Alternative Approaches for Ablation of Resistant Ventricular Tachycardia

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KEYWORDS

• Ventricular tachycardia • Alcohol ablation • Coil embolization • Simultaneous unipolar RF ablation • Bipolar RF ablation • Surgical ablation • Stereotactic ablative radiosurgery

KEY POINTS

- Unipolar radiofrequency (RF) ablation can be ineffective for ventricular tachycardias (VTs) with a deep intramural origin or cases in which epicardial access is not attainable due to prior cardiac surgery.
- Alternative approaches include alcohol ablation or coil embolization, simultaneous unipolar or bipolar RF ablation, surgical ablation, or noninvasive ablation with stereotactic radiosurgery.
- Alcohol ablation is commonly used to treat resistant VT with good acute and long-term results, although it is limited to the territories vascularized by the target vessel.

INTRODUCTION

Ventricular tachycardia (VT) ablation is usually performed with an ablation catheter that delivers unipolar radiofrequency (RF) energy to eliminate the re-entry circuit responsible for VT. However, there are some instances when unipolar RF ablation fails, notably in VTs with a deep intramural origin or cases in which epicardial access is not attainable due to prior cardiac surgery. To overcome these limitations, several alternative approaches have been used in clinical practice, including alcohol ablation, coil embolization, simultaneous unipolar or bipolar RF ablation, surgical ablation, or noninvasive ablation with stereotactic radiosurgery. This review article describes some of these alternative techniques.

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ALCOHOL ABLATION

Transcoronary ethanol ablation (TCEA) is performed by intracoronary injection of ethanol. Via direct chemical injury and ischemic injury secondary to vascular damage, ethanol causes coagulative necrosis of the myocardium, which is later replaced by a permanent scar, thereby affecting the circuit that sustains VT.[1]

TCEA can be performed either anterogradely via a coronary artery or retrogradely via the coronary venous system. In anterograde TCEA, selective coronary angiography allows identification of the arterial branches that supply the tachycardia-related region. The target artery is engaged with an angioplasty wire and occluded with an over-the-wire balloon. It is important to exclude vessels with a pronounced collateral circulation to avoid unnecessary damage to distant areas. The angioplasty wire can also be used to record a unipolar electrogram from within the myocardium and select the vessels in close proximity to the area of VT origin with more precision.[2] To do so, only the distal end of the guidewire should be exposed, using either an uninflated angioplasty balloon or a subselector catheter. Once the target vessel is identified, confirmation of the potentially successful site is achieved by inducing the VT and observing its termination after injecting iced saline (2–3 mL). To follow, slow ethanol injection (95%–100%, 1 mL at 1 mL/min up to 5 mL per vessel) is then performed and the balloon remains inflated for approximately 10 minutes after the infusion to prevent backflow of ethanol and ensure good tissue penetration. An alternative approach to TCAE is retrograde intracoronary venous infusion of ethanol.[3] A selective coronary venogram can show the target venous branches that drains the area of VT origin, as determined with activation mapping. As with anterograde TCAE, the target vessel can be cannulated with an angioplasty wire and occluded with an over-the-wire balloon to infuse ethanol (95%–100%, 1 mL at 0.5 mL/min with the balloon inflated for 2 minutes).

Compared with unipolar RF ablation, TCEA allows creation of deeper myocardial lesions; however, it is limited to the territories vascularized by the target vessel. Moreover, the target vessel itself might be inadequate (too small, stenotic, occluded, or with prominent collaterals) and complications are not negligible. In addition to the complications inherent to coronary artery instrumentation (eg, coronary arterial dissection and thrombosis), the reflux of ethanol to nontargeted areas can cause complete heart block (septal alcohol ablation) and myocardial infarction of distant unwanted regions. Additionally, a case of fatal free wall rupture secondary to intramyocardial dissection has been described.[4]

Several case reports and a few case series (Table 1) have demonstrated the feasibility of TCAE for VT ablation; however, both the acute and long-term success rates, as well as the complication rates, remain suboptimal.[2–16] Most of these studies were performed in the setting of ischemic cardiomyopathy, although cases of successful TCAE have been reported for valvular,[4] Chagas',[13] hypertrophic,[17] and dilated idiopathic cardiomyopathies.[2,9–11,15,16]

CORONARY COIL EMBOLIZATION

A recently described approach is transcoronary coil embolization. After selecting the target vessel, coils can be deployed, resulting in coronary occlusion and subsequent myocardial infarction.[18] This might be an alternative in cases with severely reduced systolic dysfunction, given the unpredictable amount of injury when performing TCAE.

SIMULTANEOUS UNIPOLAR OR BIPOLAR RADIOFREQUENCY ABLATION

In conventional unipolar RF, current is delivered from the ablation catheter tip to a grounding patch positioned on the patient's skin: this results in larger current density at the catheter tip (given the smaller surface area) with resistive tissue heating at the catheter-myocardium interface, as well as conductive heating of deeper tissues. To increase efficacy, it is possible to deliver RF current between 2 electrodes positioned on opposing sides of the target deep myocardial tissue. This can be done simultaneously both in a unipolar or bipolar RF fashion. In simultaneous unipolar RF ablation, 2 ablation catheters are connected to 2 RF generators each with their own return electrode, whereas in true bipolar RF ablation, RF current flows between the 2 ablation catheters using 1 as the active electrode and the other as the return electrode. Bipolar RF has been shown to improve lesion transmurality in animal studies compared with both sequential and simultaneous unipolar RF ablation, probably because it depends less on catheter contact and alignment.[19] However, to deliver bipolar RF energy, noncommercially available custom-engineered cable and switch box are necessary to attach the return catheter record and display the temperature from the tip of both catheters, as well as their location on the electroanatomic system. In contrast, simultaneous unipolar RF ablation can be more easily applied, provided 2 RF generators are available.

Table 1
Cases series on ventricular tachycardia alcohol ablation

Author, Year	N	Age (y)	ICM	Acute Success	Complications	Follow-up	Recurrence
Brugada et al,[5] 1989	3	56 ± 10	100%	100%	33% (CHB)	1–6 mo	33%
Dailey et al,[6] 1992	4	NA	100%	100%	25% (CHB)	4–25 mo	50%
Kay et al,[7] 1992	10	62 ± 12	100%	90% any VT	40% (CHB)	372 d	50%
Nellens et al,[8] 1992	10	NA	100%	100%	NA	2–44 mo	14%
Segal et al,[2] 2007	5	70 ± 4	80%	100%	0%	19 ± 17 mo	0%
Sacher et al,[9] 2008	9	55 ± 9	67%	56% any VT 89% clinical VT	33% (1 severe hypotension; 2 groin hematoma)	29 ± 23 mo	33%
Steven et al,[10] 2009[a]	3	NA	NA	100%	0%	NA	NA
Tokuda et al,[11] 2011	22	63 ± 13	52%	46% any VT 82% clinical VT	38% (CHB)	16 d	64%
Baher et al,[3] 2012[b]	2	~67	0%	100% clinical VT	50% (pericarditis)	5 mo	0%

Abbreviations: CHB, complete heart block; ICM, ischemic cardiomyopathy; N, number; NA, not available.
[a] Part of a case series on VT originating from the aortomitral continuity in structural heart disease.
[b] Retrograde TCEA.

Clinically, there is 1 reported case of successful simultaneous unipolar RF ablation (a patient with incessant septal VT secondary to nonischemic cardiomyopathy). A nonirrigated 8 mm ablation catheter delivered 55 W of RF energy opposed to an irrigated 3.5 mm ablation catheter delivering 50 W determining termination of VT.[20] However, bipolar RF using 2 irrigated 3.5 mm ablation catheters delivering up to 40 W of energy has been successfully used in a few cases of refractory septal VT (ischemic and nonischemic), free-wall VT (ischemic), and outflow tract VT (idiopathic), with good acute but mixed long-term results (Table 2).[21–23] Studies directly comparing these various different modalities of RF delivery are needed to determine their true additional value.

SURGICAL ABLATION

Surgical treatment of VT was the first used for drug-resistant VT. Aneurysmectomy, encircling endocardial ventriculostomy, and subendocardial resection have been used for decades, before the advent of electroanatomical mapping made transcatheter ablation of VT feasible.[24–26] Over the years, mapping-guided surgical ablation has emerged as an alternative strategy for the surgical management of VT because it allows delivery of

Table 2
Clinical studies on bipolar radiofrequency ablation

Author, Year	N	Age (y)	ICM	Acute Success	Complications	Follow-up	Recurrence
Koruth et al,[21] 2012	6	~65	67%	67% any VT	17% (CHB)	1 y	50%
Gizurarson et al,[22] 2014	1	56	100%	100% clinical VT 0% any VT	0%	1 y	0%
Iyer et al,[20] 2014	1	56	100%	100% any VT	0%	1 mo	0%
Teh et al,[23] 2014	4	~53	0%	75%	0%	4 mo	25%

Abbreviations: CHB, complete heart block; ICM, ischemic cardiomyopathy; N, number.

RF or cryoenergy after precise localization of the arrhythmogenic focus or substrate. Moreover, epicardial surgical ablation might be the only feasible alternative in case of difficult pericardial access (adhesions from prior cardiac surgery or extensive epicardial ablation), especially when the substrate is not limited to a single coronary branch distribution.

Surgical access can be minimally invasive, achieved either with a subxiphoid window or with a limited anterior or left thoracotomy, allowing preferential exposure of the inferior versus anterior or lateral left ventricular walls. Alternatively, a full median sternotomy may be used to expose the whole heart, with or without cardiopulmonary bypass. Surgically based ablation is mainly a substrate-based ablation, due to the difficulty of inducing the clinical arrhythmia in this setting and the impossibility to compare the QRS morphology on the electrocardiogram. Although visual inspection can be used to detect the scar, it is often not easy to do so given the presence of epicardial fat; therefore, intraprocedural electroanatomic guidance, ideally with image integration, is useful. Once the substrate is localized, both RF (bipolar or unipolar) and cryoablation can be applied epicardially using standard electrophysiological ablation catheters or dedicated surgical ablation tools.[27,28]

Few observational studies have systematically reported the results of surgical ablation (Table 3). Although acute success is achieved in a good number of patients, complication rates, and long-term success are poor, influenced by the invasiveness of the procedure and the highly selected high-risk population.[10,27–34]

STEREOTACTIC ABLATIVE RADIOSURGERY

Stereotactic ablative radiosurgery (SABR) is a form of radiotherapy that focuses high-dose ionizing radiation beams to be delivered in a small, localized area of the body and it is widely used for the

Table 3
Clinical studies on surgical ablation

Author, Year	N	Age (y)	ICM	Acute Success	Complications	Follow-up	Recurrence
Soejima et al,[29] 2004	6	57 ± 10	33%	67%	33% (1 prolonged pericarditic pain, 1 hemorrhagic effusion)	106–675 d	33%
Maury et al,[30] 2007	1	74	100%	100%	0%	6 mo	0%
Steven et al,[10] 2009[a]	2	NA	NA	100%	0%	NA	NA
Maury et al,[31] 2009[b]	1	62	0%	100%	100% (pleural effusion)	9 mo	0%
Michowitz et al,[32] 2010	14	63 ± 10	71%	57%	29% (3 hemorrhagic effusion, 1 wound infection)	19 ± 12 mo	50%
Anter et al,[33] 2011	8	58 ± 11	0%	NA	25% (2 deaths, sepsis and progressive HF)	23 ± 6 mo	25%
Mathuria et al,[27] 2011	1	62	100%	100% clinical VT 0% any VT	0%	6 mo	0%
Mulloy et al,[28] 2013	7	48 ± 11	29%	NA	57% (tamponade, prolonged ventilation, pneumonia, GI bleeding, AF)	5 ± 3 mo	0%
Patel et al,[34] 2016	5	60 ± 11	40%	60% any VT	10% (mediastinal bleeding)	12 ± 12 mo	0%

Abbreviations: AF, atrial fibrillation; GI, gastrointestinal; HF, heart failure; ICM, ischemic cardiomyopathy; N, number.
[a] Part of a case series on VT originating from the aortomitral continuity in structural heart disease.
[b] Lateral thoracotomy approach.

treatment of various types of cancers. In contrast to traditional radiotherapy, SABR creates radiation-induced necrosis in the targeted tissue, minimizing the exposure to surrounding tissues.[35] Compared with other forms of ablation, SABR is noninvasive and can be used in patients whose comorbidities render them unsuitable for invasive treatment (RF ablation or cardiac surgery).[36,37] So far, SABR has been used in 2 patients with refractory VT. A 25 Gy dose was delivered to the target volume, corresponding to the ventricular arrhythmogenic substrate as determined with electrophysiological-imaging integration, without acute complications. At follow-up, no late complications (eg, extracardiac toxicity) occurred and both patients showed a clinical benefit with substantial VT burden reduction.

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