Samsung VT symposium
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Summit VT

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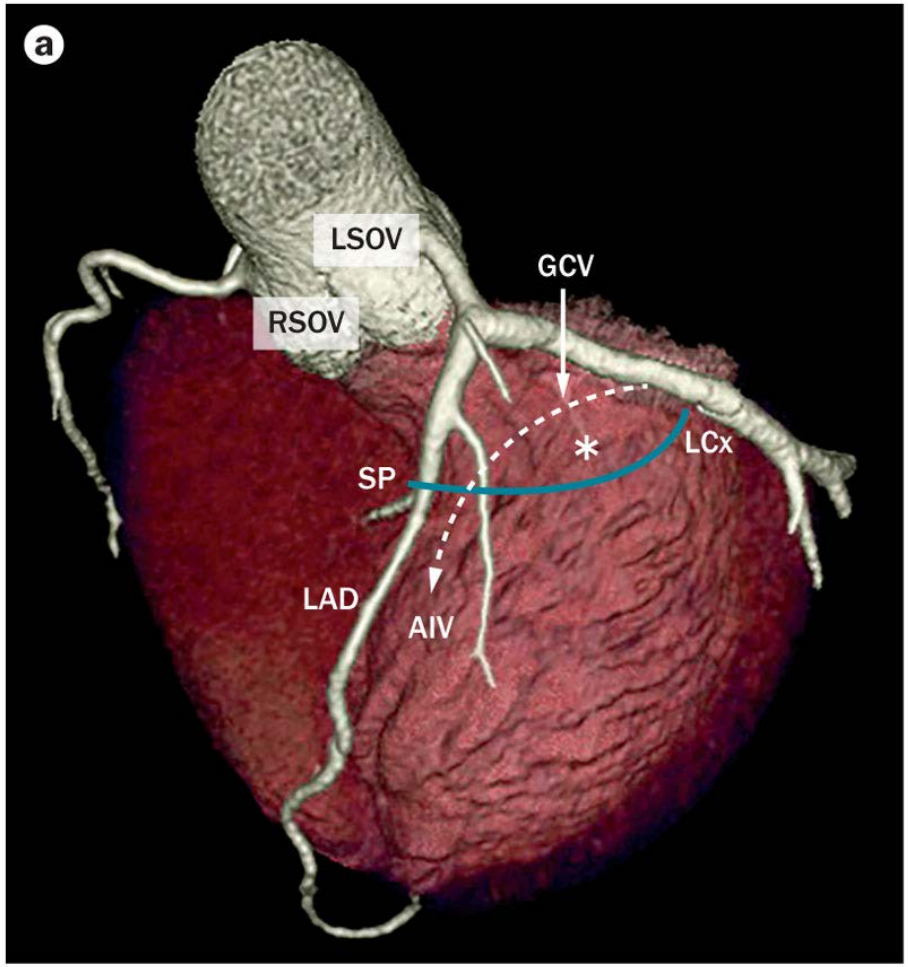
1. Anatomical definition of LV summit

Anatomical definition of LV summit

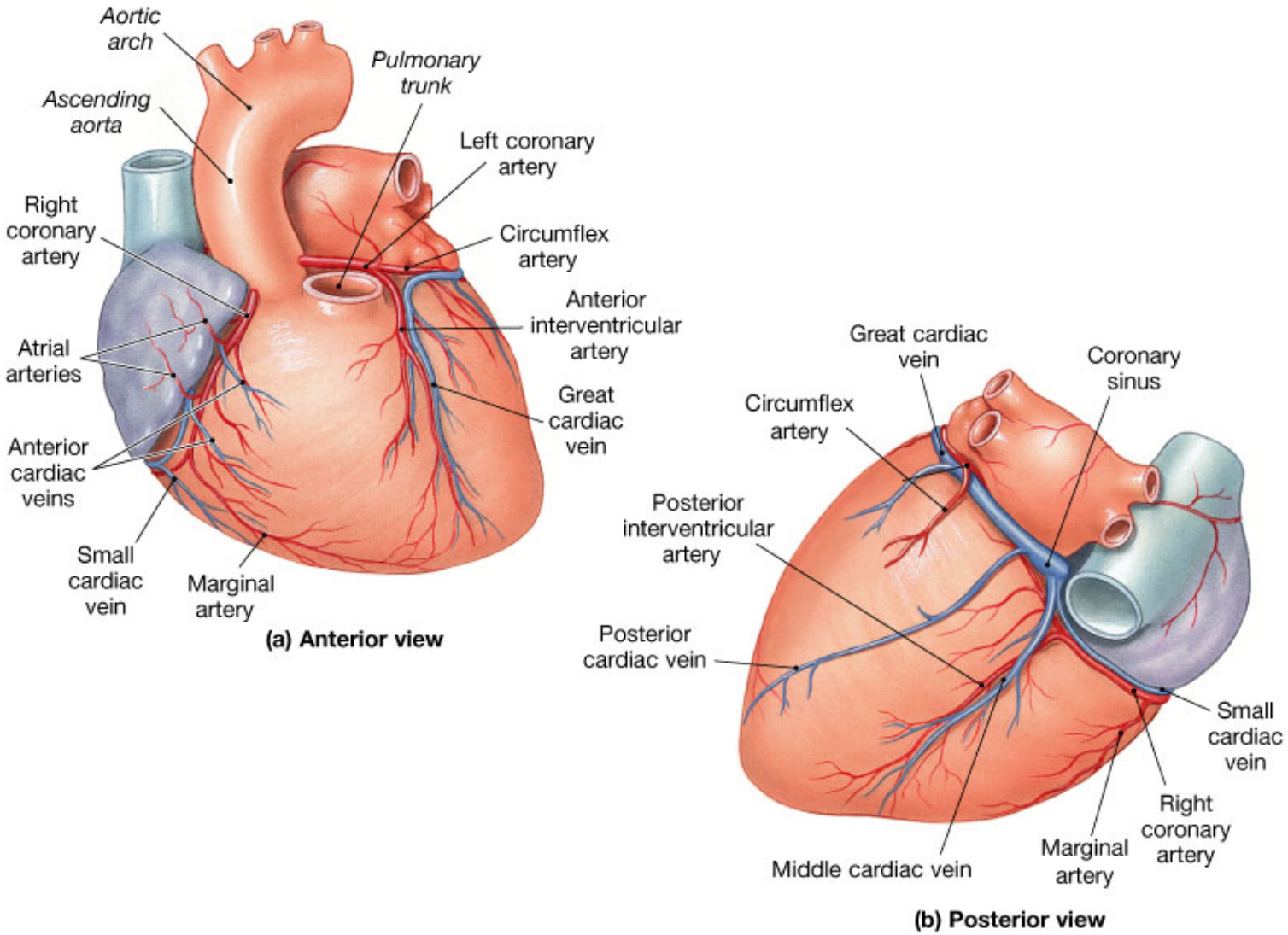


Summit

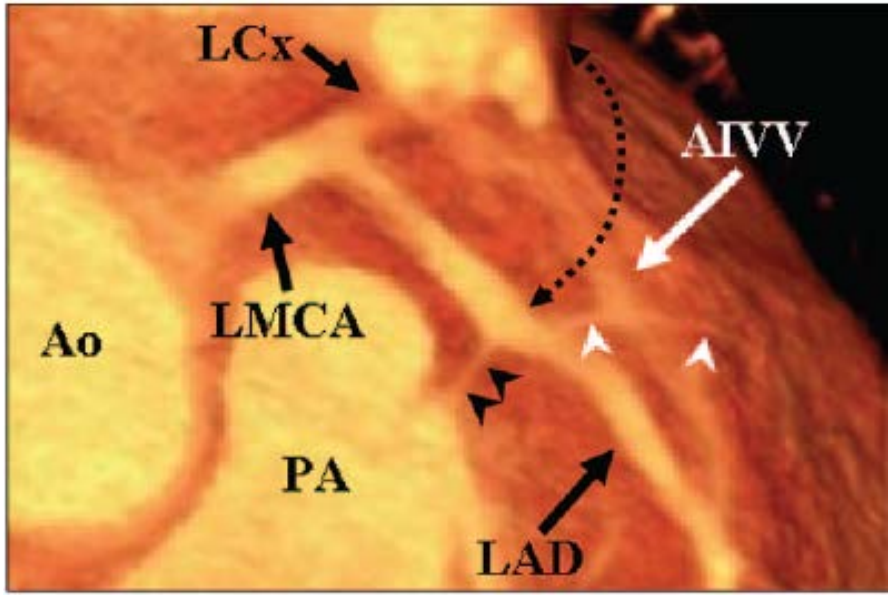
- the highest point of LV
- A point located above both the upper end of the ant.interventricular sulcus and the aortic portion of the ostium of the LV
- region on the epicardial surface of the LV near the bifurcation of the left main coronary artery that is bounded by an arc from the LAD superior to the first septal perforating branch anterior to the LCx laterally

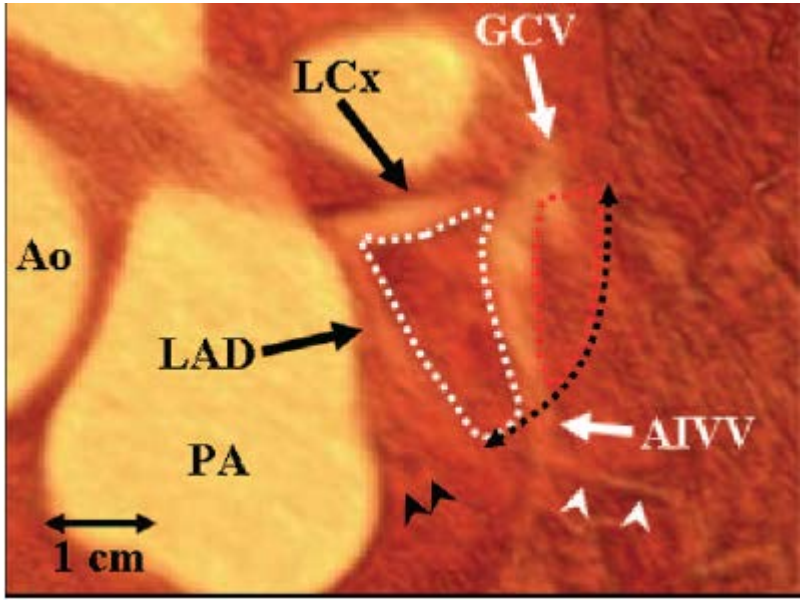
W.A.McAlpine, 1971

Summit & GCV


Aortic arch
Pulmonary trunk
Ascending aorta
Left coronary artery
Right coronary artery
Circumflex artery
Anterior interventricular artery
Atrial arteries
Great cardiac vein
Anterior cardiac veins
Small cardiac vein
Marginal artery
(a) Anterior view
Great cardiac vein
Coronary sinus
Circumflex artery
Posterior interventricular artery
Posterior cardiac vein
Small cardiac vein
Right coronary artery
Marginal artery
Middle cardiac vein
(b) Posterior view

Anatomical definition of LV summit

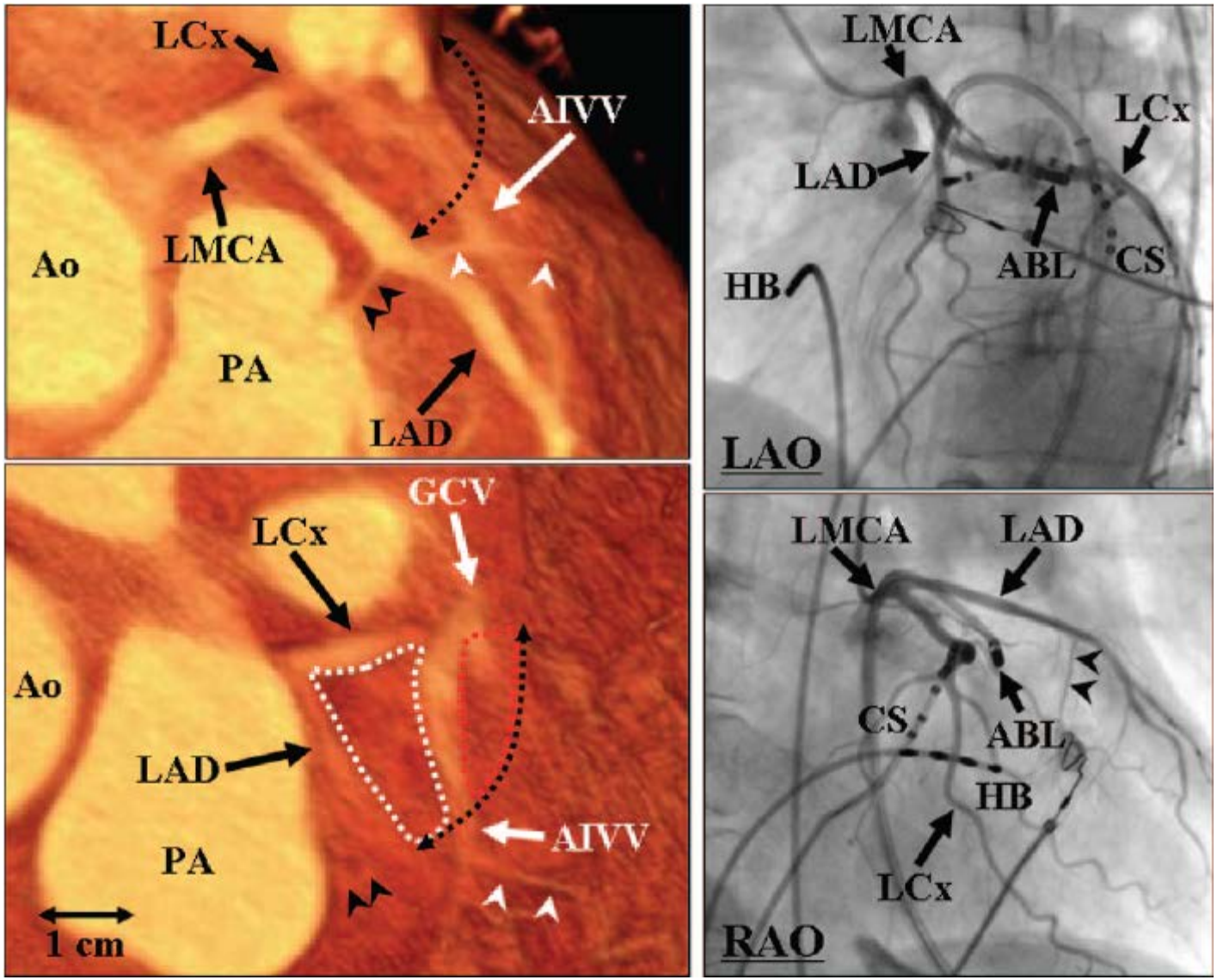




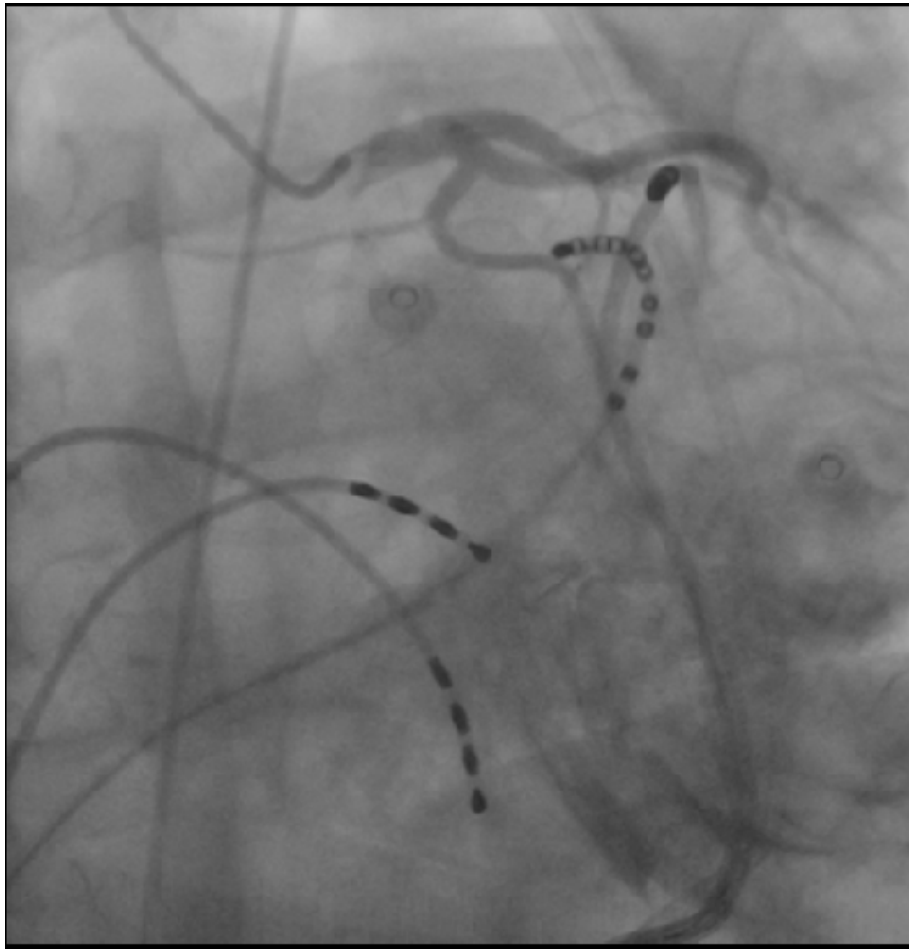
- GCV bisect Inaccessible and accessible area
  - ✓ **Inaccessible**: superior portion that is in close proximity to the proximal coronary arteries and overlying epicardial fat
  - ✓ **Accessible**: inferior portion that may be accessible to epicardial catheter ablation

Circ Arrhythm Electrophysiol 2010;3:616

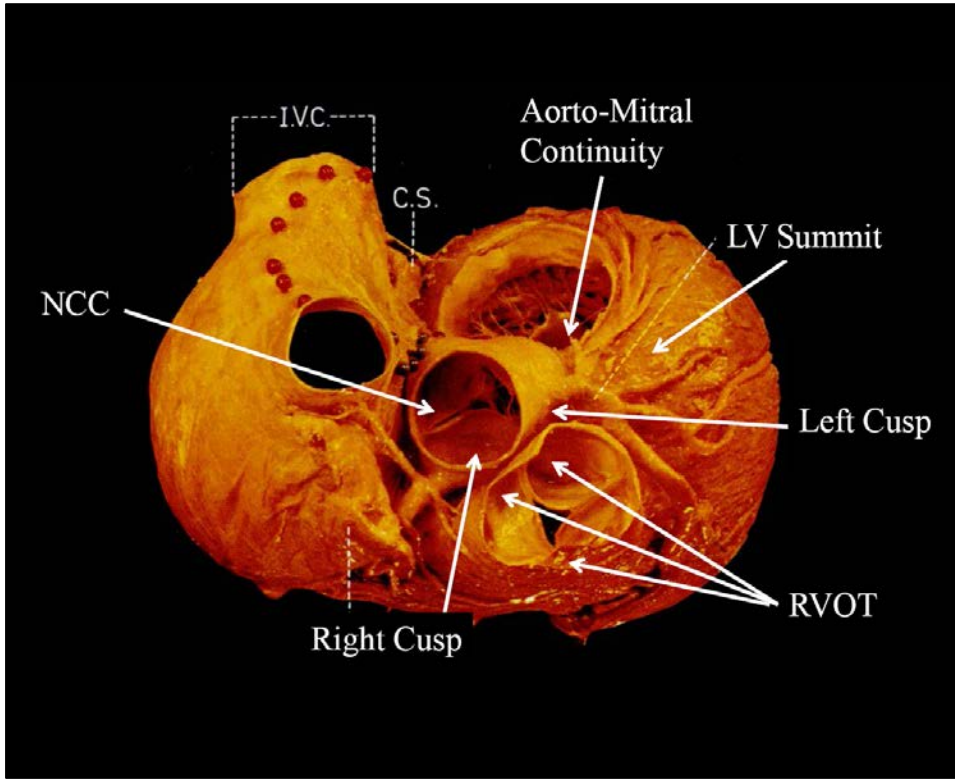
Relationship between imaging and fluoroscopy

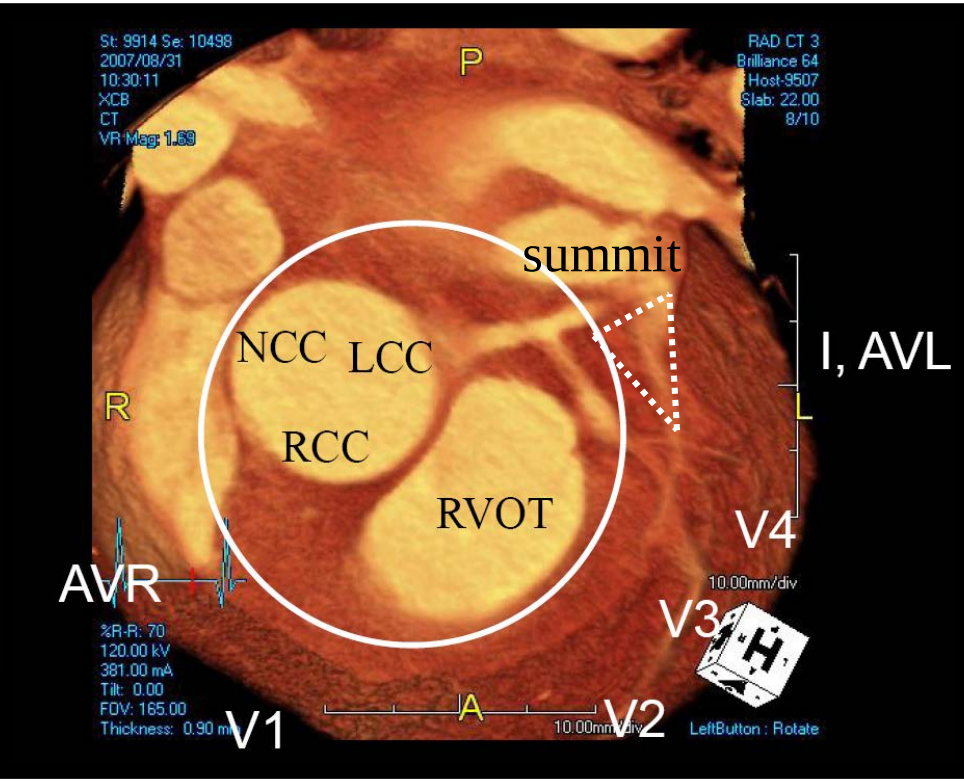


Great Cardiac Vein and Accessible arrea

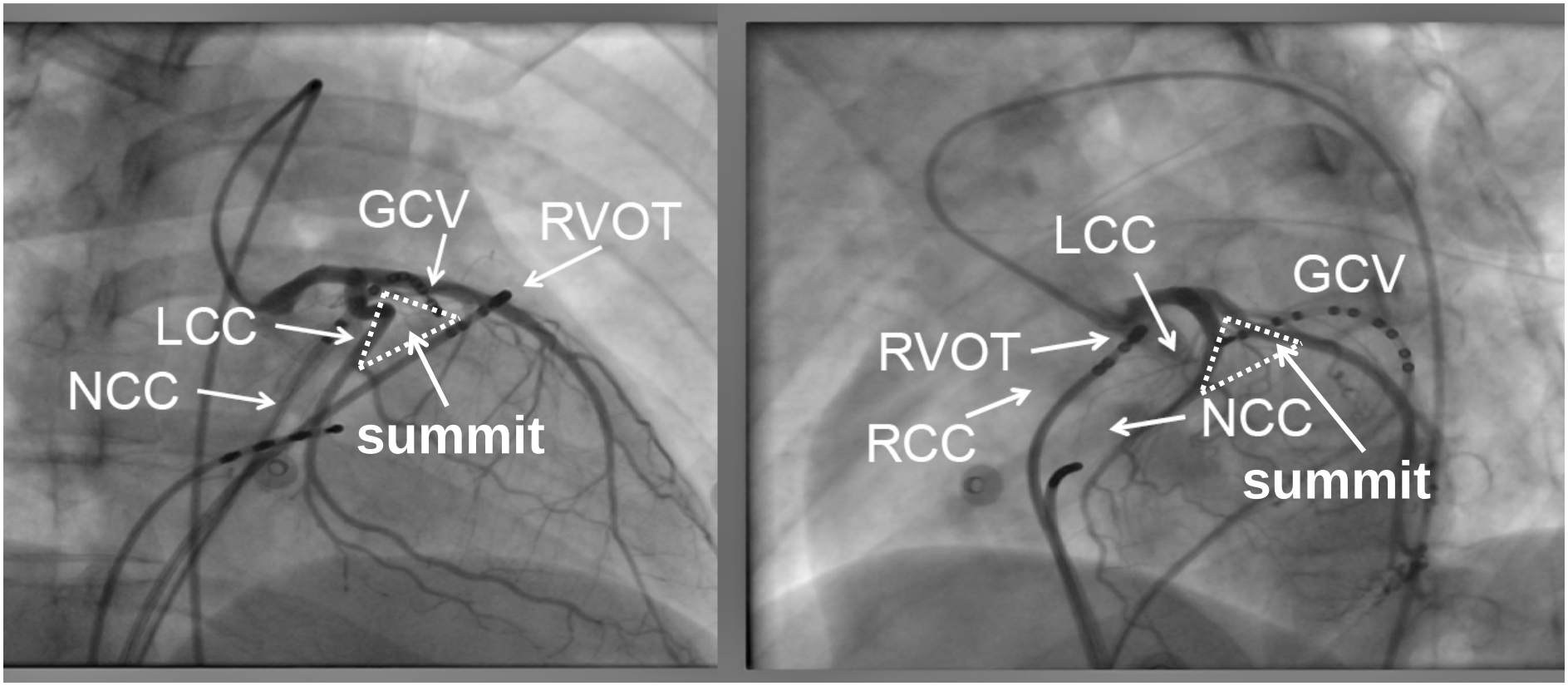


Outflow tract and summit





Outflow tract and summit

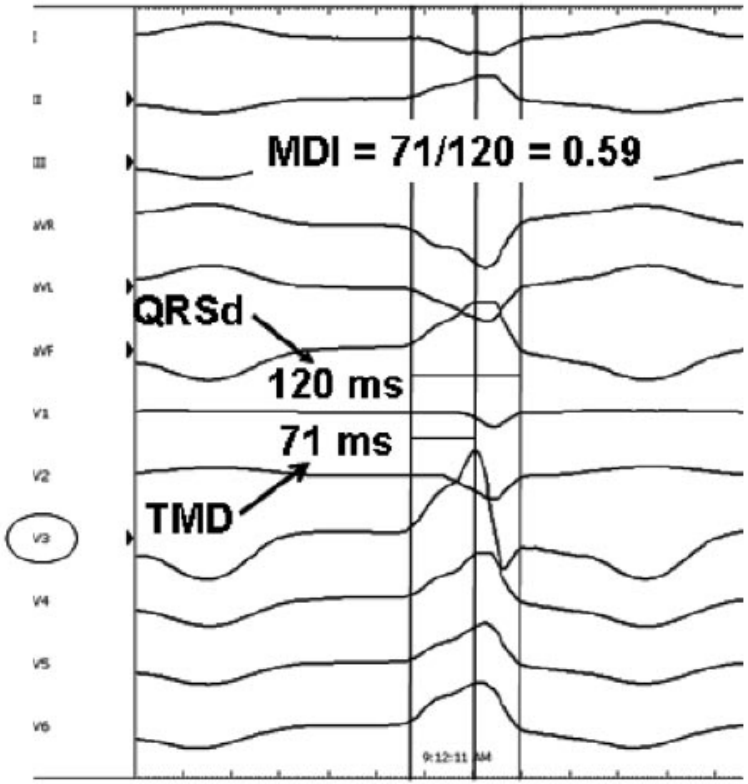


RAO

LAO

2. ECG features

Maximum deflection index (MDI)



$$MDI = \frac{\text{shortest time to max.deflection}}{\text{QRS duration}}$$

MDI ≥ 0.55: epicardial VA

Circulation 2006;113:1659

Key features for summit VT ECG

1. **Lead I: absence of R wave**
   - Activation vector R -> L, VA located in LV free wall
2. **V5,6: absence of S wave**
   - s in V5,6: aortomitral continuity VA
   - s in V5,6 + RBBB: endocardial VA
3. **MDI ≥ 0.55: epicardial VA**

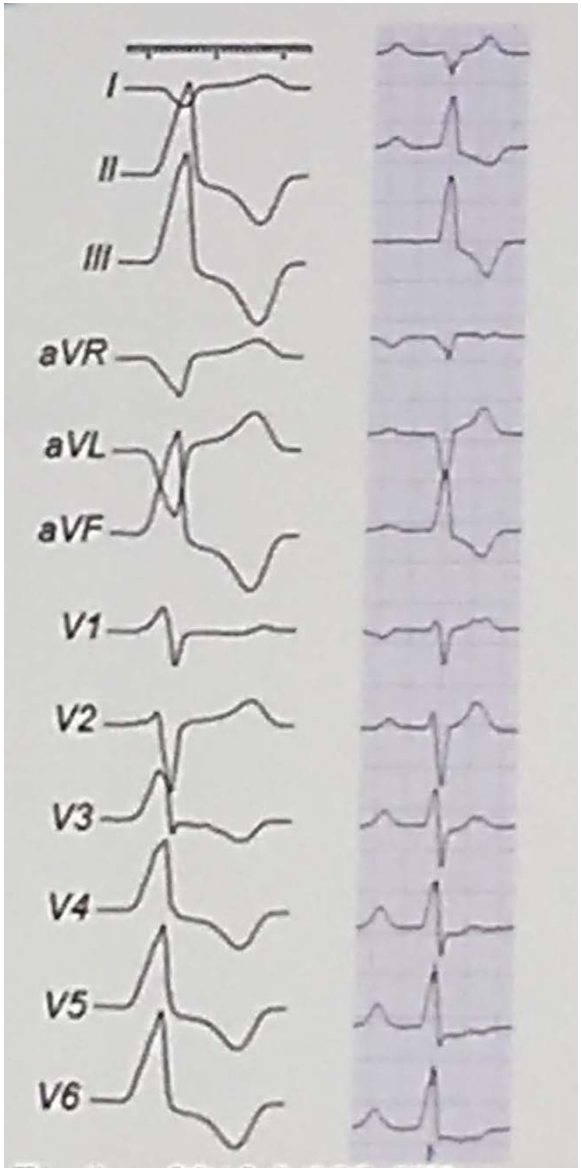
Origin	QRS Morphology	Transition	Lead I
GCV+AIVV	RBBB+		
(n=12+7)	RIA; 14	<V_1; 13	QS; 4
	LBBB+	V_2-V_3; 5	rS; 15
	RIA; 5	V_3; 1	
Accessible area			
(n=4)	RBBB+	<V_1; 3	QS; 3
	RIA; all	V_2-V_3; 1	qrs; 1
Inaccessible area	RBBB+		
(n=4)	RIA; 1	V_2-V_3; 4	QS; 1
	LBBB+		rS; 2
	RIA; 2		rsr′; 1
	LBBB+		
	LIA; 1		
P value	0.052	0.126	0.006

Origin	S (+) in V_5 or V_6	MDI (% of >0.54)
GCV+AIVV (n=12+7)	5 (26%)	0.53 (0.49 to 0.57) (47%)
Accessible area (n=4)	1 (25%)	0.53 (0.49 to 0.57) (50%)
Inaccessible area (n=4)	0 (0%)	0.54 (0.38 to 0.70) (50%)
P value	0.511	0.963

Takumi Yamada. Circ Arrhythm Electrophysiol 2010;3:616

ECG criteria for summit VT

1. (+) in II, III, aVF
   - More (+) in III than II
2. More (-) in aVL
   - aVL/aVR ratio > 1.4
   - Rarely positive in I
3. Precordial transition
   - RBBB no transition
   - LBBB transition V2 or V3
   - Pattern break in V2



Heart rhythm 2012;9:865

ECG criteria for summit VT

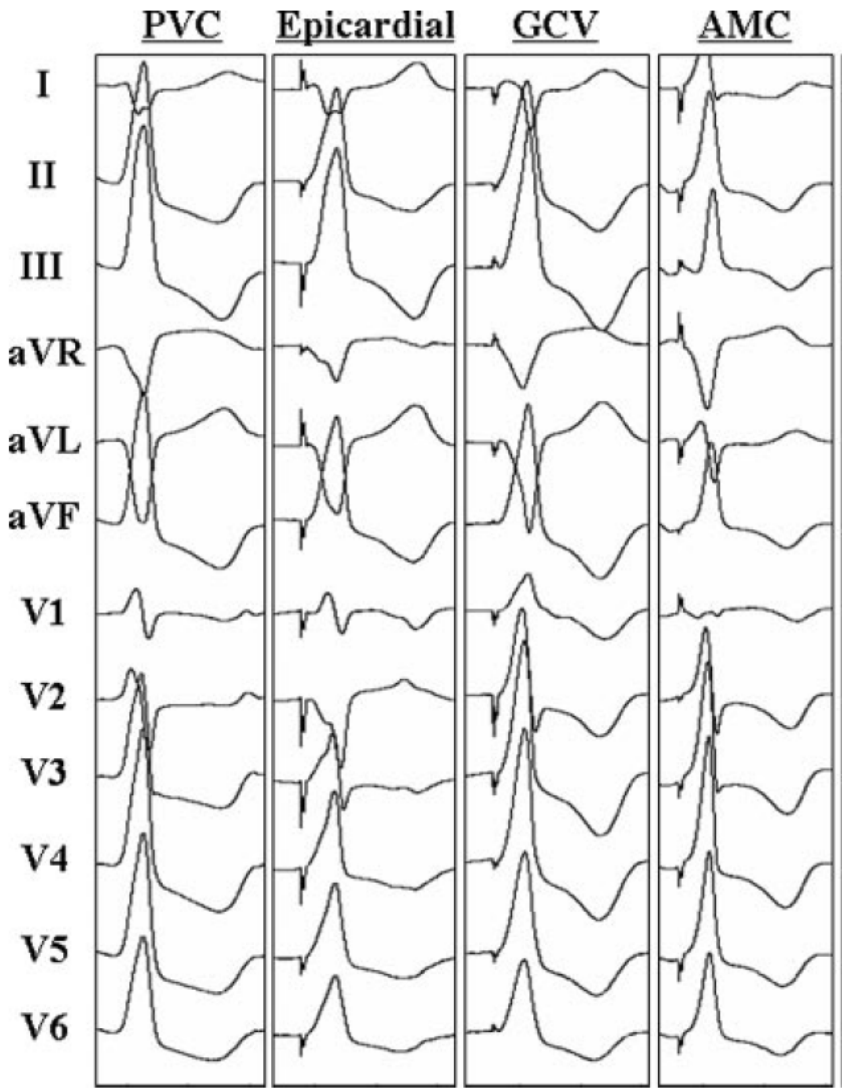
Origin	III/II Ratio	aVL/aVR Ratio	S (+) in V_5 or V_6	MDI (% of >0.54)	Pre-P (+)
GCV+AIVV (n=12+7)	1.2 (1.1 to 1.3)	1.5 (1.2 to 1.8)	5 (26%)	0.53 (0.49 to 0.57) (47%)	16 (84%)
Accessible area (n=4)	1.4 (1.2 to 1.6)	2.3 (1.6 to 3.0)	1 (25%)	0.53 (0.49 to 0.57) (50%)	3 (75%)
Inaccessible area (n=4)	1.1 (0.9 to 1.3)	0.9 (0.6 to 1.2)	0 (0%)	0.54 (0.38 to 0.70) (50%)	N/A
P value	0.010	0.005	0.511	0.963	N/A

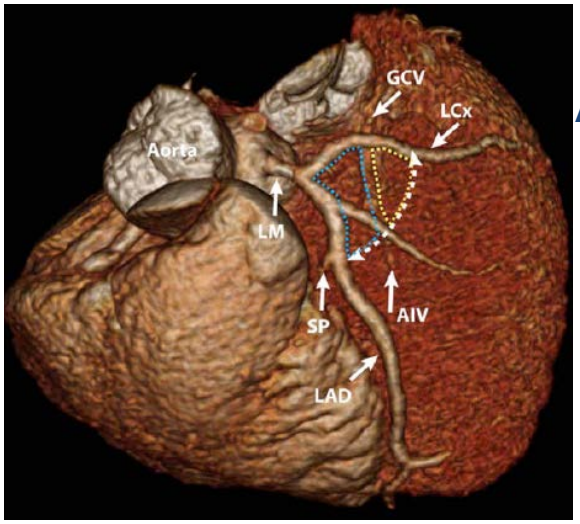
QRS Characteristics	Subject	Site of Prediction
RBBB	LV summit (n=27)	GCV+accessible area (n=23)
Transition zone $<V_1$	LV summit (n=27)	GCV+accessible area (n=23)
aVL/aVR ratio >1.1	LV summit (n=27), Avg=1.56, 95% CI=1.56 ±0.27	GCV+accessible area (n=23), Avg=1.68, 95% CI=1.68 ±0.29
S waves in V_5 or V_6	LV summit (n=27)	GCV+accessible area (n=23)
III/II ratio >1.25	GCV+accessible area (n=23), Avg=1.23, 95% CI=1.23 ±0.08	Accessible area (n=4), Avg=1.43, 95% CI=1.43 ±0.21
aVL/aVR ratio >1.75	GCV+accessible area (n=23), Avg=1.68, 95% CI=1.68 ±0.29	Accessible area (n=4), Avg=2.34, 95% CI=2.34 ±0.66

Circ Arrhythm Electrophysiol 2010;3:616

ECG & EGM at accessible area

ECG & EGM at inaccessible area





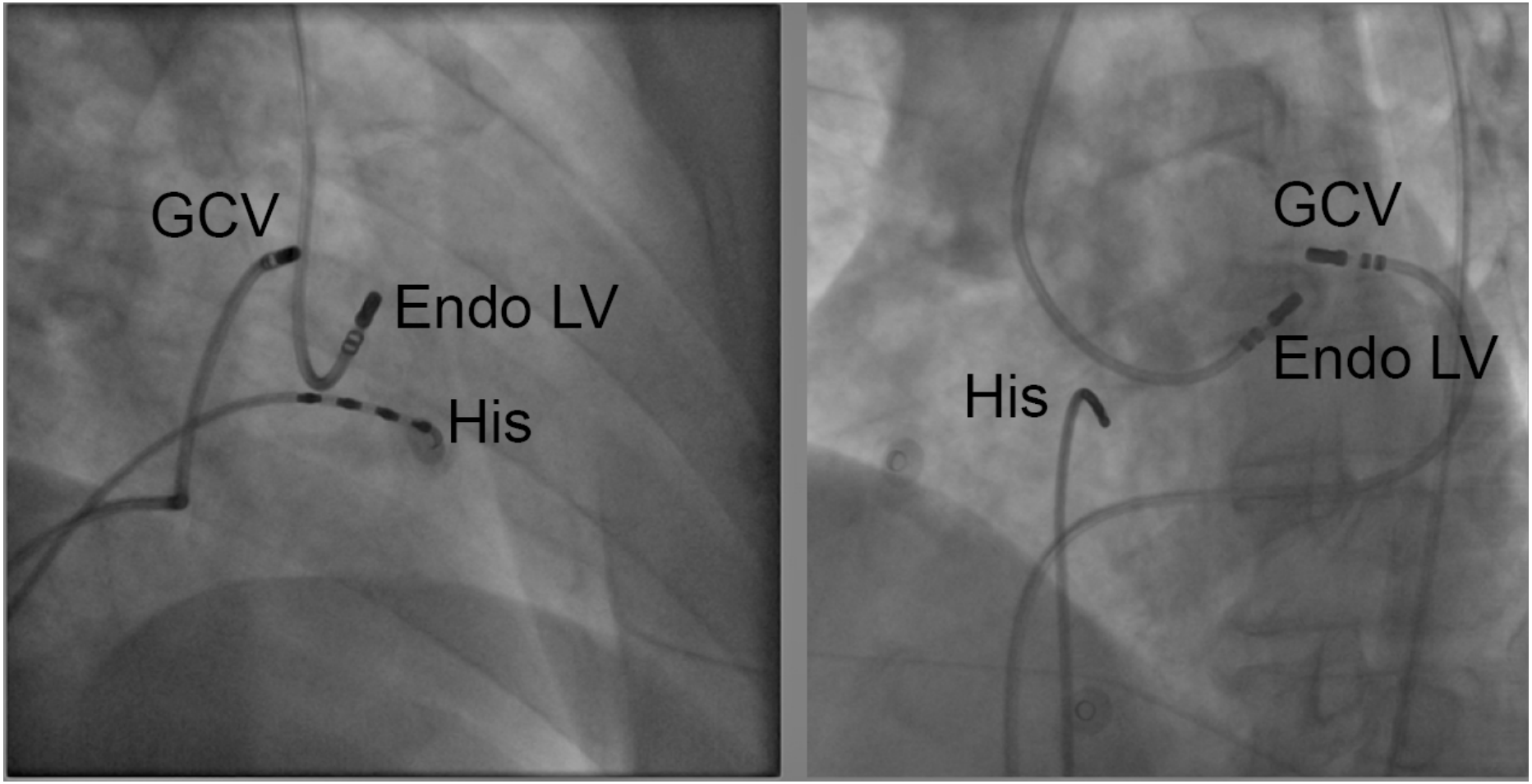
Apex of summit
Near LM bifurcation

Variable	Successful Ablation (n=5)	Unsuccessful Ablation (n=18)	*P* Value*
Qualitative findings			
RBBB morphology, n (%)	4 (80)	9 (50)	0.339
LBBB morphology, n (%)	1 (20)	9 (50)	0.339
QS in lead I, n (%)	3 (60)	4 (22)	0.142
Initial q in V1, n (%)	0 (0)	6 (33)	0.272
Ratio Q in aVL/aVR >1.85, n (%)	4 (80)	2 (11)	0.008
Ratio R/S in V1>2, n (%)	4 (80)	5 (28)	0.056

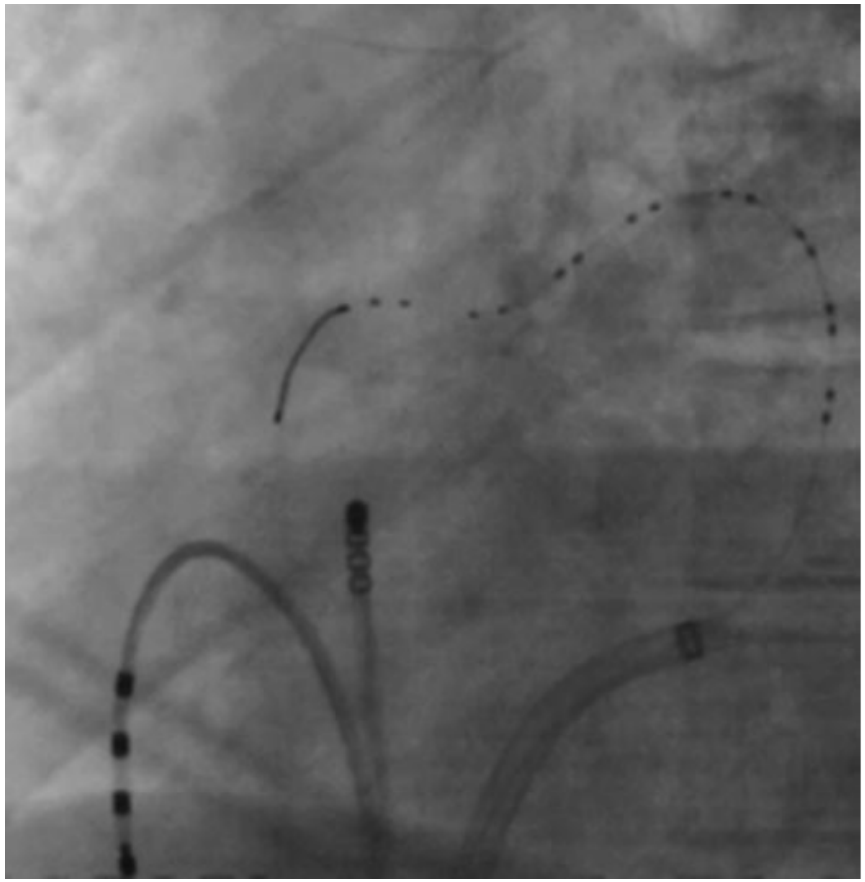
Circ Arrhythm Electrophysiol 2015;8:337

3. Mapping

Endocardial & transvenous mapping



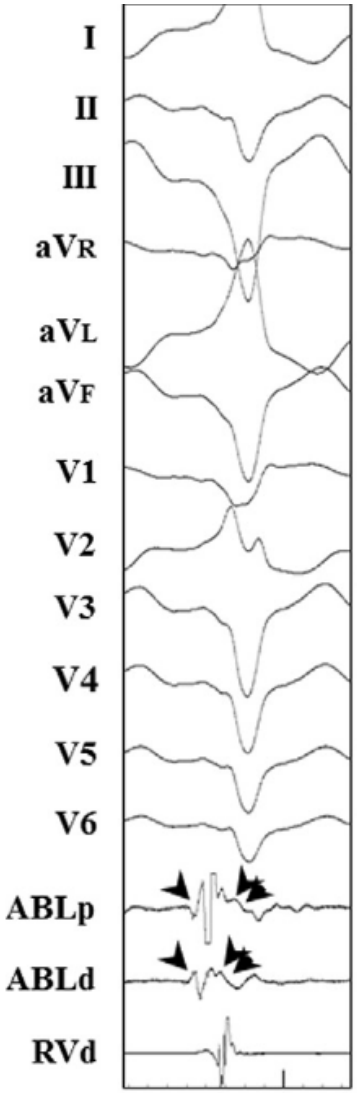
Micro-mapping catheter within small cardiac vein



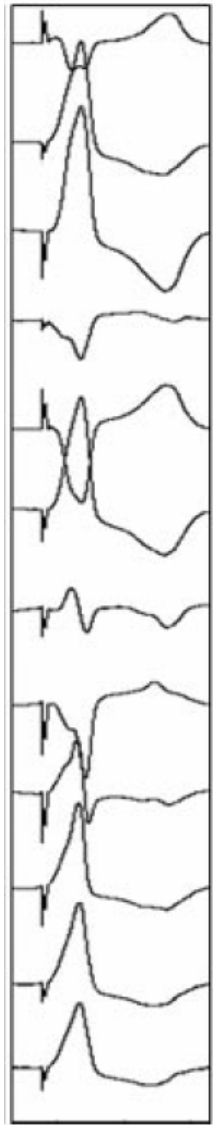
2.5F multipolar catheter (Pathfinder, CARDIMA, Inc, Fremont, Calif)

Circ Arrhythm Electrophysiol 2010;3:274

Activation map



pacing map



- **LBBB**

  ROVT -> CVS -> Ao.cusp -> LV

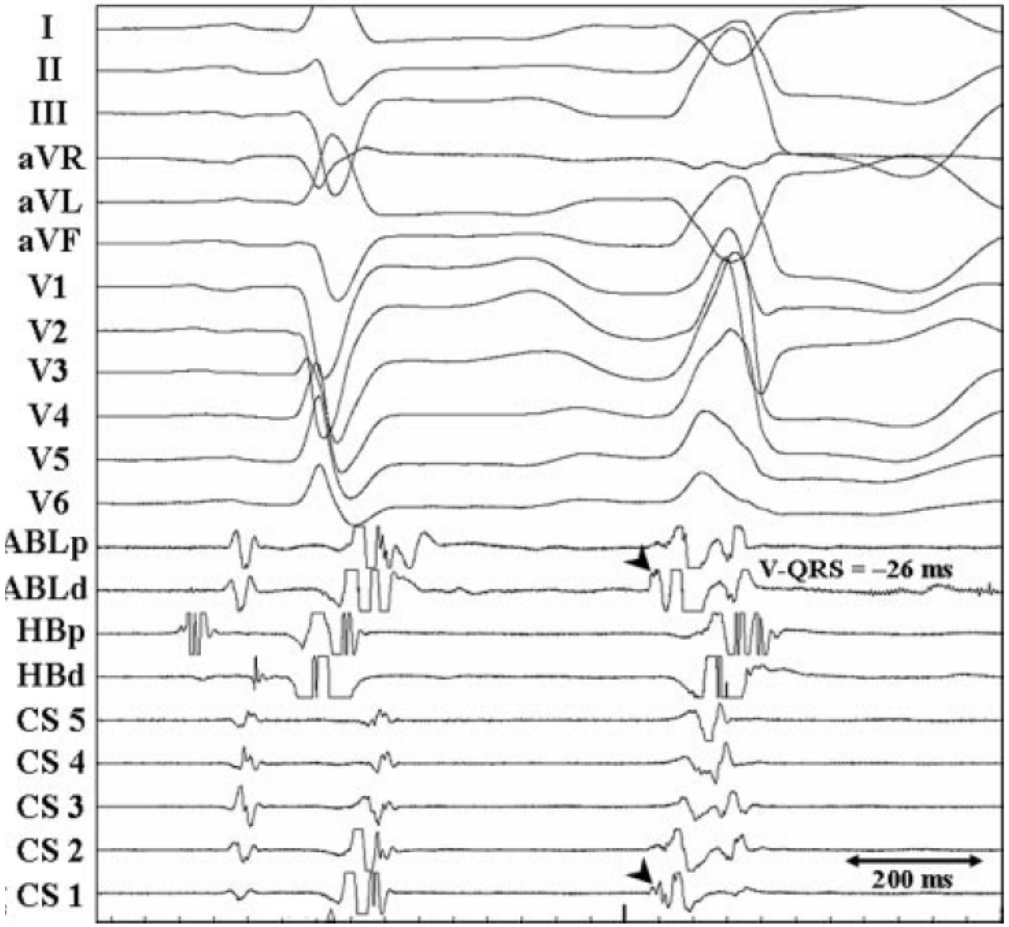
- **RBBB**

  Ao.cusp -> LV -> CVS

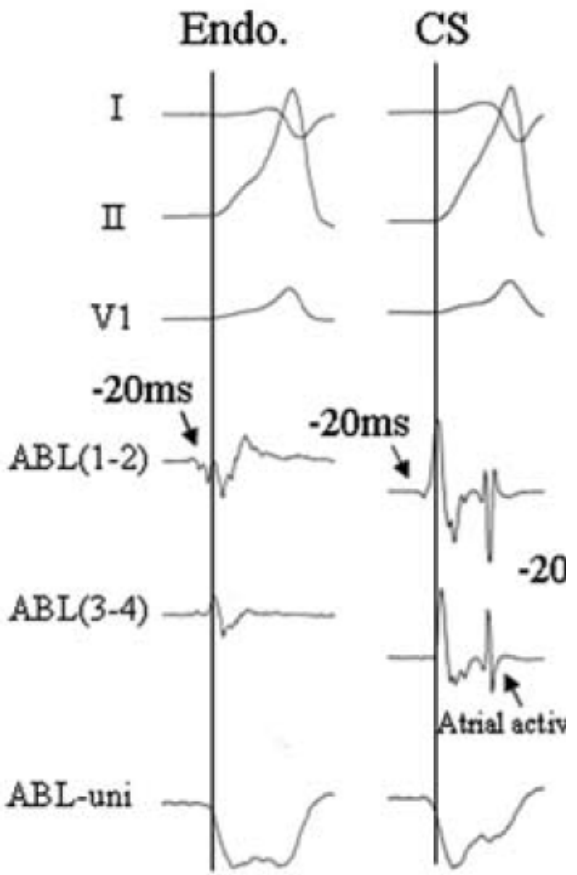
Circ Arrhythm Electrophysiol 2010;3:274

Epicardial mapping

Ventricular pre-potential in CS

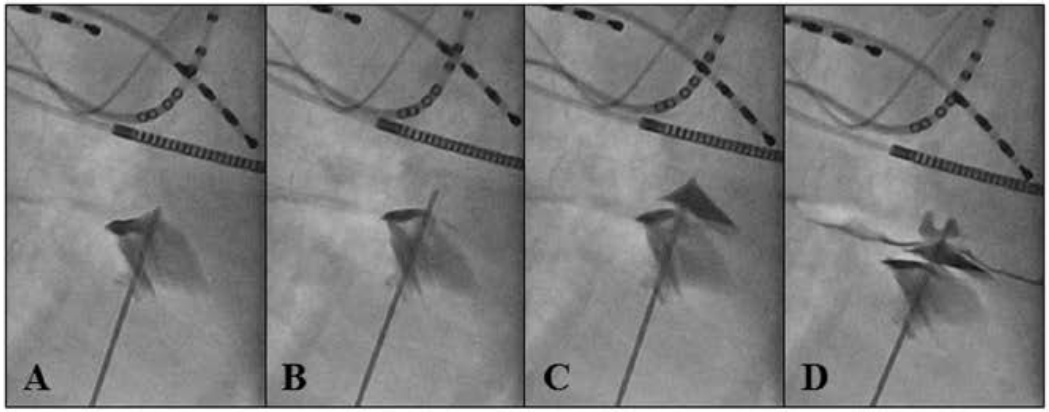


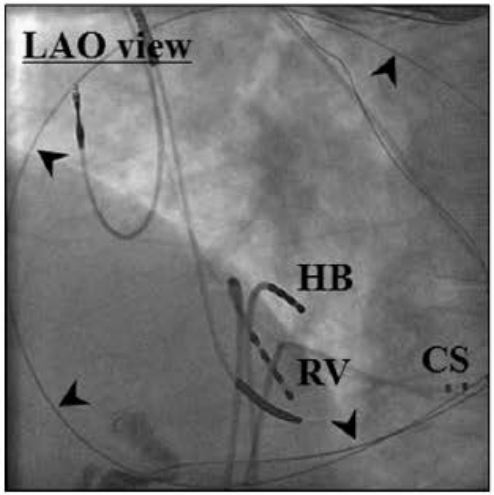
Local ventricular activation do not precede QRS onset ≥20ms

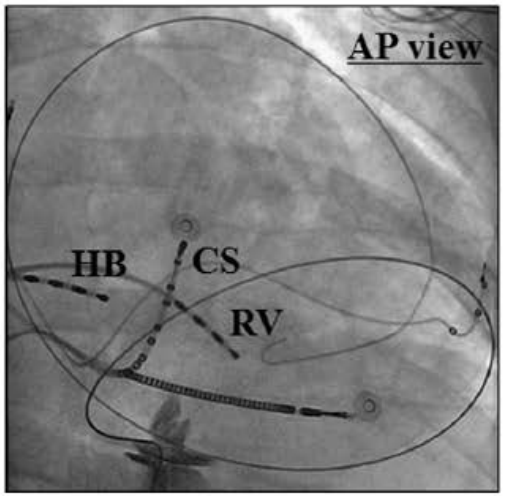


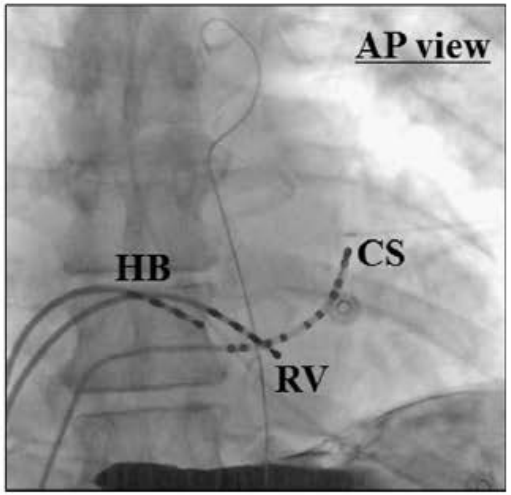
Go to epicardial mapping !!

Epicardial mapping







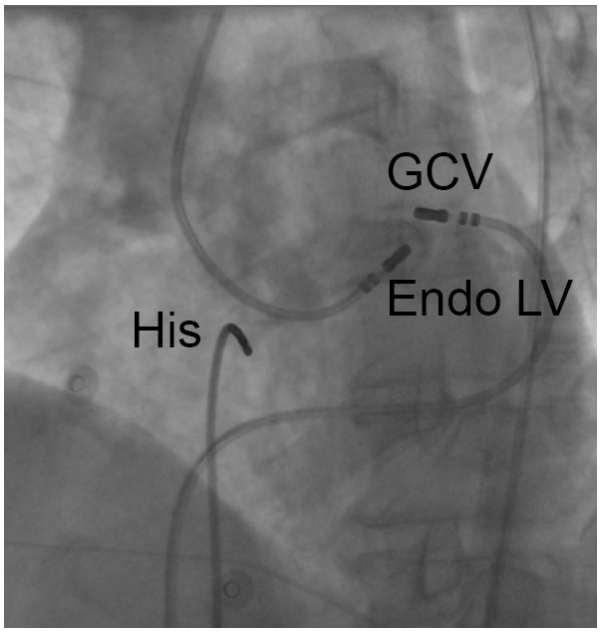


Epicardial mapping

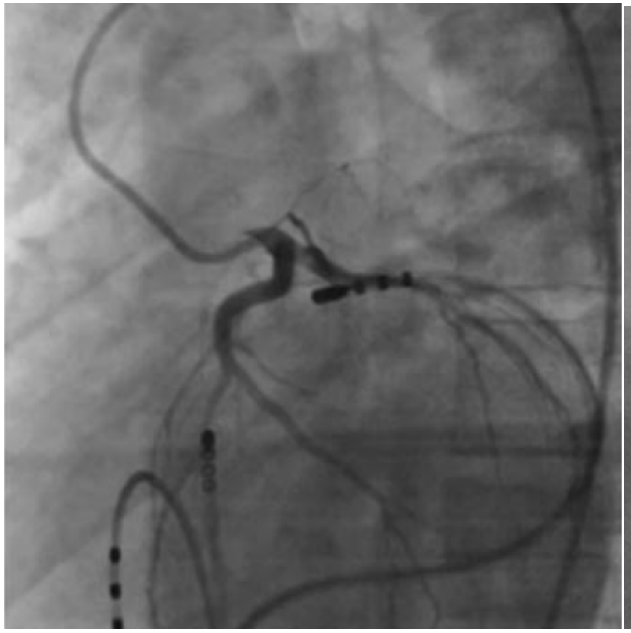
4. Summit VT ablation route

Ablation route

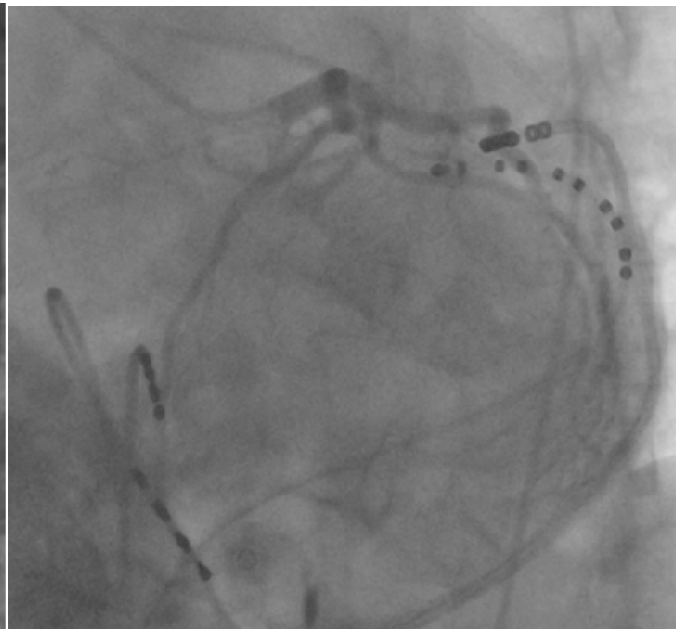
Endo LV



CS to GCV



Epicardial (20~40%)

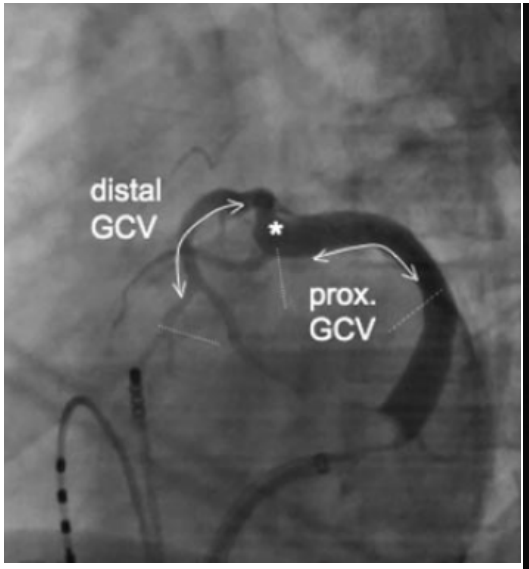


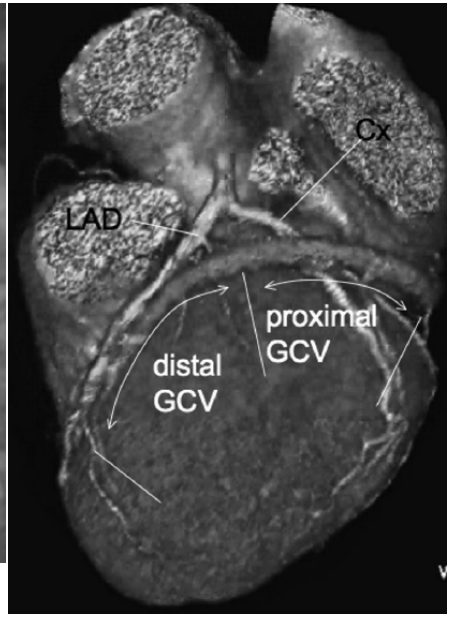
	No. of cases	Ablation sites	Acute success	Recurrence during follow-up
Daniels et al[40] (2006)	12	Endo GCV/AIV: 5, Epi subxiphoid: 5, Surgical: 2	9/12 (75%)	Not available
Yamada et al[5] (2010)	27	Endo GCV/AIV: 14, Epi subxiphoid: 4	18/27 (67%)	No recurrence
Jauregui et al[41] (2012)	16	Endo ASV: 5, Endo below ASV: 2, Endo ASV and below ASV: 2	9/16 (56%)	No recurrence
Nagashima et al[42] (2014)	30	Endo GCV/AIV: 8, Endo LV: 4, Endo ASV: 1, Surgical: 3	16/30 (53%)	3/16 (19%)
Total	85		52/85 (61%)	

Circ J 2016;80:1073

Effective ablation in GCV

	Total (n=27)	Ablation Effective (n=20)	Ablation Ineffective (n=7)	*P* Value
Procedure time, min	296±56	292±55	303±63	1.0
Fluoroscopy time, min	57±15	56±16	60±14	1.0
Radiofrequency ablation time, min	6.2±7.6	5.5±4.7	6.3±6.8	0.78
QRS width V_1, ms	147±20	152±23	137±9	0.11
R-wave width in V_1, ms	82±48	113±40	76±7	0.03
S-wave width in V_1, ms	61±43	39±24	61±8	0.03
Activation time at SOO, ms	−29±8	−30±7	−29±9	0.65
Location of the SOO within GCV distal/proximal		1/20	6/7	0.001
Distance from coronary artery, mm	8.1±3.6	8.7±3.3	6.8±4.3	0.94
Coronary sinus diameter at SOO, mm	5.6±2.5	5.5±2.4	5.7±3.0	0.99





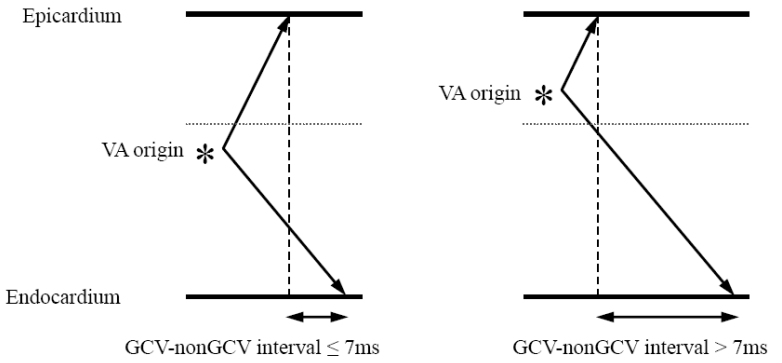
Circ Arrhythm Electrophysiol 2010;3:274

Ablation failure in GCV

1. inability to advance the ablation catheter to the SOO in the distal segment of the great cardiac vein
2. inadequate power delivery
3. proximity to a major coronary artery

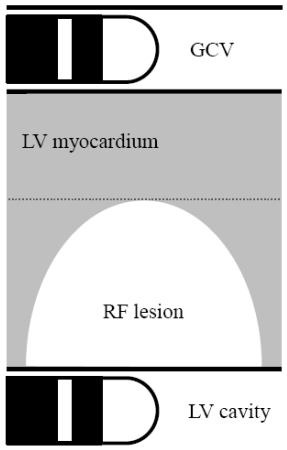
Effective ablation at LV endocardium

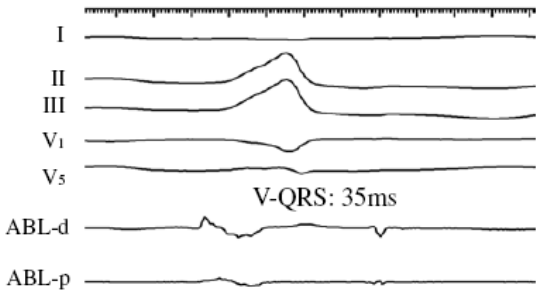
	Successful (n=5)	Failure (n=21)	*P* Value
Limb leads			
Initial r wave in lead I	5 (100)*	7 (33) *	0.01*
Mapping			
Activation time at GCV, ms	31.0±5.0	38.1±8.7	0.09
Activation time at the earliest endocardial site, ms	25.8±4.0	19.6±6.6	0.06
Interval between these 2 sites, ms	5.8±1.6*	18.9±8.5*	0.003*



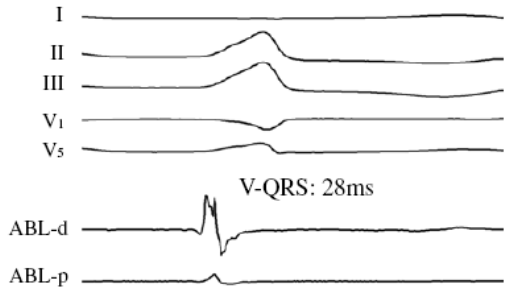
Successful endocardial ablation

Endocardial ablation failure





GCV



Endocardium (AMC)

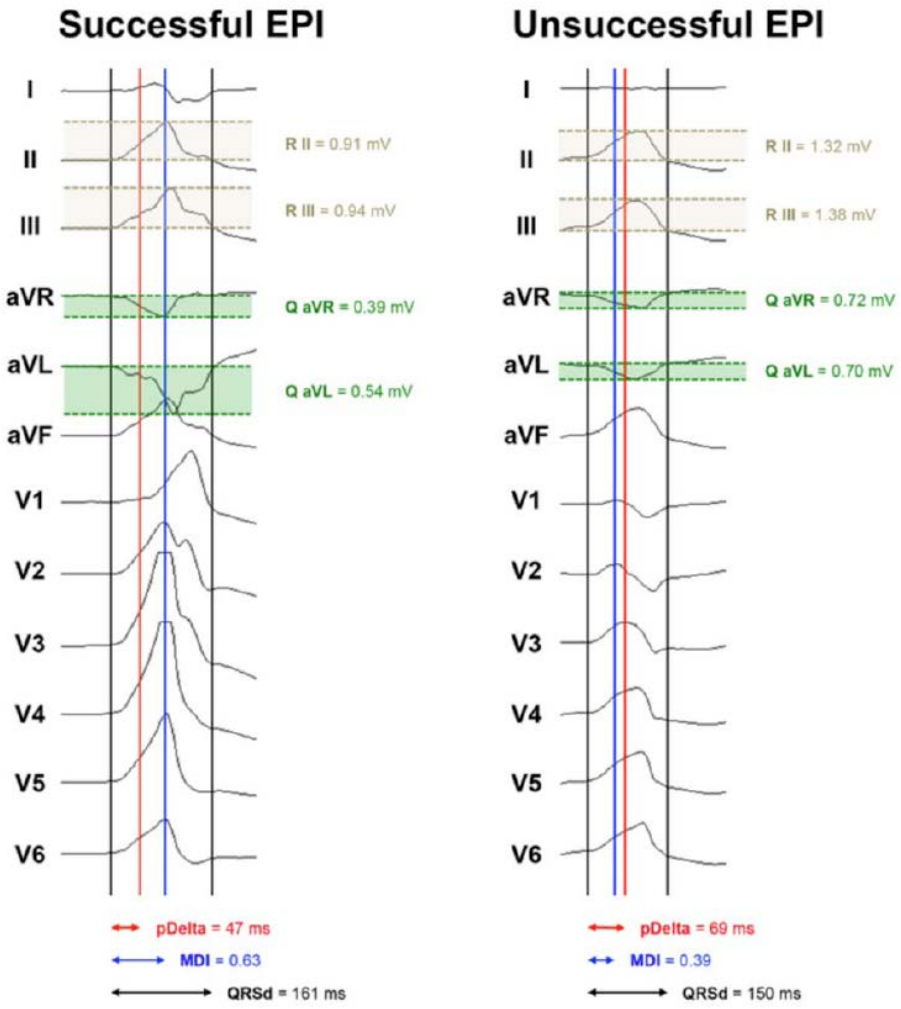
Circ Arrhythm Electrophysiol 2014;7:906

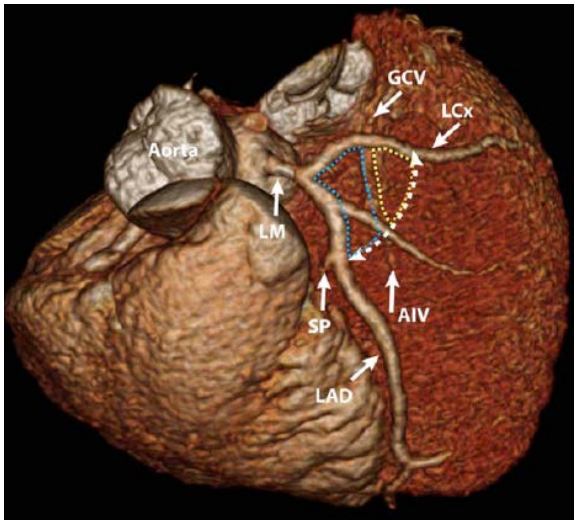
Epicardial origin

QRS Characteristics	Subject	Site of Prediction	Sensitivity	Specificity	PPV	NPV
RBBB	LV summit (n=27)	GCV+accessible area (n=23)	78%	75%	95%	38%
Transition zone $<V_1$	LV summit (n=27)	GCV+accessible area (n=23)	70%	100%	100%	36%
aVL/aVR ratio >1.1	LV summit (n=27), Avg=1.56, 95% CI=1.56 ±0.27	GCV+accessible area (n=23), Avg=1.68, 95% CI=1.68 ±0.29	87%	100%	100%	57%
S waves in V_5 or V_6	LV summit (n=27)	GCV+accessible area (n=23)	74%	100%	100%	40%
III/II ratio >1.25	GCV+accessible area (n=23), Avg=1.23, 95% CI=1.23 ±0.08	Accessible area (n=4), Avg=1.43, 95% CI=1.43 ±0.21	100%	74%	44%	100%
aVL/aVR ratio >1.75	GCV+accessible area (n=23), Avg=1.68, 95% CI=1.68 ±0.29	Accessible area (n=4), Avg=2.34, 95% CI=2.34 ±0.66	100%	74%	44%	100%

Circ Arrhythm Electrophysiol 2010;3:616

Successful EPI ablation





Variable	Successful Ablation (n=5)	Unsuccessful Ablation (n=18)	*P* Value*
Qualitative findings			
RBBB morphology, n (%)	4 (80)	9 (50)	0.339
LBBB morphology, n (%)	1 (20)	9 (50)	0.339
QS in lead I, n (%)	3 (60)	4 (22)	0.142
Initial q in V1, n (%)	0 (0)	6 (33)	0.272
Ratio Q in aVL/aVR >1.85, n (%)	4 (80)	2 (11)	0.008
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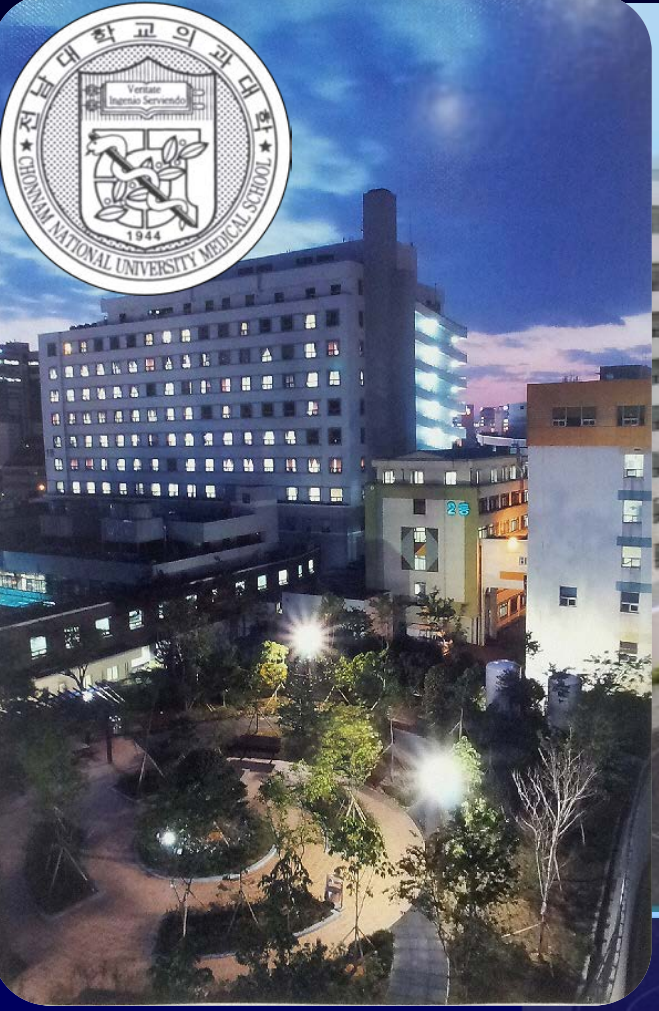
Circ Arrhythm Electrophysiol 2015;8:337



Thank you for your attention !!