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ORIGINAL ARTICLE

# Angiographic patterns of coronary sinus anatomy and its relation to successful ablation sites in accessory pathway patients

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**KEYWORDS**

CS angiography;
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**Abstract** *Background:* The epicardial coronary venous system assumes importance in accessory pathway (AP) ablation especially in case of lengthy or failed attempts of ablation. Epicardial accessory pathways may be related to CS myocardial coat along one of its tributaries or to a CS diverticulum. The purpose of the present study was to use CS angiography to evaluate the relation of different patterns of CS anatomy to successful ablation sites of APs.
*Methods and results:* The CS-angiographic features and incidence of structural anomalies were prospectively studied in 56 patients undergoing AP radiofrequency ablation. Retrograde CS angiography was successfully performed in 46/56 pt (82%), (33 males/13 females). The CS angiographic findings of the 46 patients were compared to the AP localization established by electrophysiological mapping and to the successful ablation sites. CS anomalies were identified in 17 (37%) patients and included the following: CS diverticulum (seven patients), funnel shaped ostium (three patients), CS aneurysm (two patients), subthebasian pouch (one patient), sharp angulation (one patient), and bulbous malformation (one patient). CS diverticuli represented (41%) of the encountered CS anomalies. Seventy-one percent of the CS diverticuli were seen in posteroseptal and left posterior locations of APs. Successful ablation site was related to CS-anomalies in seven (15.2%) patients (five patients with CS diverticulum, one patient with CS aneurysm, and one patient with CS angulation). Successful ablation was achieved from within the CS (coronary sinus – accessory pathway) (CS AP) in 10 patients (21.7%) (in relation to CS tributary in six (13%) and in relation to the neck of a CS diver-

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ticulum in four patients). CS AP represented 50% of the encountered posteroseptal and left posterior APs.

*Conclusion:* CS angiography can guide us in reaching successful ablation sites of AP inside or outside the CS. CS diverticulum is the most common CS anomaly in posteroseptal and left posterior APs.



## 1. Introduction

Though catheter ablation of accessory pathways (APs) is well established, an epicardial course of APs accounts for the failure of ablation of some of these cases necessitating an epicardial approach for ablation.[1] So, the coronary sinus (CS) anatomy assumes great importance during RF-ablation of APs especially in the presence of CS anomalies. This study was designed to explore the angiographic features of the CS and evaluate the relation of different patterns of CS anatomy to successful ablation sites in APs patients.

## 2. Methods

The study included 56 patients with accessory pathway mediated tachyarrhythmia who underwent detailed electrophysiological (EP) study and RF-catheter ablation at our institute. EP studies were performed after obtaining written consent from all the patients.

### *2.1. Electrophysiological study and CS angiography*

Electrophysiological study was performed on all the patients under sedation.[2,3] Multielectrode catheters were positioned under fluoroscopic guidance in the high right atrium (HRA), CS via left the subclavian vein puncture, His bundle and RV, an additional multi-electrode catheter was used for mapping the tricuspid annulus (TA) in case of right sided AP.

Programed stimulation as well as incremental pacing from HRA, CS and RV apex was used to study antegrade and retrograde AP conduction properties and refractory periods. Orthodromic reciprocating tachycardia (ORT) was induced in all patients. Participation of an accessory pathway as the retrograde limb of the tachycardia circuit was proven with the use of the standard criteria.[4] Mapping of the accessory pathway was performed by recording retrograde atrial activation during orthodromic reciprocating tachycardia at various locations in the coronary sinus and around the tricuspid annulus searching for the earliest retrograde atrial activation.

Programed stimulation of the posterolateral CS, anterobasal right ventricular septum (para-Hisian pacing)[5] was performed verifying the presence of septal pathways. Mapping of the TA, CS, and in selected patients the MA (transseptal or retrograde transaortic approach) was performed during antegrade and retrograde AP conduction for better localization of AP. Filtered (30–500 Hz) bipolar electrograms were recorded simultaneously from the mapping catheters.

CS angiography was attempted in all patients after completing electrophysiological study; using either 8F Mullen's sheath or 6F guiding catheter for CS cannulation followed by rapid injection of 20 mL contrast media few millimeters distal to the CS ostium. Balloon occlusive technique was also used during CS angiography; a balloon tipped catheter (arrow balloon catheter) was inserted into the CS and the great cardiac vein (GCV) via 8F Mullen's sheath. The balloon was inflated with 0.5–1.5 mL of air in two different locations, first few millimeters distal to the CS ostium and the second at the junction between the CS and the GCV. Contrast media (5–10 mL) was slowly injected in the two locations filling the venous system distal to the balloon with retrograde filling of venous tributaries. Angiography was performed in held midexpiration and venograms were obtained in each of the three fluoroscopic projections (RAO 30°, LAO 30° and anteroposterior), the nature and number of the venous tributaries as well as structural anomalies were recorded. A CS angiogram was considered optimal when there was complete visualization of the CS from its ostium and the course of its main tributaries.

### *2.2. RF-ablation*

After determination of the electrophysiological properties of the APs and accurate localization, RF ablation was performed using 7F deflectable 4 mm tip ablation catheter. Radiofrequency current was delivered using temperature controlled mode using (Stockert, EP Shuttle, Germany) When accessory pathway conduction was lost within 10–15 s, the application of energy was maintained for 60–120 s. Antegrade and retrograde conduction properties were evaluated immediately after each application.

A posteroseptal or left posterior AP is considered a CS AP if ventricular activation recorded from MCV, PCV or CS diverticulum preceded the earliest endocardial ventricular activation (at TA or MA) by $\geqslant 15$ ms during antegrade AP conduction. A high frequency potential similar to an antegrade accessory pathway activation potential known as CS extension potential (CSE) presumably generated by an extension of the CS myocardial coat was recorded from the MCV, PCV or neck of a CS diverticulum before the earliest far-field ventricular potential. Or when the earliest high-frequency potential (similar to a retrograde AP potential) was recorded from the MCV, PCV or neck of a CS diverticulum, and was presumably generated by an extension of the CS myocardial coat during retrograde AP conduction (CSE). The CSE potential was followed by activation of the CS myocardial coat, with the earliest CS myocardial coat potential recorded near the orifice of the vein.[6,7] The site of successful RF-ablation was correlated to the CS angiographic findings.

### *2.3. Statistical analysis*

All data were collected and subjected to the following tests. X mean, SD standard deviation test was used to measure the central tendency of data and the distribution of data around their mean. Students *t*-test was used for testing statistical significant difference between means of two samples while $\chi^2$ test (chi square) was used to test statistical significant relation between different variable or grades (qualitative data) or percentages.

Significant result was considered if $P$ value $<0.05$.

Highly significant result was considered if $P$ value was 0.01.

## 3. Results

### 3.1. Clinical characteristics

The initially recruited population was 56 patients with AP mediated tachycardia, CS angiography was attempted in all patients and CS angiography was considered optimal in 46 patients who form the basis of our studied population while the 10 patients with suboptimal CS angiography were excluded from the study.

Among the 46 patients included in the study, there were 33 (71.7%) males and 13 (28.3%) females with a mean age of 37 ± 1.5 years. All patients had structurally normal hearts. ORT was the prevailing arrhythmia responsible for patients' symptoms; AF was documented in seven (15%) patients.

### 3.2. Electrophysiological characteristics and CS angiography

A total of 47 APs were detected in the 46 patients, there were 28 with manifest and 19 with concealed conduction. The locations of the APs and their types are shown in Table 1. The most common AP location was the left lateral (13 patients, 28.3%) followed by the posteroseptal (12 patients, 26%) and left posterior (seven patients, 15.2%). Multiple APs (MAP) were found in only one patient who had a posteroseptal and a right posterolateral concealed APs.

Retrograde CS angiography was successfully performed in all the patients included in the study using femoral vein approach in 38 (82.6%) patients and subclavian vein approach in the remaining eight (17.4%) patients. Different catheters were used for CS cannulation, the most commonly used was Mullen's sheath (21 patients, 45.7%) followed by Multipurpose catheter (10 patients, 21.7%) and right judkins catheter (six patients, 13%), while occlusive balloon catheter was used in (four patients, 8.7%).

Regarding the CS tributaries, the location, number, and size of major CS tributaries were variable among study population. The mean number of tributaries seen was 4.1 ± 0.28 ranging from 0 to 8 tributaries, the most frequently visualized tributaries were the GCV (46 patients, 100%) and MCV (42 patients, 91.3%). The number of PCV (s) was variable (ranging from 0 to 3) (Fig. 1).

### 3.3. CS anomalies

Retrograde CS angiography demonstrated anomalous CS in 17 patients (37%) (Table 1), CS diverticuli were the most commonly encountered anomaly (seven patients, 15.3%) representing 41% of the detected CS anomalies, followed by funnel shaped CS ostium (three patients, 6.5%). The distribution of CS anomalies is shown in Table 2. The CS diverticulum extended directly from the CS in six patients and from the MCV in only one patient. Diverticuli opened into the CS by either a narrow or wide neck (Fig. 2).

CS anomalies were more frequently encountered in LL location of APs (found in 41% of CS anomalies), and PS location (found in 29.4% of CS anomalies), and less commonly among other AP locations as LP location (found in 17.6% of CS anomalies), MS location (found in only 5.9% of CS anomalies) and RFW (found also in 5.9% of CS anomalies. The difference was not statistically significant ($\chi^2 = 9.038$, $P = 0.25$).

The most common AP location found in the seven patients with CS diverticuli was PS location seen in four patients while LL location was found in two patients and LP location in only one patient.

The prevalence of CS anomalies among the studied population was compared to the type of AP conduction (manifest vs. concealed conduction), among those with manifest AP conduction 10 patients had CS anomalies and among those with concealed AP conduction seven patients had CS anomalies with no statistically significant difference between both groups ($\chi^2 = 0.047$, $P = 0.832$).

CS APs were diagnosed in 10 patients (21.7%), CSE potential was recorded at the neck or orifice of a diverticulum which opens directly into the CS in four patients, or opens into the MCV in one patient (five out of the seven patients with CS diverticuli had CS AP, 71%). Also the shortest AV or VA times during antegrade or retrograde AP conduction were recorded at the ostia of CS tributaries in six patients, involving the ostium of MCV in four patients and the ostium of PV in two patients. Among those six patients with CS AP in relation to a CS tributary, four of them had structurally normal CS while the remaining two patients had anomalous CS (subthebasian pouch which connected to the ostium of the MCV and a

**Table 1** AP locations and incidence of CS anomalies.

| AP location | *N* | M | C | CS anomaly |
|---|---|---|---|---|
| LL | 13 (28.3%) | 2 | 11 | 7 |
| LPL | 2 (4.3%) | 2 | 0 | 0 |
| AS | 6 (13%) | 2 | 4 | 0 |
| PS | 12 (26.1%) | 10 | 2 | 5 |
| MAP (PS + RP) | 1 (2.2%) | 0 | 1 | 0 |
| MS | 4 (8.7%) | 4 | 0 | 1 |
| LP | 7 (15.2%) | 6 | 1 | 3 |
| RFW | 1 (2.2%) | 1 | 0 | 1 |

AP, accessory pathway; AS, anteroseptal; C, concealed; LL, left lateral; LPL, left posterolateral; LP, left posterior; M, manifest; MAP, multiple accessory pathways; MS, midseptal; *N*, number; PS, posteroseptal; RP, right posterior; RFW, right free wall.

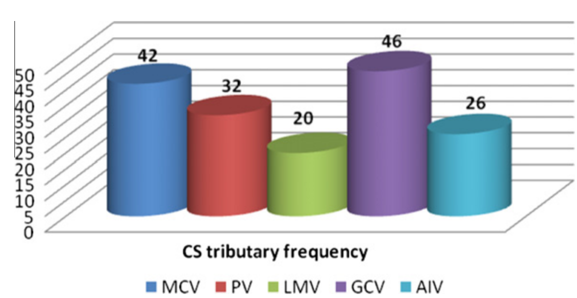


**Figure 1** CS tributaries frequency among studied population. AIV, anterior interventricular vein; GCV, great cardiac vein; LMV, left marginal vein; MCV, middle cardiac vein; PV, posterior vein.

**Table 2** Distribution of CS anomalies in relation to AP location.

| AP location | Funnel shaped ostium | CS divert. | Hypoplasia | Subth. P | Bulbous malf. | Aneurysm | Sharp angul. | Total |
|---|---|---|---|---|---|---|---|---|
| LL | 1 | 2 | 1 | 1 | 1 | 0 | 1 | 7/13 (53.8%) |
| LPL | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0/2 |
| AS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0/6 |
| PS | 0 | 4 | 0 | 1 | 0 | 0 | 0 | 5/12 (41.7%) |
| MAP | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0/1 |
| MS | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1/4 (25%) |
| LP | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 3/7 (42.9%) |
| RFW | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1/1 (100%) |

AP, accessory pathway; AS, anteroseptal; angul.: angulation; C, concealed; divert., diverticulum; LL, left lateral; LPL, left posterolateral; LP, left posterior; M, manifest; MAP, multiple accessory pathways; MS, midseptal; malf., malformation; PS, posteroseptal; RP, right posterior; RFW, right free wall; subth. P, subthebasian pouch.

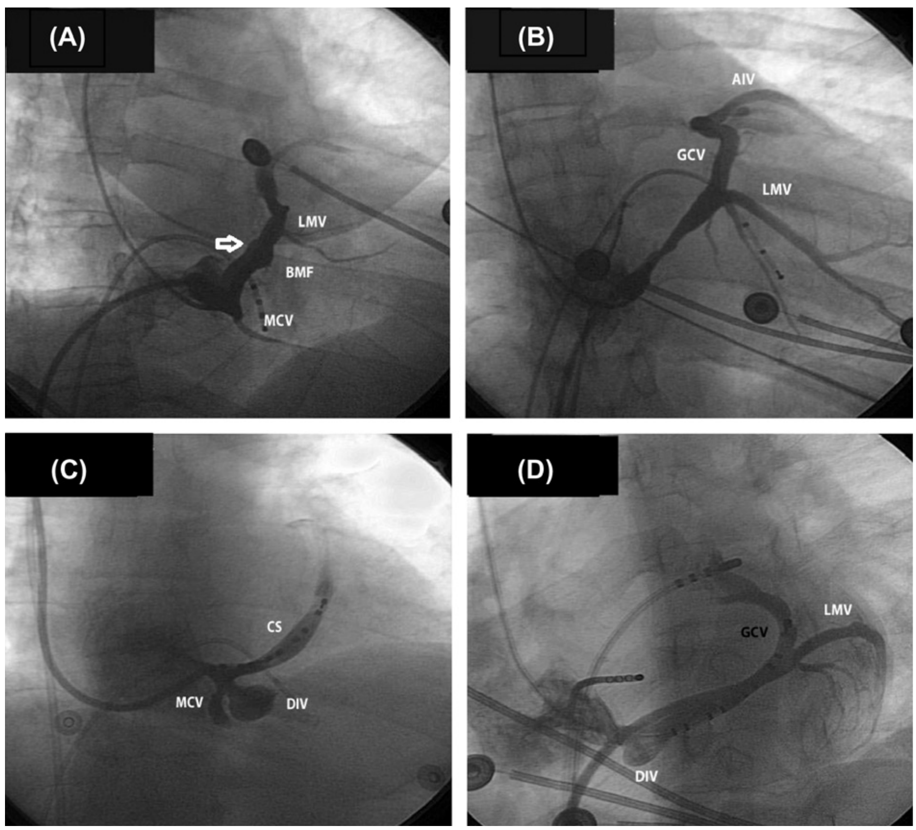


**Figure 2** (A) Retrograde CS angiograms in RAO view showing bulbous malformation (BMF) seen at mid segment CS; (B) mid segment narrowing of CS on RAO view; (C) a diverticulum (DIV) measuring $15 \times 10$ mm, the neck of the diverticulum opens at the MCV 2 mm distal to its ostium and (D) retrograde CS angiogram in RAO view showing a small diverticulum measuring $8 \times 6$ mm that opens with a wide neck into the CS just distal to its ostium.

CS diverticulum that opens with its neck into the MCV) (Fig. 2 and 3).

*3.4. RF ablation*

Successful ablation was achieved in 44 patients (95.7%), RF-ablation was performed using the femoral vein approach in 25 patients (54%), retrograde aortic approach in 16 patients (34.8%) and transseptal approach in five patients (10.9%).

Successful ablation sites were related to CS anomalies in six patients (13%), the ostium of a CS tributary in five patients (10.8%) and to both in one patient (2.2%) (Table 3).

Ablation was successfully achieved from within the CS in 10 patients out of these 12 patients who had the diagnosis of CS AP.

Successful ablation sites in relation to a CS anomaly or CS tributary were associated most commonly with posteroseptal and left posterior AP locations (eight and three patients,

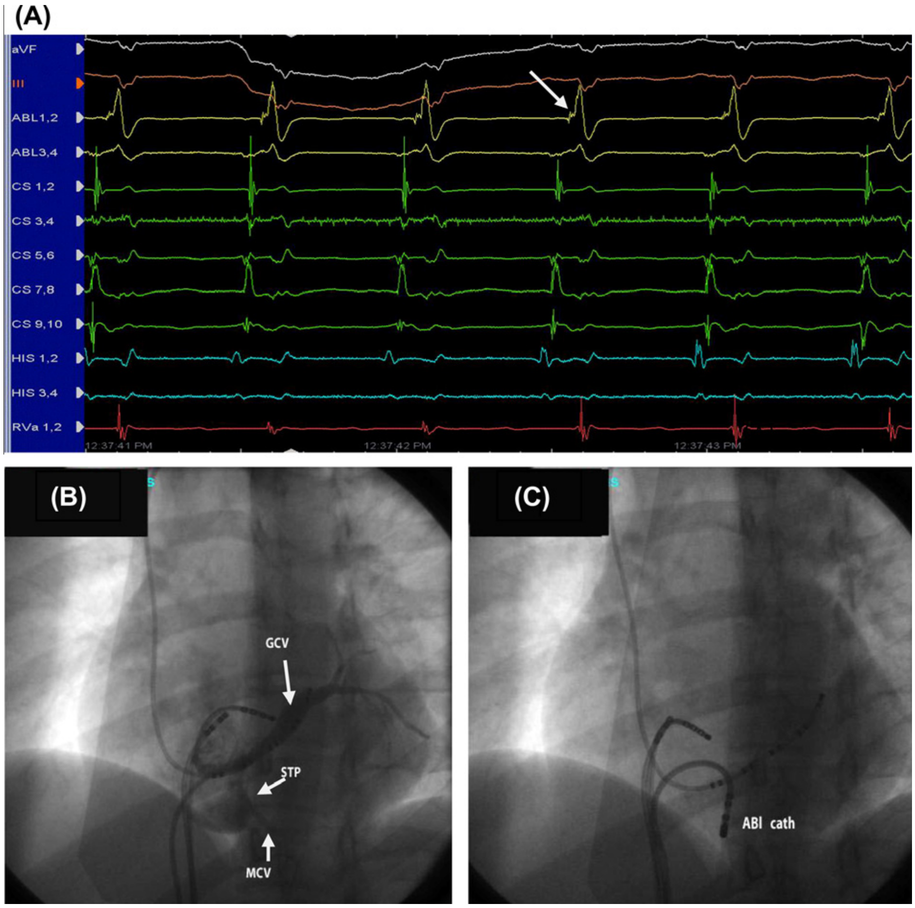


**Figure 3** (A) The intracardiac recording showing the earliest ventricular activation was recorded at the ablation catheter (ABL1, 2) which is preceded by a sharp potential (CSE potential) (white arrow) and both were preceding the delta on surface ECG by 30 ms. This recording was obtained at the ostium of MCV (C) which was seen to be opening into a subthebasian pouch (STP) as seen during the CS angiography (B).

**Table 3** Relation of successful ablation site to CS anomalies and CS tributaries based on AP location.

| Relation of successful ablation site | CS anomalies | | | CS tributaries | | Both (CS anomaly + CS tributary) (*n*) |
|---|---|---|---|---|---|---|
| | Aneurysm (*n*) | CS div. (*n*) | Sharp ang. (*n*) | MCV (n) | *PV (n)* | |
| LL (13) | 0 | 0 | 0 | 0 | 0 | 0 |
| LPL (2) | 0 | 0 | 0 | 0 | 0 | 0 |
| AS (6) | 0 | 0 | 0 | 0 | 0 | 0 |
| PS (12) | 0 | 4 | 0 | 2 | 0 | 1 |
| MAP (1) | 0 | 0 | 0 | 1 | 0 | 0 |
| MS (4) | 1 | 0 | 0 | 0 | 0 | 0 |
| LP (7) | 0 | 0 | 1 | 0 | 2 | 0 |
| RFW (1) | 0 | 0 | 0 | 0 | 0 | 0 |

AP, accessory pathway; LL, left lateral; LPL, left posterolateral; AS, anteroseptal; PS, posteroseptal; MAP, multiple accessory pathways; RP, right posterior; MS, midseptal; LP, left posterior; RFW, right free wall; divert., diverticulum; angul., angulation.

respectively) compared to other AP locations and the difference was statistically significant ($\chi^2$ = 41.81, $P$ = 0.04).

Regarding the 10 patients with the diagnosis of CS AP(80% PS location and 20% LP location), ablation was successfully achieved at the neck of CS diverticulum in four patients (all with PS APs), at the ostium of MCV in three patients (all with PS APs), the ostium of PV in two patients who had LP location of APs. The last patient had his successful ablation site at the neck of a small diverticulum 2 mm distal to the ostium of the MCV (PS location of AP) (Table 3 and Fig. 2).

## 4. Discussion

Though catheter ablation of accessory pathways (APs) is well established, an epicardial course accounts for the failure of some of these cases necessitating an epicardial approach to ablation.[1] The cardiac venous system assumes importance especially in cases of posteroseptal (PS) and left posterior (LP) APs due to their known association with coronary venous anomalies like CS diverticula.[8] These diverticula contain myocardial fibers that connect to both the ventricle and the CS myocardial coat.[9,10] The CS myocardial coat, present in all individuals,[11] is anatomically[11–14] and electrically[15] connected to both atria, completing the accessory connection.

The myocardial coat of the CS has extensive connections to both atria. Occasionally, sleeve-like extensions of the CS myocardial coat extend along the distal portion of the middle cardiac (MCV) and posterior cardiac (PCV) veins to the epicardial LV surface. This could form the basis of PS and LP APs (or CS-ventricular APs or CS AP) which are often oblique with the ventricular end oriented close to the MCV or PCV, and the atrial end oriented more laterally. Such accessory connections may be associated with venous anomalies (CS diverticula, fusiform/bulbous dilations) and may require catheter ablation from within the venous system.[7]

In light of all these findings, the angiographic features of the coronary venous system were prospectively studied in 46 out of 56 recruited patients with AP mediated tachycardia to evaluate the relation of different patterns of CS anatomy to successful ablation sites of APs.

### 4.1. CS tributaries

In the present study, the location, size, number (mean number 4.1) and course of major coronary veins varied considerably among studied population. Two veins were consistently visualized: the GCV (100%) and the MCV (91%), less frequently PCV (70%) while the LMV was the least frequently visualized (43%).

In Meisel et al.[16] study an intraventricular vein and MCV could be identified in all but one patient. One, two or more substantial lateral or posterior veins could be discerned in 51%, 46%, and 2%, respectively, and one patient had neither vein. Schumacher et al.[17] study showed a mean of 3.3 ± 1.5 venous branches draining into the coronary sinus or the great cardiac vein (GCV).

In the Abbara et al.[18] study, the MCV and the GCV, which extend into the anterior interventricular vein (AIV), were found in nearly all the patients. First (64.8%) and 2nd degree (20.4%) branching of the AIV was frequently visualized. Localization and size of the lateral and posterior venous branches were more variable, and in 1–3% of patients no vein of substantial size could be found along the posterolateral ventricular wall.

## 5. The major findings

In our patients, the most common AP locations were LL location (28%) with the majority of them having concealed conduction (84%) and PS location (26%) with the majority of them having manifest conduction (83%). The prevalence of CS anomalies among the studied population which included only patients with accessory pathway mediated tachyarrhythmias was 37%. This finding was relevant to the prevalence reported by other authors who demonstrated CS anomalies incidence ranging from 9% to 22.2%. The Schumacher et al. study reported 9% CS anomalies among a diverse population of patients with various types of supraventricular tachyarrhythmias while the Weis et al. study reported 22.2% prevalence among patients with only posteroseptal and left sided APs.[17,19] Most of the documented CS anomalies were seen with LL APs (41%), PS and LP APs (29% and 17% of CS anomalies, respectively). This finding could be explained by the fact that these are the most common AP locations seen in the studied population. One previous study which examined the occurrence and significance of major CS abnormalities in SVT patients showed exclusive location of CS abnormalities in left free wall and PS areas[20] which is similar to our findings.

The most commonly encountered anomaly in our study was CS diverticuli (41%), the less commonly encountered anomalies were (funnel shaped ostium, CS aneurysm, subthebasian pouch, bulbous malformation, sharp angulation and hypoplasia). The majority of CS diverticuli were reported in PS area (57%).

One of the primary findings of this study was that 26% of successful ablation sites were related to CS anomaly or CS tributary and in 83% (10 patients) of these ablation sites, RF-ablation was achieved from within the CS since they were found to have CS APs with successful ablation at the neck of a diverticulum in 50% or at the ostium of a CS tributary in the other 50% after recording CSE potentials at the neck of the diverticulum or within the MCV and PCV. In a study conducted only on PS and LP APs patients , CS APs were identified in 36% of the 480 patients, 30% of CS APs were related to a CS diverticulum or another CS anomaly while 70% of CS APs were related to a CS tributary.[7] Most interestingly, CS APs were identified in 34 out of 36 patients (94%) with CS diverticulum[7] while it was identified in 74% of CS diverticula detected in our study. These findings outline the close associations between PS or LP APs, CS diverticula and epicardial successful ablation site which have almost always been found at the neck of the diverticulum.[21]

Hence, early recognition of such anatomical variations is important to reduce procedure times and failure rates. We postulate that angiography of the CS should be an important adjunct in ablation of posteroseptal and left posterior APs, especially if initial attempts at ablation from the endocardial aspect were not successful.

To the best of our knowledge, our study is considered the only study which included patients with different locations and patterns of conduction of accessory pathways and correlating successful ablation sites to CS angiographic patterns.

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