Involvement of the left ventricular summit as a critical isthmus in a cardiac sarcoidosis patient with biventricular tachycardia

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Introduction

The delayed treatment of cardiac sarcoidosis leads to irreversible cardiac dysfunction owing to the progressive nature of the inflammatory process.[1] Cardiac sarcoidosis exhibiting ventricular tachycardia (VT) is characterized by predominant right ventricular scarring involving the endocardium and epicardium.[2] Catheter ablation is an effective treatment for VT management in cardiac sarcoidosis, and QRS morphology of VT facilitates prediction of the location of the arrhythmogenic substrate.[3,4] In a patient with VT demonstrating the superior axis, a reentrant circuit involving the inferior segment of the cardiac chamber is expected; thus, detailed mapping focuses on this area. Nevertheless, broad scarring of the myocardium results in an atypical electrocardiography (ECG) presentation during VT; thus, an algorithm to localize the VT circuit may have limited value. Here we report the case of an untreated cardiac sarcoidosis patient with an extensive right ventricular intramural scar presenting with VT with a predominant S wave in the inferior leads and the critical isthmus of the reentrant circuit at the left ventricular (LV) summit region.

Case report

A 69-year-old woman complained of dyspnea and was referred to our hospital for the treatment of systemic sarcoidosis. Five years prior, systemic sarcoidosis was suspected to be caused by uveitis and the uptake of gallium scintigraphy in the interventricular septum. Twelve-lead ECG during sinus rhythm showed a typical right bundle branch block pattern (Figure 1A). Cardiac involvement was suspected, but the patient refused further work-up and anti-inflammatory drugs. After 5 years, a slight prolongation of the PR interval and QRS width and disappearance of the S wave in leads I and aVL developed. In addition, a negative deflection appeared in the latter part of the QRS waveform in the inferior leads (Figure 1B). Computed tomography revealed severe LV dilatation with thinning of the interventricular septum. Transthoracic echocardiography revealed impaired systolic function (ejection fraction 30%). During echocardiography, incessant VT with predominant S waves appeared in the inferior leads (Figure 1C). As the VT was refractory to antiarrhythmic drugs, an emergent catheter ablation was performed.

Initially, detailed mapping using a 1-mm multielectrode mapping catheter (PentaRay; Biosense Webster, Irvine, CA) was performed in the right ventricle (RV) during VT. An extensive low-voltage area was distributed at the septum, and the VT propagated cranial-to-caudal direction. The earliest site was identified at the septal side of the right ventricular outflow tract (RVOT) despite 12-lead ECG showing predominant S waves in the inferior leads.

KEY TEACHING POINTS

- Untreated cardiac sarcoidosis results in disrupted transseptal activation owing to extensive intramural scarring.
- An extensive septal scar in the intraventricular septum contributes to a macroreentrant circuit for the biventricular tachycardia.
- Detailed mapping including the epicardial site was required to confirm the entire ventricular tachycardia with a phased activation pattern.

KEYWORDS Biventricular tachycardia; Cardiac sarcoidosis; Entrainment pacing; Left ventricular summit; Transseptal activation
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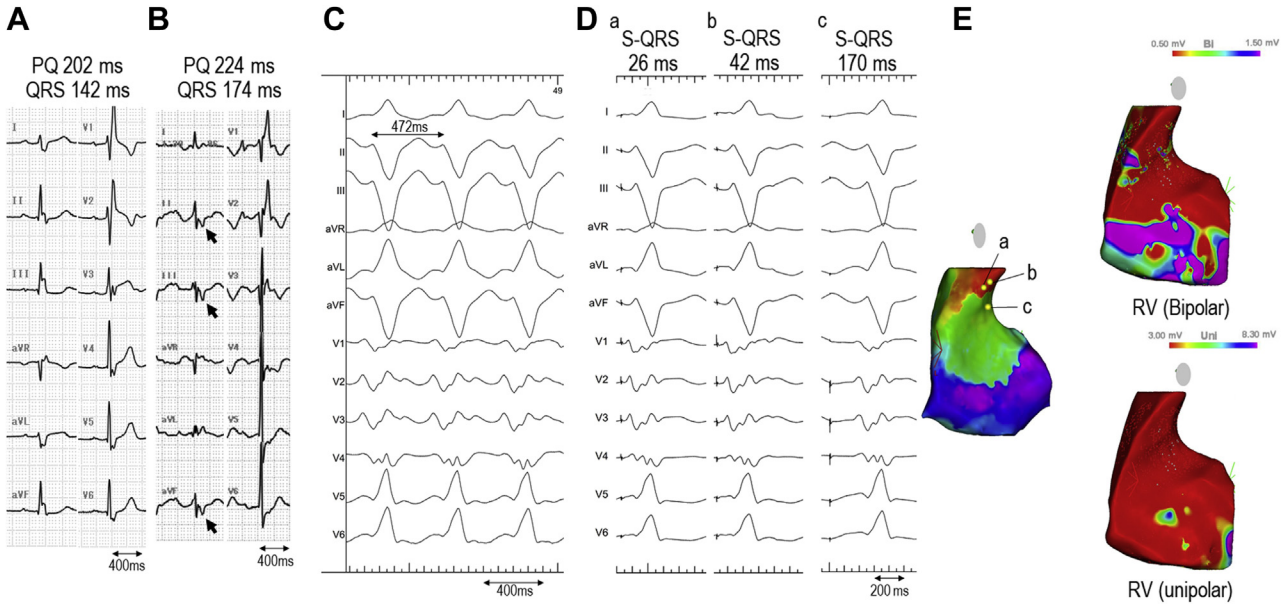

Figure 1 **A,B:** Twelve-lead electrocardiograms recorded 5 years previous (**A**) and upon admission (**B**). Of note, the late components in the inferior leads changed from positive to negative (*arrow*). **C:** Sustained ventricular tachycardia (VT) in the catheter laboratory demonstrated a left bundle branch block configuration and prominent S waves in the inferior leads. **D:** Activation mapping during VT in the right ventricle and pace mapping QRS morphologies in 3 different locations obtained during sinus rhythm. **E:** Bipolar and unipolar voltage mapping of the right ventricle (RV) during sinus rhythm.

Entrainment pacing at the RVOT and anterior wall showed differences in the postpacing interval (PPI) and VT cycle length (VTCL) of +4 ms and +6 ms, respectively. Entrainment pacing at the RVOT demonstrated concealed fusion with a short-stimulus QRS interval of 54 ms, and entrainment pacing at the anterior wall demonstrated minimal manifest fusion. The duration of local activation time in the RV was 202 ms (43%) and did not fill up the total VTCL (472 ms); thus, further mapping was performed in the LV. Additional mapping in the LV demonstrated caudal-to-cranial propagation, and entrainment pacing at the inferior septum and lateral mitral annulus resulted in manifest fusion with PPI-VTCL of +24 ms and 42 ms, respectively. A biventricular activation map combined with entrainment pacing suggested a large reentrant circuit rotating around the extensive low-voltage area at the RV septum in a counterclockwise manner involving both ventricles (Figure 2A and Supplemental Movie 1). Notably, the local activation time histogram of biventricular mapping demonstrated the lack of the diastolic phase of VT activation (Figure 2B); therefore, a 2F microcatheter (EPstar Fix 2F; Japan Lifeline, Tokyo, Japan) was introduced through the lumen of a 6F decapolar catheter (EPstar Fix CS with inner lumen; Japan Lifeline) and advanced into the distal branch of the great cardiac vein (GCV) to allow direct recording of epicardial activation in the LV outflow tract (LVOT) region. Advancing the catheter into the septal branch of the anterior interventricular vein was not possible owing to the presence of narrow and tortuous veins. Fragmented potentials with a long duration (120 ms) were recorded during the diastolic phase of VT at the LV summit region. The alternation of downstream far-field capture owing to a high-output stimulus to capture a continuous, fractionated, and low-amplitude electrogram with an excellent pace map to VT was observed. The difference between stimulus-QRS and electrogram-QRS was within $\leq$20 ms and the distal GCV was considered a critical isthmus (Figure 3). The VT propagated from the septal RVOT to the apical septum, conducted to the LV, and propagated to the LVOT. Finally, the impulse returned to the RVOT via epicardial conduction. Although direct sampling of intraseptal activity was not possible, the phased activation and response to entrainment pacing suggested biventricular tachycardia (BVT) as a mechanism. We initially attempted to target the diastolic potential in the LV summit, but we could not advance the ablation catheter (ThermoCool SmartTouch; Biosense Webster) into the distal GCV owing to the small vessel size and strong tortuosity. Energy application with a maximum of 35 W for 90 seconds using normal saline irrigation was delivered (total 875 seconds) between the left and right coronary cusps, which transiently prolonged the VTCL but did not terminate the VT. Unfortunately, mechanical catheter stimulation terminated the VT, and clinical VT was not induced thereafter. During sinus rhythm, biventricular mapping demonstrated ascending activation of the RV, suggesting the disappearance of the left-to-right transseptal activation at the basal septum (Supplemental Movie 2). Excellent pace maps with various stimulus latencies were obtained within an extensive low-voltage area at the RV septum (Figure 1D and 1E). We extensively ablated the RVOT (maximum 30 W and 60 seconds; total 790 seconds), opposite side of the electrode catheter placed in the distal GCV, and rendered noninducibility of any VT. Cardiac positron emission tomography revealed

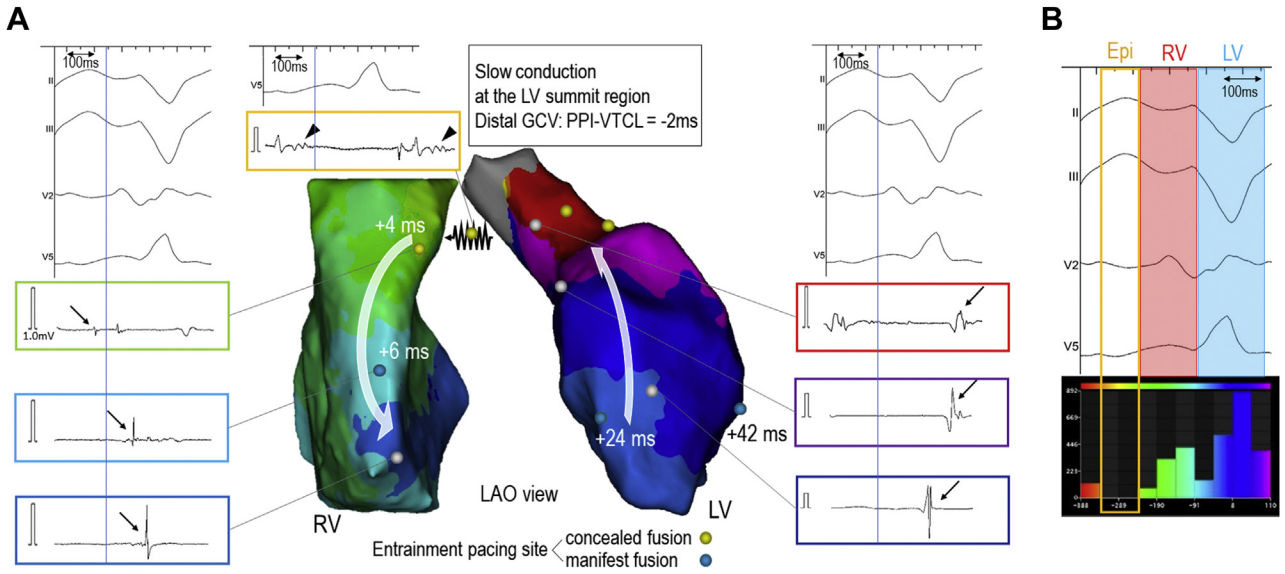

Figure 2 **A:** Local activation time map of both ventricles during ventricular tachycardia (VT). Annotated electrograms at each site are indicated by arrows. Moreover, the difference between the postpacing interval of entrainment pacing and the VT cycle length is exhibited at the sites indicated by yellow and blue tags. Biventricular activation map combined with entrainment pacing suggested a large reentrant circuit rotating around the interventricular septum in a counterclockwise manner (*white arrow*) involving both ventricles. Of note, a fragmented potential (*arrowhead*) was recorded at the left ventricle (LV) summit region. **B:** Histogram of the local activation time and activation timing of both ventricles and the epicardium corresponding to the 12-lead electrocardiogram. The diastolic phase of VT activation (*orange rectangle*) was absent in both ventricles, which was complemented using a 2F microcatheter in the distal great cardiac vein (GCV). LAO = left anterior oblique view; PPI = postpacing interval; RV = right ventricle; VTCL = ventricular tachycardia cycle length.

diffuse myocardial uptake, and cardiac magnetic resonance imaging demonstrated late gadolinium enhancement at the interventricular septum. Immunosuppression therapy was initiated after cardiac resynchronization therapy with a defibrillator. During 1 year of follow-up, the patient was free of VT recurrence.

Discussion

Cardiac sarcoidosis exhibiting VT is characterized by predominant RV scarring that often involves the interventricular septum.[2] In patients with extensive septal scarring, disruption of transseptal activation occurs, and transseptal breakthrough occurs at the apical edge of the scar border.[5] In the present

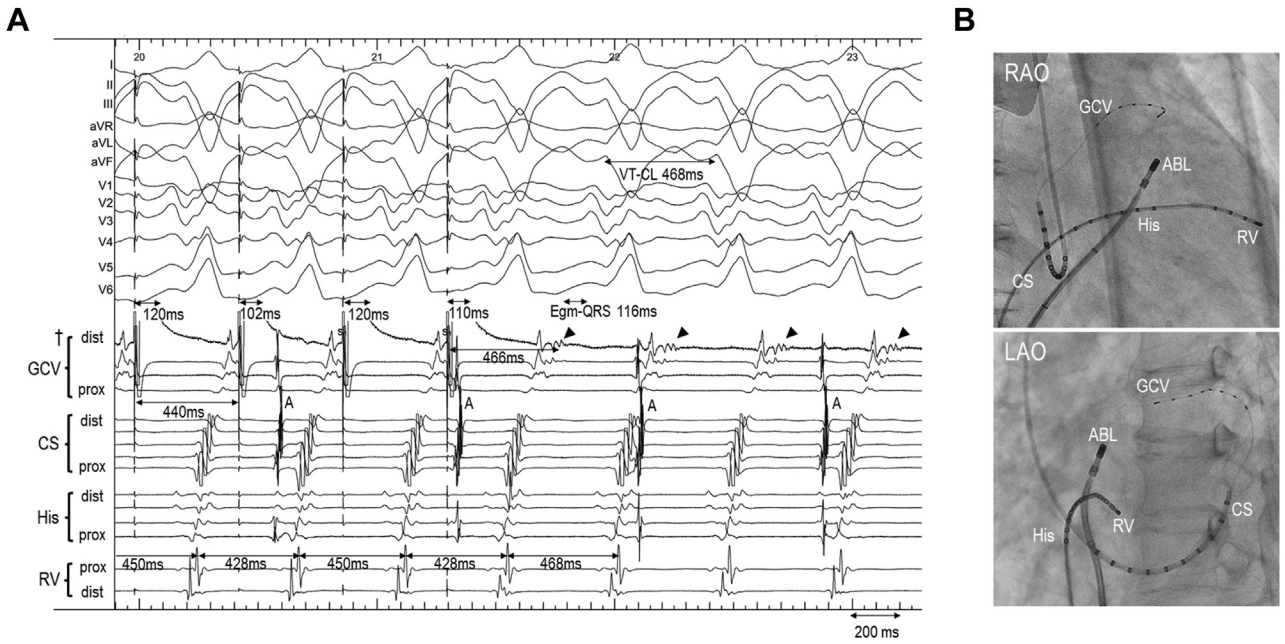

Figure 3 Intracardiac electrocardiograms of the entrainment pacing at the distal branch of the great cardiac vein (GCV) (**A**) and catheter position on the fluoroscopic images (**B**). Entrainment pacing at the distal branch of the GCV showed an excellent pace map to the clinical ventricular tachycardia with alternate pacing capture. ABL = ablation catheter; CS = coronary sinus; dGCV = distal branch of the great cardiac vein; LAO = left anterior oblique view; RAO = right anterior oblique view; RV = right ventricle; VTCL = ventricular tachycardia cycle length.

case, extensive intramural enhancement in the interventricular septum disrupted transseptal activation. BVT is a rare form of macroreentrant VT that includes both ventricles as a circuit. In the present case, the activation durations in the LV, RV, and epicardial circuit were 202 ms (43%), 146 ms (31%), and 124 ms (26%), respectively. Our case may be similar to biatrial tachycardia using the left and right atrial septum with 2 interatrial connections, that is, a single-loop macroreentrant tachycardia involving the right and left atria that usually arises after anterior linear ablation or a surgical procedure.[6,7] Unlike interatrial connections, there are no distinct pathways connecting both ventricles, and impulses conduct directly opposite the interventricular septum.[6] In the present case, the progression of the cardiac sarcoidosis during the untreated 5-year period resulted in extensive fibrosis of the interventricular septum, leading to disrupted transseptal activation. Consequently, an extensive intramural scar in the interventricular septum with 2 transseptal breakthroughs, 1 in the apical edge of the scar and the other in the LVOT epicardium, provided a critical component of BVT rotating around the septum.

The ECG features of interatrial block were characterized by a prolonged P wave with biphasic morphology (positive/negative) in the inferior leads.[8] A detailed electroanatomical mapping study in patients with interatrial block demonstrated ascending activation of the left atrium, suggesting a Bachmann bundle block.[9] In the present case, serial 12-lead ECG records suggested progression of the interventricular block similar to an interatrial block. The initial 12-lead ECG demonstrated a notched R wave with positive deflection in the latter half of the QRS waveform in the inferior leads (Figure 1A), suggesting that the impulse propagated over the left bundle followed by left-to-right transseptal activation at the basal septum. Phased descending activation of both ventricles resulted in a notched R wave in the inferior leads. After 5 years, the latter half of the QRS waveform in the inferior leads was altered to negative and ascending activation in the RV, suggesting that left-to-right transseptal activation at the basal septum was diminished but conducted at the apical septum (Figure 1B and Supplemental Movie 2). Moreover, disappearance of the S wave in leads I and aVF despite the right bundle branch block pattern in V_1 suggested bilateral bundle branch delay/block, which further implied progression of the conduction delay in the left bundle branch.[10] Similar to an interatrial block and new-onset atrial arrhythmia,[11] these unique QRS morphological changes during sinus rhythm suggested the progression of an interventricular conduction block and subsequently caused scar-related VT.

The importance of septal coronary venous mapping to guide substrate characterization and ablation of intramural septal ventricular arrhythmia was recently reported.[12] In that study, intramural septal VT was identified when any of the following conditions suggested an intramural origin: (1) activation mapping showing isochronal local activation times in multiple anatomical sites without the identification of an earlier site; (2) best pace mapping intraseptally in cases in which the activation time was isochronic with that of other adjacent structures; (3) absence of presystolic electrograms or concealed entrainment with a return cycle within 30 ms from the tachycardia cycle length from LVOT-adjacent structures; and (4) failed ablation attempts from the adjacent structures. Ideally, septal coronary venous mapping with a 2F microcatheter would provide further insight into the mechanism of reentrant tachycardia. Nevertheless, phased biventricular activation, the earliest activation site in the RVOT, concealed entrainment in the distal GCV, and achievement of no inducibility of tachycardia from the RVOT suggested that BVT was likely a mechanism of this unique tachycardia.

Conclusion

Disrupted transseptal activation owing to extensive intramural scarring in an untreated cardiac sarcoidosis patient provided a unique circuit for BVT. Detailed mapping including the epicardial site was required to confirm the tachycardia circuit.

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Appendix

Supplementary data

Supplementary data associated with this article can be found in the online version at https://doi.org/10.1016/j.hrcr.2022.03.004.

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