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RESEARCH ARTICLE

PROMINENT CRISTA TERMINALIS MAGNETIC RESONANCE IMAGING FINDINGS

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ABSTRACT

Purpose: Prominent Crista Terminalis (PCT) is a frequent variation of the right atrium (RA) posterior wall with a pseudotumor image. This study aims to evaluate PCT image characteristics and cardiac functional effects with cardiac magnetic resonance imaging (CMR).
Material and Methods: Between 2016 and 2020, 140 patients (58 ±14 years) were evaluated retrospectively. PCT was measured in 2 planes with the longest thickness at the atrial end-diastole. Patients with crista terminalis thickness greater than 8 mm were evaluated. Patients were assessed by the RA, right ventricular (RV) end-diastolic diameter (ED), RV, left ventriculi (LV) ejection fraction (EF), and PCT diameter was included in the study. After the Kolmogorov-Smirnov normality test, cases were compared with the paired student t-test. The effect of the increase in PCT diameter on the RVEF, LVEF, and RAED, RVED was investigated with Pearson's correlation test.
Results: We did not find significant correlation (r<0,5) between PCT thickness and RVEF (r=0.49), LVEF (r=0,115), RAED (r=0.32), RVED (r=0.07). Fourteen patients (10%) with PCT had a history of arrhythmia. Arrhythmia was not observed in patients with PCT less than 10 mm. It was observed that the risk of arrhythmia increased with PCT thickness.
Conclusion: CMR image features provided reliable data for patient management in PCT diagnosis and follow-up. There was not detected a statically significant change in right and left heart functions in patients with PCT. It was observed that there was a relationship between arrhythmia incidence and PCT dimension in patients

Keywords: crista terminalis, right atrial mass, anatomical variants, ımaging pitfalls, cardiac magnetic resonance

INTRODUCTION

Crista terminalis is a fibromuscular structure that extends along the posterolateral free wall of the right atrium between the superior and vena cava inferior. Crista terminalis studies in the literature are echocardiography or cadaver studies (1,2). It has been reported that crista terminalis reaches up to 6 mm thickness in adolescents and adults (1). Crista terminalis thickness of more than 7 mm is considered as Prominent Crista Terminalis (PCT) (3-7). On echocardiography, PCT can be seen as a hyperintense misleading mass in the posterior wall of the right atrium (4). PCT is seen in a similar signal to the myocardium on cardiac magnetic resonance (CMR) (Fig. 1). Further examination with CMR is required for the differentiation of PCT and cardiac tumors.

Echocardiography is the primary imaging method in the evaluation of cardiac pathologies. Cardiac computed tomography angiography (CTA) or CMR cross-sectional imaging methods are also used in cardiovascular imaging (8). CMR is very important for morphological imaging of the heart and the differentiation of cardiac masses. PCT cross-sectional imaging findings in the literature are limited to case reports, and studies describing PCT cross-

Table 1. The distribution of the cases is shown. The cases are shown in the table according to crista terminalis thickness, sex, age, and right ventricular functions.

	Number of cases	Gender (K-E)	Age	RVEF (%)	RVSV (ml)
Group 1 (8-9 mm)	43	19-24	69	57	85
Group 2 (9-10 mm)	35	15-20	59	54	83
Group 3 (10-11 mm)	27	16-11	65	59	88
Group 4 (11-12 mm)	24	9-15	63	56	86
Group 5 (12-13 mm)	4	2-2	45	57	85
Group 6 (13-14 mm)	3	1-2	64	55	84
Group 7 (>15 mm)	2	1-1	49	52	88

sectional imaging features are few (3,9). PCT cross-sectional imaging findings were evaluated by CMR.

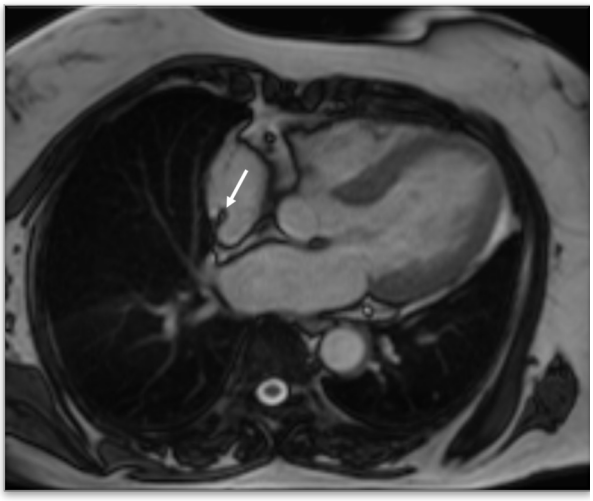

Figure 1. Cardiac MR white blood cine sequence (SSFP) four-chamber plane of 56 years old man. On the right posterolateral atrial wall extending into the atrium lumen, a 13 mm PCT (arrow) is seen in a similar signal to the myocardium.

Table 2. Shows the crista terminalis thickness and the number of patients.

Crista terminalis thickness	Number of cases
8-9 mm	43
9-10 mm	35
10-11 mm	27
11-12 mm	24
12-13 mm	4
13-14 mm	3
>15 mm	2

The purpose of this study is to evaluate the PCT image features, which can be defined as pseudo masses, by CMR, and to examine whether PCT dimensions are associated with right ventricular functions and the incidence of arrhythmia.

MATERIAL AND METHODS

Study Design

Ethical approval was obtained from the Izmir Katip Celebi University, Non-Interventional Clinical Studies Institutionel Review Board (Date 02.07.2020, No: 783). This study was designed as a single-center, retrospective study.

An observational cross-sectional study was conducted to evaluate CMR imaging findings in patients with PCT between 2016 and 2020. In the study, patients with a PCT over 8 millimeters in routine CMR were evaluated. Similar to the literature, cases with crista terminalis thickness less than 8 mm were not evaluated as prominent crista terminalis. Patients who had a history of thoracic surgery and inadequate images due to movement, metal artifact were not included in the study.

It was not included in the study because there was no crista terminalis thickness measurement in the echocardiography examinations.

CMR technique

CMR protocol with routine imaging was performed in all cases. CMR studies were applied with a 1.5 Tesla scanner (Aera®, Siemens Healthineers, Erlangen, Germany). Patients were scanned using 16-channel surface phased array body coils with the electrocardiogram triggering (ECG). After Standard localizer scan images, breath-hold cine images were

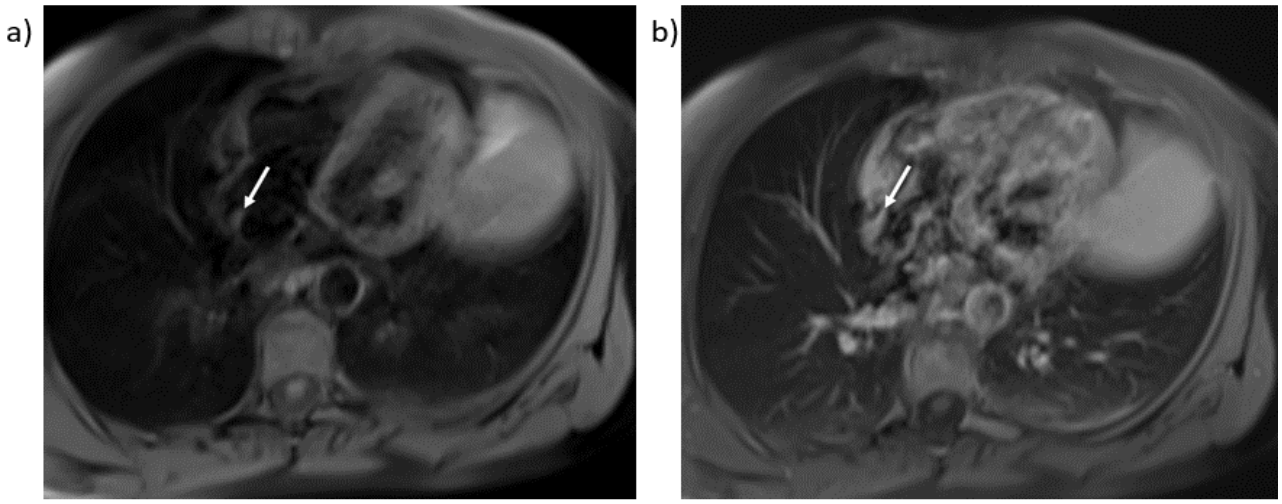

Figure 2. A 38-year-old woman, (a) four-chamber fat-suppressed T 1 and (b) PSIR sequence, in the right atrium posterior wall PCT (10 mm).

acquired in the 2-chamber and 4-chamber views for the heart. SSFP cine imaging was performed in a two-chamber multi-slice cine imaging view for biplanar assessment of right ventricular (RV) end-diastolic volume (RVEDV), and RV ejection fraction (RVEF). SSFP parameters were TE 1.23 ms, TR 33.35 ms, flip angle 55°, matrix minimum 192 x 156 mm, FOV maximum 340 mm, bandwidth 930 Hz, 30 phases per heart cycle, and iPAT GRAPPA acceleration factor 2. Contours were drawn automatically or manually before functional parameters were calculated automatically with Syngo. via for MRI.

We administered an intravenous injection of contrast agent into the antecubital vein at 0.2 mmol/kg (Magnevist; Schering, Berlin, Germany). The flow rate of 2 mL/sec was used. Minimum 10 minutes after contrast administration, IR inversion time scouting sequence was performed myocardial signal was suppressed for late gadolinium enhancement (LGE) imaging.

Image Review and Data Analysis

CMR cardiac examinations were evaluated by a board-certified radiologist who is more than 8 years of experience in cardiac imaging. On the Syngo.via MRI workstation, RV EF, LV EF, and RA ED, RV ED EF were calculated over functional sequences. The presence of right and left ventricular myocardial fibrosis was analyzed as present or absent in late gadolinium enhancement (LGE) images.

CT thickness measurements were performed in 4-chamber cine SSFP white blood sequences in the section with the maximum extension towards the lumen in the atrium end-diastolic phase. For the PCT measurement, 4-chamber multi-section sequences, sections perpendicular to the PCT plane were preferred to avoid the partial volume effect. The atrium wall was not included in the measurement. Atrial systolic phase measurements were not performed, as this may cause over measurement due to contraction. All images were evaluated together with functional CMR data at the workstation. Imaging findings and functional data were archived in picture archiving and communication systems (PACS).

Data were collected, including age, gender, CMR imaging features, and both ventricular morphological data. Data were evaluated as right and left heart functional data and PCT thickness. RV EF, LV EF, and RA ED, RV ED with PCT thickness were compared.

Statistical Evaluations

All statistical analyses were done with the help of SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Shapiro Wilk-W normality test was performed before performing a paired student t-test since the number of patients was (n >50). A paired student t-test was used to determine the significant differences between the variables of PCT cases. Mann-Whitney test was used for non-parametric variables. Pearson correlation coefficient was used for correlation between PCT diameter and RV ED, RA ED, RV EF, and LV EF. If the found r value is (-1), it is interpreted as a fully negative linear relationship, (+1) is a fully

positive linear relationship, and if r = 0 there is no linear relationship between the two variables. The closer the absolute value of the correlation coefficient is to the value of 1, the stronger is the linear association.

RESULTS

In patient selection, 140 patients (58 ± 14 years) with PCT of 8 millimeters or above based on the measurements made from the posterior wall of the right atrium between 2016 and 2020 were evaluated. 63 (45%) were women, 77 (55%) were men, and the mean age was 58 ± 14 years. The patients were grouped according to their PCT thickness (Table 1). Statistical analysis was made between PCT thickness groups. Thirty-four patients with a prediagnosis of mass in the posterior wall of the right atrium on echocardiography were accepted for CMR examination. (Fig. 2). PCT was detected incidentally in 106 patients.

The mean PCT thickness of the patient group was 9.12 mm. PCT thickness was measured 43 patient (8-9 mm), 35 patient (9-10 mm), 27 patient (10-11 mm), 24 patient (11-12 mm), 4 patient (12-13 mm), 3 patient (13-14 mm), 2 patient (14-15) mm and 2 patient (15 mm) (Table 2) (Fig 3). PCT showed polypoid extension towards the lumen in 13 patients. In patients with a preliminary diagnosis of a mass in the posterior wall of the right atrium in echocardiography examinations, PCT thickness was 20 patients (11-12 mm), 6 patients (12-13 mm), 5 patients (13-14 mm), 2 patient (14-15 mm) and 15 mm in one patient (Fig. 4). PCT contrast enhancement was not observed in patients with routine contrast and non-contrast fat suppression T1 sequences. EF values were within normal limits for both ventricles in patients with PCT (mean 60%; min 45%; max 72%).

Some additional findings were also observed in the CMR examination in PCT. For example, the fat thickness was <3 mm in the interatrial septum (IAS) in 95 patients. IAS fat thickness was 4-5 mm in 25 patients, 5-6 mm in 14 patients, and 6-8 mm in 3 patients based on the thickest measurements. Atrial septal lipomatosis hypertrophy (IAS fat thickness >8 mm) was observed in 3 patients (Fig. 5). In addition

Table 3. Table shows all Pearson correlation values between variables. Because the number of patients with a history of arrhythmia was low, the measurement could not be made.

	PCT	Arrhythmia	RV ED	RA ED	RV EF	LVEF
PCT	1	-	,070	-,342	,490	,115
Arrhythmia	.[a]	.[a]	.[a]	.[a]	.[a]	.[a]
RV ED	,412	.	1	,949	,088	-,185*
RA ED	,000	.	,949	1	,080	,157
RV EF	.490**	.[a]	.145	-.148	1	-.039

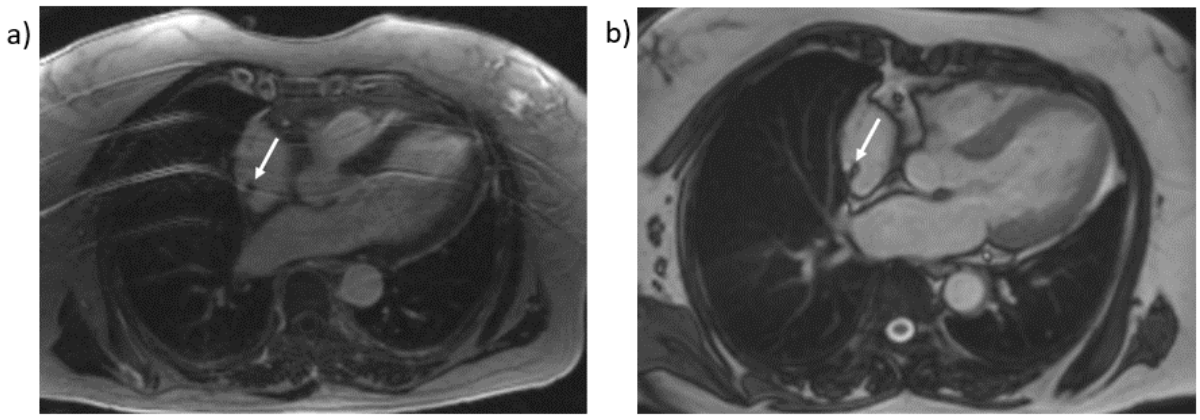

Figure 3. PCT in 40 y old man four-chamber PSIR (a) and cine SSFP (a) sequence seen 9 mm PCT (arrow).

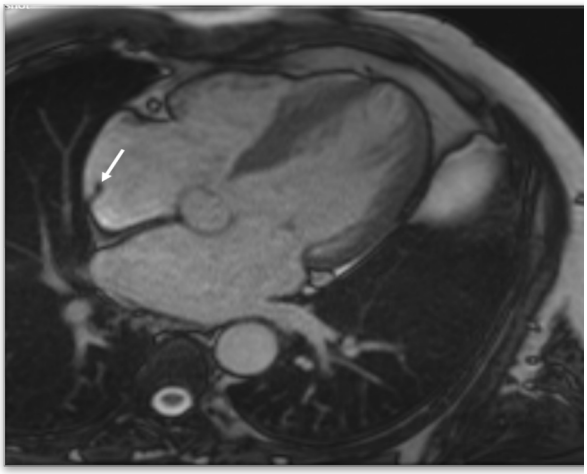

Figure 4. A 46 years old man who has PCT 13 mm on the right posterolateral atrial wall had a preliminary diagnosis of a mass in the posterior wall of the right atrium in echocardiography examination.

to right atrial PCT findings, 15 patients had pericardial effusion, 30 patients had left ventricular hypertrophic cardiomyopathy, 10 patients had pleural effusion, 5 patients had sigmoid septum, and 42 patients had ischemic viability losses in the myocardium. There was no free movement in CMR cine images.

14 (10%) of the patients defined the use of drugs for arrhythmia treatment on the CMR information and consent form. The hospital medical records of these patients were examined. 9 of these patients had atrial arrhythmia (5 premature atrial contractions, 3 atrial tachycardia, 1 supraventricular tachycardia) and 6 patients had a history of treatment for ventricular arrhythmia (4 patients' premature ventricular contractions, 1 patient ventricular tachycardia). PCT thickness in arrhythmia patients was 10-11 mm in 5 patients, 11-13 mm in 4 patients, 12-13 mm in 4 patients, and 15 mm in 1 patient. Arrhythmia was not observed in patients with PCT less than 10 mm. It was observed that the risk of arrhythmia increased with PCT thickness. However, a statistical study could not be done because the number of arrhythmia patients was few.

Signal enhancement was observed in 5 patients in right ventricular myocardial late gadolinium enhancement (LGE). PCT thickness was 9-10 mm in 2 patients, 10.7 mm in 1 patient, and 10-11 mm in 2 patients. LGE was detected in 12 patients in the LV myocardium. PCT thickness in these patients was 8-9 mm in 5 patients, 9-10 mm in 2 patients, 10-11 mm in 4 patients, and 13.4 mm in 1 patient. In 2 of these patients, a signal increase was observed in LGE in

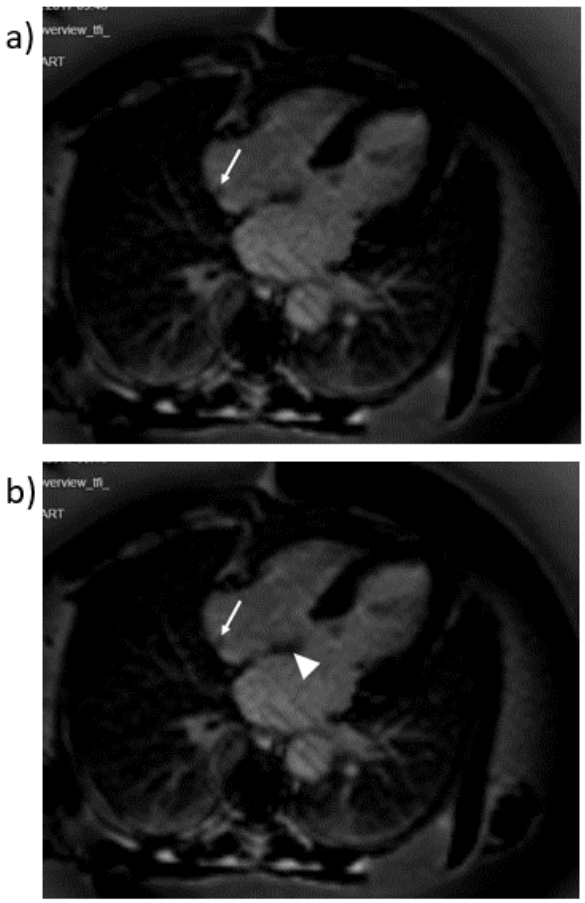

Figure 5. PCT in 40 y old man four-chamber PSIR (a) and cine SSFP (a) sequence seen 9 mm PCT (arrow).

the left ventricle. All patients had a history of ischemic heart disease. There was no significant correlation (r = 0.13) between left ventricular LGE signal increase and PCT thickness.

There was no significant correlation (r<0,5) PCT thickness and RVEF (r=0.49), LVEF (r=0,115), RAED (r=0.32), RVED (r = 0.07) [Table 3].

DISCUSSION

Prominent crista terminalis (PCT) is an anatomical variation in the posterior wall of the right atrium that causes a misleading mass in echocardiography. Finding of this study; PCT was observed as a non-contrast enhancing variation that did not contain significant heterogeneity and was not affected by RA systole in cardiac magnetic resonance imaging (CMR). Relationships between PCT and right, left heart functional data were examined in this study. There was no correlation between PCT thickness change and right ventricular (RV) end-diastolic diameter (ED) [Fig 6], right atrium (RA) ED [Fig 7],

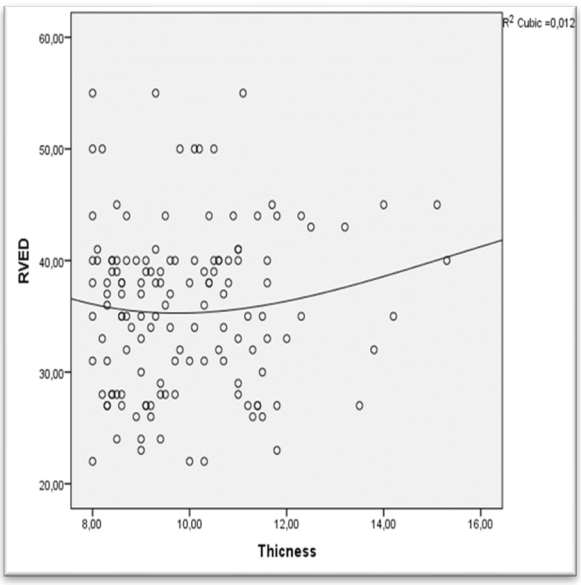

Figure 6. In this scatter plot graphic was observed that the change between PCT thickness and RV EF showed nominal distribution.

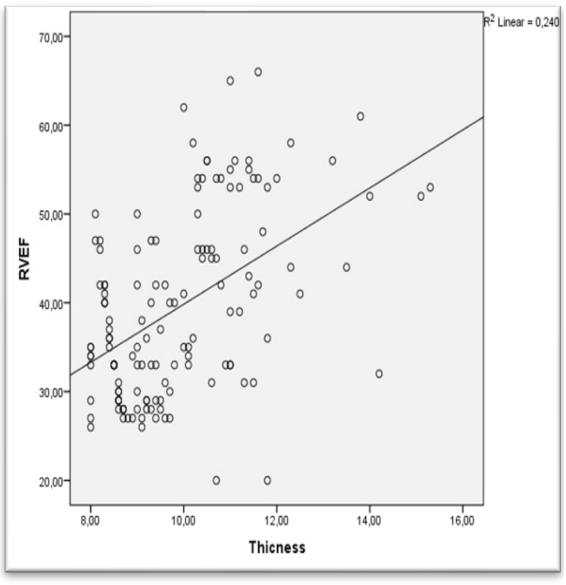

Figure 8. In this simple scatter plot graphic is seen that the change between PCT and RV EF showed nominal distribution.

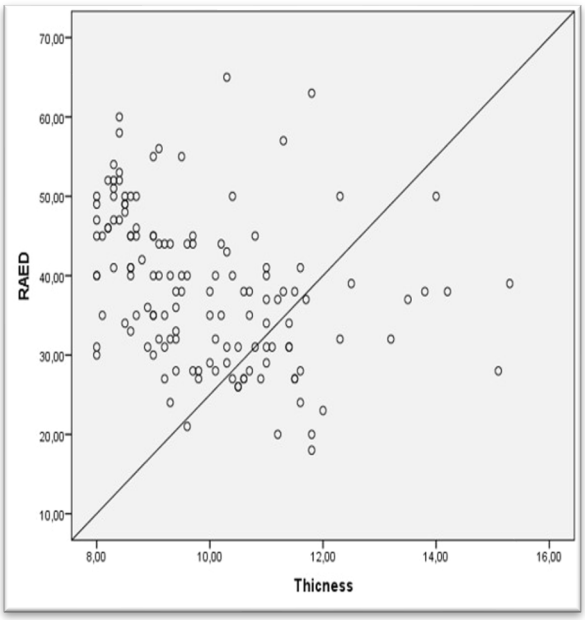

Figure 7. In this scatter plot graphic was observed that the change between PCT thickness and RV EF showed nominal distribution.

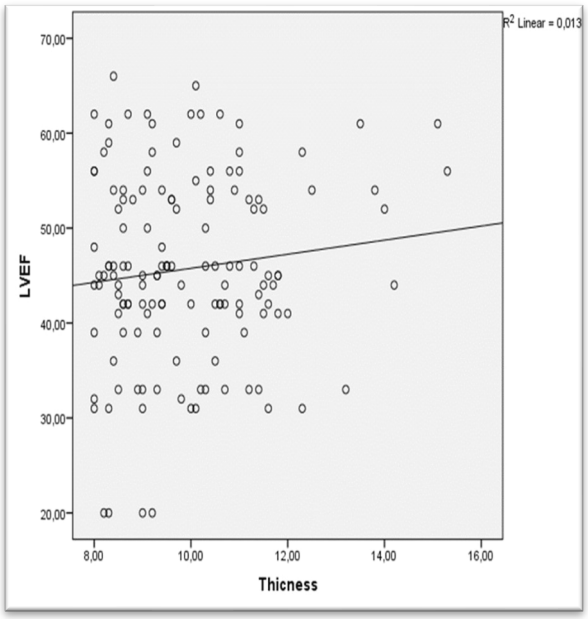

Figure 9. In this simple scatter plot graphic is seen that the change between PCT and RV EF showed nominal distribution.

right ventriculi (RV) ejection fraction (EF) [Fig 8], left ventriculi (LV) EF [Fig 9]. It was observed that the risk of arrhythmia increased with PCT thickness therefor PCT classification system has a clinical importance.

The benefits of using CMR in evaluating normal right atrial structures have been reported in the literature (2). Thebesian valve, persistent sinus venous, Eustachian valve, crista terminalis, and Chiari network are these structures. PCT imaging is difficult in echocardiography due to the right atrium posterior wall placement. Imaging is more difficult in some patients due to the chest structure. A posterior

angulation technique has been described to shorten the anterior ventricle in the apical four-chamber view for a clearer view of the CT. Confirming the diagnosis of PCT with 3D echocardiography methods, including TEE and transthoracic 3D imaging, may be insufficient (2). PCT is particularly confused with thrombus and myxoma. CMR image characteristics have been described in the literature for thrombus, rhabdomyoma, fibroma, and myxoma. Thrombus is observed as non-contrast enhancing intraluminal pathologies. Myxoma is the most common mass of the heart, which is generally pedunculated, can be contrast-enhancing, and can be heterogeneous in its internal structure, especially in the atrium (10). Examination of PCT CMR image characteristics is insufficient in the literature available to us. The incidence of arrhythmia with PCT (10%) was higher than in the literature (2). Crista terminalis arrhythmias are defined as "crystal tachycardia" (2,11).

Rastogi et al. examined the morphological pattern of crista terminalis (CT) in a cadaver study. In the study, all 80 specimens had CT. If CT was not visible in echocardiography and CMR examination, CT should be considered as thin. CMR represents a superior non-invasive modality to differentiate benign and malignant cardiac masses due to its high tissue contrast, higher spatial resolution, wider field of view, and unique ability for tissue characterization. Differentiation of PCT and real masses using CMR will provide very important clinical results. Standard CMR protocols for PCT assist in performing high-quality, diagnostic studies necessary to guide physician decisions regarding patient management, from initiating anticoagulation to attempting surgical resection (12,13).

Strengths and Limitations

This study has some limitations. The study is a single-center and retrospective study. A limitation is that there were no additional sequences for PCT imaging. The exclusion of the patients' echocardiography details in the study was accepted as a limitation. Another limitation was the absence of a pathological or surgical diagnosis in the patients.

CONCLUSION

In conclusion, CT is an anatomical fibromuscular structure in the posterior wall of the right atrium. CMR imaging characteristics should be well known, as PCT can be confused with mass and thrombus. In this study, CMR imaging characteristics of PCT patients were examined. This study should be expanded in a multi-cantered manner with studies that evaluate echocardiography findings together.

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