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Catheter ablation of accessory pathways near the coronary sinus: Value of defining coronary arterial anatomy

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BACKGROUND Accessory pathways can lie near or within the coronary sinus (CS). Radiofrequency catheter ablation of accessory pathways is a well-established treatment option, but this procedure can cause damage to adjacent coronary arteries.

OBJECTIVE The purpose of this study was to evaluate the anatomic relationship between the coronary arteries and the CS.

METHODS Retrospective data of patients who underwent catheter ablation of supraventricular tachycardia between June 2011 and August 2013 was reviewed. In addition, detailed analysis of coronary computed tomographic angiography (CTA) data from 50 patients was performed.

RESULTS Between June 2011 and August 2013, 427 patients underwent catheter ablation of supraventricular tachycardia, of whom 105 (age 28 ± 17 years, 60% male) had accessory pathway–mediated tachycardia. Of these, 23 patients had accessory pathways near the CS, and 60% (N = 14) underwent concurrent coronary angiography. In 4 patients, the posterolateral (inferolateral) branch (PLA) of the right coronary artery was in close proximity to the CS, and 2 patients (18%) had stenosis of the PLA at the site of ablation. On CTA at their closest proximity, the PLA was 1.9 ± 1.3 mm and the left circumflex artery (LCx) was 2.0 ± 0.8 mm from the body of the CS, in right and left coronary artery–dominant patients, respectively. CS ostium and PLA were 3.6 ± 1.9 mm apart. In left-dominant patients, LCx and CS ostium were 3.8 ± 1.2 mm apart.

CONCLUSION The PLA and LCx are in close proximity to the anteroinferior aspect of the CS ostium and proximal CS. The relationship of the CS and coronary arteries should be evaluated before ablation at these sites.

KEYWORDS Catheter ablation; Coronary sinus; Coronary artery stenosis; Coronary artery injury

ABBREVIATIONS CA = coronary artery; **CS** = coronary sinus; **CTA** = computed tomographic angiography; **LCx** = left circumflex artery; **PDA** = posterior descending (inferior interventricular) coronary artery; **PLA** = posterolateral (inferolateral) ventricular arterial branch of the right coronary artery; **RCA** = right coronary artery

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Introduction

Accessory pathways are a common cause of supraventricular tachycardia. Approximately 19%–33% of accessory pathways can lie near or within the coronary sinus (CS) ostium, proximal CS, or CS diverticulum,[1–3] often referred to as inferior paraseptal (and previously posteroseptal) accessory pathways.[4] Although accessory pathway–mediated AV reentrant tachycardia can be managed pharmacologically, radiofrequency catheter ablation has become a well-established treatment option for these patients. However, ablation of accessory pathways from within the CS may lead to collateral damage to nearby coronary arteries (CAs) because of the anatomic proximity of these structures. In many patients, the posterolateral (inferolateral) ventricular branch (PLA) of the right coronary artery (RCA) and the left circumflex artery (LCx) run inferiorly and in close proximity to the CS. The CS can run above the left atrioventricular groove and the attachment of the left atrium to the left ventricle. As a result, in right-dominant patients. the RCA and, in particular, the PLA run along its anteroinferior aspect (Figure 1).[5] In left-dominant patients, the LCx often runs deep and, occasionally, superior to the CS.[5] Use of radiofrequency catheter ablation within the CS has been reported to cause damage to these arteries in the form of CA stenosis or complete occlusion.[1,6–15] The risk of CA injury appears to be related to the distance from the CAs at the site of ablation.[1]

The purpose of this study was evaluate the precise anatomic relationship of the CAs to the CS in patients undergoing catheter ablation of accessory pathways near the CS as well as in patients referred for coronary computed tomographic angiography (CTA).

Methods

Retrospective analysis of patient data was approved by the University of California Los Angeles Institutional Review Board.

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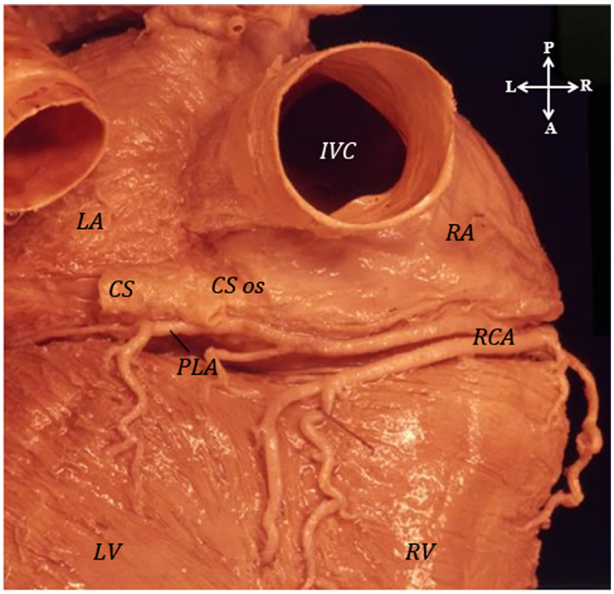

Figure 1 Relationship of the branches of the right coronary artery to the coronary sinus ostium. The mid to distal coronary sinus (CS) has been removed. IVC = inferior vena cava; LA = left atrium; LV = left ventricle; PLA = posterolateral (inferolateral) ventricular arterial branch of the right coronary artery; RA = right atrium; RCA = right coronary artery; RV = right ventricle. (Reproduced with permission from Wallace A. McAlpine Collection. UCLA Cardiac Arrhythmia Center).

Study cohorts

Cohort 1

Between June 2011 and August 2013, 427 patients underwent catheter ablation of supraventricular tachycardia at University of California, Los Angeles Medical Center. Data from patients (n = 105) who were found to have accessory pathway–mediated tachycardia were reviewed. Electrophysiologic findings, including site of ablation and proximity of the CAs to the preferred ablation site at the time of ablation, as well as acute outcome after catheter ablation in patients with accessory pathways near or within the CS (inferior paraseptal) were noted.

Cohort 2

Data from patients (n = 50) who were referred for coronary CTA were analyzed. CTA had been obtained as part of the workup for CA disease or angina, or before cardiac surgery. Using a Siemens Sensation 64 scanner (Siemens Medical Solutions USA, Malvern, PA), axial images through the lower thoracic region were obtained with a slice thickness of 0.75 mm. Coronary angiograms were acquired during administration of 80 mL of Omnipaque 350 followed by 50 mL of saline. Postprocessing, maximum intensity projection was performed on the Siemens Syngo scanner workstation and on the Vitrea 3-dimensional processing workstation (Vital Images, Minnetonka, MN).

The distance between the CS and nearby major CAs was measured on the inferior surface of the heart, at the CS ostium, and at the point of its nearest proximity to the CAs by 2 separate observers. Other measurements obtained were the distance for which the 2 vessels ran along each other and how far the point of nearest proximity was from the CS ostium (Figure 2).

Results

Cohort 1

A total of 105 of 427 patients were identified as having accessory pathway–mediated supraventricular tachycardia (Table 1). In 23 cases (21.9%), the accessory pathway was located near the CS (inferior paraseptal). Patient characteristics are listed in Table 1. Sixty percent of these patients (n = 14) had concurrent coronary angiography at the time of electrophysiologic study. Of these patients, 4 had CAs near the CS (<5 mm), leading to deferral of ablation in 2 patients. One patient had a CA very close to the site of ablation in the CS; however, the decision was made to proceed with ablation given the patient's severe symptoms (syncope with bodily injury). This led to the anticipated acute occlusion of the posterior (inferior) left ventricular artery (Figure 2). The patient underwent successful percutaneous coronary angioplasty and stenting postablation. In the second patient, coronary angiography showed occlusion of this artery at the site of a previous attempt at catheter ablation of the accessory pathway. In the 10 remaining patients, CAs were noted to be >5 mm away from the CS at desired sites of ablation. These patients underwent successful ablation of accessory pathways without injury to the CAs.

Cohort 2

Patient characteristics for 50 patients who underwent coronary CTA are listed in Table 2. In right-dominant (N = 42) and co-dominant patients (N = 2), the PLA was most often the artery running in close proximity to the CS. At its closest segment, the PLA was an average of 1.9 ± 1.3 mm (mean ± SD) from the CS and ran along the CS for a distance of 7.7 ± 4.3 mm (mean ± SD) (Figure 3 and Table 3). In 1 patient, the posterior descending (inferior interventricular) coronary artery (PDA) was a distance of 0.8 mm from the CS. In right-dominant patients, the point of closest proximity of the CS to the PLA occurred 12.7 ± 6.4 mm (mean ± SD) away from the CS ostium (into the body of the CS). The separation between the anteroinferior aspect of the CS ostium and PLA was 3.6 ± 1.9 mm (mean ± SD) Table 3.

In left-dominant patients, the LCx was the artery in closest proximity to the CS, running an average of 2.0 ± 0.8 mm (mean ± SD) from the inferior aspect of the proximal CS for a distance of 10.8 ± 7.4 mm (mean ± SD) (Figure 4). The sites of closest proximity often extended further into the CS and occurred 15.6 ± 6.1 mm (mean ± SD) from the CS ostium. The LCx and the anteroinferior aspect of the CS ostium were separated by a distance of 3.8 ± 1.2 mm (mean ± SD) Table 3.

Discussion

Major findings

The major findings of this study are as follows:

1. In right-dominant patients, the PLA runs <2 mm from the proximal CS, whereas in left-dominant patients, the LCX runs <2 mm from the CS.

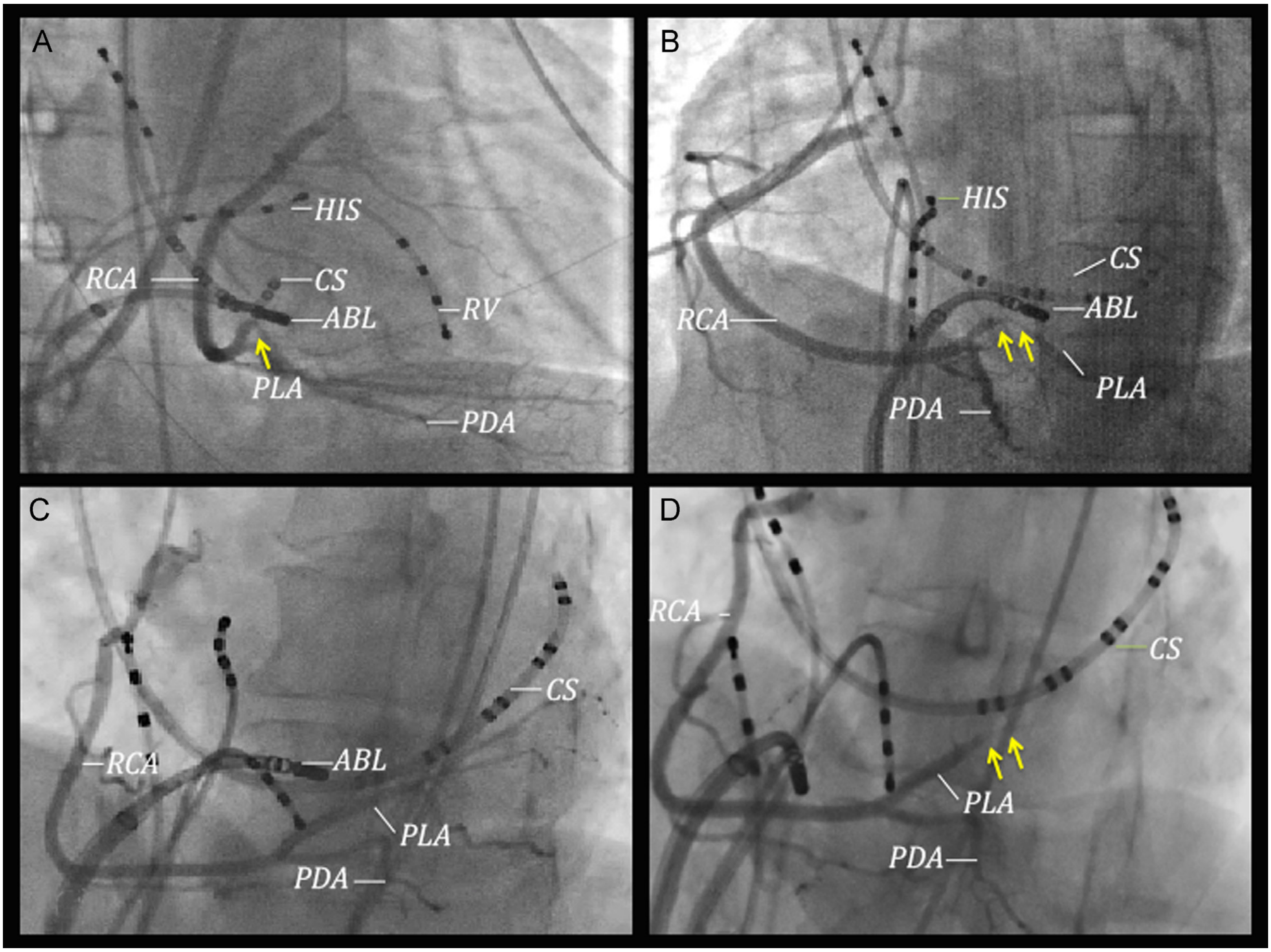

Figure 2 Right anterior oblique **(A)** and left anterior oblique **(B)** fluoroscopic views of a patient with previous ablation in the coronary sinus (CS) for supraventricular tachycardia due to an accessory pathway with earliest activation in the proximal CS demonstrate occlusion of the posterolateral (inferolateral) ventricular arterial branch of the right coronary artery (PLA). **C:** Fluoroscopic images in the left anterior oblique view showing the PLA preablation. **D:** After catheter ablation of the accessory pathway from within the CS, the PLA is acutely occluded. The ablation catheter (ABL) has been pulled out of the CS and back into the right atrium. The patient underwent successful angioplasty and stenting of the PLA. Arrows point to the occluded posterolateral artery (PLA) status post ablation. HIS = His-bundle catheter; PDA = posterior descending (inferior interventricular) coronary artery; RCA = right coronary artery; RV = right ventricle.

2. The length for which the CAs and the CS are in close proximity is >7 mm for both right- and left-dominant patients.
3. At the CS ostium, a common site of ablation for accessory pathways, CS ostial atrial tachycardia, and, at times, AV nodal reentrant tachycardia, the PLA and LCx often track within 4 mm of the inferior aspect of the ostium.

Table 1 Characteristics of patients referred for catheter ablation of accessory pathways

All accessory pathways	
Total no. of patients	105
Age (years)	28 ± 17
Sex (male)	60%
Accessory pathways near the CS	
Total no. of patients	23 (22%)
No. of coronary angiographies	14 (60%)
Age (years)	30 ± 15
Sex (male)	65%

Coronary injury during catheter ablation

CA stenosis is a documented complication of catheter ablation, often occurring as a late complication after 12–24 months,[15] although it also may present acutely or within weeks.[16,17] In this study, the patient who presented with coronary occlusion of his PLA from previous ablation attempts in the CS had only noted symptoms of shortness of breath and chest heaviness with severe exertion. These symptoms had begun insidiously 3 months after his ablation procedure.

In 1998, the North American Society of Pacing and Electrophysiology registry noted only 1 coronary occlusion leading to acute myocardial infarction in 3357 ablation procedures, 654 of which involved ablation of accessory pathways.[18] Similarly, low incidences were found by Chen et al[19] in a single-center study of 3966 procedures and in the Multicentre European Radiofrequency Survey.[20] Chugh et al[21] documented 8 cases of CA injury among 853 patients undergoing catheter ablation of atrial fibrillation with

Table 2 Characteristics of patients referred for cardiac computed tomographic angiography

Age (years)	57 ± 15
Sex (male)	66%
Coronary artery dominance	
Right-dominant	41 (82%)
Co-dominant	2 (4%)
Left-dominant	7 (14%)
Reason for procedure	
History of coronary artery disease/coronary artery bypass graft	13
Chest pain with or without equivocal stress test or syncope	27
Presurgical evaluation	3
Other	7
Structural abnormalities	
Mild left ventricular dilation	3
Small ventricular septal defect	2
Right atrial enlargement	3
Bicuspid aortic valve	2

radiofrequency ablation delivered within the CS. Although the incidence of CA damage in these studies appears to be low, the differences likely are due to the location of catheter ablation, the often clinically asymptomatic nature of these occlusions, and the occurrence of late occlusions. In addition, both the lower incidence of ablation in the CS in the past (due to lack of irrigated radiofrequency ablation catheters) and the lack of concurrent coronary angiography likely led to underdiagnosis and underreporting. Furthermore, symptoms of chest pain and pericardial irritation often are common, vague, and multifactorial during and after ablation, and a high index of suspicion is required to obtain additional workup. In contrast, in studies in which coronary angiography was consistently performed and radiofrequency within the CS delivered, the incidence of stenosis or proximity of the CAs to the CS were reported to be much higher. Wong et al[10] found that 15 of 54 patients undergoing mitral isthmus ablation had CA injury, 14 of which involved stenosis of the LCx. All patients had catheter ablation

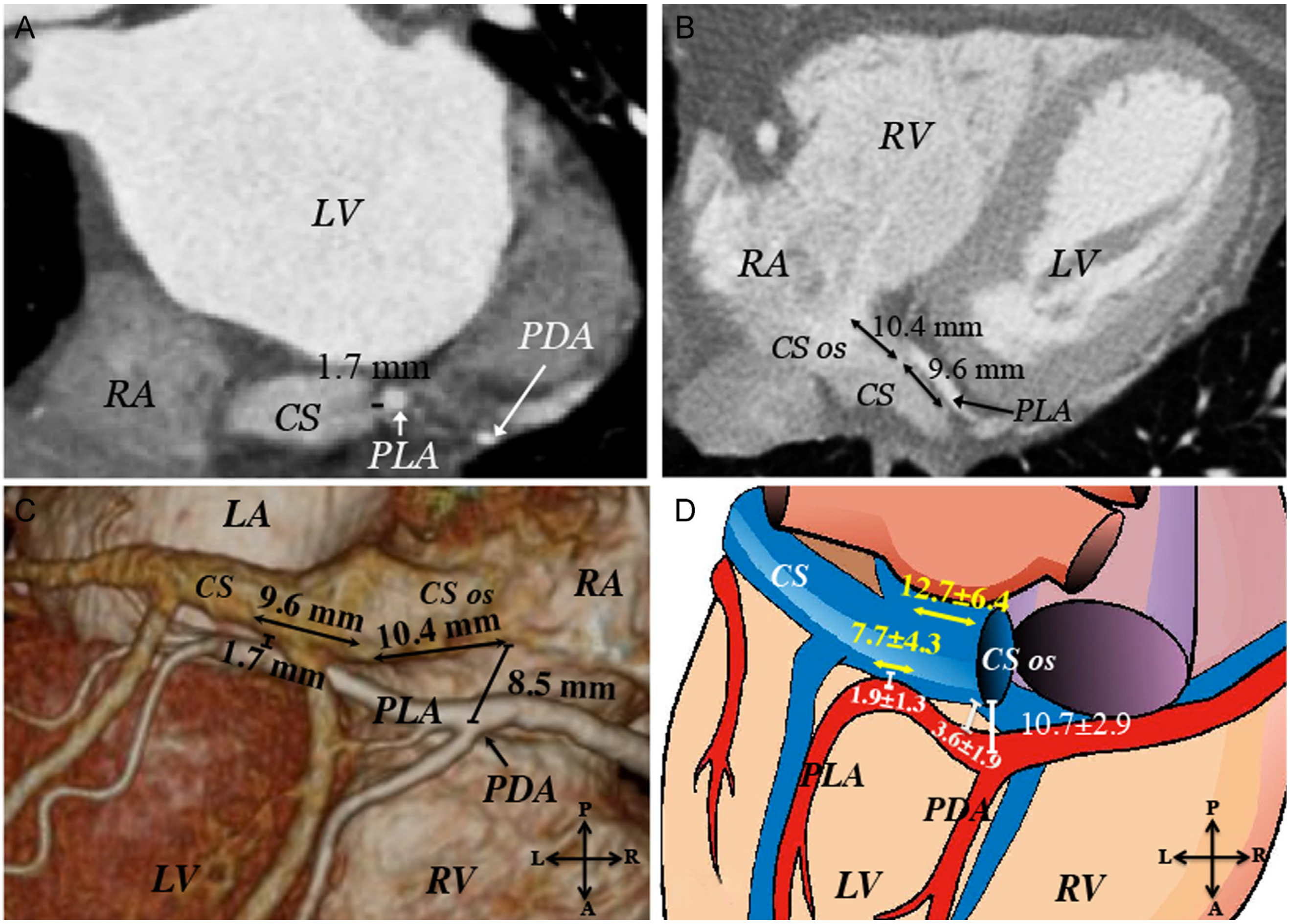

Figure 3 **A:** Coronal view of a right-dominant coronary artery patient showing the distance between the coronary sinus (CS) and posterolateral (inferolateral) ventricular arterial branch of the right coronary artery (PLA) to be 1.7 mm at the point of closest proximity. The posterior descending (inferior interventricular) coronary artery (PDA) in this patient is not in proximity to the CS. **B:** Coronary computed tomography axial view showing that the location of the closest proximity of the coronary artery to the CS is 10.4 mm from the CS ostium. The CS and PLA remain in close proximity for 9.6 mm in this patient. **C:** Volumetric 3-dimensional reconstruction of computed tomographic angiography (CTA) images for the same patient. The proximity of the CS to the PLA and PDA can be seen on the inferior surface of the heart. **D:** Schematic diagram summarizing the mean distances obtained from all right coronary artery–dominant patients undergoing coronary CTA. Results are given as mean ± SD. CS os = coronary sinus ostium; LA = left atrium; LV = left ventricle; RA = right atrium; RV = right ventricle.

Table 3 Measurements obtained from patients undergoing coronary computed tomographic angiography

Coronary artery dominance	CA–CS ostium distance (mm)	CA–CS distance at closest point (mm)	Length of CA–CS proximity (mm)	Distance of closest point from CS ostium (mm)
Right				
PLA	3.6 ± 1.9	1.9 ± 1.3	7.7 ± 4.3	12.7 ± 6.4
PDA	10.7 ± 2.9	10.5 ± 3.2	2.7 ± 0.5	7.5 ± 6.5
Left circumflex	3.8 ± 1.2	2.0 ± 0.8	10.8 ± 7.4	15.6 ± 6.1
Co-dominant	4.2 ± 3.3	1.0 ± 0.4	7.3 ± 2.1	7.9 ± 1.6

CA = coronary artery; CS = coronary stenosis; PDA = posterior descending (inferior interventricular) coronary artery; PLA = posterolateral (inferolateral) ventricular arterial branch of the right coronary artery.

performed from within the CS. Hasdemir et al[22] showed that among patients referred for supraventricular tachycardia, coronary angiography demonstrated that the PLA was <2 mm from the CS os in 20% of patients and the LCx was <2 mm from the lateral and anterolateral mitral annulus in 14% of patients. In a study of 20 patients undergoing left atrial catheter ablation for atrial fibrillation, 75% of patients were noted to have RCAs that decreased in diameter postablation compared to preablation.[23] Finally, Stavrakis et al[1] stratified the risk of CA injury by the proximity of CAs to the CS in patients undergoing radiofrequency catheter ablation. In patients with CA–CS distance <2 mm on coronary angiography, 50% had arterial stenosis postablation. In patients with a CA–CS distance of 3–5mm, 7% developed arterial occlusion postprocedure.[1] Endocardial ablation of atrial sites of accessory pathways appears to carry a decreased risk compared to ablation within the CS.[24] In our study, all 50 patients who underwent coronary CTA had a CA–CS distance <4 mm at the inferior aspect of the CS os and <2 mm at some point along the CS. In 4 of 14 patients with

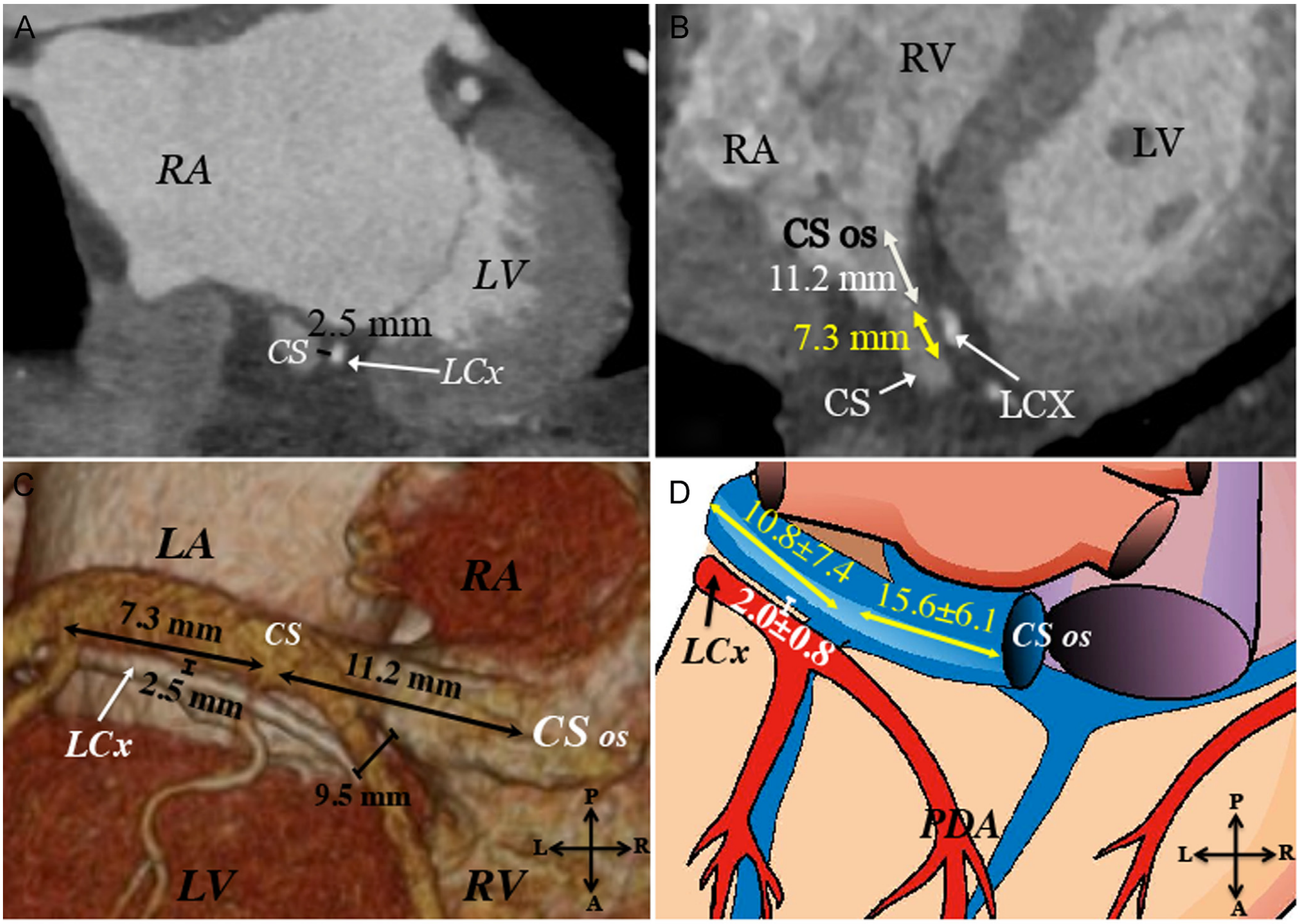

Figure 4 **A:** Coronary computed tomographic (CT) angiography coronal view of a left-dominant coronary artery patient showing the distance between the coronary sinus (CS) and left circumflex artery (LCx) to be 2.5 mm at the point of closest proximity. **B:** Coronary CT axial view showing the point of closest proximity of the CS and LCx to be 11.2 mm from the coronary sinus ostium (CS os). The LCx remains in close to proximity to the CS for a distance of 7.3 mm. **C:** Volumetric 3-dimensional reconstruction of CT angiography images from the same patient. The inferior aspect of the heart is shown. **D:** Schematic diagram summarizing the mean distances obtained from all left coronary artery–dominant patients undergoing CT angiography. Results are given as mean ± SD. LA = left atrium; LV = left ventricle; PDA = posterior descending (inferior interventricular) coronary artery; RA = right atrium; RV = right ventricle.

concurrent coronary angiography for accessory pathways near the CS, a CA was in close proximity to the desired ablation site. Therefore, coronary angiography should be strongly considered before catheter ablation within the CS.

Although we focused on patients presenting with accessory pathway–mediated tachycardia in this study, many patients with CS os atrial tachycardia as well as those with AV nodal reentrant tachycardia are also often ablated from the CS ostium. This study demonstrates that given the proximity of the CAs to the CS ostium, especially along its anteroinferior aspect, coronary angiography should be performed before ablation in these patients. In a study of 212 pediatric patients (112 with accessory pathway–related supraventricular tachycardia, 84 with AV nodal reentrant tachycardia, 16 with both), Schneider et al[7] found that a CA was in proximity to the likely site of ablation within the CS or CS ostium in 48 patients. As a result, these patients were treated with cryoablation rather than radiofrequency catheter ablation. In this series, 2 patients suffered postablation CA stenosis.[7]

The anatomic location of the CAs is an important issue to consider in all cardiac procedures. Ghersin et al[25] noted the relationship of the CAs in the left AV groove to the mitral valve annulus with the purpose of minimizing iatrogenic damage to the arteries during mitral valve annuloplasty. They demonstrated significant proximity between the LCx and the mitral valve hinge point, at a distance of 6.4 ± 2.1 mm. In this study, it can also be appreciated that the CS is at an even closer distance to the CAs.

Catheter ablation near the CAs can often present with chronic histopathologic changes. In a porcine model, epicardial radiofrequency catheter ablation near the CAs was characterized by thickening of the tunica intima and media and replacement of the smooth muscle cells with extracellular matrix.[26] Sturm et al[27] showed that intimal lesions of the CAs were first noted 6 months postablation in 3 of 8 porcine hearts, and Paul et al[28] reported 25%–40% narrowing of the RCA 6 months after catheter ablation. Therefore, despite successful acute outcomes, chronic damage to the CAs can often occur and may present months to years after the procedure.

It is important to note that although the posterolateral ventricular artery and the posterior descending artery have established nomenclature, these names can be anatomically misleading. Rather, these vessels are located on the inferior surface of the heart and would be more appropriately referred to as the inferolateral ventricular artery and inferior interventricular artery, respectively. For this reason, it was also advocated that the posteroseptal accessory pathways be referred to as inferior paraseptal accessory pathways.[4] This delineation is important to remember when assessing the location of these structures on fluoroscopic imaging and, in particular, in observing that catheter ablation in the *anteroinferior* aspect of the CS is most likely to cause damage to CAs.

Study limitations

In this study, CTAs from adult patients were analyzed. Therefore, although these results are not directly applicable to a pediatric population, the measurements in a pediatric population are likely to be even less and the need for coronary angiography more critical. Furthermore, only a small percentage of patients with accessory pathways near the CS underwent coronary angiography, so the risk of injury in asymptomatic or mildly symptomatic patients is difficult to assess, particularly given the late presentation of symptoms. However, even in the small population that did undergo coronary angiography, 33% of patients had CAs in close proximity to the "ideal" site of catheter ablation.

Conclusion

The CAs, in particular the PLA in right-dominant patients and the LCx in left-dominant patients, are in close proximity to the anteroinferior aspect of the proximal CS, the site of ablation for many accessory pathway–mediated tachycardias. In addition, the CS ostium often lies <5 mm from the CAs. To avoid collateral injury, patients who require ablation from within the CS should undergo CS angiography for initial assessment of ablation site and also undergo CA angiography before radiofrequency catheter ablation. This is of special importance when actively cooled radiofrequency ablation catheters are used for energy delivery within the CS.

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CLINICAL PERSPECTIVES

In this study, detailed analysis of the relationship of the coronary arteries to the coronary sinus was peformed. The study demonstrated that the branches of the right coronary artery in right-dominant patients, particularly the posterolateral (inferolateral ventricular) branch, run <2 mm from the proximal coronary sinus (CS) along its anteroinferior aspect. The left circumflex artery is at risk for injury during catheter ablation within the coronary sinus in left coronary artery–dominant pateints. This study has significant implications for catheter ablation of tachycardias from within the CS and near the CS ostium. Before catheter ablation in this region, coronary angiography should be performed, particularly with the use of actively cooled/irrigated ablation catheters, to avoid collateral injury to the nearby coronary arteries.