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Unique features of epicardial ventricular arrhythmias/premature ventricular complexes ablated from coronary venous system in veteran population

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ABSTRACT

Introduction: Ventricular arrhythmias/premature ventricular complexes (VA/PVCs) that can be ablated from within the coronary venous system (CVS) have not been described in the United States Veterans Health Administration (VHA) population. We retrospectively studied the VA/PVCs ablations that were performed in the VHA population.

Methods: Data from 42 consecutive patients who underwent VA/PVCs ablation at Veterans Affairs Hospital, Indianapolis, IN, with 44 VA/PVCs was included in the study. Patients were divided into two groups (CVS group [n = 10], and non-CVS group [n = 32]) based on where the earliest pre-systolic activation was seen with >95% pacematch.

Results: The mean age in CVS group was 65 ± 8 years versus 64 ± 12 years (p = 0.69) in non-CVS group. Overall there was a statistically significant reduction in PVC burden post ablation (27.7% (pre-ablation) versus 4.7% (post-ablation). In the 10 patients in the CVS group, either ablation or catheter-related mechanical trauma resulted in complete (n = 6 [60%]) or partial (n = 4 [40%]) long-term suppression of VA/PVCs. Right bundle branch block-type VA/PVC (9/11: 82%) was the most common morphology in the CVS group, whereas in the non-CVS group, this type was seen in only 3/33 (9%). The CVS group (25% of total VA/PVCs) had shorter activation time compared to non CVS group.

Conclusion: In our experience VA/PVCs with electrocardiograms suggestive of epicardial origin can often be safely and successfully ablated within the coronary venous system. These arrhythmias have unique features in Veterans patient population.

1. Introduction

Mapping and ablation of ventricular arrhythmias (VA; non-sustained or sustained ventricular tachycardia [VT] or fibrillation (VF) or premature ventricular complexes (PVCs) from within the coronary venous system (CVS) has previously been described in the literature. The prevalence of VA/PVCs with earliest activation localized to the CVS among all other VA/PVCs varies in the literature from 9% to 15% [1–5] and the success rate among those who received ablation within the CVS also varies between 36% to nearly 100% in smaller studies [5–8]. Ablation from within the CVS poses significant potential risk, with complications include venous perforation, damage to adjacent coronary arteries or the phrenic nerve [7,9,10]. Nevertheless, the CVS is a valuable site for mapping VA/PVCs, especially those arising from the right or left ventricular outflow regions and in the portion of the left ventricle (LV) known as the LV summit, where ablation success is limited due to need for epicardial access as well as presence of epicardial fat and proximity to coronary arteries and phrenic nerve [4–6,11].

Abbreviations: CVS, coronary venous system; PVC, Premature ventricular complexes; VA, Ventricular arrhythmia; VT, Ventricular tachycardia; EP, Electrophysiology; LVEF, Left ventricular ejection fraction.

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However, ablation of VA/PVCs from CVS has not been described in the American Veteran Health Administration (VHA) patient population. This population is unique because of overall poorer health and more comorbid medical conditions, compared to the general population. The purpose of the present study is to report the experience with catheter ablation of VA/PVCs at a single-center, VHA hospital and describe the prevalence and electrophysiologic characteristics of VA/PVCs localized to the CVS, along with outcomes of ablation within the CVS.

2. Methods

2.1. Study population

The study population included veterans who underwent cardiac electrophysiology (EP) procedures for evaluation and treatment of ventricular arrhythmias (non-sustained or sustained ventricular tachycardia or fibrillation) or premature ventricular complexes at Roudebush Veterans Affairs Hospital, Indianapolis, IN. There were 42 patients who underwent EP procedures for this indication from April 2015 until December 2018. Of these, 2 had more than one morphology of clinical (spontaneously-occurring) PVC/VA; thus, a total of 44 VA/PVCs were included in this study. In two cases no ablation was performed because of the arrhythmia source's proximity to a major coronary artery. Both of these cases have been included in final analysis.

Among the 44 VA/PVCs, 11 had origins mapped to within the coronary venous system. All patients had echocardiogram with left ventricular ejection fraction (LVEF) estimation prior to the procedure; all but 6 had long-term ambulatory ECG monitoring prior to the procedure for quantification of PVC burden. All patients were symptomatic from their arrhythmia. Of the 6 patients who did not have long-term ambulatory ECG monitoring prior to their procedure, 5 had ablation for ventricular tachycardia and one for ventricular fibrillation initiated by PVC. All patients with VA/PVCs localized in the CVS had pre-procedure ambulatory ECG monitoring. Post-ablation ambulatory monitoring was not done in 11 of the 42 patients, among whom 6 did not have pre procedure PVC quantification data.

2.2. Electrophysiological studies

The electrophysiological study was performed in patients in the fasting state and all antiarrhythmic medications were stopped at least 5 half-lives prior to procedure except for Amiodarone which was stopped two weeks prior to elective procedure. Conscious sedation or general anesthesia was used based on individual patient's comfort level. Surface ECG and intracardiac recordings were made on a CardioLab system (GE Medical, Milwaukee, WI, USA). Surface electrocardiographic (ECG) leads were placed in the standard positions and recorded simultaneously using a digital multichannel system, filtered to 30–400 Hz for bipolar signals and 0.05–400 Hz for unipolar electrograms. A 3.5 mm ablation catheter (ThermoCool®, force-sensing, Biosense Webster, Irvine, CA, USA) was used for mapping and ablation. In a few cases, a 7F PentaRay® catheter (Biosense-Webster, Irvine, CA, USA) was also used for mapping. Three-dimensional activation mapping of arrhythmias was performed using the CARTO system (Biosense-Webster, Irvine, CA, USA). An 8Fr phased array, intracardiac echocardiography (ICE) catheter (SOUNDSTAR®, Biosense-Webster, Irvine, CA, USA) was

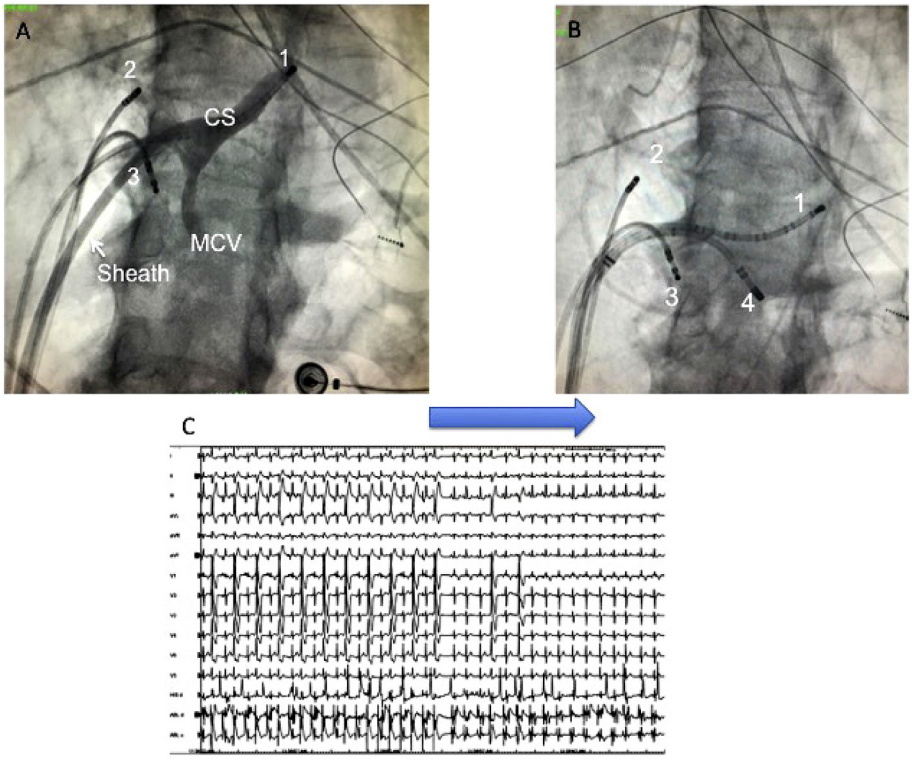

Fig. 1. Corornary sinus venogram done in a case where site of earliest activation was in middle cardiac vein.
2A: Shows coronary sinus venogram with decapolar bidirectional catheter inside the coronary sinus and SR0 sheath used for venogram.
2B: Shows ablation catheter (4) in middle cardiac vein
2C: Shows mechanical pressure resulted in suppression of the PVCs. In this case site with earliest activation and successful ablation was in the middle cardiac vein.
1: Decapolar bidirectional coronary sinus catheter, 2: Quadripolar deflectable catheter positioned at His, 3: Quadripolar deflectable catheter positioned at base of right ventricle. CS: Coronary sinus, MCV: middle cardiac vein, Sheath: SR0 sheath used for venogram.

used in all cases to assist in visualization of intracardiac structures and catheter positioning. In all cases a detailed ultrasound-based map was made for right ventricular (RV) body, left ventricle (LV), right ventricular outflow tract (RVOT), aortic sinuses of Valsalva and aortic root. The ablation catheter was used to make anatomical map of the coronary venous system. A 6Fr deflectable quadripolar catheter was placed in the right ventricle apical septum and another at the His position. Heparin was administered intravenously as boluses to maintain the activated clotting time between 250 and 300 s. For patients with infrequent PVCs at the time of the study, an infusion of isoproterenol was started and titrated to effect. A left coronary arteriogram was performed in both the right and left anterior oblique views prior to any ablation within the CS to ensure no major coronary arteries were within 4 mm [12] of the site of planned ablation. Whenever considered necessary, a coronary sinus venogram was performed (Fig. 1).

2.3. Radiofrequency ablation

Earliest QRS onset on the twelve lead ECG was used as the reference for mapping. Activation timing was measured from the sharpest ventricular deflection of the catheter/electrode of interest to the earliest deflection on the ventricular signal of the surface ECG (Fig. 2). Pace mapping of PVCs was performed at a pacing cycle length equal to the spontaneous VT or at the coupling interval of the spontaneous PVCs [13] (Fig. 3).

Radiofrequency ablation was performed at the site of earliest activation and >95% pace match with the 3.5 mm ablation catheter. When the site of earliest activation was localized to the CVS, a left coronary arteriogram was performed to assess the distance of the catheter tip to a major epicardial coronary artery (Fig. 4). If this distance was <4 mm, ablation was not performed (2 patients). In one case, the site of earliest activation was 2.5 mm from the left

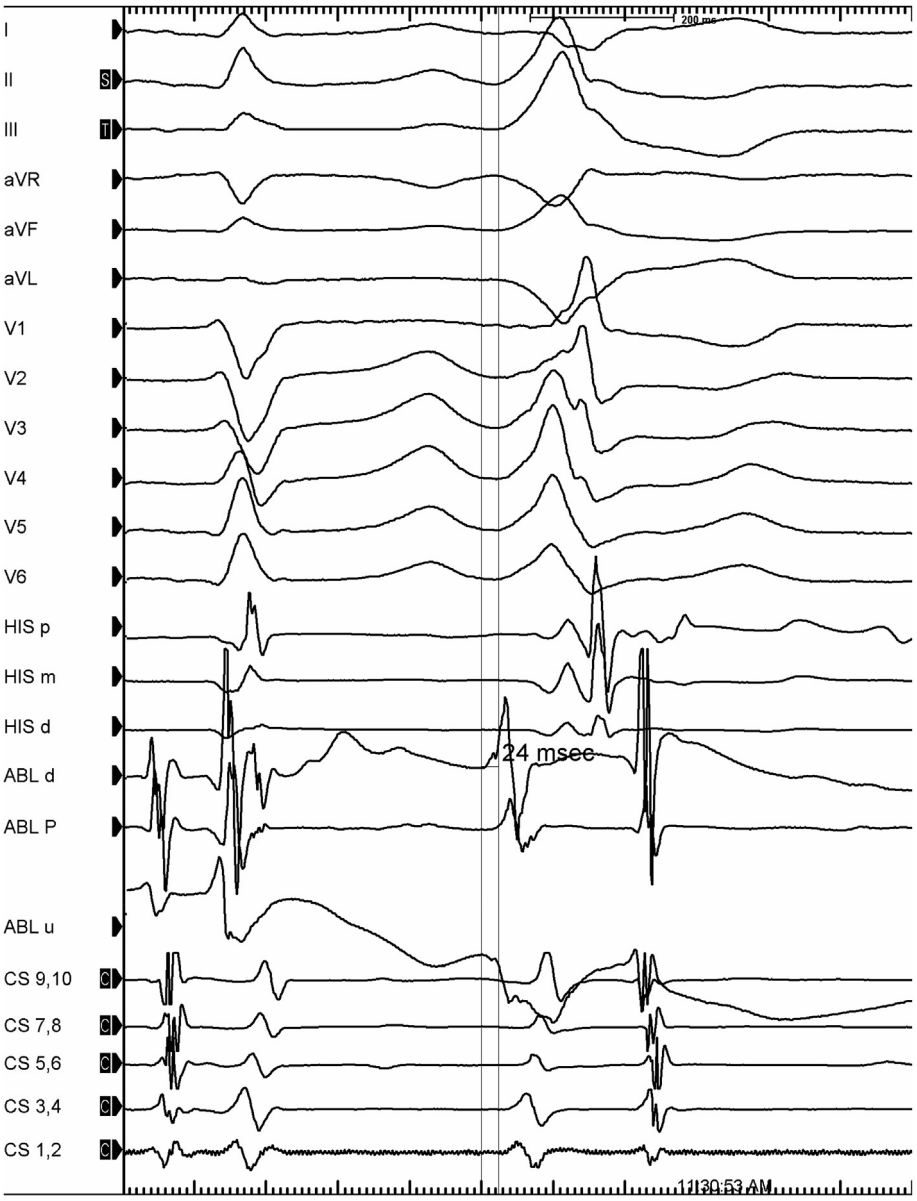

Fig. 2. Intracardiac electrograms in a case with site of earliest activation in distal Coronary venous system.
The near field earliest electrograms was 24 ms earlier than the PVC QRS onset. The unipolar electrograms shows a QS pattern and starts earlier than bipolar electrograms.

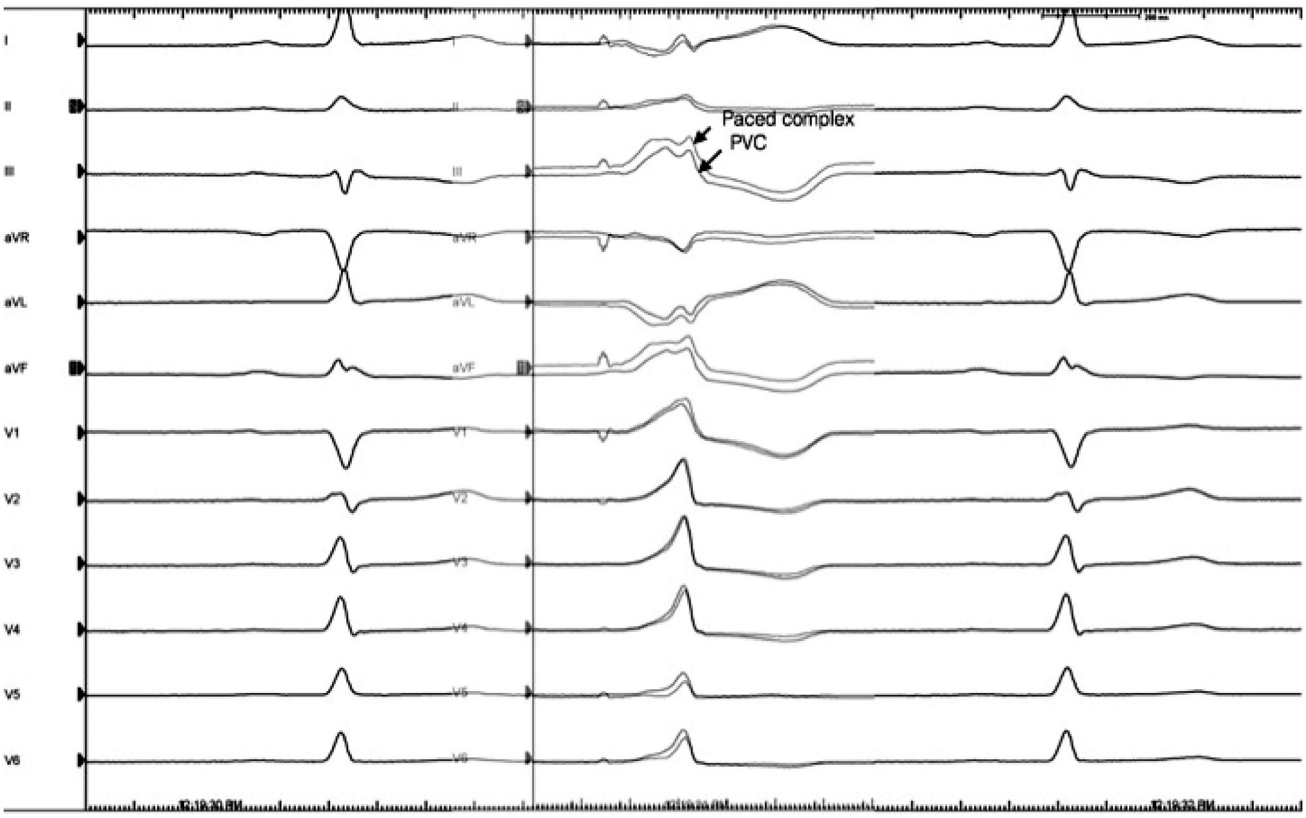

Fig. 3. Pacing from the site with earliest activation has been superimposed on the clinical PVC. It showed more than 95% pacematch.

circumflex origin (Fig. 4). In the other case, the site of earliest activation was 2 mm from the left anterior descending artery. To avoid phrenic nerve injury, high output pacing was performed to assess for diaphragmatic contraction when pacing at the site of earliest activation. In none of the cases in which earliest activation was found in the CVS was phrenic nerve capture demonstrated with stimulation.

Radiofrequency energy was delivered at a power of 20–50 W for 30–60 s. Impedance was monitored during RF delivery, that was ceased in case of rapid impedance increase (100 Ω/3 s) or at an impedance value of ≥250 Ω. (using Stockert 70 RF Generator, Stockert GmbH, Freiburg, Germany). Impedance change cut offs and maximum impedance values in some cases were adjusted to optimize minimal impedance changes to allow RF delivery and lowest maximal impedance cut off to allow for safe and effective RF delivery. Thereafter, multiple short applications of energy were used to avoid impedance increases.

Intracardiac echocardiography was used continuously to monitor for developing pericardial effusion. After completion of ablation, a 30–45 min waiting period ensued to monitor for PVC

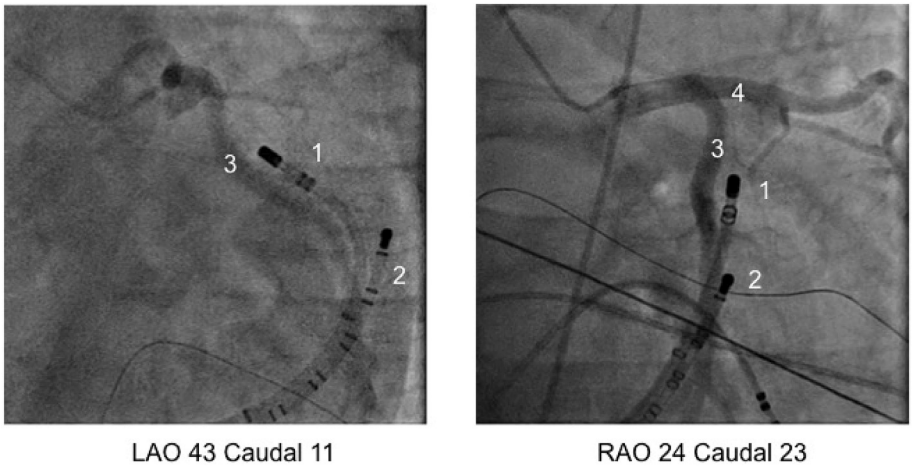

Fig. 4. Coronary arteriogram done in subject 134. Note the relative proximity of the ablation catheter (marked 1) to the left circumflex coronary artery (marked 3) in both left (LAO) and right (RAO) anterior oblique views; numbers in caption refer to viewing angles in degrees.
1: Ablation catheter, 2: Decapolar bidirectional coronary sinus catheter, 3: Left circumflex coronary artery, 4: Left anterior descending coronary artery.

Table 1
Clinical characteristics of patient population.

Parameter	Overall (N = 40)	CVS Group (N = 11)	Non CVS Group (N = 33)	P value
Age (years)	64 ± 11	66 ± 8.42	64 ± 12	0.70
Height (cm)	70 ± 3	71 ± 3	70 ± 3	0.65
Weight (pounds)	211 ± 54	223 ± 61	207 ± 52	0.40
BMI (kg/m^2)	30 ± 6	31 ± 7	30 ± 6	0.41
Gender	Males = 41 (93%) Females = 3 (7%)	Males = 11 (100%)	Males = 30 (91%) Females = 3 (9%)	0.3
Race	Caucasian = 39 (89%) African American = 5 (12%)	Caucasian = 11 (100%)	Caucasian = 28 (85%) African American = 5 (15%)	0.10
LVEF (prior to ablation) %	40. ± 16	33 ± 14	43 ± 15	0.07
LVEF % (post ablation) N = 31	51 ± 11	48 ± 13	52 ± 10	0.34
PVC burden (pre ablation) N = 38	27 ± 13	26 ± 16	27 ± 12	0.84
PVC burden (post ablation) N = 33	8 ± 6	4 ± 6	5 ± 7	0.86

Table 2
Procedural details in PVCs with sites of earliest activation within the coronary venous system versus not within the coronary venous system.

Parameters	CVS Group (N = 11)	Non CVS Group (N = 33)	P value
Earliest Activation Time (ms)	19 ± 9	27 ± 14	0.08
Procedure Time (mins)	211 ± 27	218 ± 18	0.83
Fluoroscopy Time (mins)	24 ± 11	21 ± 16	0.56
Post Procedure PVC burden	4.4 ± 6	5 ± 7	0.86
Post Procedure LVEF (%)	48 ± 13	52 ± 10	0.34
Acute Procedural Success	10/10 (100%)	28/33 (85%)	0.19
Coupling interval variation <60 ms	9 (82%)	23 (72%)	0.51

Data presented as mean ± standard deviation for continuous variables as as % for categorical variables.

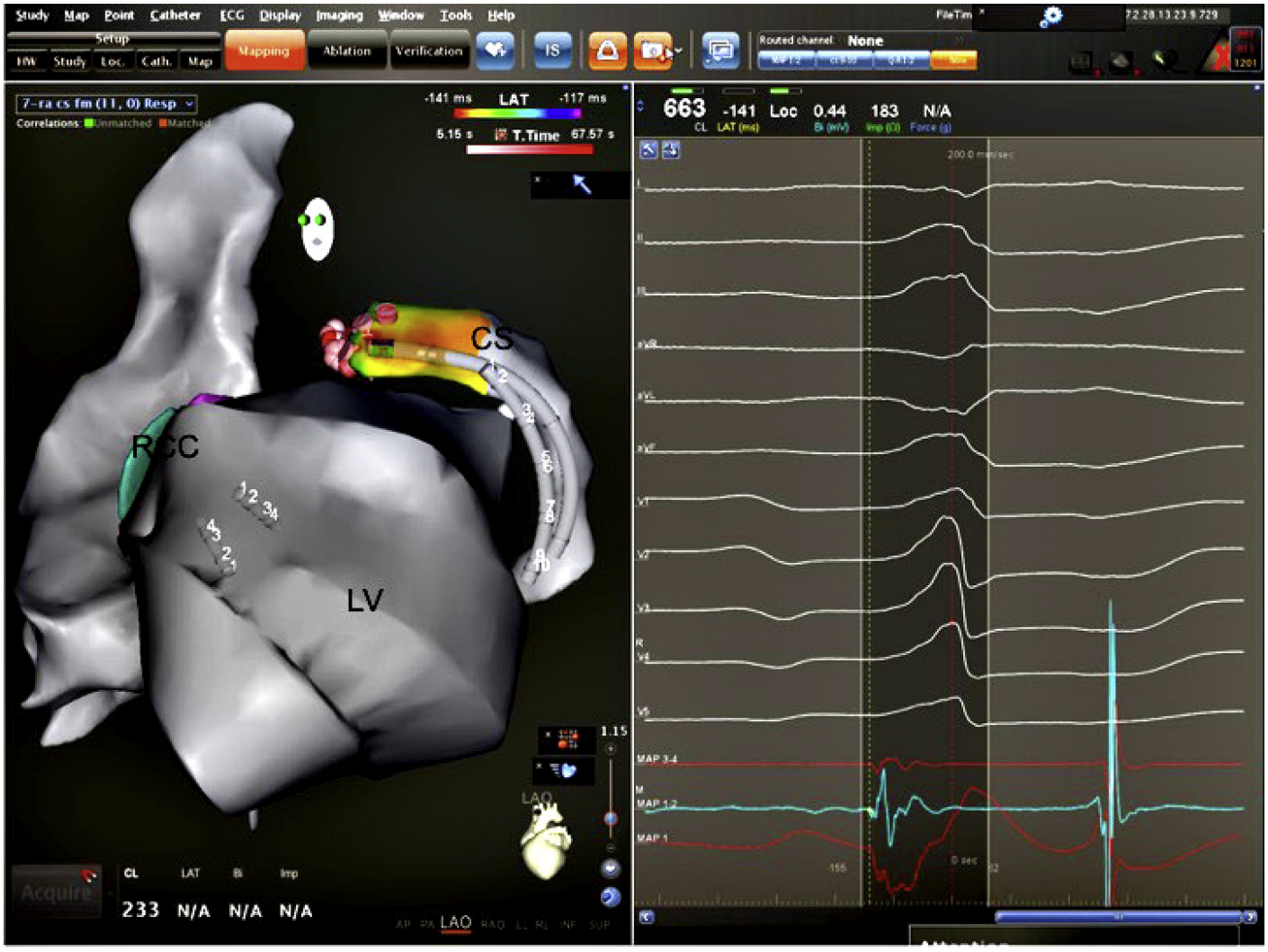

Fig. 5. CARTO map showing ablation of a PVC in the coronary venous system.
CS: Coronary sinus
LV: Left ventricle
RCC: Right coronary cusp (aortic sinus of Valsalva)
The catheter with green tip in CS is the ablation catheter. The other catheter in CS is the decapolar bidirectional catheter.

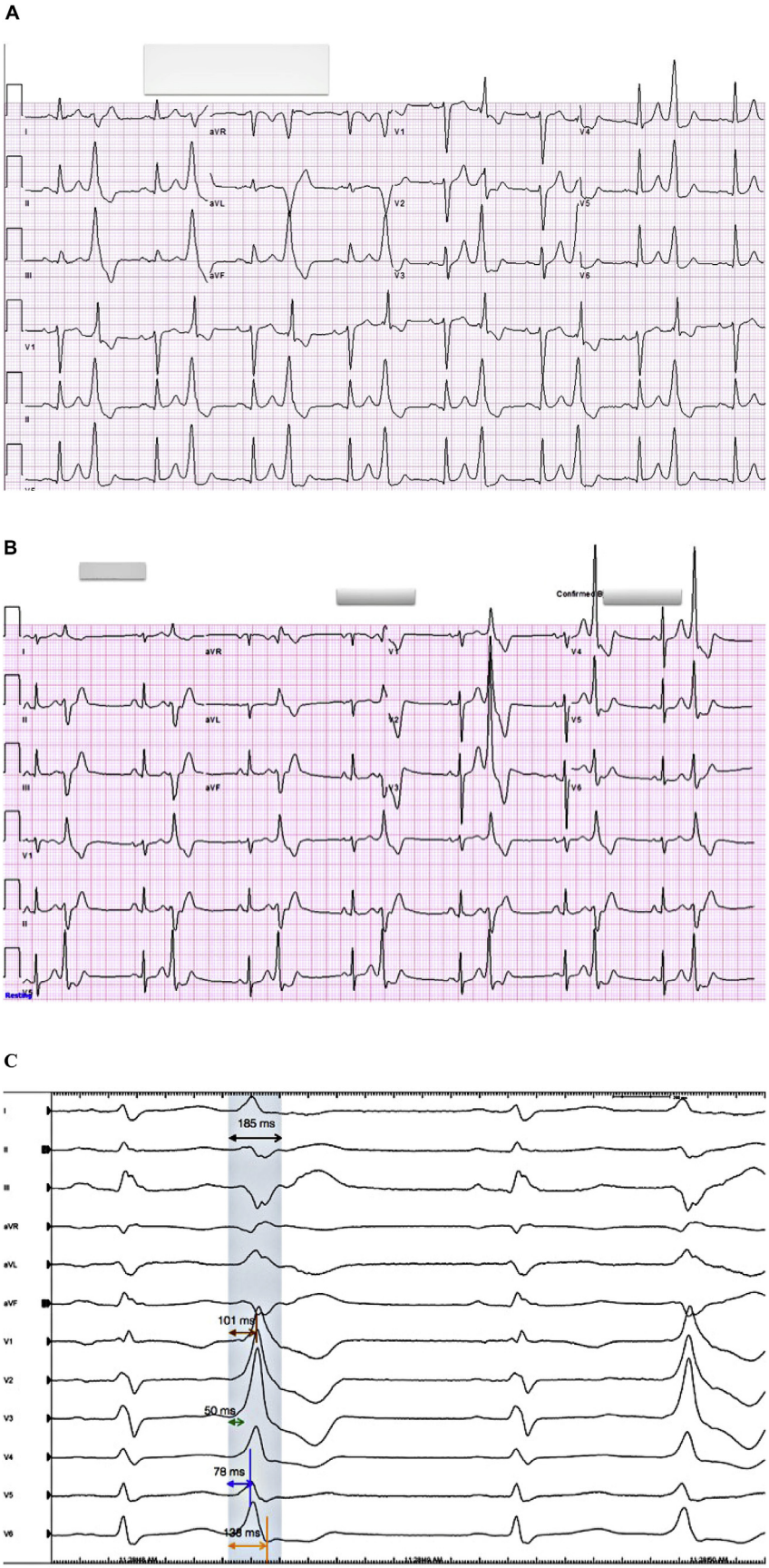

Fig. 6. A: 12 Lead Electrocardiogram showing premature ventricular complex with right bundle branch block type, right inferior axis morphology. The successful ablation site was in the distal coronary venous sysetm.

recurrence. Acute procedural success was defined as the inability to induce the targeted PVC at the end of the procedure. Complete long term success was defined as reduction in clinical PVC burden by $\geq$ 75% and partial long-term success as reduction in PVC burden by < 75%.

2.4. Follow-up

All patients had post-procedure ECG and stayed in hospital overnight while monitored on telemetry. Patients who were previously taking antiarrhythmic drugs including beta blockers were not restarted on these at time of discharge. No immediate post procedure complications were seen. Post ablation VA/PVCs burden data was not available for 11 VA/PVCs.

2.5. Statistical analysis

Continuous data are expressed as mean ± SD. Means were compared by use of Student's *t*-test for paired data and 1-way ANOVA when appropriate. Statistical analysis was performed with the STATA/IC 13.010.0 statistical package (STATACorp LLC, College Station, TX). A value of $P < 0.05$ was considered significant.

3. Results

3.1. Baseline characteristics

There were total of 42 patients. Two patients had two different morphologies of VA/PVCs, giving a total of 44 VA/PVCs for final analysis. The mean age in the overall study population was 64 ± 11 years with 93% male and 89% Caucasian. The earliest activation was seen in the CVS in 11 different VA/PVCs in 11 patients (25%).

The mean age in CVS group was 66 ± 8 years versus 64 ± 12 years (p = 0.69) in the non-CVS group. The mean body mass index (BMI) for the study population was 30 ± 6. The overall mean left ventricular ejection fraction (LVEF) prior to the procedure was 43 ± 15%. The CVS group versus non-CVS group LVEF was 33 ± 5% and 43 ± 3% respectively (p = 0.05).

There was no statistically difference in the PVC burden pre-procedure between the two groups (26% in CVS group and 27% in non-CVS group, p = 0.84). Overall there was a statistically significant reduction in PVC burden post ablation (28%–5%, P < 0.005). The PVC QRS duration in CVS group was 167 ± 4 ms versus 160 ± 6 ms in the non-CVS group (p = 0.50) (Table 1).

3.2. Catheter ablation

In the CVS group, the earliest activation was 19 ± 9 ms prior to QRS onset compared to 27 ± 14 ms in the non-CVS group (p = 0.08) (Table 2). Activation mapping was used in all CVS and non-CVS patients (Fig. 5). As mentioned earlier, in two patients ablation was not performed because of proximity of the site of earliest activation to the major coronary arteries. In one such case, it was noticed that catheter-tip pressure at the site with earliest activation resulted in transient suppression of PVCs. Therefore, the distal electrode of the ablation catheter was used to rub at that site. This resulted in immediate suppression of PVCs and post-procedure reduction in PVCs load from 27% to 5%. This reduction has persisted in last 2 years of follow up.

3.3. Sites of earliest activation in coronary venous system

In one patient the earliest activation was in middle cardiac vein (MCV). In 10 VA/PVCs cases the site of earliest activation was in distal portion of the coronary sinus and its branches. In one patient there were two different morphologies of PVCs. For one morphology the earliest activation was in the right aortic sinus of Valsalva (SOV) and the second PVC had earliest activation in the distal CS. However, it was not possible to position the ablation catheter to the site with earliest activation in the CVS seen on the CS catheter. Ablation in the right SOV resulted in complete suppression of PVC morphology from ROS as well as partial suppression of the PVC from the CVS. Earliest electrograms were not seen with percutaenous epicardial approach in the case. In the follow up ambulatory ECG monitor the overall PVC burden decreased from 39 to 19%. In the 10 patients in whom PVC/VA earliest activation site was in the CVS and either ablation or mechanical rub was performed, there was complete long-term suppression in 6/10, and partial suppression in 4/10 PVCs/VA (in one patient neither rub nor ablation was performed).

In the CVS group, the mean procedure time was 211 ± 27 min compared to 218 ± 18 min in the non-CVS patients (p = 0.83). Right bundle branch block (RBBB)-type PVC (9/11: 82%) was the most common morphology in CVS group, and 7/11 (64%) had RBBB, right inferior axis morphology (Fig. 6). In the non-CVS group, this type was seen in only 3/33 (9%). Sites closer to the junction of the anterior interventricular vein and great cardiac vein had left bundle branch block type instead of RBBB-type configuration.

4. Discussion

To our knowledge this is the first report of VA/PVCs ablation from CVS at a Veterans Affairs Hospital. In our study population, there was considerably greater percentage of patients with PVCs/VA that had earliest activation in CVS (25%) compared to other studies [4,5,13]. The reason for this is unclear but could be related to our strategy of advancing the coronary sinus catheter almost to the distal great cardiac vein and targeting earliest activation points seen on this catheter. Another possible reason could be the unique population, which has different comorbidities.

In our study we found a shorter time of earliest activation (electrogram to QRS onset), 19 ± 9 ms compared to 27 ± 14 ms in the non-CVS group. This is in contrast to earliest activation time of 29 ± 8 ms in CVS group seen in Baman et al. study [1]. Another interesting finding was mechanical trauma with the catheter tip resulting in suppression of PVCs without ablation. Both of these points suggest that the site of origin in cases in which VA/PVCs can be ablated from the CVS are very superficial in the vein or nearby epicardium. This could result in higher success rates and fewer complications compared to using a percutaneous epicardial approach. The mechanism of catheter-tip trauma resulting in suppression in one case has been described earlier and involves alteration in the electrophysiological characteristics of tissue with mechanical pressure [14]. Earlier studies have shown its benefits for localization of points of interest in ventricular and supraventricular arrhythmias [15,16]. However, there is no long-term data on the effect of mechanical suppression as the only mode of therapy. We report a single case in which we have long term data for pure mechanical suppression of PVC. This phenomenon of mechanical

B: Electrocardiogram showing premature ventricular complex with right bundle branch block type, right superior axis morphology. The successful ablation site was in the middle cardiac vein.

C: PVC from middle cardiac vein in cardiac electrophysiology laboratory with measurements.

PVC duration of 185 ms, QRS onset to peak of Lead V2 = 101 ms, Pseudo-delta wave duration = 50 ms, RS duration of 138 ms, precordial maximum deflection index (MDI) = 78 ms/185 ms = 0.42. A majority of the measurements suggest an epicardial origin of the PVC.

suppression was seen in other cases too (Fig. 1). However, in other cases RF ablation was subsequently performed.

Overall there was statistically significant improvement in LVEF post procedure ($p = 0.01$). This finding is consistent with prior reports where the lowest PVC burden of 10,000 per day, or 10% showed reversible cardiomyopathy with ablation [17,18]. Previous publications have shown reduction of PVC burden by 80% can result in improvement in LVEF [19].

4.1. Study limitations

The study has number of limitations. The sample size is small. This is a single center, single operator (RJ) study. However, ventricular arrhythmia ablations are not performed universally at Veterans Affairs hospitals. Therefore, it provides an insight into these arrhythmias in this unique population.

5. Conclusions

In patients in whom ECG features suggest epicardial origin of VA/PVCs, a coronary sinus catheter positioned in the distal great cardiac vein can suggest if the arrhythmia can be ablated from coronary venous system. In our experience with this distinct patient group, VA/PVCs with ECGs suggestive of epicardial origin can be safely and successfully ablated within the coronary venous system.

These arrhythmias have unique features in Veterans that have not been reported in other patient population.

Funding

None.

Ethical approval/informed consent

This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The Human Investigation Committee (IRB) of Indiana University approved this study.

Declaration of competing interest

John M. Miller: He is a consultant for: Biosense Webster; MediLynx; BioSig, Inc.; He gives lectures sponsored by: Biosense Webster; Medtronic, Inc.; Abbott Electrophysiology; Boston Scientific Corp.; Biotronik, Inc.; He has received fellowship training grants from Biosense-Webster; Medtronic, Inc.; Boston Scientific Corp.; Biotronik, Inc.

Rahul Jain: He has given lectures sponsored by Biosense Webster but none in the last two years.

No other authors have any conflict of interest related to this manuscript.

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