

Alcohol Ablation for Ventricular Tachycardia

Adi Lador, MD; Akanibo Da-Wariboko, MD; Liliana Tavares, MD; Miguel Valderrábano, MD

HOUSTON METHODIST DEBAKEY HEART & VASCULAR CENTER, HOUSTON METHODIST HOSPITAL, HOUSTON, TEXAS

ABSTRACT: Catheter-based radiofrequency (RF) ablation is an effective, well-established therapy for ventricular tachycardia (VT). However, a large number of patients still have recurrences, particularly those with substrates arising from intramural locations that are inaccessible through endo- or epicardial catheter approaches. Several unconventional ablation techniques have been proposed to treat RF-refractory VT, including transarterial coronary ethanol ablation and retrograde coronary venous ethanol ablation. We review the evidence regarding the mechanisms, procedural aspects, and alcohol ablation outcomes for ventricular arrhythmias.

INTRODUCTION

Catheter-based radiofrequency (RF) ablation is a well-established, guideline-recommended therapy for ventricular tachycardia (VT).^{1,2} However, it is not universally effective, especially in patients with substrates arising from intramural locations that are not accessible by conventional catheter-based endo- or epicardial approaches.^{3,4} Even when a catheter can reach an intramural substrate via an epicardial approach, there are other impediments to RF ablation, such as proximity to coronary vessels and possible collateral or phrenic nerve damage.^{5,6} This is particularly true for VT that originates from the left ventricular summit (LVS).⁵ The LVS lies underneath the left main coronary artery bifurcation, in the most superior and septal region of the LV outflow tract, and its boundaries are the left anterior descending artery, left circumflex coronary artery, and great cardiac vein (GCV). Radiofrequency ablation of the LVS is especially challenging given the difficulty reaching this region by either trans-septal, retroaortic, or epicardial approaches.^{3,4} For RF-refractory VT, numerous unconventional ablation approaches have been described, including simultaneous unipolar right ventricular (RV) ablation,⁷ bipolar RF ablation,⁸ needle ablation,⁹ and ethanol ablation. Transarterial coronary ethanol ablation (TCEA) and retrograde coronary venous ethanol ablation (RCVEA) are two alternative treatment options for ventricular arrhythmias (VAs) arising from intramural substrates that cannot be targeted.^{5,10,11} Branches of the coronary arteries and coronary veins offer a unique opportunity to reach intramural substrates and effectively deliver ethanol to areas that are not accessible to conventional RF catheter ablation. High concentrations of ethanol solubilize the cell membranes and cause immediate cell destruction.¹²

TRANSARTERIAL ETHANOL FOR VENTRICULAR TACHYCARDIA

The first transcortical arterial ethanol injection for VT was described in 1987 by Inoue et al.¹³ The team induced focal

VT in dogs via intramyocardial injection of aconitine and then suppressed it by injecting phenol or ethanol (at least 50% concentration) into the artery supplying the aconitine-injected myocardial tissue. Myocardial necrosis and arterial thrombus formation were associated with successful VT elimination, although it was not achieved with lower (25%) ethanol concentrations.

Brugada et al. reported cases of 3 patients with incessant post-myocardial-infarction (MI) VAs in which transcortical chemoablation in a target arrhythmogenic artery prevented further episodes of VT.^{10,14} Following this case series, additional case and series reports of the use of TCEA have been published.¹⁵⁻¹⁷

Successful TCEA depends on both the presence of an arterial branch that supplies blood to arrhythmogenic ventricular tissue and the feasibility of selective cannulation with an angioplasty balloon. Identifying at least one blood supply to the previous infarction area is possible in most but not all patients with late-occurring sustained VT after MI.¹⁸ Collateral circulation to the targeted arrhythmogenic myocardial territory may affect the efficacy of the ablation. After ethanol ablation, reported rates of VT noninducibility ranged from 56% to 84%, with 64% of later any-VT recurrence.¹⁹⁻²¹ Approximately 14% of patients are unsuitable to receive TCEA.¹⁶ Reasons for unsuitability are failure to identify proper coronary artery targets and multiple collateral vessels that are concerning for collateral damage.¹⁶

Reported complications include reentrant VT because ethanol ablation produces an incomplete lesion, leaving surviving myocardial cells to create reentry circuits.²² Other described complications include complete atrioventricular block when targeting basal septal VA substrate, nontarget coronary vessel occlusion, contrast nephropathy, systemic embolization, coronary vasospasm, arterial perforation,¹⁶ myocardial dissection,²³ and potential damage outside the targeted area by unintended ethanol reflux into nontargeted arterial branches.²⁴

Although not consistently effective, TCEA remains a feasible alternative for those who were unsuccessful with previous RF ablation attempts. To that effect, case reports continue to be published on the bail-out technique of ethanol ablation for RF ablation refractory VT.²⁵⁻²⁷

RETROGRADE CORONARY VENOUS ETHANOL ABLATION FOR VENTRICULAR TACHYCARDIA

A priori, retrograde coronary venous ethanol ablation (RCVEA) for VT is advantageous compared with transarterial coronary ethanol ablation. First, it reduces the risk of collateral myocardial damage since the backflow of ethanol is diluted by retrograde flow into the coronary sinus, rendering it harmless. Second, it does not require the same technical expertise and equipment other than those used in cardiac resynchronization. And third, it avoids complications related to arterial vessel cannulation. The approach was first reported in animal studies.^{13,28}

PROCEDURAL APPROACH FOR RETROGRADE CORONARY VENOUS ETHANOL ABLATION

The initial procedural approach for RCVEA is similar to RF catheter ablation. The patient, under conscious sedation, undergoes endocardial 3-dimensional (3D) mapping with a conventional mapping system (eg, CARTO® from Biosense Webster, or EnSite NavX™ from St Jude Medical) to identify the PVC or VT site of origin. For focal LVS VAs, initial mapping also includes endocardial mapping of the left and right ventricular outflow tracts using a retrograde approach. Either activation or pace-map correlation mapping methods can be used. After identifying the VT's endocardial earliest activation site, the coronary sinus (CS) is cannulated. We usually advance a long 8F sheath through the right femoral vein into the CS. Then we insert a multipolar catheter (DECANAV®, Biosense Webster) in the CS for 3D local activation time or pace-map correlation maps. New smaller multipolar catheters (2F EPstar, Baylis

Medical, and 3F duodecapolar Map-iT™, APT EP) can penetrate smaller CS tributaries and also be used to map.

After delineating the earliest site in the GCV and anterior interventricular vein (AIV), we perform coronary venograms to locate suitable target branches close to that site. Finding the best fluoroscopic projection for visualization is essential and also highly variable. The use of balloon occlusion venograms is ideal although not mandatory, and it has to be used with care since dissection of the GCV is possible. Next, angioplasty guidewire (Balance Middleweight 0.014 inches, Abbott) is advanced into the vein with the help of a left internal mammary artery or JR4 angioplasty guide catheter (Boston Scientific) to add stability and torquability. The wire can be used for unipolar

mapping, pacing, and selective cannulation of the targeted branches. Any electrically conductive wire can be used, including a targeted designed wire with an active distal electrode (VisionWire, Biotronik).¹²

As a reference electrode, we can use: (1) a needle in the skin at the groin, (2) the Wilson central terminal, or (3) an electrode at the inferior vena cava. Appropriate pace maps and unipolar signals help to verify the targeted vein's candidacy for ethanol ablation. Then, a preloaded angioplasty balloon (typically 6x2 mm) is advanced, leaving the wire's most distal portion (approximately 3 mm) exposed; this is configured as a unipolar electrode connected with an alligator clip to the input of the recording amplifier.²⁹ A Finecross® microguide catheter (Terumo) can be used instead of the angioplasty

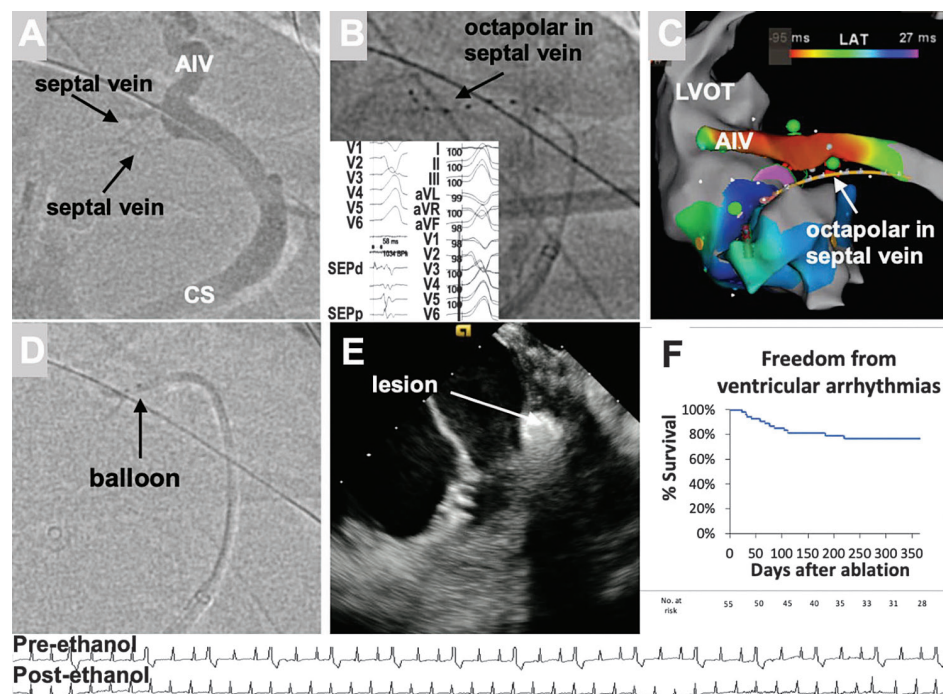


Figure 1.

Venous mapping and ethanol ablation technique. (A) Coronary sinus venogram (left anterior oblique caudal projection) showing two septal branches at the take-off of the anterior interventricular vein (AIV). (B) Octapolar catheter in the first septal vein. Intramural vein signals precede QRS by 58 ms, and pace-mapping reproduces exact QRS morphology (inset). (C) 3-dimensional activation map shows early (red) signals in the AIV and the location of the octapolar catheter. (D) Balloon cannulation of the septal vein. (E) Intramural echogenicity after venous ethanol, which leads to elimination of ectopy (bottom). (F) Kaplan-Meier plot of ablation success over 1-year follow-up in 55 patients with previous failed radiofrequency ablations. CS: coronary sinus; LVOT: left ventricle outflow tract

balloon if the targeted branch is tortuous. Once the signals from the wire in the cannulated vein support adequacy, the wire is removed, the angioplasty balloon is inflated, and contrast is injected in the targeted venule to determine the size and extent of myocardial staining (indicating that the tissue has been reached).

No therapeutic effect is expected if the injected vein has collateral vessels back to the CS, circumventing the myocardium, or if targeted signals are only present proximally to the injected large vein. Typically, we start with 1 cc of 96% to 98% ethanol infused over 2 minutes. Then contrast is injected to

verify myocardial staining. The angioplasty balloon stays inflated until a therapeutic response is detected. Since leaked ethanol is diluted by CS flow in the right atrium, a complete seal is not required. Up to four 1-cc doses of ethanol, each injected over 2 minutes, are needed for a full therapeutic effect since myocardial tissue accessed by retrograde venous ethanol may be compromised by competing antegrade arterial flow.¹² The VT recurrences noted in our first experience have been reduced by repeat injections.¹¹ An area of increased echogenicity in intracardiac echocardiograms and myocardial staining indicates ethanol tissue ablation.

As with collateral vein–ethanol shunting or no intramural veins at the targeted site, unfavorable venous anatomy reduces the efficacy of this technique. Using a “double-balloon technique” that blocks collateral flow with a second balloon can enhance ethanol delivery to target isolated vein segments or target extensive areas and broaden the utility of venous ethanol for VA treatment.³⁰ Figure 1 shows an example of venous mapping and ethanol ablation.

For VT substrates that do not originate from the left ventricular summit, we explore potential veins in the area of the substrate after conventional endocardial mapping and RF ablation. Signals from the CS, GCV, AIV, or lateral veins are collected, and appropriate veins can be targeted. Figure 2 is an example of mapping and ethanol ablation of an infarct-related vein in a patient with nonischemic cardiomyopathy.¹²

OUTCOMES

Our group reported the initial feasibility, efficacy, and safety of retrograde venous ethanol infusion in two small case series.^{5,11} Multiple groups have reproduced the technique in patients with LVS VAs.^{31–34} We recently published a report on the technical aspects of RCVEA, presented our approach for LVS substrates, and expanded the use of RCVEA to non-LVS VT substrates.^{12,34} As opposed to LVS substrates, non-LVS VTs are usually complex scar-related VTs in the context of structural cardiomyopathy.

A multicenter international registry of long-term efficacy and other outcomes of RCVEA for refractory VAs was recently completed; the majority of the 56 described cases had VT originating from the LVS (76%) while the remaining were from a non-LVS origin (24%). Overall, RCVEA was acutely successful in 55 out of 56 patients (98%). After 1-year follow-up, 77% of patients had no recurrent arrhythmias, and there were only two venous dissections leading to pericardial effusions.³⁵

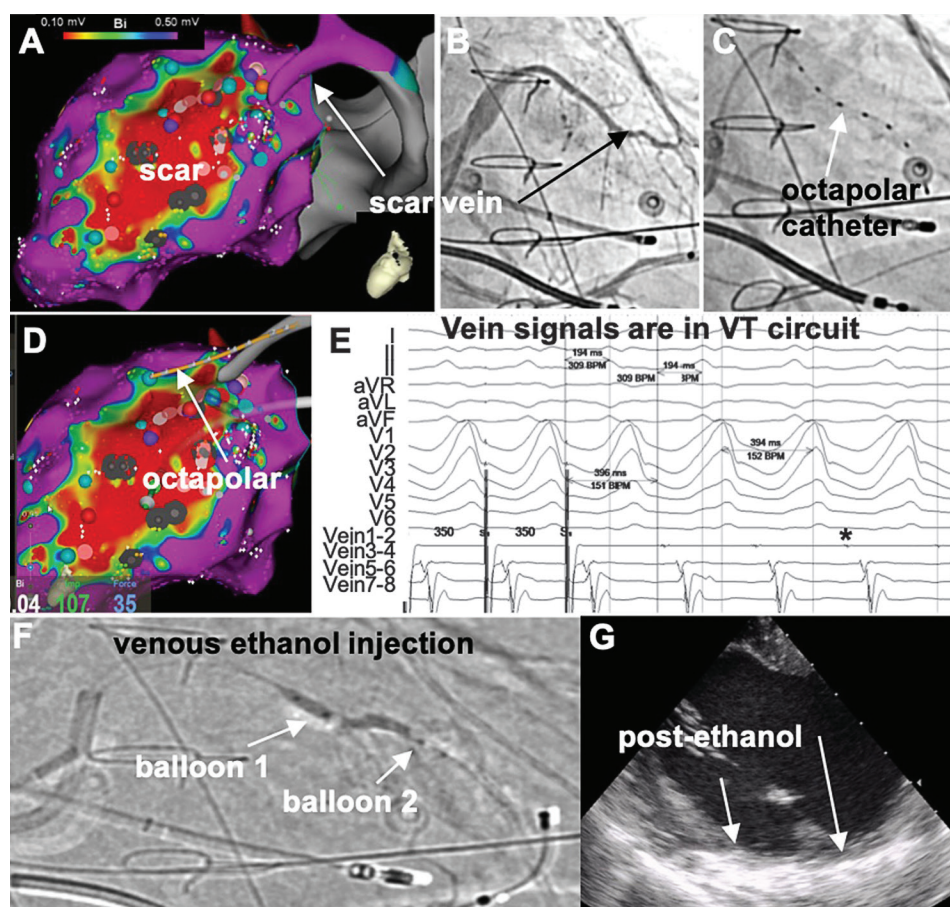


Figure 2.

Mapping and ethanol ablation of an infarct-related vein in ischemic ventricular tachycardia (VT). (A) Endocardial 3-dimensional bipolar voltage map of the left ventricle (LV) showing a dense (< 0.5 mV) scar, with a scar vein directly on its epicardial aspect. (B) Venography. (C) Octapolar catheter in the vein. (D) Localization of octapolar relative to scar. (E) Entrainment and mid-diastolic signals confirm participation in VT circuit. (F) Double balloon ethanol vein injection. (G) Transmural echogenicity in lateral LV after ethanol.

LIMITATIONS

RCVEA requires procedural skills including coronary sinus venography, selective venous cannulation and wiring (similar to LV lead placement), ethanol injection, and angioplasty balloon inflation. RCVEA can be technically challenging and may have limited reproducibility, but new operators can successfully adopt it despite the steep learning curve.

CONCLUSION

Radiofrequency refractory VT poses a challenge for the invasive electrophysiologist. RCVEA offers an effective treatment for both LVS and non-LVS substrates and is found to be generally safe in observational data. This is an inexpensive and readily available technique that has utility in a range of health systems using routine existing equipment.

KEY POINTS

- Transarterial coronary ethanol ablation has been described as an alternative treatment option for ventricular arrhythmias arising from intramural substrates that cannot be targeted with endocardial or epicardial catheter approaches.
- Retrograde coronary venous ethanol ablation (RCVEA) is an effective tool for ventricular arrhythmia arising from the left ventricular summit and challenging non-left ventricular summit areas.
- RCVEA has the advantage of causing less collateral myocardial damage and avoiding complications related to arterial vessel cannulation.
- RCVEA is an inexpensive and readily available approach that can be used with existing equipment.

Corresponding Author:

mvalderrabano@houstonmethodist.org

Conflict of Interest Disclosure:

The authors have completed and submitted the *Methodist DeBakey Cardiovascular Journal* Conflict of Interest Statement and none were reported.

Keywords:

ventricular tachycardia, LV summit, alcohol ablation

REFERENCES

1. Cronin EM, Bogun FM, Maury P, et al. 2019 HRS/EHRA/APHRS/LAHR expert consensus statement on catheter ablation of ventricular arrhythmias. *Europace*. 2019 Aug 1;21(8):1143-1144. doi: 10.1093/europace/euz132.
2. Pedersen CT, Kay GN, Kalman J, et al. EHRA/HRS/APHRS expert consensus on ventricular arrhythmias. *Heart Rhythm*. 2014 Oct;11(10):e166-96. doi: 10.1016/j.hrthm.2014.07.024.
3. Yamada T, Akrawinhawong K, Tabereaux PB. Successful transcatheter ethanol ablation of a ventricular tachycardia originating from the crux of the heart. *J Cardiovasc Electrophysiol*. 2019 May;30(5):777-778. doi: 10.1111/jce.13874.
4. Santangeli P, Marchlinski FE, Zado ES, et al. Percutaneous epicardial ablation of ventricular arrhythmias arising from the left ventricular summit: outcomes and electrocardiogram correlates of success. *Circ Arrhythm Electrophysiol*. 2015 Apr;8(2):337-43. doi: 10.1161/CIRCEP.114.002377.
5. Baher A, Shah DJ, Valderrábano M. Coronary venous ethanol infusion for the treatment of refractory ventricular tachycardia. *Heart Rhythm*. 2012 Oct;9(10):1637-9. doi: 10.1016/j.hrthm.2012.06.003.
6. Lin CY, Chung FP, Lin YJ, et al. 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 Jan;13(1):111-21. doi: 10.1016/j.hrthm.2015.08.030.
7. Chang RJ, Stevenson WG, Saxon LA, Parker J. Increasing catheter ablation lesion size by simultaneous application of radiofrequency current to two adjacent sites. *Am Heart J*. 1993 May;125(5 Pt 1):1276-84. doi: 10.1016/0002-8703(93)90995-I.
8. Nguyen DT, Tzou WS, Brunnquell M, et al. Clinical and biophysical evaluation of variable bipolar configurations during radiofrequency ablation for treatment of ventricular arrhythmias. *Heart Rhythm*. 2016 Nov;13(11):2161-2171. doi: 10.1016/j.hrthm.2016.07.011.
9. Stevenson WG, Tedrow UB, Reddy V, et al. Infusion Needle Radiofrequency Ablation for Treatment of Refractory Ventricular Arrhythmias. *J Am Coll Cardiol*. 2019 Apr 2;73(12):1413-25.
10. Brugada P, de Swart H, Smeets JL, Wellens HJ. Transcatheter chemical ablation of ventricular tachycardia. *Circulation*. 1989 Mar;79(3):475-82. doi: 10.1161/01.cir.79.3.475.
11. Kreidieh B, Rodriguez-Manero M, Schurmann P, Ibarra-Cortez SH, Dave AS, Valderrábano M. Retrograde Coronary Venous Ethanol Infusion for Ablation of Refractory Ventricular Tachycardia. *Circ Arrhythm Electrophysiol*. 2016 Jul;9(7):10.1161/CIRCEP.116.004352 e004352. doi: 10.1161/CIRCEP.116.004352.
12. Tavares L, Valderrábano M. Retrograde venous ethanol ablation for ventricular tachycardia. *Heart Rhythm*. 2019 Mar;16(3):478-483. doi: 10.1016/j.hrthm.2018.09.010.

13. Inoue H, Waller BF, Zipes DP. Intracoronary ethyl alcohol or phenol injection ablates aconitine-induced ventricular tachycardia in dogs. *J Am Coll Cardiol*. 1987 Dec;10(6):1342-9. doi: 10.1016/s0735-1097(87)80139-0.
14. Brugada P, de Swart H, Smeets JL, Bar FW, Wellens HJ. Termination of tachycardias by interrupting blood flow to the arrhythmogenic area. *Am J Cardiol*. 1988 Sep 1;62(7):387-92. doi: 10.1016/0002-9149(88)90964-2.
15. Ramana RK, Wilber DJ, Leya F. Ethanol septal ablation for refractory ventricular tachycardia. *J Invasive Cardiol*. 2007 May;19(5):E142-5.
16. Kumar S, Barbhaiya CR, Sobieszczyk P, et al. Role of alternative interventional procedures when endo- and epicardial catheter ablation attempts for ventricular arrhythmias fail. *Circ Arrhythm Electrophysiol*. 2015 Jun;8(3):606-15. doi: 10.1161/CIRCEP.114.002522.
17. Kay GN, Epstein AE, Bubien RS, Anderson PG, Dailey SM, Plumb VJ. Intracoronary ethanol ablation for the treatment of recurrent sustained ventricular tachycardia. *J Am Coll Cardiol*. 1992 Jan;19(1):159-68. doi: 10.1016/0735-1097(92)90068-x.
18. Stevenson WG, Wilber DJ, Natale A, et al. Irrigated radiofrequency catheter ablation guided by electroanatomic mapping for recurrent ventricular tachycardia after myocardial infarction: the multicenter thermocool ventricular tachycardia ablation trial. *Circulation*. 2008 Dec 16;118(25):2773-82. doi: 10.1161/CIRCULATIONAHA.108.788604.
19. Sacher F, Sobieszczyk P, Tedrow U, et al. Transcatheter ethanol ventricular tachycardia ablation in the modern electrophysiology era. *Heart Rhythm*. 2008 Jan;5(1):62-8. doi: 10.1016/j.hrthm.2007.09.012.
20. Tokuda M, Sobieszczyk P, Eisenhauer AC, et al. Transcatheter ethanol ablation for recurrent ventricular tachycardia after failed catheter ablation: an update. *Circ Arrhythm Electrophysiol*. 2011 Dec;4(6):889-96. doi: 10.1161/CIRCEP.111.966283.
21. Saxon LA, Sherman CT, Stevenson WG, Yeatman LA, Wiener I. Ventricular tachycardia after infarction: sources of coronary blood flow to the infarct zone. *Am Heart J*. 1992 Jul;124(1):84-6. doi: 10.1016/0002-8703(92)90923-j.
22. Reek S, Geller JC, Schildhaus HU, Mahnkopf D, Mittag J, Klein HU. Catheter ablation of ventricular tachycardia by intramyocardial injection of ethanol in an animal model of chronic myocardial infarction. *J Cardiovasc Electrophysiol*. 2004 Mar;15(3):332-41. doi: 10.1046/j.1540-8167.2004.03409.x.
23. Verna E, Repetto S, Saveri C, Forgione N, Merchant S, Binaghi G. Myocardial dissection following successful chemical ablation of ventricular tachycardia. *Eur Heart J*. 1992 Jun;13(6):844-6. doi: 10.1093/oxfordjournals.eurheartj.a060267.
24. Kumar S, Tedrow UB, Stevenson WG. Adjunctive interventional techniques when percutaneous catheter ablation for drug refractory ventricular arrhythmias fail. *Circ Arrhythm Electrophysiol*. 2017 Feb;10(2):e003676. doi: 10.1161/CIRCEP.116.003676.
25. Miller MA, Kini AS, Reddy VY, Dukkupati SR. Transcatheter ethanol ablation of ventricular tachycardia via an anomalous first septal perforating artery. *Heart Rhythm*. 2011 Oct;8(10):1606-7. doi: 10.1016/j.hrthm.2010.07.016.
26. Atienza F, Arenal A, Perez-David E, et al. New diagnostic and therapeutic approaches to treat ventricular tachycardias originating at the summit of the left ventricle: role of merged hemodynamic-MRI and alternative ablation sources. *Circ Arrhythm Electrophysiol*. 2013 Dec;6(6):e80-4. doi: 10.1161/CIRCEP.113.000430.
27. Gabus V, Jeanrenaud X, Eeckhout E, Pruvot E. Transcatheter ethanol for incessant epicardial ventricular tachycardia. *Heart Rhythm*. 2014 Jan;11(1):143-5. doi: 10.1016/j.hrthm.2013.09.058.
28. Wright KN, Morley T, Bicknell J, Bishop SP, Walcott GP, Kay GN. Retrograde coronary venous infusion of ethanol for ablation of canine ventricular myocardium. *J Cardiovasc Electrophysiol*. 1998 Sep;9(9):976-84. doi: 10.1111/j.1540-8167.1998.tb00138.x.
29. Segal OR, Wong T, Chow AW, et al. Intra-coronary guidewire mapping—a novel technique to guide ablation of human ventricular tachycardia. *J Interv Card Electrophysiol*. 2007 Mar;18(2):143-54. doi: 10.1007/s10840-007-9084-2.
30. Da-Wariboko A, Lador A, Tavares L, et al. Double-balloon technique for retrograde venous ethanol ablation of ventricular arrhythmias in the absence of suitable intramural veins. *Heart Rhythm*. 2020 May 26;S1547-5271(20)30523-3. doi: 10.1016/j.hrthm.2020.05.027.
31. Okishige K, Nakamura R, Yamauchi Y, Keida T, Sasano T, Hirao K. Chemical ablation of ventricular tachycardia arising from the left ventricular summit. *Clin Case Rep*. 2019 Sep 19;7(11):2036-2041. doi: 10.1002/ccr3.1397.
32. Sasaki T, Yamashita S, Suzuki M, Okishige K, Goya M, Sasano T. Successful ablation with ethanol infusion to coronary sinus branch in a case with scar-related ventricular tachycardia with left ventricular epicardial reentrant circuit. *Heart-Rhythm Case Rep*. 2020 Jan 13;6(4):226-229. doi: 10.1016/j.hrcr.2020.01.002.
33. Baszko A, Kalmucki P, Siminiak T, Szyszka A. Telescopic coronary sinus cannulation for mapping and ethanol ablation of arrhythmia originating from left ventricular summit. *Cardiol J*. 2020;27(3):312-315. doi: 10.5603/CJ.a2019.0064.
34. Kato K, Tanaka A, Hasegawa S, Kametani R. Successful ethanol injection into the anterior interventricular cardiac vein for ventricular premature contractions arising from the left ventricular summit. *Heart Rhythm Case Rep*. 2018 Apr 18;4(7):310-313. doi: 10.1016/j.hrcr.2018.04.002.
35. Tavares L, Lador A, Fuentes S, et al. Intramural venous ethanol infusion for refractory ventricular arrhythmias: Outcomes of a multicenter experience, prospective international registry. *JACC Clin Electrophysiol*. 2020 Oct 26;6(11):1420-31. doi: 10.1016/j.jacep.2020.07.023.