Bipolar Radiofrequency Catheter Ablation of Left Ventricular Summit Arrhythmias

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KEYWORDS

• Left ventricular summit • Bipolar ablation • Ventricular tachycardia • Premature ventricular complex

KEY POINTS

- Left ventricular (LV) summit architecture may prevent sufficient heating of the targeted area during standard radiofrequency catheter ablation.
- Bipolar ablation can overcome some problems of ablation of LV summit arrhythmias and increase a chance of achieving a transmural lesion.
- Targeting the LV summit area using bipolar ablation provides several configurations.

BACKGROUND

The left ventricular (LV) summit is a frequent source of origin of ventricular arrhythmias (VA), and thus a common target for radiofrequency catheter ablation (RFCA). Challenging anatomic and morphologic conditions of the LV summit architecture and its surrounding sites, including proximity of major coronary arteries, presence of substantial epicardial fat layer, and fibrotic components of the aortic and pulmonic valves, may prevent sufficient heating of the targeted LV ostium area using standard RFCA approach.[1] Radiofrequency (RF) applications applied near the LV summit can be performed from accessible adjacent structures, such as subvalvular left ventricular outflow tract (LVOT), great cardiac vein (GCV), anterior interventricular veins (AIV), or aortic and pulmonic cusps. Nevertheless, long-term efficacy of RFCA drops substantially if a multisite ablation for such LV summit VA is required.[2] Alternatively, RF current can be delivered in bipolar fashion, between distal electrodes of 2 separate ablation catheters (AC), as this will result in higher RF current delivery in the area of interest. Bipolar ablation can result in higher likelihood of efficacy for ablation of LV summit arrhythmias from inaccessible regions and lesion transmurally. In this review, the authors describe the present approaches for bipolar radiofrequency catheter ablation (Bi-RFCA) of the LV summit VAs refractory to standard approaches.

From a historical standpoint, bipolar ablation in the very early era of RFCA was initially used for treatment of lateral accessory pathways, as an alternative for direct current ablation.[3] In this approach, one of the solid-tip electrodes was advanced into the coronary sinus (CS), and the second one was positioned in the opposing endocardial mitral annulus. This approach was abandoned because of poor blood flow in the CS, causing overheating and impedance mismatch resulting in nonuniform lesion creation. Thus, most accessory pathway ablation cases from the study by Jackman and colleagues[3] were completed using the standard unipolar approach. However, Bi-RFCA has subsequently been described for the treatment of refractory

Conflict of interest: none.

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Card Electrophysiol Clin 15 (2023) 57–62
https://doi.org/10.1016/j.ccep.2022.07.001
1877-9182/23/

posteroseptal accessory pathways.[4] In addition, Bi-RFCA has also been used for ablation of aortic cusps and septal and free wall VTs[5,6] and most recently for septal outflow tract and LV summit arrhythmias.[7–9]

Biophysical rationale for bipolar ablation of LV summit VA comes from complex anatomic relations in the LV ostium area, which contribute to impaired RFCA efficacy. One study showed that the epicardial fat layer can reach up to 12.1 mm, and this can prevent conventional RF delivery to effectively treat an underlying LV summit arrhythmia.[10] The presence of the epicardial adipose tissue illustrates the need for improved RF energy delivery, which has been demonstrated in ex vivo studies.[11] Alternatively, Bi-RFCA can lead to increased lesion depth in cases of moderate levels of adipose tissue.[12,13] In addition, the presence of multiple sites surrounding LV summit, which are accessible to classic ablation approaches, provides a broad spectrum of configurations for Bi-RFCA, leaving the field clear for numerous approaches.

ANATOMIC ASPECTS OF THE LEFT VENTRICULAR SUMMIT AND VARIABILITY OF BIPOLAR ABLATION CONFIGURATIONS

From the anatomic standpoint, Bi-RFCA targeting the LV summit area provides several configurations (**Fig. 1**). Locations capable of hosting 1 of 2 ACs for Bi-RFCA include the following:

- Aortic cusps
- Left/right interleaflet triangle of the aortic valve
- Left ventricular outflow tract (LVOT)
- Right ventricular outflow tract (RVOT)
- Left pulmonic cusp (LPC)
- Great cardiac vein (GCV)
- Anterior intraventricular vein (AIV)

Table 1 summarizes to-date literature reporting outcomes of Bi-RFCA at the LV summit area. Although multiple sites suitable for bipolar ablation introduces opportunities for RF delivery through the LV summit, several challenges should be taken into account. In one of the initial reports, Bi-RFCA was performed between the left aortic cusp and subvalvular LVOT.[5] Such an approach requires double arterial access for both AC, leaving no space for additional arterial access necessary for performing a coronary angiogram at the time of ablation, which is often necessary for exact determination of coronary artery route, in order to avoid its injury. Distance above 5 mm from the tip of each AC to coronaries in 2 projections and avoiding the presence of coronary artery in between the 2 catheters used for Bi-RFCA should be provided. As the aortic root and subvalvular region of the LVOT are delineated by only thin leaflets of the aortic valve, it should be also taken into account that the intercatheter distance during Bi-RFCA can be too close, and this may result in thrombus formation or RF current preferential conduction through blood. For similar reasons, Bi-RFCA at the intercatheter distance less than 5 mm was avoided in 1 study.[14]

BIPOLAR ABLATION OF THE SEPTAL REGION OF THE LEFT VENTRICULAR SUMMIT

Anteromedial LV summit VAs will include the common target of the upper interventricular septum, also called the septal portion. In one of earliest studies on Bi-RFCA, such an approach was performed successfully in 4 patients without complications and with a notable success rate of 75%.[7] Despite the fact that the investigators use the nomenclature of “outflow tract” PVC/VT in their study, electrocardiographic (ECG) features provided by Teh and colleagues[7] demonstrate abrupt V3 transition zone are suggestive for typical LV summit VA.[15] The possible advantage of ablation between RVOT and LVOT is the fact that it does not require any special maneuvers with AC. Second, when bipolar ablation between RVOT and LVOT is performed, both catheters operate in a similar blood pool, making the impedance mismatch affect less impactful on lesion creation, thus allowing unconstrained energy and RF time titration. However, such an approach may not reach some VA originating in the inaccessible LV summit area covered by the left anterior descending artery (LAD) of the left main coronary artery or septal perforators. The most lateral part of the LV summit appears also to be out of range of Bi-RFCA RVOT-LVOT catheter configuration. The use of large-tip electrodes can provide some advantages when targeting anteromedial LV summit; however, literature data on utilization of two 8-mm catheters are scarce.[16]

BIPOLAR ABLATION OF THE LEFT VENTRICULAR SUMMIT UTILIZING CORONARY VEINS

Coronary veins, particularly GCV and AIV, are a common target for mapping and ablation of the LV summit arrhythmias. Nevertheless, as mentioned previously, classic unipolar ablation can be insufficient to achieve desired lesion depth, mainly because of 2 reasons:

- Epicardial adipose tissue
- Coronary vein caliber

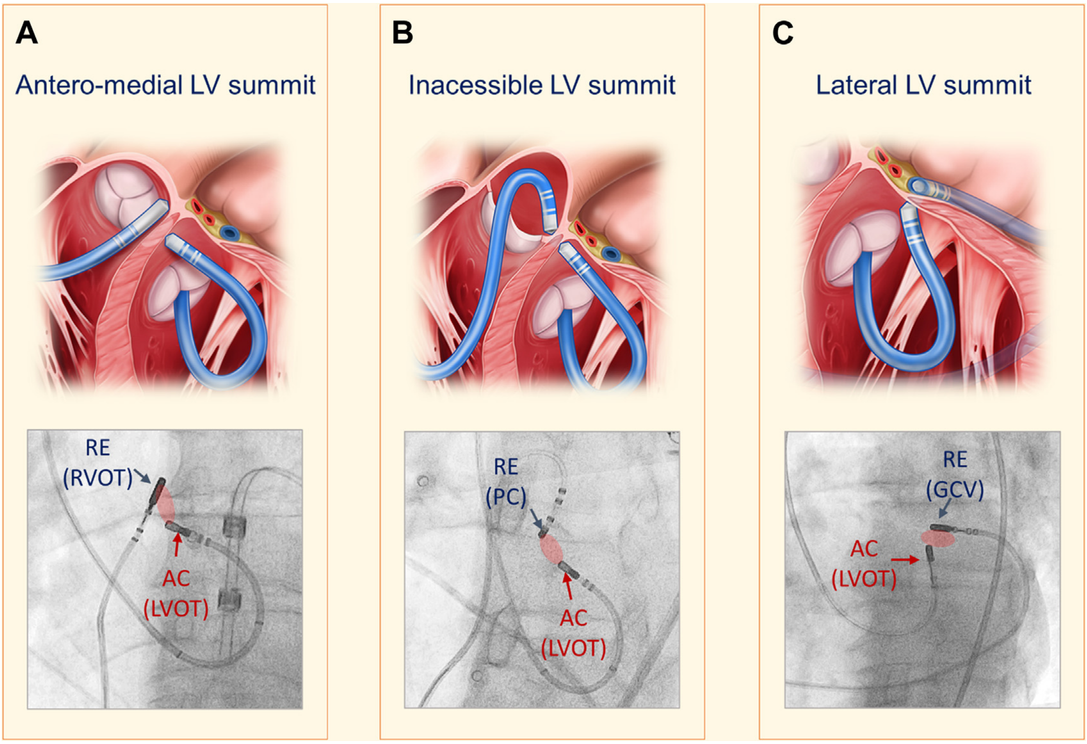

Fig. 1. Representative fluoroscopic images depicting approaches of the LV summit Bi-RFCA. (*A*) Ablation of the anteromedial LV summit. Bi-RFCA is performed between 2 AC: the first 8-mm AC is positioned using reversed U-curve in the RVOT and serves as a return electrode (RE) during Bi-RFCA, and the second, open irrigated U-curved AC is located in the subaortic region of LVOT. (*B*) Ablation of the inaccessible LV summit. Bi-RFCA is performed between 2 open-irrigated AC: the first AC (acting as RE) is positioned using reversed U-curve in the LPC and the second U-curved AC is located in the subaortic region of LVOT. PC, pulmonic cusp. (*C*) Bi-RFCA of more lateral LV summit aspect. An open irrigated U-curved AC is located in LVOT, whereas a nonirrigated 8-mm-tip AC is positioned in the GCV. This catheter serves as RE. The use of a large 8-mm tip is justified to minimize the impedance mismatch effect.

By advancing one of the AC into GCV/AIV and a second to the opposite endocardial LVOT or aortic cusp, the path of RF current can be redirected toward LVS using Bi-RFCA.[17] This Bi-RFCA configuration can result in reduction of VA burden and lesion transmurality.[8] The challenges regarding advancing an AC to a vessel of a small diameter can be overcome using a telescopic approach.[18] Issues during Bi-RFCA, such as electrode overheating in the GCV/AIV, impedance variability, or impedance increase resulting in premature Bi-RFCA application termination, can be solved by advancing an 8-mm-tip catheter into the coronary vein.[19] A possible overheating and subsequent char formation on a nonirrigated AC should be taken into account.[20,21]

BIPOLAR ABLATION OF THE INACCESSIBLE LEFT VENTRICULAR SUMMIT

RFCA of arrhythmias arising from the most superior aspect of the LV summit region, which has been defined as “inaccessible” owing to proximity to the left main coronary artery and its bifurcation into the left anterior descending and left circumflex coronary arteries together with a thick layer of epicardial fat, is particularly challenging, as direct ablation at the earliest site of activation is frequently not possible. Moreover, RF delivery from GCV/AIV would violate the 5-mm rule for safe distance from a coronary artery. Recently, a reversed U-curve technique was implemented for mapping of the pulmonic valve cusps.[22,23] This technique allows positioning of the tip of the AC anatomically below the level of the proximal LAD artery. However, the success of this approach alone for refractory LV summit PVC/VT remains anecdotal.[24] In these patients, with LV summit VAs arising from an inaccessible region and refractory to conventional RFCA, a purely anatomic approach using Bi-RFA from the LPC and opposite LVOT can be an effective alternative approach.[9] Advancing the LPC using U-curved AC can be supported by the use of a long sheath.

Table 1
Summary of literature data describing outcomes of bipolar ablation of the left ventricular summit arrhythmias

Study	Patients	Ablation Targets	Power (W)	Complications	Follow-Up
Teh et al,[7]	4	Anteromedial LV summit	Up to 35	None	75% success during follow-up
Nguyen et al,[25] 2016	1	Anteromedial LV summit	50	None	Recurrence
Futyma et al,[8]	4	Lateral LV summit	24 ± 6	None	No VT recurrence, 83% PVC burden reduction
Tokioka et al,[19] 2020	3	Lateral LV summit	35–40	None	Acute success
Igarashi et al,[26] 2020	4	LV summit	Up to 45	None in the LV summit cohort	Acute success
Futyma et al,[9] 2020	7	Inaccessible LV summit	36 ± 7	None	No VT recurrence in VT group, overall 84% PVC burden reduction
Enriquez et al,[27] 2019	1	Anteromedial LV summit	Up to 45 with half normal saline (HNS) irrigation	None	No PVC after 4 wk
Sauer et al,[29] 2018	1	Anteromedial LV summit	50	None	No VT after 6 mo

Remote magnetic navigation can be particularly useful for reversed U-curve mapping and ablation above the pulmonic valve.[25] Safety concerns should include a possible dislodgement of U-curved AC during Bi-RFCA, which can especially occur during deep breath.

In summary, for each case, the anatomic configuration of Bi-RFCA should be determined individually, based on ECG characteristics, anatomic features, cavital and sometimes intramural mapping outcomes, as well as effects of prior ablations on transient VA suppression. The combination of listed features can help to determine the most optimal Bi-RFCA approach.

COMBINATION OF BIPOLAR ABLATION WITH OTHER EMERGING TECHNIQUES

Bipolar ablation can be freely combined with other ablation methods. The most straightforward combination is additional unipolar ablation toward LV summit during the Bi-RFCA procedure, which frequently precedes other techniques tailored to the deep intramural arrhythmia sites. Other techniques include concomitant alcohol ablation.[26] Effects of Bi-RFCA can be augmented with irrigation of AC using low- or nonionic coolants, such as half normal saline (HNS)[27] or dextrose-5 in water.[9] Mapping wires or microcatheters in the septal perforators can be helpful not only for better definition of exact Bi-RFCA target but also to enhance RF delivery using the antenna effect.[28]

FUTURE DIRECTIONS

Standard unipolar RFCA remains the most common strategy for ablative treatment of LVsummit arrhythmias. However, some patients with intramural LVS PVC/VT site of origin can benefit from bipolar ablation implemented at an earlier stage of ablative treatment. Optimization of catheter shape, size, and interelectrode distance using dedicated equipment can allow for the safe delivery of Bi-RFCA of the LV summit VA earlier.

LIMITATIONS

A few limitations are worth highlighting. First, the clinical data of LV summit Bi-RFCA come from small retrospective multicenter studies. Second, the long-term efficacy of LV summit Bi-RFCA remains unknown. Last, outcomes of LVS Bi-RFCA can be dependent of equipment used and may differ between centers. Bi-RFCA often involves the off-label use of equipment designed for standard unipolar ablation, limiting the utility of this approach in some centers.

CLINICS CARE POINTS

- Locations capable of hosting 1 of 2 ablation catheters during bipolar ablation of the left ventricular summit include aortic and pulmonic cusps, interleaflet triangle, left and right ventricular outflow tract, and coronary veins.
- The use of large-tip electrodes can be especially useful when coronary veins are involved during bipolar ablation.
- Particular attention should be given to the presence of the nearby coronary arteries during bipolar ablation of the left ventricular summit arrhythmias.

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