JACC: CASE REPORTS VOL. 4, NO. 18, 2022

CASE REPORT

ADVANCED

CLINICAL CASE SERIES: PROCEDURAL COMPLICATIONS

Sinus Node Artery Occlusion During Cardiac Denervation Procedures

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ABSTRACT

Cardioneural ablation is a novel treatment for functional bradycardia. However, the risk of acute complications is still unknown. The aim of this case report is to describe acute occlusion of the sinus node artery after cardiac denervation procedures in 2 patients and to encourage measures to prevent it, such as evaluating the aortic angulation in older patients before the procedure and by monitoring signs of sinus failure during ablation in patients with electroanatomical maps showing a constricted aspect of the right atrium. **(Level of Difficulty: Advanced.)** (J Am Coll Cardiol Case Rep 2022;4:1169–1175) © 2022 The Authors. Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Radiofrequency (RF) catheter ablation of a ganglionated plexus (GP) has been used to treat patients with symptomatic functional bradycardia as an alternative to pacemaker implantation.[1,2]

A comprehensive targeting of a few main ganglia identified in the interatrial septum and the pulmonary veins antra has proved to be effective at preventing episodes of bradycardia.[3-6] However, the proximity of these anatomical regions to vascular structures, such as the sinus node artery (SNA), represents a significant technical challenge.[7] The purpose of this case report is to describe acute occlusion of the SNA after denervation procedures in 2 patients.

LEARNING OBJECTIVES

- To review the cases of 2 patients who experienced sinus node artery occlusion after cardioneural ablation.
- To be able to detect the sings of SNA occlusion during ablation of the septal ganglionated plexus.
- To understand the role of increased aortic angulation in the mechanism of this complication.

Cardiac denervation procedures were performed in 42 patients (50% men, age 38.5 years [median age, 41.2 years] [Q1, Q3: 27, 51 years]) after a conventional electrophysiological study ruled out sustained arrhythmias and primary conduction system dysfunction. The primary indication was cardioinhibitory syncope (VASIS 2B [VAsovagal Syncope International Study type 2b (severe cardioinhibition/asystole)]) in 19 patients (45.2%), advanced atrioventricular block in 16 (38.0%), and sinus arrest in 7 (16.7%).

Endocardial electroanatomical mapping of the right and left atria was performed with the Carto 3 system (Biosense-Webster) or the EnSite Velocity (St. Jude Medical) system. GP sites have been identified by anatomical mapping (presumed anatomy of main GP) based on previous studies.[4-6] A 3.5-mm irrigated tip catheter (Navistar ThermoCool) or a 4-mm irrigated tip catheter (Therapy Cool Path) delivered radiofrequency energy (50 °C, 20-30 W, for ≤60

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The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

Manuscript received December 16, 2021; revised manuscript received April 14, 2022, accepted April 28, 2022.

ISSN 2666-0849 https://doi.org/10.1016/j.jaccas.2022.04.021

JACC: CASE REPORTS, VOL. 4, NO. 18, 2022
SEPTEMBER 21, 2022:1169–1175

ABBREVIATIONS AND ACRONYMS

AA = aortic angulation

AV = atrioventricular

CTA = computed tomography imaging

GP = ganglionated plexus

RA = right atrium

RF = radiofrequency

rPV = right pulmonary veins

SNA = sinus node artery

SVC = superior vena cava

seconds or until the ablation index reached the target value of 500) with a 20 mL/min irrigation flow.

The order for ablation was prespecified. It started by targeting the right atrium (RA) GP, beginning with the superior right GP and then the inferior right GP. Ablation of the superior and then inferior septal left atrium (LA) GP followed (**Figure 1**). The RF application time was limited to 300 seconds in each GP site. The RF application data are shown in **Table 1**.

Acute occlusion of SNA was suspected and investigated when signs of acute sinus node failure (sinus pauses or junctional bradycardia) were observed during RF pulses. The complication was ultimately confirmed in 2 cases (4.76%) by using coronary computed tomography angiography (CTA). One patient (2.38%) remained with persistent symptomatic sinus node failure and required a pacemaker implant.

CASE 1

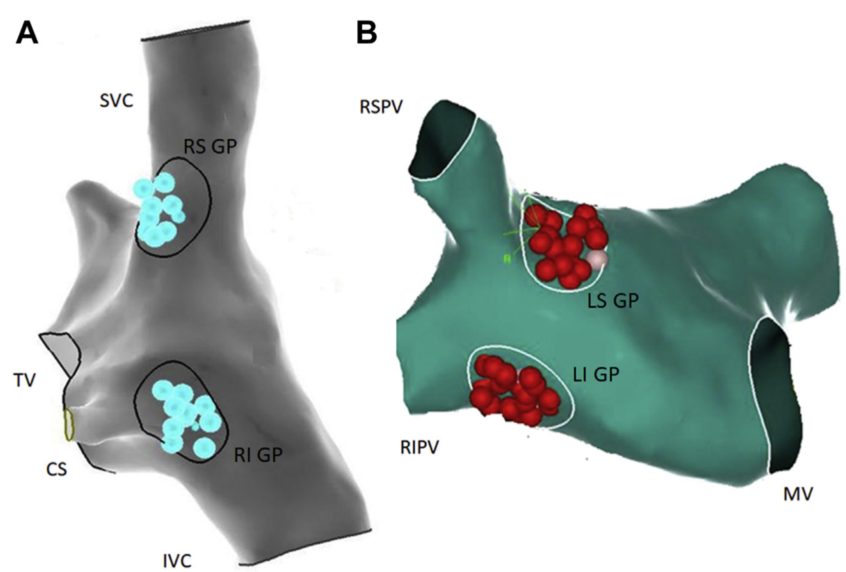
A 55-year-old woman (patient identification number 37) was experiencing recurrent syncope episodes and advanced atrioventricular (AV) block, resulting in pauses of ≤5.6 seconds on a Holter monitor recording (**Figure 2**). The electroanatomical map showed a constricted aspect of the RA and superior vena cava (SVC) that seemed to be due to an extrinsic compression by the aorta (**Figure 3B**). When RF pulses started to be delivered at the atriocaval junction, a sudden junctional bradycardia was observed (**Figure 4**). Intravenous dobutamine was started at an infusion rate of 1.0 μg/kg/min and uptitrated to 3.0 μg/kg/min, in an attempt to stimulate the sinus activity, without success. A postablation CTA demonstrated a SNA arising from the right coronary artery with a total occlusion at its distal portion (**Figure 5**), at the point where it reached the RF application site (**Figure 6**). Additionally, it was observed that the angle between the horizontal plane and the plane of the aortic annulus (**Figure 7**) was remarkably accentuated (51°), although the maximum aortic diameter was normal (31 mm).

TABLE 1 Characteristics of RF Applications

	Study Population	Patient 1	Patient 2
RF applications/GP	16.8 ± 9.2	17.8 ± 5.2	18.2 ± 3.8
RF time(s)/GP	258.2 ± 21.3	286.2 ± 6.3	278.6 ± 9.3
Median AI/GP	459.9 ± 62[a]	451.9 ± 44	441.9 ± 36

Values are mean ± SD. [a]When available.
AI = ablation index; GP = ganglionated plexus; RF = radiofrequency.

FIGURE 1 Electroanatomical Mapping of the Main Septal GP



Example of an electroanatomical mapping of the right **(A)** and left **(B)** atria during a cardiac denervation procedure. The order for ablation was prespecified. It started by targeting the right atrial (RA) ganglionated plexus (GP), beginning with the superior right GP and then the inferior right GP. Ablation of the septal left atrial (LA) GPs followed. CS = coronary sinus; IVC = inferior vena cava; LI GP = left inferior ganglionated plexus; LS GP = left superior ganglionated plexus; MV = mitral valve; RI GP = right inferior ganglionated plexus; RS GP = right superior ganglionated plexus; RIPV = right inferior pulmonary vein; RSPV = right superior pulmonary vein; SVC = superior vena cava; TV = tricuspid valve.

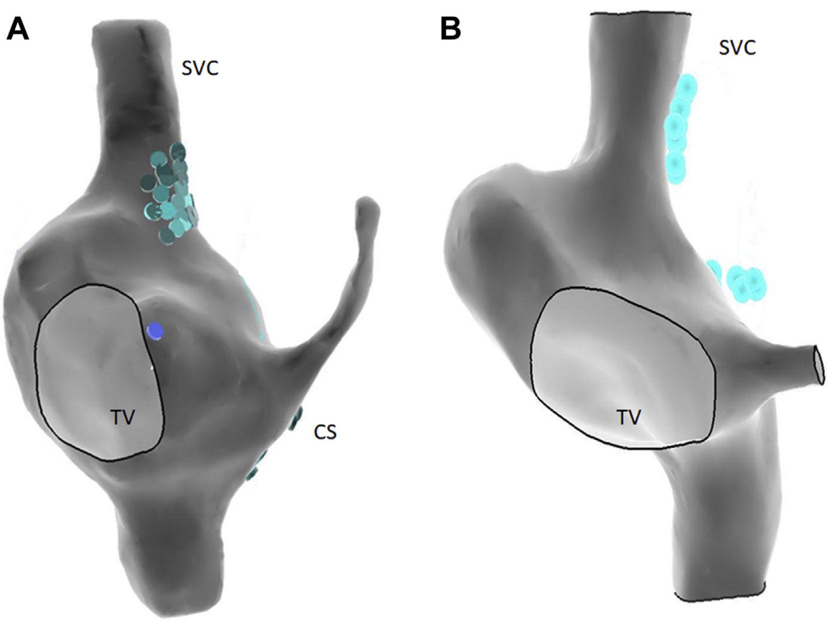
FIGURE 2 Electrocardiogram Depicting Advanced Atrioventricular Block on a Holter Monitor Recording in Patient 1

After 2 days, sinus failure persisted, and a pacemaker was implanted.

CASE 2

A 61-year-old woman (patient identification number 41) was experiencing recurrent cardioinhibitory syncope (Figure 8). Similarly to patient 1, the electroanatomical map presented a compressed-looking RA and SVC. After uneventful ablation at the right side of the septum, left-sided applications triggered sinus bradycardia that evolved to junctional bradycardia, prompting interruption of the RF pulse. The patient experienced no hemodynamic instability and no symptoms after recovering from anesthesia; therefore, no inotropic agents or devices were required. The CTA showed a SNA arising from the right coronary artery with a total occlusion at its distal portion (Figure 9). Again, the maximum aortic diameter was normal (35 mm), but the aortic angulation (AA) was

FIGURE 3 Anatomy of the Atriocaval Junction



(A) Electroanatomical mapping of the right atrium (anteroseptal view) from a patient (patient identification number 25 with normal aortic angle. **Green dots** represent radiofrequency pulses; **blue dot** represents His bundle recording site. **(B)** Electroanatomical mapping of the right atrium (anteroseptal view) from a patient with an extremely angulated aorta complicated with sinus node artery (SNA) occlusion (patient identification number 41). The compression, resulting from bulging of the interatrial septum into the right atrium cavity, may be considered a sign of high risk for this complication. SVC = superior vena cava; TV = tricuspid valve; CS = coronary sinus.

JACC: CASE REPORTS, VOL. 4, NO. 18, 2022
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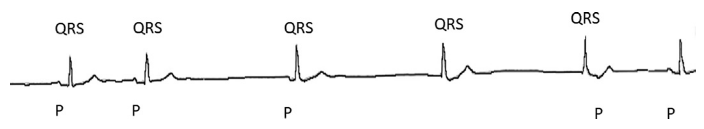
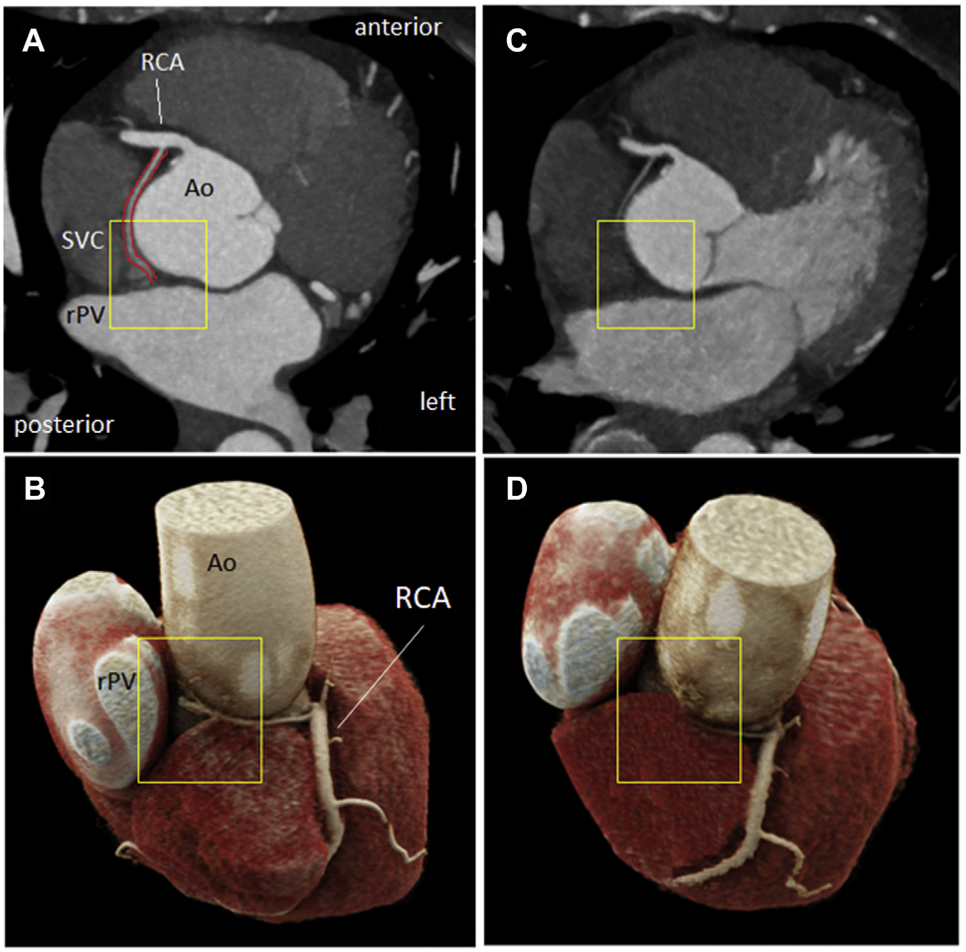
FIGURE 4 **Sudden Junctional Bradycardia in Patient 1 Immediately After Radiofrequency Pulses Were Applied at the Atriocaval Junction**



significantly high (50°). The patient remained asymptomatic, and an electrocardiogram 7 days after discharge showed a restored sinus rhythm. A control 24-hour Holter monitor recorded 30 days after discharge demonstrated full recovery of the sinus rhythm, with a mean heart rate of 68 beats/min and no pauses.

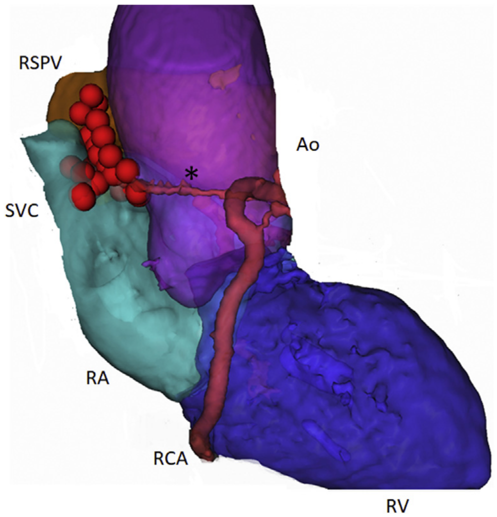
A sample of 20 patients (60% men, age 58.5 years [median age: 47.6 years] [Q1, Q3: 51, 61 years]) with no structural heart disease and no aorta dilatation, who underwent coronary tomography for coronary occlusion investigation were analyzed in order to verify how the SNA anatomy and the AA relate to the targets for denervation. Coronary CTA was able to visualize the distal portion of the SNA in 80% of the patients. It arose from the right coronary artery in 13 examinations (65%) and from the left coronary artery in 7 (35%). Regardless of its origin, the anatomical course of the SNA crossed the pericardial recess between the SVC and the right pulmonary veins in 10 (50%) examinations. The maximum aortic diameter was 31 mm (Q1, Q3: 30, 33 mm), and the mean AA was 42 (Q1, Q3: 39.5, 45.0).

FIGURE 5 **Coronary Computed Tomography Angiograms of Patient 1**



Before ablation, angiography **(A)** and 3-dimensional tomographic imaging **(B)** show a precaval sinus node artery, highlighted in red, arising from the right coronary artery (RCA) and crossing the area between the superior right pulmonary vein (rPV) and the atriocaval junction. After radiofrequency ablation **(C, D)**, distal occlusion of the sinus node artery is demonstrated. Ao = aorta; SVC = superior vena cava.

FIGURE 6 Anatomical Relationship Between the Atriocaval Junction and the SNA



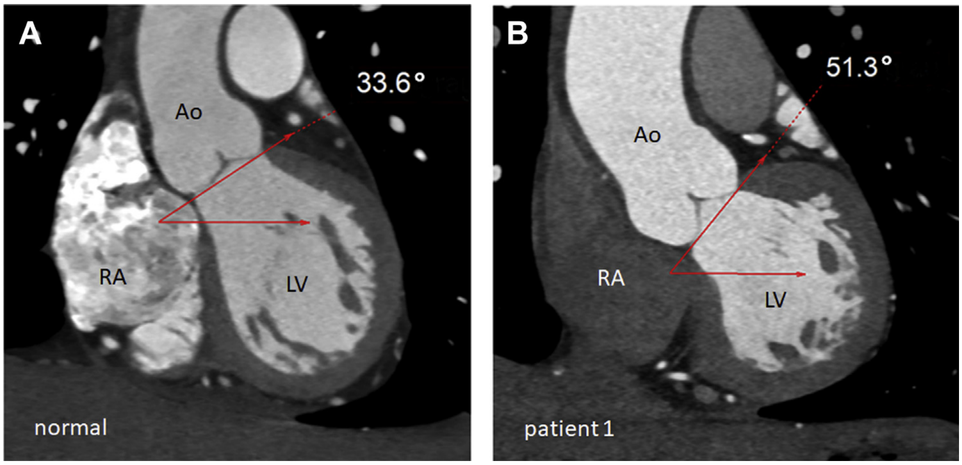
Integration image of the electroanatomical 3-dimensional map and computed tomography angiography (anterior oblique view) using the Adas 3-dimensional system in patient 1. The merged image displays the right ventricle (RV) in **dark blue**, superior vena cava (SVC) and right atrium (RA) in **light blue**, aorta (Ao) in **purple**, right superior pulmonary vein (RSPV) in **brown**, and the sinus node artery (SNA) **(*)** arising from the RCA. The SNA has a precaval path crossing the radiofrequency pulses region **(red dots)** between the RSPV and the atriocaval junction.

DISCUSSION

The main findings of the present work are that SNA injury may occur in patients undergoing cardiac denervation procedures. Additionally, it was verified that the anatomical course of SNA crosses the atrio-caval junction in 50% of patients and that a high AA characterized the patients who experienced complications with thermal SNA occlusion.

Since its original description in 2004,[1] the cardiac denervation technique has evolved from biatrial extensive procedures with complex mapping methods[1,2] into simpler approaches based on presumed anatomy resulting in small RF lesions.[3,4,6] Among the most relevant GP areas, the superior right GP, which encompasses the atriocaval junction and the area between the SVC and the aorta, stands out as possibly the most important region for cardiac denervation, mainly because of its differential effect on the sinoatrial function, implying the presence of selective vagal pathways to the sinus node arising from this critical spot.[4,6] By contrast, clinical reports suggest that specific vagal innervation to the atrioventricular node could be located in the left atrium.[8] Therefore, to achieve sinus and atrioventricular denervation, a biatrial procedure is usually required. The atriocaval junction, however, is a technically challenging region for interventional procedures, in close proximity with important structures such as the phrenic nerve and coronary arteries, SNA included. In particular, the prevention of vascular injuries

FIGURE 7 Cardiac Computed Tomography Angiography, Coronal Projection



(A) Example of a normal aortic angulation (33.60°) in a normal patient. **(B)** Significantly higher aortic angulation (51.30°) in patient 2. Ao = aorta; LV = left ventricle; RA = right atrium.

FIGURE 8 Cardioinhibitory Response (Sinus Pause) During Tilt Table Test in Patient 2

requires direct visualization strategies that have not been routinely implemented so far.

A coronary CTA may identify the SNA distal course in most patients and provides 2 relevant parameters for the detection of procedures with high risk for SNA injury: the proximity of the SNA course to the critical ablation area (Figure 10) and the AA. In agreement with previous authors,[7] we found that the SNA may cross the critical area in nearly half of the procedures regardless of its origin.

It was noteworthy that both patients had a compressed-looking RA and high AA (50° and 51°) as compared with the control angiograms (42 [Q1, Q3: 39.5, 45.0]). The AA is a simple parameter that has been adopted in other cardiovascular procedures to identify technically challenging situations.[9] A high AA (Figure 7B) pushes the aortic root against the right atrium wall, bringing the SNA closer to the RF application sites. Furthermore, the patients with SNA injury were older (age 55 and 61 years) as compared with the study population (38.5 years [Q1, Q3: 27, 51 years]). Taking into account the well-established association between age and changes in aortic arch geometry (particularly aortic unfolding) in individuals without cardiovascular disease,[10] these data stimulate a more detailed investigation into the effects of age and AA on the risk of SNA occlusion.

CLINICAL IMPLICATIONS

To our knowledge, this is the first report of a complication after cardiac catheter denervation procedures. These results encourage the study of the SNA anatomy and the AA before the procedure to minimize the risk of SNA occlusion.

CONCLUSIONS

SNA injury may occur during cardiac denervation procedures. Increased AA characterized the patients with thermal SNA occlusion.

FUNDING SUPPORT AND AUTHOR DISCLOSURES

The authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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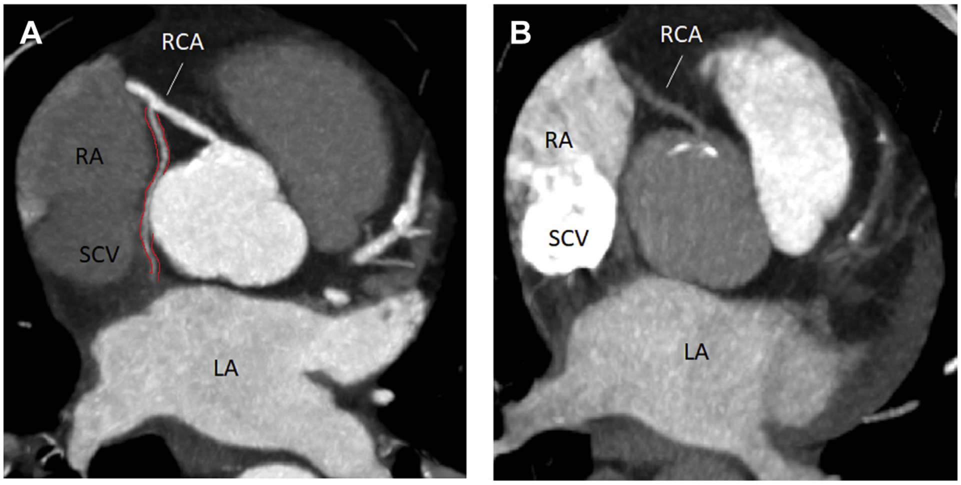
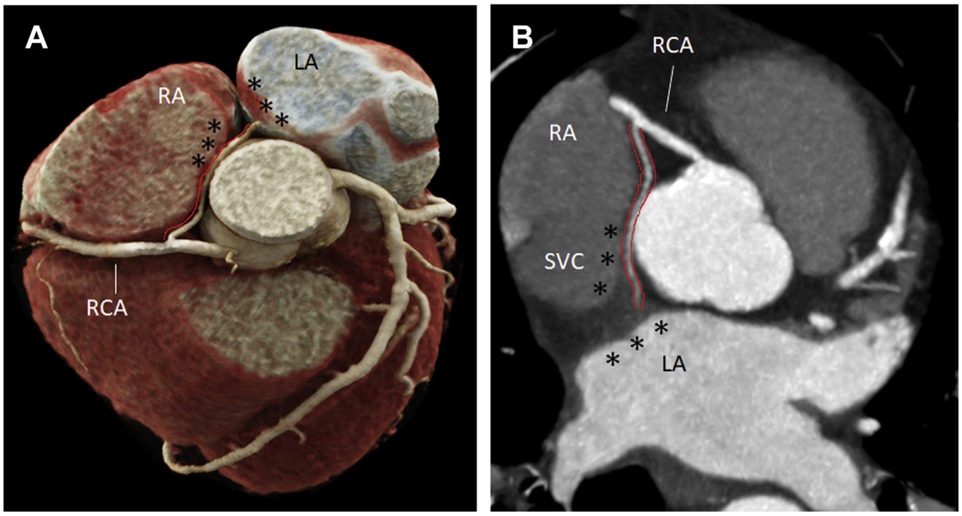
FIGURE 9 Coronary Computed Tomography Angiograms in Patient 2



Before ablation, angiography **(A)** and 3-dimensional tomographic imaging **(B)** show a precaval sinus node artery (highlighted in **red**) arising from the right coronary artery (RCA) and crossing the area between the superior right pulmonary vein and the atriocaval junction. After radiofrequency ablation **(C, D)**, proximal occlusion of the sinus node artery is demonstrated. LA = left atrium; RA= right atrium; RCA = right coronary artery; SVC = superior vena cava.

FIGURE 10 **Coronary Computed Tomography Views Before Ablation**



(A) 3-dimensional tomographic imaging. **(B)** Angiography. Imaging performed before ablation may identify the course of the sinus node artery course and its proximity to the critical ablation area **(asterisks)**. LA = left atrium; RA = right atrium; RCA = right coronary artery; SVC = superior vena cava.

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KEY WORDS ablation, aortic valve, bradycardia, coronary circulation, electroanatomical mapping, electrophysiology