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ORIGINAL ARTICLE

Endocardial, epicardial, and right atrial approach for catheter ablation of premature ventricular contractions from the inferoseptal process of the left ventricle

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Abstract

Background: Inferoseptal process of the left ventricle (ISP-LV) might be a source of idiopathic ventricular arrhythmias. In these cases, ectopic foci are accessible from the LV endocardium, epicardially from the middle cardiac vein as well as from the right atrium (RA). This study reports a series of patients with premature ventricular contractions (PVCs) arising from the ISP-LV that were successfully ablated following access from different structures.

Methods and Results: Five patients (4 males, age 61 ± 12.8 years) with PVCs arising from the ISP-LV were successfully ablated using three different approaches for ablation—endocardial, epicardial (through coronary sinus or its branches), and RA approaches. Endocardial LV mapping, RA, and coronary sinus (CS) mapping were performed in all five cases. PVCs demonstrated RBBB or LBBB-like morphology and left superior axis. The three patients ablated endocardially had a maximum deflection index (MDI) of 0.36, 0.43, and 0.54, whereas in the remaining 2 patients, MDI was 0.57 and both demonstrated QS morphology in the inferior leads. Local activation time at the successful ablation site was 35 ± 8.9 (26–55) msec pre-QRS. Pacemapping at the successful ablation site resulted in a good (11/12) or perfect (12/12) QRS match in all cases. Three of the patients demonstrated frequent monomorphic PVCs of another morphology suggesting a remote exit site. All patients remained arrhythmia-free after a mean follow-up of 21 ± 15 (6–36) months.

Conclusion: Successful ablation of PVCs from ISP-LV may require access from the CS or even RA apart from LV endocardial approach. Not infrequently patients demonstrate additional PVC foci.

KEYWORDS
catheter ablation, crux arrhythmias, Inferoseptal left ventricular process, premature ventricular contraction

1 | INTRODUCTION

Premature ventricular contractions (PVCs) arising from the left ventricular (LV) inferoseptal process (ISP-LV) are a relatively rare entity. This structure is situated on the most basal and inferior areas of the LV septum.[1] ISP-LV was first described as the posterior–superior process of the LV across which the superior septal and the atrioventricular node arteries run. Later on, the more attitudinally correct term inferoseptal process was introduced to describe this structure. The septal segment of the right atrium (RA) and the proximal coronary sinus (CS) are located in its immediate vicinity.[2]

In this study, we describe the clinical characteristics, ECG, and electrophysiological findings of consecutive patients with PVCs arising from ISP-LV ablated using endocardial, epicardial, and RA approaches.

2 | METHODS

In the period between August 2016 and June 2020, there were 110 patients with PVCs referred for ablation to our center. Five of them (4.6%) demonstrated symptomatic recurrent PVCs that were ablated from the ISP-LV and were included in this retrospective analysis.

Baseline characteristics of the patients—age, gender, ECG, and routine echocardiographic parameters were studied. Preprocedural resting 12-lead ECG was recorded at 25 mm/s and with a standard gain of 1 mV/cm (filtering between 0.05 Hz and 100 Hz). The polarity and relative amplitude of each component of the QRS complexes of the PVCs were analyzed in each lead. Precordial QRS transition was evaluated by characterizing the ratio between the positive (R wave) and the sum of positive and negative components of the QRS across each precordial lead. The likelihood of epicardial exit site of PVC was assessed by the published ECG criteria: q wave in lead I and absent q waves in inferior leads;[3,4] interval criteria: pseudo-delta wave ≥34 ms, intrinsicoid deflection time ≥85 ms, shortest RS complex ≥121 ms, and a maximum deflection index (MDI) calculated as the shortest interval from QRS onset to maximum deflection (above or below the isoelectric line) in any precordial lead divided by the total QRS duration as previously described.[5,6] An MDI ≥ 0.55 was considered to suggest an epicardial origin of PVC.

2.1 | Electrophysiological study

All patients underwent electrophysiological study after withdrawal of antiarrhythmic drugs for at least five half-lives. Following femoral venous vein access multielectrode catheters were introduced in the CS (decapolar catheter, interelectrode distance 2–5-2 mm), the right ventricular apex (RVA) (quadripolar catheter, interelectrode distance 5 mm). In case PVCs were frequent we proceeded to mapping. If PVCs were rare or absent at the beginning of the procedure, induction was attempted by burst stimulation with progressive cycle length (CL) shortening down to 200 ms and programmed ventricular stimulation with two drive CLs—400 and 600 ms and up to three extrastimuli. A bolus of 10 mcg hexoprenaline i.v. was administered and the stimulation protocol was repeated at the operator's discretion.

2.2 | Mapping and ablation

All patients underwent LV endocardial mapping with a quadripolar steerable 4 mm irrigated tip catheter (Flexability™, Abbott) via transseptal or retrograde aortic approach at operator's discretion. Intracardiac ultrasound (ICE) to guide mapping and ablation was also used. Three-dimensional (3D) anatomical maps of the LV, RA, and CS were created using one of the commercially available mapping systems (EnSite Precision, Abbott). In cases of frequent ectopy an activation map was also created. Activation times defined as the point of maximal negative slope of the initial downstroke when using unipolar EGMs and the onset of the signal when using bipolar EGMs, were measured by two independent observers and displayed on the 3D mapping system as well as on the EP recording system. Pacemapping at the successful ablation site was performed in all five cases. Morphology of the paced QRS was visually assessed by two experienced electrophysiologists (V.T. and D.M.) who compared each of the 12 ECG leads of the pacemap to the PVC morphology in terms of QRS vector, morphology, and the presence of major notching. A perfect match was regarded as the presence of identical QRS morphology between the paced beats and the PVCs in 12 of 12 ECG leads and a good match was considered to be present when 11 of 12 ECG leads showed identical morphology.

Ablation was targeted at the site of earliest ventricular activation during PVC and/or the site of good or perfect pacemap. In the LV endocardium and the RA, RF current was delivered in the power-control mode (temperature cutoff limit 42°C) using a power of 25–35 W and a flow rate of 17 mL/min. During applications in the CS branches power was gradually up-titrated in 5 W increments starting from 10 W and reaching a maximum of 25 W. RF delivery was terminated if PVCs were not suppressed after 20 s. In the RA ablation was delivered at the site of the earliest far-field ventricular electrogram in the inferoseptal RA adjacent to the LV as described before.[7] The endpoint of the procedure was the absence of the clinical PVCs after a 30-min waiting period and following a reinduction attempt with the protocol described above.

2.3 | Follow-up

All patients were followed up at the first, third, and sixth months after the procedure by clinical examination including 12-lead surface ECG as well as 24-h Holter monitoring. Additional visits were performed upon occurrence of symptoms, possibly associated with PVC recurrence.

All the patients signed a written informed consent for the procedure and the study was approved by the local ethics committee.

2.4 | Statistical analysis

Continuous variables are presented as mean ± standard deviation (minimum-maximum) for the normally distributed data. Nonnormally distributed data are presented as median (IQR 25–75 percentile). Categorical variables are expressed as numbers (%). Analysis was performed using the software package SPSS 16.0.

3 | RESULTS

3.1 | Clinical characteristics

The clinical and demographical characteristics of the patients are shown in Table 1. The mean age of the studied patients was 61.0 ± 16.3 (42–73) years with a mean PVC burden of 11.16% (range 5.2–20%). Four of the patients had no evidence of LV systolic dysfunction and the mean LV ejection fraction of the patients was 52.8 ± 12.6 (37–70)%. All patients had a failure of at least one antiarrhythmic drug. None of the patients had evidence of significant coronary artery disease assessed by preprocedural stress test or coronary angiography. Four of the patients had a history of hypertension and none had diabetes mellitus.

3.2 | ECG characteristics

The predominant morphology of PVCs in the studied series was consistent with an inferior and basal exit site demonstrating RBBB or LBBB-like morphology and left superior axis (Figure 1). The patient with LBBB-like morphology demonstrated early precordial transition in lead V_2. R or Rs configuration in lead V_6 and QS in the inferior leads were seen in two of the patients (cases 2 and 5) and RS configuration in V_6 and rS in lead II in the rest of the patients. A monophasic R wave in lead I and aVL was present in all patients. The morphology in lead aVR was either biphasic or showed a small r wave. The calculated MDI was 0.49 ± 0.07 (0.36–0.57) with a value of >0.55 measured in cases 2 and 5. All the ECG characteristics of the studied series are presented in Table1.

Three of the five patients (cases 3, 4, and 5) demonstrated frequent monomorphic PVCs with a very different morphology at the outset suggesting a separate exit site. PVCs with RBBB patterns, inferior axis, and qR in lead V_1 (in case 3), PVCs with inferior QRS axis, LBBB morphology, and late transition in V_4 likely originating from the right ventricular outflow tract (RVOT) in case 4, and PVCs with inferior QRS axis, LBBB morphology, and transition in V_3 supposedly arising from the right coronary cusp (RCC) in case 5.

3.3 | Electrophysiologic findings, mapping, and ablation

In three of the patients, the earliest local activation time was recorded in the LV endocardium and PVC was successfully ablated with the endocardial approach (cases 1, 3, and 4) (Table 1 and Figure 2). The other two patients (cases 2 and 5) were ablated from the CS branches or from the RA where the earliest ventricular electrograms were recorded. In the whole series, mean LAT at the successful

TABLE 1 Demographic, electrocardiographic, and electrophysiological characteristics of the patients represented in the current series.

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5
Age, years	42	79	51	56	77
Gender	M	M	M	F	M
LVEF, %	59	60	37	65	70
ECG					
Number of PVC morphologies	1 (ISP-LV)	1 (ISP-LV)	2 (ISP-LV; AMC)	2 (ISP-LV; RVOT)	2 (ISP-LV; RCC)
ISP-LV PVC morphology	RBBB	RBBB	RBBB	LBBB	RBBB
Frontal plane axis	Left superior	Left superior	Left superior	Left superior	Left superior
MDI	0.36	0.57	0.43	0.54	0.57
QS in the inferior leads	No	Yes	No	No	Yes
R > S in lead V_6	Yes	Yes	Yes	Yes	Yes
Precordial RS transition	No	No	No	Yes (V_2)	No
Mapping and ablation					
Chamber of successful ablation	LV endo	MCV	LV endo	LV endo	RA
LAT at the successful ablation site, msec	−26	−55	−31	−32	−31
Follow-up, months	18	36	16	30	6

Abbreviations: AC, aortic cusps; AMC, aortomitral continuity; CS, coronary sinus; ISP-LV, inferoseptal process of the left ventricle; LAT, local activation time; LVEF, left ventricular ejection fraction; LV, left ventricle; LVH, left ventricular hypertrophy; MCV, middle cardiac vein; MDI, maximum deflection index; RA, right atrium; RCC, right coronary cusp; RF, radiofrequency; RVOT, right ventricular outflow tract; TTE, transthoracic echocardiogram.

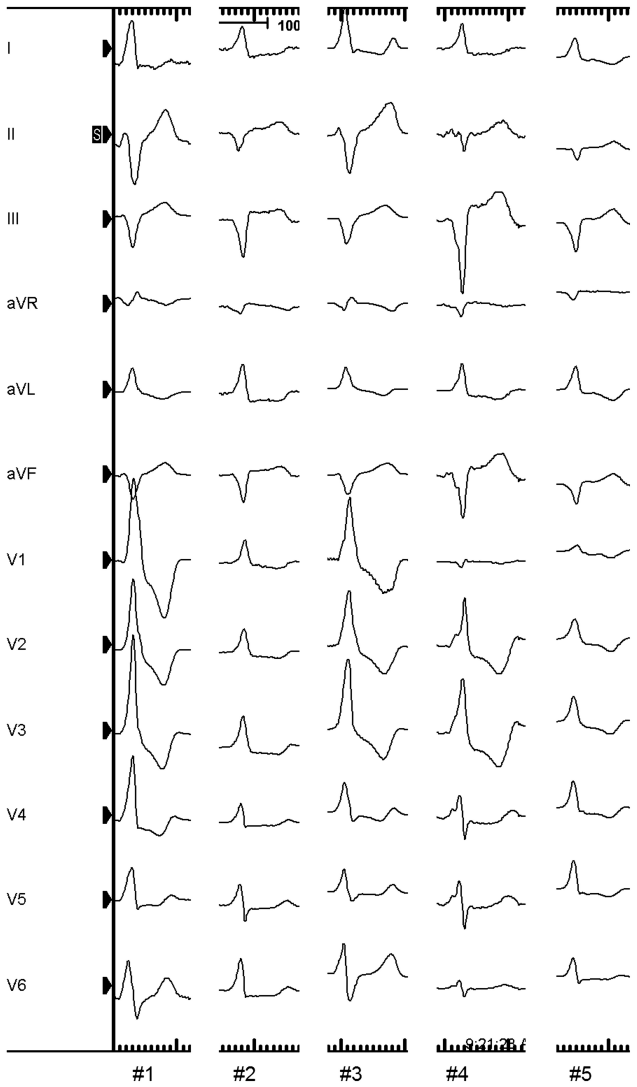

FIGURE 1 Twelve lead surface ECG describing the morphology of the premature ventricular contractions arising from the inferoseptal process of the ISP-LV. All five patients had left superior QRS axis in the frontal plane and right bundle branch block morphology (RBBB) with no RS transition in the precordial leads except patient #4 who demonstrated left bundle branch block morphology (LBBB) in precordial lead V1 and early RS transition in V2.

ablation site preceded QRS onset by 35 ± 8.9 (26–55) ms, and good (11/12) or perfect (12/12) pace-map match was found at these sites. The two cases ablated from the CS or RA demonstrated an MDI of ≥0.55 and QS in the inferior leads. In contrast to them, all the remaining cases had an MDI of <0.55 and none of them demonstrated QS in the inferior leads. In case 5, ablated within the RA (Figure 3), a larger atrial signal and small ventricular signal (5:1 AV ratio) were recorded at the successful ablation site from where LV was captured by pacing with 10 mA at 2 ms pulse width. In this patient, ablation in the inferoseptal region of the RA did not elicit a junctional rhythm. Fluoroscopic images along with the surface ECG and intracardiac recordings with the corresponding pace-map from the successful ablation site in the LV endocardium and the coronary venous system in two of the studied patients are shown in Figure 4.

3.4 | Mapping and ablation of additional PVCs

As mentioned above, three of the patients (pts no. 3, 4, and 5) from our case series had an additional PVCs/VT burden which was ablated in time of the index procedure. Patient No 3 had PVCs that were mapped to the aortomitral continuity and successfully ablated. Patient No 4 had PVCs arising from the RVOT which were successfully ablated and Patient No 5 had additional PVCs arising from the right coronary cusp that were only transiently suppressed with the ablation over the RCC region and disappeared permanently with the ISP-LV PVC ablation.

3.5 | Follow-up

After a mean follow-up of 21 ± 15 (6–36) months, no arrhythmia recurrence was documented, and patients have been asymptomatic for the whole of the follow-up period. In case 3, who presented with left ventricular systolic dysfunction, there was a complete reverse remodeling (EF = 55%) by the 6 months of the follow-up.

3.6 | Complications

One of the patients (pt. no 3) had a major complication related to arterial vascular access (arteriovenous fistula) requiring surgical intervention. No other complications were observed.

4 | DISCUSSION

The main findings from the study are: first, successful ablation of PVCs from ISP-LV might also necessitate epicardial approach from CS tributaries or from RA; second, the presence of QS in the inferior limb leads and MDI > 0.55 may serve to predict the need for approach from the epicardium via the CS or RA; third, ISP-LV PVCs could occur in combination with additional PVC foci.

4.1 | ECG characteristics

The presence of nondominant R waves in the inferior leads suggests initial forces pointing inferiorly. Such a sequence could be explained by a focus situated endocardially or superiorly along the pyramidal shape of the ISP-LV. Therefore, the earliest activity is expected on the endocardial side and endocardial ablation is expected to be successful as demonstrated in cases 1, 3, and 4. Conversely, the presence of QS inferior leads, especially lead II would suggest entirely superiorly oriented initial forces supporting a focus demonstrating earliest activity on the epicardial side and therefore easily ablated from the CS or RA as was the case with two patients from our series. In addition, the PVCs in both patients demonstrated MDI > 0.55 also suggesting epicardially located focus. This finding is in line with the

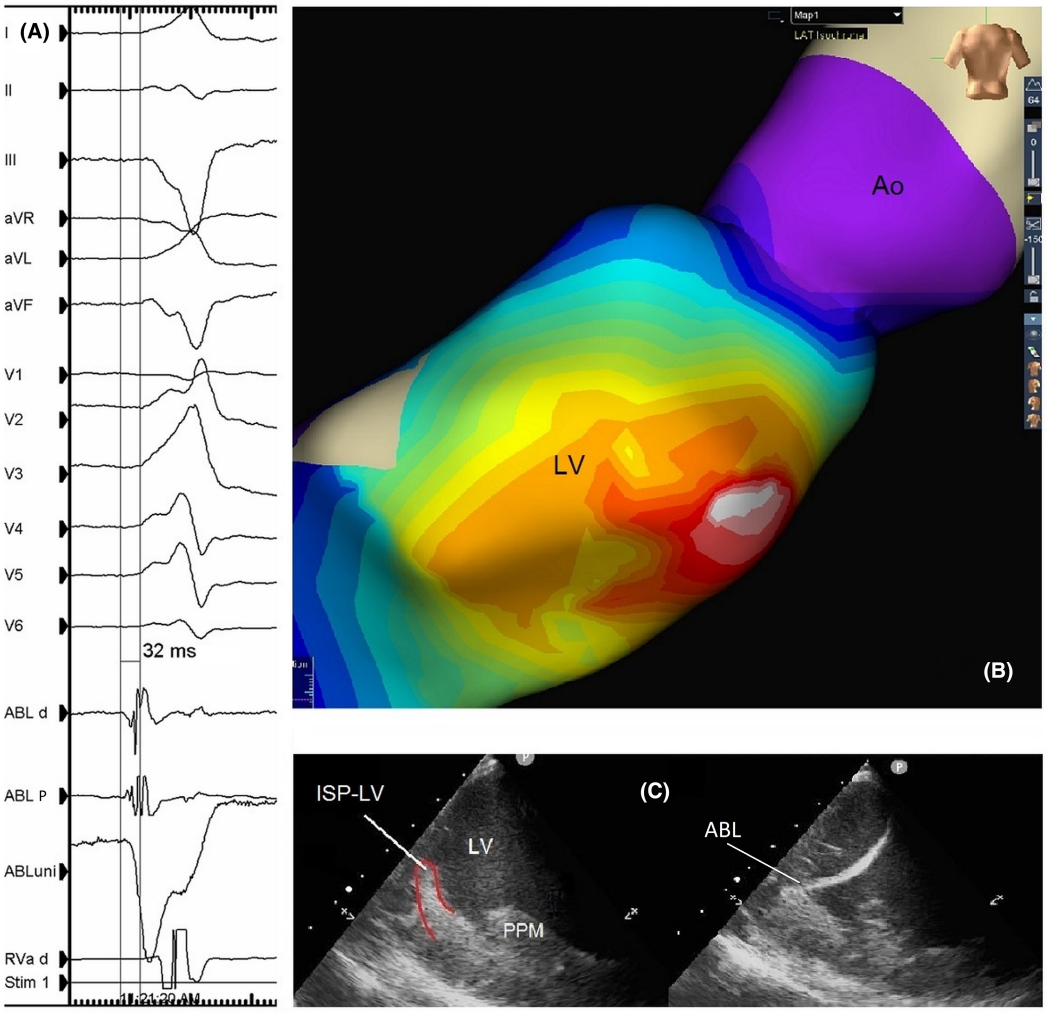

FIGURE 2 Panel (A) Twelve lead ECG and intracardiac electrograms during the clinical ectopy at the site of successful ablation in patient 4; Panel (B) electroanatomical map of the basal portion of the left ventricle in the posteroanterior view showing the earliest ventricular activation site (white isochrone) at the endocardium of the inferoseptal process of the left ventricle (ISP-LV); Panel (C): left—intracardiac echocardiography image of the ISP-LV (marked by the red line); right—the position of ablation catheter at the successful ablation site at the ISP-LV. ABL, mapping/ablation catheter; ABLd, intracardiac electrogram from the distal bipole of the mapping/ablation catheter; ABLp, intracardiac electrogram from proximal bipole of the mapping/ablation catheter; ABLuni, unipolar intracardiac electrogram from the tip of the mapping/ablation catheter; Ao, Aorta; ISP-LV, inferoseptal process of the left ventricle; LV, left ventricle; PPM, posterior papillary muscle; RVAd, intracardiac electrogram from the distal bipole of the catheter, positioned at the right ventricular apex; Stim, stimulation channel.

study by Li et al.,[1] where none of the 7 patients effectively ablated from the endocardium showed these two characteristics.

In another study, Santangeli et al. reported a case series of five patients with PVCs arising from the ISP-LV who were successfully ablated using the RA approach.[7] In this report, ECG patterns were quite heterogenous showing LBBB-like morphology with left superior and left inferior axis and RBBB-like morphology with left superior axis, and early or no precordial transition (positive concordance). Despite this heterogeneity, the calculated MDI was 60% ± 4% (range 53%–65%) and an R wave amplitude in lead II greater than lead III was present in all patients. A potential explanation for this could be different exit sites along the ISP-LV. In our case series, patients had a more homogeneous ECG morphology (mostly RBBB-like morphology with superior axis), except one patient (case 4) who had PVC with LBBB-like, left superior axis morphology. Probably, this difference is due to the small number of patients. We report only one case ablated from the RA with RBBB-like morphology and superior axis.

In a recently published article, Larsen et al.[8] performed detailed mapping from five adjacent chambers as an approach in the ablation of PVCs arising from the basal inferoseptal (BIS) area in 17 patients. Successful ablation site was in LV in 10 (59%), RV in 2 (12%), CS/MCV in 1 (6%), RA in 1 (6%), and was located epicardially in 2 (12%) patients. Consistent with our findings they described a predominantly leftward superior axis in all patients (monophasic R in lead I and lead III more negative than lead II) and RBBB-like morphology in

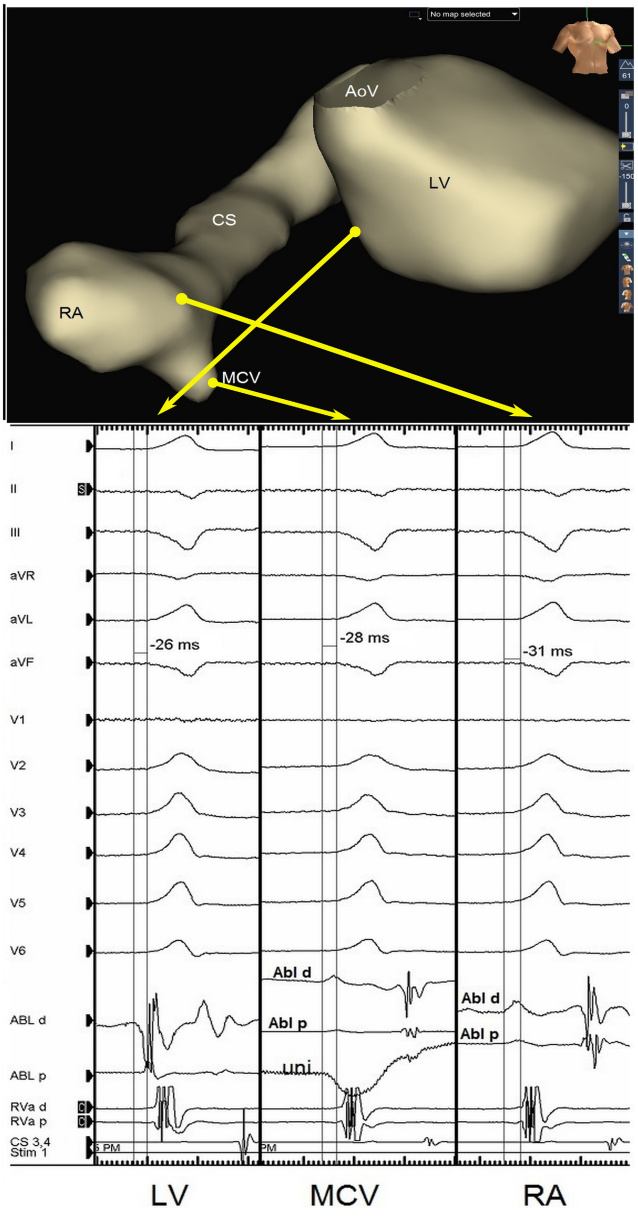

FIGURE 3 The upper panel shows an anatomical map of the basal portion of the left ventricle (LV), inferoseptal region of the right atrium (RA), and coronary sinus (CS) in case no. 5. The lower panel shows the earliest LV endocardial activation preceding the QRS onset by 26 ms positioned at the ISP-LV (left). Subsequent mapping revealed earlier activation in the CS, especially at the MCV ostium where the earliest electrogram preceded the QRS onset by 28 ms (middle). Mapping the RA inferoseptal region demonstrated even earlier activation preceding the surface ECG by 31 ms (right). Ablation at this latter point eliminated the ectopic activity from both the ISP-LV. AV ratio between 3:1 and 5:1 could be seen while mapping MCV and RA inferoseptum. AoV, aortic valve; CS, coronary sinus. The other abbreviations as in Figure 2.

53% (9 of 17) of the patients. Premature ventricular complexes with an LBBB-like morphology and MDI of >0.55 were mapped and ablated in the proximal CS and/or MCV in 4 patients. Of them only one had an initial R in limb lead II. One patient required a percutaneous epicardial approach for successful ablation after ablation in the coronary venous system failed. Two patients in their series were ablated from the RA, only one of whom demonstrated an MDI of >0.55 and the absence of an initial R wave in lead II. During follow-up only this patient of the two remained free from PVCs. Consistent with this data we report that in our case that was successfully ablated from the RA, MDI was more than 0.55 and there was QS in the inferior leads.

4.2 | Approach to ablation

Due to the anatomical relations with adjacent structures, ISP-LV is accessible from the LV endocardium and inferoseptal RA.[2] Several reports have demonstrated the feasibility and safety of the different approaches (endocardial and epicardial from CS and RA) for the ablation of PVC originating from ISP-LV (Figure 5).[1,7–9] While endocardial access is associated with all the inherent risks of access to the left heart–vascular access complications, embolism, etc. a major safety issue with RA and CS approaches is thought to be the potential risk for AV block following RF application in the pyramidal space, where the AV node artery runs and in the slow pathway region with the RA approaches. Larsen et al.[8] reported that one patient of their 17 patients study had a transient 2:1 AV nodal block that resolved within 5 min. Li et al.[1] have reported brief periods of accelerated junctional rhythm during LV endocardial ablation. For this reason, Santangeli et al. reported using cryoenergy for two of their cases.[7] In contrast to these reports, we used RF energy to ablate all five cases from our series and did not observe any impairment of AV conduction. No junctional rhythm was elicited during RF application in any of the patients from our series.

4.3 | Additional PVC morphologies

Patients 3, 4, and 5 had additional PVC ectopy, arising from AMC, RVOT, and RCC, respectively. The presence of pleomorphic PVCs might affect ablation outcomes. Successful elimination of the predominant PVC often results in optimal clinical outcomes, even if not all PVCs are targeted. Although pleomorphic PVCs infrequently require repeat ablation procedures, most recurrences are due to the reemergence of the originally targeted predominant PVC morphology.[10] Whether the additional PVC morphologies observed in our series were due to the presence of two separate foci or due to changes in the exit site cannot be confirmed with certainty. It can be speculated, however, that case 5 shows additional PVCs arising from the RCC region, and case 3 demonstrates additional PVCs arising from the AMC intramural foci with different preferential exits may be present. This is corroborated to some extent by the permanent suppression of the ectopy demonstrating early activation in the RCC in case 5 following ablation of the ISP-LV ectopy.

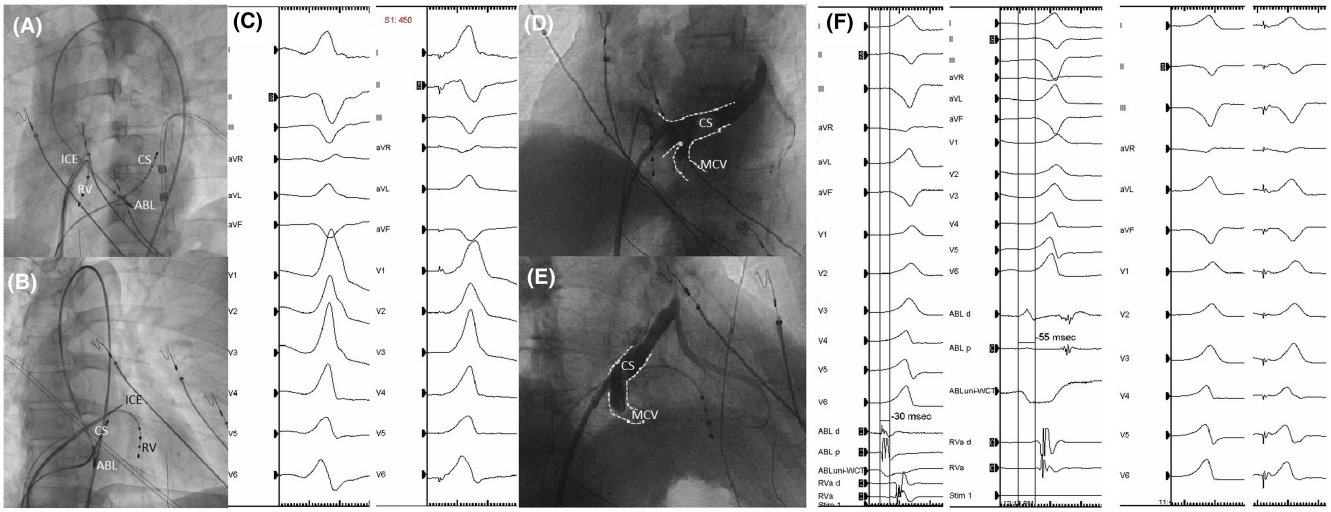

FIGURE 4 Panel (A, B, and C) represent the left anterior oblique (LAO) and right anterior oblique (RAO) fluoroscopic view of the catheter position and pace-map from the successful endocardial ablation site of PVCs arising from the inferoseptal process of the left ventricle (ISP-LV) in patient 1. The ablation catheter lies on the basal and septal portion of the left ventricle, just beneath the aortic valve where a good pace-map match at the successful ablation site was achieved. Panels (D and E) represent the LAO and RAO view of retrograde venography of the CS in patient 2 in whom the PVCs were successfully ablated from the coronary venous system as explained in the text. Panel F shows local ventricular activation timing endocardially (30 ms pre-QRS) and epicardially (55 ms, pre-QRS), recorded into the proximal part of the middle cardiac vein (MCV) in the same patient. The good PVC pace-map match was recorded from the same location as the mapping/ablation catheter. ABL, mapping/ablation catheter; CS, coronary sinus catheter; ICE, intracardiac echocardiography catheter; RV, right ventricle catheter. Sweep speed for all recordings is 100 mm/s.

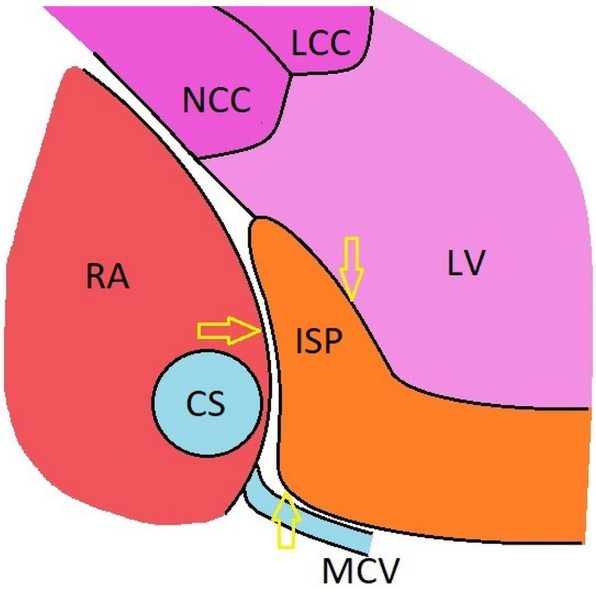

FIGURE 5 Schematic representation of the anatomical relations of the inferoseptal process of the left ventricle (ISP-LV) to the adjacent structures. The yellow arrows show the three possible approaches (endocardial and epicardial from CS and RA) for the ablation of PVCs originating from the ISP-LV. CS, coronary sinus ostium; LV, left ventricle; MCV, Middle cardiac vein; NCC, noncoronary cusp of the aortic valve; LCC, left coronary cusp of the aortic valve; RA, right atrium.

5 | CONCLUSION

PVCs from the ISP-LV are a rare entity readily amenable to ablation but may require access from the CS or even RA in addition to the most frequent LV endocardial approach. The presence of QS in the inferior leads in combination with MDI of ≥0.55 might serve to identify the patients who might require CS or RA approach for successful ablation. Not uncommonly, patients with ISP-LV ectopy might also elicit other PVC foci. Further studies into the underlying mechanism behind this relationship are needed.

FUNDING INFORMATION

None.

CONFLICT OF INTEREST STATEMENT

VT has received speakers' honoraria and consultancy fees from Boehringer Ingelheim, Astra Zeneca, Teva, Berlin Chemie Menarini, Pfizer, Novatis, Bayer, Merck Sharp & Dohme, and Abbott, none of the declared conflicts of interest are relevant to the current work. The other authors declare no conflicts of interest relevant to the current work.

DATA AVAILABILITY STATEMENT

Data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS APPROVAL

The study has been approved by the local ethics committee and complies with the declaration of Helsinki.

INFORMED CONSENT

All the study subjects signed informed consent.

CLINICAL TRIAL REGISTRATION

N/A.

PATIENT CONSENT

All the study subjects signed informed consent.

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