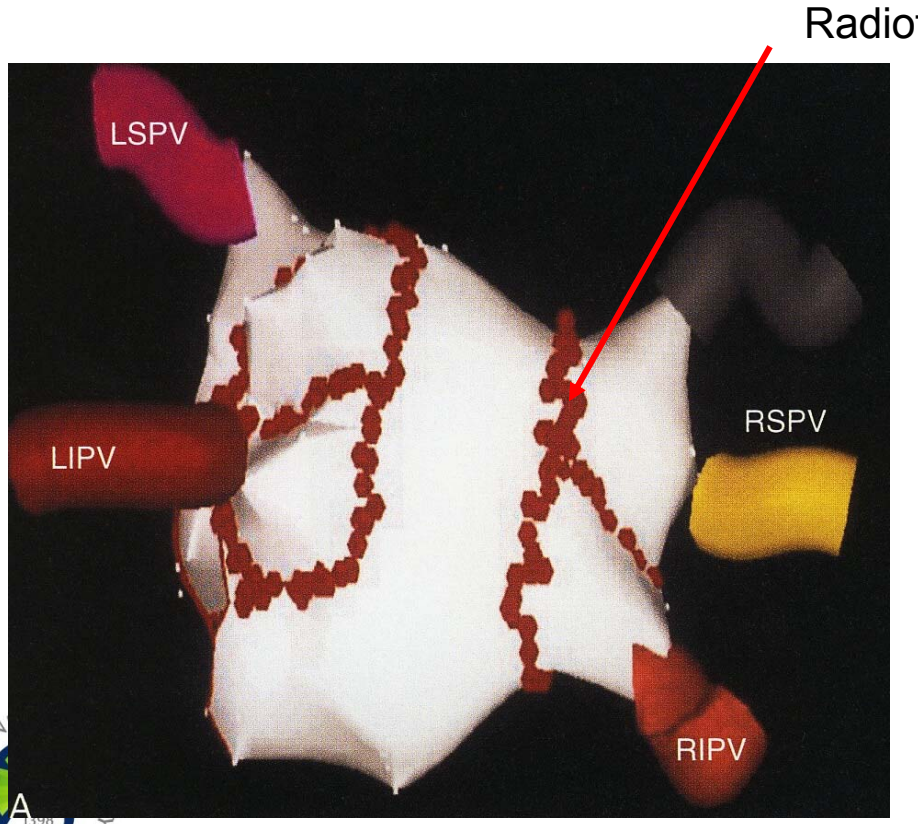
  PV isolation

  LA linear ablation

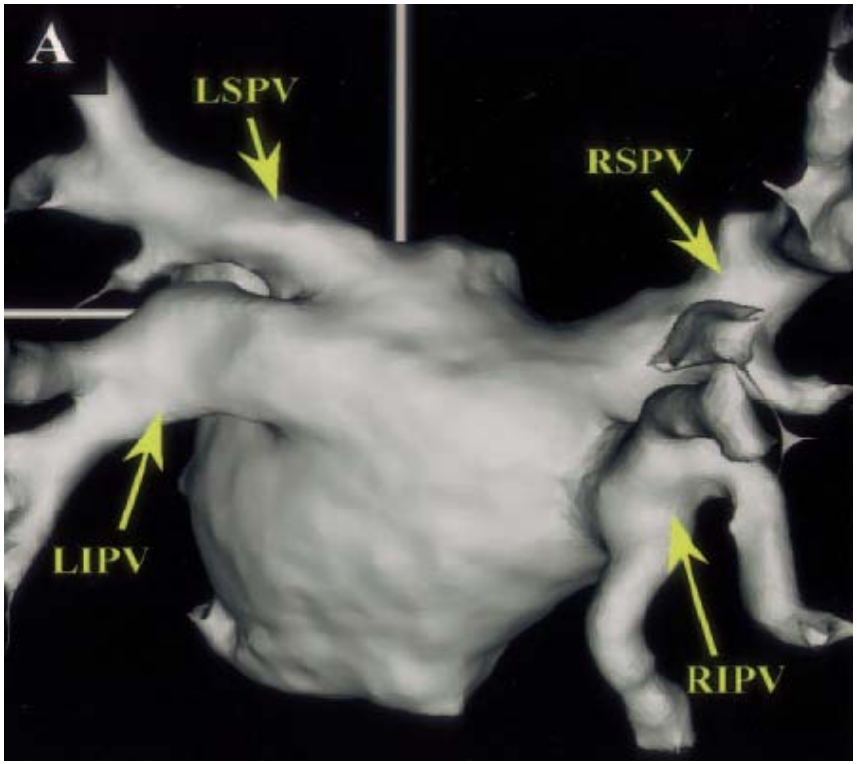
  Ablation of LA electrophysiological targets.

PV isolation

- Isolating the LA from proarrhythmic PV activity.
  confirmed by absence or dissociation of PV potentials:
  end point for treatment of most patients with PAF
- Success rates of 60~85% in patients with PAF without antiarrhythmics

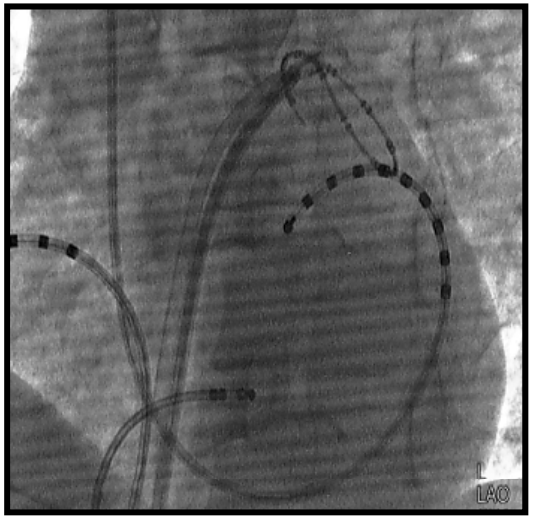


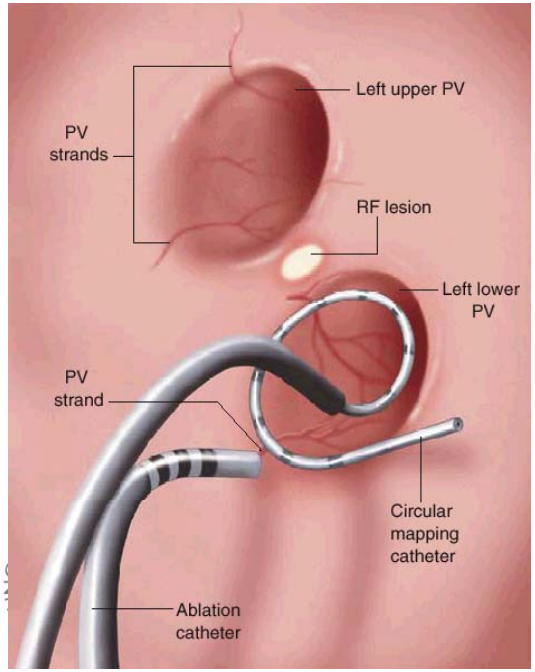
CARTO

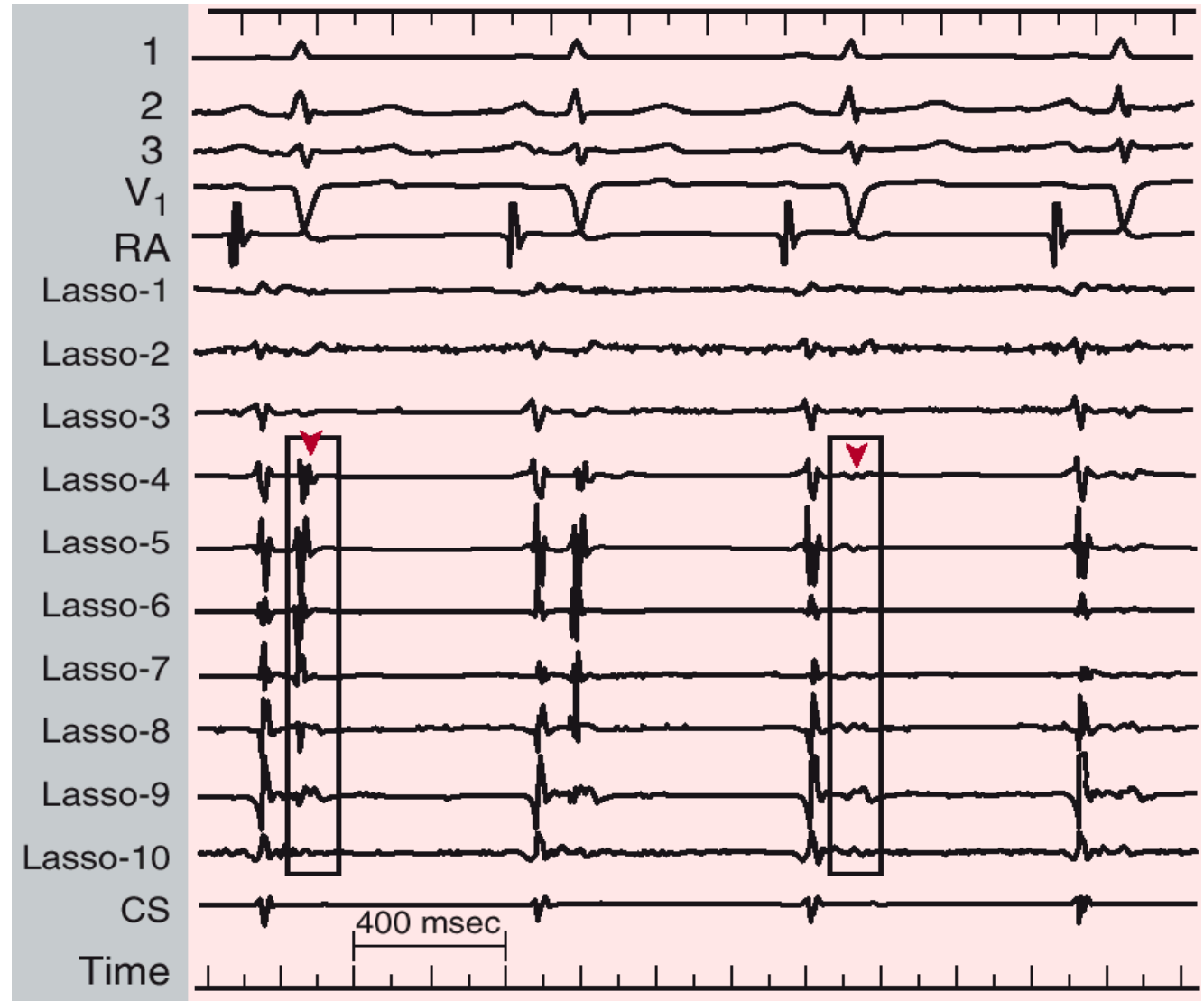


Cardiac CT

Disappearance of pulmonary vein potentials during segmental PV ablation







Isolating all PV versus arrhythmogenic PV

- 105 patients, PAF (73%) and PeAF, 57 YO, All PVI vs arrhythmogenic PVI
- Trigger identification by stimulation protocol

  (1) isoproterenol infusion (starting at 3~5 μg and increasing by 3~5 μg every 3 minutes to a maximum of 20 μg)

  (2) cardioversion of AF induced by LA or RA pacing (15-beat runs at 10-mA and 2-ms, decrementing from 250 to 180 ms with and without isoproterenol infusion).
- AF triggers identified in 2 veins in 29%, 3 veins in 40%, and 4 veins in 31%
- Non-PV triggers: 13%
- sparing of ≥ 1 PV in 69% of arrhythmogenic PV group (mean 2.9 PVI)
- AAD for 6 wks
- 1 yr FU, single procedure AF free without AAD, 59% vs 61%, *p=ns*
- repeat ablation 24%, (20% vs 29%, *p=ns*)
- FU 17 mo with ≥ 1 ablation, AF control, 92% vs 94%, *p=ns*

Dixit S. *Heart Rhythm 2008*

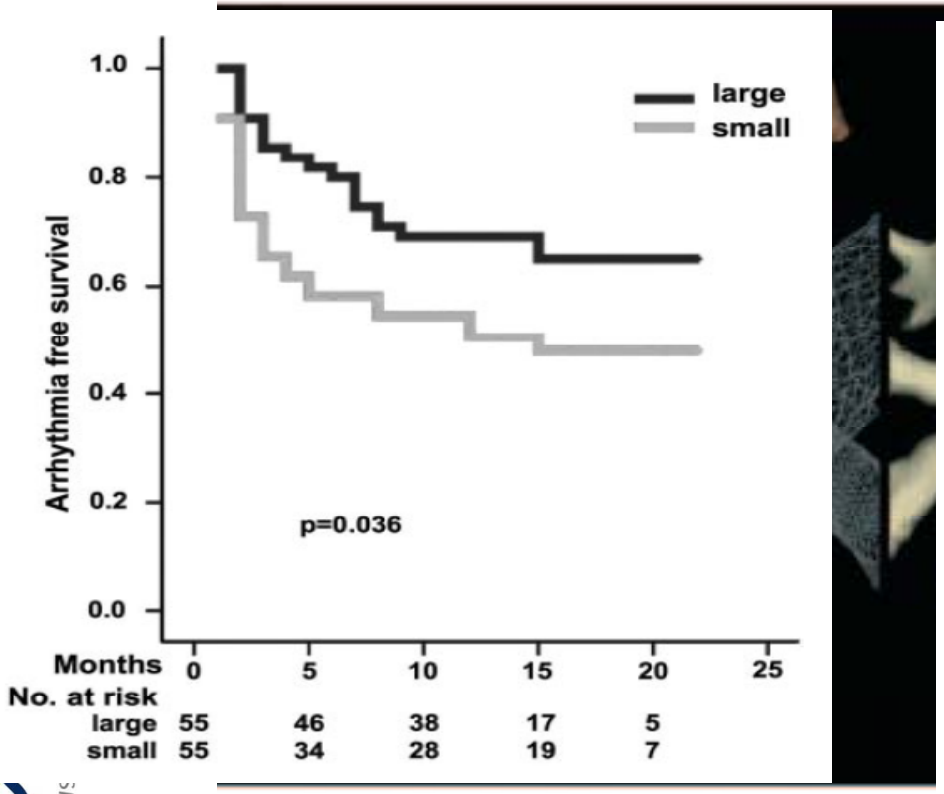
Segmental PVI vs Wide-Area Circumferential Ablation

- After a single procedure without antiarrhythmic drugs
- Wide-area circumferential ablation had a higher rate of success (freedom from recurrence of AF) than ostial PVI.

Large vs small (67% vs. 49%, *p<0.05,* FU 15 mo) in PAF and PeAF for 5.5 yrs

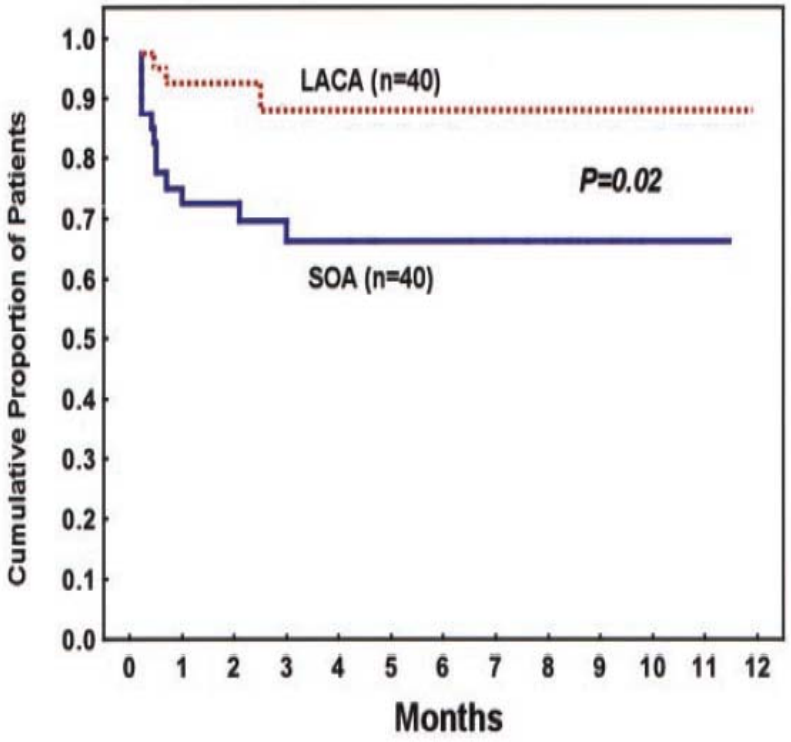
LACA vs SOA (88% vs. 67%, *p=0.02,* FU 6 mo) in PAF

LACA: MI ablation+, posterior LA line+



Arentz T. *Circulation 2007*

Freedom from recurrent PAF



Oral H. *Circulation 2003*

- Large circumferential area around both ipsilateral PVs with verification of conduction block is a more effective than isolation of each individual PV.

- Mechanisms
  1. Atrial myocardium surrounding the PVs is involved in the pathophysiology of AF.
  2. Arrhythmogenic ostial foci
  3. Parasympathetic innervation
  4. Sustained rotors related to stretch around the PVs

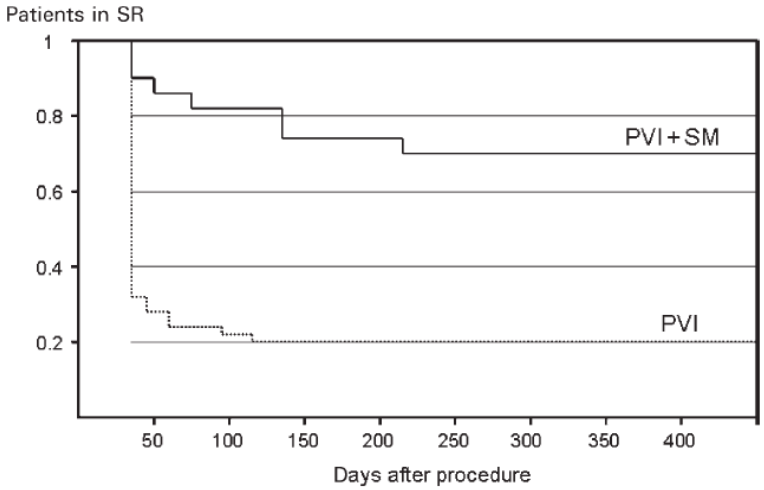
LA linear ablation

- In persistent AF, PVI alone is insufficient.
- 62 patients with PeAF
- PVI, CTI ablation plus ablation at the roof and mitral isthmus

  vs PVI and CTI ablation in PeAF lasting for 7 mo

  FU 1.3 yr, sinus rhythm: 69% vs 20%

Willems S. *Eur Heart J 2006*



- Macroreentrant arrhythmias during follow-up are frequently related to gaps in previous linear lesions.

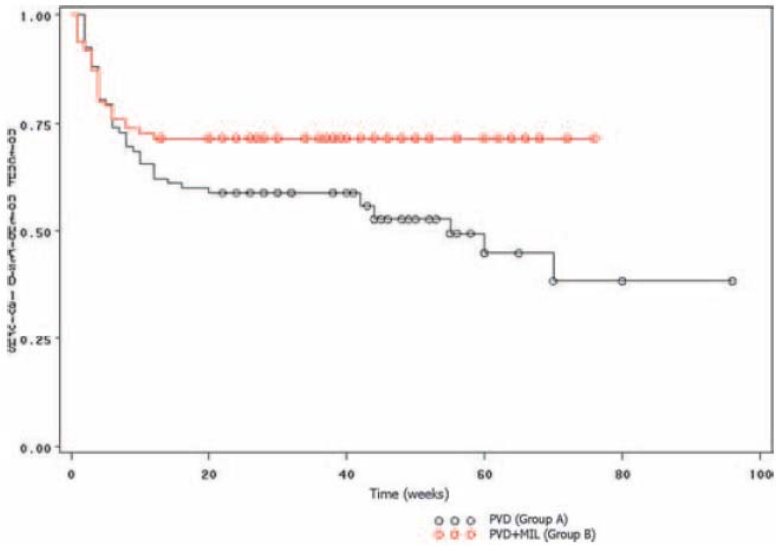
RF Catheter Ablation With Additional Ablation Lines
(mitral isthmus, roof, or posterior LA lines)

• PVI + mitral isthmus line vs PVI, 71% vs 53%, in PAF & PeAF, *p<0.01,* FU 1 yr

74% vs 36% in PeAF, *p<0.01*

76% vs 62% in PAF, p<0.05

continued antiarrhythmics 56% vs 50% , in PAF & PeAF, *p=ns*



Fassini G. *J Cardiovasc Electrophysiol 2005*

RF Catheter Ablation With Additional Ablation Lines
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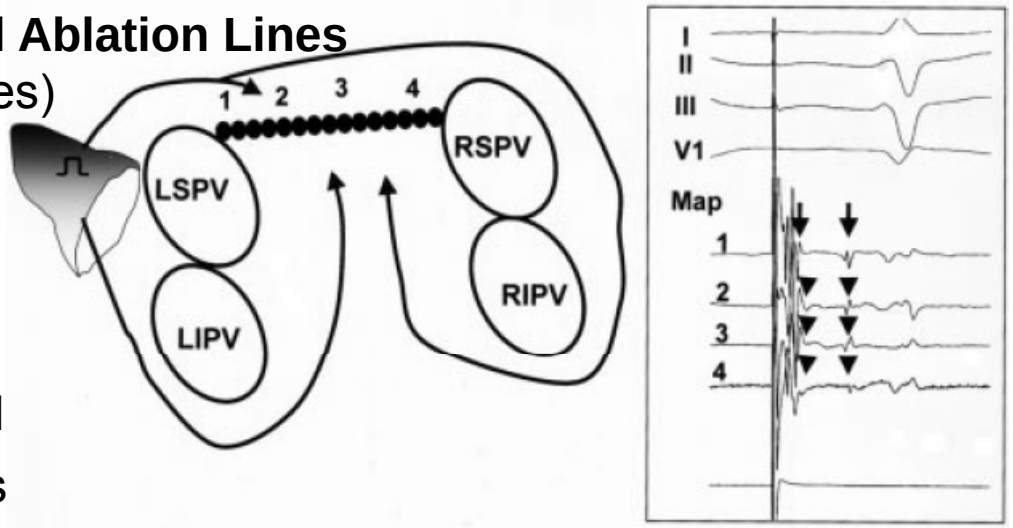
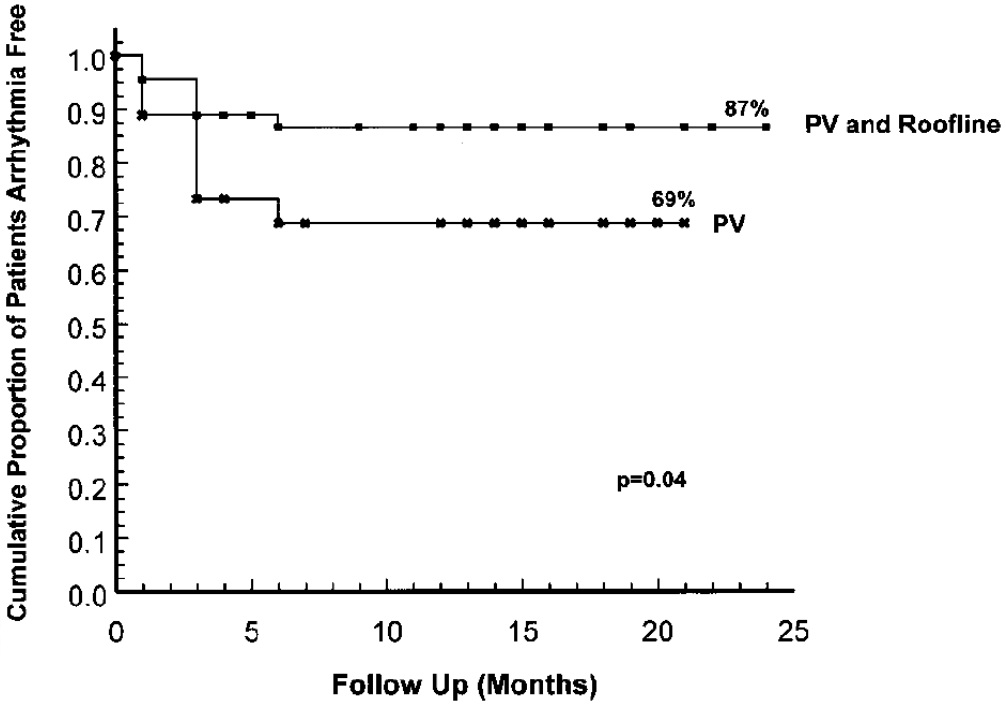


- Additional roof line
- in PAF, PVI+CTI+roof line vs PVI+CTI

  55 yrs, symptomatic AF for 63 months

  complete block at the LA roof could be achieved in 96%

  FU 15 mo, Arrhythmia free without antiarrhythmics: 87% vs 69%, *p<0.05*



Hocini M. *Circulation 2005*

Radiofrequency Catheter Ablation With Additional Ablation Lines

(mitral isthmus, roof, or posterior LA lines)

Some studies did not find a significant difference in recurrence of AF.

• PVI+mitral isthmus line+superior LA line vs PVI, in PAF

86% vs 58 %, *p<0.05*, FU 1 mo

90% vs 82%, with additional Mx, *p=ns,* FU 9 mo

continued antiarrhythmics 54% vs 62% , *p=ns*

Sheikh I. *J Interv Card Electrophysiol 2006*

Radiofrequency Catheter Ablation With Additional Ablation Lines

(mitral isthmus, roof, or posterior LA lines)

PAF %	PeAF %	Pt No				Duration AF		age	EF	LA	procedure	add	%	control	add AAD		repeat ablation	FU		Free Arrhy case	Free Arrhy Control		
100		200	**MI line**	Jais	Circul 2004	7	yr	55	71	46	PVI	**CTI+MI**	100	PVI+CTI			41%	1	yr	**87**	69	%	
67	33	187	**MI line**	Fassini	JCE 2005			55	56	43	PVI	**MI block**	76	PVI	6	mo		1	yr	**71**	53	%	
100		200	**MI line**	Haissaguerre	Circul 2004	7	yr	54	71	46	PVI	**CTI+MI**	92	PVI+CTI				7	mo	**83**	74	%	
	100	62	**LA line**	Willems	EHJ 2006	7	mo	59		48	PVI	**CTI+ LA line**	100	PVI+CTI	2	mo		1.3	yr	**69**	20	%	
												MI block	72										
												Roof line block	44										
100		90	**Roof line**	Hocini	Circul 2005	6	yr	55	67	41	PVI	**CTI+roof line**	100	PVI+CTI				15	mo	**87**	69	%	
100		100	**MI+roof line**	Sheikh	JICE 2006			61	54	41	PVI	**MI+roof line**	100	PVI	1	mo		9	mo	**90**	82	%	AAD 62% AAD 54%
63	27	560	**MI+pLA line**	Pappone	Circul 2004	7	yr	57		40	CPVA	**MI+pLA line**		CPVA				1	yr	**83**	76	%	

PVI, LA ablation and additional CTI ablation only for typical atrial flutter

PVI+LA ablation+ CTI ablation vs PVI+LA ablation, PAF & PeAF

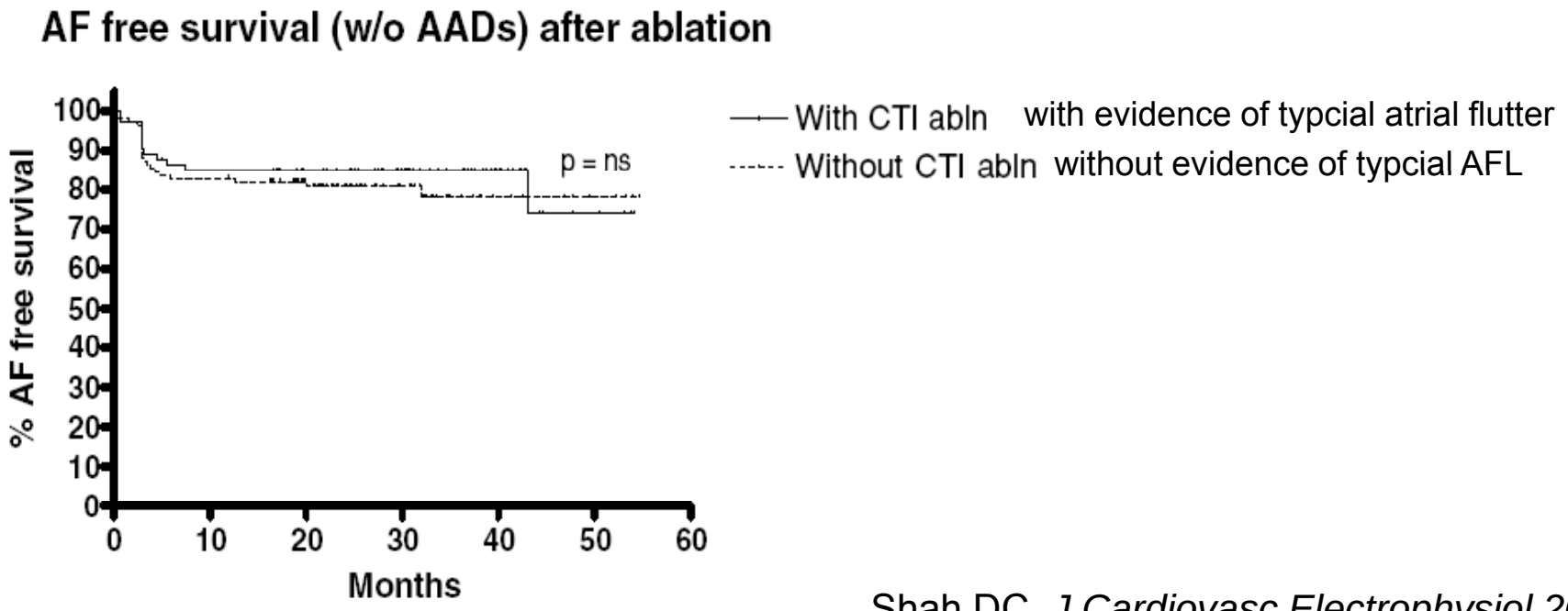
118 patients, FU 30 mo

AF recurrence (25% vs 28%, *p=ns*)

Typical AFL (1.3% vs 2.6%, *p=ns*)

Atypical AFL *(4% vs 14%, p<0.05).*

Arrhythmia free without antiarrhythmic drug (82% vs 79%, p=ns)



Shah DC. *J Cardiovasc Electrophysiol 2007*

CTI ablation line in patients with AF and typical atrial flutter

: no difference in recurrence of AF with the addition of C

PVI+CTI ablation vs PVI, in PAF & PeAF for 5

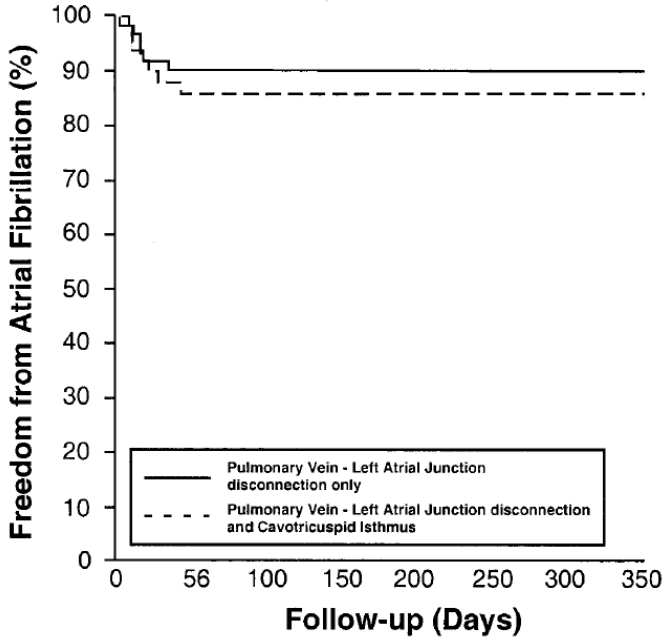
AADs for 2 mo and stopped

AFL, 0%(0/49) vs 55%(32/59), *p<0.01*, FU 2 m

0%(0) vs 5%(3/59), *p=ns*, FU 1 yr

AF, 14% vs 11%, *p=ns*, FU 1 yr

Wazni O. *Circulation 2003*



CPVI with SVC isolation in PAF

: no difference in recurrence of AF with the addition of SVC ablation at 1 yr FU

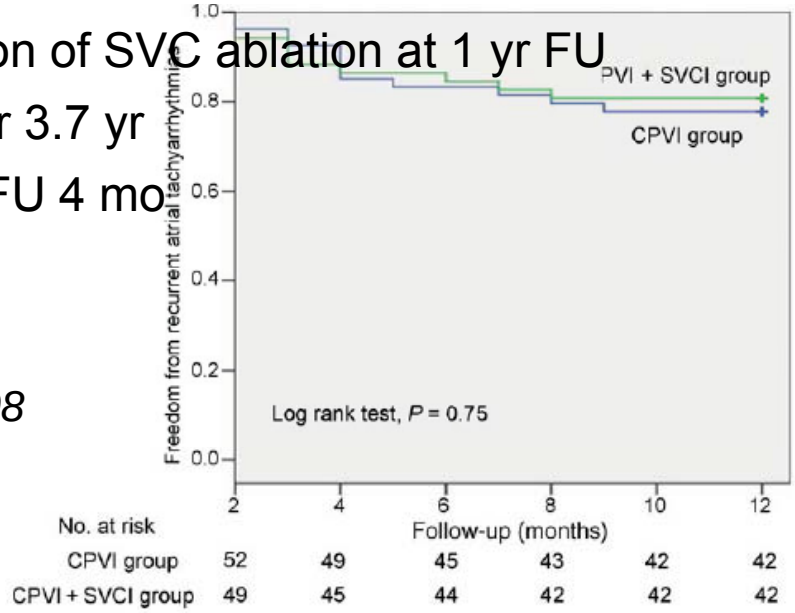
CPVI+SVC isolation vs CPVI, in PAF for 3.7 yr

ATa, 19%(10/52) vs 22%(12/54), *p=ns*, FU 4 mo

Re-ablation, 8/10 vs 9/12, *p=ns*

Free of ATa, 94% vs 93%, *p=ns*, FU 1 yr

Wang XH. *Europace 2008*



Substrate Modification of AF

- Additional linear lesions

  LA roof line

  mitral isthmus line

  anterior LA line

  posterior LA line

- The incidence of non-PV triggers: approximately 20% and may be as high as 35% in persistent AF.

  SVC, LA posterior wall, crista terminalis, CS, ligament of Marshall,

  or interatrial septum

- CFAE in both the LA and RA may represent substrate for AF maintenance.
  : more then two deflections that are fractionated, have a short cycle length (< 120 ms) and/or continuous electrical activity

  : its value is most likely as an adjunct to PV isolation

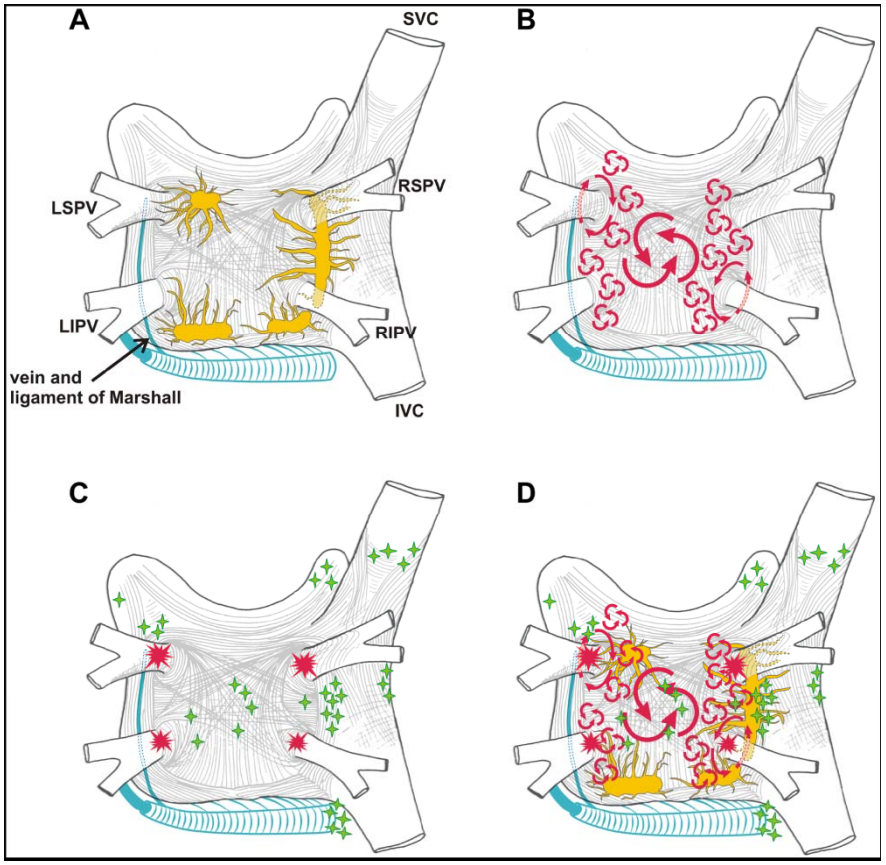
- Modification of ganglionic plexi around the LA.

  : role of the autonomic nervous system in triggering and/or maintaining AF

  : Ganglionix plexi are located in epicardial fat pads at the PV antrum.

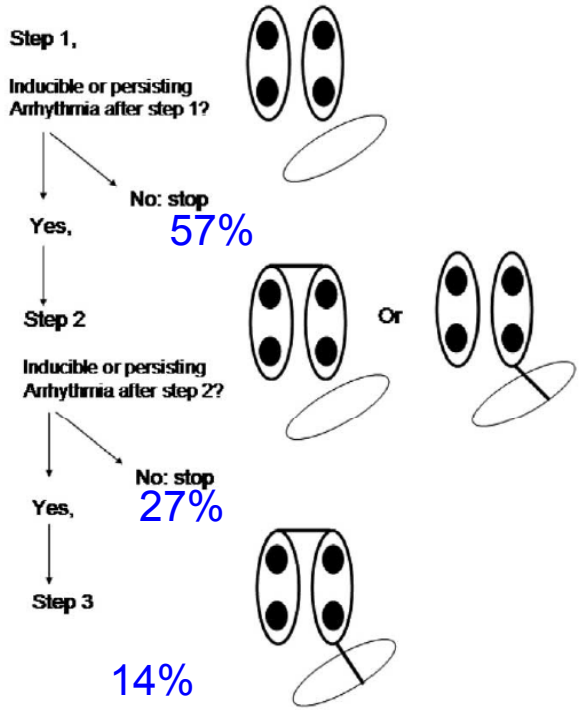
  : Endocardial ablation targets are identified using high-frequency stimulation, which results in a vagal response.

  : Endpoint of ablation - elimination of this vagal response to high-frequency stimulation.



Calkins H. *Heart Rhythm 2007*

Stepwise AF ablation guided by noninducibility



- paroxysmal AF, 74 patients, mean age 53 yrs
- PV isolation + CTI ablation
- Mitral isthmus and/or LA roof line
- Noninducibility of AF or AFL (93%)

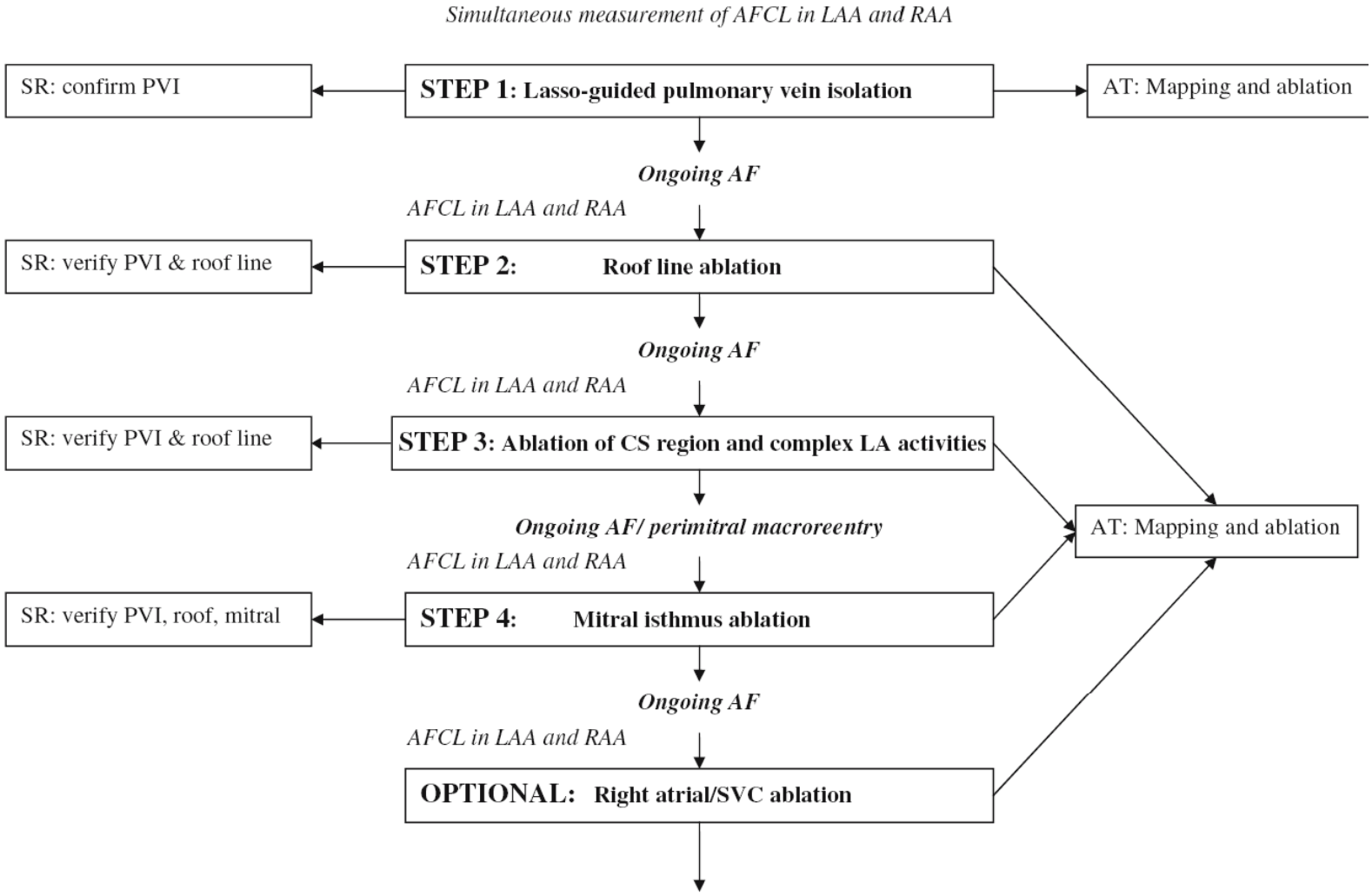
  Inducibility using 10-second burst pacing at 20 mA
  starting at 250 ms decreasing down to refrac
  from the CS and both atrial appendages.
  three times at each site

- FU 18 mo, 91% free of arrhythmia without AADs
- Repeat ablation 31% (prior target 20%, new line 11%)
- 3 of 5 with persistent or inducible arrhythmia after ablation required a repeat ablation.(gap in mitral isthmus, LA roof, or both)

Jais P. *Heart Rhythm 2006*

Combination of Ablation Techniques

- Stepwise approach: termination of long-lasting persistent AF: 87%



O'Neill MD. *J Interv Card Electrophysiol 2006*

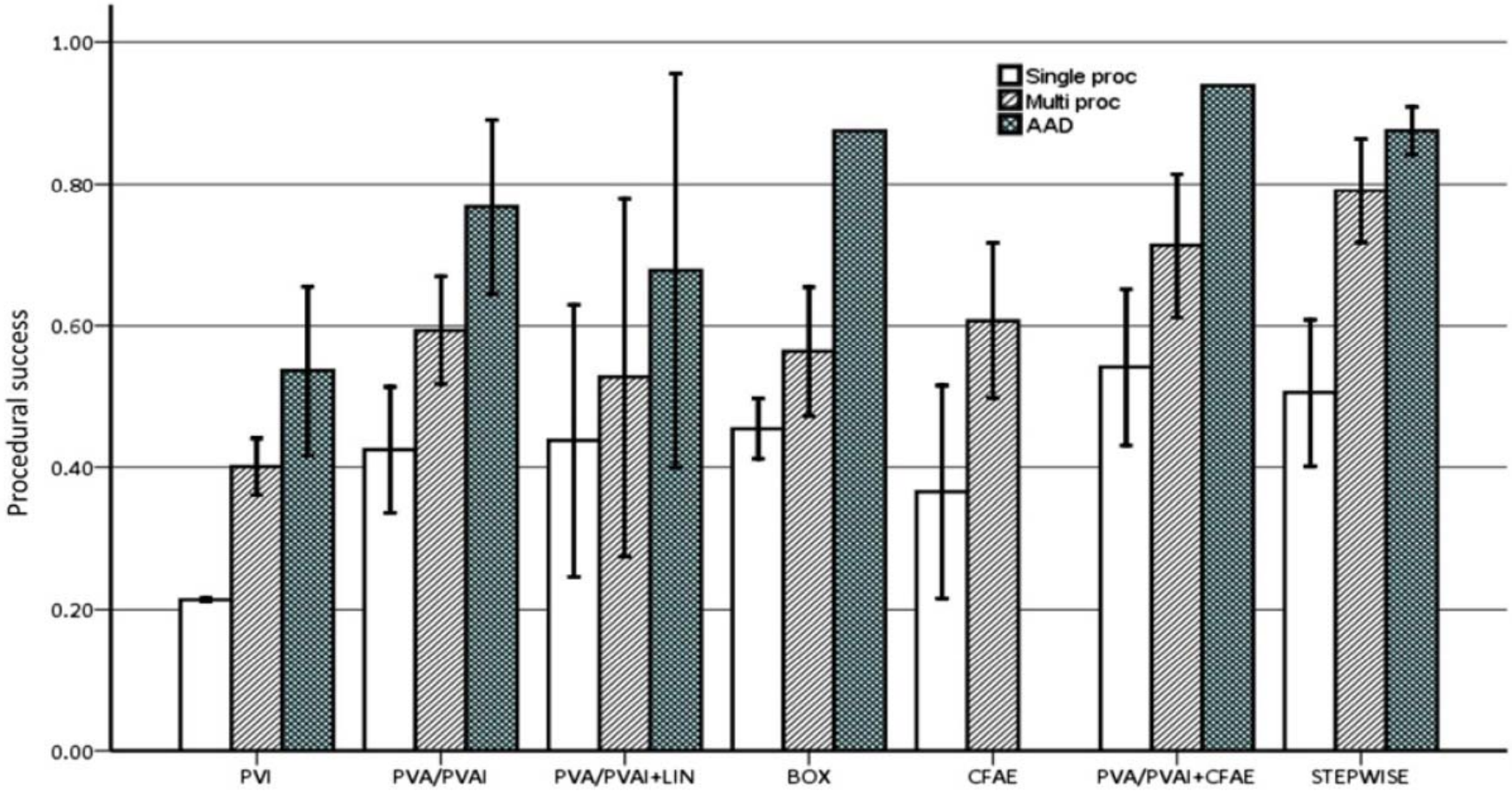
Persistent/long-standing persistent AF

- Systematic review, single procedure drug-free success
- PVI alone(4): 21~22% success
- PV antrum ablation with isolation (PVAI:2): 38~40% success
- PV antrum ablation without confirmed isolation (PVA:2): 37~56% success
- Linear ablation in addition to PVA(5): 11~74% success
- Linear ablation in addition to PVAI(5): 38~57% success
- Posterior wall box isolation(3): 44~50% success
- CFAE ablation(5): 24~63% success
- CFAE ablation in addition to PVA(2): 50~51% success
- CFAE ablation in addition to PVAI(3): 36~61% success
- CFAE ablation in addition to PVAI and linear ablation(1): 68% success
- Stepwise ablation(5): 38~62% success

(n= no. of studies)

Brooks AG. *Heart Rhythm 2010*

Clinical success of various ablation techniques for persistent/long-standing persistent AF



Brooks AG. *Heart Rhythm 2010*

• While linear lesions probably improve the effectiveness of ablation for persistent AF, incomplete linear lesions have been shown to increase the incidence of AT and atypical AFL during follow up.

• Extensive ablation in the posterior left atrium may increase the risk of procedural complications (e.g., stroke, pulmonary vein stenosis, cardiac tamponade, atrial esophageal fistula, and very rarely death).

• Ablation to extensive areas of the atrial myocardium potentially results in loss of LA mechanical function and alteration of intra-atrial conduction.

Anticoagulation

- TEE: to screen for a thrombus
- In persistent AF: enoxaparin 0.5~1 mg/kg x2/day until the evening prior to the ablation

- Loading dose (100 U/kg) of heparin immediately upon septal puncture → standard heparin infusion of 10 U/kg/hour
- Activated clotting times (ACT): 300~350 seconds
  10~15-minute intervals→ 30 minute
- Significant atrial enlargement or spontaneous echo contrast:
  higher ACT range of 350~400 seconds
- Sheath removal from groin: ACT < 200 seconds
- Protamine: to reverse heparin
  avoided in patients who have received NPH insulin, or have a fish allergy
- Re-initiation of anticoagulation within 4~6 hr
  IV heparin or subcutaneous LMWH(enoxaparin) until a therapeutic INR warfarin

Warfarin

• for at least two months following an AF ablation

• Decisions regarding the use of warfarin more than two months following ablation should be based on the patient's risk factors for stroke and not on the presence or type of AF.

• Discontinuation of warfarin therapy post ablation is generally not recommended in patients who have a CHADS score 2.

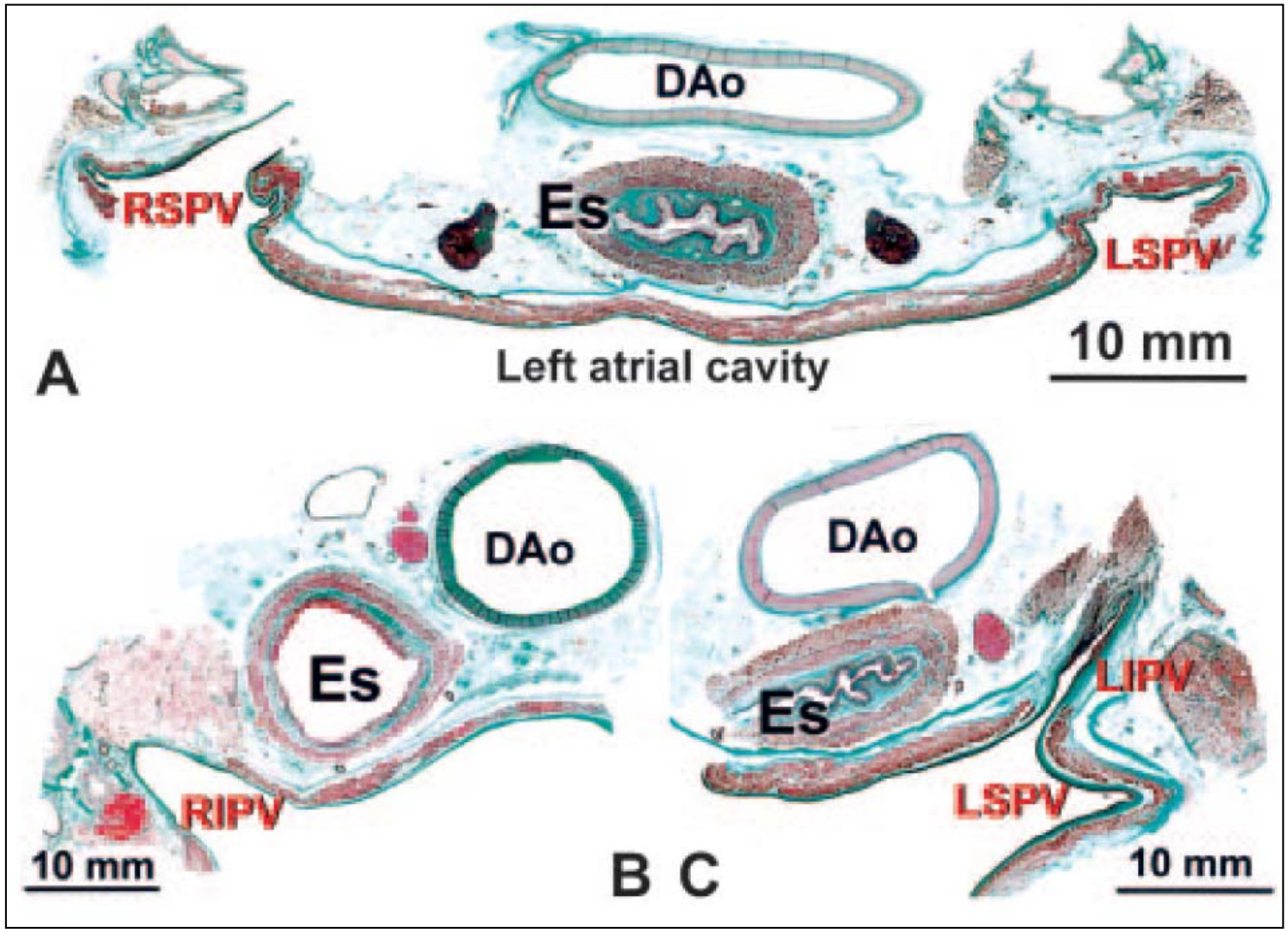
Safety

Major complication : up to 4.5% of procedures performed worldwide

Type of Complication	No. of Patients	Rate, %
Death	25	0.15
Tamponade	213	1.31
Pneumothorax	15	0.09
Hemothorax	4	0.02
Sepsis, abscesses, or endocarditis	2	0.01
Permanent diaphragmatic paralysis	28	0.17
Total femoral pseudoaneurysm	152	0.93
Total artero-venous fistulae	88	0.54
Valve damage/requiring surgery	11/7	0.07
Atrium-esophageal fistulae	6	0.04
Stroke	37	0.23
Transient ischemic attack	115	0.71
PV stenoses requiring intervention	48	0.29
Total	741	4.54

Cappato R. *Circ Arrhythm Electrophysiol 2010*

Proximity of the esophagus to LA and PV



Sanchez-Quintana D. *Circulation 2005*

Worldwide Survey

- included paroxysmal AF, 85.9% also included persistent and 47.1% also included long-lasting AF.
- Mean 1.3 procedures per patient
- Carto-guided LA circumferential ablation (48.2% of patients) and Lasso-guided ostial electric disconnection (27.4%)
- Median, 70%(58~75%) became asymptomatic without antiarrhythmic drugs
- Median, 10%(0.5~17%) became asymptomatic in the presence of previously ineffective antiarrhythmic drugs over 18 (3~24) months of follow-up.
- Success rates free of antiarrhythmic drugs and overall success rates
  - paroxysmal AF (74.9% and 83.2%)
  - persistent AF (64.8% and 75.0%)
  - Long-lasting AF (63.1% and 72.3%)
- Major complications: 4.5%

Cappato R. *Circ Arrhythm Electrophysiol 2010*

Procedural End Points of Catheter Ablation

(1) completion of a predetermined lesion set: PVI or LA lines

(2) termination of AF during ablation

(3) noninducibility of AF after ablation.

: improved outcome in PAF (20% greater success), but may lead to further unnecessary ablation and associated LA tissue damage.

- Persistent and long-standing perAF: The procedural end point is less clear. Completion of a predetermined lesion set that incorporates PV isolation and LA ablation remains the basic procedure.

Clinical End Points

- Freedom from AF, both symptomatic and asymptomatic, at specified intervals after ablation without the use of antiarrhythmic medication : ideal clinical end point.

- Monitoring methods
  - 3-monthly Holter, event monitor, and ECG recording;
  - event monitor for 1 year with 3-minute daily recordings, 5 days per week when asymptomatic and at any time when symptomatic;
  - continuous 7-day ECG recording at 3, 6, and 12 months after ablation;
  - continuous inpatient telemetry for 3 to 5 days after ablation and at 1, 3, 6, and 12 months.

- Absence of symptoms: not reliable proof of the absence of AF.

- The minimum acceptable AF burden(< 3~30 seconds)

Definition of success

- Freedom from AF/flutter/tachycardia off antiarrhythmic therapy
  : primary endpoint of AF ablation.
- For research purposes, time to recurrence of AF following ablation
  : an acceptable endpoint after AF ablation,
  but may under represent true benefit.
- Freedom from AF at various points following ablation may be a better marker of true benefit and should be considered as a secondary endpoint of ablation.

- Single procedure success
- A blanking period of 3 months after ablation

The Mechanisms of Recurrences of AF

- Recurrence of PV to LA conduction
- Gaps in previous linear lesions (roof-dependent or perimitral macroreentry)
- Locally abnormal conduction at the site of ablated tissue or LA scar

"Blanking period" of 1~3 months after ablation, during which time antiarrhythmic medication may be continued or modified and DC cardioversion performed for early arrhythmia recurrences

This watchful waiting may prevent unnecessary intervention in up to 1/3 of patients in whom AT resolves spontaneously within 3~4 months of ablation.

Repeat AF Ablation

- 20~40% of patients
- Recurrent conduction in PVs rather than new arrhythmogenic foci.
- Reconnection of PVs does not consistently predict recurrent AF.
  mechanism is not known.

- In arrhythmias due to reconduction from the PVs, re-isolation of the PV is frequently sufficient.
- Additional linear lesions may only be required when a macroreentrant mechanism is present.
- Non PV focal triggers: identified by high dose isoproterenol

Future directions

• questions:

(1) What is the role of ablation in the therapy of all AF patient groups?

(2) Mortality benefit?

• Future trials for chronic AF, elderly patients (70~75 years), and patients with LA enlargement (55~65 mm), structural heart disease, and heart failure (LVEF<30~35%)

• New, effective, and safe alternative energy sources

: cryoablation, ultrasound, laser

Systematic Literature Reviews from a variety of sources including anonymous surveys, nonrandomized clinical trials, randomized clinical trials, and meta-analyses.

- Single-procedure success rate of catheter ablation of AF
  : approximately 60%
- The performance of additional ablation procedures and/or the addition of AAD therapy increases the success rate to approximately 75%.
- The success rate for AAD therapy: approximately 50%
  Side effects of AAD therapy: approximately 30%
- Complication rate of ablation: approximately 5%

Calkins H. *Circ Arrhythm Electrophysiol 2009*

Conclusions

- Benefits of AF ablation
  improvement in quality of life: symptomatic AF.
  decrease stroke or heart failure risk.
  may improve survival.
- The superior success rate of ablation (mean FU: 1 yr) vs AAD
  60%-75%
- Recommendations: Catheter ablation should be considered after failure of at least one AAD for recurrent AF.
- Studies for mechanisms and roles of ablation in AF
  Studies for ablation strategy and new techniques