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Aortic Cusp PVC : Mapping and Ablation of Aortic Cusp PVC

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COI Disclosure

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The authors have no financial conflicts of interest to disclose concerning the presentation

Introduction

- **Premature ventricular contractions (PVCs)** are known to **originate from Aortic sinus of Valsalva** and typically are described as originating from the individual **right coronary cusp (RCC) or left coronary cusp (LCC) sinuses**

- Previous studies described the **general ECG morphologic characteristics** of **Aortic cusp PVCs** with **early QRS transition** and, did **originate from the base of Aortic cusps and RCC/LCC commissure**.

Heart Rhythm 2010;7:312–322.

Circ Arrhythm Electrophysiol. 2014;7:445-455.

Journal of Interventional Cardiac Electrophysiology (2020) 59:145–298.

Basic anatomical considerations

- Using an **attitudinal orientation is particularly relevant** both to interpretation of **<u>site of origin and to the ECG pattern of OT PVC</u>**.

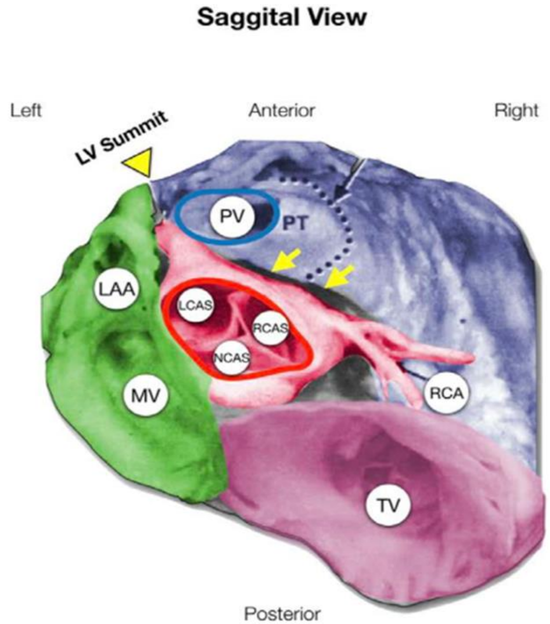
- When viewing the heart from its correct anatomical position, it can be divided into **<u>3 mutually perpendicular, symmetrical planes</u>**:

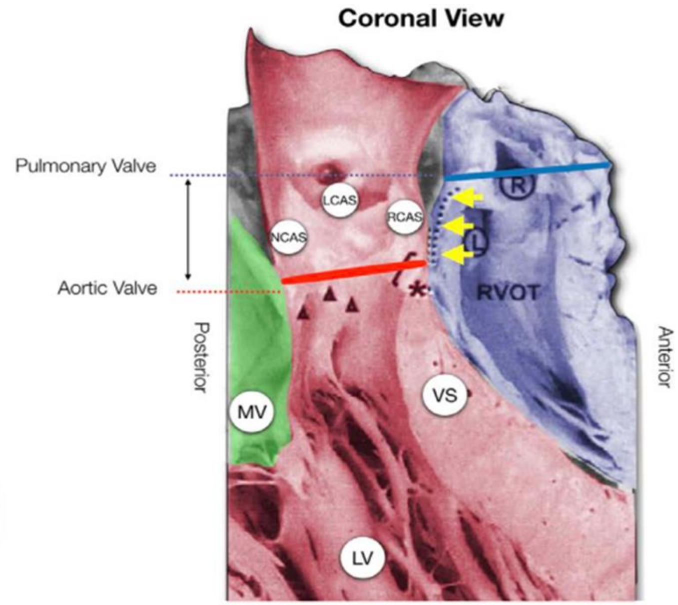
(1) “transverse” - superior/inferior

(2) “coronal” - front/back

(3) “sagittal” - left/right.

Gross Valvular Relationships





- As normally positioned in chest, **right ventricular OT** is located **anterior and leftward relative to aortic root**.

- **Pulmonic valve** is positioned **approximately 1–2 cm superior to** and **offset 90◦ from aortic valve** in horizontal plane.

- From **tricuspid valve, RVOT projects in a superior, anterior, and leftward direction**.

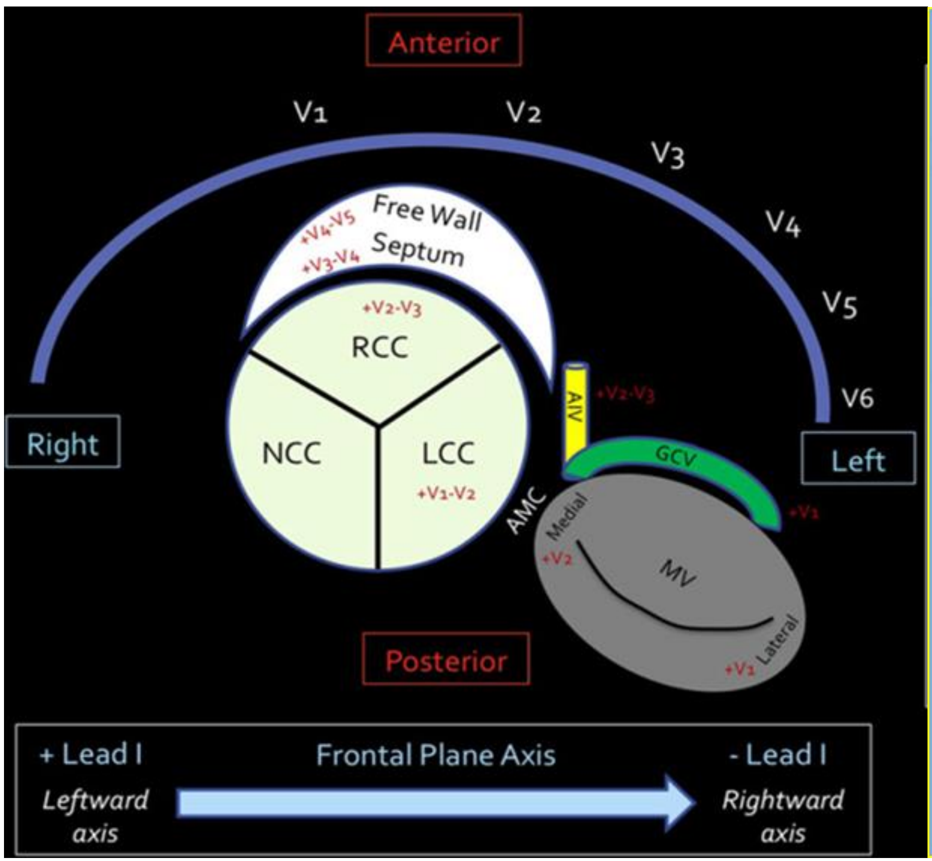
- The **mitral annulus is inferior, posterior, and leftward** relative to aortic root

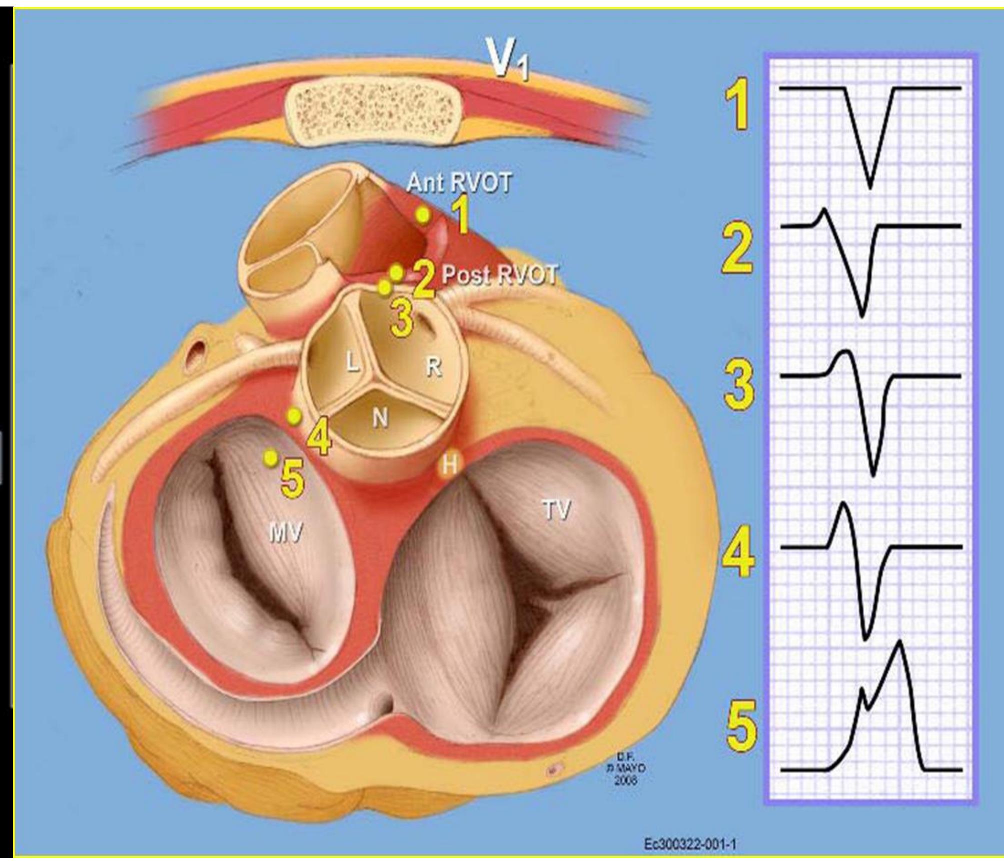
Circ Arrhythm Electrophysiol. 2019;12:e007392.

Gross Valvular Relationships

- From <u>attitudinal perspective</u>, **<u>NCC is posterior and rightward</u>** and **<u>LCC is posterior and leftward</u>**. **<u>RCC is the most anterior and inferior cusp</u>** relative to the sternum.

- **<u>AV plane tilts rightward in the horizontal plane,</u>** reported between **<u>30–45°</u>**.





Microscopic Considerations

- **NCC is continuous anteriorly** with the **membranous ventricular septum** and **posteriorly with central fibrous body**;

→ both **atrial and His bundle electrograms** are routinely **recorded** from **NCC & RCC junction**.

- **Posterior aspect of LCC** is **contiguous with left fibrous trigone**, which attaches to lateral aspect of the **anterior mitral leaflet**.

- **Entire RCC** and **anterior half of LCC** are in contact with ventricular myocardium of **LV ostium**.

- Thus, **PVCs are targeted** within **aortic root primarily from right and (anterior aspect of) left cusps**.

ECG Patterns of OT PVC

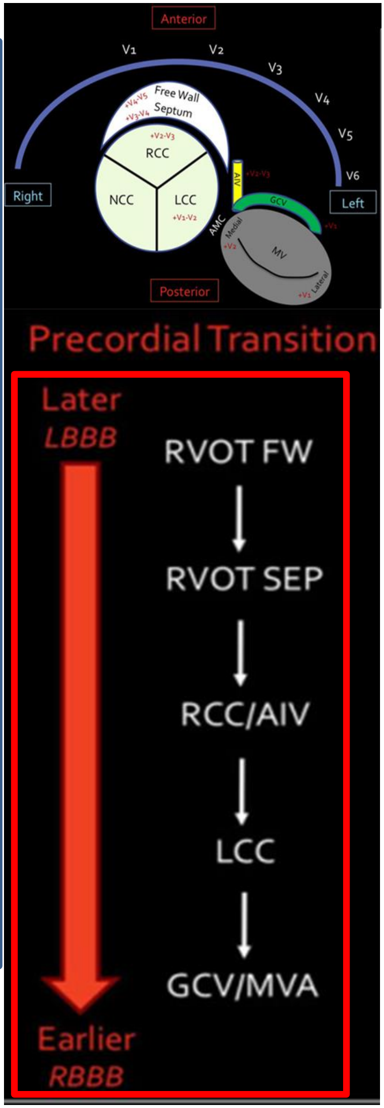
- When determining ECG site of origin, it is important to analyze the **precordial transition and frontal plane QRS axis** of spontaneous PVC

Precordial Transition

- **V1 is a unipolar** lead at anterior chest wall, structures closer to chest will produce **LBBB pattern**; more posterior structures have **RBBB pattern**.

- Due to its anterior location, **PVCs originating from RVOT have LBBB pattern** with rare exceptions. Likewise anterior structures in **LVOT (e.g., RCC) typically have LBBB pattern**.

- As site of **PVC origin shifts progressively more posterior** from RCC (i.e., R/L junction, LCC, AMC), lateral mitral annulus, LV summit, AIV/GCV) **V1 configuration transforms** from an **LBBB to RBBB** pattern



Precordial Transition

- **RCC is directly posterior to mid septal RVOT**, morphologies of PVCs originating from these sites may appear **quite similar**

- In general, **RCC PVCs have a precordial transition at V2 or V3**, while those ablated from **LCC commonly have significant R wave in V1** (resulting from LCC's more posterior location relative to RCC).

- **LCC PVCs** may also have **multiphasic appearance in V1** (previously described as **"m" or "w" pattern**).

- **R/L commissure** is **common source of idiopathic PVCs** .

- **PVCs successfully eliminated from R/L commissure** (based upon imaging confirmation with ICE and/or CT) commonly demonstrate **QS complex with notching of the downstroke in lead V1**, and a **precordial transition at lead V3**

Heart Rhythm 2010;7:312–322.

Twelve-lead electrocardiographic characteristics of the aortic cusp region guided by intracardiac echocardiography and electroanatomic mapping

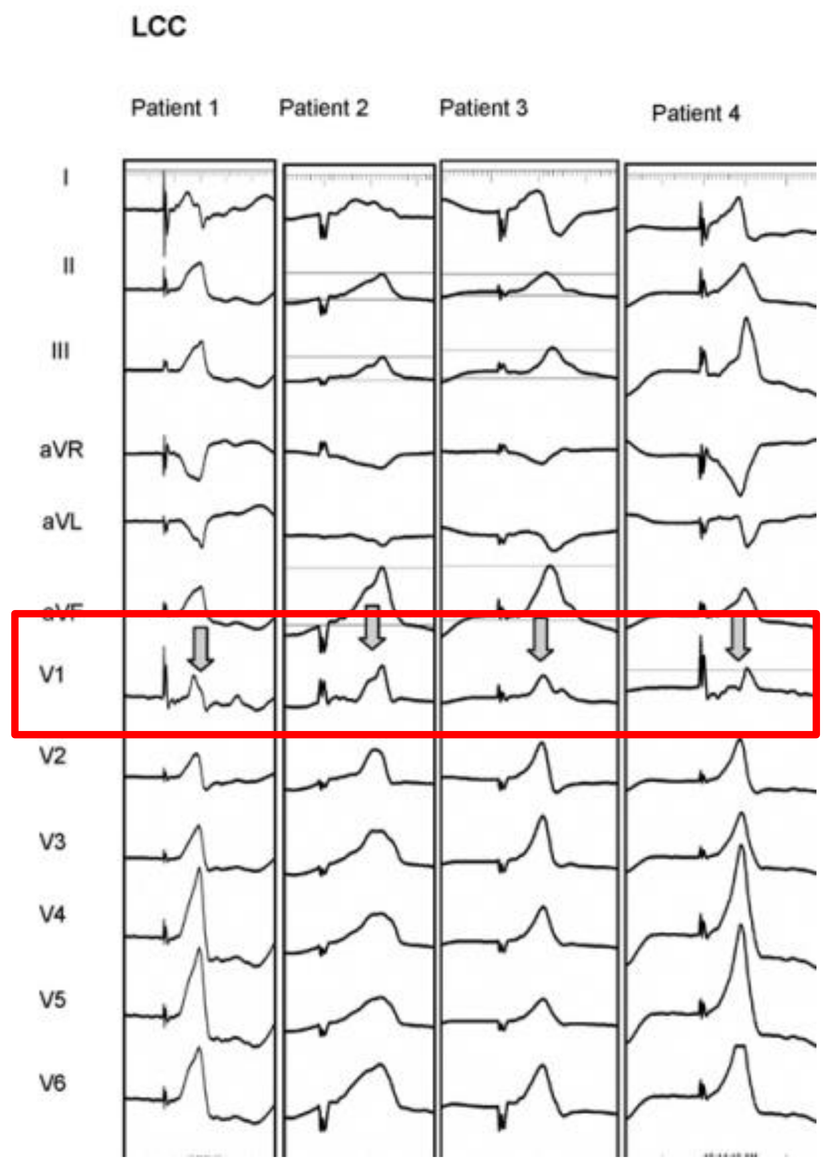


Table 1 Electrocardiographic features of aortic cusp/aortomitral continuity pacing

	RCC	LCC
V_1	QS or Qr with overall negative vector V_1 (20/24)	Multiphasic M or W pattern (19/24)
Precordial transition	Small broad R wave in V_2 (20/24) Overall positive vector By V_2 (5/24) By V_3 (15/24) By V_4 (4/24)	Overall positive vector at V_1 Positive by V_2 (20/24)
QRS duration (mean)	159.7 ms*	144.8 ms* *P = .02
Amplitude of lead II (mean)	1.6*	1.4 *P <.02
II/III ratio (mean)	1.07†	1.13† †P = NS; *P = .01

AMC = aortomitral continuity; LCC = left coronary cusp; RCC = right coronary cusp.

- **<u>The most notable characteristic</u>** about these **<u>pacemapped beats</u>** was **<u>multiphasic nature of V1.</u>**

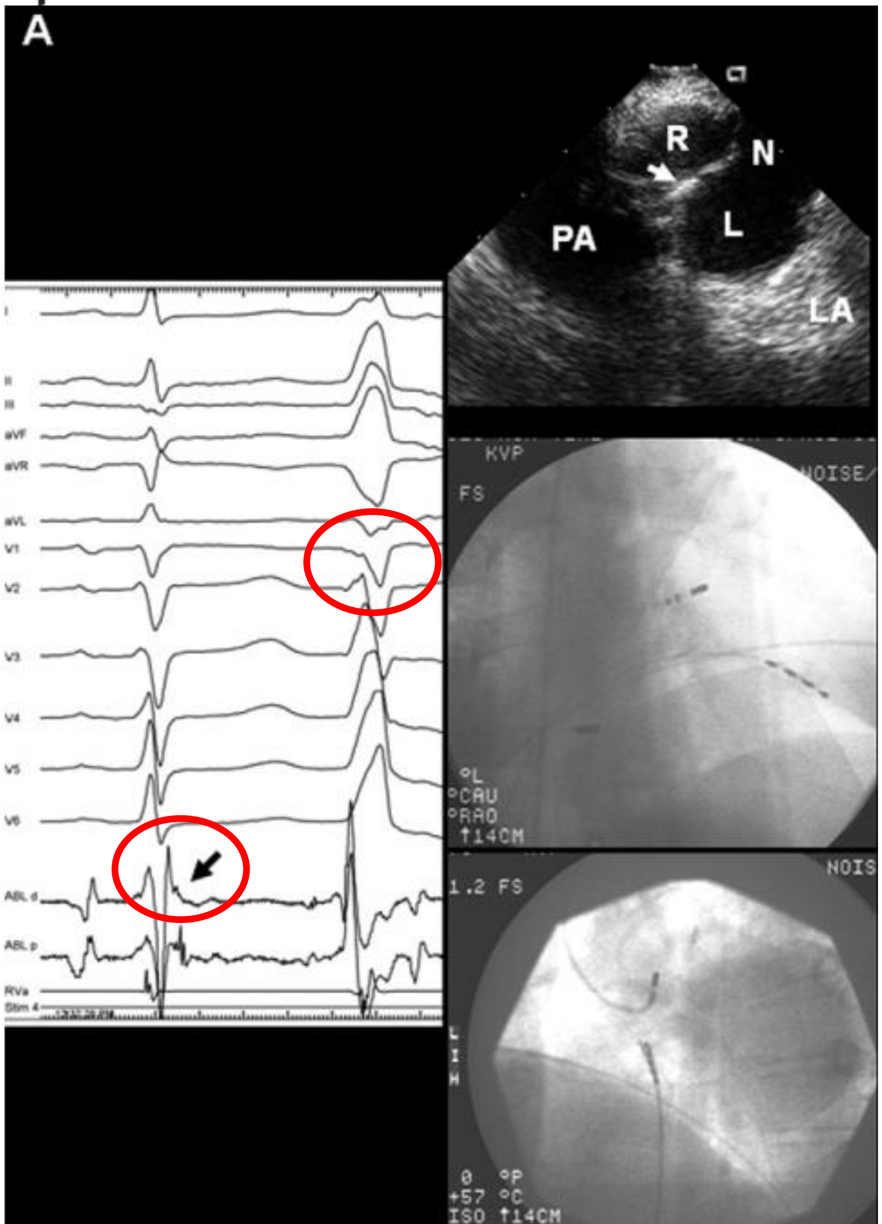
→ Perhaps it represents a more complex wave-front or spread of activation between the ventricles.

- **LCC is closer to main muscle of the LV**

→ significantly **<u>shorter QRS</u>** durations pacing from **LCC compared to RCC**.

Heart Rhythm 2008;5:663-669.

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



Conclusion

- **<u>RCC–LCC aortic cusp</u>** ventricular arrhythmias are **<u>common</u>** and have a **<u>QS morphology in lead V1 with notching</u>** on the **downward deflection** with precordial transition at **lead V3**.

- In majority of cases, <u>site of successful ablation</u> has **late potentials in sinus rhythm (black arrow)**

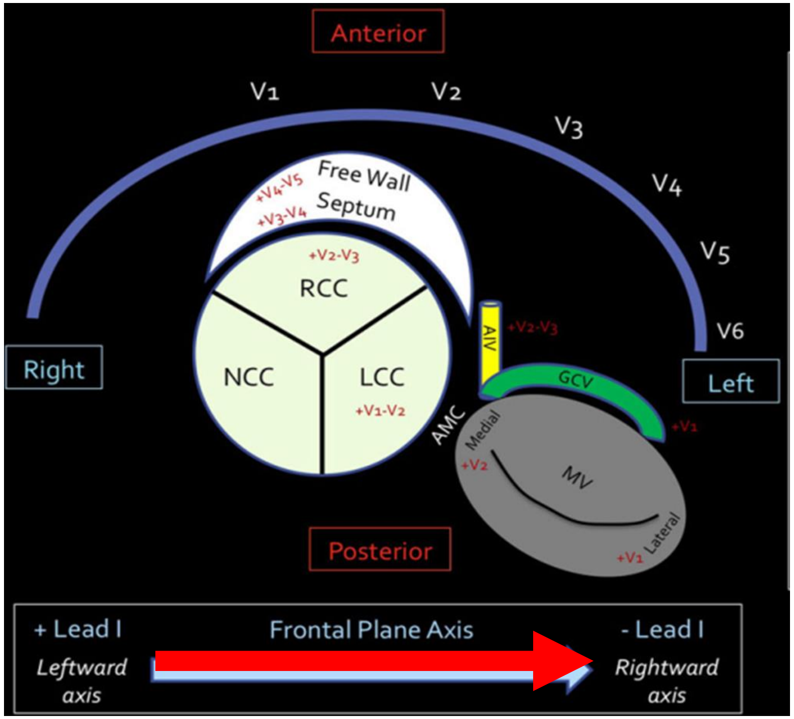
Heart Rhythm 2010;7:312–322.

Frontal & Vertical Plane QRS Axis

- When describing **frontal plane QRS** axis, it is important to consider both **horizontal and vertical dimensions**.

- **Horizontal dimension** is most reflected by **bipolar limb lead I**.

- **Structures closer to left axilla** will produce **deeply negative complex in lead I (rightward axis);** conversely structures closer to **right axilla are strongly positive in lead I (leftward axis)**

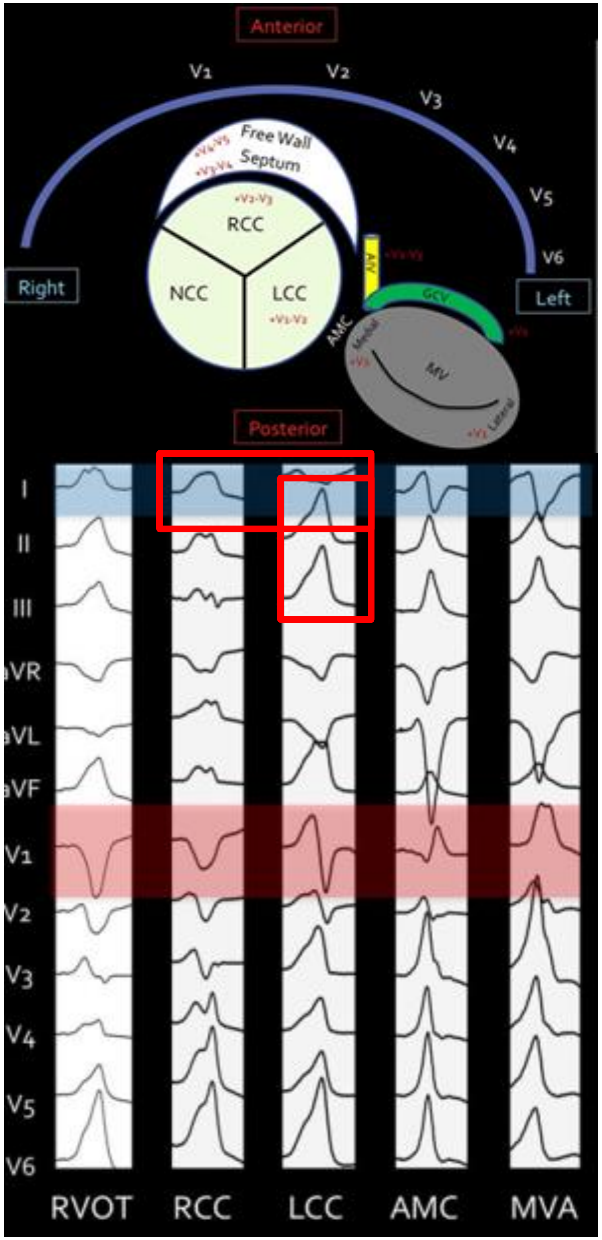


- **Vertical dimension** is reflected by **QRS axis in leads II, III, and aVF**.

- **Mean QRS axis for OT PVCs** is always **inferiorly directed**, though magnitude of the vector diminishes toward inferior regions of OT.

J Cardiovasc Electrophysiol. 2013 Oct;24(10):1189-97.

Frontal Plane QRS Axis



- **<u>LCC abuts LV ostium laterally</u>** and **<u>posteriorly</u>**, <u>relative to **RCC**</u>.
- when <u>compared to **RCC**</u>, **<u>PVCs originating adjacent to LCC</u>** are **<u>less positive (and often negative) in lead I</u>**, and **<u>have greater R</u>** wave amplitude in **<u>lead III compared to lead II</u>**.
- Due to **<u>rightward tilting of AV</u>** from **<u>horizontal plane</u>**, **<u>LCC is positioned more cranial or superior</u>** relative to **RCC**

J Cardiovasc Electrophysiol. 2013 Oct;24(10):1189-97.

QRS complex maximum deflection index in aortic cusp premature ventricular complexes

Table 1

Patient demographic and electrocardiographic characteristics in cases of premature ventricular complexes successfully ablated at the aortic cusps.

Patient	Age (years)	Gender	Successful site	PVC V1 morphology	SR QRS width (ms)	PVC QRS width (ms)	Net amp I (mV)	Net amp aVF (mV)	Precordial transition SR	Precordial transition PVC	MDI	Pseudodelta
1	54	F	LCC	rS	82	148	0.24	1.32	V3–V4	V1	0.48	No
2	21	F	LCC	rS	86	128	−0.48	1.68	V4	V4	0.58	No
3	64	F	LCC	rS	86	146	0.16	1.60	V3	V4	0.68	No
4	64	M	LCC	rS	94	162	0.12	1.40	V2	V3	0.59	No
5	75	F	LCC	qR	86	125	0	1.24	V4	V2	0.45	No
6	42	F	RCC–LCC commissure	rS	82	123	−0.53	1.67	V4	V2	0.46	No
7	72	F	LCC	qS	92	146	−0.32	2.72	V5	V4	0.66	No
8	42	M	RCC	rS	94	128	1.36	1.36	V2	V2	0.61	Yes
9	65	M	LCC	Rs	88	146	0.64	1.32	V4	V1	0.49	No
10	59	M	LCC	rS	82	131	0.24	1.68	V3	V3	0.28	No
11	52	M	RCC	rS	84	125	1.24	1.79	V4	V3	0.66	No
12	72	M	LCC	rS	Paced rhythm	143	1.51	0.93	V2	V3	0.56	No
13	66	M	LCC	rS	96	130	−0.36	1.98	V4	V3	0.50	No
14	77	M	RCC	rS	108	131	0.12	1.56	V3	V2	0.50	No
15	42	F	LCC	rS	74	121	−0.12	1.64	V4	V3	0.46	No
16	57	F	RCC	rS	80	150	0.64	0.80	V3	V4	0.52	No
17	44	M	LCC	rS	90	140	−1.08	4.88	V2	V3	0.49	No

Abbreviations: PVC, premature ventricular complex; SR, sinus rhythm; MDI, maximum deflection index; RCC, right coronary cusp; LCC, left coronary cusp; M, male; F, female.

IJC Heart & Vasculature 7 (2015) 6–8.
Circ Arrhythm Electrophysiol 2010;3:63–71.

Mapping the arrhythmia

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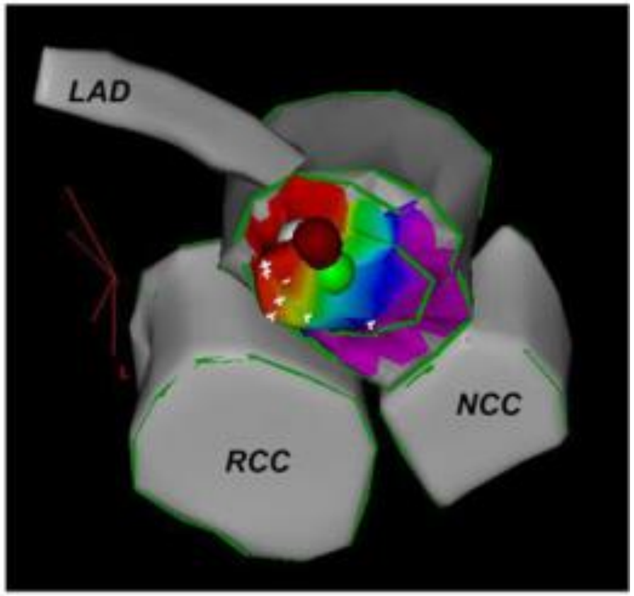

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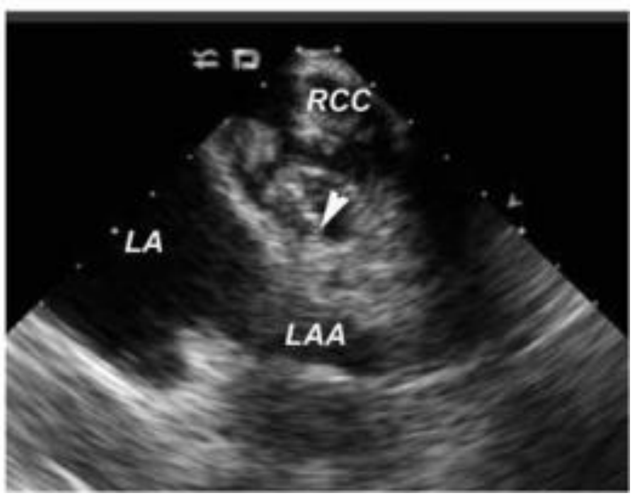


**** Routine mapping procedure**

- Integration of **3D mapping with/without phased-array ICE** can greatly demystify complex OT relationships.

- **By sweeping ICE probe** through adjacent imaging planes, 3D surface can be rapidly constructed from 2D contours.

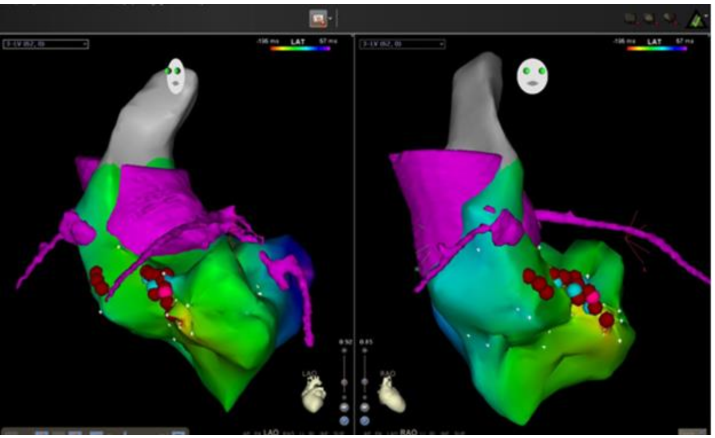
- **Important structures** such as **LM coronary ostium** can be tagged and projected into the 3D map especially in cases with PVCs ablated from the LCC.

J Cardiovasc Electrophysiol, Vol. 24, 1189-1197.

Rev Cardiovasc Med. 2022 Mar 16;23(3):10.

Outflow tract ventricular arrhythmia originating from the aortic cusps: our approach for challenging ablation

Ibrahim Marai[1] · Monther Boulos[1] · Jonathan Lessick[1] · Sobhi Abadi[2] · Miry Blich[1] · Mahmoud Suleiman[1]



- <u>**Imaging techniques are used to localize important anatomic structures**</u> and <u>ablation catheter at aortic cusps</u> including biplane fluoroscopy, aortography, CAG, ICE, CT, and 3D electroanatomic mapping (EAM) systems

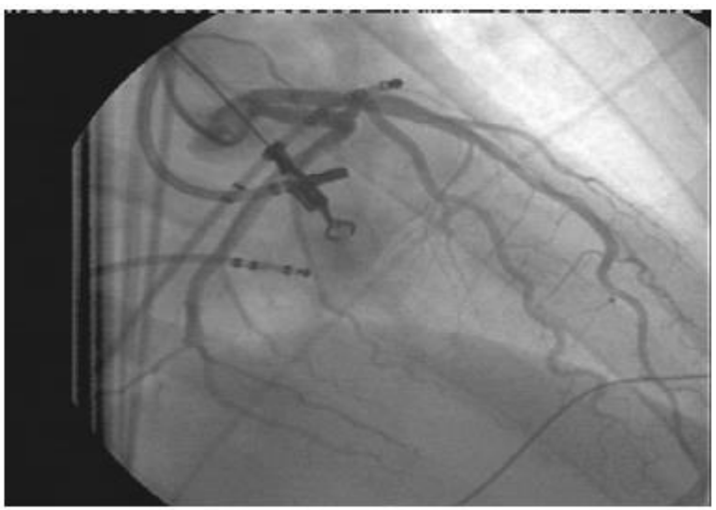


Fig. 4 Coronary angiogram showing injection to left main coronary artery (RAO projection). Point at the ostium of left main coronary artery was acquired by the ablation catheter. This point was used for point-based registration of CT image and electroanatomic map

Conclusions

- Catheter ablation of PVC originating from aortic cusps is safe and effective.
- <u>**CT image integration into electroanatomic mapping system can be helpful**</u> in this challenging ablation.

J Interv Card Electrophysiol (2016) 45:57–62.

Role of intracardiac echocardiography (ICE)

- **ICE has emerged as effective tool in PVC ablation**,

  : clearly help in identification of Aorta, coronary ostia and proximity to LM artery, especially in cases with PVCs from LCC.

→ **Real time visualization of ablation catheter stability** in Aorta, **limiting complications and radiation exposure**.

- Furthermore, **steam pops, thrombus formation and pericardial effusion can be immediately identified** during procedure, while ensuring perpendicular catheter-tissue orientation, **for optimal ablation results**

Rev Cardiovasc Med. 2022 Mar 16;23(3):10.
Circulation: Arrhythmia and Electrophysiology. 2008; 1: 110–119.

Mapping the arrhythmia

- For patients **with frequent spontaneous ectopy**, usually **prefer activation mapping** to identify site with **earliest presystolic activity from Aortic cusp**

- **Routinely record continuous ECG data in EP lab** during patient preparation and set-up

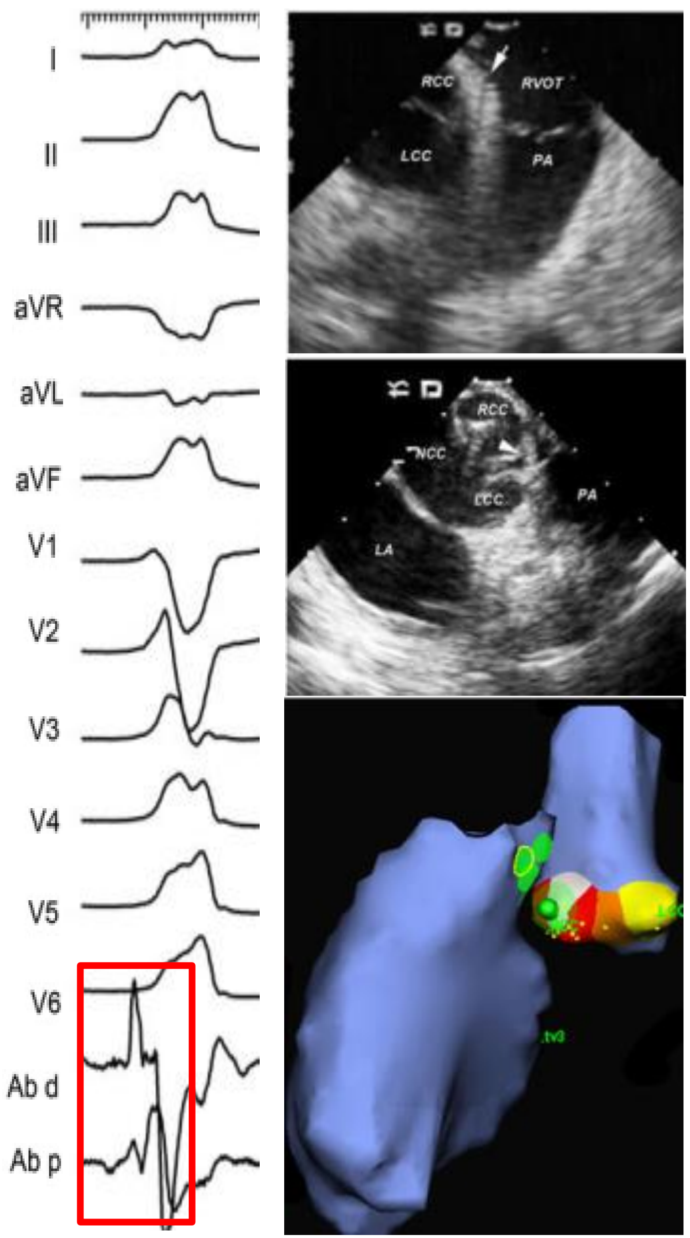
→ provides **pace-mapping template of patient's spontaneous PVCs** in the event of its suppression during the procedure

- **Pace-mapping can be extremely useful** in patients with **infrequent spontaneous ectopy**, particularly in **RVOT!!!**.

- Given the **frequent lack of ventricular myocardium within recesses** of **Aortic leaflets**, **pace-mapping in aortic root may fail** to **replicate morphology of PVCs** originating from **adjacent LV ostium**.

J Cardiovasc Electrophysiol. 2013 Oct;24(10):1189-97.

Mapping the arrhythmia



- **with early presystolic activation from RVOT**, but in whom **pace-mapping fails to replicate** the 12-lead ECG morphology of spontaneous PVCs (or produces a long stimulus-QRS for pace-map), typically **perform activation mapping of RCC prior to energy application**.

- **Presence of isolated or late sharp** components of **bipolar electrogram** that **reverse and become presystolic during spontaneous PVCs** have been described within Aortic root, and **often represent sites of successful PVC elimination**.

J Cardiovasc Electrophysiol, Vol. 24, 1189-1197.

Mapping the arrhythmia

- **Rightward tilting of aortic root** causes **LCC to be situated higher than RCC**, so **entering LCC often requires moderate upward deflection** and **leftward displacement of mapping catheter**.

- **Aortic commissures are situated approximately 1cm above cusp** nadirs, so when mapping these structures **catheter tip will also be positioned higher** than when in adjacent cusps.

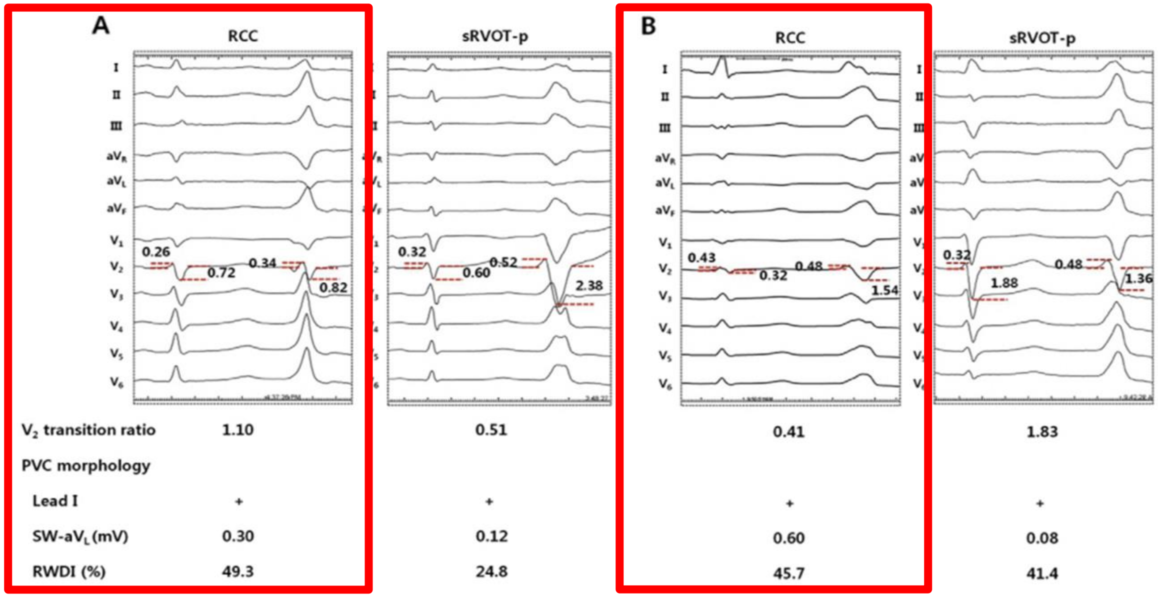
- **Catheter mapping of aortic root requires modest learning curve**.

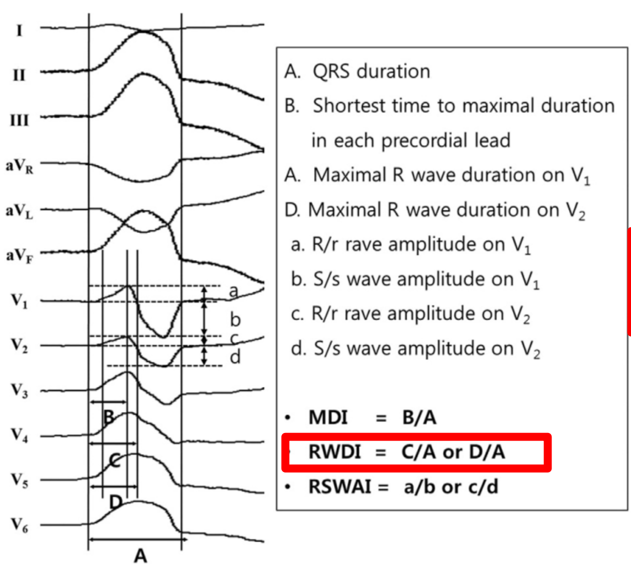
  :It is helpful to maintain a mental 3-dimensional representation of **anatomical relationships of cusps while mapping**.

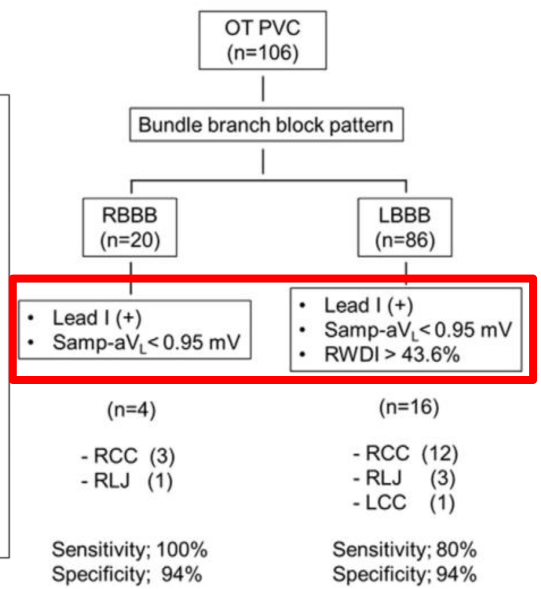
J Cardiovasc Electrophysiol. 2013 Oct;24(10):1189-97.

New electrocardiographic criteria for predicting successful ablation of premature ventricular contractions from the right coronary cusp

Sung Il Im [a,1], Kyoung-Min Park [b,*,2], Seung-Jung Park [b], June Soo Kim [b], Young Keun On [b]







- **Background**: ECG features for predicting successful ablation sites of outflow tract PVCs have been previously presented, but effective predictors of RCC remain elusive.
- **Conclusions**: The presence of dominant positive lead I, RWDI >43.6% and S-wave amplitude in aVL <0.95 mV predicted RCC PVCs with sensitivity of 83% and specificity of 94%

Int J Cardiol. 2016 Dec 1;224:199-205..

Electrocardiographic characteristics for successful radiofrequency ablation of right coronary cusp premature ventricular contractions

Sung Il Im, MD[a], Sung Ho Lee, MD[b], Hye Bin Gwag, MD[c], Youngjun Park, MD[c], Seung-Jung Park, MD[c], June Soo Kim, MD[c], Young Keun On, MD[c], Kyoung-Min Park, MD[c,*]

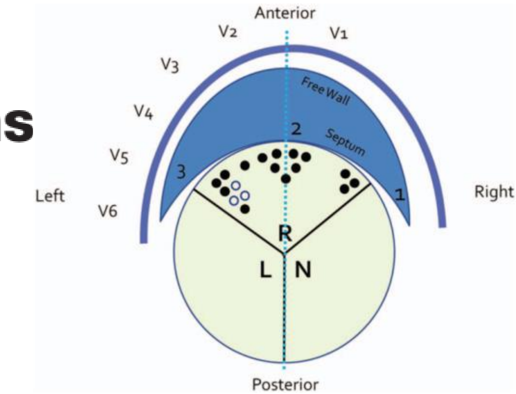
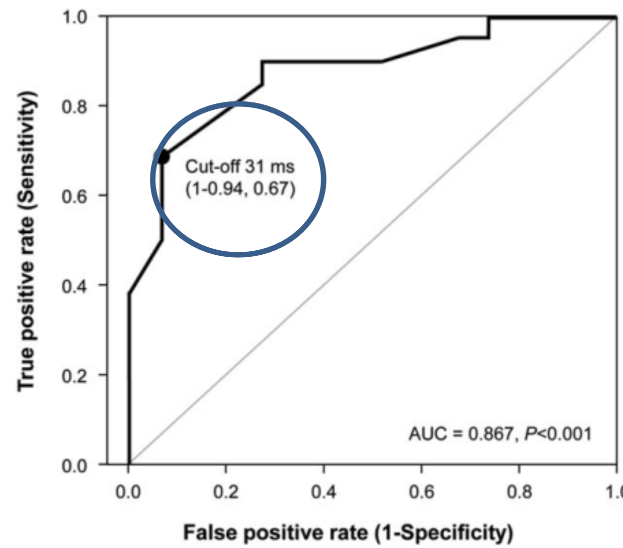


Table 2

ECG characteristics of PVCs, according to site of origin.

	RCC (n=18)	sRVOT-p (n=20)	sRVOT-a (n=8)	*P* value	*P* value
QRS axis (°)	20.6±33.9	22.6±32.6	22.6±32.6	.45	.91
PVC QRSd, ms	156±21	156±22	151±14	.57	.38
Precordial transition					
Sinus beat				.09	.03
V_1-V_2	6	2	4		
V_3	1	4	8		
V_4-V_6	11	2	8		
PVC				.11	.12
V_1-V_2	4	0	1		
V_3	11	4	9		
V_4-V_6	3	4	10		
BBB pattern				.28	.52
RBBB	3	0	1		
LBBB	15	8	19		
Positive lead I	18 (100)	15 (75)	2 (25)	<.001	.43
S amplitude in lead I (mV)	0.03±0.05	0.06±0.09	0.02±0.2	<.001	.35
R amplitude in lead II (mV)	1.7±0.9	1.7±0.8	1.9±0.7	.81	.99
R amplitude in lead III (mV)	1.3±0.8	1.3±0.4	1.8±0.5	.07	.95
R amplitude lead II/III ratio	1.4±0.8	1.4±0.9	1.1±0.4	.15	.84
S amplitude in aV_R (mV)	1.0±0.5	0.7±0.0	0.7±0.3	.04	.22
S amplitude in aV_L (mV)	0.4±0.3	0.5±0.2	0.9±0.4	.004	.91
S amplitude lead aV_R/aV_L ratio	2.0±1.5	1.7±0.6	1.6±0.6	.11	.61
V_{1-2} R-wave duration, ms	81.4±31.1	44.8±7.0	48.2±24.8	.001	.02
V_{1-2} RWDI (%)	51.3±22.0	31.2±7.5	30.6±15.4	.005	.06
RSWAI (%)	28±26	28±22	27±23	.89	.89
MDI	51±8	52±8	53±11	.82	.79
V_2 transition ratio	1.3±1.2	0.7±0.4	0.6±0.6	.09	.28



Conclusion

RCC is usually located opposite the septal RVOT. A predominantly positive QRS in lead I, longer R-wave duration and RWDI in lead V1 or V2 with local ventricular activation preceding QRS onset by average of -31 ms suggests effective RCC ablation site

Medicine (Baltimore). 2020 Mar;99(11):e19398.

Ablation Strategy

- Due to **frequent occurrence of high tip temperatures** limiting power delivery, typically **use irrigated catheters** ablating within **Aortic root or coronary veins**.

- There is **no accepted standard for power delivery** or **titration** within **Aortic root or coronary veins**; typically **start with 20 W and titrate to 40 W** for **60–120 seconds**.

- **Impedance changes during ablation** are somewhat inconsistent, and can often be dramatic when ablating within coronary veins.

- Previous study reported that when **early suppression of PVC** is noted at the onset of ablation there is very **low incidence of either acute or chronic recurrence**.

Heart Rhythm 2010;7:312–322.

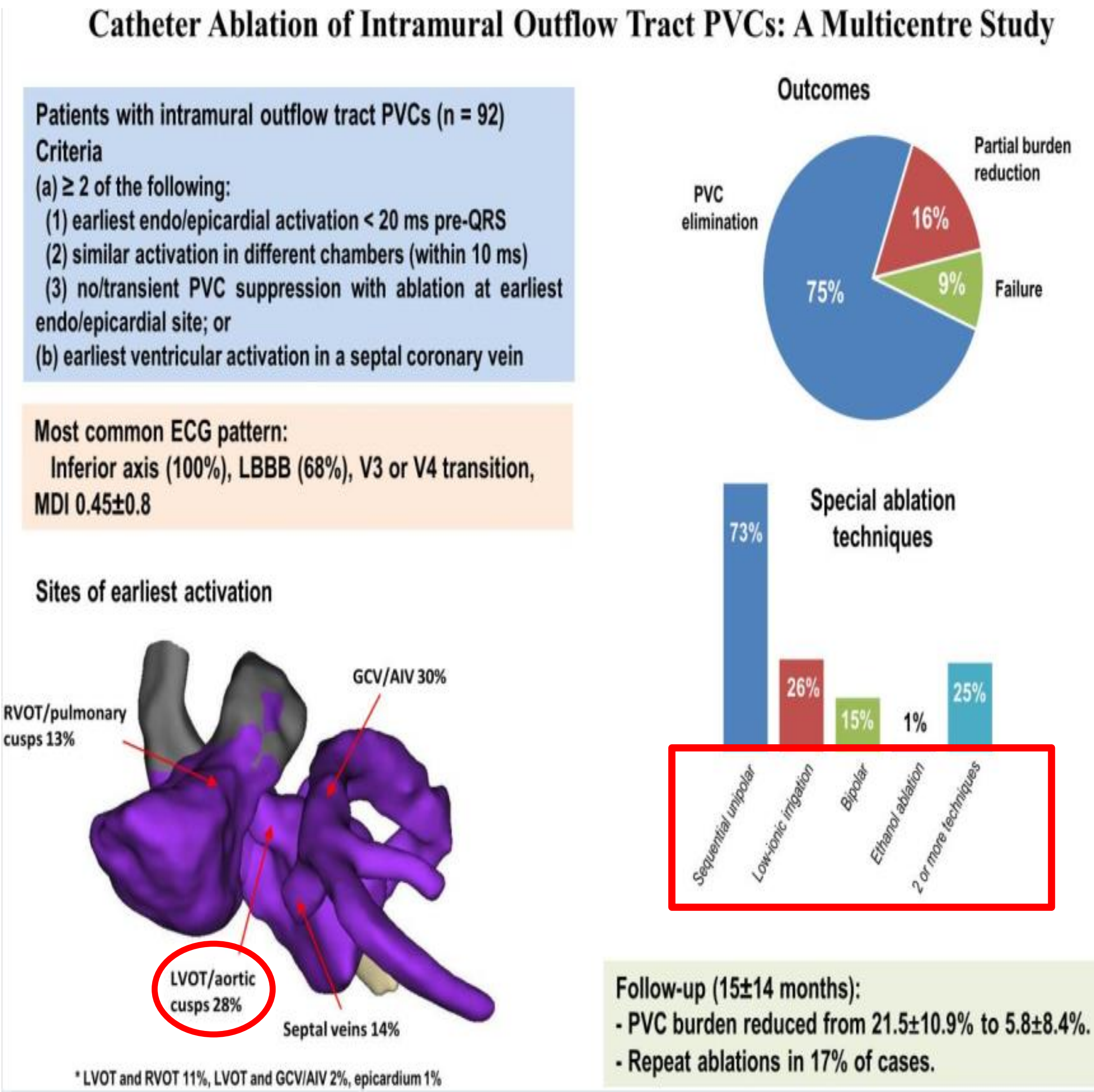
Ablation Strategy

- **Late suppression during RF is more commonly** seen with ablation of **LV ostial and LV summit PVCs**, and **signifies a site of origin remote** from the site of ablation (**most commonly seen** with **intramural foci**).

- If **PVC recurs after transient suppression from ablation**, it is **important to reexamine its 12-lead ECG morphology** to confirm that it is unchanged.

J Cardiovasc Electrophysiol. 2013 Oct;24(10):1189-97.

Catheter ablation of intramural outflow tract premature ventricular complexes: a multicentre study



Conclusion

- Ablation of intramural PVCs is challenging; acute arrhythmia elimination is achieved in 3/4 patients, and non-conventional approaches are often necessary for success

Europace. 2023 May 19;25(5):euad100.

Ablation Strategy

- **Failure to durably suppress PVC targeted within first site** should prompt the operator **to explore another site**.

→ **important to reconfirm site of origin**; this may **necessitate mapping adjacent structure**.

- Routinely **challenge** the patient with **beta agonists (e.g., isoproterenol) after successful PVC suppression can be helpful**, and recommend **standard waiting period of 60 minutes** after ablation

J Cardiovasc Electrophysiol. 2013 Oct;24(10):1189-97.

Bipolar Radiofrequency Catheter Ablation for Refractory Ventricular Outflow Tract Arrhythmias

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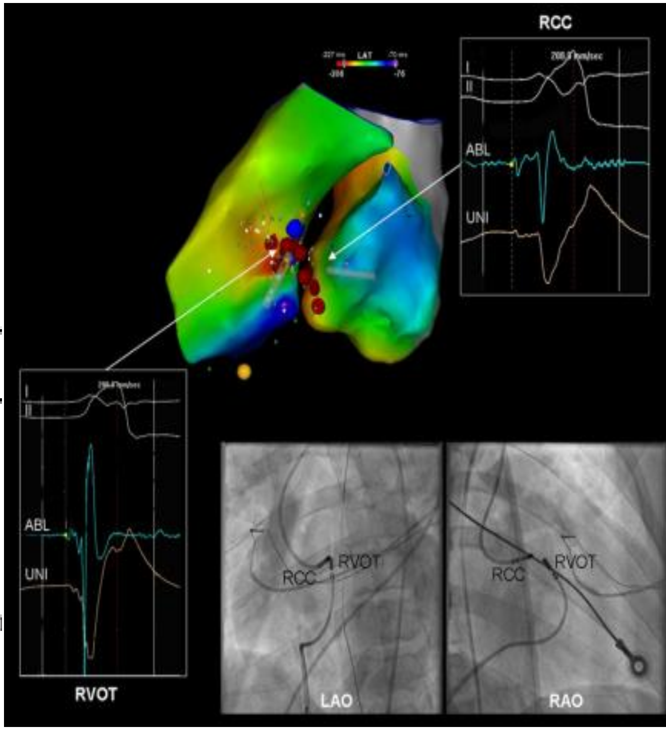
TABLE 3

Electrophysiology Study and Ablation Data

	#1	#2	#3	#4
RVOT—earliest (milliseconds)*	Septum: –35	Septum: –35	Septum: –20	Septum: –17
Aorta—earliest (milliseconds)*	LCC: –25	RCC: –40	RCC: –8	LCC: –12
RVOT RFA effect	Transient suppression	No effect	Transient suppression	No effect
Aorta RFA effect	Transient suppression	Transient suppression	No effect	No effect
Distance RVOT and aorta sites (mm)	15	10	20	8
Bipolar RFA effect	Rare PVCs	Termination	Termination	Transient suppression
Time to termination (seconds)	-	23	7	-



- Previous study reported that **bipolar ablation lesions are larger than unipolar lesions.** In this study, **bipolar RFA delivery was attempted to eliminate outflow tract PVCs after standard unipolar ablation failed**

- **This approach may improve outcomes** in patients where the use of standard **unipolar RF energy is unsuccessful** despite careful identification of the target site

J Cardiovasc Electrophysiol, 2014;1093-1099.

Novel utility of cryoablation for ventricular arrhythmias arising from the left aortic cusp near the left main coronary artery: A case series

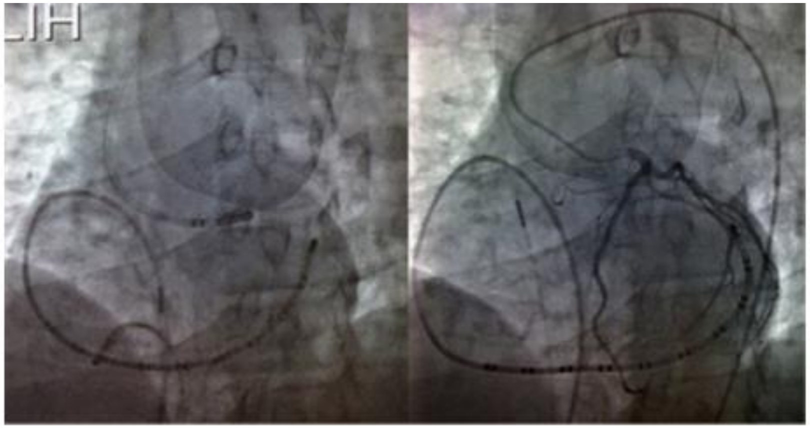
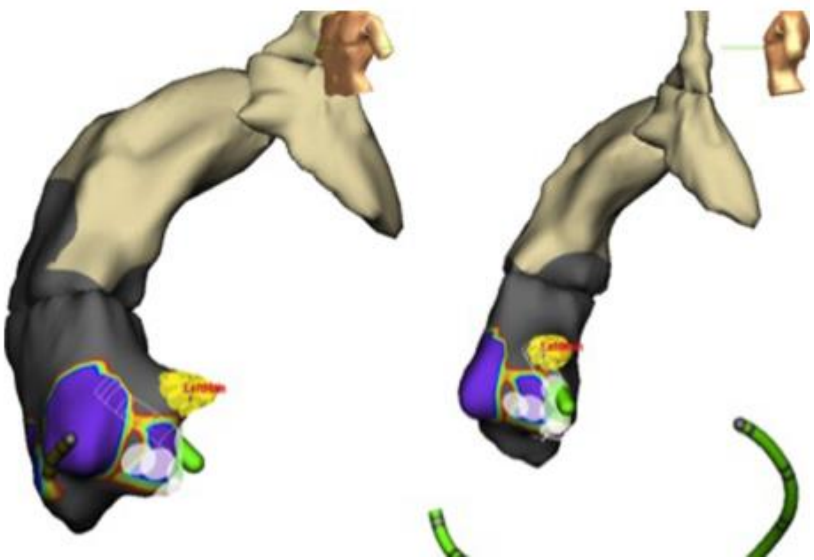


Figure 6 Coronary angiography demonstrating relationship of the ablation catheter to the left main coronary artery. The left panel shows the location of the ablation catheter in the aorta. The right panel shows angiography of the left main coronary artery.



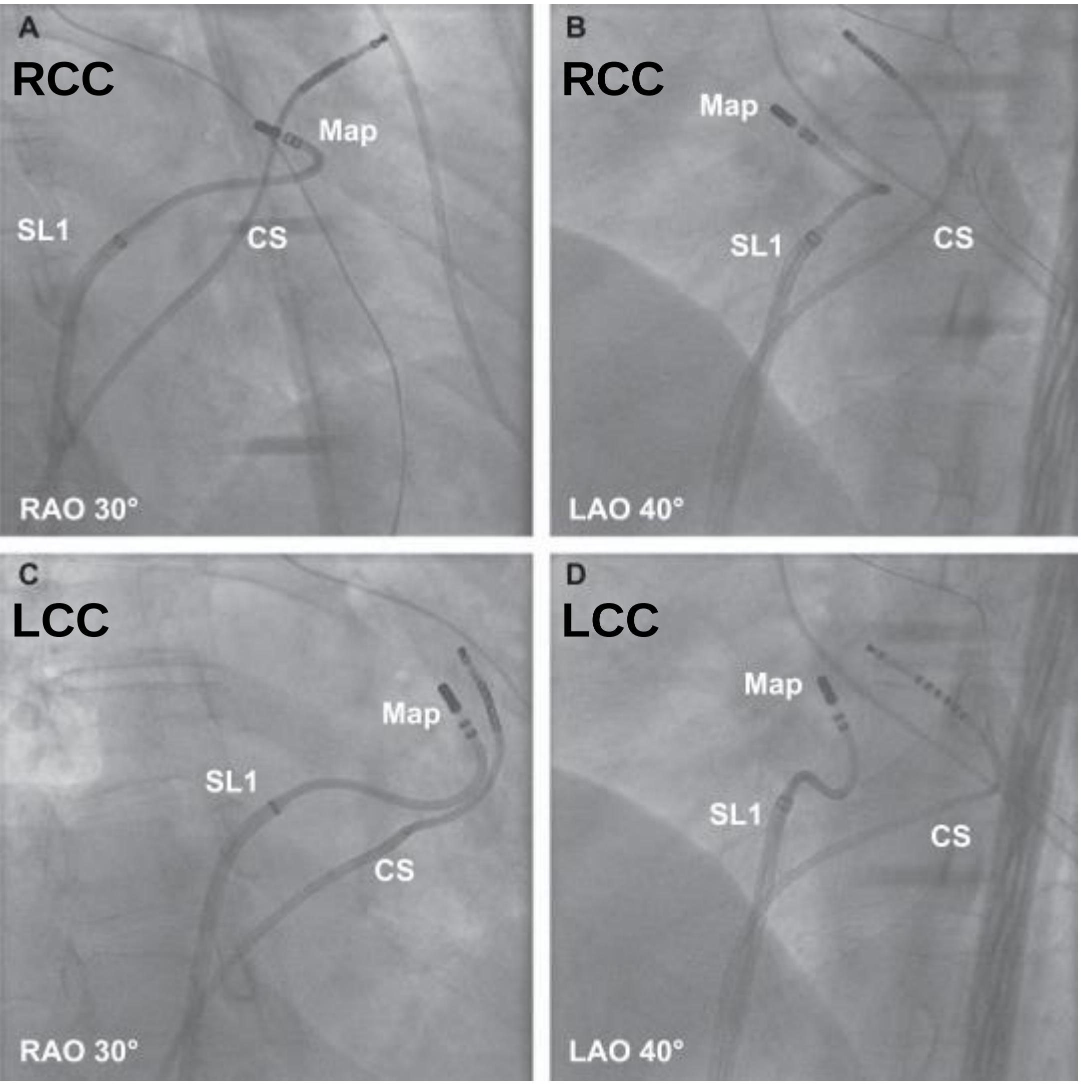
Conclusions

- Aortic root ventricular arrhythmia RF ablation carries an increased risk for collateral damages.
- Cautious **cryoablation near the ostia of the left main coronary artery can be performed and is a safe, effective alternative energy** source for ablation at the aortic root

Heart Rhythm 2014;11:34–38.

Ventricular Arrhythmias Arising From the Left Ventricular Outflow Tract Below the Aortic Sinus Cusps

Mapping and Catheter Ablation via Transseptal Approach and Electrocardiographic Characteristics



- **PVCs originating from the anterosuperior LVOT** represent a **challenging location for catheter ablation**.

Conclusions

- Anterosuperior LVOT can be reached **via a trans-septal approach with a reversed S curve** of the ablation catheter.

Circ Arrhythm Electrophysiol. 2014;7:445-455.

Predictors of long-term success after catheter ablation of premature ventricular complexes

TABLE 5 Univariate and multivariate Cox analyses for long-term success in PVC patients after RF ablation at 1-year follow-up

Variable N (%)	Univariate analysis OR (95% CI)	*p* value	Multivariate analysis OR (95% CI)	*p* value
Age (years)	0.976 (0.957–0.995)	.014		
Sex (female)	2.845 (1.583–5.112)	<.001	2.578 (1.171–5.675)	.019
DM (%)	0.378 (0.161–0.887)	.025		
Alcohol use (%)	0.474 (0.254–0.886)	.019		
Ablation time (minutes)	0.957 (0.927–0.988)	.007		
Successful site—RV(%) versus LV	1.804 (1.050–3.100)	.033		
Single PVC morphology (%)	4.384 (1.916–10.030)	<.001	6.201 (1.777–21.643)	.004
Earliest time pre-QRS of PVC—bipolar lead ≥24 ms	2.671 (1.443–4.944)	.002	2.760 (1.302–5.849)	.008

Conclusion

- Our findings suggest **additional mapping should be performed before ablation at sites** of local bipolar activation **<15 ms pre-QRS**.

J Cardiovasc Electrophysiol. 2021 Aug;32(8):2254-2261.

Summary

- Aortic cusps are common sites of origin for idiopathic PVCs, and their complex topography creates unique challenges for catheter mapping and ablation.

- However, the interpretation of the 12-lead ECG morphology of spontaneous PVCs using attitudinal anatomical relationships can provide valuable clues to the anticipated site of PVC origin, and thereby inform the most appropriate ablation strategy

Thank You for Your Attention!!