

Incidence and appearances of coronary sinus anomalies in adults on cardiac CT

Kotaro Ouchi¹ · Toru Sakuma¹ · Makoto Kawai² · Kunihiko Fukuda¹

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Abstract

Purpose The aim of this study was to analyze the frequency and appearances of coronary sinus (CS) anomalies on cardiac computed tomography (CT) of adult patients and to compare them with transthoracic echocardiography (TTE) findings.

Methods We retrospectively evaluated cardiac CT images for the presence of CS anomalies in 6936 adult patients who underwent imaging from April 1 2008 to March 31 2015 at our institution. We also reviewed and compared with TTE findings for the cases of CS anomalies.

Results CS anomalies were diagnosed in 23 of the 6936 (0.33 %) and included persistence of the left superior vena cava (PLSVC) in 19 cases, unroofed CS (UCS) in two, coronary artery-CS fistula in two, and CS atresia in one. TTE revealed CS dilatation in only five of the 16 cases of PLSVC and suggested CS anomaly in the two cases of coronary artery-CS fistula. The other cases of CS anomaly were detected incidentally on CT.

Conclusion The incidence of CS anomalies was 0.33 %. Precise diagnosis of CS anomalies with TTE and the original transverse images on cardiac CT alone was difficult for some conditions. We should be alert for the presence of CS anomalies which can cause clinical or procedural complications.

Keywords Cardiac computed tomography · Coronary artery-coronary sinus fistula · Coronary sinus atresia · Persistent left superior vena cava · Unroofed coronary sinus

Introduction

Precise anatomical knowledge of coronary sinus (CS) has become increasingly important because of its relevancy in various cardiac interventions, including left ventricular pacing, mapping, and ablation of arrhythmias. As the use of cardiac computed tomography (CT) to assess the coronary artery and guide preprocedural planning of cardiac interventions has increased, so does the incidental discovery of asymptomatic congenital CS anomalies. The aim of this study was to analyze the frequency and appearance of CS anomalies in adult patients who underwent cardiac CT images for cardiac diseases or preprocedural planning and to compare them with transthoracic echocardiography (TTE) findings.

Materials and methods

Our institutional review board approved the protocol for this retrospective study. This retrospective study evaluated the frequency and appearances of CS anomalies on cardiac CT and compared with TTE findings.

Patients

We evaluated imaging findings of 6936 adult patients (5232 men and 1704 women; aged from 20 to 102 years) who underwent cardiac CT from April 1 2008 to March 31 2015 in our institution.

✉ Kotaro Ouchi
kotaro-alex@jikei.ac.jp

¹ Department of Radiology, The Jikei University School of Medicine, 3-25-8 Nishi-Shimbashi, Minato-Ku, Tokyo 105-8461, Japan

² Department of Cardiology, The Jikei University School of Medicine, 3-25-8 Nishi-Shimbashi, Minato-Ku, Tokyo 105-8461, Japan

Cardiac computed tomography

All patients were examined with a dual-source CT system (SOMATOM® Definition Flash or SOMATOM® Definition, Siemens Medical Solutions, Forchheim, Germany). For cardiac CT, each patient had intravenous injection of contrast material (Iopamiron; 370 mg I/ml, Bayer AG, Leverkusen, Germany) with administration controlled by bolus tracking in the ascending aorta. During scan acquisition, the contrast enhancement was achieved by an initial bolus of contrast material, followed by 30 ml of pure saline at the same injection speed. The injection speed and volume of the iodine bolus were individually computed with the formula: injection speed (ml/s) = body weight (kg) × 0.07 ml/s, and volume (ml) = injection speed × [duration of CT data acquisition (s) + 5]. The scan parameters were: slice collimation 2 × 64 × 0.6 mm (SOMATOM® Definition Flash) or 2 × 32 × 0.6 mm (SOMATOM® Definition) with a z-flying focal spot; gantry rotation time 280 ms (SOMATOM® Definition Flash) or 330 ms (SOMATOM® Definition); pitch 0.2–0.5; tube voltage 120 kVp; and tube current 330 mAs (SOMATOM® Definition Flash) or 300 mAs (SOMATOM® Definition). Retrospective electrocardiography (ECG) gating and ECG-dependent tube current modulation were used. Scanning ranged from the level of the carina to just below the dome of the diaphragm. All reconstructed image data were transferred to workstations (MultiModality Workplace, Siemens).

Transthoracic echocardiography

Conventional echocardiographic examinations were performed using an $\alpha 10$ (SSD- $\alpha 10$) equipped with a UST-52105 probe (1.5–4.3 MHz) (Aloka Medical Systems, Tokyo, Japan), an Artida (SSH-880CV) equipped with a PST-25BT probe (2.5 MHz) (Toshiba Medical Systems, Tochigi, Japan), a Vivid E9 equipped with an M5Sc probe (3.3 MHz with the tissue harmonic mode), and also a Vivid 7 equipped with an M4S probe (3.3 MHz with the tissue harmonic mode) (GE Healthcare, Tokyo, Japan) in 20 of the 23 patients diagnosed with CS anomalies.

Image evaluation

Two experienced radiologists retrospectively reviewed all CT images. The CS anomalies were evaluated with the original transverse images and multiplanar reformations including the cardiac short-axis view. They also reviewed and compared with TTE findings for cases with CS anomalies. In this study, we used Mantini et al.'s classification [1] to discuss the imaging appearances of CS anomalies.

Results

Among 6936 patients, CS anomalies were diagnosed in 23 (0.33 %) which included 19 cases with persistent left superior vena cava (PLSVC; Fig. 1), two cases with unroofed

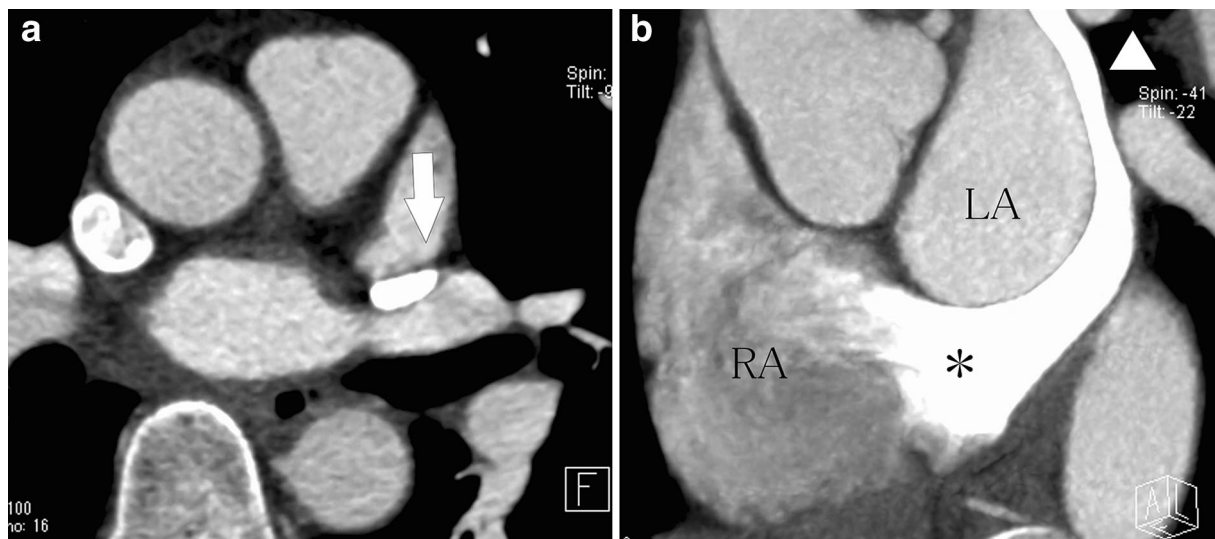


Fig. 1 Cardiac CT image of PLSVC in a 41-year-old woman. **a** Axial image shows PLSVC (arrow). **b** Short axis image shows a PLSVC (arrowhead) draining into the CS (asterisk). LA left atrium, RA right atrium

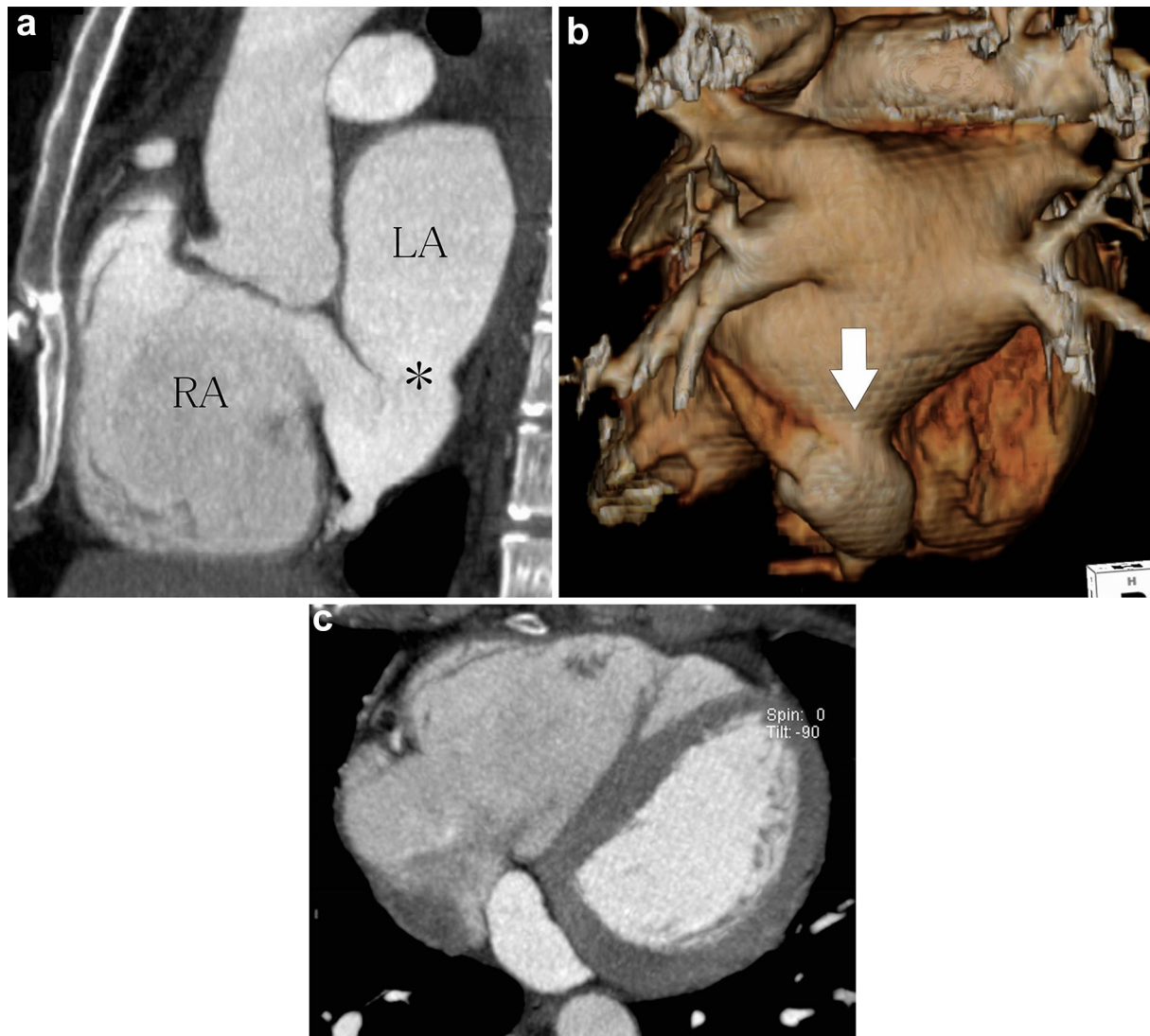


Fig. 2 Cardiac CT image of UCS in a 51-year-old woman. **a** Short axis image shows a defect (*asterisk*) in the wall partitioning the CS from the LA with associated dilatation of the CS. The patient did not have a PLSVC. There was a left-to-right shunt from the LA to the right atrium (RA) through the CS. **b** Volume-rendered image shows

dilatation of the CS and communication (*arrow*) between the LA and CS. It is difficult to identify the defect in the wall partitioning the CS from the left atrium in a case of UCS with the original axial images (**c**)

CS (UCS; Fig. 2), two cases with coronary artery-CS fistula (Fig. 3), and one case with CS atresia (Fig. 4), which coexisted with one of the 19 cases with PLSVC described above (Table 1). The two cases of UCS were associated with CS dilatation and were not accompanied by PLSVC. The two cases of coronary artery-CS fistula draining into CS were associated with a dilated and tortuous left circumflex (LCX) coronary artery. TTE was performed in 20 of the 23 cases. TTE revealed CS dilatation in five of the 16 cases of PLSVC and suggested CS anomaly in the 2 cases of coronary artery-CS fistula. The other cases of CS anomaly were detected incidentally on CT (Table 2). It was difficult to identify a defect in the wall partitioning the CS from

the left atrium in a case of UCS with the original transverse images (Fig. 2). The cardiac short-axis view allowed us to identify the defect.

Discussion

In this study, the incidence of CS anomalies was 0.33 %. Diagnosed anomalies included: PLSVC, UCS, coronary artery-CS fistula and CS atresia, PLSVC; enlargement of CS without left-to-right shunt, UCS; enlargement of CS with left-to-right low pressure shunts, coronary artery-CS fistula; enlargement of CS with left-to-right high pressure

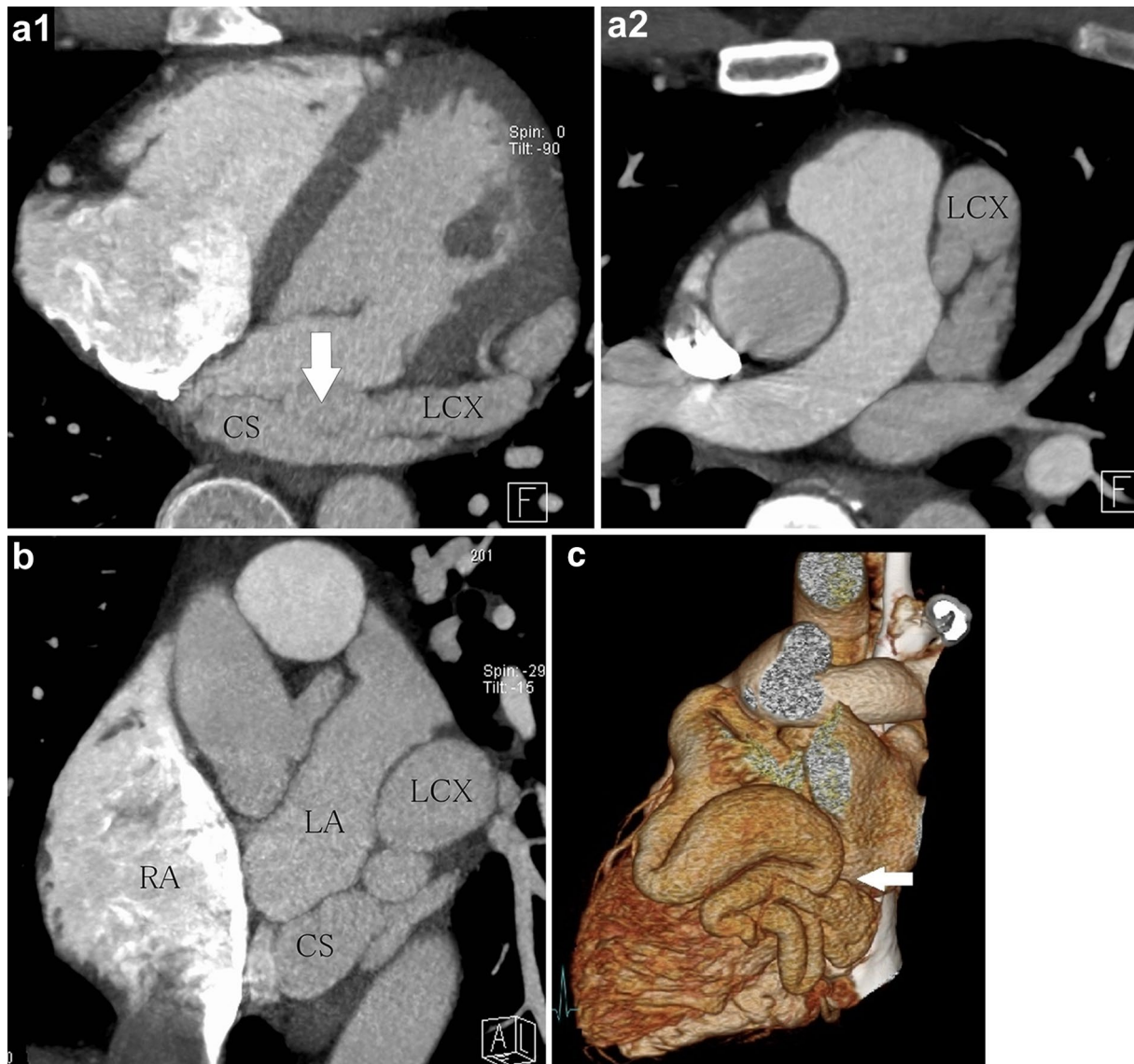


Fig. 3 Cardiac CT image of coronary artery-CS fistula in a 44-year-old man. Axial image (a), short axis image (b), and volume-rendered image (c) show a dilated and tortuous LCX with a fistula (arrow in a-1, c) to the CS

shunts, and CS atresia with narrow PLSVC and gross communication of CS with the left atrium which was probably a major coronary sinus flow [1]. TTE and the original transverse images only on cardiac CT were not enough for precise diagnosis of UCS. To our knowledge, this is the first large-scale study to analyze the frequency and appearances of CS anomalies in adult patients who underwent cardiac CT images for cardiac diseases or preprocedural planning.

The estimated occurrence of PLSVC is 3–10 % in patients with congenital cardiac disease [2] and 0.3 % in the general population [3]. Although the true prevalence of UCS, a rare congenital anomaly and the most uncommon type of atrial septal defect, is unknown, it accounts for less than 1 % of all types of atrial septal defect. The

presence of coronary arterial fistulas has been estimated in 0.05–0.25 % of patients who undergo coronary angiography (CAG) and 0.002 % of the general population [4]. Approximately 7 % are estimated to drain into the CS, which leads to left-to-right shunting [5]. CS atresia has a reported incidence of 0.1 % [6] to 0.25 % [7] of cases and usually consists of a membranous occlusion at the ostium [8], which prevents direct venous drainage from the CS to the right atrium. Approximately 53 % of patients with CS atresia have concomitant coronary artery fistulae and UCS [6]. The prevalence of PLSVC on CT was almost the same as that of the previous report. On the other hand, the prevalence of the other CS anomalies on CT was different from that of the previous report. It may lead to biases because

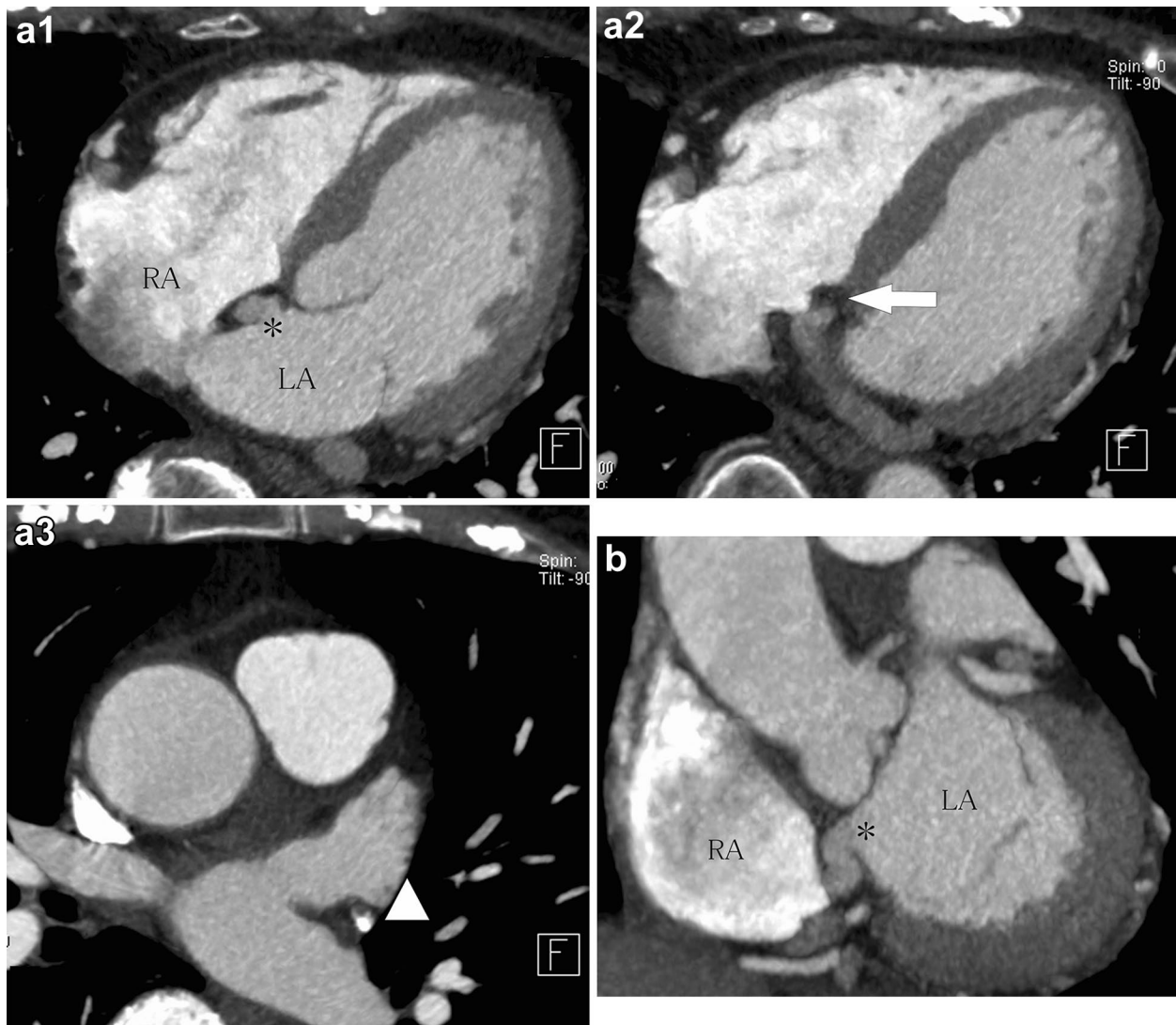


Fig. 4 Cardiac CT image of CS ostial atresia with PLSVC in a 64-year-old woman. **a** Axial image shows a CS atresia near the ostium (*arrow*). **b** A small-caliber PLSVC (*arrowhead*). **c** Short axis image shows communication (*asterisk*) between the CS and LA

Table 1 Incidence of coronary sinus (CS) anomalies in 6936 patients

CS anomalies	Number	Prevalence (%)
PLSVC	19 ^a	0.27
Unroofed coronary sinus	2	0.029
Coronary artery-CS fistula	2	0.029
CS atresia	1 ^a	0.014

PLSVC persistent superior vena cava

^a CS atresia coexisted with one case of PLSVC

they are much more uncommon congenital anomaly. This study did not show other CS anomalies including partial anomalous hepatic venous connection to CS, continuity of inferior vena cava with left superior vena cava through hemiazygos vein; enlargement of CS without left-to-right

shunt, pulmonary venous connection to CS; enlargement of CS with left-to-right high pressure shunt, absence of coronary sinus and hypoplasia of the coronary sinus.

Transthoracic echocardiography and the original transverse images alone on cardiac CT were not enough for precise diagnosis of CS anomalies. In adults, precise diagnosis of CS anomalies with TTE can be difficult because of poor visualization resulting from the limited sonic window and contrast resolution [9]. Cardiac CT allows comprehensive noninvasive assessment of the coronary artery and other non-coronary artery anatomical structures. Its high spatial and temporal resolutions, multi-plane reconstruction capabilities, and wide field of view make it an excellent modality for the detection and identification of CS anomalies. Some of our cases were also detected incidentally on CT but not on TTE. CS runs transversely in

Table 2 Clinical characteristics, computed tomography (CT) and transthoracic echocardiography (TTE) findings in patients with coronary sinus (CS) anomalies

ID	Age (years)	Sex	Purpose of CT examination	CT findings	TTE findings
1	67	M	CAD assessment	PLSVC	CS dilatation
2	74	F	CAD assessment	PLSVC	Not performed
3	20	M	Preparation for ablation of AF	PLSVC	CS dilatation
4	52	M	CAD assessment	PLSVC	CS dilatation
5	27	F	Cardiac murmur assessment	PLSVC	CS dilatation
6	46	M	CAD assessment	PLSVC	No abnormality
7	52	M	CAD assessment	PLSVC	Not performed
8	74	M	CAD assessment	PLSVC	No abnormality
9	65	M	Preparation for ablation of AF	PLSVC	No abnormality
10	68	M	CAD assessment	PLSVC	Not performed
11	41	F	CAD assessment	PLSVC	No abnormality
12	60	M	Preparation for ablation of AF	PLSVC	No abnormality
13	31	F	Preparation for surgical treatment of mitral stenosis	PLSVC	CS dilatation
14	74	F	Preparation for ablation of AF	PLSVC	No abnormality
15	63	M	Preparation for ablation of AF	PLSVC	No abnormality
16	44	M	Preparation for ablation of AF	PLSVC	No abnormality
17	35	F	CAD assessment	PLSVC	No abnormality
18	47	M	Preparation for ablation of AF	PLSVC	No abnormality
19	51	F	Preparation for surgical treatment of ASD	UCS	ASD suspected
20	54	M	Preparation for ablation of AF	UCS	No abnormality
21	68	M	Abnormal TTE findings	Coronary artery-CS fistula	Coronary artery-RA shunt suspected
22	44	M	Abnormal TTE findings	Coronary artery-CS fistula	UCS suspected
23	64	F	CAD assessment	CS atresia + PLSVC	No abnormality

AF atrial fibrillation, ASD atrial septal defect, CAD coronary artery disease, PLSVC persistent left superior vena cava, RA right atrium, UCS unroofed CS

the groove between the left atrium and ventricle of the heart. CS structure is considered as having a vertical segment superiorly that “turns” to join a horizontal segment inferiorly. The horizontal segment is parallel to the transverse CT images [10]. Although PLSVC can be diagnosed by routine CT examinations, it can be difficult to evaluate CS anomalies such as UCS with the original transverse images on cardiac CT because of the anatomical relationship. The cardiac short-axis view is most suited for depiction of CS anomalies on CT because it is perpendicular to the long axis of CS.

The presence of PLSVC and CS atresia can cause procedural difficulties [11] and the presence of UCS and coronary artery-CS fistula can cause various clinical complications such as heart failure, cerebral embolism, brain abscess, myocardial ischemia or sudden cardiac death as a result of the coronary steal phenomenon, endocarditis, or rupture or embolization from an associated coronary artery aneurysm. These conditions are often difficult to diagnose because the clinical signs and symptoms are nonspecific [12–14]. Therefore, we should carefully and precisely evaluate CS anomalies.

Our investigation has some limitations that must be considered. First, it is a single-center study and requires multi-center confirmation to authenticate the findings and reproducibility. Second, some sort of heart disease had been diagnosed or suspected in all patients who underwent cardiac CT. They may lead to biases. TTE suggested CS anomalies in three cases of coronary artery-CS fistula and UCS. TTE findings, however, could not describe the CS anomalies in detail. It is, therefore, necessary to confirm the CS anomalies by cardiac CT when they are suggested by TTE. Cardiac CT is an excellent modality for identifying CS anomalies.

In conclusion, we could show the incidence and appearances of coronary sinus anomalies in adults on cardiac CT images and could compare with TTE findings for the cases. Precise diagnosis of CS anomalies with TTE and the original transverse images alone on cardiac CT was difficult. Although cardiac CT is an excellent modality for identifying the CS anomalies, CS anomalies such as UCS could be missed with the original transverse images only because of the anatomical relationship between CS and the left atrium. We should carefully evaluate from multiple directions,

including the cardiac short-axis view, by reconstructing cardiac CT images of all patients for the presence of CS anomalies regardless of the inspection purpose, because CS anomalies can cause clinical or procedural complications that can be avoided with detailed knowledge of them.

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Compliance with ethical standards

Conflict of interest The authors have no conflict of interest directly relevant to the content of this article.

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