Received: 20 January 2018 | Accepted: 23 August 2018
DOI: 10.1002/joa3.12122

ORIGINAL ARTICLE

WILEY Journal of Arrhythmia Open Access

Evaluation of coronary sinus morphology by three-dimensional transthoracic echocardiography in patients undergoing electrophysiological study

Serhat Emre Senturk MD[1] | Yahya Kemal Icen MD[1] | Ayşe Selcan Koc MD[2] | Yurdaer Donmez MD[1] | Ahmet Oytun Baykan MD[1] | İlker Unal PhD[3] | Hilmi Erdem Sumbul MD[4] | Mevlüt Koc MD[1]

[1]Adana Health Practices and Research Center Cardiology Department, Health Sciences University, Adana, Turkey
[2]Adana Health Practices and Research Center Radiology Department, Health Sciences University, Adana, Turkey
[3]Department of Biostatistics, Faculty of Medicine, Cukurova University, Balcali, Saricam, Adana, Turkey
[4]Internal Medicine Department, Health Sciences University Adana City Education and Research Hospital, Adana, Turkey

Correspondence
Yahya Kemal Icen, Adana Health Practices and Research Center Cardiology Department, Health Sciences University, Adana, Turkey.
Email: dryahyakemalicen@gmail.com

Abstract

Background: In this study, we aimed to evaluate the coronary sinus (CS) morphology with three-dimensional transthoracic echocardiography (3D-TTE) in patients with supraventricular tachycardia (SVT) who underwent electrophysiological study (EPS).

Methods: This cross-sectional study was conducted with 187 patients who underwent EPS between November 2016 and April 2017. Patients were divided into three groups: atrioventricular nodal reentrant tachycardia (AVNRT) (n = 72), non-AVNRT SVT (n = 58), and normal EPS (n = 57). All patients were evaluated with electrocardiography, TTE, and 3D-TTE.

Results: The CS diameter (CSD) and area (CSA) were found significantly lower in the normal EPS group than in the other groups. There was no significant difference in the CSD between AVNRT and non-AVNRT SVT groups. However, it was found that the CSA was significantly larger in the AVNRT group than in the non-AVNRT SVT group. In linear regression analysis, age and left atrial diameter were determined as independent predictor for CSD and CSA ($P < 0.001$ for each one).

Conclusions: The CSD and CSA assessed by 3D-TTE were different and dilated in the patients with SVT compared to those in the normal individuals. There was no significant difference in the CSD between the AVNRT and non-AVNRT SVT groups. However, the AVNRT group had a larger CSA than the non-AVNRT SVT group.

KEYWORDS
arrhythmias, cardiac, coronary sinus, echocardiography, three-dimensional

1 | INTRODUCTİON

Larger coronary sinus (CS) ostium in patients with atrioventricular nodal reentrant tachycardia (AVNRT) may cause separation of the atrial entries. These entries can reach the atrioventricular (AV) node or a different node physiology by creating an increased anisotropic conduction, when compared to other supraventricular tachycardia (SVT) types.[1,2]

Previous studies have reported that CS cannulation was easier and simpler in patients with AVNRT diagnosis than in patients with other types of SVT.[3] The CS morphology was evaluated by fluoroscopy in previous studies.[4,5] The CS can be visualized by using zoom M-mode recordings of it in apical two- and four-chamber views. However, the CS ostium size changes by cardiac cycle, which leads to varying CS measurements and limits the applicability of two-dimensional (2D) echocardiography.[6] Conca et al[7] used three-dimensional (3D) real-time echocardiography to measure the CS ostium and demonstrated that 3D echocardiography provided adequate images of the CS with accurate determination of the CS size in a short acquisition and reconstruction time.

The aim of our study was to evaluate the CS morphology by 3D transthoracic echocardiography (3D-TTE) in patients, with or without SVT diagnosis, who underwent electrophysiological study (EPS).

2 | METHODS

2.1 | Patient population and demographic data

The present cross-sectional study included 187 patients who underwent EPS between November 2016 and April 2017. These patients had palpitation or SVT diagnosis. The study protocol was prepared according to the principles of the Declaration of Helsinki. The Local Ethics Committee approved the study protocol, and each participant provided written informed consent. Patients with coronary artery disease, severe cardiac valve diseases, heart failure, pregnancy, and/or suspected pregnancy were excluded. Systolic and diastolic blood pressure measurements, risk factors, and demographic data of all patients were recorded.

2.2 | Transthoracic echocardiography and measurements

Standard TTE examinations were performed by an EPIQ 7 (Philips Healthcare, Andover, MA, USA) device. M-mode, 2D, color Doppler, and pulse wave Doppler echocardiography modalities were applied while the patient was in a supine position or lying on their left side. Parasternal long-axis images were obtained according to the suggestions of the American Society of Echocardiography. The left ventricle (LV) end-systolic and end-diastolic dimensions, end-diastolic interventricular septum (IVS) and posterior wall thicknesses, and left atrium (LA) dimensions were measured. The wall movements, valvular formations and functions, and pericardial pathologies of both ventricles were inspected. The patient was instructed to lie on the left side and apical four-chamber images were obtained. The end-systolic and end-diastolic volumes of LV and ejection fraction were calculated according to Simpson's rule. LA areas were calculated from two- and four-chamber images according to Simpson's rule.

2.3 | Three-dimensional transthoracic examination

Electrocardiogram (ECG)-guided 3D-TTE images were reviewed by an experienced operator using an EPIQ 7 (Philips Healthcare) echocardiography device, which has 3D data collection software. All patients were asked to hold their breaths at the end of expiration for 8-10 seconds to create better multiplanar images from apical frames. The CS was recorded through the highest density setting. At least two or three images were digitally stored for further offline analysis. The multiplanar images were separated from the anterior to posterior side until the short axis of the CS could be visualized. After determination of the CS, the images were cut again from the atrial or ventricular plane. The coronary sinus area (CSA) was determined from the point where the CS opens into the right atrium (RA). The lower and upper borders of the CS ostium were taken as reference points. Consequently, the best image of the CS ostium was achieved. The CSA and CS diameter (CSD) were measured after the 3D image of the CS was created (Figure 1).

2.4 | Electrophysiological analysis

The EPS was performed through the standard right femoral vein path. The Shimadzu (Kyoto, Japan) brand angiographic device was used in the catheterization laboratory of our clinic. The catheters were placed into the RA, the bundle of His, and the apex of the right ventricle. Standard procedures were performed through the protocols determined by the guidelines. The basal cycle length, automaticity, and conduction of the sinoatrial node, and conduction time and refractory periods of the AV node and the Purkinje system were evaluated. We attempted to simulate supraventricular arrhythmia using programmed atrial and ventricular pacing or drugs (atropine or isoproterenol). The patients without inducible SVT were defined as the normal EPS group. The diagnosis of patients was labeled as AVNRT, non-AVNRT, or normal EPS according to the standards of the EPS. Ablation treatment was administered to the patients, with AVNRT and without AVNRT, using appropriate protocols.[8]

2.5 | Statistical analysis

The variables were divided into two groups as categorical and continuous. The Kolmogorov-Smirnov test was used to assess whether

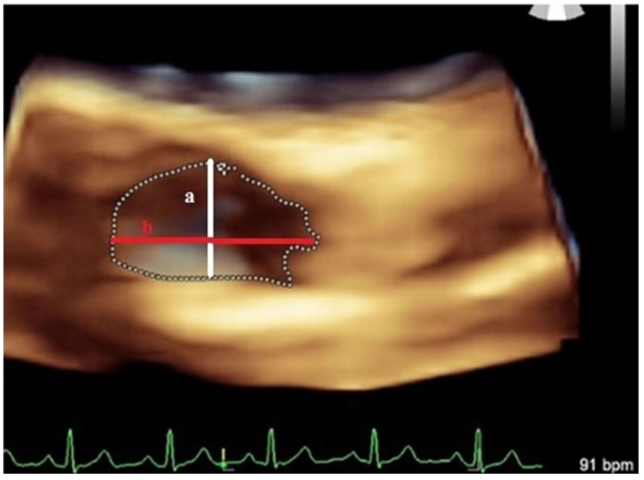

FIGURE 1 Coronary sinus area and diameter measurement with 3D transthoracic echocardiography

continuous variables comply with the normal distribution. Continuous variables were expressed as the mean ± standard deviation (mean ± SD). Categorical variables were provided as numbers and percentage. Comparison of continuous variables was done through the one-way analysis of variance (ANOVA) or the Kruskal-Wallis one-way ANOVA test according to the distribution. For normally distributed data, considering the homogeneity of variances, the Scheffe, and Games-Howell tests were used for multiple comparisons of groups. For not n-normally distributed data, the Bonferroni adjusted Mann-Whitney *U* test was used for multiple comparisons of groups. The Chi-squared test was used to compare categorical variables. Single variable correlation analysis was performed by the Pearson's Correlation method. Statistically significant parameters were included in a multivariable model and linear regression analysis was performed with these parameters. Independent predictor were determined for CS diameter and area. The statistical significance level was accepted as $P < 0.05$. All analyses were performed by using the SPSS 20.0 (Chicago, IL, USA) statistical software package.

3 | RESULTS

The patients were divided into three groups: AVNRT (n = 72), non-AVNRT SVT (n = 58), and normal EPS (n = 57). The comparison of general demographics revealed that the distribution and values of all parameters were similar between the groups (Table 1). The interventricular septum thickness was significantly higher in the normal EPS group than in the non-AVNRT SVT group. The diameter of the ascending aorta was significantly larger in the AVNRT group than in the normal EPS group. The other TTE findings were similar between the groups (Table 2). The evaluation of the 3D-TTE data revealed that the CSD and CSA were significantly lower in the normal EPS group than in the non-AVNRT SVT group. There was no significant difference in the CSD between the AVNRT and non-AVNRT groups. However, the CSA was significantly larger in the AVNRT group than in the non-AVNRT SVT group (Table 3). A correlation analysis was performed between the CSD, CSA, and other parameters. Some of the parameters were shown to be significantly correlated with the CSA and CSD (Table 4). A linear regression analysis was performed using parameters which that significantly correlated with the CSA and CSD. The LV systolic diameter, LA diameter, and the body mass index were independently associated with the CSD (Table 5). The LA diameter and age were independently associated with the CSA (Table 6).

TABLE 1 Comparison of demographic characteristics

	Normal EPS (n = 57)	AVNRT (n = 72)	Non-AVNRT SVT (n = 58)	*P*
Age (year)	45.3 ± 15.5	46.1 ± 12.4	45.0 ± 12.5	0.886
Gender (female/male)	28/29	40/32	31/27	0.647
Systolic blood pressure (mm Hg)	120.1 ± 16.6	121.1 ± 17.2	122.2 ± 16.6	0.775
Diastolic blood pressure (mm Hg)	75.8 ± 11.1	77.5 ± 11.7	76.7 ± 10.2	0.683
Pulse (pulse/minute)	77.7 ± 10.7	78.1 ± 11.8	78.4 ± 12.6	0.721
Body weight (kg)	73.7 ± 11.3	73.7 ± 11.2	77.5 ± 11.8	0.113
Body length (cm)	170.9 ± 9.2	168.8 ± 9.5	171.1 ± 9.7	0.309
Body mass index (kg/m^2)	25.3 ± 3.7	26.1 ± 3.3	27.0 ± 3.9	0.184
Smoking, n (%)	10 (17.5)	13 (18)	12 (20.7)	0.930
Diabetes, n (%)	8 (14)	10 (13.9)	13 (22.4)	0.227
Hypertension, n (%)	20 (35)	28 (38.9)	21 (36.2)	0.904
Hyperlipidemia, n (%)	9 (15.8)	14 (19.4)	8 (13.8)	0.770
Family arrhythmia history, n (%)	9 (15.8)	11 (15.3)	8 (13.8)	0.880

EPS, electrophysiological study; AVNRT, atrioventricular reentrant tachycardia; SVT, supraventricular tachycardia.
The values were shown as mean ± SD or n (%).

4 | DİSCUSSİON

In the present study, the CSD and CSA were detected to be larger in patients with SVT than in those without SVT. The CSD was similar in the AVNRT and non-AVNRT SVT groups. The CSA was significantly larger in the AVNRT group than in the non-AVNRT SVT group. To the best of our knowledge, this study is the first to evaluate the CSD and CSA by using 3D-TTE. Furthermore, age and the LA diameter were found to be independently associated with the CSD and CSA.

Conflicting outcomes were reported in previous studies about the CSD of patients with SVT. A study conducted by Doig et al[3] compared the CS ostium diameter of 15 patients with AVNRT and 14 patients without AVNRT. They found that the mean CS ostium diameter was larger in the AVNRT group. By contrast, Hummel et al[4] evaluated 22 patients with AVNRT and 22 patients without AVNRT, and reported similar CS ostium diameters in both groups. These two studies evaluated the CS images by using retrograde venography. Weiss et al[8] reported that there was a wider, but not statistically significant, CSD in patients with AVNRT. They also stated that CS anomalies such as diverticula, persistent superior vena cava, and enlargement of the CS ostium were predominantly found in patients with accessory pathway-related tachycardias. In contrast to previous researchers, Delurgio et al[9] used intracardiac echocardiography (ICE) to assess the CS. They compared 11 patients with AVNRT and 9 patients without AVNRT, and found no difference in terms of the CSD. Okumura et al[10] assessed the anatomy of the CS through 3D reconstructed ICE images. They reported that the patients with AVNRT had a wider CSD and CSA.

TABLE 2 Comparison of transthoracic echocardiography data

	Normal EPS (n = 57)	AVNRT (n = 72)	Non-AVNRT SVT (n = 58)	P
IVS diastolic thickness (mm)	10.2 ± 1.62[a]	9.7 ± 1.44[b]	9.5 ± 1.76[b]	**0.027**
PW diastolic thickness (mm)	10.2 ± 1.99	10.3 ± 1.38	10.2 ± 1.37	0.944
LV end-diastolic diameter (mm)	43.2 ± 4.89	43.4 ± 5.42	43.8 ± 5.24	0.848
LV end-systolic diameter (mm)	27.3 ± 4.51	27.9 ± 4.30	28.1 ± 4.38	0.644
LV end-diastolic volume (mL)	83.4 ± 7.16	80.1 ± 17.8	82.2 ± 17.8	0.568
LV end-systolic volume (mL)	30.9 ± 6.40	32.5 ± 11.1	32.7 ± 8.91	0.550
LV ejection fraction (%)	68.1 ± 5.68	66.4 ± 6.13	65.4 ± 8.61	0.108
LA end-diastolic diameter (mm)	28.5 ± 3.6	29.4 ± 5.2	29.3 ± 5.1	0.550
LA area (2 chambers) (cm^2)	12.7 ± 2.74	11.9 ± 2.68	13.1 ± 3.11	0.078
LA area (4 chambers) (cm^2)	12.8 ± 2.84	12.7 ± 3.33	12.9 ± 3.41	0.957
Aorta diameter (mm)	23.9 ± 3.5[a]	25.6 ± 3.6[b]	25.2 ± 3.5[b]	**0.020**

EPS, electrophysiological study; AVNRT, atrioventricular nodal reentrant tachycardia; SVT, supraventricular tachycardia; IVS, interventricular septum; PW, posterior wall; LV, left ventricle; LA, left atrium.
The values were shown as mean ± SD.
[a]The significant association between the normal EPS group and AVNRT group ($P < 0.05$).
[b]The significant association between the normal EPS group and non-AVNRT SVT group ($P < 0.05$).

TABLE 3 Comparison of three-dimensional transthoracic echocardiographic coronary sinus data

	Normal EPS (n = 57)	AVNRT (n = 72)	Non-AVNRT SVT (n = 58)	P
CSD (mm)	6.79 ± 1.74[a,b]	8.98 ± 3.24	8.10 ± 2.04	**<0.001**
CSA (mm^2)	9.45 ± 2.24[a,b]	13.8 ± 4.57[c]	12.1 ± 3.21	**<0.001**

CSD, coronary sinus diameter; CSA, coronary sinus area; EPS, electrophysiological study; AVNRT, atrioventricular nodal reentrant tachycardia; SVT, supraventricular tachycardia.
Statistically significant *P* values were shown in bold.
The values were shown as mean ± SD.
[a]The significant difference between normal EPS group and AVNRT group ($P < 0.05$).
[b]The significant difference between normal EPS group and non-AVNRT SVT group ($P < 0.05$).
[c]The significant difference between AVNRT group and non-AVNRT SVT group ($P < 0.05$).

There are conflict results about the CSD in patients with or without AVNRT. The usage of different methods for CSD evaluation may be one of the causes of this conflict. The two aforementioned studies were performed using retrograde venography, whereas the

TABLE 4 The parameters associated with coronary sinus diameter and coronary sinus area

	CSD		CSA	
	P	*r*	*P*	*r*
Age (year)	<0.001	0.407	<0.001	0.448
Bodyweight (kg)	<0.001	0.263	0.003	0.218
Body mass index (kg/m^2)	<0.001	0.338	<0.001	0.337
Systolic blood pressure (mm Hg)	<0.001	0.333	<0.001	0.338
Diastolic blood pressure (mm Hg)	<0.001	0.283	<0.001	0.283
Pulse (pulse/minute)	0.012	0.184	0.009	0.191
SV end-diastolic volume (mL)	<0.001	0.255	0.033	0.156
LV end-systolic volume (mL)	<0.001	0.392	<0.001	0.369
SV end-diastolic diameter (mm)	<0.001	0.301	0.002	0.229
SV end-systolic diameter (mm)	<0.001	0.406	<0.001	0.364
Left atrium diameter (mm)	<0.001	0.409	<0.001	0.422
LA area (4 chambers) (cm^2)	<0.001	0.317	0.002	0.227
LA area (2 chambers) (cm^2)	<0.001	0.284	<0.001	0.261
LV ejection fraction (%)	<0.001	0.321	<0.001	0.396
Aorta diameter (mm)	0.003	0.213	0.001	0.231

CSD, coronary sinus diameter; CSA, coronary sinus area; *r*, Pearson's coefficient; IVS, interventricular septum; PW, posterior wall; LV, left ventricle; LA, left atrium.
Statistically significant *P* values were shown in bold.

TABLE 5 Linear regression analysis for parameters significantly correlated with coronary sinus diameter

	P	β	95% CI for β
LV end-systolic diameter (mm)	0.033	0.012	0.001-0.023
LA diameter (mm)	0.012	0.116	0.026-0.206
BMI (kg/m^2)	0.031	0.013	0.001-0.024

BMI, body mass index; LA, left atrium; LV, left ventricular; CI, confidence interval.
$R^2_{Adjusted}$ = 0.320.

TABLE 6 Linear regression analysis for parameters significantly correlated with coronary sinus area

	P	β	95% CI for β
LA diameter (mm)	0.001	0.163	0.069-0.256
Age (year)	<0.001	0.007	0.004-0.011

CI, confidence interval; LA, left atrium.
$R^2_{Adjusted}$ = 0.538.

others were assessed using ICE. We used 3D-TTE for the evaluation of CS. In our study, the mean CSA was detected to be larger in the AVNRT group than in the non-AVNRT SVT group. This finding complies with the previous studies. Okumura et al[10] examined the anatomy of the CS using the 3D ICE method. We used the 3D-TTE method for the measurements of the CSD and CSA, which can be easily used in regular practice.

The structure of the CS ostium is usually elliptic. The CS morphology is generally seen in two types: windsock and tubular. It is logical to measure a windsock-type CS from different points. We performed measurements only from the CS ostium, and did not make any distinction between the tubular or windsock morphology. The ostium diameter is wide in the windsock-type CS, but it gets narrower in the distal parts. Perhaps, we could not find any difference between the groups because we made the measurements from the inner parts of the CS. Okumura et al[11] found that the CSA and the occurrence of windsock type were significantly higher in the AVNRT group.

When compared to other studies, the inclusion of patients without SVT is an advantage of our study. One of the significant findings in our study was that the CSD and CSA were larger in patients with SVT than in those without SVT. We hypothesize that the larger CSD value in patients with AVNRT may have a role in the pathogenesis of tachyarrhythmia. The dual AV node pathway physiology is a common finding that may represent a variation from the normal; this is explained by the existence of multiple atrionodal entrances into the AV node.[2] An increased CS ostium may stretch surrounding the normal atrial tissue and change the conduction characteristics of the periosteal tissue. Therefore, it may create a decelerated potential area. Previous studies have showed that increased stretching might change the electrophysiological characteristics of the cardiac tissue.[11,12]

As a known fact, the most common explanation of the pathophysiology of AVNRT is dual AV node pathway physiology which means that two different conduction routes, with different conduction rates and refractory periods, exist together. However, some additional factors are needed for the occurrence of such arrhythmias. The most commonly adopted hypothesis is that there is a slow conduction area that may lead to anisotropy. A dilated CS ostium may increase the conduction distance and create such a potential.[13] Besides, such anatomical structures may have different functional lengths and conduction times. The association between anatomical and electrophysiological characteristics seems more complex than expected. The existence of different AVNRT forms in a single patient also supports this idea. LA diameter and age were closely associated with the CSA in our study. There may be structural changes or enlargement in the CSA and CSD, like the other cardiac and vascular tissues, with aging. We also think that the following reasons may explain the association between the increased LA diameter and CSA-CSD values: (a) The LA and CS are close to each other; hence, they are exposed to the same pathophysiological processes, and (b) they may both be enlarged by frequent tachyarrhythmias.

4.1 | Limitations

In addition to the CS shape, the venous phase of coronary angiography was not evaluated by coronary computed tomography angiography, transesophageal echocardiography, or ICE. Therefore, there was no comparison between these methods and the 3D-TTE measurements. If we used 3D-transoesophageal echocardiography or ICE, we would have obtained more accurate CS measurements. ICE is not a routine imaging method in patients with SVT undergoing EPS; hence, we did not use this method. 3D-TTE is a simpler, non-invasive, reproducible, and much cheaper evaluation method. Further studies, to be conducted using direct imaging methods of the CS, would overcome such limitations. Besides, cannulation of the CS would not be ethical as a part of EPS in this patient group.

5 | CONCLUSİON

The CSD and CSA were assessed by 3D-TTE, which detected differences and dilatation in the patients with SVT compared to the normal individuals. No significant difference was found in the CSD between the AVNRT and non-AVNRT SVT groups. However, patients the AVNRT group were found to have a larger CSA than those in the non-AVNRT SVT group.

CONFLICT OF INTEREST

The authors declare no conflict of interests for this article.

ORCID

Yahya Kemal Icen http://orcid.org/0000-0003-0070-5281

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How to cite this article: Senturk SE, Icen YK, Koc AS, et al. Evaluation of coronary sinus morphology by three-dimensional transthoracic echocardiography in patients undergoing electrophysiological study. *J Arrhythmia*. 2018;34:626–631. https://doi.org/10.1002/joa3.12122