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Cardiac Magnetic Resonance Imaging Findings and Evaluation of Heart Functions in Atrial Septal Defect Patients

Atriyum Septum Defekti Hastalarında Kardiyak Manyetik Rezonans Görüntüleme Bulguları ve Kalp Fonksiyonlarının Değerlendirilmesi

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ABSTRACT

Objective: Atrial septal defect (ASD) is the most common congenital heart disease in adults and is evaluated by cardiac magnetic resonance (CMR) imaging. This study aimed to evaluate CMR results in ASD cases and to investigate ASD diameter and cardiac functional change.

Methods: Forty-two adult patients diagnosed with ASD in CMR were evaluated retrospectively. Cases were assessed by the right atrium (RA), right ventricular (RV) end-diastolic diameter (ED), left ventricle (LV) ejection fraction (EF), and ASD maximum diameter. After the Kolmogorov-Smirnov normality test, cases were compared with the paired Student's t-test, and non-parametric variables were compared with the Mann-Whitney test. The effect of the ASD diameter on the RVEF, LVEF, and RAED, RVED was investigated using Pearson's correlation coefficient.

Results: Low correlation was found between ASD diameter and RVEF (r=0.369), LVEF (r=0.329). A medium correlation was found between ASD diameter and RVED size (r=0.511). The highest correlation was found between ASD size and RAED diameter (r=0.54). The ASD diameter was found to be correlated with the deterioration in the right heart and LV functions.

Conclusion: CMR is an important examination in obtaining morphological and functional data in ASD cases. changes in heart function observed in patients significantly correlated with ASD.

Keywords: Heart septal defects, cardiac magnetic resonance, heart ventricles, ventricular function

ÖZ

Amaç: Atriyum septum defekti (ASD) erişkinlerde en sık görülen doğuştan kalp hastalığıdır ve kardiyak manyetik rezonans görüntüleme (KMR) ile incelenmektedir. Bu çalışmanın amacı ASD olgularında KMR sonuçlarını tanımlamak ve ASD ile kalp fonksiyonel değişimlerini araştırmaktır.

Yöntem: KMR'de ASD tanısı alan 42 erişkin hasta geriye dönük olarak değerlendirildi. Olgular sağ atriyum (RA), sağ ventrikül (RV) diyastol sonu çapı (ED), sol ventrikül (LV) fırlatma fraksiyonu (EF) ve ASD çapı ile değerlendirildi. Kolmogorov-Smirnov normallik testinin ardından olgular eşleştirilmiş Student's t-testi ile, parametrik olmayan değişkenler ise Mann-Whitney testi ile karşılaştırıldı. ASD çapının RVEF, LVEF ve RAED, RVED üzerindeki etkisi Pearson korelasyon katsayısı kullanılarak araştırıldı.

Bulgular: ASD çapı ile RVEF (r=0,369), LVEF (r=0,329) arasında düşük korelasyon bulundu. ASD çapı ile RVED boyutu (r=0,511) arasında orta korelasyon bulundu. En yüksek korelasyon ASD çapı ile RAED çapı (r=0,54) arasında bulundu. ASD çapı ve kalp fonksiyonlarındaki değişim koraledir.

Sonuç: KMR, ASD olgularında morfolojik ve fonksiyonel verilerin elde edilmesinde önemli bir incelemedir. ASD çap artışı ile sağ ve sol kalp fonksiyonları ve kalp boşlukları çaplarında anlamlı değişiklikler bulundu.

Anahtar Kelimeler: Doğuştan kalp hastalıkları, kardiyak manyetik rezonans, kalp ventrikülleri, ventriküler fonksiyon

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INTRODUCTION

Atrial septal defect (ASD) is one of the most common congenital heart diseases in adults.[1] ASD is the most common cause of chronic right heart volume overload.[2] In addition to loading on the right heart, ASD can cause right heart failure, pulmonary arterial hypertension, and atrial arrhythmia.[3] Right heart volume overload and other pathologies with ASD origin progress over time and adversely affect cardiac performance, even in asymptomatic patients.[3] Therefore, the diagnosis and treatment of ASD are essential for preventing progressive right heart failure. Surgical repair is the only treatment method for sinus venous ASD, and the most suitable surgical strategy depends on the configuration of the pulmonary veins.

ASD cases were mostly investigated by transthoracic echocardiography (TTE) and transesophageal echocardiography (TOE) studies. Computed tomography (CT) is useful for the morphological evaluation of ASD. But functional changes resulting from ASD can be examined by Cardiac magnetic resonance imaging (CMR). CMR examination is the most accurate examination method to check the size and function of the right ventricle (RV) in ASD cases.[4] It is the best non-invasive diagnostic method in the assessment of the reality of enlargement of the right heart chambers by CMR and the variations in pulmonary venous return.[5] In ASD cases, MR Imaging results are insufficient in the literature.

This study aimed to evaluate CMR results in adult ASD cases and to investigate the RV and atrial functional impacts of ASD.

METHODS

Study Population

This retrospective study was conducted with 42 patients over the age of 25 who were diagnosed with ASD between 2015 and 2020 in CMR. Patients with right and/or left ventricular (LV) failure, previous myocardial infarction, known coronary artery disease, advanced stage 3 tricuspid valve stenosis (TVS), or tricuspid valve insufficiency (TVI) valvular disease, and thoracic surgery of chronic obstructive pulmonary disease were excluded from the study. Patients with stage 1 or mild level TVS and TVI, were included in the study, while patients with stage 2 and 3 TVI or TVS were excluded from the study due to their negative impacts on RA functions. Patients with severe arrhythmia and conduction disorders were excluded. Cases with persistent left superior vena cava variation and cases without RV function measurement due to technical reasons were excluded from the study.

Data were collected, including age, gender, CMR imaging features, and ventricular morphological data. Data were evaluated as right atrium (RA), RV end-diastole diameter (ED), ASD diameter. RV and LV ejection fractions (EF) were measured. All lumen diameter measurements and ASD diameter measurements were measured at maximal diameter. The ASD diameter was measured in the end-systolic phase on four-chamber images. RA and RV measurements were made between the inner walls according to the largest diastolic dimension in 4-chamber imaging.

CMR can give to the treatment of these patients by detecting sinus venous defects or partial abnormal pulmonary venous return anomalies. Pulmonary venous return anomalies were not evaluated. In 2 cases of ASD, persistent left superior vena cava variation was observed, and these cases were excluded from the examination.

Magnetic Resonance Imaging

CMR studies were conducted on a 1.5 Tesla scanner (Aera®, Siemens Healthineers, Erlangen, Germany). Patients were scanned with the electrocardiogram (ECG) triggering using 16-channel surface-phased array body coils. After standard localizer scan images, breath-hold cine images were acquired in the 2 and 4 chamber views for ventricles. bSSFP cine imaging (TE 1.23 ms, TR 33.35 ms, flip angle 55°, retrospective ECG-triggered gating, matrix minimum 192x156 mm, a field of view maximum 340 mm, slice thickness 2 mm, bandwidth 930 Hz, 30 phases per heart cycle, iPAT GRAPPA acceleration factor 2) was performed in long axis 2 and 4 chamber view for biplanar assessment of RV ejection fraction (RVEF). Contours were drawn manually. Biplanar anatomical and functional parameters are calculated automatically by the post-processing Syngo for MR. In the CMR examination, fat-suppressed contrast, and non-contrast T1 weighted 4 chamber imaging was performed.

We administered 0.2 mmol/kg intravenous injection of contrast agent (Magnevist; Schering, Berlin, Germany) into an antecubital vein. The flow rate was 2 mL/sec.

CMR examinations were evaluated by a radiologist who has a cardiac imaging certificate.

Approval for the study was obtained from the Ethics Committee of İzmir Katip Çelebi University, Atatürk Training and Research Hospital (approval no: 783, date: 02.07.2020).

Statistical Analysis

All statistical analyses were performed with the help of Statistical Package for the Social Sciences version 24.0 (IBM Corp., Armonk, NY, USA). Kolmogorov-Smirnov normality test was performed before performing a paired Student's

t-test since the number of patients was (n<50). Paired Student's t-test was used to find the significant differences between the variables of parametric data in the ASD cases. Mann-Whitney test was used for non-parametric variables. P value <0.05 was considered statistically significant. The Pearson correlation coefficient was used for the correlation between ASD diameter and RVED, RAED, RVEF, and LVEF. 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 to the value of 1, the stronger is the linear association.

RESULTS

In the study, 22 women (mean age 37±12 years) and 20 men (mean 38±11 years) with ASD were detected in 42 cases. The mean ASD diameter was found to be 9.36 mm (6-17 mm) (Figure 1). The mean RA size was 45.24 mm (±8.21 mm), the RV size means 54.14 mm (±7.21 mm), LVEF mean (±15) 47.5% and the RVEF was 41.47% (±14) (Table 1).

In addition to ASD results in CMR examination, stage 1 TVI in 5 cases (3 women). TVS was observed in stage 1 in 6 cases (4 women).

The distance between ASD diameter and RVEF was (r=0.369) and that between LVEF was (r=0.329) (Table 2). It was found that between ASD diameter and RVED size was (r=0.511), between RAED was (r=0.540) (Table 3). Figure 2 was shows that the change between ASD diameter and RVED showed nominal distribution. RAED, RVED, and RVEF, LVEF changes were correlated with the increase in ASD diameter (Tables 1, 3). The highest correlation was found between the ASD size and RAED diameter. The increased ASD diameter was found to be correlated with the deterioration in the right heart and LV functions (Figures 3, 4, 5). Statistically, ASD diameter and right heart diameter were significantly correlated (r=0.5).

On the back wall of RA, crista terminalis was measured to be thicker than 8 mm in 3 cases. Contrast enhancement was not observed in the myocardium in LGE images.

DISCUSSION

Weighted TTE is used for the diagnosis and evaluation of ASD.[1-6] However, CMR is considered the gold standard in the evaluation of ASD and pulmonary venous structures.[4] The findings of the RA and RV changes in patients ASD patients have been identified in TTE studies. CMR results have not been adequately studied in the literature. In this study, RV and RA functional data were evaluated together with literature reference values in CMR examination in adult ASD cases.[3-6] In ASD cases, RV function showed a deterioration in correlation with the increase in ASD diameter (Figures 6, 7, 8).

RA and RV end-diastolic diameter (ED), RVEF, and LVEF were evaluated by CMR. In the literature, studies with TTE

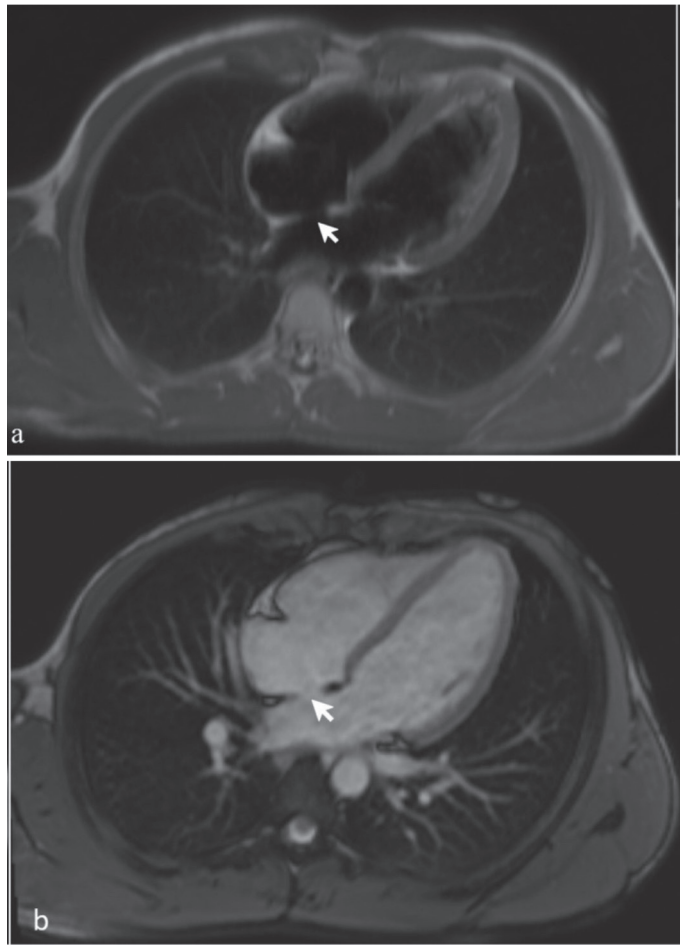

Figure 1. A 20-year-old male patient is observed in the interatrial septum inferior, 4-chamber with T 1 (a) and cine-SSFP 4-chamber images (b), 10 mm ASD (arrow). In biventricular enlargement and increased left ventricular wall trabeculations are observed

ASD: Atrial septal defect

Table 1. The distribution of the case data is shown in the table

	ASD cases
RAED (mm)	49.24 (±8.21)
RVED (mm)	54.14 (±7.21)
ASD (mm)	9.36 (±3 mm)
RVEF (%)	59.45% (±17)
LVEF (%)	47.5% (±15)

RAED: Right atrium end-diastolic diameter, RVED: Right ventricular end-diastolic diameter, ASD: Atrial septal defect, RVEF: Right ventricular ejection fraction, LVEF: Left ventricular ejection fraction

Table 2. In this correlation table, it is observed that the change between ASD diameter and RVEF, LVEF showed			
Correlations	**ASD**	**RVEF**	**LVEF**
ASD	1	-0.369 (p=0.003)	-0.329 (p=0.003)
ASD: Atrial septal defect, RVEF: Right ventricular ejection fraction, LVEF: Left ventricular ejection fraction, ASD: Atrial septal defect			

Table 3. This table shows correlation values between ASD diameter and RVED, RAED			
	ASD	**RVED**	**RAED**
ASD	1	0.511 (p=0.005)	0.540 (p=0.005)
ASD: Atrial septal defect, RVED: Right ventricular end-diastolic diameter, RAED: Right atrium end-diastolic diameter			

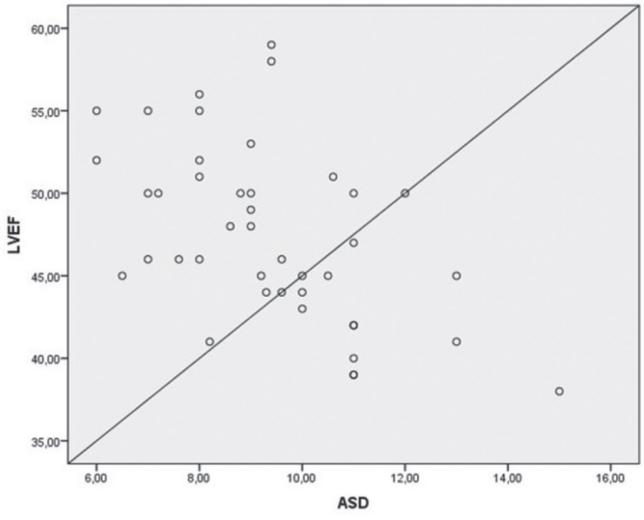

Figure 2. This scattergram graphic shows the results of the linear regression between ASD diameter and LVEF showed correlation and nominal distribution

ASD: Atrial septal defect, LVEF: Left ventricular ejection fraction

were evaluated. Supomo et al.[1] examined right heart values in 45 cases before and after surgical closure of ASD. There was no significant difference in male and female cases before ASD surgery. Significant improvements in RA, RV dimensions, and RVEF values were observed after ASD closure. Kumar et al.[3] examined the right and left heart functions in 32 patients before and after treatment in a study with TTE. Significant changes were observed in right and left heart function values within 6 months. Akula et al.[6] evaluated RV function in 77 ASD cases before and after ASD closure. There were no CMR data in all these studies. This study evaluated the right heart structures with CMR before treatment in ASD cases. The data found were like

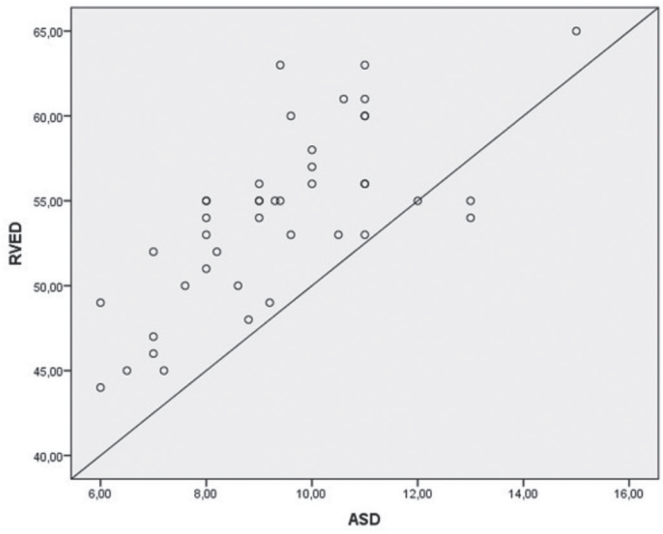

Figure 3. This scattergram graphic shows a linear correlation between ASD diameter and RVED

ASD: Atrial septal defect, RVED: Right ventricular end-diastolic diameter

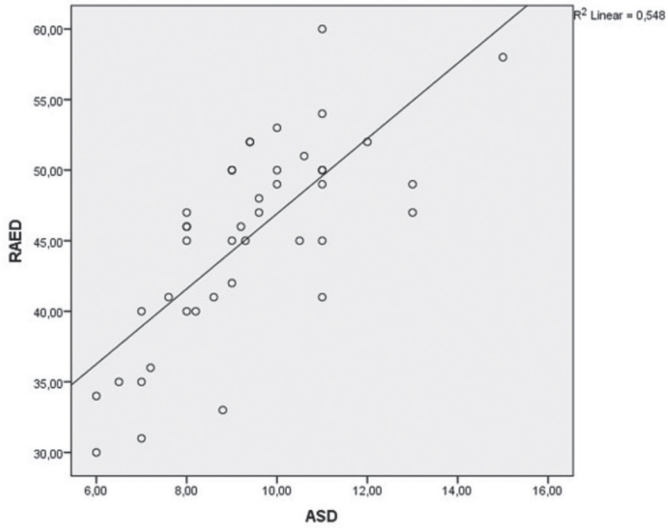

Figure 4. This scattergram graphic shows the change between ASD diameter and RAED showed correlation analyzed

ASD: Atrial septal defect, RAED: Right atrium end-diastolic diameter

the literature data before treatment in adult ASD cases.[7] In addition to the literature TTE examinations, superior vena cava return anomalies and pulmonary venous pathologies were defined in CMR.

Clinically, adult ASD cases show changes due to the right heart load. TTE examination may be inadequate in evaluating the right atrial pathology and variations, depending on the chest wall structures of the patients.

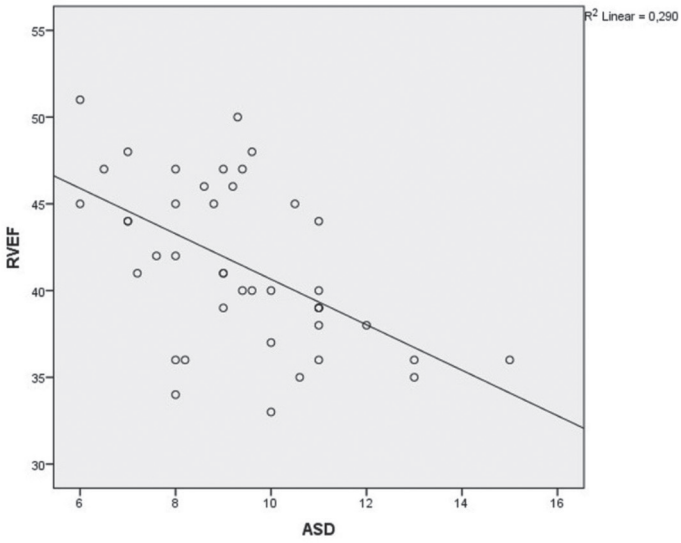

Figure 5. This scattergram shows that the change between ASD diameter and RVEF showed correlation analyzed

ASD: Atrial septal defect, RVEF: Right ventricular ejection fraction

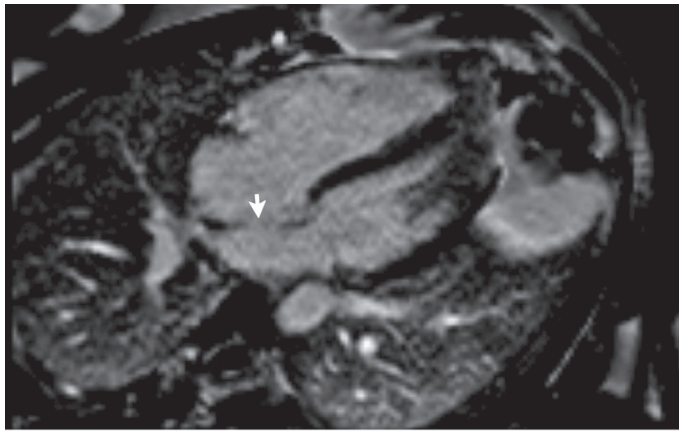

Figure 6. Thirty-two-year-old female patient with 5 mm ASD in the fourth chamber phase-sensitive inversion recovery imaging (arrow). Left to right shunt results in a significant enlargement of the right ventricle

ASD: Atrial septal defect

Pulmonary venous variations are extremely important in surgical planning and can be overlooked during TTE examination.[8,9] In these cases, further examinations such as TOE or CMR may be required.[10,11] Being aware of the CMR imaging results in ASD cases is important for diagnostic reliability in cases where TTE examination cannot be performed or is inadequate due to the chest wall structure. In these cases, there is no need for more tests invasive and expensive after the CMR results. Teo et al.[12] found that CMR examination was more reliable than the TOE in measuring ASD diameter. In this study, CMR findings were defined in ASD cases.

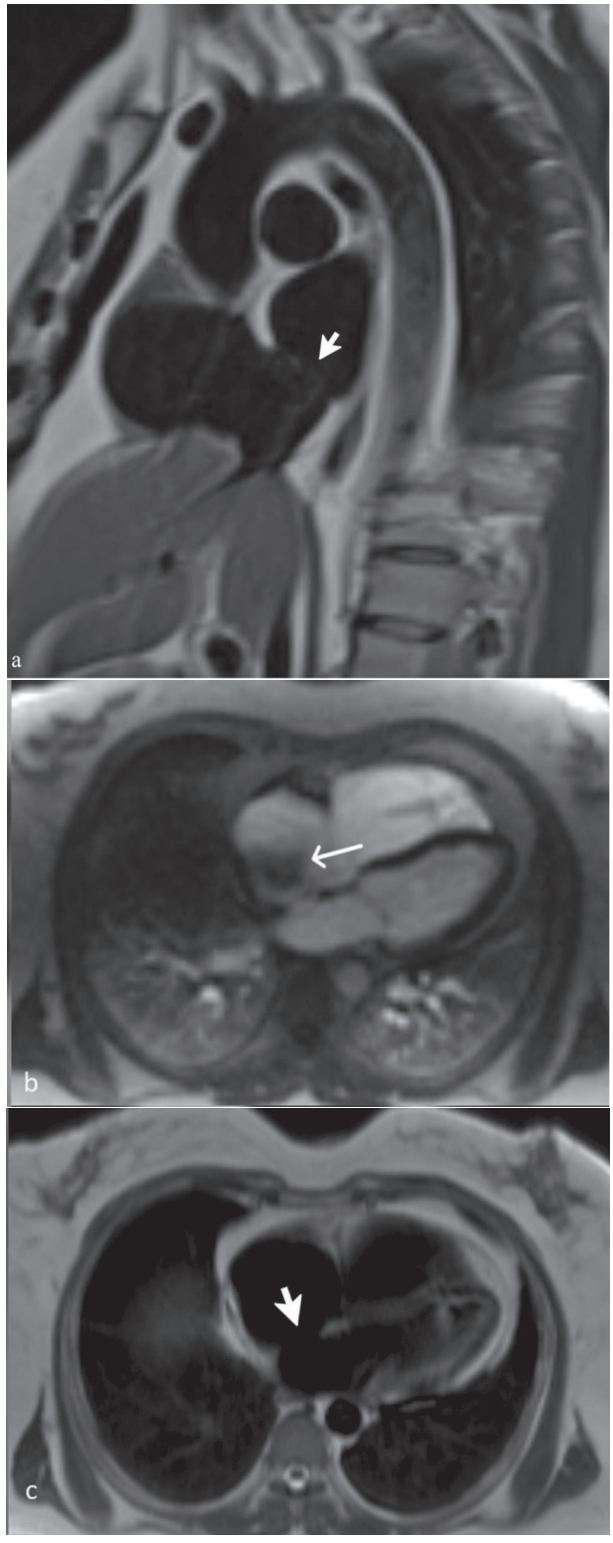

Figure 7. In a 23-year-old female case, parasagittal T1-weighted (a) and the fourth chamber HASTE (c) images show a large ASD (arrow) up to 25 mm in size. Right-to-left shunt flow (thin arrow) is observed in 4-chamber imaging in perfusion examination (b)

ASD: Atrial septal defect

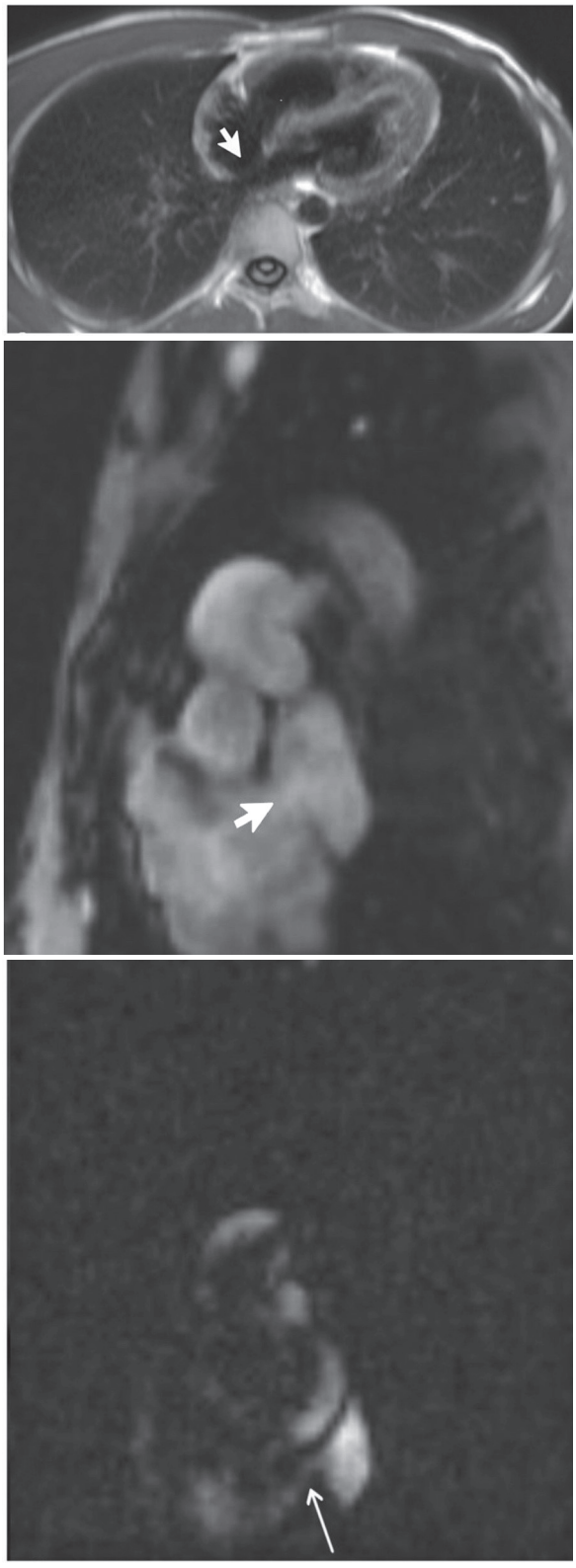

Figure 8. In a 23-year-old male patient, 11 mm ASD (arrow) is observed in a 4-chamber of pre-contrast T1 fat-suppressed (a), parasagittal 2-D flow magnetic resonance (b, c), ASD (arrow), and a shunt flow (thin arrow) are seen

ASD: Atrial septal defect

Study Limitations

The limited sample size of this study is an important limitation. These findings need to be confirmed with more cases. An important limitation is the lack of comparison between CMR and echocardiography data, as echocardiogram exams are not standard. Another limitation is that the age and gender groups of the cases are not homogeneous, and our control group is not prospective. At this stage, this restriction was attempted to eliminate by using the literature reference data.[13,14] The absence of surgical data or follow-up CMR data was an important limitation. In this study, pulmonary venous variations could not be evaluated because imaging was directed specifically at cardiac structures. Thoracic CT examinations of the cases can be prospectively evaluated for variations in the next step.

CONCLUSION

The use of CMR is necessary to detect ASD and concomitant cardiac or vascular anomalies. Surgical closure of ASD is necessary for improving right and left heart functions. For surgical planning, variations, and heart functional data should be identified by CMR.

Ethics

Ethics Committee Approval: Approval for the study was obtained from the Ethics Committee of İzmir Katip Çelebi University, Atatürk Training and Research Hospital (approval no: 783, date: 02.07.2020).

Informed Consent: Retrospective study.

Peer-review: Externally and internally peer-reviewed.

Authorship Contributions

Concept – Design - Data Collection or Processing - Analysis or Interpretation - Literature Search - Writing: S.A., M.Y., O.K.A., M.E.U.

Conflict of Interest: No conflict of interest was declared by the authors.

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