



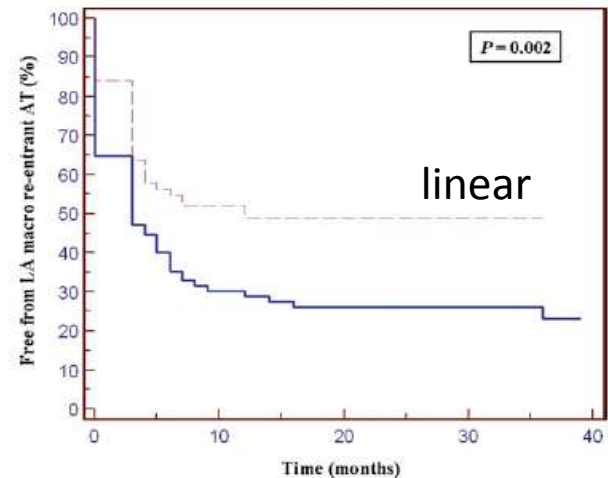
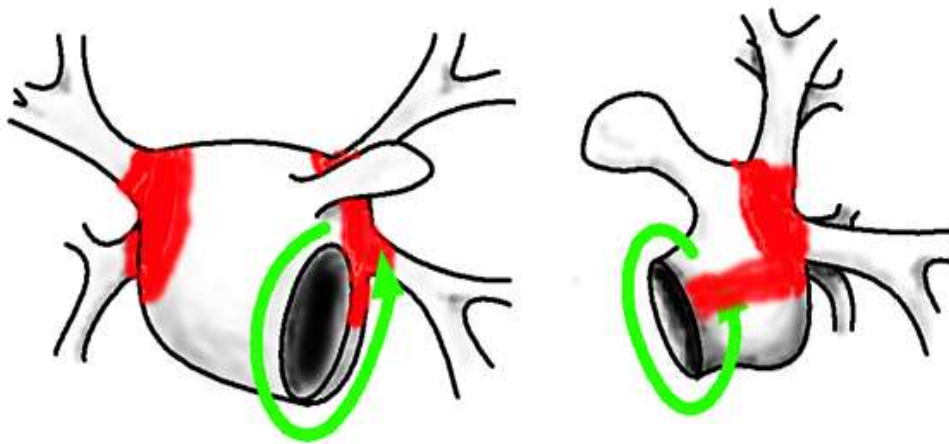
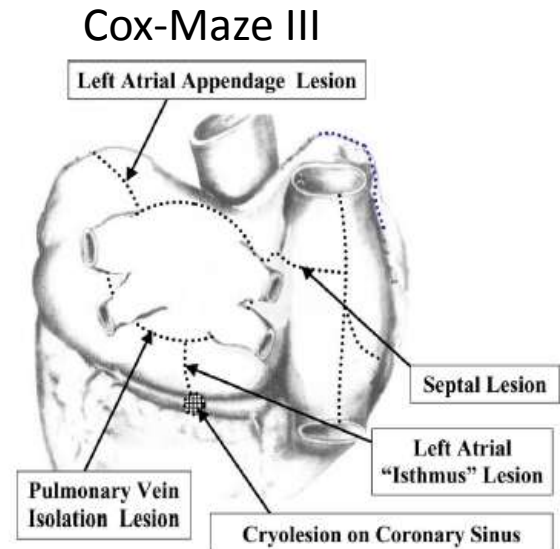
Balloon occlusion of the coronary sinus facilitates mitral isthmus ablation (BOCS study)

Kelvin Wong, Michael Jones, Norman Qureshi, Praveen Sadarmin, Joe De Bono, Kim Rajappan, Yaver Bashir, Timothy Betts
John Radcliffe Hospital, Oxford

Supported by unrestricted educational grants from St Jude Medical and Medtronic

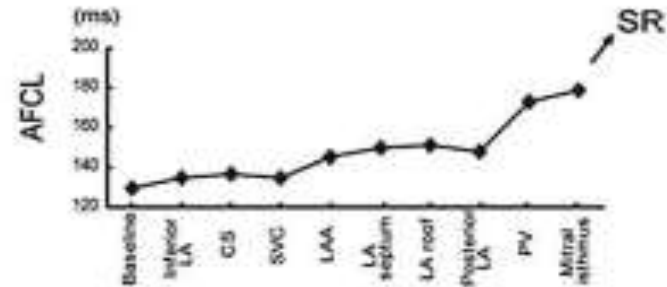
Background

- Incremental benefit of mitral isthmus ablation in paroxysmal (15-20%) and persistent AF (20-40%) (*Jais Circ 2004, Fassini JCE 2005, Willems EHJ 2006, Gaita Circ EP 2008*)
- Treatment and prevention of perimitral flutter (*Chae JACC 2007, Pappone Circ 2004, Haissaguerre JCE 2005, Knecht EHJ 2008*)



Part of the “stepwise” approach

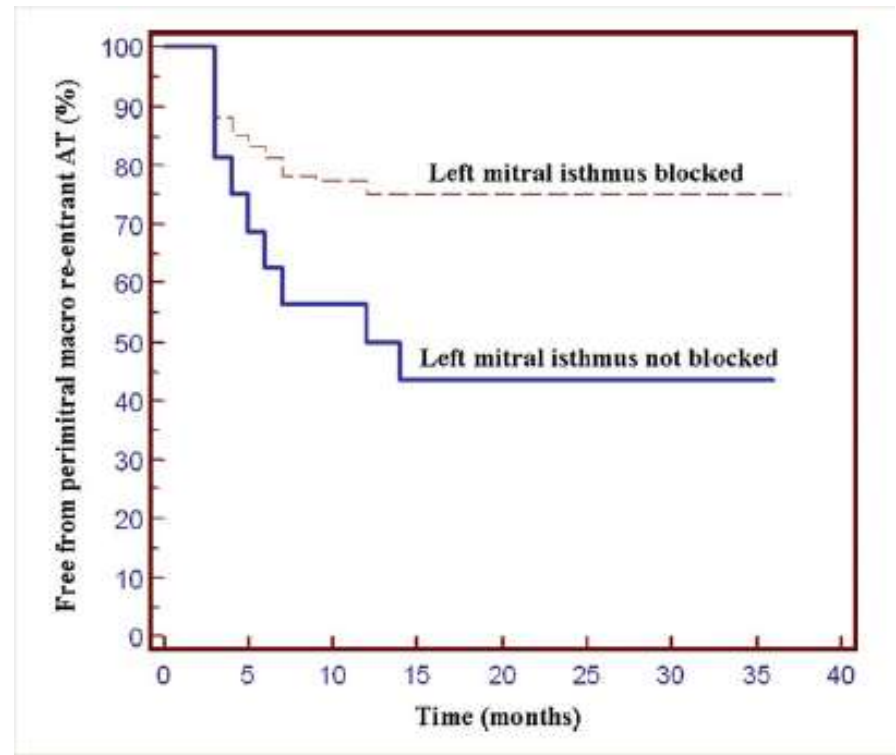
- Linear ablation responsible for termination in about 20% of cases (Haissaguerre JCE 2005; O’Neil EHJ 2009)
- 40% of patients had significant AFCL prolongation during linear ablation (Haisaguerre JCE 2005)
- 86% of patients ultimately needed a mitral isthmus line (Knecht EHJ 2008)



Site of AF termination	Number of patients
Left atrium (n = 118)	
Inferior LA	11
CS os	2
CS (epicardial)	17
Left atrial appendage	25
Mitral isthmus	17
Pulmonary veins	14
Interatrial septum	12
Roof	8
Posterior LA	6
Anterior LA	4
Lateral LA	2
Right atrium (n = 12)	
Right atrial appendage	4
Intercaval	3
Cavotricuspid isthmus	2
Superior vena cava	2
Foramen ovale	1

Complete block is important

- Patients with block have better outcomes (*Ernst JACC 2003; Willems EHJ 2006; Gaita et al. Circulation 2005 (111):136; Fassini JCE 2005 (16):1150; Knecht EHJ 2008 (29):2359*)
- Pro-arrhythmic effects of incomplete lines (*Chae JACC 2007; Rostock et al. JCE 2006; Haissaguerre et al. JCE 2005; Matsuo HR 2010*)



Mitral isthmus ablation is challenging!

- Mitral isthmus ablation often requires
 - substantial ablation: >15 min
 - High ablation powers
 - epicardial ablation in the CS to achieve block: >70%
 - Only moderate success: 31% - 92%

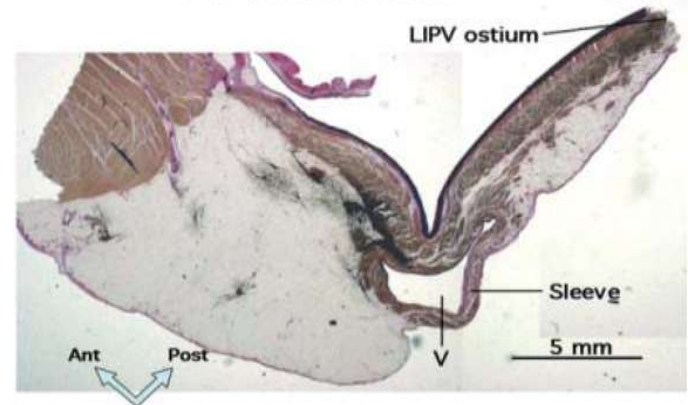
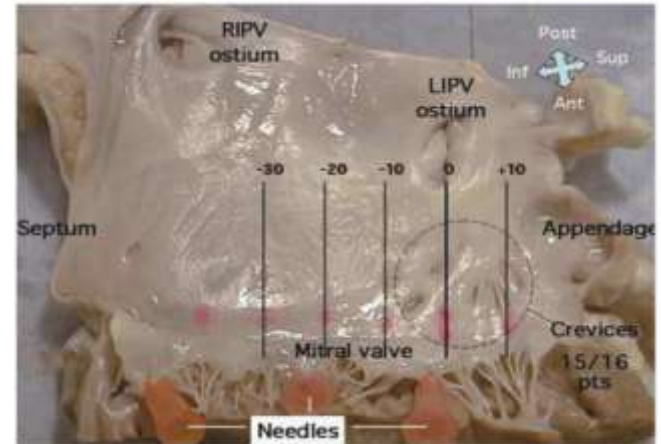
(Jais et al. Circ 2004; Fassini et al. JCE 2005; Knecht et al. EHJ 2008; Willems et al. EHJ 2006; Gaita et al. Circ EP 2008)
- Higher complication rates of tamponade and circumflex artery injury associated with the use of higher ablation powers *(Jais Circulation 2004; Takahashi JCE 2005; Takatsuki EP 2009; Wong EP 2010)*

Literature review

	n	Ablation catheter	Power (endo/CS)	Temp (°C)	Total ablation (min)	Endo ablation (min)	CS ablation (min)	% CS	Success (%)
<i>Jais et al. 2004</i>	100	4mm irrigated	40-60W; then 42W/20-30W	50		20±10	5±4	68	92
<i>Matsuo et al. 2010</i>	50	4mm irrigated	40W/25W	50	14±7			76	92
<i>Sawhney et al. 2010</i>	33	8mm non-irrigated	50W/50W	55				97	91
<i>Knecht et al. 2008</i>	118	3.5mm irrigated	20-35W /?	42	18 (IQR 13-28)				86
<i>Anousheh et al. 2010</i>	60	8mm non-irrigated	50W/50W	55				97	83
<i>Fassini et al. 2005</i>	95	4mm irrigated	40W/20W	ns	26±1			75	76
<i>Takatsuki et al. 2009</i>	81	4mm irrigated	45W/25W		26±13	22±11	4±3	91	76
<i>Willems et al. 2006</i>	32	4mm irrigated	50W then 40W	50	16±9		0	0	73
<i>Choi et al. 2009</i>	54	Irrigated tip	30W/20W	47				83	65
<i>Gaita et al. 2008</i>	137	4mm irrigated	45W	45			0	0	31

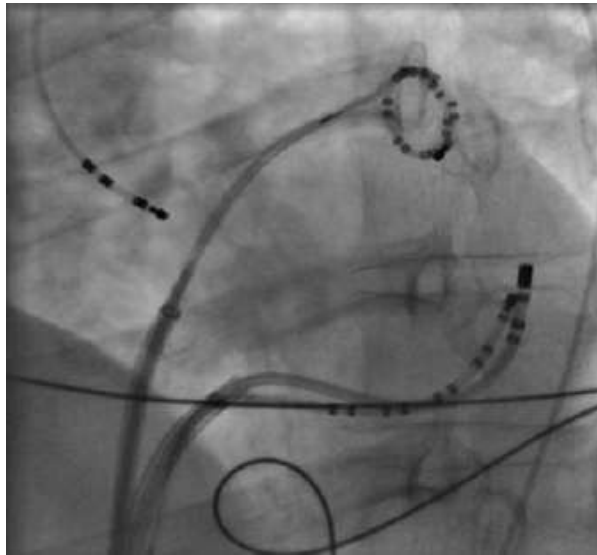
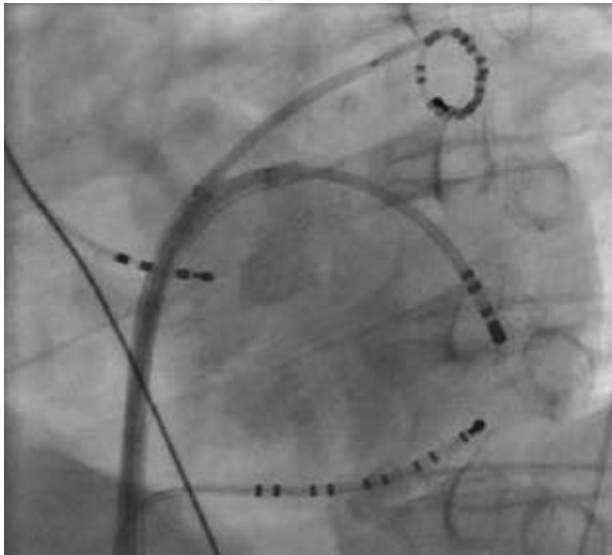
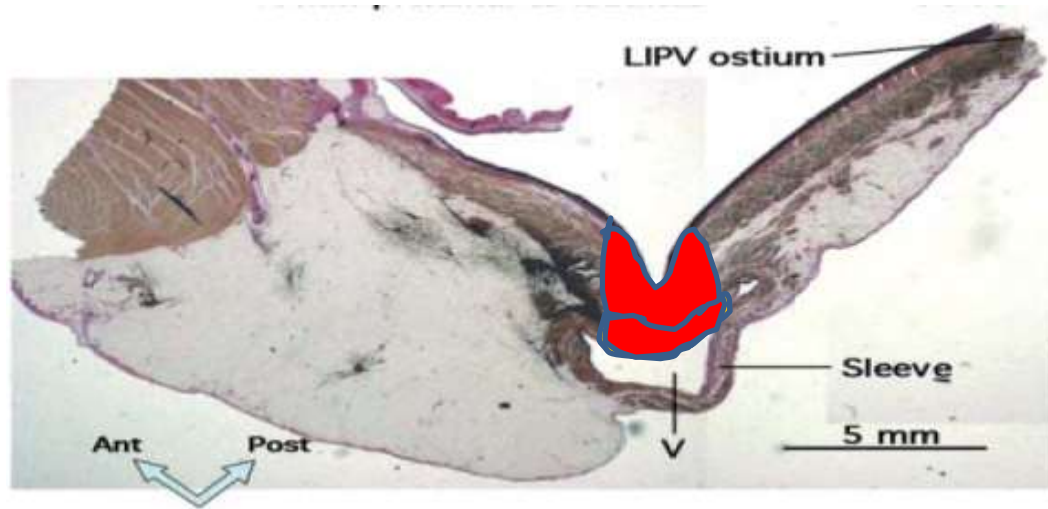
Obstacles to mitral isthmus ablation

- Depth (2-6mm)
- Length (35mm;1.5x CTI)
- Recesses and crevices
- Myocardial sleeve around CS
- Extension of atrial myocardium to MV
- “high take off” LIPV
- Epicardial bridges/LOM

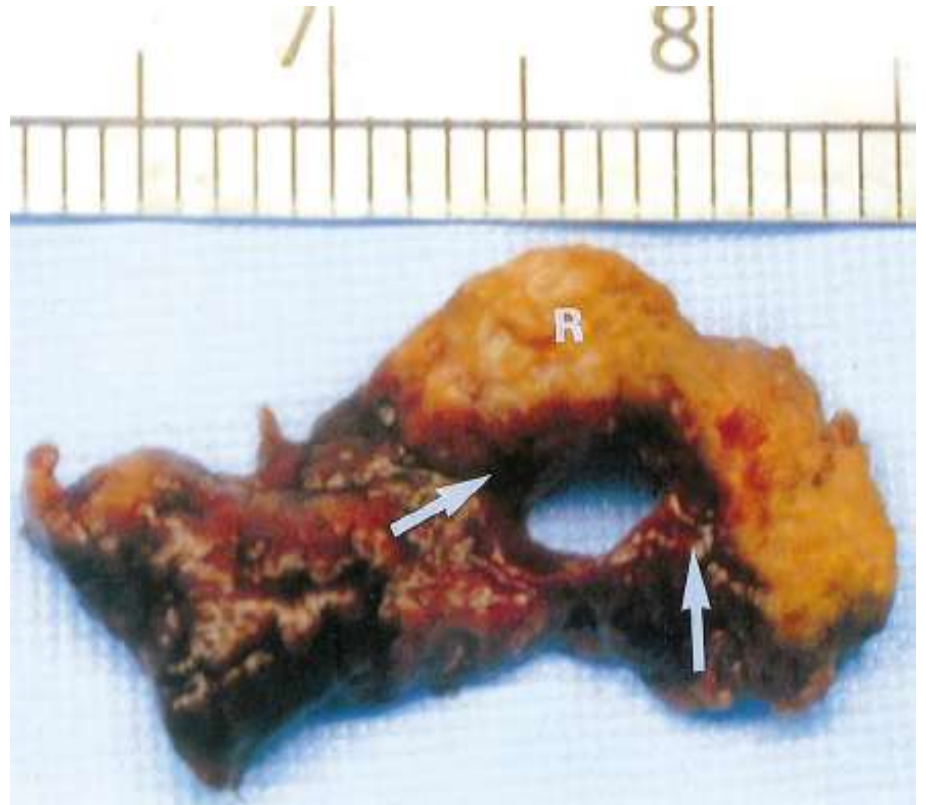
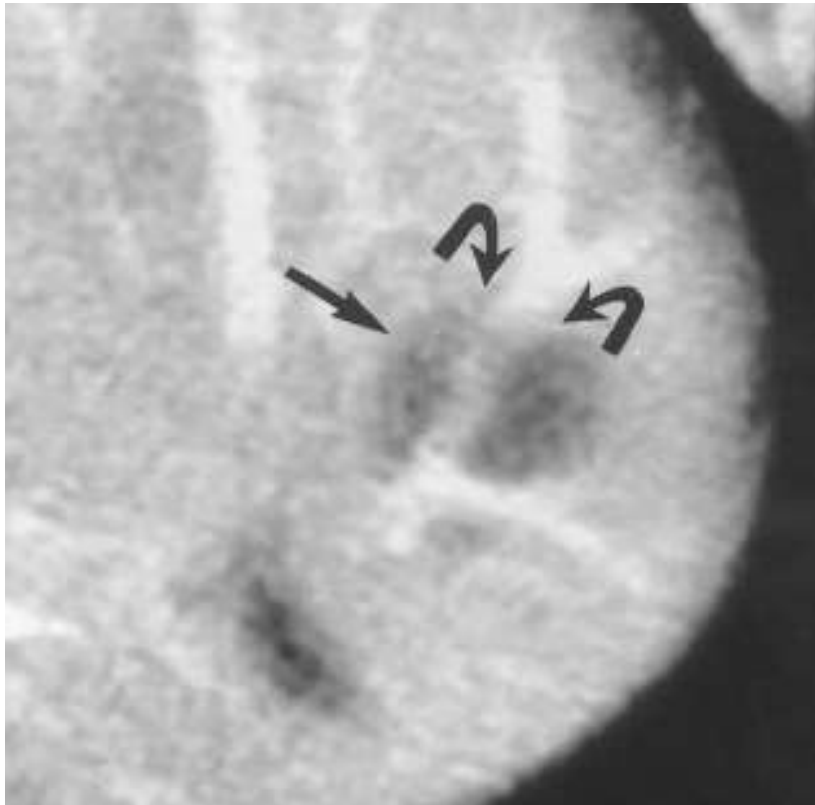


Wittkampf EHJ 2005; Becker JCE 2004; Takatsuki EP 2009

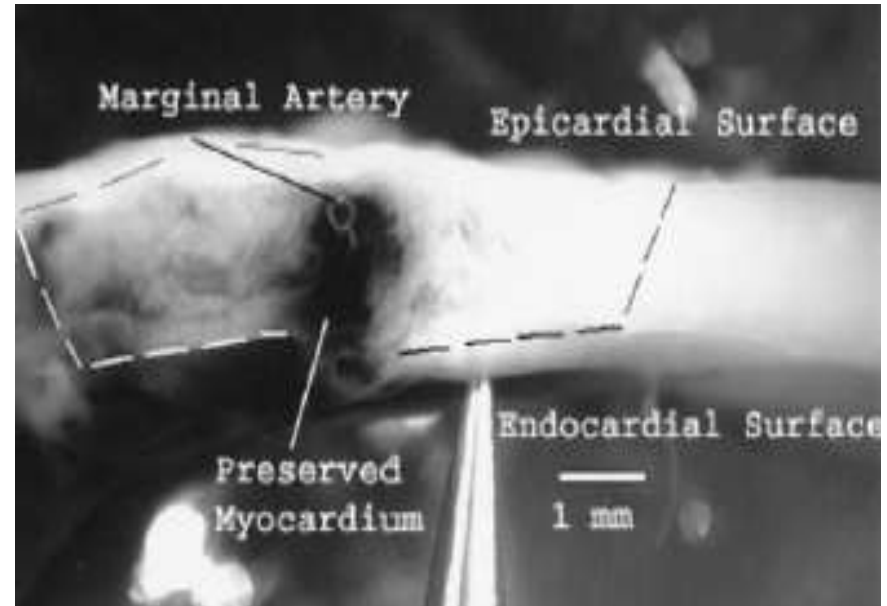
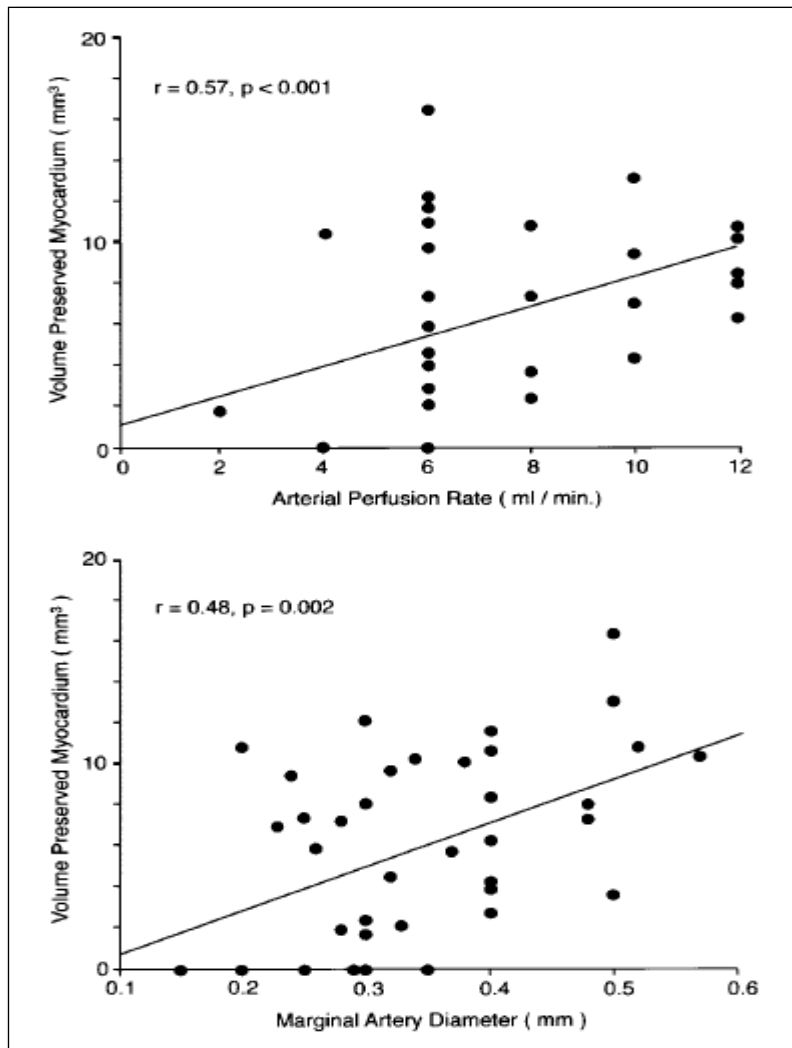
CS acting as “heat sink”



“Heat sink” effect in hepatic RFA



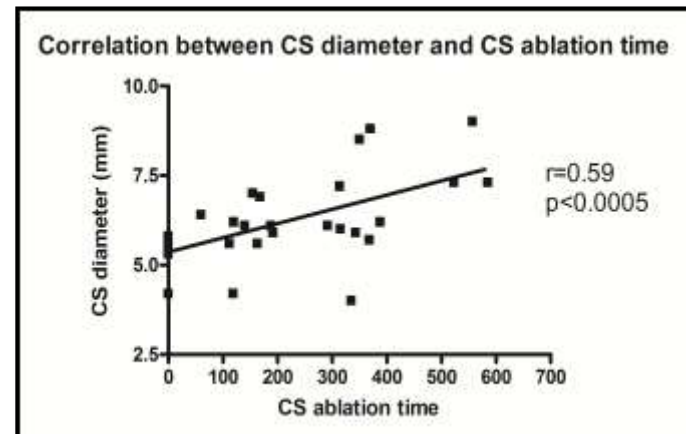
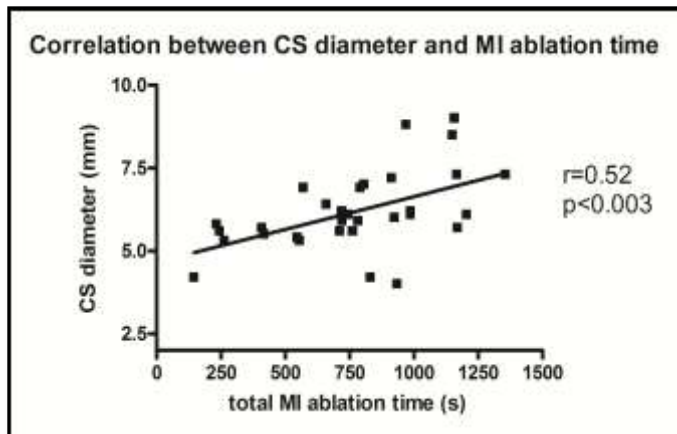
In vitro study



Fuller Circulation 2003

Oxford: Larger CS diameter predicts need for epicardial CS ablation

- CS diameter significantly correlated with total and CS ablation times



- CS diameter $> 59\text{mm}$ predicted the need for CS ablation (sensitivity:78%, specificity100%; AUC=0.88)

Unpublished data

Objective

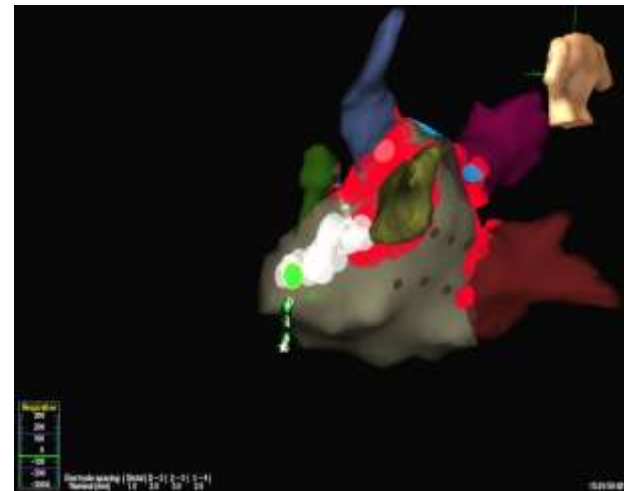
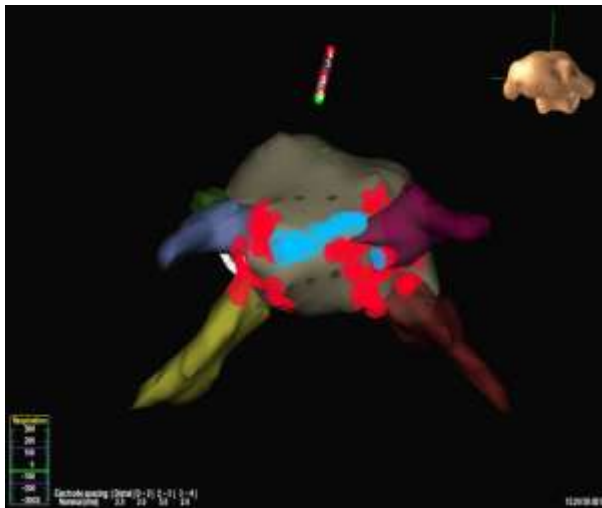
- To investigate if inflation of an air-filled balloon at the great cardiac vein (to eliminate the “heat sink” effect at the site of mitral isthmus ablation) facilitates mitral isthmus ablation

Methods

- Prospective, single centre, randomized controlled trial
- Patients with persistent and paroxysmal (long paroxysms) who had AF ablation including mitral isthmus line were recruited
- Exclusion criteria:
 - Previous mitral isthmus ablation
 - LV lead in situ

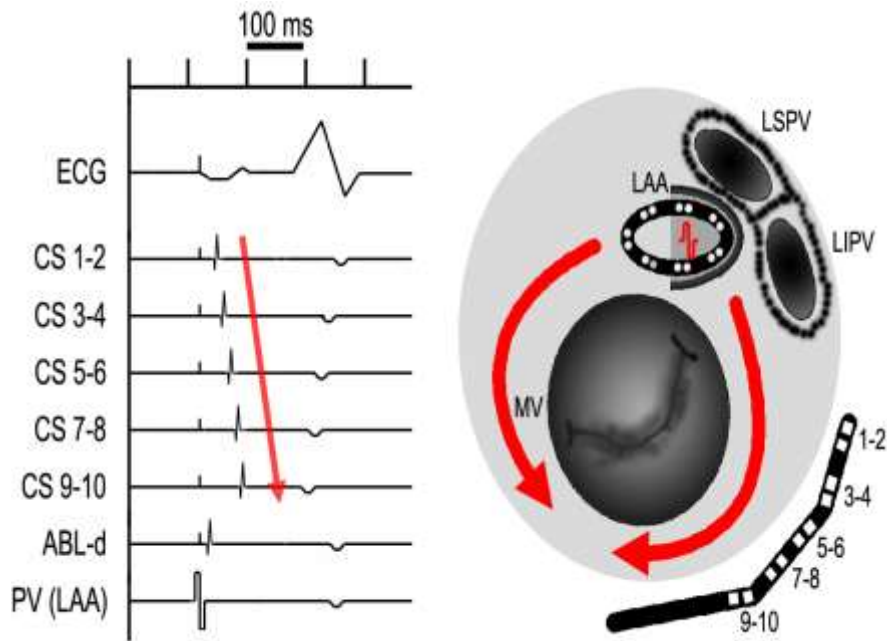
Study protocol

- Circumferential pulmonary vein isolation and roof line was performed initially. Patients still in AF had DCCV to SR
- Mitral isthmus ablation performed during left atrial appendage (LAA) pacing with the following settings:
 - Endocardial: max power:40W at the annular end, 30W at the venous end; max temp:48°C; flow rate: 17ml/min
 - CS: max power:25W; max temp:48°C; flow rate: 17ml/min
- After at least 10 minutes of endocardial ablation and no atrial EGMs along line, ablation was performed in the great cardiac vein for up to 5 minutes. Further ablation was at the discretion of the operators.

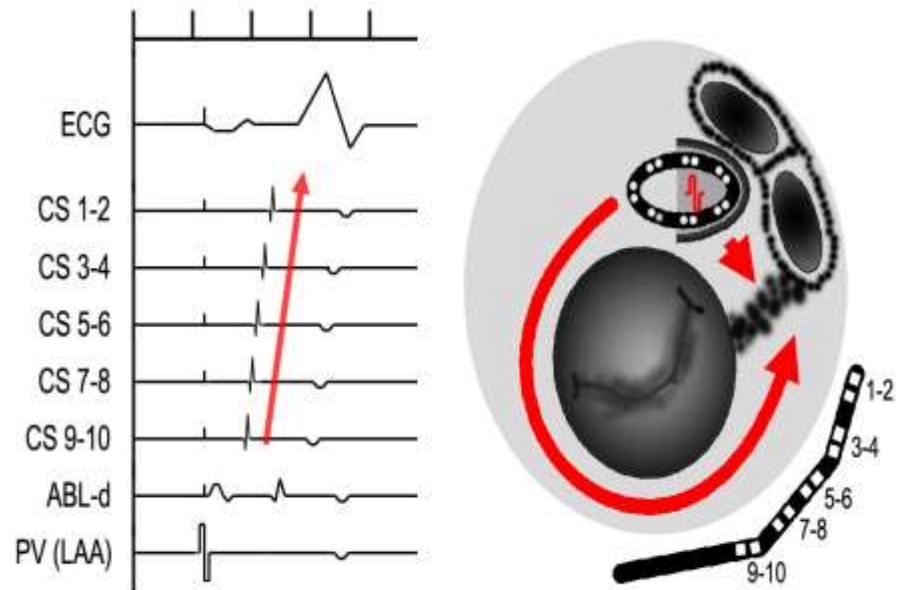


Assessing mitral isthmus block

No mitral isthmus block



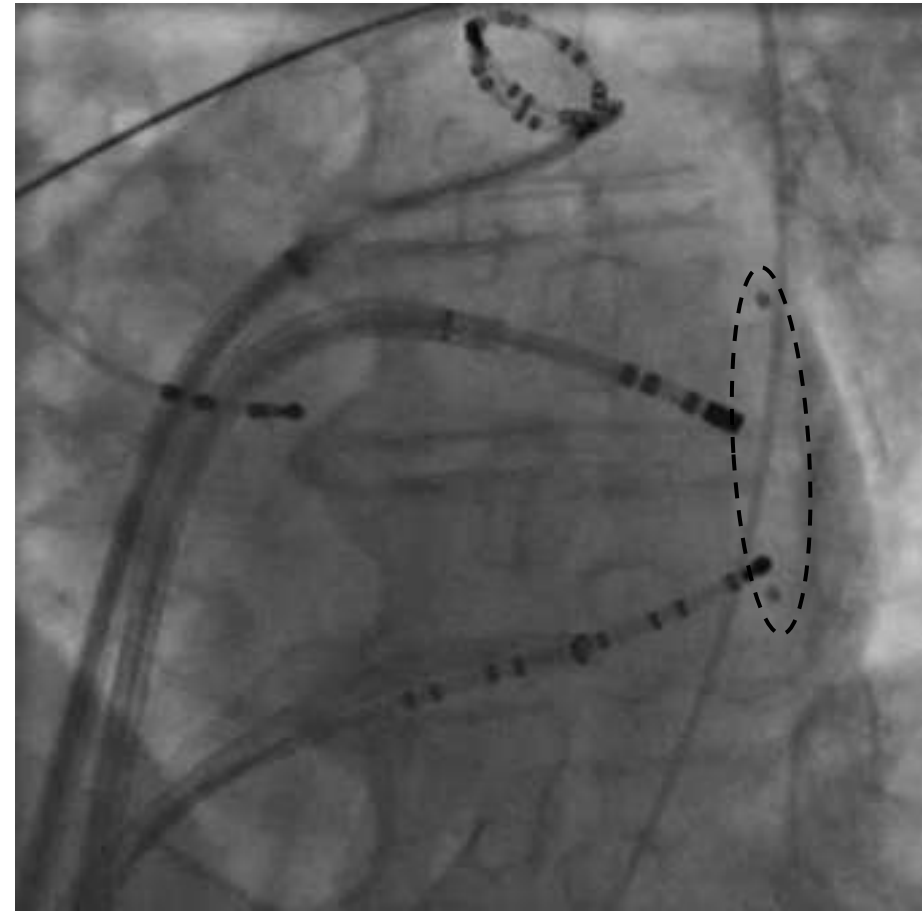
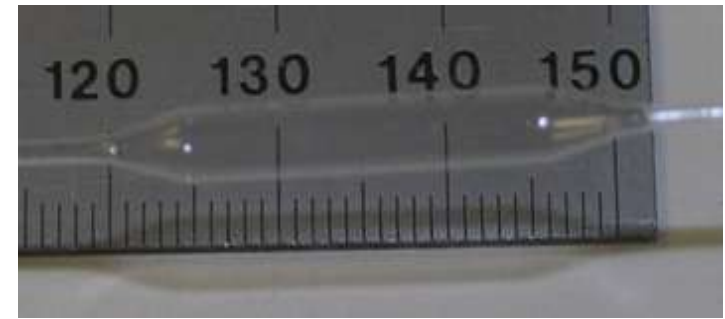
Mitral isthmus block



Change to a proximal to distal CS activation signifies block
(Paisey et al. JCE 2009)

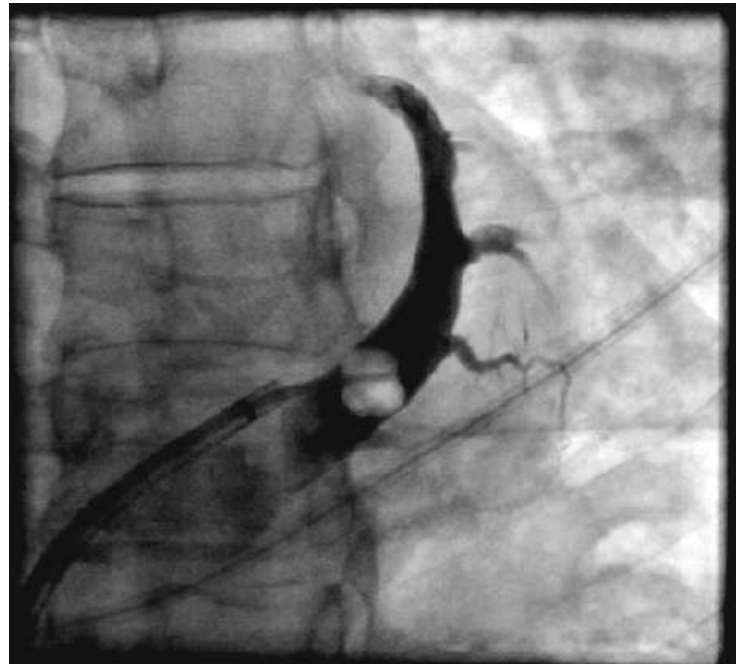
CS balloon occlusion

- 4.0 x 10 mm PTA dilatation catheter (OPTA® Pro Dilatation catheter, Cordis)
- Positioned in great cardiac vein over the mitral isthmus line with the help of pre-shaped long sheaths
- Hand inflation with 5-10 mls air under fluoroscopy
- Maximum duration of continuous balloon inflation was limited to 5 minutes. Balloon was deflated for a minute before further inflation if necessary
- Balloon removed prior to CS ablation



Safety monitoring

- Left coronary and CS angiography were performed pre- and post-ablation in 3 fixed caudal views
- For CS venography, a balloon occlusion catheter (Arrow International, Inc.) was positioned in the CS with the aid of a pre-shaped long sheath (SR(0), St Jude Medical) before being inflated for venography



Study endpoints

Primary endpoint: percentage of patients who required ablation within the CS to achieve mitral isthmus block acutely

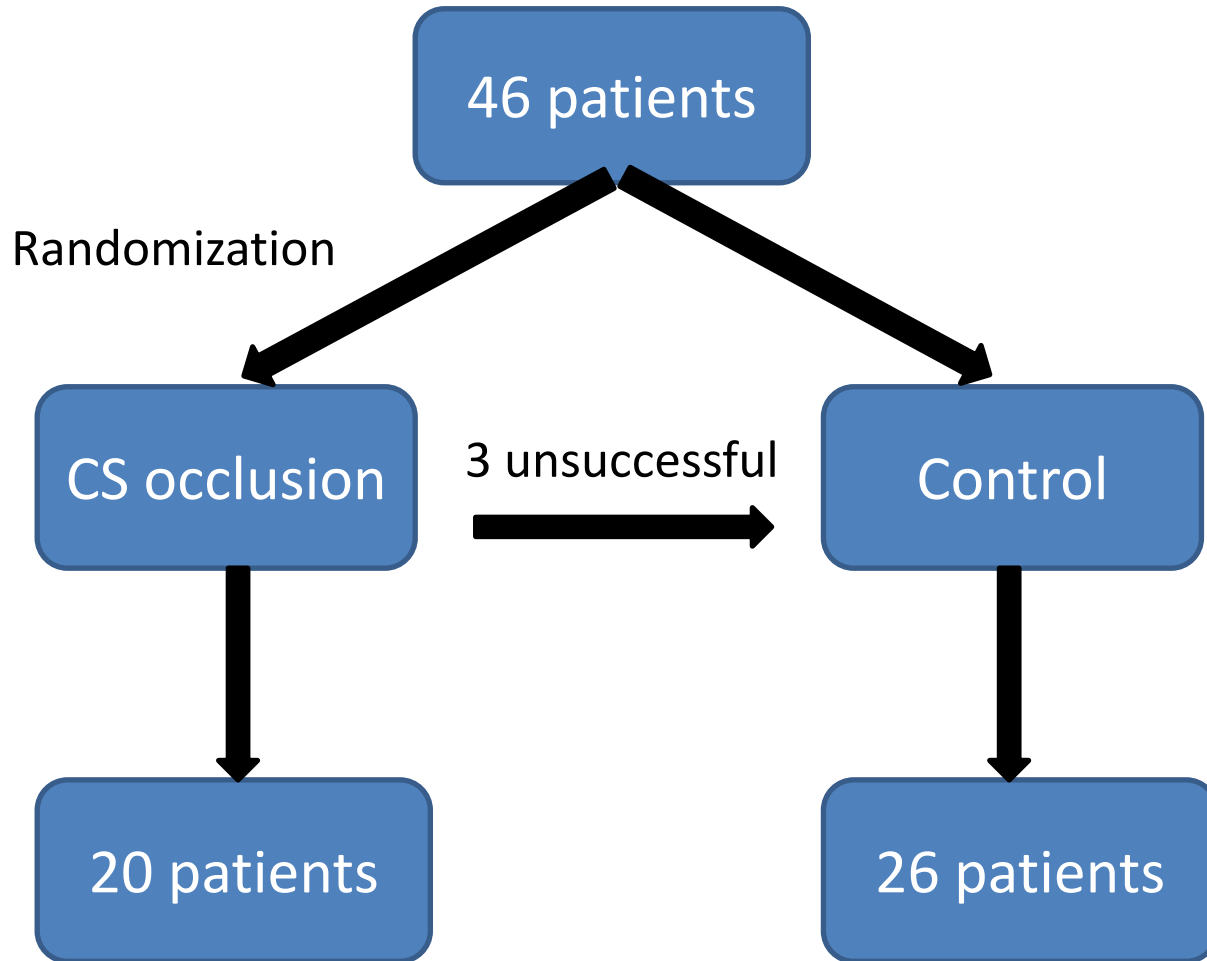
Secondary endpoints:

1. acute success rate of mitral isthmus block
2. mitral isthmus ablation time
3. mitral isthmus procedure time
4. acute complication rates

Sample size calculation

A reduction in the need to perform epicardial CS ablation to achieve mitral isthmus block from 80% (in controls) to 40% (in cases) was considered significant. For a study with a power of 80% and significance of 0.05, the sample size needed was a total of 46 patients.

Randomization



Baseline characteristics

	CS occlusion (n=20)	Control (n=26)	P value
Baseline characteristics			
Age	62±10	60±10	0.43
Male	15 (75%)	19 (73%)	0.99
Persistent AF	17 (85%)	18 (69%)	0.30
Cardiovascular disease	5 (25%)	11 (42%)	0.35
Impaired LV function	0 (0%)	3 (12%)	0.25
Amiodarone use	5 (25%)	8 (31%)	0.74
CHADS2 score (median)	0	0	0.38
LA diameter (mm)	42±5	45±7	0.13
MI length (mm)	41±13	35±10	0.11
CS diameter @ 3 o'clock (mm)	6.5±1.2	6.3±1.1	0.68
Procedure characteristics			
Total procedure time (min)	171±38	172±29	0.93
Total fluoroscopy time (min)	53±22	58±20	0.39
First time procedures	15 (75%)	22 (85%)	0.47
Pulmonary vein isolation	20 (100%)	26 (100%)	NS
Roof line block	19 (95%)	24 (92%)	1.0

Results

- Mean time to position balloon in great cardiac vein was 4 ± 1 min
- Unsuccessful in 3 patients due to valves and unfavourable anatomy of CS (acute inferior angulation in the proximal part)
- All mitral isthmus ablations were performed distal to the junction of the CS and great cardiac vein between 3 and 4 o'clock (LAO view)

Patients with mitral isthmus block

	Balloon occlusion	Control	P value
Patients with block	17/ 20 (85%)	24 (92%)	0.43
Percentage of patients requiring ablation in CS for mitral isthmus block	33%(6/17)	79% (19/24)	<0.005
Mean total ablation time (min)	9.4±5.5	13.3±4.6	<0.02
Mean CS ablation time (min)	1.5±2.8	3.4±2.7	0.04
Mean mitral isthmus procedure time (min)	17±14	23±15	0.18
Ablation @ 3 o'clock	10 (59%)	13 (54%)	1.0
Block with first pass	3 (18%)	2 (8%)	0.64
Percentage of patients needing higher ablation powers for success	2 (12%)	6 (25%)	0.29

Patients with no mitral isthmus block

	CS occlusion	Control	P value
PATIENTS WITH NO BLOCK	3/20 (15%)	2/26 (8%)	0.64
Mean total ablation time (min)	21.6±3.0	22.5±3.3	0.79
Mean CS ablation time (min)	8.6±2.4	5.5±0.7	0.19
Mean procedure time (min)	49±17	51±1	0.93

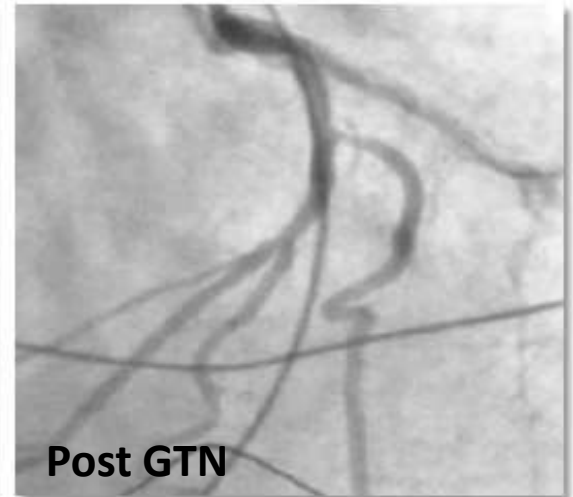
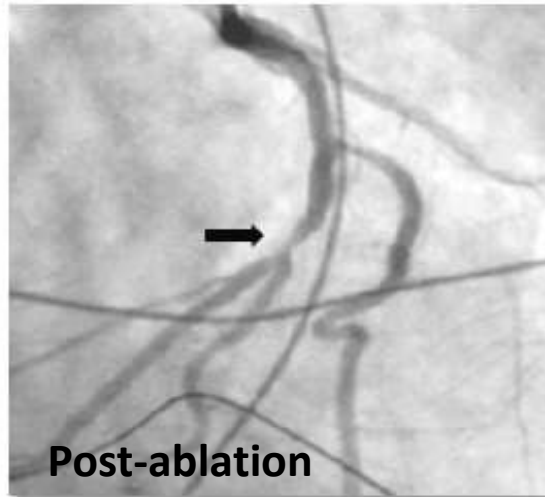
Mitral isthmus was significantly longer (54 ± 8 vs 35 ± 10 mm, $p=0.0002$). LA was not significantly bigger (48 ± 4 vs 43 ± 6 mm, $p=0.16$)

Acute complications

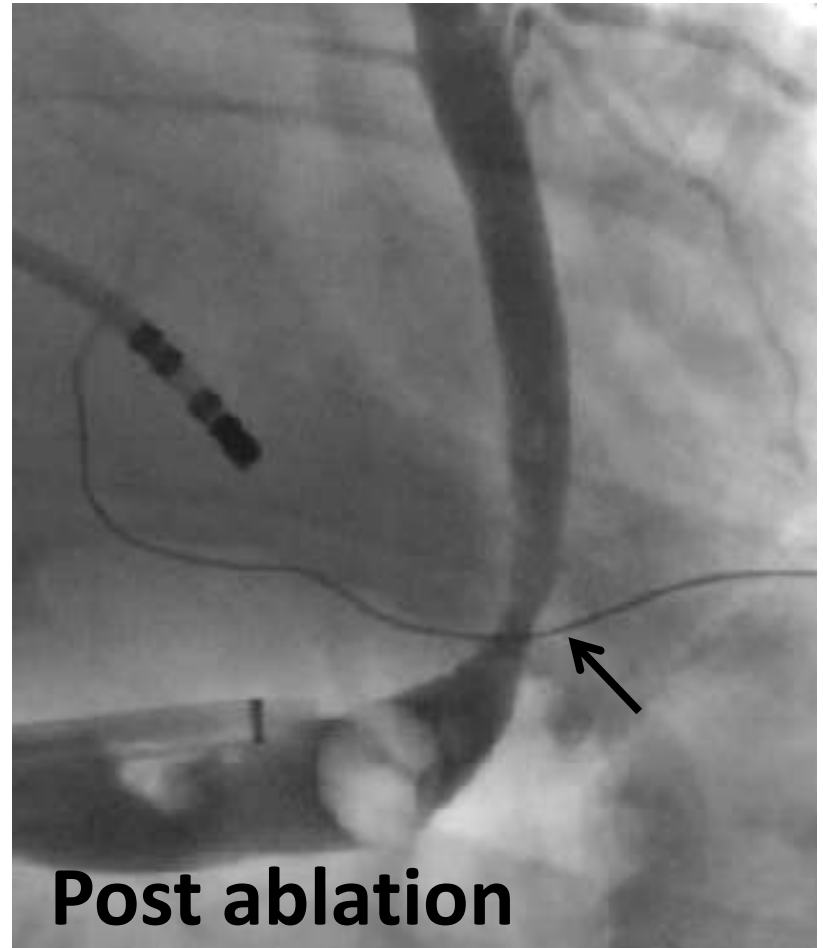
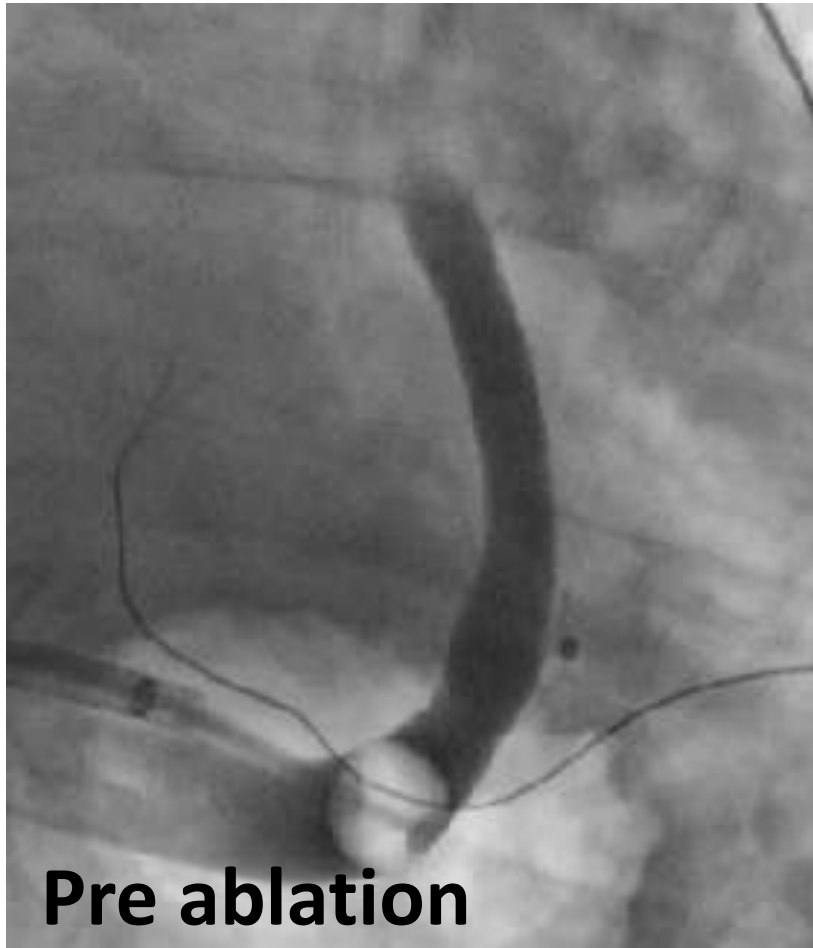
	CS occlusion	Control	P value
CS dissection	0	0	ns
Cardiac tamponade	0	0	ns
Vascular injury	1	0	ns
Thromboembolic events	0	0	ns
Subclinical Cx artery injury	4/20 (20%)	8/26 (31%)	0.41
Significant (>50%)	2	3	
CS stenosis	9/20 (45%)	73%(19/26)	0.03
Mild (<20%)	6	5	
Moderate	1	10	
Significant (>50%)	2	4	

Sub-clinical circumflex artery “injury”

- The response to intra-coronary GTN would suggest thermally-mediated spasm
- Strongly associated with CS ablation
- No ECG or ECHO abnormalities acutely or during follow up
- Patients do not report any angina symptoms



CS stenosis



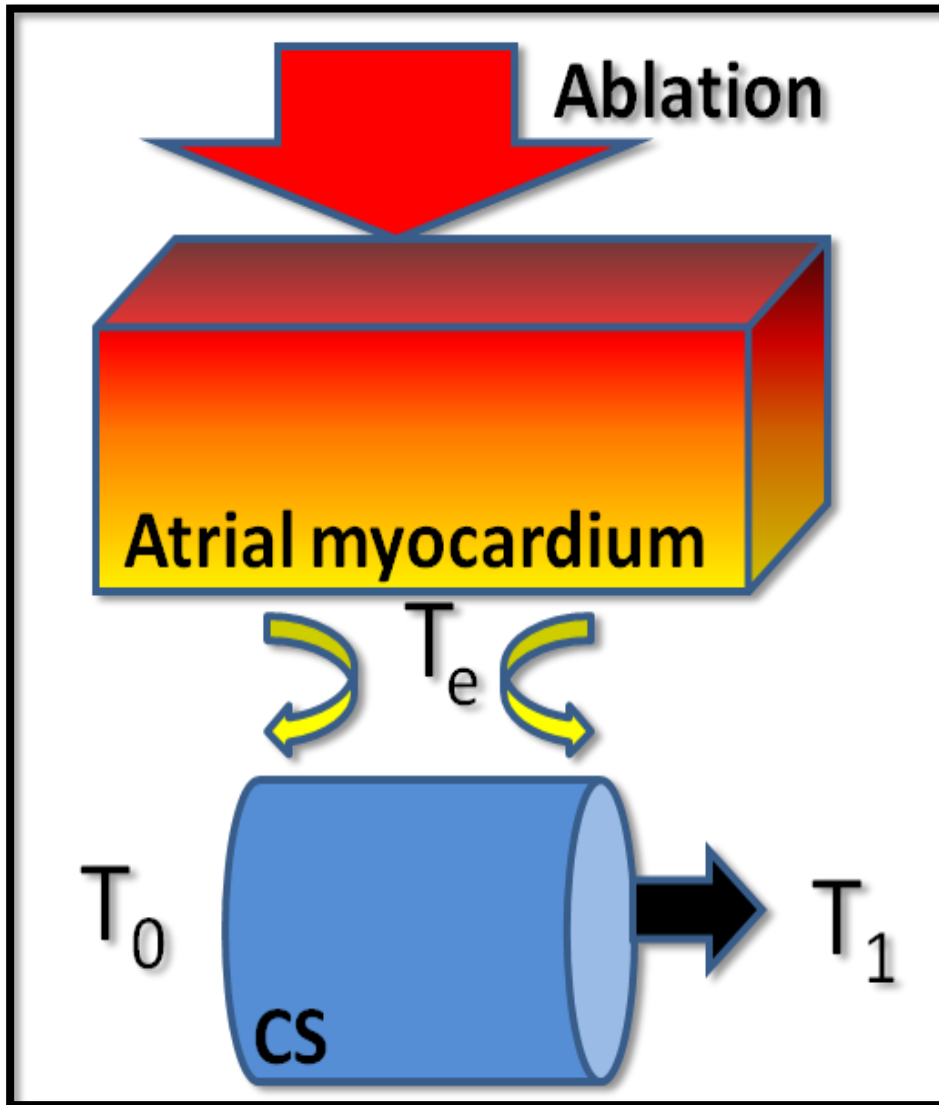
Further observations

In 1 patient, there was recurrence of conduction (after acute block) following balloon deflation (x3)

Follow up

- Mean follow up was 12 ± 2 months
- Overall single procedural success (no AF off AAD) is 77% (CS occlusion 79% vs control 77%, n.s.)
 - 9/10 patients had recurrence of AF
 - 1/10 patient had AF/AT

CS acting as “heat sink”



$$h = \frac{\rho c u (T_1 - T_0) b}{[0.25(2T_s + T_1 + T_0) - T_m] a}$$

H = convective heat transfer coefficient

P = the density of blood

C = the specific heat of blood

U = the mean blood velocity

T_0 = inlet blood temperature

T_1 = outlet blood temperature

T_s = max temperature at vessel wall,

T_m = mean of T_1 and T_0 ,

A = length of vessel

b = diameter of vessel

Rationale:

- Use of air vs saline
- Use of long balloon (40mm)
- Occlusion at the site of ablation

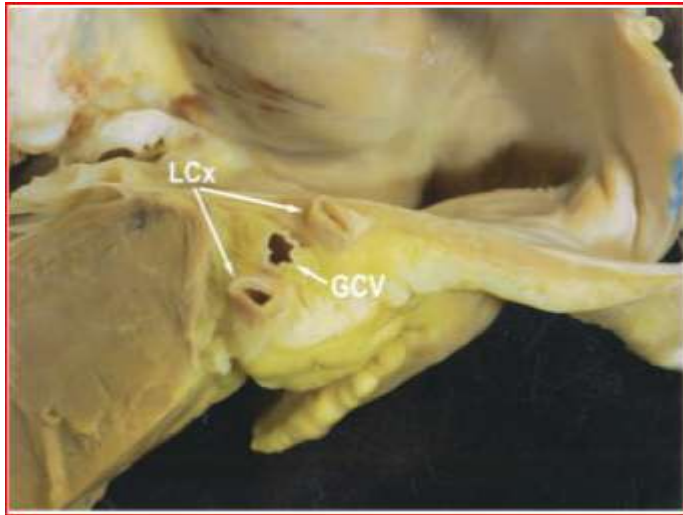
Consiglieri et al. Phys Med Biol 2003

Shah et al. (Bordeaux) @ Cardiostim 2010

	Bordeaux	Oxford
n	15	20
Mean age	59±9	62±10
Paroxysmal AF:Persistent AF	53%	18%
LA diameter (mm)	42±6	42±5
Maximum power (irrigated tip catheter)	Endo: 30-35W CS: 25W	Endo: 40W CS: 25W (2 patients: 30W)
Occlusion balloon	Swan Ganz (1cc)	Opta®Pro (4cc)
Acute success (%)	66%	85%
Total MI ablation time (min)	21±9	9.4±5.5
Endocardial ablation time (min)	18±7	8.5±3.5
CS ablation time (min)	2±2	1.5±2.8
Mean CS occlusion time (min)	25±9	<9
Procedure time (min)	33±15	17±14
Assessment of block during ablation	CS pacing	LAA pacing
Complication	1 CS dissection	None

Clinical implications

- Avoid ablation in the CS which may be associated with a greater risk of complication (i.e. circumflex artery)



Wittkamp et al. EHJ 2005

- Shorten ablation times
- In cases when getting into the CS with ablation catheter may be tricky, e.g. Hansen Robotics

Study limitations

- Inflated balloon may have modified the anatomy of the CS and the mitral isthmus in such a manner so as to facilitate ablation
- Did not verify complete occlusion of great cardiac vein by contrast injection
- Assessment of the maintenance of mitral isthmus block over the long term was not part of the study protocol

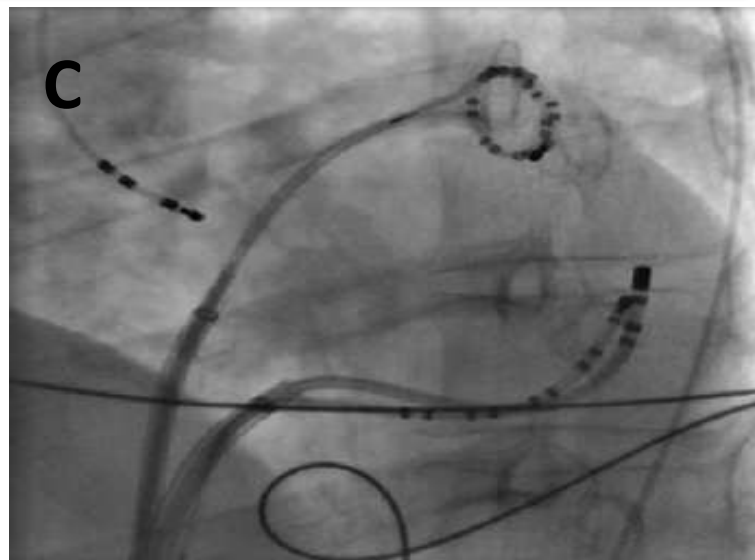
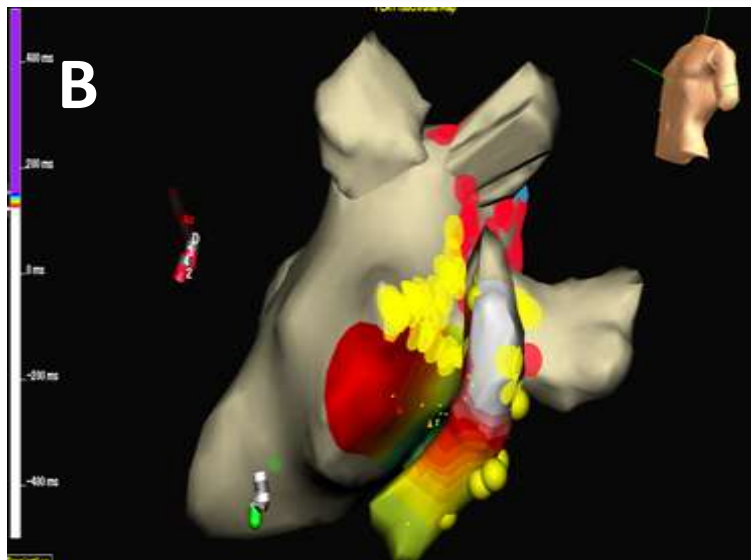
Conclusions

- Air-filled balloon occlusion of the great cardiac vein facilitates mitral isthmus ablation by significantly reducing the need for epicardial CS ablation and shortening total mitral isthmus and CS ablation times
- It does not appear to improve overall acute success rate (the baseline success rate is already high)
- The technique is feasible and safe and may be facilitated by custom-designed balloon catheters (? Balloon at the end of deflectable CS catheter)

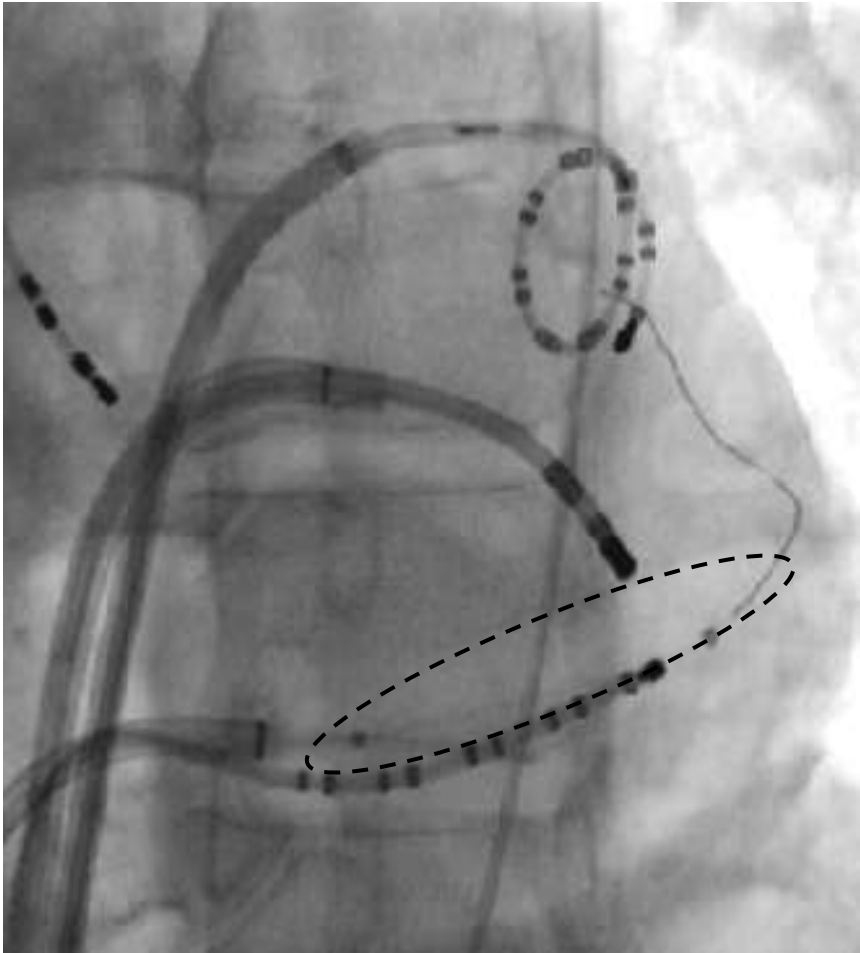
Support the hypothesis that “heat sink” effect due to blood flow in the CS is one of the factors that hinder mitral isthmus ablation

Acknowledgement

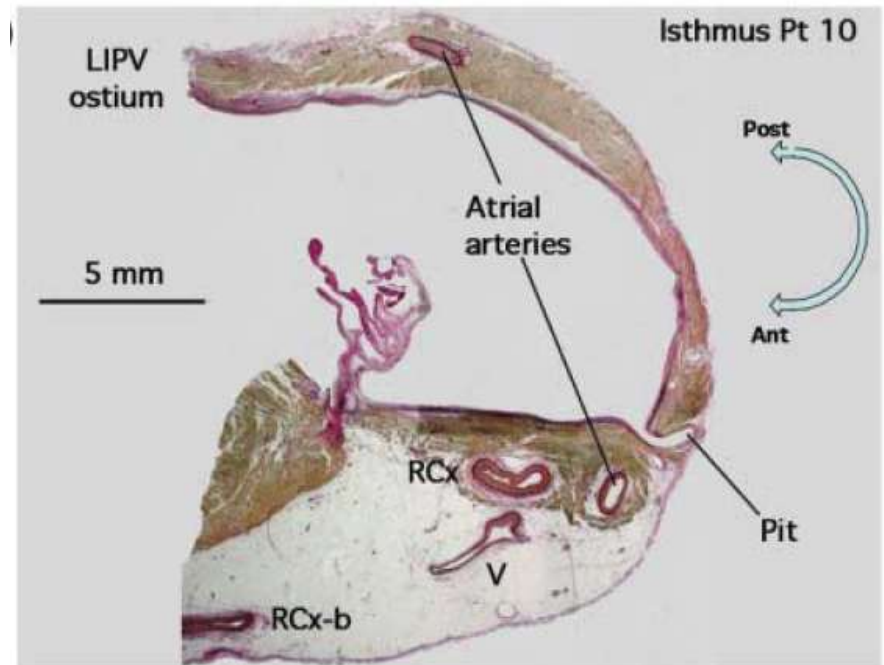
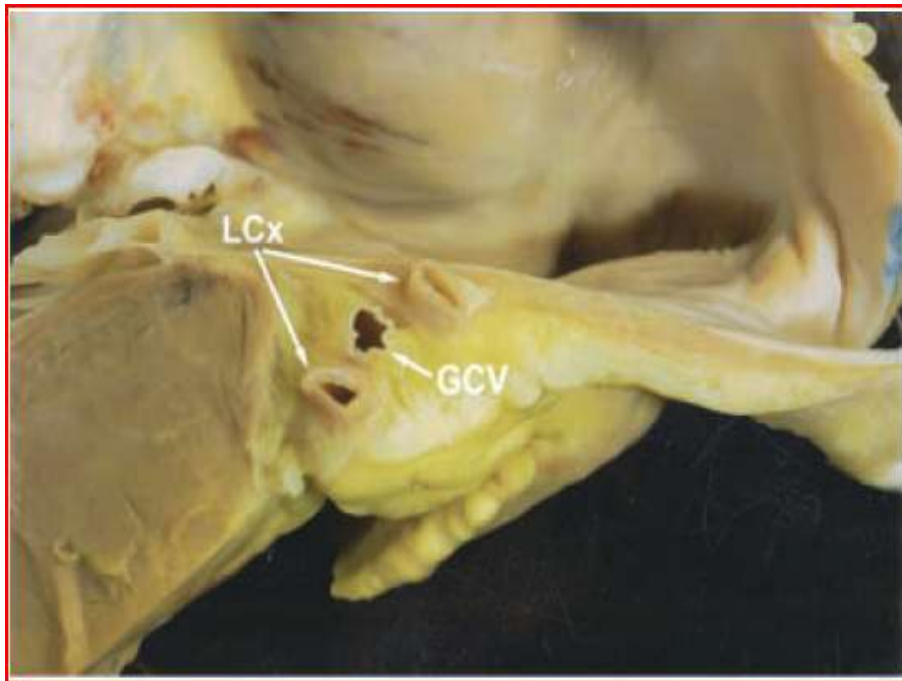
- Medical team: T Betts, K Rajappan, Y Bashir, M Jones, N Qureshi, J De Bono, P Sadarmin
- Arrhythmia nurses: A Griffiths, T Meredith
- Physiologists: J Cole, T Webb, H Tumman
- Catheter laboratory nursing staff
- Radiographers



Sub-optimal occlusion of great cardiac vein



Close relationship between circumflex artery, coronary sinus and mitral annulus



Wittkamp et al. EHJ 2005

Circumflex artery occlusion

Acute Occlusion of the Left Circumflex Coronary Artery During Mitral Isthmus Linear Ablation

YOSHIHIDE TAKAHASHI, M.D., PIERRE JAÏS, M.D., MÉLÈZE HOCINI, M.D.,
PRASHANTHAN SANDERS, M.B.B.S., Ph.D., MARTIN ROTTER, M.D.,
THOMAS ROSTOCK, M.D., FRÉDÉRIC SACHER, M.D., CATHERINE JAÏS, M.D.,
JACQUES CLÉMENTY, M.D., and MICHEL HAÏSSAGUERRE, M.D.

SHORT COMMUNICATION

doi:10.1093/europace/eup447
Online publish-ahead-of-print 29 January 2010

Acute occlusion of left circumflex artery following radiofrequency catheter ablation at the mitral isthmus

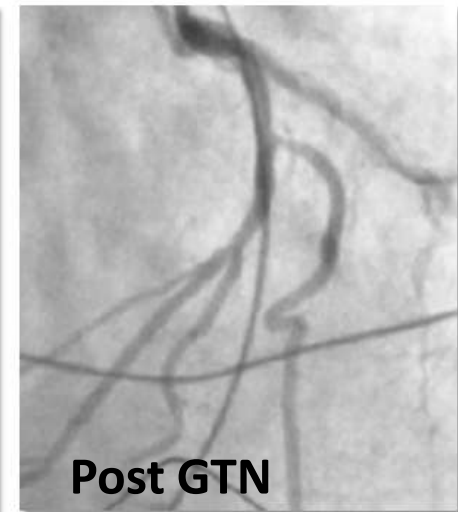
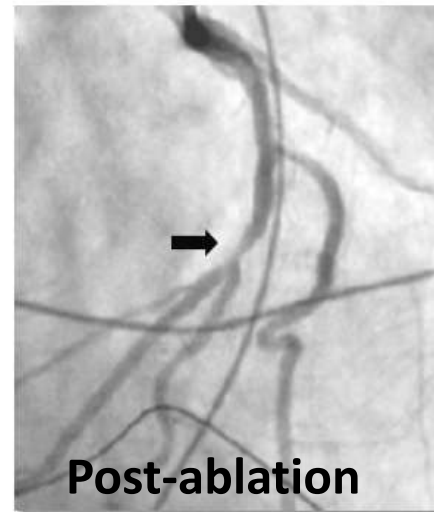
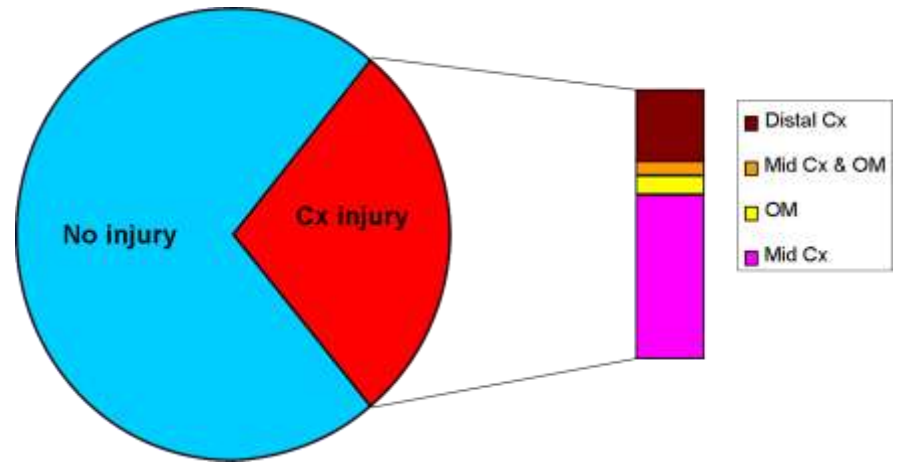
Kelvin C.K. Wong, Praveen P. Sadarmin, Bernard D. Prendergast, and Timothy R. Betts*

Oxford Heart Centre, Oxford Radcliffe Hospitals NHS Trust, Oxford OX3 9DU, UK



Incidence of subclinical circumflex artery “injury”

- 15/54 patients (28%) had angiographic changes following mitral isthmus ablation
- Risk factors for circumflex artery “injury”:
 - Ablation in CS
 - Duration of CS ablation
 - Proximity of CS to Cx



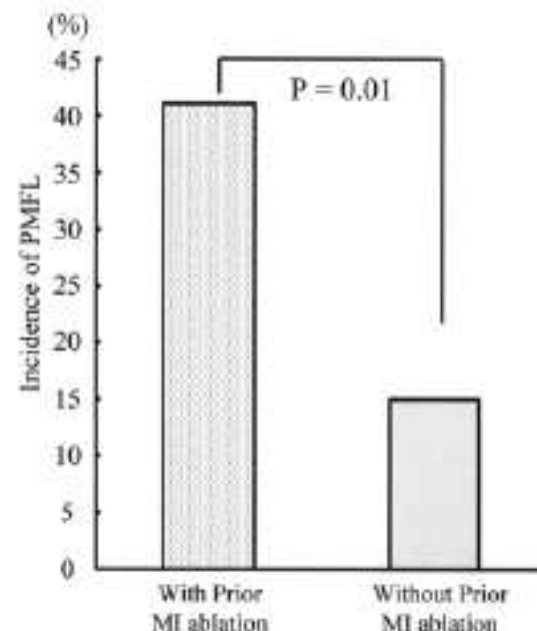
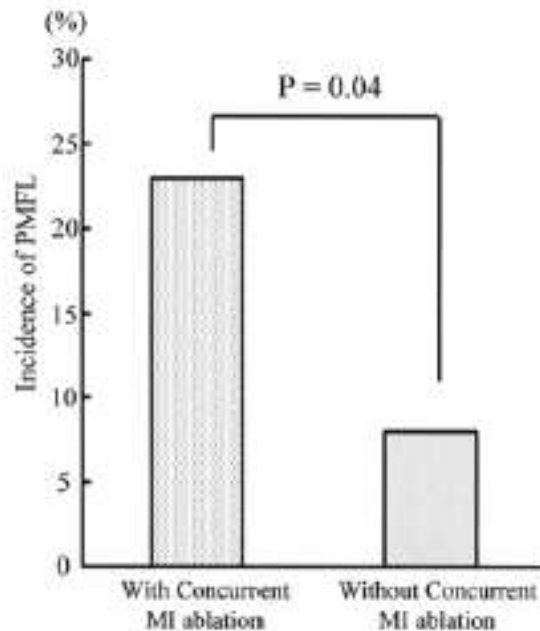
Unpublished Data

Oxford: Mitral isthmus ablation case series

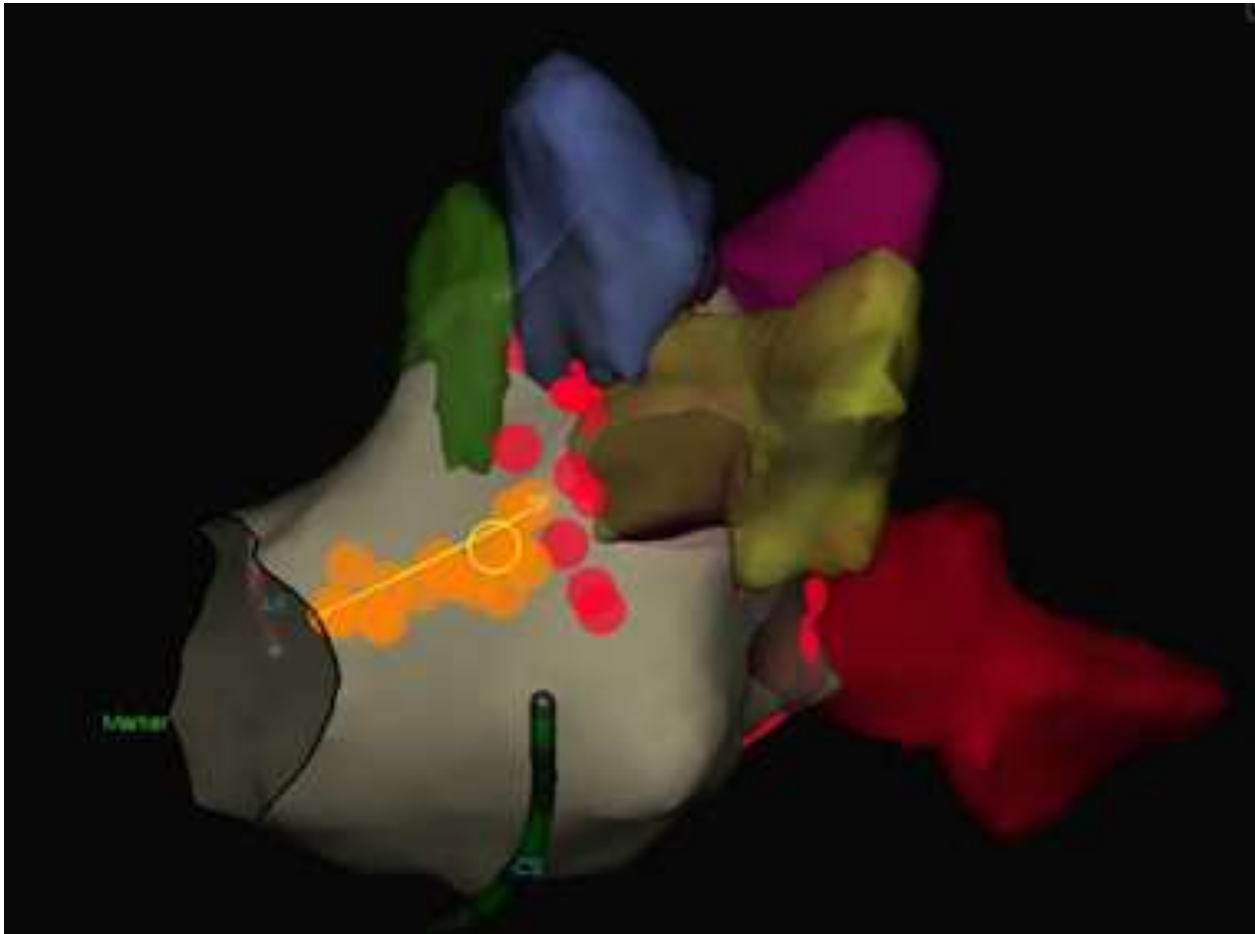
- In a series of 192 patients, 4 mm irrigated tip catheter with high power of 40-50W limited to the annular end of the mitral isthmus line achieved:
 - high success rate (91%),
 - frequency of CS ablation (67%)
 - Shorter total RF time of 12 ± 6 min (endo: 10 ± 3 min; CS: 3 ± 1)
 - no tamponade attributed to mitral isthmus ablation; but 1 circumflex artery occlusion (cf. *Jais Circulation 2004*)

Blocked lines can recover!

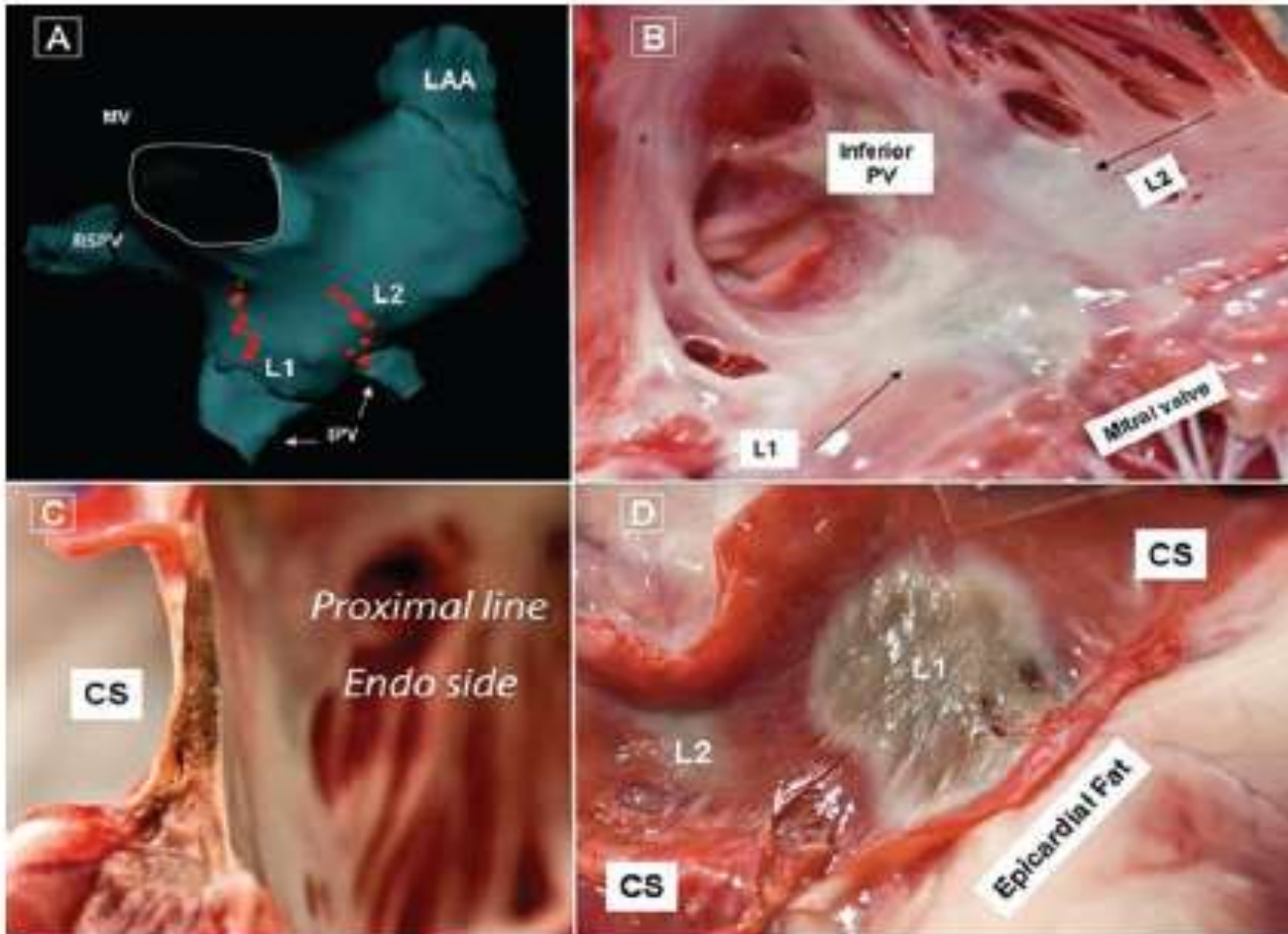
- Recent suggestions that even with block, macroreentrant tachycardia may develop due to the resumption of conduction (*Haissaguerre JCE 2005; Matsuo Heart Rhythm 2010 (7):2; Anousheh PACE 2010 (33): 460; Sawhney Circulation Arrhythmia & Electrophysiology 2010 (3);243*)



Measurement of mitral isthmus length



In vivo animal study

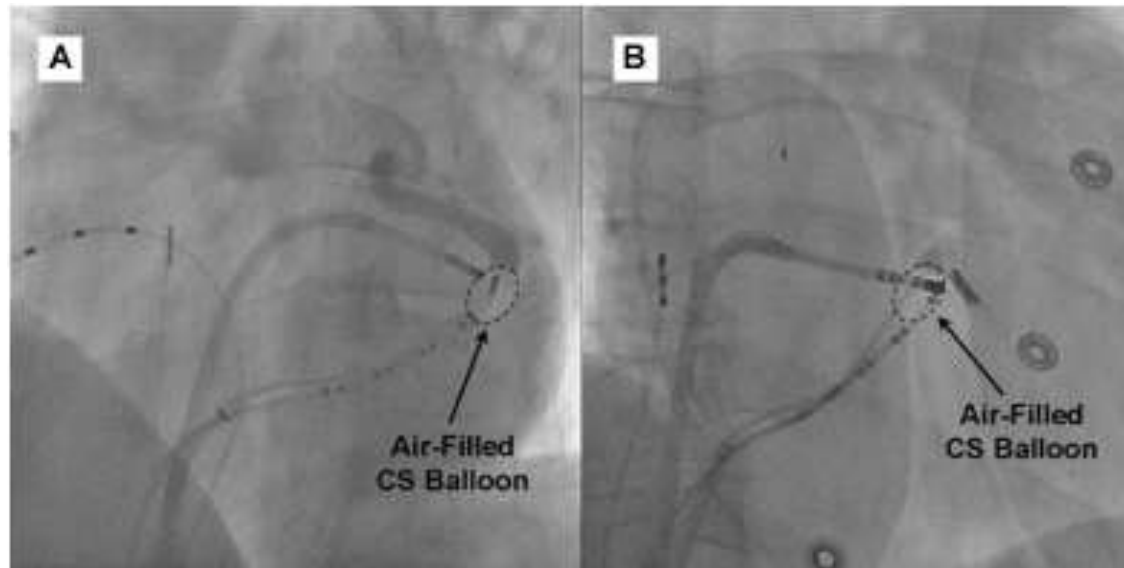


Human case report

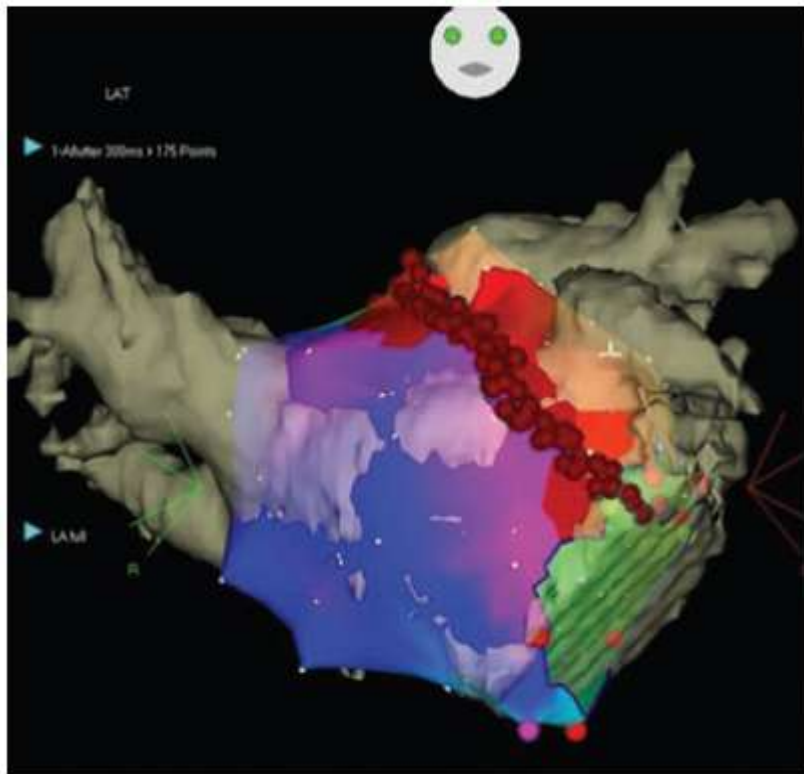
Balloon Occlusion of the Coronary Sinus to Facilitate Mitral Isthmus Ablation

VIVEK Y. REDDY, M.D., JEREMY N. RUSKIN, M.D., and ANDRE D'AVILA, M.D.

From the Cardiac Arrhythmia Service, Massachusetts General Hospital, and Harvard Medical School, Boston, Massachusetts, USA



Alternative “isthmus lines”



“U” LESION

