Localization of Aortic Cusp VT Foci: Cusp or Cusp Junction

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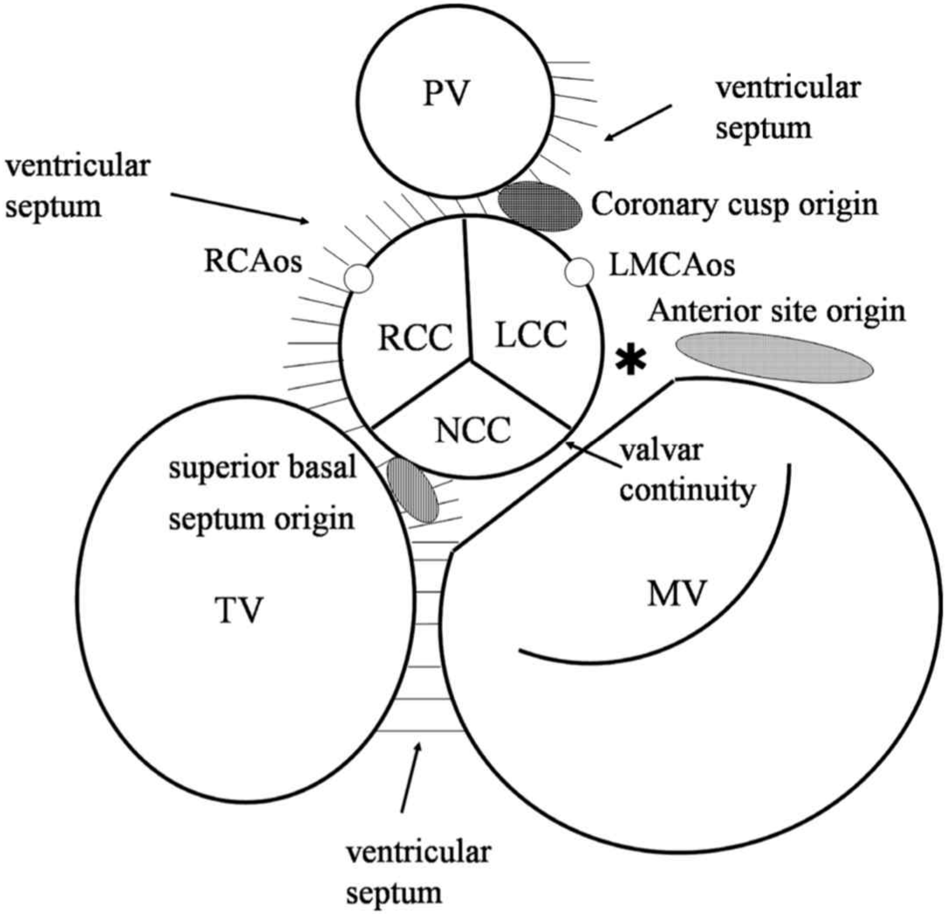
VT/PVCs from LVOT



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Kumagai K et al. J Cardiovasc Electrophysiol. 2008;19:495-501.

VT/PVCs from the Aortic Root

Table 1 Basic Demographics of the Patients With Successful Ablation

Origin	Age (yrs)	Gender, n (M/F)	Type, n (NSVT/SVT/PVC)	Heart Diseases, n	Risk Factors, n	LVEF (%)	Mapping Technique, n
Ao root (n = 44)	53 ± 14	26/18	9/9/26	AP: 2	HT: 14	61 ± 11 (23–81)	Con.: 20
16.6%				AF: 1	DM: 2		EA: 24
				AFL: 1	HL: 8		
RVOT (n = 188)	54 ± 15	77/111	40/17/131	AP: 5	HT: 53	62 ± 8 (41–77)	Con.: 75
				PSVT: 2			
				AF: 9	DM: 11		EA: 113
				AFL: 4	HL: 29		
LVOT (n = 10)	59 ± 6	6/4	1/2/7	SSS: 2	HT: 3	58 ± 11 (43–69)	Con.: 5
				AFL: 1	DM: 1		EA: 5
					HL: 2		
LV epi (n = 8)	49 ± 15	6/2	2/4/2	AP: 2	HT: 1	62 ± 7 (55–76)	Con.: 2
				AF: 1	DM: 1		EA: 6
				AFL: 1	HL: 1		
PA (n = 3)	54 ± 14	2/1	1/1/1	None	HT: 1	61 ± 5 (55–65)	Con.: 2
							EA: 1

AF = atrial fibrillation; AFL = atrial flutter; Ao = aortic; AP = angina pectoris; Con. = conventional mapping; DM = diabetes mellitus; EA = electro-anatomic mapping; epi = epicardium; F = female; HL = hyperlipidemia; HT = hypertension; LV = left ventricular; LVEF = left ventricular ejection fraction; LVOT = left ventricular outflow tract; M = male; NSVT = nonsustained ventricular tachycardia; PA = pulmonary artery; PSVT = paroxysmal supraventricular tachycardia; PVC = premature ventricular contraction; RVOT = right ventricular outflow tract; SSS = sick sinus syndrome; SVT = sustained ventricular tachycardia; VT = ventricular tachycardia.

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Yamada T et al. J Am Coll Cardiol 2008;52:139–47

VT/PVC from the Aortic Root

Table 2 Clinical, Electrocardiographic, and Electrophysiologic Characteristics

Origin	Age (yrs)	Gender, n (M/F)	Type, n (NSVT/SVT/PVC)	QRS Duration (ms)	QRS Morphology, n	QRS Transition, n	QRS Lead I, n	QRS Lead aVL, n	QRS R Amplitude (mV) in Inferior Leads	QRS III/II Ratio
LCC (n = 24)	53 ± 14	16/8	6/3/15	176 ± 21	LL: 7 LR: 11 RR: 6	V_1: 7 V_{2-3}: 11 V_3: 3 V_{3-4}: 2 V_{4-5}: 1	rS: 17 R: 3 rsr′: 3 rSr′: 1	QS: 15 rS: 9	2.1 ± 0.8	1.1 ± 0.1
RCC (n = 14)	56 ± 15	6/8	2/4/8	168 ± 14	LL: 9 LR: 5	V_1: 1 V_{1-2}: 2 V_2: 1 V_{2-3}: 7 V_{3-4}: 3	Rr′: 4 R: 4 rS: 4 rSr′: 1 rsr′: 1	QS: 9 rS: 5	1.5 ± 0.4*	0.9 ± 0.2†
L-RCC (n = 5) 11.4%	45 ± 13	3/2	1/1/3	186 ± 16	LL: 3 LR: 2	V_{1-2}: 1 V_{2-3}: 2 V_3: 2	qrS: 1 R: 2 rsr′: 1 rS: 1	QS: 5	2.1 ± 0.8	1.0 ± 0.1
NCC (n = 1)	32	1/0	0/1/0	178	LL: 1	V_{2-3}: 1	R: 1	R: 1	0.9	0.1#

Origin	V-QRS (ms) ABL Site	V-QRS (ms) HB Region	ABL Site A (mV)	ABL Site V (mV)	ABL Site A/V	RF Duration (min)	No. of RF Lesions
LCC (n = 24)	−29 ± 10	38 ± 14‡	0.10 ± 0.15	0.67 ± 0.75	0.26 ± 0.30‡	2.0 ± 1.0	2.3 ± 0.9
RCC (n = 14)	−35 ± 12	−15 ± 5	0.04 ± 0.08	0.35 ± 0.28	0.14 ± 0.24‡	2.3 ± 1.0	2.3 ± 0.7
L-RCC (n = 5)	−26 ± 6	34 ± 3‡	0.08 ± 0.06	0.90 ± 0.94	0.19 ± 0.21‡	2.6 ± 0.8	3.4 ± 1.0
NCC (n = 1)	−28	−25	0.22	0.08	2.75	1.0	1.0

*$p < 0.05$; †$p < 0.01$ versus LCC; ‡$p < 0.0001$ versus each of the other sites.

A = atrial electrogram; ABL = ablation; A/V = amplitude ratio in atrial and ventricular electrograms; HB = His bundle; III/II ratio = R-wave amplitude ratio in leads II and III; LCC = left coronary cusp; LBBB = left bundle branch block; LL = left bundle branch block + left inferior axis; L-RCC = junction of left and right coronary cusps; LR = left bundle branch block + right inferior axis; NCC = non-coronary cusp; RCC = right coronary cusp; RF = radiofrequency; RR = right bundle branch block + right inferior axis; V = ventricular electrogram; V-QRS = local ventricular activation time relative to the QRS onset; other abbreviations as in Table 1.

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Yamada T et al. J Am Coll Cardiol 2008;52:139–47

PVCs from LCC-RCC Junction

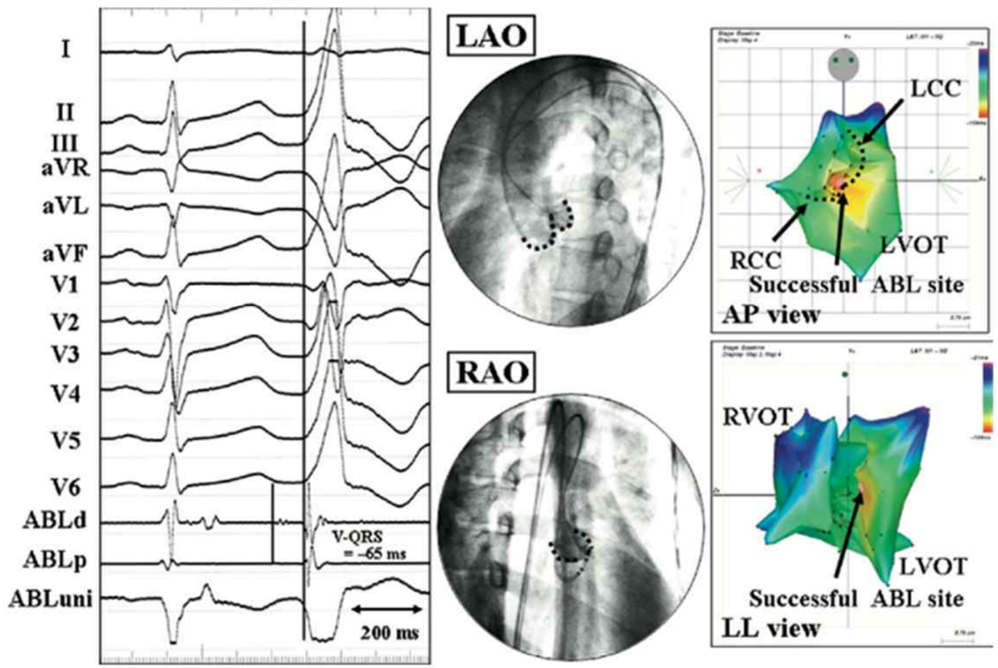

Figure 1 **Successful Ablation Site of PVCs Originating From the L-RCC**

The first beat is a sinus beat and the second is a premature ventricular contraction (PVC). At the successful ablation site, 2 ventricular activation components and no atrial activations were recorded during sinus rhythm **(left panel)**. The sequence of the 2 components was reversed during the PVCs. The first of the 2 components preceded the QRS onset by 65 ms. The aortagram showed that the ablation catheter was located in the junction of the left and right aortic sinus cusps (L-RCC) **(center panels)**. Note that the tip of the ablation catheter was positioned at the L-RCC by deflecting the loop of the ablation catheter in the left ventricular cavity. The activation map during the PVCs revealed the earliest activation at the L-RCC **(right panels)**. ABLd = distal electrode pair of the ablation catheter; ABLp = proximal electrode pair of the ablation catheter; ABLuni = distal unipolar electrode of the ablation catheter; AP = anteroposterior; LAO = left anterior oblique view; LCC = left coronary cusp; LL = left lateral; LVOT = left ventricular outflow tract; RAO = right anterior oblique view; RCC = right coronary cusp; RVOT = right ventricular outflow tract.

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Electrocardiographic characteristics of ventricular arrhythmias originating from the junction of the left and right coronary sinuses of Valsalva in the aorta: The activation pattern as a rationale for the electrocardiographic characteristics

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BACKGROUND Ventricular arrhythmias (VAs) may arise from the aortic sinuses and have electrocardiographic and electrophysiological characteristics that suggest a left (LCC) or right coronary cusp (RCC) origin. However, VAs that arise near the junction of those two cusps (L-RCC) may have unusual features.

OBJECTIVES The purpose of this study was to examine the electrocardiographic and electrophysiological characteristics of VAs arising from the L-RCC.

METHODS We studied 155 patients with idiopathic VAs with either left or right bundle branch block and an inferior QRS axis morphology and five control subjects undergoing a pacing study.

RESULTS For 146 of the 155 patients, the origin determined by the successful ablation site was at the L-RCC in five, LCC in 13, RCC in six, non–coronary cusp in two, right ventricular outflow tract in 108, left ventricular outflow tract in five, left ventricular epicardium in four, and pulmonary artery in three. A qrS pattern in leads V1–V3 was observed only in the VAs with an L-RCC origin. The propagation map revealed that the direction of the propagating wave front from the L-RCC origin produced a vector compatible with a q wave and that the anterior activation to the right ventricular outflow tract via the LCC or RCC formed the r wave. Pacing performed at multiple sites in the aortic root in the control subjects demonstrated that only pacing from the L-RCC could reproduce a qrS pattern in leads V1–V3.

CONCLUSIONS This study revealed that a qrS pattern in leads V1–V3 suggests a site of origin at the L-RCC.

KEYWORDS Aortic sinus cusp; Ventricular arrhythmia; Electroanatomic mapping; Radiofrequency catheter ablation

(Heart Rhythm 2008;5:184–192)

ECG of PVCs from LCC-RCC Junction

- A qrS pattern was observed in at least one of the leads V1–V3.

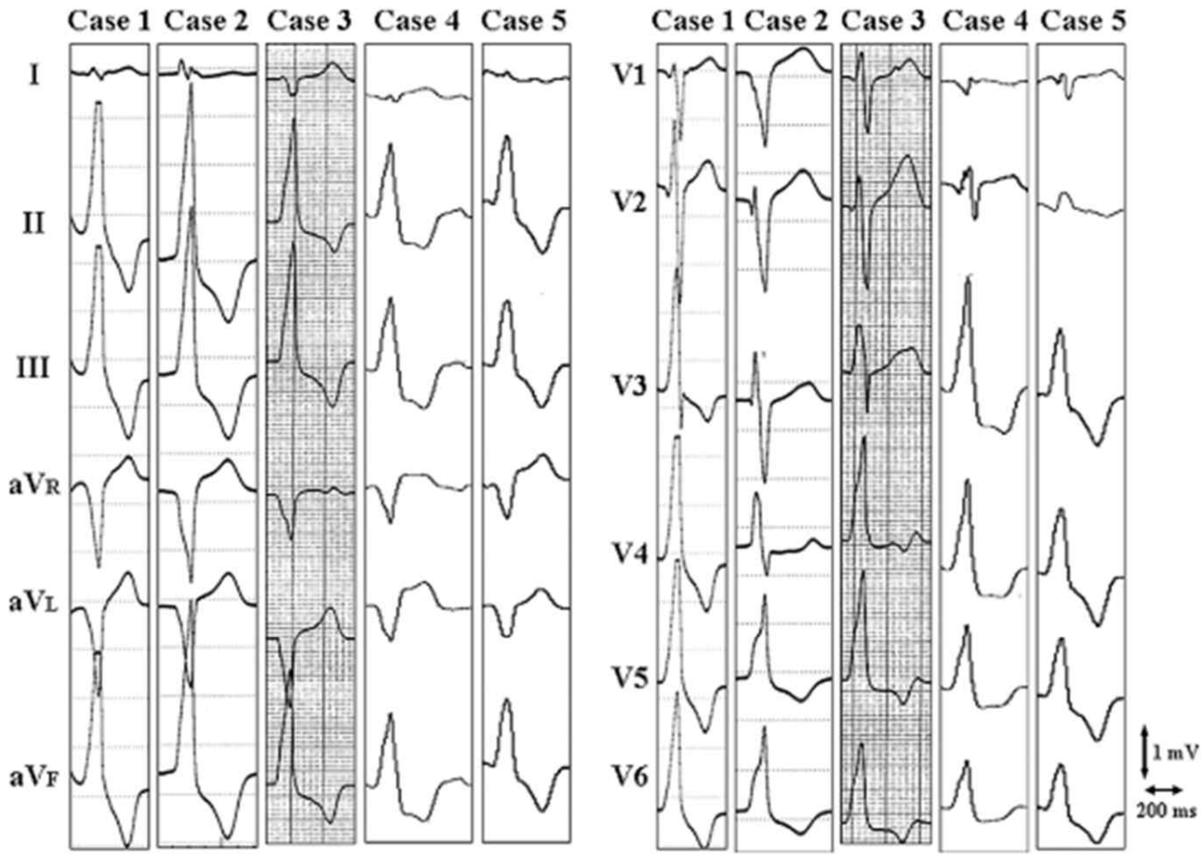

Figure 5 Twelve-lead electrocardiograms of PVCs originating from the L-RCC. Note that a qrS pattern in some of the leads V1–V3 was observed in all cases.

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A propagation map of VAs from the L-RCC Jx

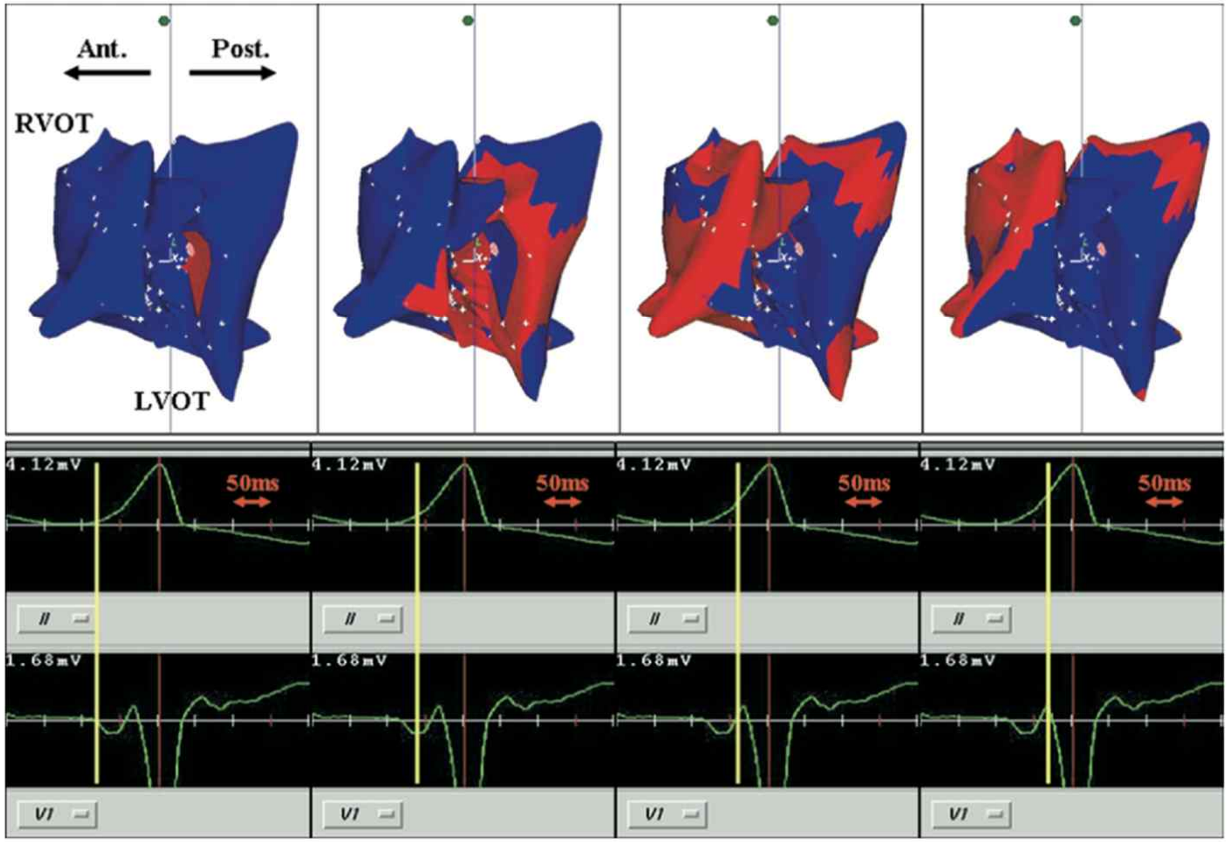

Figure 7 A propagation map of the ventricular outflow tract during the VAs originating from the L-RCC (case 1). The *upper panels* show the propagation maps, and the *lower panels* show the timing on the surface electrocardiogram corresponding to the propagation map (*yellow line*). The propagation map revealed that the activation from the origin toward the posterior side along the aortic root formed the q wave in lead V1 and that the activation from the aortic root anterior to the RVOT via the ventricular septum formed the r wave in lead V1. Ant. = anterior; Post. = posterior. The other abbreviations are as in Figure 1.

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Yamada T et al. Heart Rhythm. 2008;5:184-92.

Electrocardiographic and electrophysiologic features of ventricular arrhythmias originating from the right/left coronary cusp commissure

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BACKGROUND Ventricular arrhythmias are known to originate from the aortic sinus of Valsalva.

OBJECTIVE The purpose of this study was to identify the characteristics associated with ventricular arrhythmias originating from the right coronary cusp–left coronary cusp (RCC–LCC) commissure.

METHODS Thirty-seven consecutive patients with ventricular arrhythmias originating from the aortic cusp region were studied. Intracardiac echocardiography and electroanatomic mapping were used to define coronary cusp anatomy and catheter position. Ventricular arrhythmias from the RCC–LCC commissure were compared with ventricular arrhythmias originating from other sites in the aortic cusp region.

RESULTS Nineteen (51%) ventricular arrhythmias had an anatomic origin at the RCC–LCC commissure. Eighteen ventricular arrhythmias originated from other aortic cusp sites (4 right cusp, 7 left cusp, 3 left ventricular endocardium, 4 left ventricular epicardium anterior to aortic valve). A QS morphology in lead V_1 with notching on the downward deflection was present in 15 of 19 ventricular arrhythmias originating from the RCC–LCC commissure compared to 2 of 18 ventricular arrhythmias from other aortic cusp sites ($P < .01$). At the site of earliest activation, 13 of 19 patients with RCC–LCC ventricular arrhythmias had late potentials in sinus rhythm compared to 1 of 18 ventricular arrhythmias from other aortic cusp sites ($P < .01$). The site of successful ablation was confirmed to be above the aortic valve plane in 15 (79%) of 19 patients with RCC–LCC ventricular arrhythmias.

CONCLUSION RCC–LCC aortic cusp ventricular arrhythmias are common and have a QS morphology in lead V_1 with notching on the downward deflection with precordial transition at lead V_3. In the majority of cases, the site of successful ablation has late potentials in sinus rhythm.

KEYWORDS Catheter ablation; Echocardiography; Electrophysiology; Ventricular tachycardia

ABBREVIATIONS **CT** = computed tomography; **ECG** = electrocardiographic; **ICE** = intracardiac echocardiography; **LCC** = left coronary cusp; **LV** = left ventricle; **RCC** = right coronary cusp; **RF** = radiofrequency; **RV** = right ventricle; **RVOT** = right ventricular outflow tract; **VPD** = ventricular premature depolarization; **VT** = ventricular tachycardia

(Heart Rhythm 2010;7:312–322)

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VT/PVCs from RCC-LCC Commissure

Table 1 Electrocardiographic and electrophysiologic characteristics of right coronary cusp–left coronary cusp VPDs/VT

Pt	VPD/VT	Lead I	ECG V_1 morphology	Precordial transition	Late potential in SR	Pre-QRS at site of origin (ms)	Anatomic localization	Ablation site relative to valve plane
1	VPD	R	Notch	V_3	No	24	EAM, Cath	Above valve
2	VPD	rSr′	Notch	V_3	Yes	33	EAM, ICE	At valve
3	VPD	rS	Notch	V_4	Yes	68	EAM, ICE	Above valve
4	VPD	R	Notch	V_3	Yes	42	EAM, ICE	Above valve
5	VPD/nonsustained VT	Rsr′	Notch	V_3	Yes	40	EAM, ICE	Above valve
6	VPD	R	Notch	V_3	No	31	EAM, Cath	Above valve
7	VPD	rS	W	V_3	Yes	46	EAM, ICE	Above valve
8	VPD	R	Notch	V_3	No	28	EAM, Cath	Above valve
9	VPD	R	Notch	V_3	Yes	69	EAM, ICE	Above valve
10	VPD	rsr′	Notch	V_3	Yes	43	EAM, ICE	At valve
11	VPD	R	Notch	V_3	Yes	60	EAM	At valve
12	VPD	R	Notch	V_3	Yes	18	EAM, ICE	Above valve
13	VPD/nonsustained VT	Rs	Notch	V_3	No	38	EAM, ICE, Cath	At valve
14	VPD	rs	W	V_3	Yes	52	EAM, ICE	Above valve
15	VPD	rsr′	Notch	V_3	No	37	EAM, ICE	Above valve
16	VPD	rsr′	W	V_3	Yes	60	EAM, ICE	Above valve
17	VPD/nonsustained VT	rS	W	V_4	Yes	33	EAM, CT Merge, ICE	Above valve
18	VPD	R	Notch	V_3	Yes	80	EAM, CT Merge, ICE	Above valve
19	VPD	QS	Notch	V_4	No	30	EAM, ICE, Cath	Above valve

Cath = coronary angiogram; CT = computed tomography; EAM = electroanatomic mapping; ICE = intracardiac echocardiography; VPD = ventricular premature depolarization; VT = ventricular tachycardia.

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Bala R et al. Heart Rhythm. 2010;7:312-22

VT/PVCs from RCC-LCC Commissure

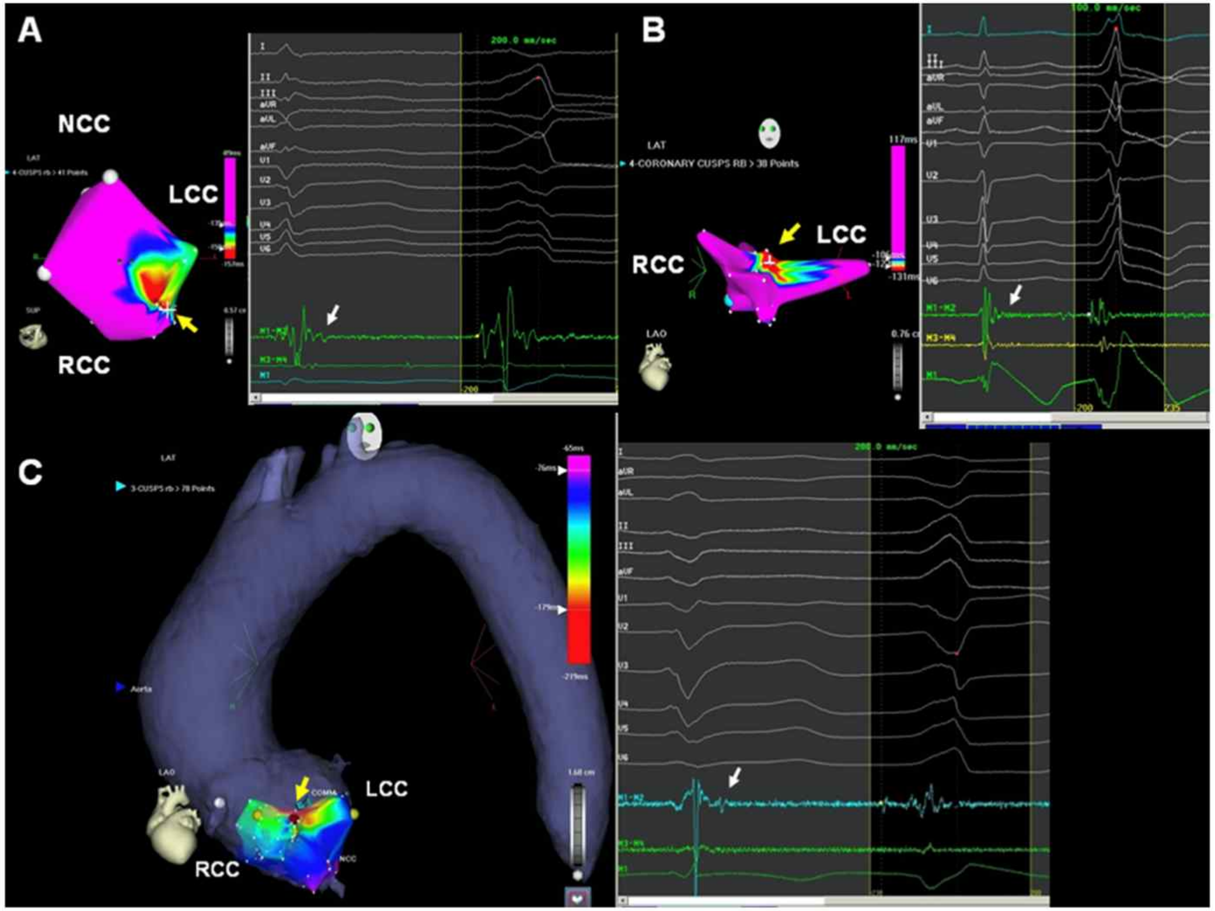

Figure 3 **A-C:** Activation maps coupled with recordings in sinus rhythm and ventricular premature depolarizations from three patients with site of origin at the right coronary cusp-left coronary cusp (RCC-LCC) commissure. The anatomic location was confirmed by intracardiac echocardiography. *White arrows* on the electrogram recordings indicate late potentials in sinus rhythm that transitioned to presystolic activation during wide-complex ventricular premature depolarizations. In **panel C**, the activation map of the aortic cusp region was merged with a computed tomographic angiogram (CTA). The site of origin of the ventricular premature depolarization is indicated by the *yellow arrow*. NCC = noncoronary cusp.

Bala R et al. Heart Rhythm. 2010;7:312-22

VT/PVCs from RCC-LCC Commissure

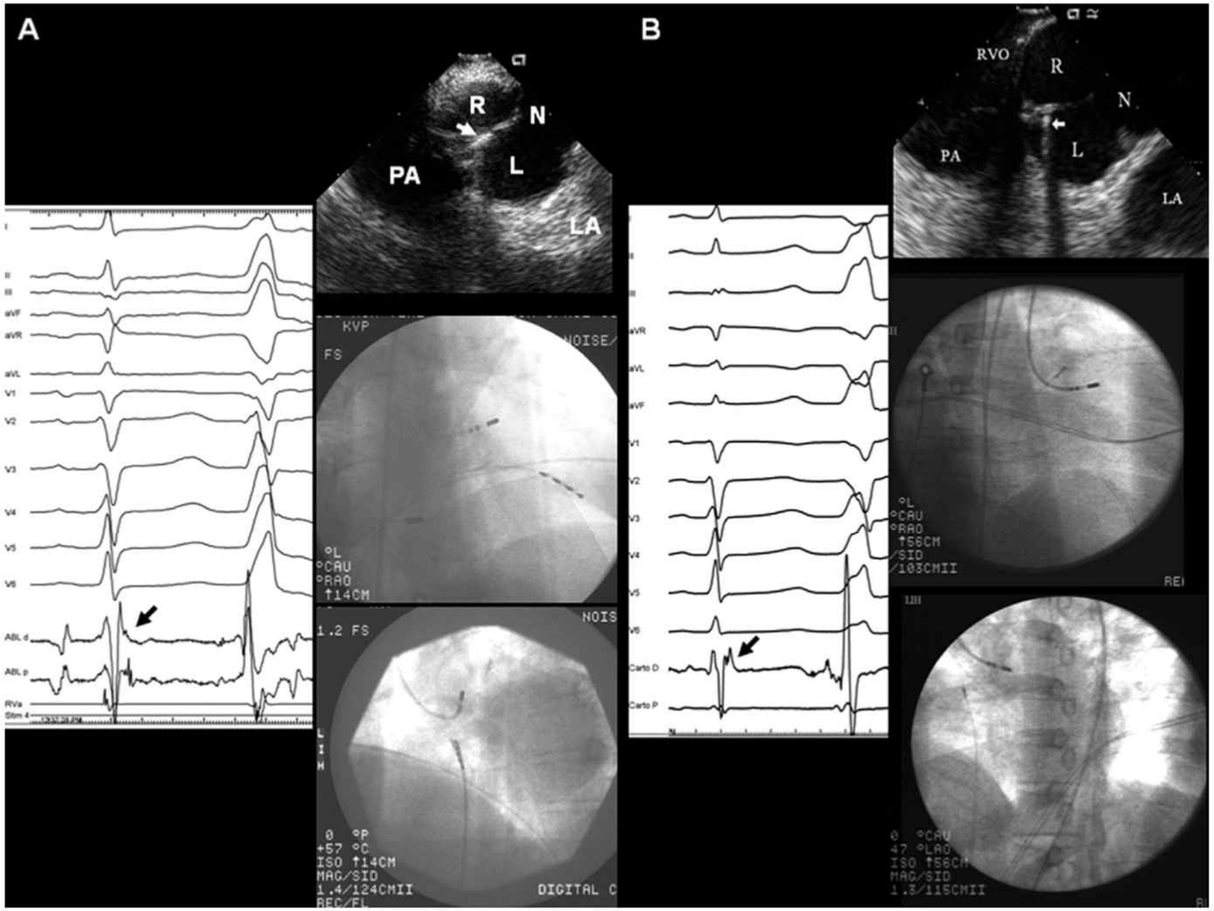

Figure 4 **A, B:** Surface ECG with intracardiac recordings, intracardiac echocardiography **(top),** and right **(middle)** and left **(bottom)** anterior oblique fluoroscopic images at successful ablation site for ventricular premature depolarizations originating from the right coronary cusp–left coronary cusp commissure in two patients. *Black arrows* indicate late potentials in sinus rhythm. *White arrows* indicate catheter location at the right coronary cusp–left coronary cusp commissure on intracardiac echocardiography. In both examples, the clinical ventricular premature depolarization has a notch on the downward deflection in lead V_1. L = left coronary cusp; LA = left atrium; N = noncoronary cusp; PA = pulmonary artery; R = right coronary cusp; RVO = right ventricular outflow.

Bala R et al. Heart Rhythm. 2010;7:312-22

ECG for VT/PVC from RCC-LCC Commissure

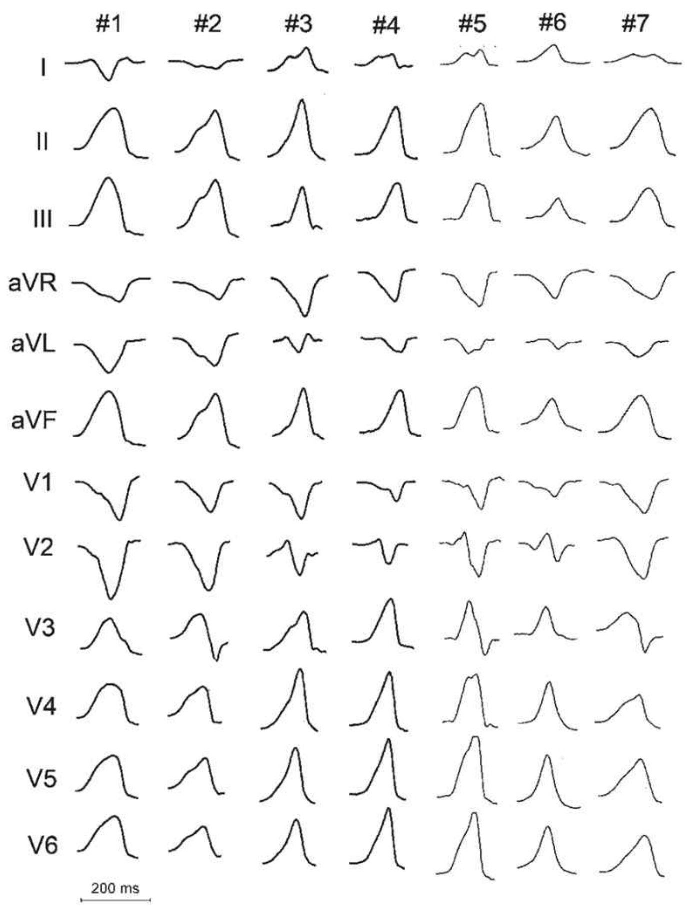

Figure 2 Twelve-lead ECGs of ventricular arrhythmias that demonstrated a site of origin from the right coronary cusp–left coronary cusp commissure from seven representative patients. A notch on the downward deflection in lead V_1 and a precordial transition at lead V_3 are identified in each example.

- QS morphology in lead V_1 with notching on the downward deflection
- Precordial transition at lead V_3

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LVOT Ablation via Transseptal Approach

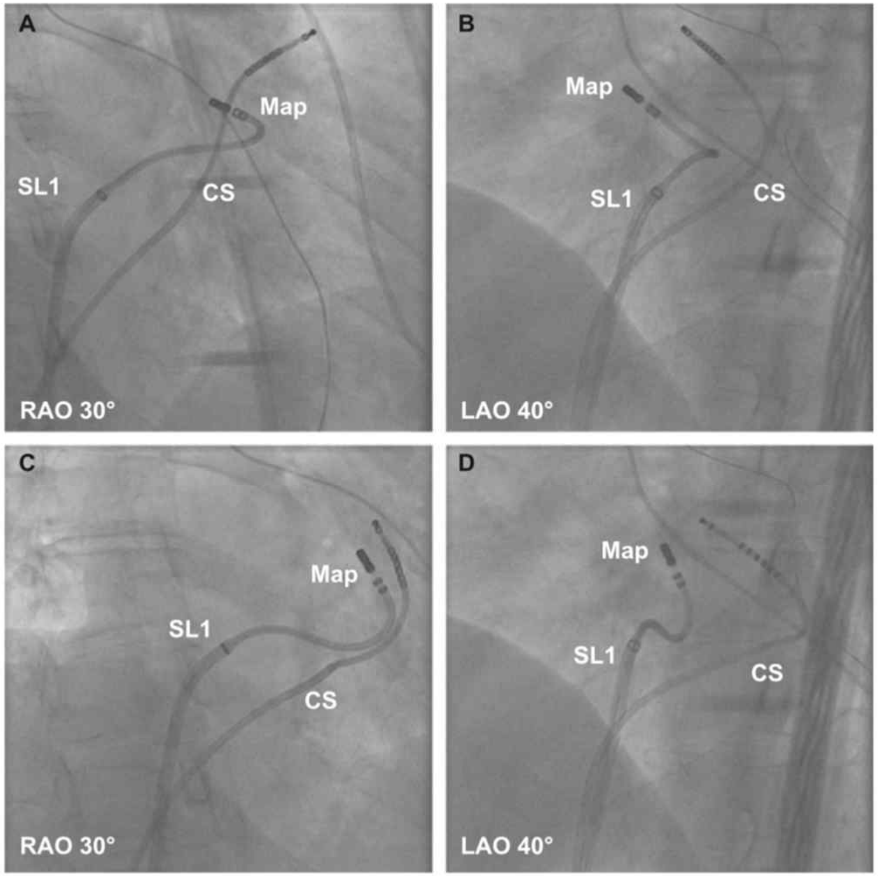

Figure 2. Fluoroscopic views (right anterior oblique [RAO] and left anterior oblique [LAO]) showing the mapping catheter in the left ventricular outflow tract (LVOT) below the right coronary cusp (RCC; **A** and **B**) and left coronary cusp (LCC; **C** and **D**). Note that the end of the SL1 sheath was kept close to the fossa ovalis to allow the mapping catheter to form a reverse S curve to reach the LVOT and to allow rotation of the mapping catheter clockwise or counterclockwise to the LCC or RCC. CS indicates coronary sinus catheter; Map, mapping catheter; and SL1, SL1 long sheath.

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Ouyang F et al. Circ Arrhythm Electrophysiol. 2014;7:445-455.

LVOT Ablation via Transseptal Approach

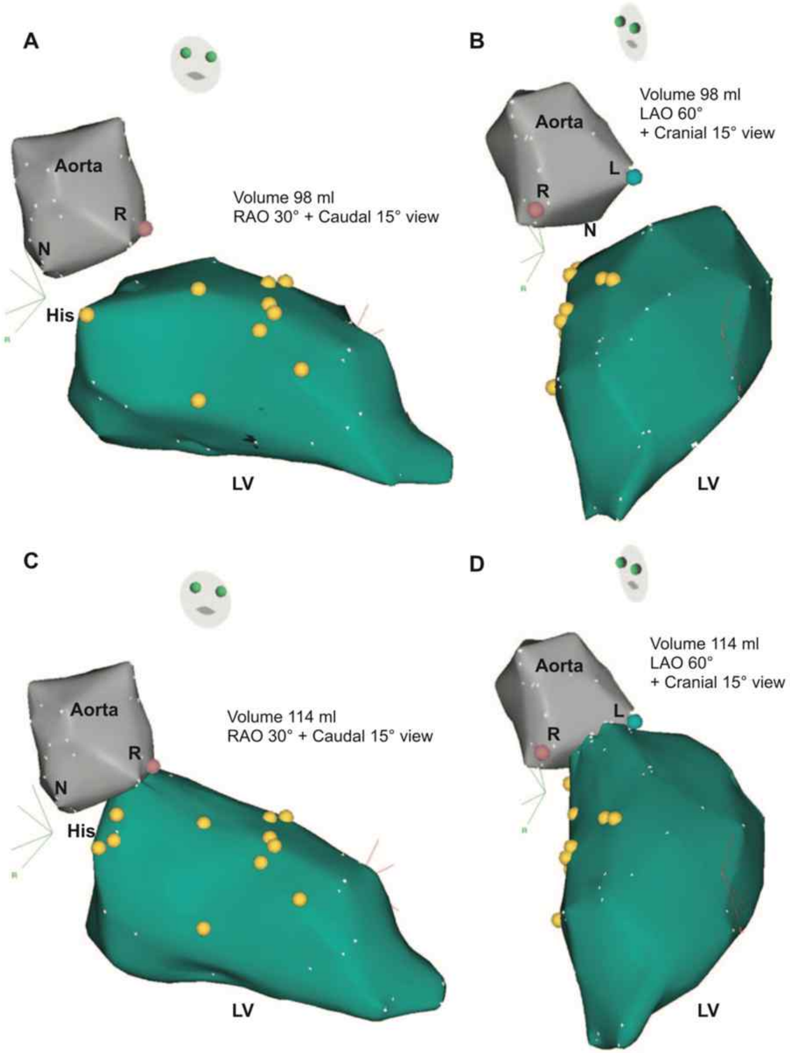

Figure 3. Electroanatomic mapping of the aortic root and left ventricle (LV) via only trans-aortic approach (**A** and **B**), and a combination of transaortic and transseptal approaches (**C** and **D**). Note that (1) there is wide separation between the LV and aortic root maps when only transaortic approach is used (**A** and **B**); (2) there is no space between the LV and aortic root when transseptal mapping is added to the transaortic approach (**C** and **D**); (3) the LV volume increases slightly after a combined approach is used; and (4) the superior His is located just under and near to the right coronary cusp after complete mapping of His bundle. L indicates left coronary cusp (blue tags); LAO, left anterior oblique; N, non-coronary sinus cusp; R, right coronary cusp (brown tags); and RAO, right anterior oblique. Yellow tags represent sites of His-Purkinje system.

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Ouyang F et al. Circ Arrhythm Electrophysiol. 2014;7:445-455.

Ablation of LCC-RCC Jx via Transseptal Approach

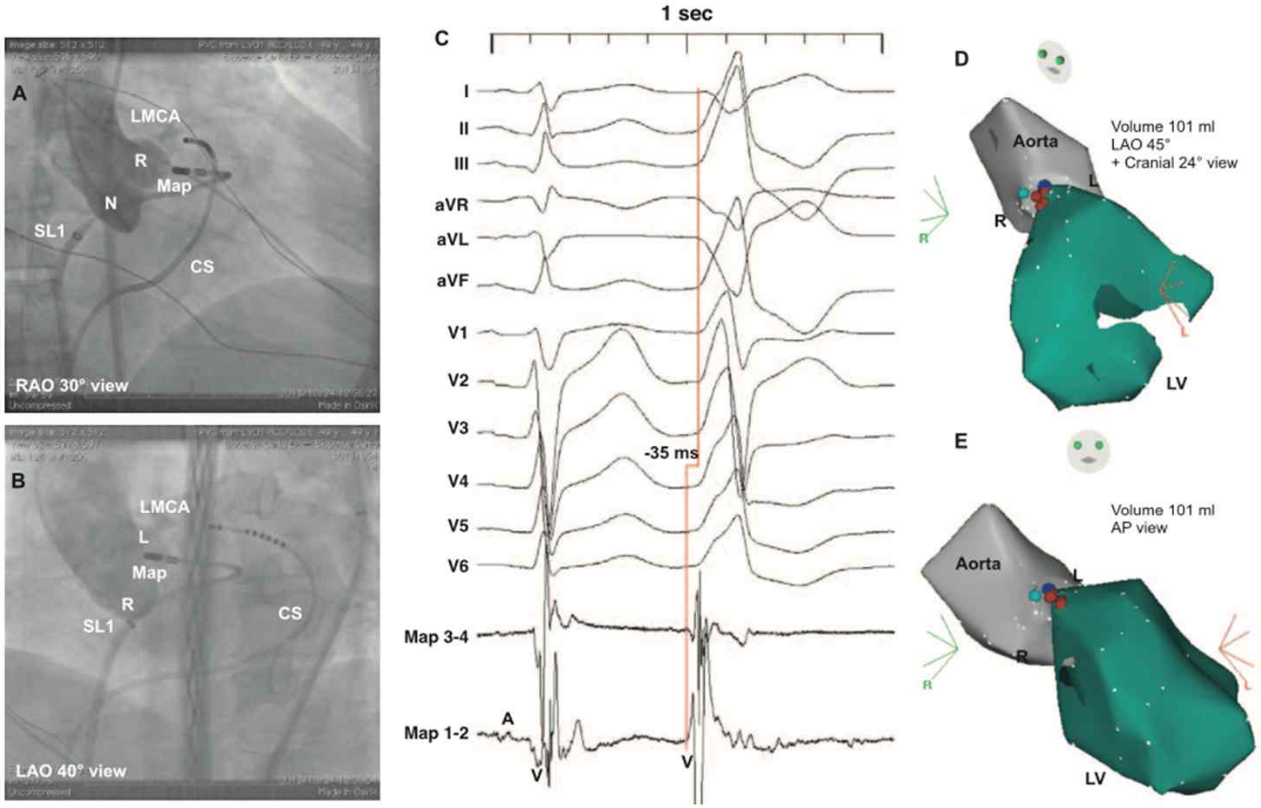

Figure 5. Fluoroscopy, activation, and 3-dimensional mapping in a 34-year-old man with previous failed ablation attempts. **Left**, Right (30°) and left (45°) oblique radiographic views of the mapping catheter (Map) at the successful ablation site just below the left coronary cusp (LCC)/right coronary cusp (RCC) junction during aortic root angiography using a 6F pigtail catheter. **Middle**, Surface ECG and intracardiac recordings from mapping catheter at the site of earliest ventricular activation below the LCC/ RCC junction. Note that the local potential precedes the QRS by 35 ms during ventricular extrasystoles. **Right**, Electroanatomic mapping of the same patient. Light blue tag represents earliest activation site in the aortic root; dark blue tag, earliest activation site in the left ventricle (LV); and red tags, successful ablation points. AP indicates anteroposterior view; CS, coronary sinus catheter; LAO, left anterior oblique; LMCA, left main coronary artery; N, noncoronary sinus cusp, R, right coronary sinus cusp; SL1, SL1 long sheath; and RAO, right anterior oblique.

Ouyang F et al. Circ Arrhythm Electrophysiol. 2014;7:445-455.

QRS Morphology

Table 3. QRS Morphology During Ventricular Arrhythmias on Surface ECG

	All	Below LCC	Below the junction of LCC/RCC	Below RCC
R-wave amplitude in II, mV	1.8±0.4 (1.1–2.6)	1.8±0.4 (1.1–2.4)	1.7±0.3 (1.3–2.2)	2.1±0.4 (1.8–2.6)
R-wave amplitude in III, mV	2.0±0.4 (1.3–3.0)	2.0±0.5 (1.3–3.0)	2.0±0.4 (1.6–2.5)	2.1±0.4 (1.7–2.5)
R-wave amplitude III>II	19/27 (70.4%)	11/16 (68.8%)	7/8 (87.5%)	1/3 (33.3%)
III/II R-wave amplitude ratio >1.1	10/27 (37.0%)	5/16 (31.3%)	5/8 (62.5%)	0/3 (0%)
Q-wave amplitude in aVL, mV	1.1±0.2 (0.7–1.4)	1.0±0.2 (0.7–1.4)	1.1±0.2 (0.7–1.4)	1.1±0.3 (0.8–1.3)
Q-wave amplitude in aVR, mV	0.9±0.3 (0.4–1.5)	0.8±0.3 (0.4–1.3)	0.9±0.4 (0.4–1.5)	0.9±0.2 (0.7–1.1)
Q-wave amplitude aVL>aVR	20/27 (74.1%)	12/16 (75%)	5/8 (62.5%)	3/3 (100%)
aVL/aVR Q-wave amplitude ratio >1.4	7/27 (25.9%)	4/16 (25%)	3/8(37.5%)	0/3 (0%)
PDI	0.58±0.06 (0.46–0.7)	0.59±0.05 (0.53–0.67)	0.57±0.05 (0.5–062)	0.57±0.12 (0.46–0.7)
No. of PDI >0.6	11/27 (40.7%)	8/16 (50%)	2/8 (25%)	1/3(33.3%)

LCC indicates left coronary cusp; PDI, peak deflection index in inferior leads; and RCC, right coronary cusp.

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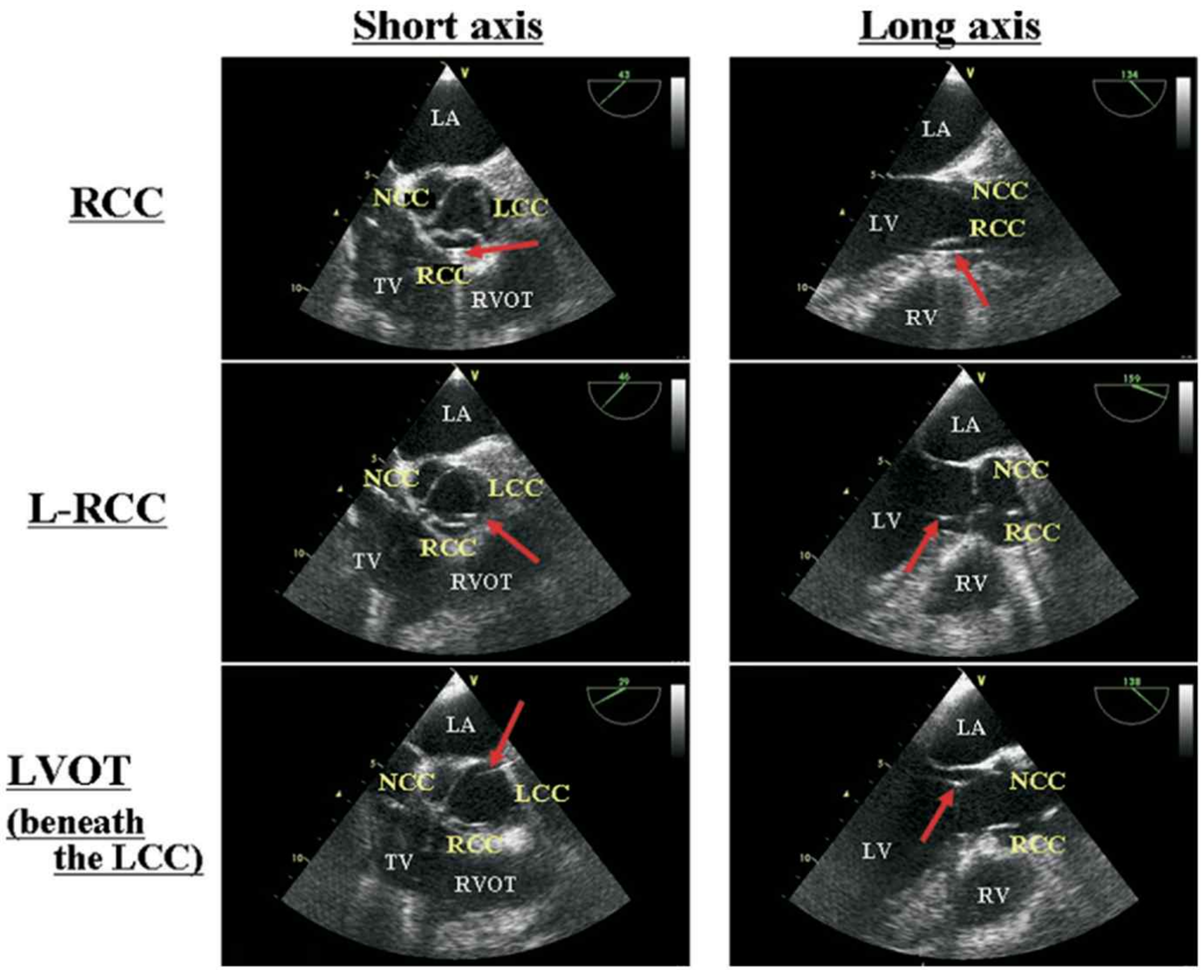
Ouyang F et al. Circ Arrhythm Electrophysiol. 2014;7:445-455.

TEE Images for LCC-RCC Jx

Figure 3 Transesophageal echocardiography images showing the position of the mapping catheter (*red arrows*) during the pacing study. Note that the tip of the ablation catheter was positioned at the L-RCC by deflecting the loop of the ablation catheter in the left ventricular cavity. LA = left atrium; LV = left ventricle; RV = right ventricle; TV = tricuspid valve. The other abbreviations are as in Figure 1.



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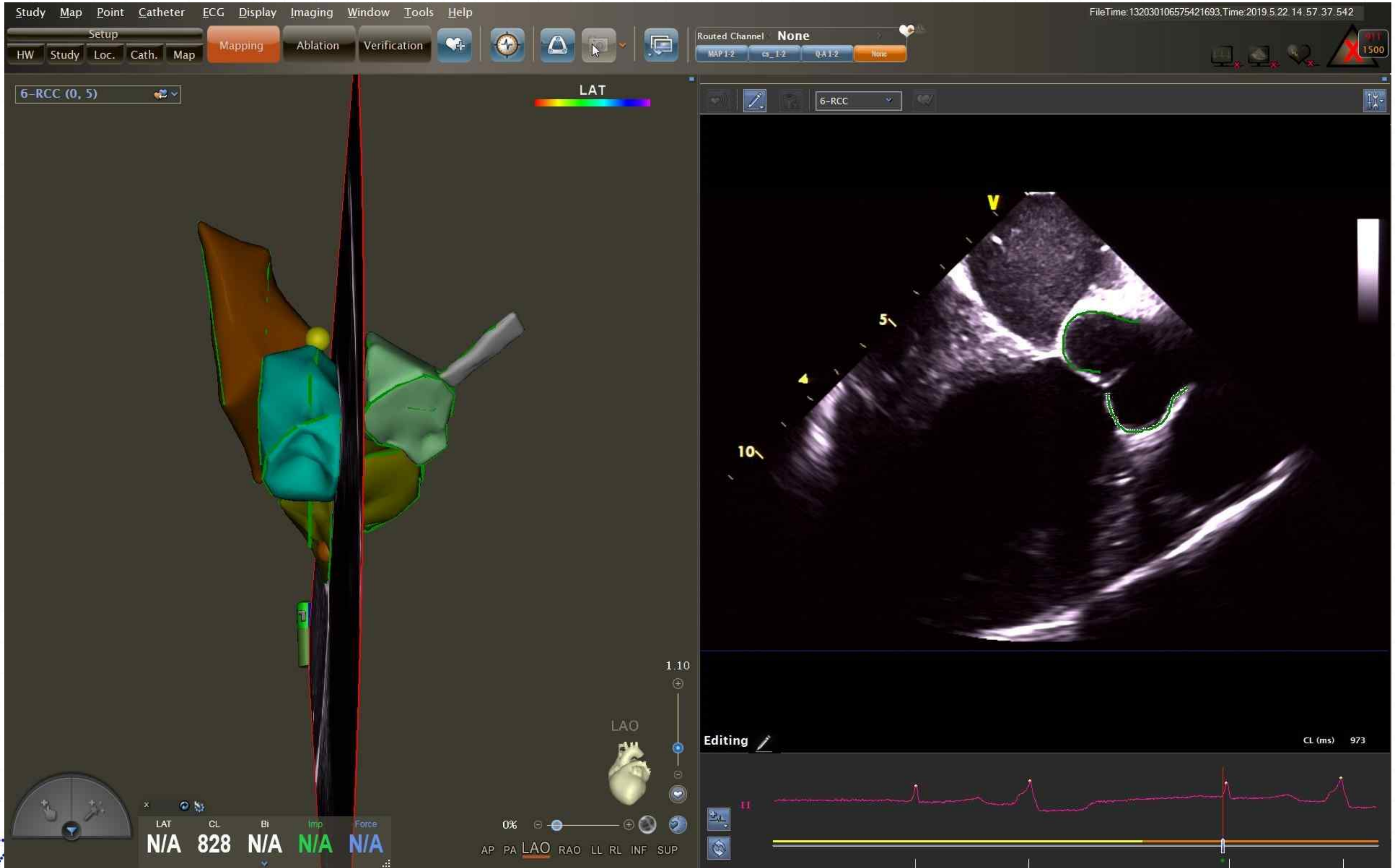
ICE images for LCC-RCC Jx



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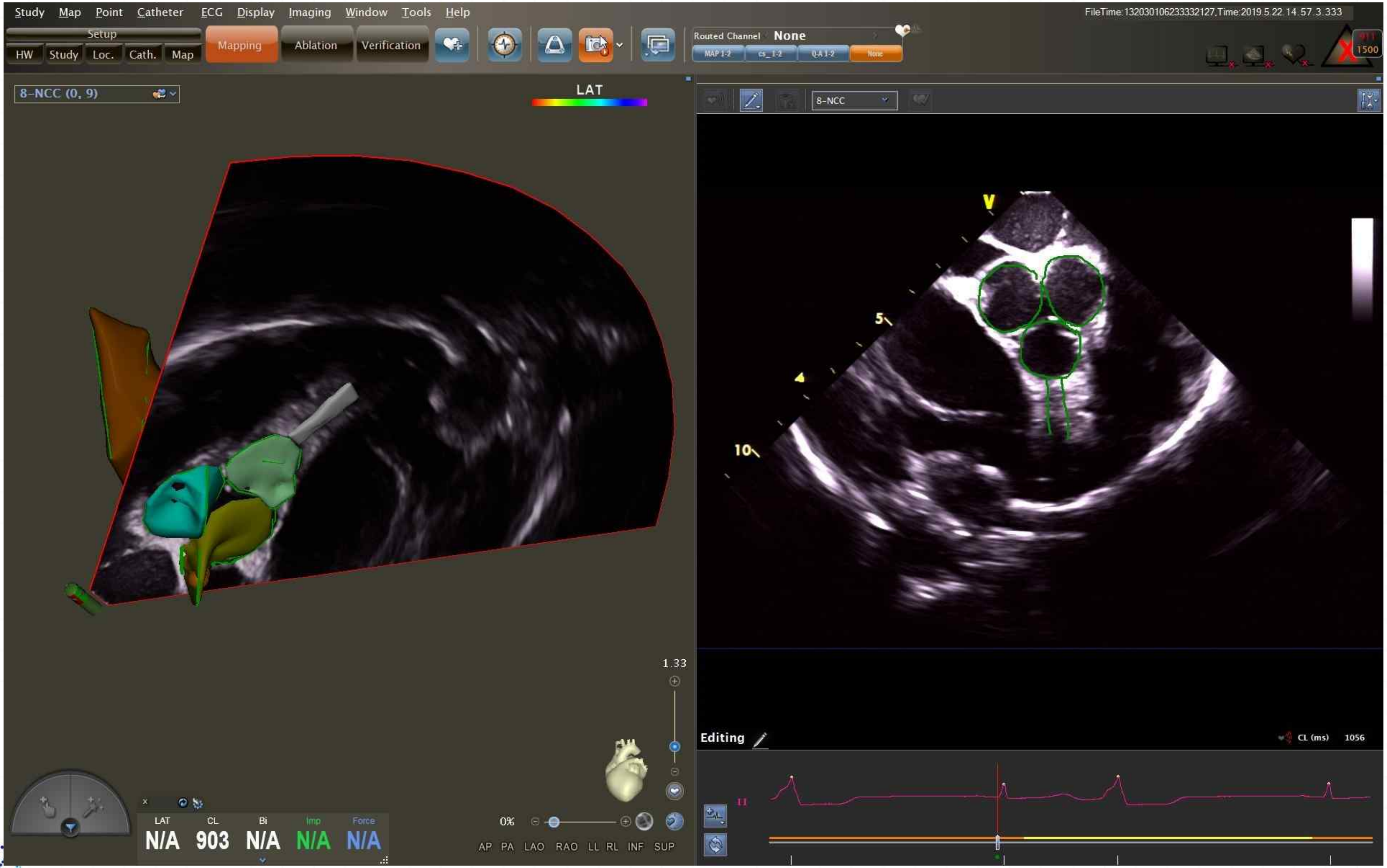
ICE images for LCC-RCC Jx



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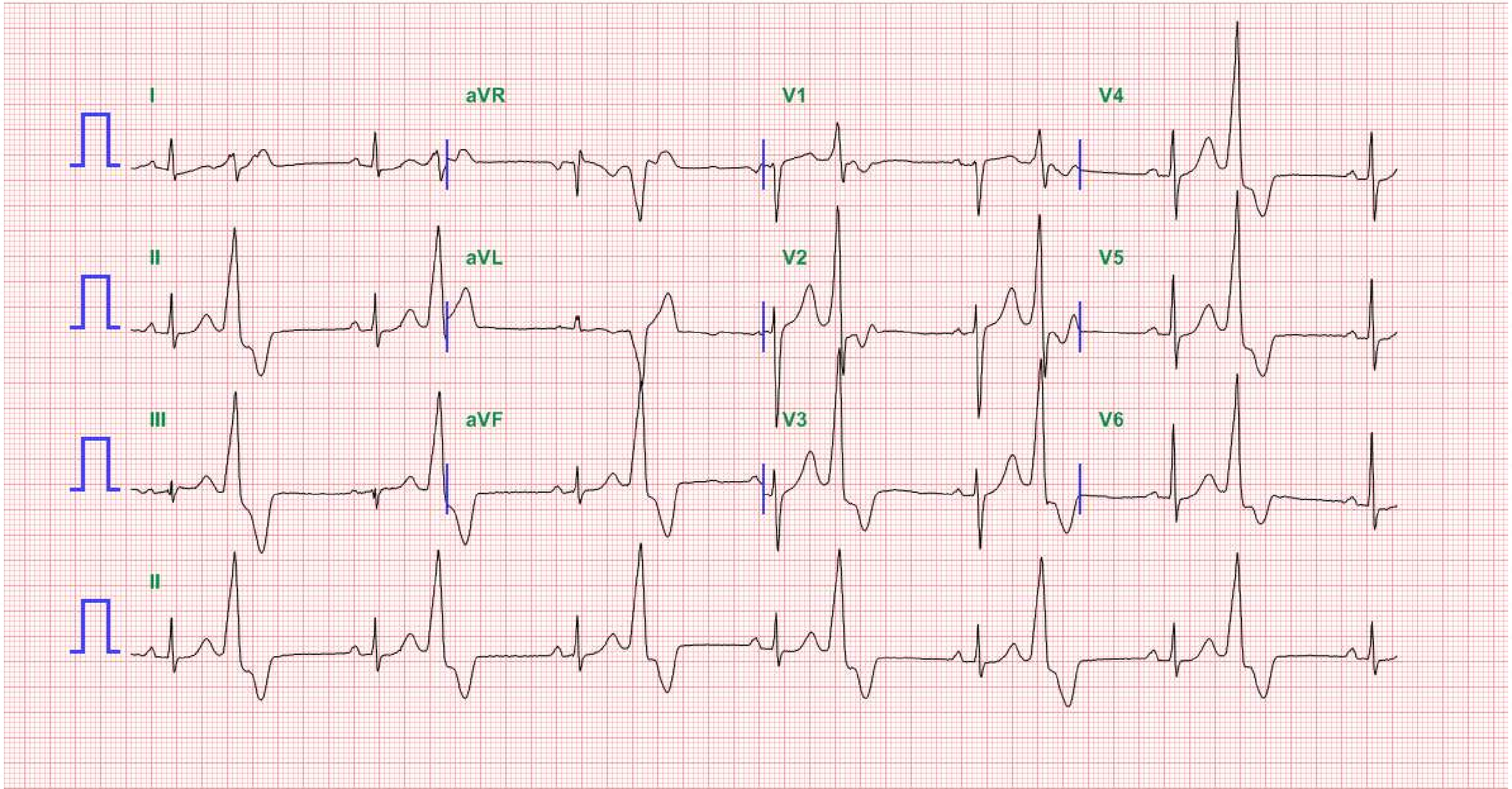
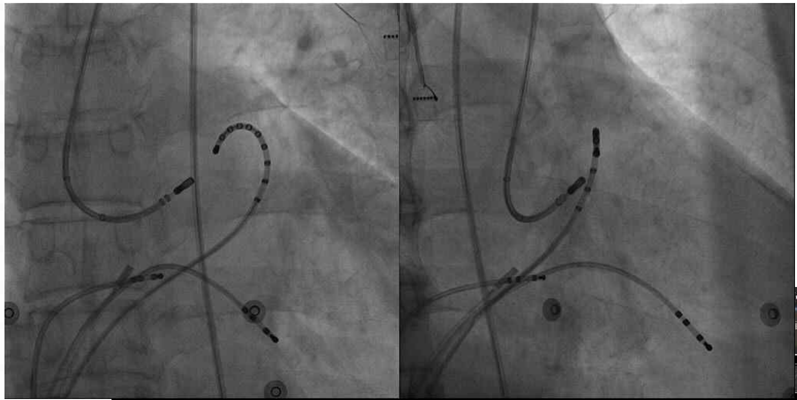
67 Y.O. Male, Frequent PVC and NSVT

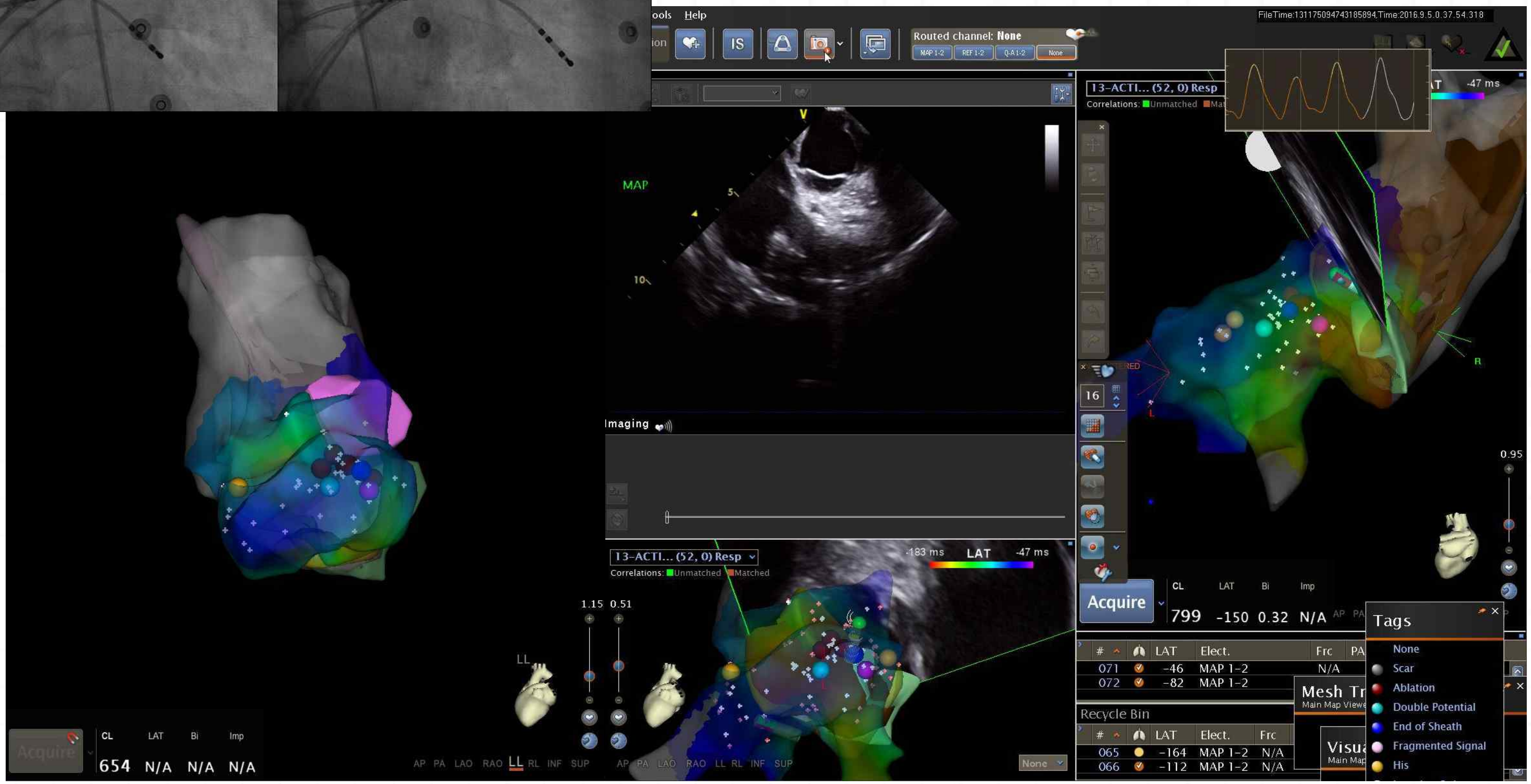


Success site

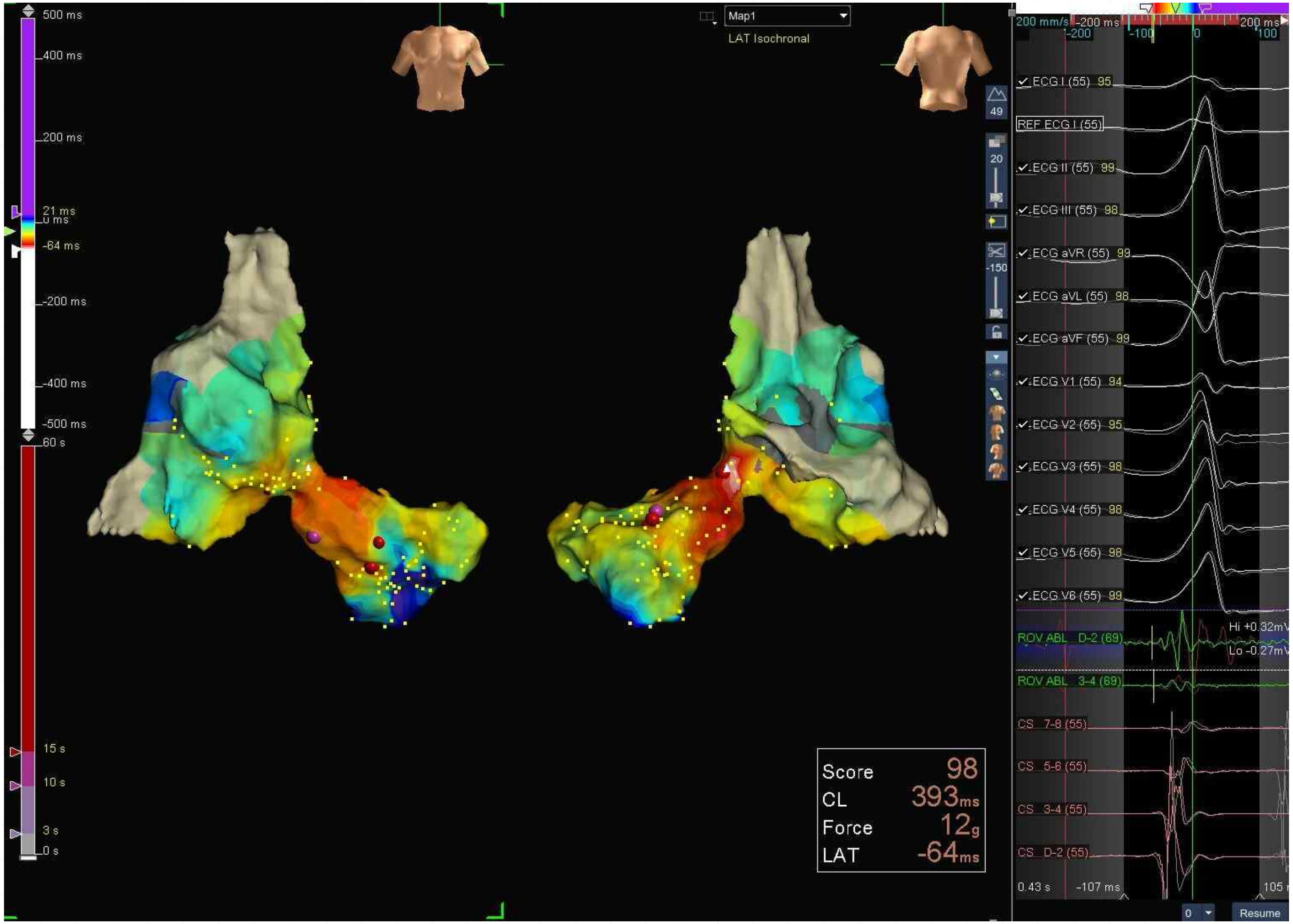
PVCs were eliminated during ablation

Success site

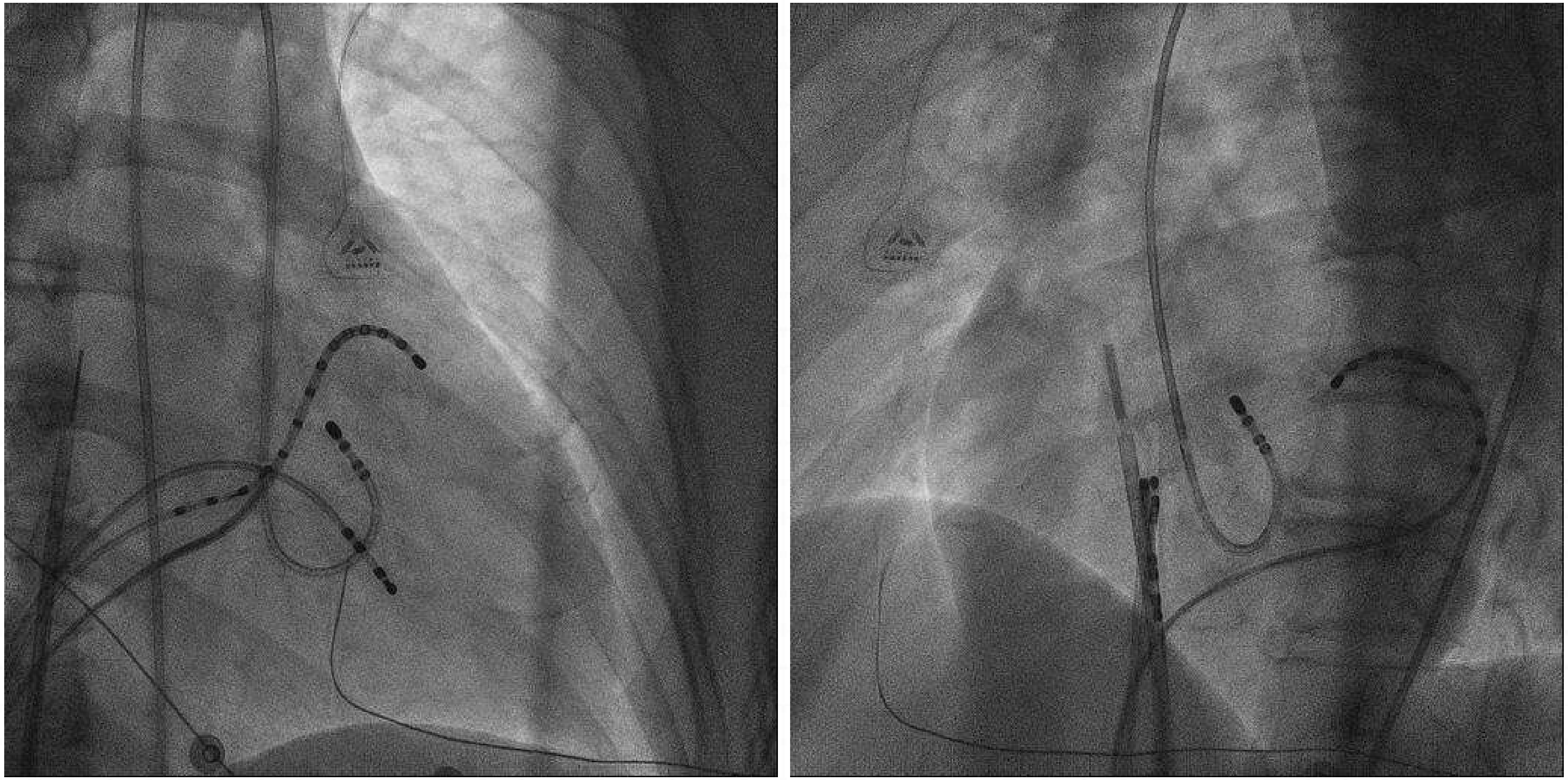




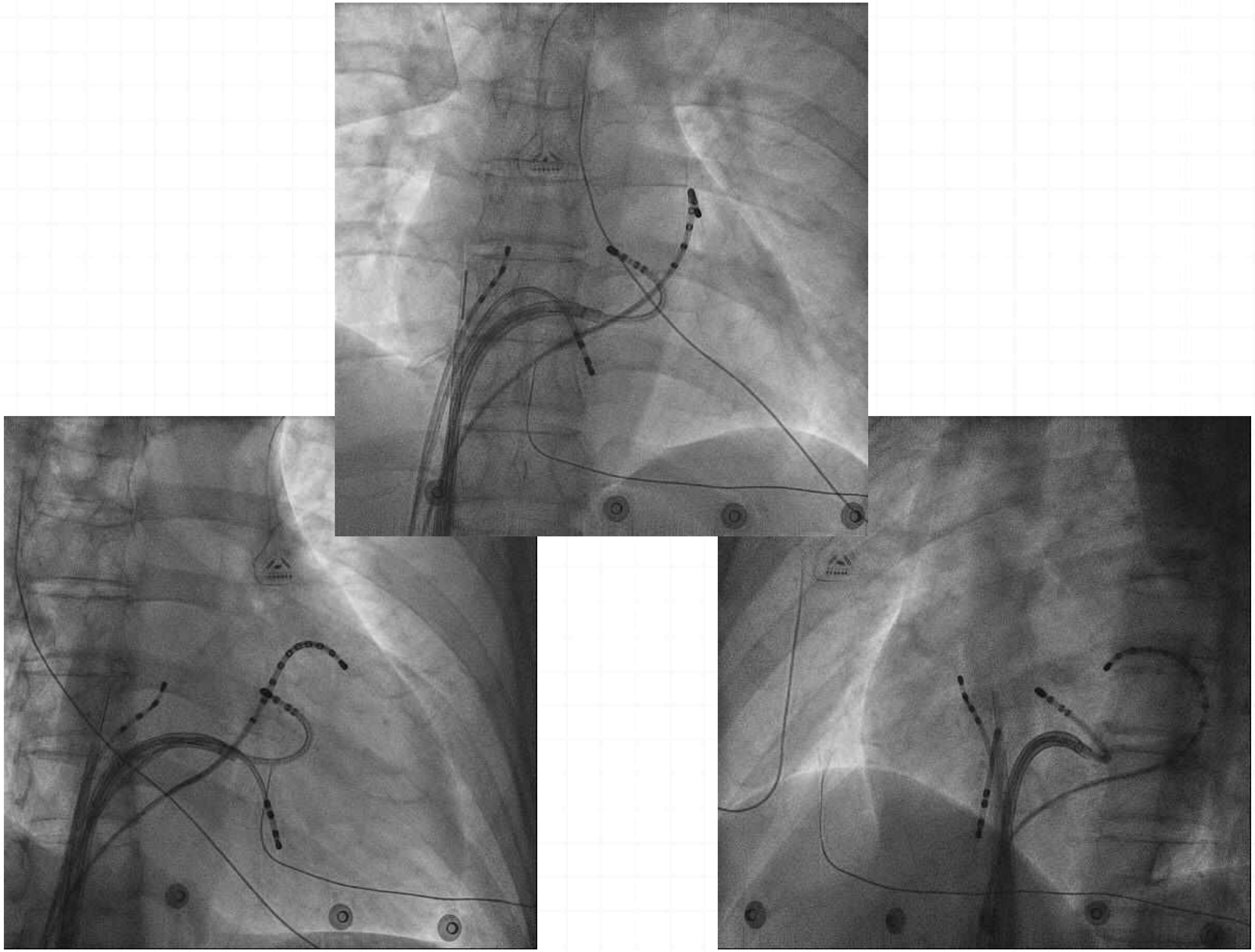
55 Y.O. female, Frequent PVCs and NSVT



Transaortic approach

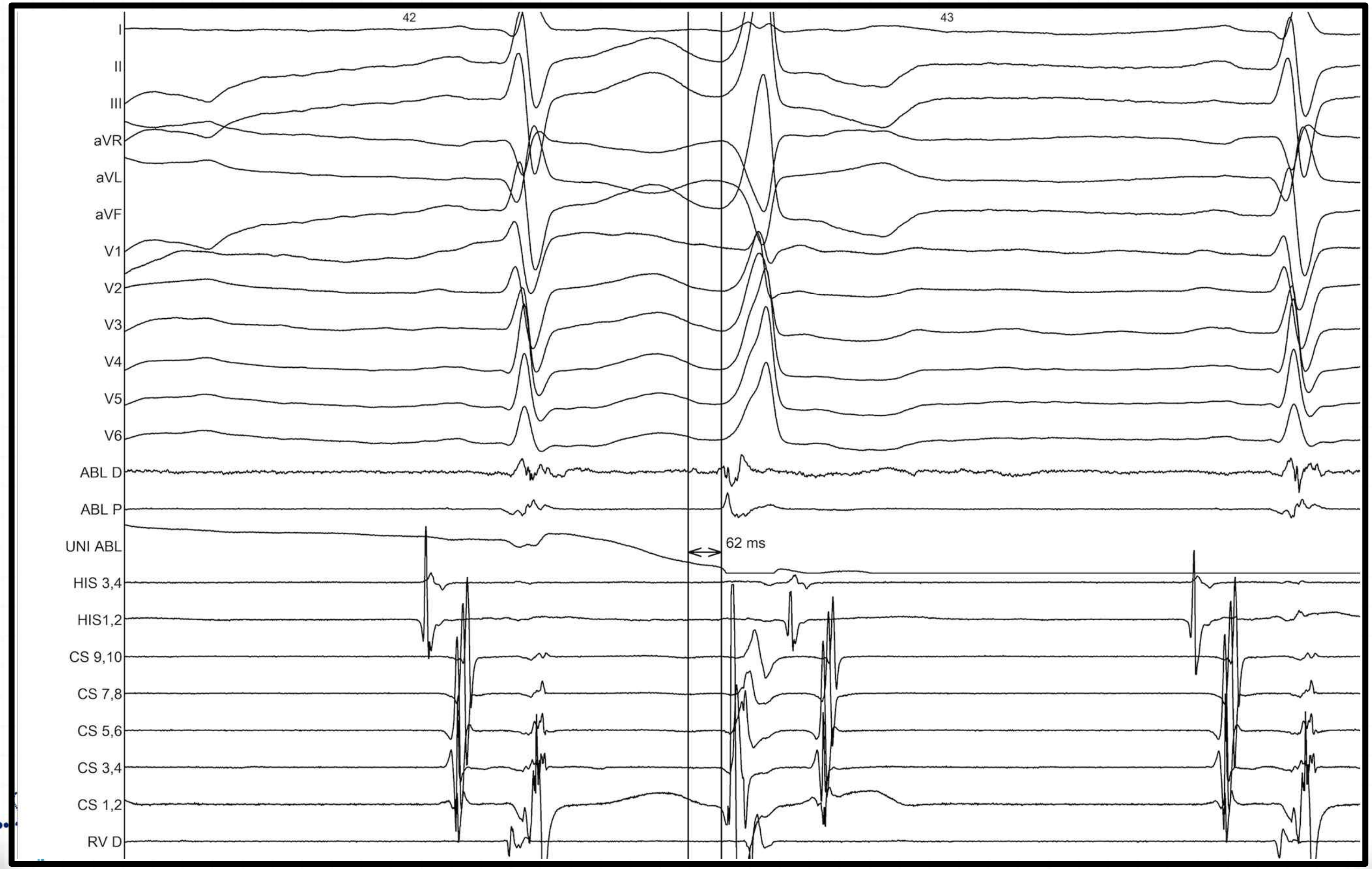


Transseptal approach with Agilis sheath

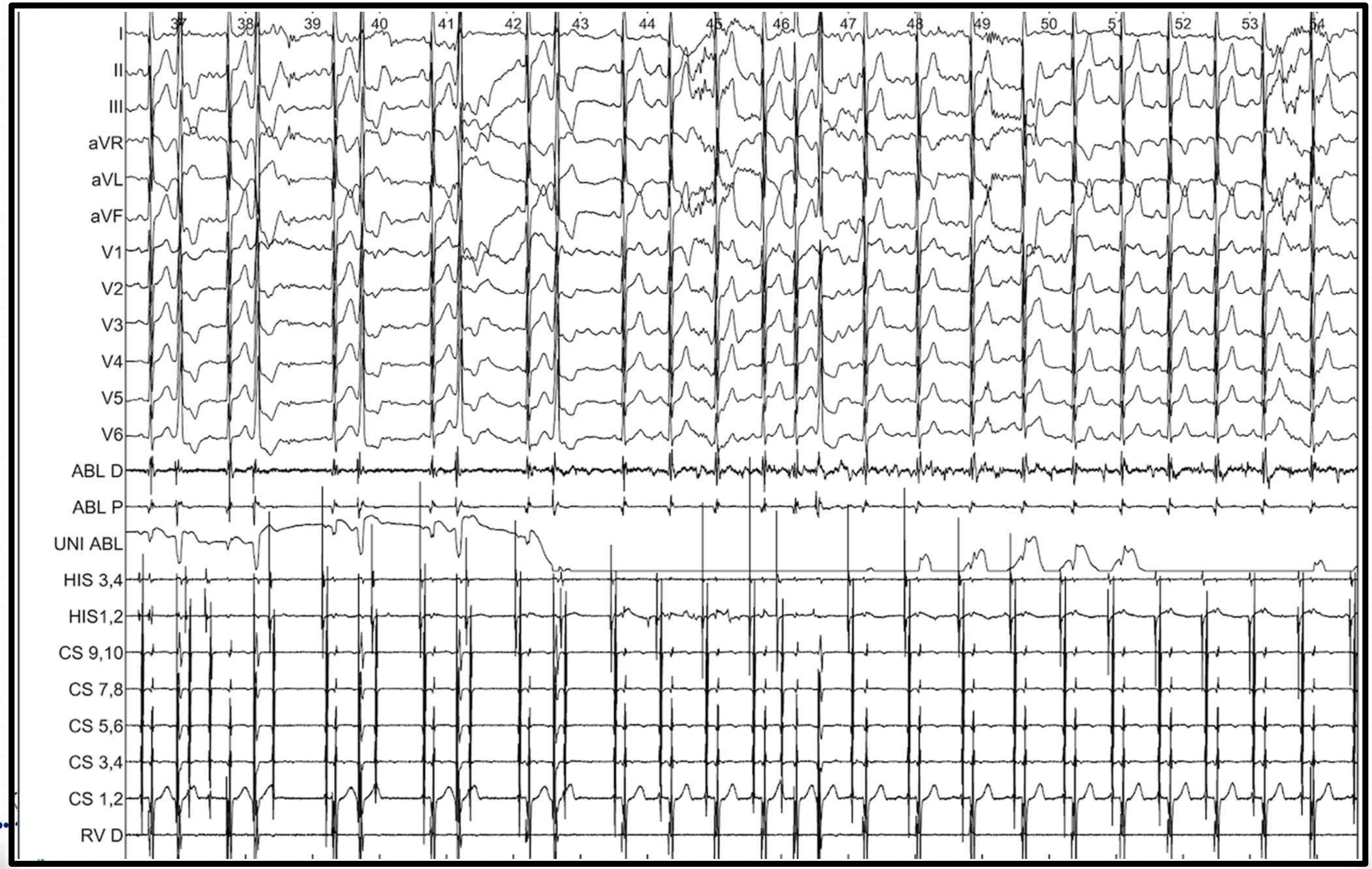


KUDH

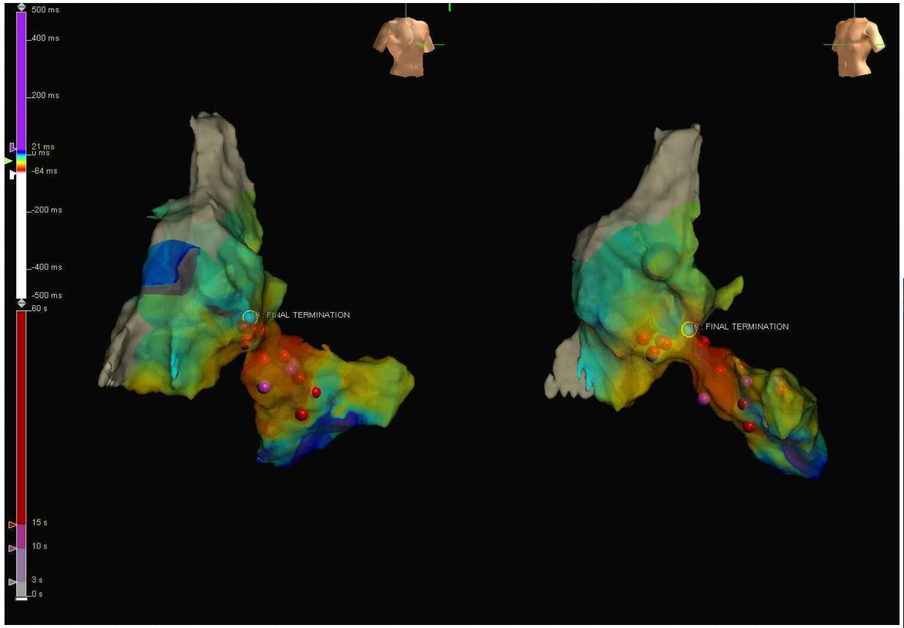
Success Site

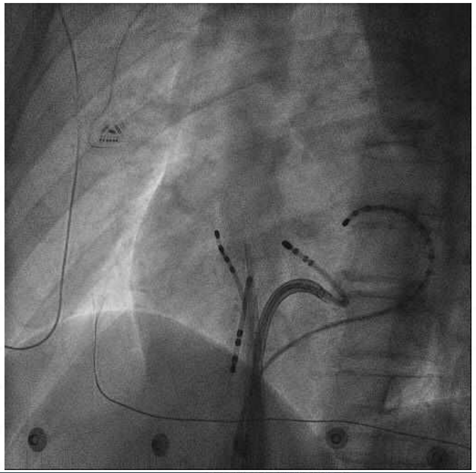


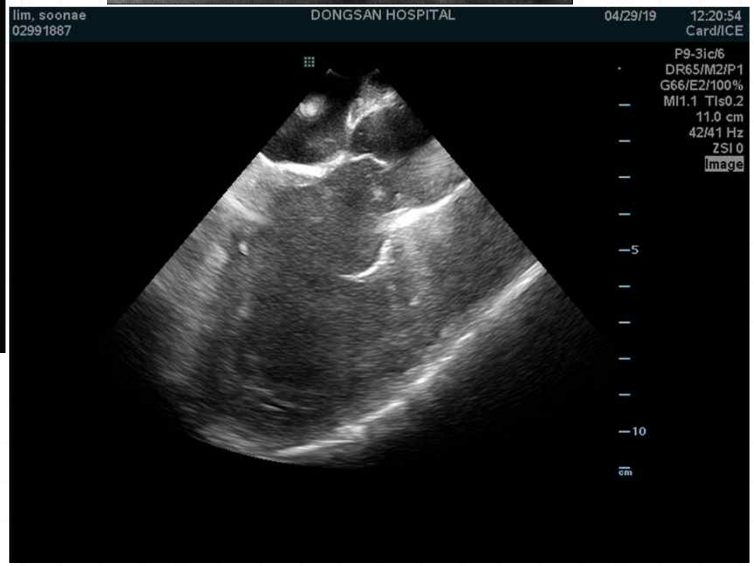
PVCs were eliminated during ablation



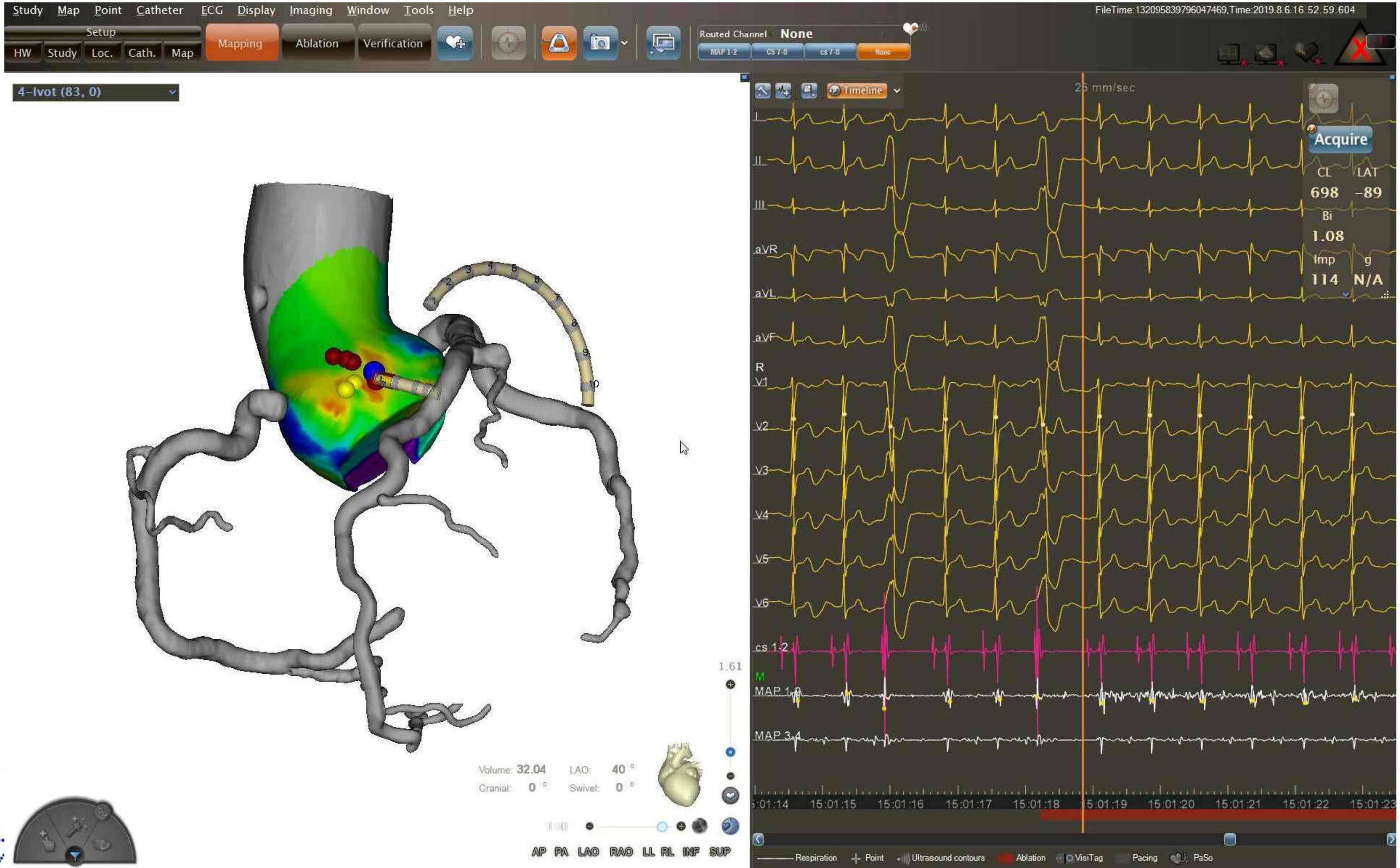
Success site







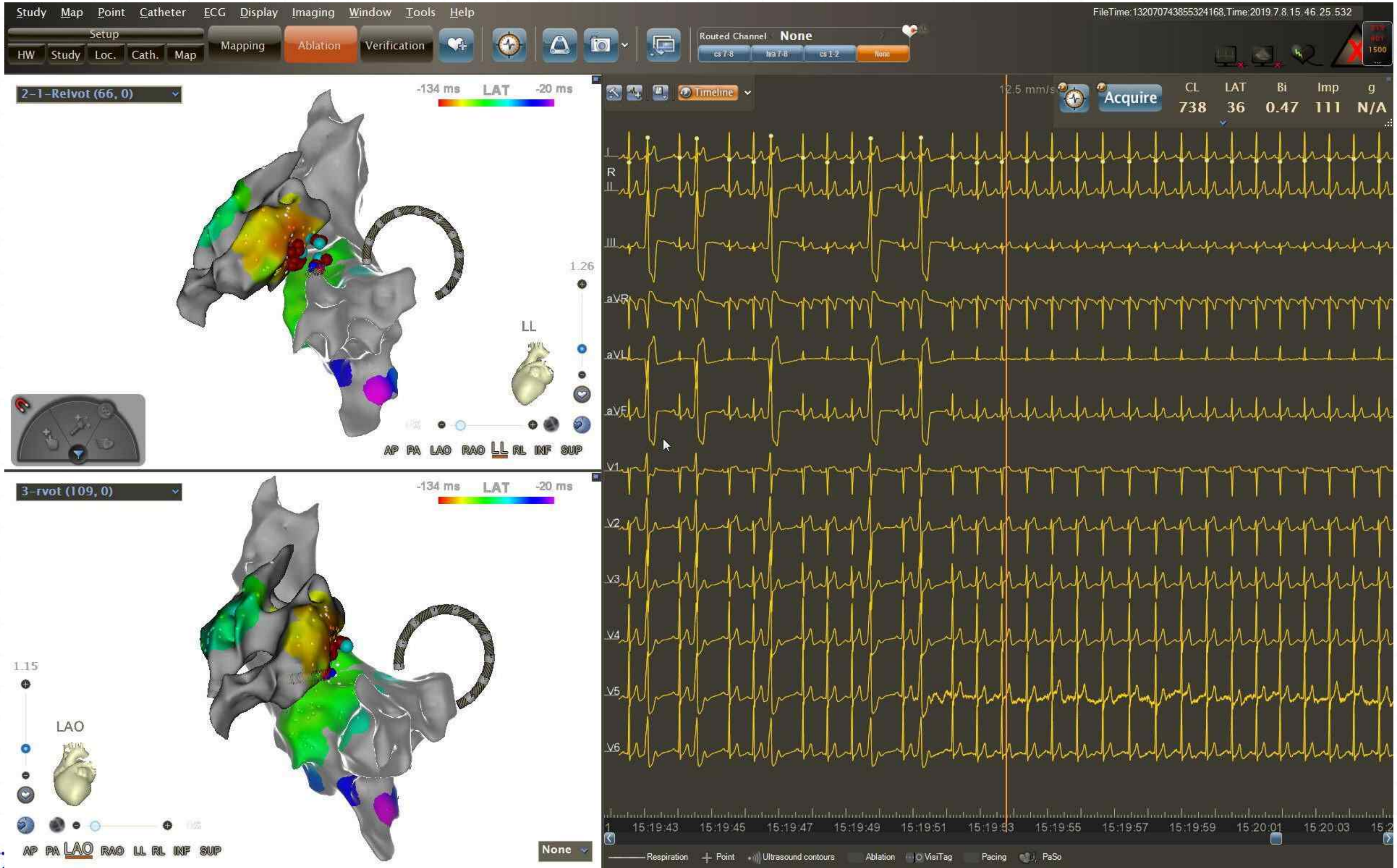
37 Y.O. male, Frequent PVCs



KUDH

Courtesy of Dr. Han Seongwook

56 Y.O. male, Frequent PVCs



KUDH

Courtesy of Dr. Han Seongwook

Summary

- A qrS pattern in leads V_1-V_3 is very helpful for predicting an origin in the LCC-RCC junction.
- LCC–RCC aortic cusp ventricular arrhythmias have a QS morphology in lead V_1 with notching on the downward deflection with precordial transition at lead V_3.
- LCC-RCC junction sites are determined by fluoroscopy, ICE, 3D mapping and CT merge integration.
- In most cases, the site of successful ablation has late potentials in sinus rhythm with early activation during ventricular arrhythmias.
- The long-term success rate of ablative therapy is excellent.

KUDH

Thanks for your attention !!