Ventricular Arrhythmias Linked to the Left Ventricular Summit Communicating Veins

A New Mapping Approach for an Old Ablation Problem

See Article by Komatsu et al

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The left ventricular summit (LVS) is the most superior portion of the epicardial LV outflow tract and is a common site of origin of idiopathic ventricular arrhythmias (VAs).[1,2] The LVS is anatomically bounded septally by the bifurcation between the left anterior descending and the left circumflex coronary arteries, and transected laterally by the great cardiac vein at the junction with the anterior interventricular vein.[3] A proper knowledge of the specific anatomic boundaries within the LVS has substantial clinical relevance with respect to the mapping and ablation approach. The junction between the great cardiac vein and the anterior interventricular vein separates the LVS into an accessible region, lateral to the venous junction and remote from the bifurcation of the left main coronary artery and the epicardial fat around the atrioventricular groove, and an inaccessible region septal to the venous junction and in close proximity to the proximal left coronary arteries and epicardial fat. Although VAs arising from the accessible LVS are rarely problematic and usually can be mapped and ablated from the distal coronary venous system or directly via a percutaneous pericardial approach,[2,4] VAs from the inaccessible region represent a major clinical challenge.

Direct epicardial mapping of the inaccessible LVS via a percutaneous epicardial access is limited mainly by the presence of a thick layer of epicardial fat which effectively insulates the underlying epicardium and prevents adequate electrogram recordings; in many cases catheter manipulation is challenging because of the anatomic proximity of the left atrial appendage. Furthermore, direct epicardial radiofrequency application to the inaccessible LVS is rarely possible because of the close proximity to the proximal left coronary system and, occasionally, to the left phrenic nerve. When ablation is possible it may be ineffective because of poor energy penetration through fat.[2,5]

To overcome these challenges, an ablation approach targeting sites anatomically adjacent to the inaccessible LVS has been proposed by several authors, with success rates ranging from 25% to ≈75%.[6–8] The choice of the optimal ablation site among different adjacent regions is usually based on a multiparametric assessment that takes into consideration activation mapping results (second best site), pacemapping data and the anatomic distance between the adjacent sites. When standard ablation approaches are not effective, alternative ablation strategies have been proposed including use of simultaneous unipolar radiofrequency ablation,[9] bipolar radiofrequency ablation,[10] alcohol arterial/venous ablation,[11] or surgical epicardial ablation with direct visualization of the coronary vessels and dissection of the epicardial fat.[5]

In this context, Komatsu et al[12] describe a new technique to obtain direct recordings from the inaccessible LVS via a 2F multipolar microcatheter introduced into the summit communicating veins (CV) which runs between the aortic and the

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Table. Summary of Studies Evaluating Catheter Ablation of Ventricular Arrhythmias Linked to the Distal Coronary Venous System

Study Reference No.	No. of Patients	Site of Earliest Activation Recorded (No. of Patients)	Earliest Activation Time (Pre-QRS), ms	Site of Ablation (No. of Patients)	Reasons for Not Performing Ablation at the Earliest Activation Site Within CVS (No. of Patients)	Acute Procedural Success, %	Complications (No. of Patients)	Follow-Up, mo	Long-Term Success (% of Patients With Acute Procedural Success)
Daniels et al[14]	12	GCV (2) AIV-GCV junction (3) Proximal AIV (4) MCV (3)	47±7	Inside CVS at earliest activation site (6) Percutaneous epicardial (6)	Inability to advance the ablation catheter to the site of earliest activation (6)	92%	Pericarditis with mild effusion related to percutaneous epicardial ablation (1)	NA	NA
Obel et al[15]	5	Distal GCV (5)	NA	Inside CVS at earliest activation site (5)	…	100%	None	Mean 25	100%
Baman et al[16]	27	Distal GCV (26) MCV (1)	29±8	Inside CVS at earliest activation site (20) Inside CVS proximal to the earliest activation site (5) Percutaneous epicardial (2)	Proximity to coronary arteries (1) Inability to advance the ablation catheter to the site of earliest activation (4) Inadequate power delivery (1) Proximity to phrenic nerve (1)	74%	None	Median 13	90%
Yamada et al[17]	14	Distal GCV/AIV (14)	37±10	Inside CVS at earliest activation site (9) Not performed (5)	Inability to advance the ablation catheter to the site of earliest activation/ inadequate power delivery (5)	64%	NA	12	64%
Yamada et al[1]	25	Distal GCV/AIV (25)	Median 32	Inside CVS at earliest activation site (20) Percutaneous epicardial (5)	Inability to advance the ablation catheter to the site of earliest activation (1) Inadequate power delivery (4) Failed ablation at the earliest activation site (1)	65%	None	Median 12	100%
Yokokawa et al[18]	33	Distal GCV/AIV (32) MCV (1)	30±6	Inside CVS at earliest activation site (10) Inside CVS proximal to the earliest activation site (4) Inside CVS proximal to the earliest activation site/ LV endocardium/ aortic cusps region (8) LV endocardium / aortic cusps region (4) Percutaneous epicardial (4) Not performed (3)	Inability to advance the ablation catheter to the site of earliest activation (5) Proximity to coronary arteries/ phrenic nerve (3) Inadequate power delivery (3)	67%	None	12 to 48	91%
Jauregui Abularach et al[6]	16	Distal GCV/AIV	12 to 75	Left sinus of Valsalva (5) Adjacent LV endocardium (2) Both of the above (2)	Inability to advance the ablation catheter to the site of earliest activation/proximity to coronary arteries/ inadequate power delivery	56%	Pericardial effusion (1) Narrowing of obtuse marginal coronary artery branch (1)	NA	NA

(*Continued*)

Table. Continued

Study Reference No.	No. of Patients	Site of Earliest Activation Recorded (No. of Patients)	Earliest Activation Time (Pre-QRS), ms	Site of Ablation (No. of Patients)	Reasons for Not Performing Ablation at the Earliest Activation Site Within CVS (No. of Patients)	Acute Procedural Success, %	Complications (No. of Patients)	Follow-Up, mo	Long-Term Success (% of Patients With Acute Procedural Success)
Steven et al[19]	14	Distal GCV	39±9	Inside CVS at earliest activation site (7)	Proximity to coronary arteries (6) Inadequate power delivery (1)	43%	NA	NA	83%
Li et al[20]	12	Distal GCV (4) Extended tributary of GCV distal to the origin of AIV (3) Proximal AIV (5)	37±3	Inside CVS at earliest activation site (12)	…	100%	None	Median 17	83%
Frankel et al[21]	2	AIV	25	Septal RVOT (2)	Close proximity to coronary arteries (2)	100%	None	Median 24	100%
Li et al[22]	30	Distal GCV (anterior-lateral mitral annulus) (8) Distal GCV (AIV opening proximal end) (6) Extended tributary of GCV distal to the origin of AIV (6) Proximal AIV (10)	36±6	Inside CVS at earliest activation site (30)	…	100%	NA	18±13	93%
Nagashima et al[23]	30	GCV (30)	37±8	Inside CVS at earliest activation site (15) Adjacent sites outside CVS (19) Percutaneous epicardial (2) Open chest surgical ablation (3)	Proximity to coronary arteries (14) Inability to advance the ablation catheter to the site of earliest activation (3) Failed ablation at the earliest activation site (7)	53%	Coronary artery occlusion requiring stenting of A marginal branch of the circumflex artery (2) GCV perforation (1)	Median 3	100%
Mountantonakis et al[4]	47	Distal GCV (25) AIV (19) MCV (3)	39±18	Inside CVS at earliest activation site (18) Inside CVS proximal to the earliest activation site (14) Adjacent sites outside CVS (15)	Proximity to coronary arteries (21) Inability to advance the ablation catheter to the site of earliest activation (4) Inadequate power delivery (2) Operator choice (2)	94% with ablation at the earliest CVS site 55% with ablation at adjacent CVS or non-CVS sites	Femoral artery Pseudoaneurysm (1) Pericardial effusion due to CS perforation (1) Stenosis of the proximal circumflex coronary artery (1)	31±21	76%
Santangeli et al[2]	23	Epicardial LVS (21) AIV (2)	31±10	Percutaneous epicardial (14)	Close proximity to coronary arteries (9)	22%	Pericardial effusion because of perforation of the GCV (1)	Median 36	60%
Yamada et al[9]	24	Distal GCV	<−20 (22) >−20 (2)	Inside CVS at earliest activation site (24) AMC (9) Simultaneous unipolar RF ablation from AMC and GCV (3)	Failed ablation at the earliest activation site (9)	100%	None	6	100%
Lin et al[24]	16	GCV/AIV	30±16 ms	Inside CVS at earliest activation site (16)	…	100%	None	Median 16	88%

(*Continued*)

Table. Continued

Study Reference No.	No. of Patients	Site of Earliest Activation Recorded (No. of Patients)	Earliest Activation Time (Pre-QRS), ms	Site of Ablation (No. of Patients)	Reasons for Not Performing Ablation at the Earliest Activation Site Within CVS (No. of Patients)	Acute Procedural Success, %	Complications (No. of Patients)	Follow-Up, mo	Long-Term Success (% of Patients With Acute Procedural Success)
Yamada et al[7]	23	GCV (16) Communicating branch of the GCV (7)	<−20	Inside CVS at earliest activation site (23) Inside CVS proximal to the earliest activation site (1) AMC (1) LCC (1)	Inadequate power delivery (1) Failed ablation at the earliest activation site (2)	100%	None	Median 55	100%
Yamada et al[25]	40	Distal GCV	<−20 (38) >−20 (2)	Inside CVS at earliest activation site (40) AMC (12) Simultaneous unipolar RF ablation from AMC and GCV (3)	Failed ablation at the earliest activation site (12)	100%	None	Median 51	NA

AIV indicates anterior interventricular vein; AMC, aorto-mitral continuity; CS, coronary sinus; CVS, coronary venous system; GCV, great cardiac vein; LCC, left coronary cusp; MCV, middle cardiac vein; NA, not available; RF, radiofrequency; and RVOT, right ventricular outflow tract.

pulmonary annulus. The study comes from a very experienced group of investigators, and describes a novel mapping technique which will have important clinical implications for mapping and ablation of LVS-VAs. Owing to the specific design of the mapping catheters used in this study, the authors were able to obtain a detailed definition of the anatomy of the distal coronary sinus. In particular, a 6F decapolar catheter equipped with an inner lumen was positioned within the distal coronary sinus and contrast was injected through the catheter to delineate the takeoff of the summit-CV and allow advancement of a 2F microcatheter via the lumen of the decapolar catheter. Notably, the summit-CV could be identified and mapped in all patients: in this respect, it is unclear how much supplemental effort in terms of both procedural and fluoroscopy time was required to instrument the summit-CV and in how easy it was to conclusively distinguish the summit-CV from other branches of the distal great cardiac vein/anterior interventricular vein.

Out of a total of 31 consecutive patients with idiopathic outflow tract VAs who underwent LVS mapping with the 2F microcatheter, the summit-CV was identified as the site of origin of the VA in 14 (45%) cases. This was based on detailed activation mapping which included interrogation of the endocardial outflow tracts, coronary cusps, and distal coronary venous system coupled with best pacemap (≥11/12 leads). The apparently high prevalence of summit-CV reported in this study very likely reflects selection bias, as also pointed out by the authors[12]; in fact, the study population was extracted from a larger group of 229 patients undergoing catheter ablation of idiopathic VAs at the same institution, and the decision to map the summit-CV was discretional. The ECG characteristics of summit-CV arrhythmias reflected the origin from the posterior and septal aspect of the LVS, with a nonspecific R/S pattern in lead V_1 without pattern break in V_1 through V_3—which instead would have pointed to the anteroseptal LVS close to the anterior interventricular groove[13]—and a slightly deeper Q wave amplitude in aVL compared with aVr suggesting origin slightly leftward to the torso midline. Notably, in none of the summit-CV cases it was possible to target the arrhythmia with direct ablation at the site of earliest activation mainly because the vein was too small to accommodate a mapping/ablation catheter, and an anatomic approach with application of radiofrequency energy at anatomically adjacent sites was used instead. The inability to directly ablate the earliest site within the LVS is a recurrent theme and, in our view, it remains the biggest challenge when tackling these arrhythmias, as also documented in prior reports (Table).

Acute success with complete elimination of the VAs was observed only in 8 (57%) cases. As expected, the anatomically adjacent sites where ablation was attempted were characterized by worse activation times and pacemaps,[8] although the successful cases had a shorter activation interval between the summit-CV and the selected adjacent site, and likely represented the second best site identified at activation mapping. As such, similar outcomes may have been obtained by a more pragmatic and less elegant ablation approach targeting the earliest site reachable with a standard ablation catheter, even without direct mapping of the site of origin within the summit-CV.

Interestingly, there appeared to be no other clinical, ECG or procedural features associated with higher likelihood of successful ablation from an adjacent site. In this regard, it would have been of value to report information on the time to VA suppression as well as the regional wall thickness between the summit-CV and the adjacent site selected for ablation. The latter could be indexed as distance between the mapping catheter at the summit-CV and the ablation site on the 3-dimensional mapping system and may have provided important clues on why some patients responded better to ablation from an adjacent vantage point, as prior studies have suggested that there may be a critical distance below which an anatomically-based ablation approach for LVS arrhythmias is more likely to be successful.[6]

In conclusion, Komatsu et al[12] should be congratulated for describing a new approach that helps determine the true site of origin of VAs within a region of the LVS that is otherwise inaccessible for mapping with a standard ablation catheter. The results of this study support the need for detailed mapping the summit-CV when tackling VAs from the inaccessible LVS. Further research should be focused on better ablation tools and approaches to enhance success from anatomically adjacent sites.

DISCLOSURES

None.

AFFILIATION

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FOOTNOTES

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REFERENCES

1. Yamada T, McElderry HT, Doppalapudi H, Okada T, Murakami Y, Yoshida Y, Yoshida N, Inden Y, Murohara T, Plumb VJ, Kay GN. Idiopathic ventricular arrhythmias originating from the left ventricular summit: anatomic concepts relevant to ablation. *Circ Arrhythm Electrophysiol*. 2010;3:616–623. doi: 10.1161/CIRCEP.110.939744.
2. Santangeli P, Marchlinski FE, Zado ES, Benhayon D, Hutchinson MD, Lin D, Frankel DS, Riley MP, Supple GE, Garcia FC, Bala R, Desjardins B, Callans DJ, Dixit S. Percutaneous epicardial ablation of ventricular arrhythmias arising from the left ventricular summit: outcomes and electrocardiogram correlates of success. *Circ Arrhythm Electrophysiol*. 2015;8:337–343. doi: 10.1161/CIRCEP.114.002377.
3. McAlpine WA. *Heart and Coronary Arteries*. New York, NY: Springer-Verlag; 1975.
4. Mountantonakis SE, Frankel DS, Tschabrunn CM, Hutchinson MD, Riley MP, Lin D, Bala R, Garcia FC, Dixit S, Callans DJ, Zado ES, Marchlinski FE. Ventricular arrhythmias from the coronary venous system: prevalence, mapping, and ablation. *Heart Rhythm*. 2015;12:1145–1153. doi: 10.1016/j.hrthm.2015.03.009.
5. Aziz Z, Moss JD, Jabbarzadeh M, Hellstrom J, Balkhy H, Tung R. Totally endoscopic robotic epicardial ablation of refractory left ventricular summit arrhythmia: first-in-man. *Heart Rhythm*. 2017;14:135–138. doi: 10.1016/j.hrthm.2016.09.005.
6. Jauregui Abularach ME, Campos B, Park KM, Tschabrunn CM, Frankel DS, Park RE, Gerstenfeld EP, Mountantonakis SE, Mountantonakis S, Garcia FC, Dixit S, Tzou WS, Hutchinson MD, Lin D, Riley MP, Cooper JM, Bala R, Callans DJ, Marchlinski FE. Ablation of ventricular arrhythmias arising near the anterior epicardial veins from the left sinus of Valsalva region: ECG features, anatomic distance, and outcome. *Heart Rhythm*. 2012;9:865–873. doi: 10.1016/j.hrthm.2012.01.022.
7. Yamada T, Doppalapudi H, Litovsky SH, McElderry HT, Kay GN. Challenging radiofrequency catheter ablation of idiopathic ventricular arrhythmias originating from the left ventricular summit near the left main coronary artery. *Circ Arrhythm Electrophysiol*. 2016;9.
8. Yamada T, Yoshida N, Doppalapudi H, Litovsky SH, McElderry HT, Kay GN. Efficacy of an anatomical approach in radiofrequency catheter ablation of idiopathic ventricular arrhythmias originating from the left ventricular outflow tract. *Circ Arrhythm Electrophysiol*. 2017;10:e004959. doi: 10.1161/CIRCEP.116.004959.
9. Yamada T, Maddox WR, McElderry HT, Doppalapudi H, Plumb VJ, Kay GN. Radiofrequency catheter ablation of idiopathic ventricular arrhythmias originating from intramural foci in the left ventricular outflow tract: efficacy of sequential versus simultaneous unipolar catheter ablation. *Circ Arrhythm Electrophysiol*. 2015;8:344–352. doi: 10.1161/CIRCEP.114.002259.
10. Teh AW, Reddy VY, Koruth JS, Miller MA, Choudry S, D'Avila A, Dukkipati SR. Bipolar radiofrequency catheter ablation for refractory ventricular outflow tract arrhythmias. *J Cardiovasc Electrophysiol*. 2014;25:1093–1099. doi: 10.1111/jce.12460.
11. Kreidieh B, Rodriguez-Manero M, Schurmann P, Ibarra-Cortez SH, Dave AS, Valderrabano M. Retrograde coronary venous ethanol infusion for ablation of refractory ventricular tachycardia. *Circ Arrhythm Electrophysiol*. 2016;9.
12. Komatsu Y, Nogami A, Shinoda Y, Masuda K, Machino T, Kuroki K, Yamasaki H, Sekiguchi Y, Aonuma K. Idiopathic ventricular arrhythmias originating from the vicinity of the communicating vein of cardiac venous systems at the left ventricular summit. *Circ Arrhythm Electrophysiol*. 2018;11:e005386. doi: 10.1161/CIRCEP.117.005386.
13. Hayashi T, Santangeli P, Pathak RK, Muser D, Liang JJ, Castro SA, Garcia FC, Hutchinson MD, Supple GE, Frankel DS, Riley MP, Lin D, Schaller RD, Dixit S, Callans DJ, Zado ES, Marchlinski FE. Outcomes of catheter ablation of idiopathic outflow tract ventricular arrhythmias with an R wave pattern break in lead V2: a distinct clinical entity. *J Cardiovasc Electrophysiol*. 2017;28:504–514. doi: 10.1111/jce.13183.
14. Daniels DV, Lu YY, Morton JB, Santucci PA, Akar JG, Green A, Wilber DJ. Idiopathic epicardial left ventricular tachycardia originating remote from the sinus of Valsalva: electrophysiological characteristics, catheter ablation, and identification from the 12-lead electrocardiogram. *Circulation*. 2006;113:1659–1666. doi: 10.1161/CIRCULATIONAHA.105.611640.
15. Obel OA, d'Avila A, Neuzil P, Saad EB, Ruskin JN, Reddy VY. Ablation of left ventricular epicardial outflow tract tachycardia from the distal great cardiac vein. *J Am Coll Cardiol*. 2006;48:1813–1817. doi: 10.1016/j.jacc.2006.06.006.
16. Baman TS, Ilg KJ, Gupta SK, Good E, Chugh A, Jongnarangsin K, Pelosi F Jr, Ebinger M, Crawford T, Oral H, Morady F, Bogun F. Mapping and ablation of epicardial idiopathic ventricular arrhythmias from within the coronary venous system. *Circ Arrhythm Electrophysiol*. 2010;3:274–279. doi: 10.1161/CIRCEP.109.910802.
17. Yamada T, McElderry HT, Okada T, Murakami Y, Doppalapudi H, Yoshida N, Yoshida Y, Inden Y, Murohara T, Epstein AE, Plumb VJ, Kay GN. Idiopathic left ventricular arrhythmias originating adjacent to the left aortic sinus of Valsalva: electrophysiological rationale for the surface electrocardiogram. *J Cardiovasc Electrophysiol*. 2010;21:170–176. doi: 10.1111/j.1540-8167.2009.01608.x.
18. Yokokawa M, Latchamsetty R, Good E, Chugh A, Pelosi F Jr, Crawford T, Jongnarangsin K, Oral H, Morady F, Bogun F. Ablation of epicardial ventricular arrhythmias from nonepicardial sites. *Heart Rhythm*. 2011;8:1525–1529. doi: 10.1016/j.hrthm.2011.06.020.
19. Steven D, Pott C, Bittner A, Sultan A, Wasmer K, Hoffmann BA, Köbe J, Drewitz I, Milberg P, Lueker J, Mönnig G, Servatius H, Willems S, Eckardt L. Idiopathic ventricular outflow tract arrhythmias from the great cardiac vein: challenges and risks of catheter ablation. *Int J Cardiol*. 2013;169:366–370. doi: 10.1016/j.ijcard.2013.09.008.

20. Li YC, Lin JF, Li J, Ji KT, Lin JX. Catheter ablation of idiopathic ventricular arrhythmias originating from left ventricular epicardium adjacent to the transitional area from the great cardiac vein to the anterior interventricular vein. *Int J Cardiol*. 2013;167:2673–2681. doi: 10.1016/j.ijcard.2012.06.119.
21. Frankel DS, Mountantonakis SE, Dahu MI, Marchlinski FE. Elimination of ventricular arrhythmias originating from the anterior interventricular vein with ablation in the right ventricular outflow tract. *Circ Arrhythm Electrophysiol*. 2014;7:984–985. doi: 10.1161/CIRCEP.114.001456.
22. Li JW, Chen XL, Li YC, Chen XX, Chen XS, Lin JF. Distinct ECG characteristics of idiopathic ventricular arrhythmias originating from four regions of left coronary veins. *Int J Cardiol*. 2014;175:181–182. doi: 10.1016/j.ijcard.2014.04.197.
23. Nagashima K, Choi EK, Lin KY, Kumar S, Tedrow UB, Koplan BA, Michaud GF, John RM, Epstein LM, Tokuda M, Inada K, Couper GS, Stevenson WG. Ventricular arrhythmias near the distal great cardiac vein: challenging arrhythmia for ablation. *Circ Arrhythm Electrophysiol*. 2014;7:906–912. doi: 10.1161/CIRCEP.114.001615.
24. Lin CY, Chung FP, Lin YJ, Chong E, Chang SL, Lo LW, Hu YF, Tuan TC, Chao TF, Liao JN, Chang YT, Chen YY, Chen CK, Chiou CW, Chen SA, Tsao HM. Radiofrequency catheter ablation of ventricular arrhythmias originating from the continuum between the aortic sinus of Valsalva and the left ventricular summit: electrocardiographic characteristics and correlative anatomy. *Heart Rhythm*. 2016;13:111–121. doi: 10.1016/j.hrthm.2015.08.030.
25. Yamada T, Doppalapudi H, Maddox WR, McElderry HT, Plumb VJ, Kay GN. Prevalence and electrocardiographic and electrophysiological characteristics of idiopathic ventricular arrhythmias originating from intramural foci in the left ventricular outflow tract. *Circ Arrhythm Electrophysiol*. 2016;9:e004079.

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