**Original article**

# Significance of cardiac CT findings of coronary sinus abnormalities in adults

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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 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 the 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 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.

### 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 achieved by 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 (seconds) + 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 to 0.5; tube voltage, 120 kVp; and tube current, 330 mAs (SOMATOM® Definition Flash) or 300mAs (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 examination were performed using an α10 (SSD-α10) equipped with a UST-52105 probe (1.5-4.3MHz) (Aloka Medical Systems, Tokyo, Japan), an Artida (SSH-880CV) equipped with a PST-25BT probe (2.5MHz) (Toshiba Medical Systems, Tochigi, Japan), a Vivid E9 equipped with M5Sc probe (3.3MHz with the tissue harmonic mode) and also Vivid 7 equipped with M4S probe (3.3MHz 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 transthoracic echocardiography (TTE) findings for cases of the CS anomalies. In this study, we used a classification of Mantini et al [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 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 not accompanied by PLSVC. The two cases of coronary artery-CS fistula drained into CS 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: enlargement of CS without left-to-right shunt[1], UCS: enlargement of CS with left –to-right shunt: low pressure shunts, coronary artery-CS fistula: enlargement of CS with left –to-right shunt: high pressure shunts , and CS atresia with narrow PLSVC and gross communication of CS with the left atrium which was probably major coronary sinus flow. 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 to 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 account for less than 1% of all types of atrial septal defect. The presence of coronary arterial fistulas has been estimated in 0.05 to 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 that 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 shunt: high pressure shunts, absence of coronary sinus and hypoplasia of the coronary sinus.

TTE 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 anatomic 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 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 coronary steal phenomenon, endocarditis, rupture or embolization from an associated coronary artery aneurysm. These conditions are often difficult to diagnose because the clinical signs and symptoms are nonspecific [12,13,14] . 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 underwent cardiac CT. TEE suggested CS anomalies in three cases of coronary artery-CS fistula and UCS. They may lead to biases. TEE 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 TEE. Cardiac CT is an excellent modality to identify 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 to identify the CS anomalies, CS anomalies such as UCS could be missed with the original transverse images only because of anatomical relationship between CS and 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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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 (*). 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 (*) 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 (arrows) between the LA and CS. It is difficult to identify defect in the wall partitioning the CS from the left atrium in a case of UCS with the original axial images. (C)

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 C) to the CS.

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

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

| CS anomalies | Number | Prevalence (%) |
|---|---|---|
| PLSVC | 19* | 0.27 |
| Unroofed coronary sinus | 2 | 0.029 |
| coronary artery–CS fistula | 2 | 0.029 |
| CS atresia | 1* | 0.014 |

PLSVC: persistent superior vena cava

* CS atresia coexisted with one case with PLSVC.

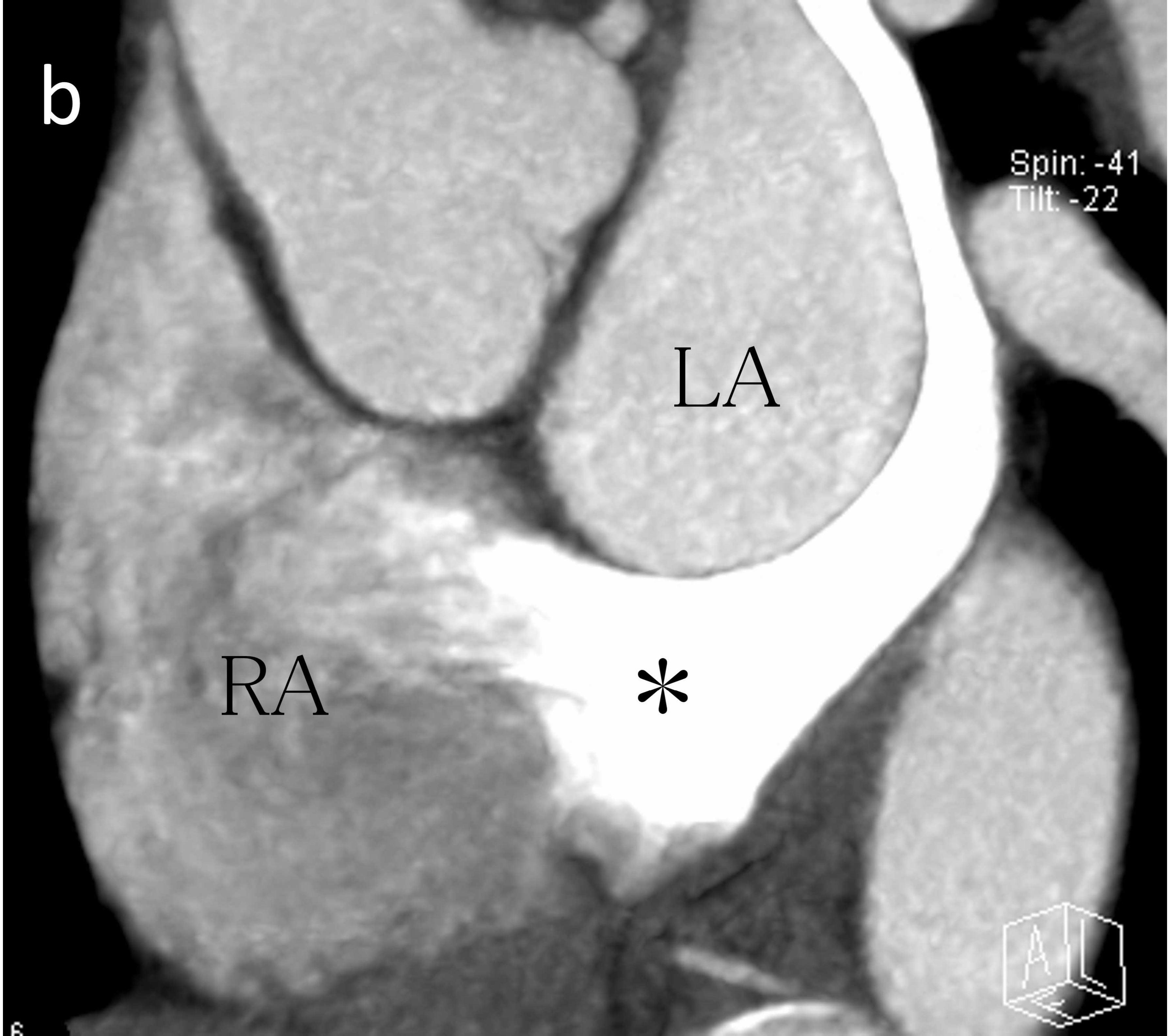
Table 2. Clinical characteristics and computed tomography (CT) and transthoracic echocardiography (TTE) findings in patients with coronary sinus (CS) anomalies

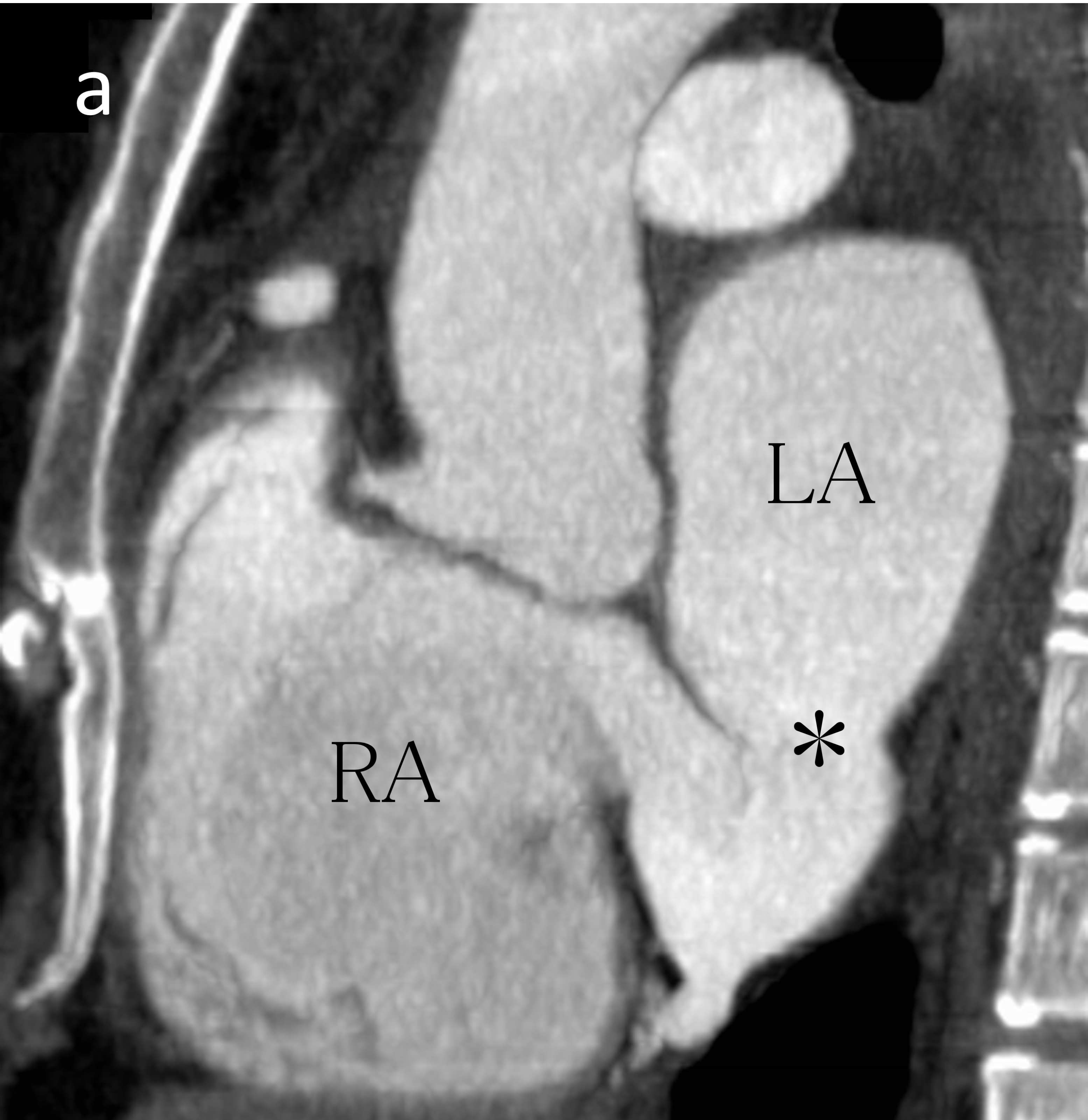
| ID | Age (yrs) | Sex | Purpose of CT examination | CT findings | TTE findings |
|---|---|---|---|---|---|
| 1 | 67 | M | CAD assessment | PLSVC | CS dilatation |
| 2 | 74 | F | CAD assessment | PLSVC | Not performed |
| 3 | 20 | M | preparation for ablation of AF | PLSVC | CS dilatation |
| 4 | 52 | 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 |

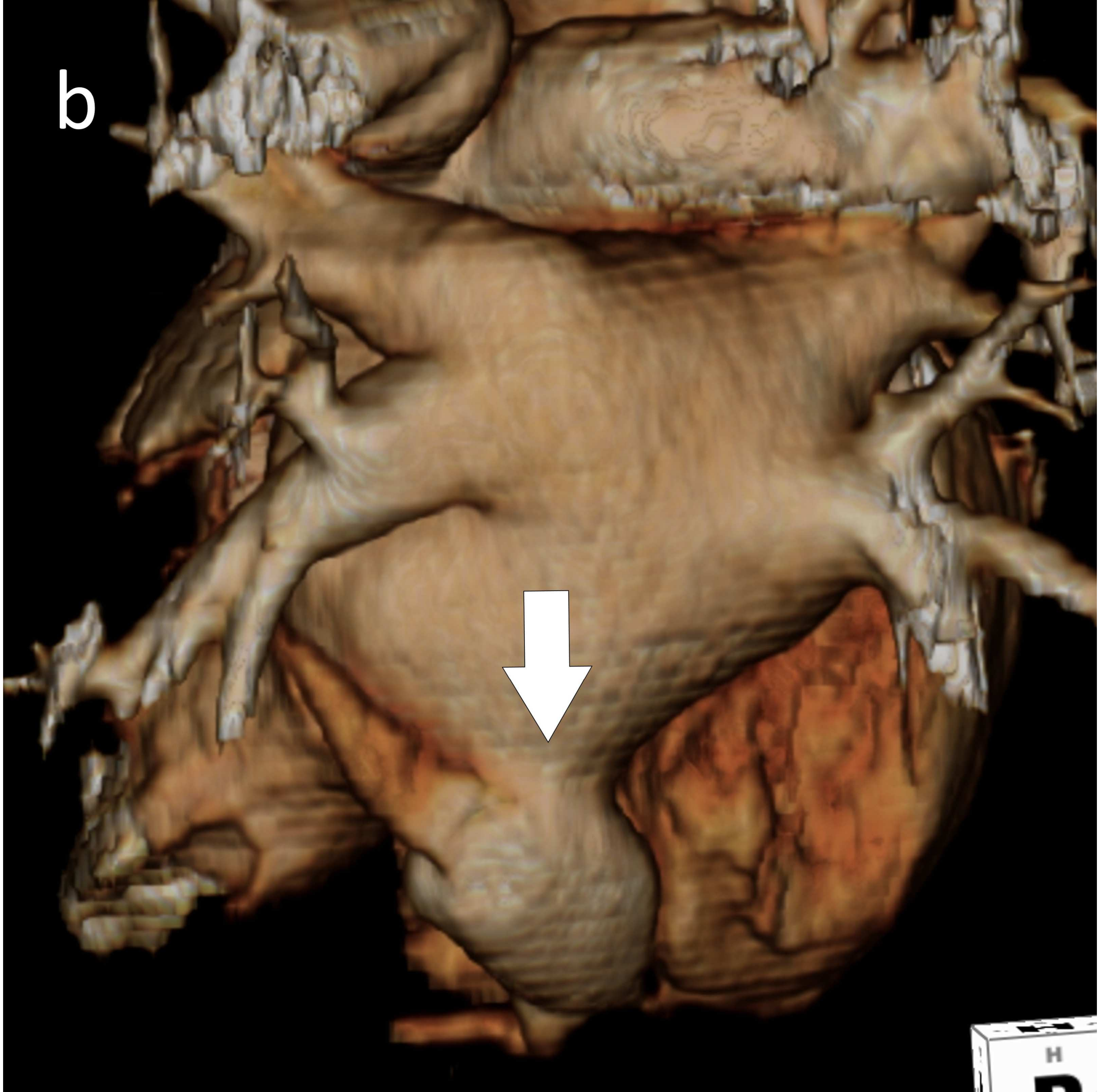
| | | | | | |
|---|---|---|---|---|---|
| 16 | 44 | M | preparation for ablation of AF | PLSVC | No abnormality |
| 17 | 35 | F | CAD assessment | PLSVC | No abnormality |
| 18 | 47 | M | preparation for ablation of AF | PLSVC | No abnormality |
| 19 | 51 | F | preparation for surgical treatment of ASD | 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


a
Spin:
Tilt: -9
100
no: 16
F

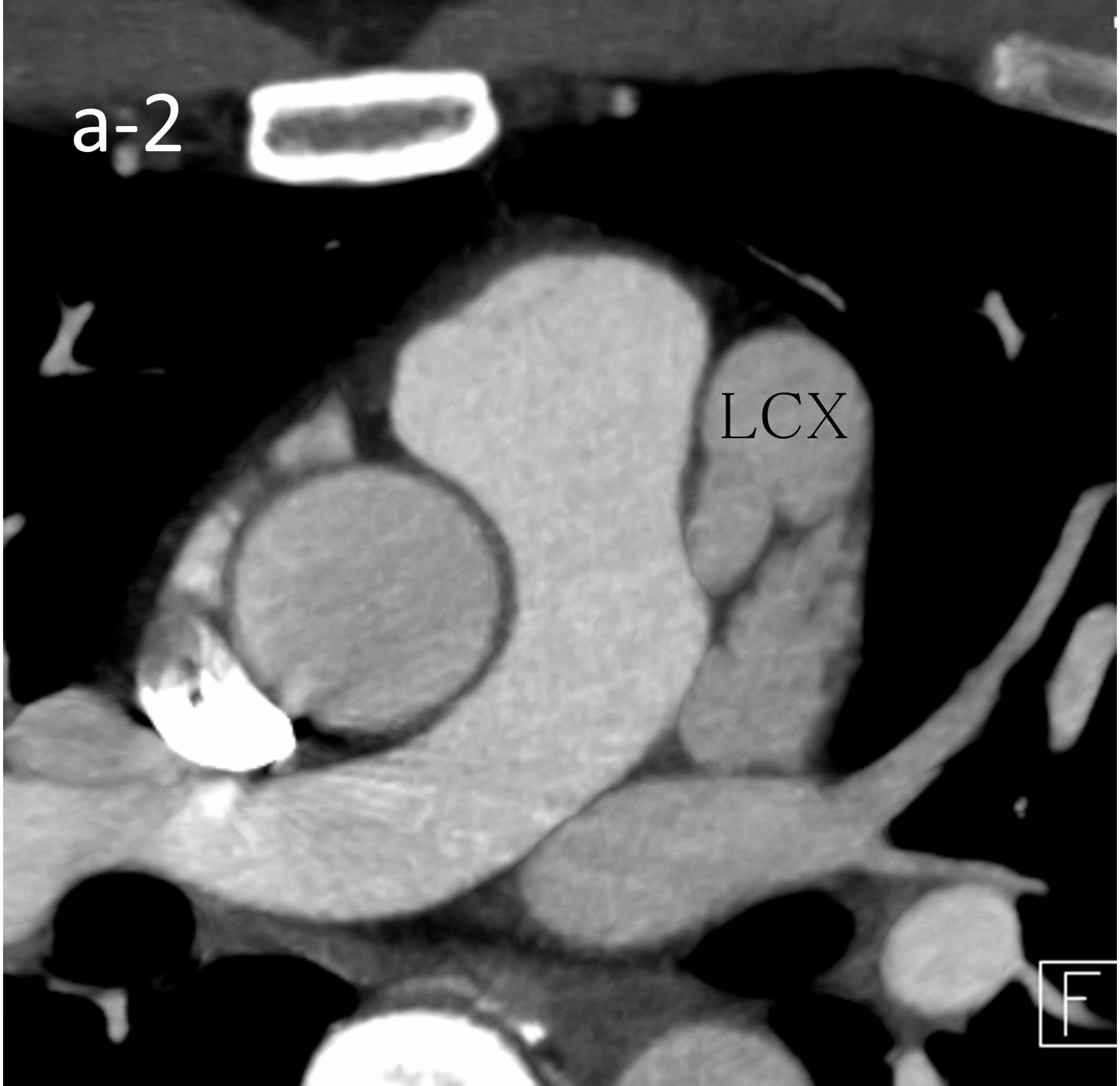

b
Spin: -41
Tilt: -22
LA
RA
*
A
L

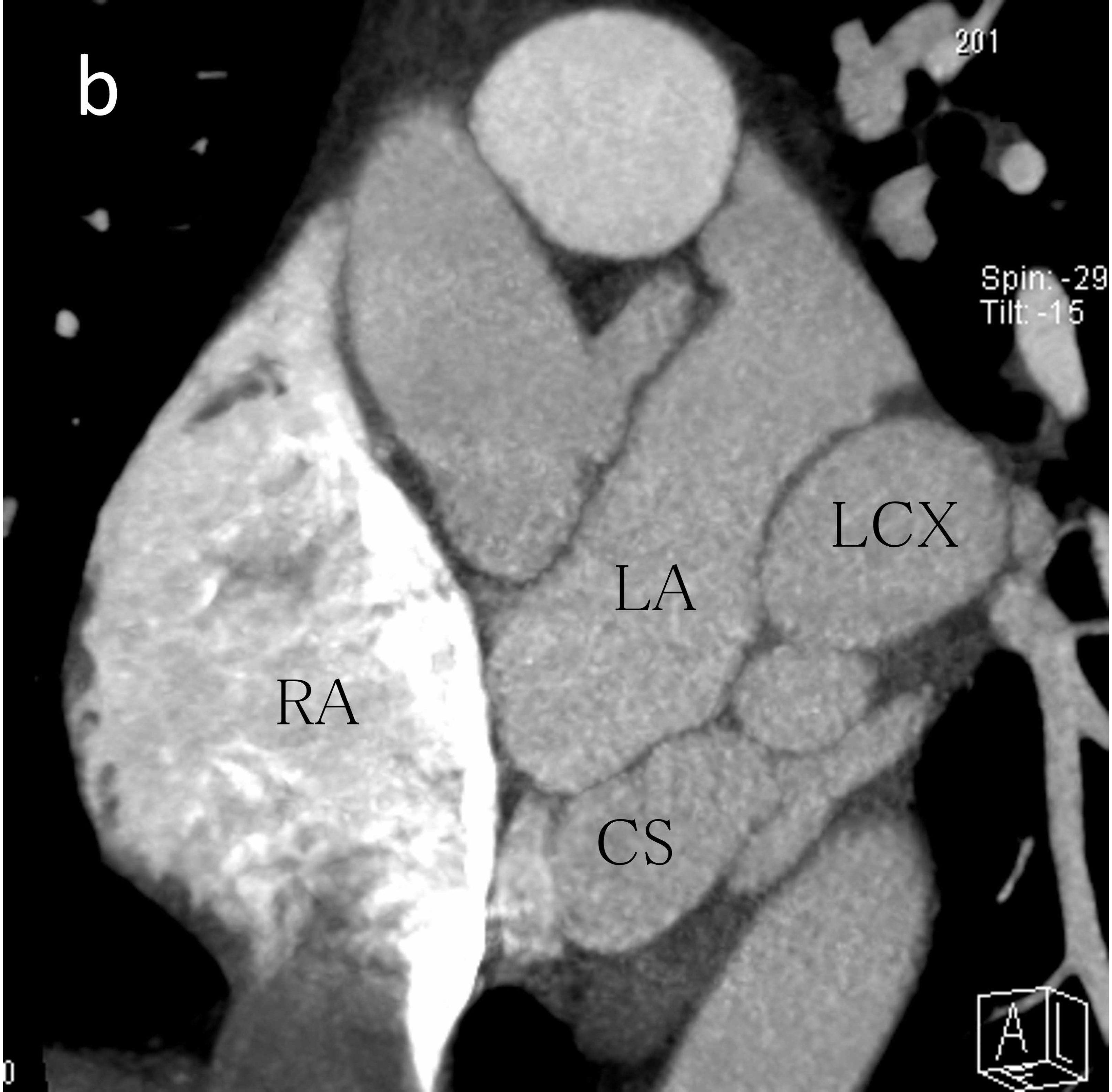

a
LA
*
RA


b
H


Spin: 0
Tilt: -90

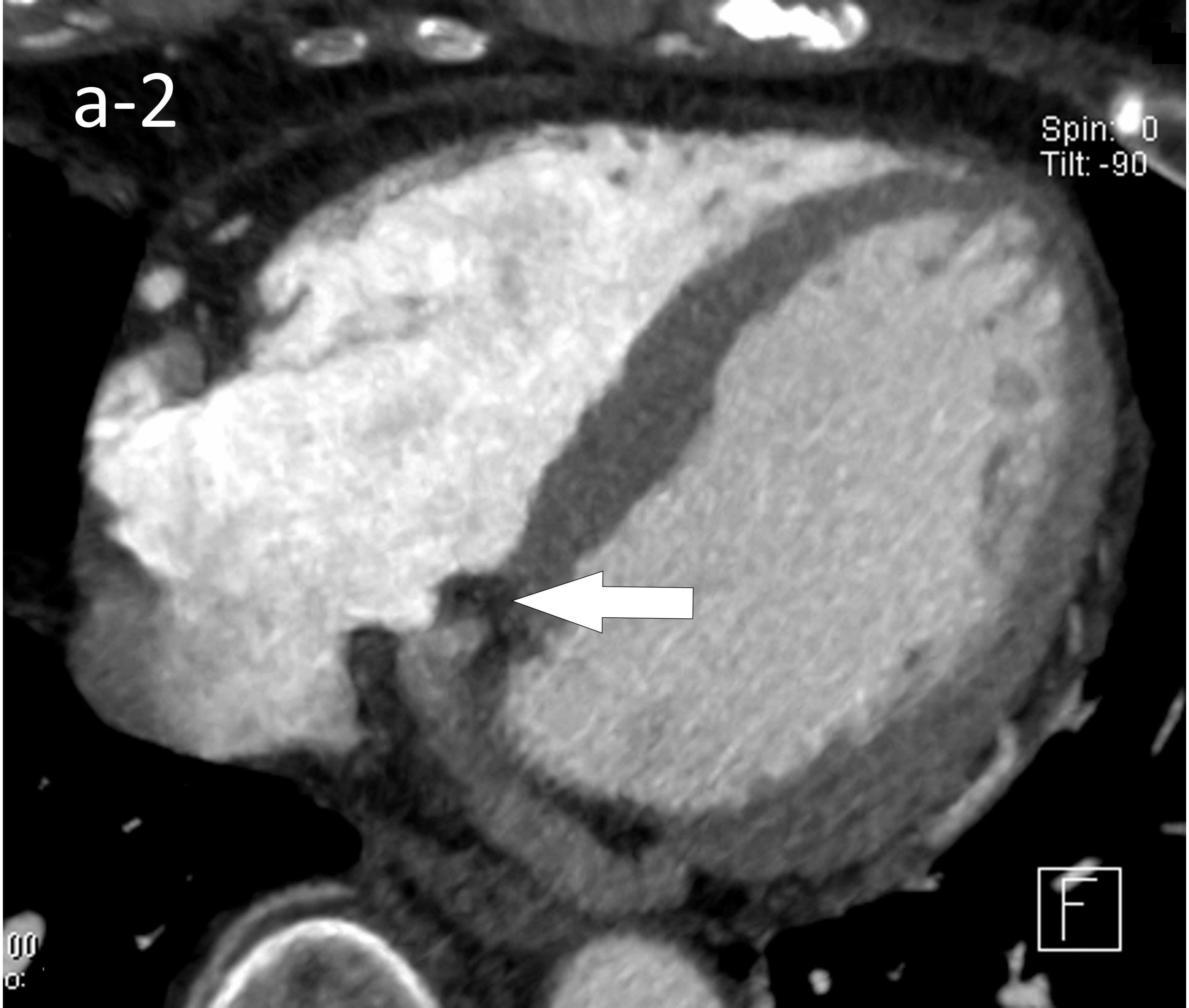

a-1
Spin: 0
Tilt: -90
CS
LCX
F

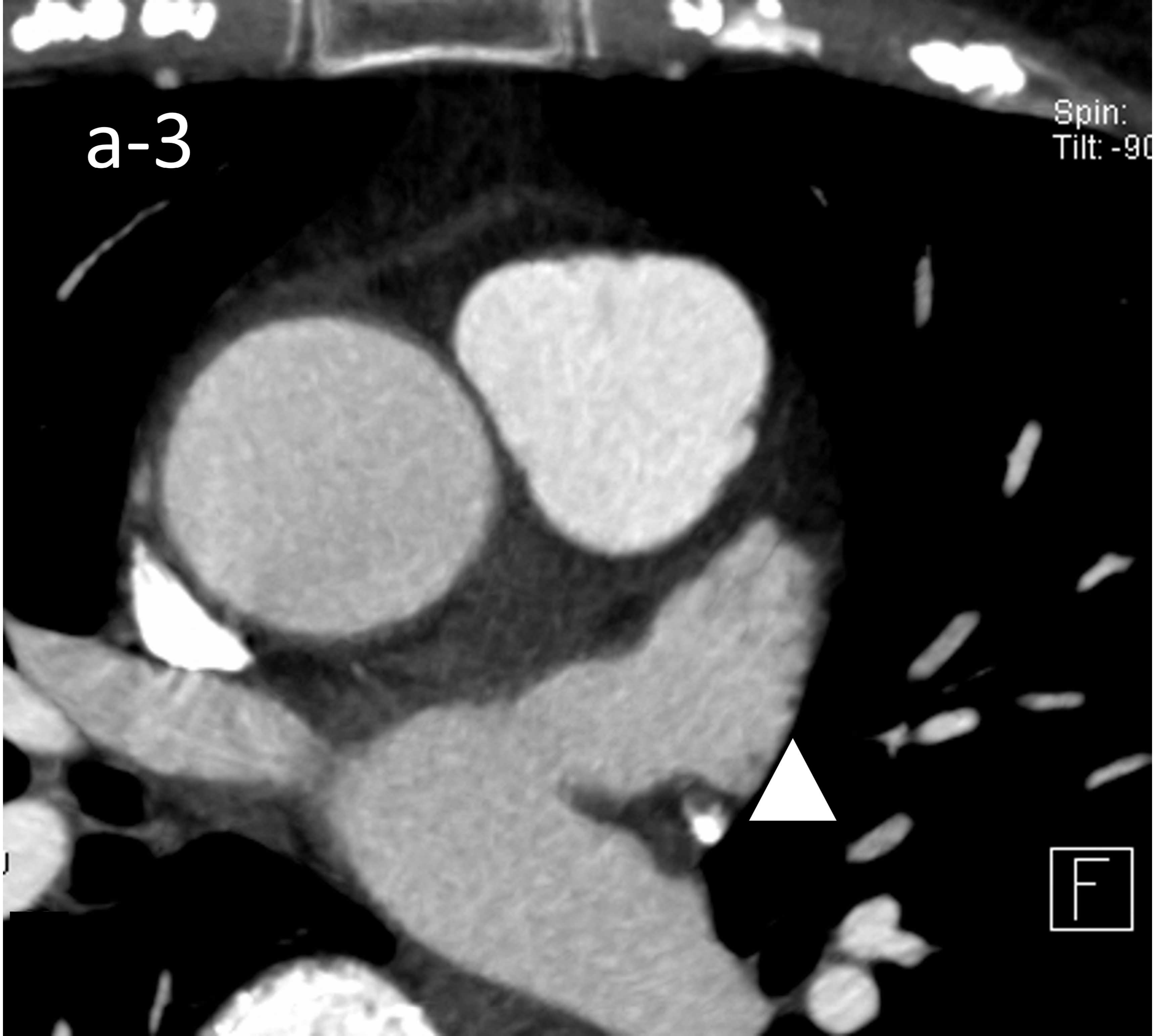

a-2
LCX
F


b
201
Spin: -29
Tilt: -15
LCX
LA
RA
CS
A
L


C


a-1
RA
*
LA
F


a-2
Spin: 0
Tilt: -90
F


a-3
Spin:
Tilt: -90
F


b
LA
*
RA