Int Cardiovasc Res J.2019;**13**(4):120-126.icrj.87529

International Cardiovascular Research Journal
www.ircrj.com

Diagnostic Efficacy of Magnetic Resonance Imaging and Echocardiography in Diagnosis of Constrictive Pericarditis

Ali Mohammadzadeh [1], Sara Tavasoli [1], Madjid Shakiba [2], Ali Borhani [2], Maryam Mohammadzadeh [3,*]

[1] Department of Radiology, Rajaie Cardiovascular and Medical Research Center, Iran University of Medical Sciences, Tehran, IR Iran
[2] Advanced Diagnostic and Interventional Radiology Research Center (ADIR), Imam Khomeini Hospital, Tehran University of Medical Sciences, Tehran, IR Iran
[3] Department of Radiology, Amiralalm Hospital, Tehran University of Medical Sciences, Tehran, IR Iran

ARTICLE INFO

Article Type:
Research Article

Article History:
Received: 14 Dec 2018
Revised: 31 Aug 2019
Accepted: 17 Sep 2019

Keywords:
Constrictive Pericarditis
Magnetic Resonance Imaging
Echocardiography

ABSTRACT

Background: Diagnosis of Constrictive Pericarditis (CP) is a clinical challenge. Echocardiography and Magnetic Resonance Imaging (MRI) are the most commonly used modalities for evaluating pericardial diseases, such as CP.
Objective: This study aimed to assess and compare the diagnostic accuracy of MRI and echocardiography in diagnosis of CP.
Methods: This cross-sectional, retrospective study was conducted on 45 patients suspicious for CP [n = 36] or non-constrictive pericarditis [n = 9]. Among the 36 patients suspicious for CP, 20 underwent pericardiectomy. Accordingly, 19 patients were proved to have CP based on histopathological assessments and were considered as the CP-positive group. In addition, the nine patients who were suspicious for pericarditis without the clinical findings of pericardial constriction were included in the CP-negative group [adding to one patient who was negative for CP after surgery, there were a total of 10 CP-negative patients]. MRI, echocardiographic, and clinical findings were obtained from the hospital digital archive and were compared with each other. Diagnostic accuracy indices of echocardiography and MRI in diagnosis of CP were also calculated.
Results: The mean age of the patients with proved CP and without CP was 48.1 ± 20.7 (12-77) and 50.6 ± 15.3 years (25 - 72), respectively. Additionally, 15 patients were male (78.9%), while six individuals were male (60%) in the CP-negative group. Among MRI and echocardiography variables, the diagnostic accuracy of MRI septal bounce was found to be the same as the gold standard. MRI pericardial thickening > 4 mm had the sensitivity of 100%, specificity of 80%, Positive Predictive value (PPV) of 90%, and Negative Predictive Value (NPV) of 100%. Echocardiographic parameters, including pericardial thickness, septal bounce, hepatic venous reversal flow, and respiratory variation in mitral flow, also showed high specificity (100%). Additionally, the Area Under the Curve (AUC) of MRI and echocardiography was 0.95 (95% CI = 0.85 - 1) and 0.89 (95% CI = 0.80 - 0.99), respectively (P = 0.43). Moreover, the sensitivity of MRI and echocardiography in diagnosis of CP was 100% and 78.9%, respectively (P = 0.045).
Conclusion: MRI was found to be more sensitive than echocardiography in diagnosis of CP. Indeed, MRI septal bounce had the best diagnostic accuracy for diagnosis of CP.

1. Background

Constrictive Pericarditis (CP) is characterized by a thick inelastic pericardium due to dense fibrosis, which restricts the diastolic filling of the heart (1). Patients with CP typically present with symptoms and signs of right heart failure (1, 2). Various diagnostic criteria have already been proposed for CP. Nonetheless, CP remains a clinical challenge and is often difficult to differentiate from restrictive cardiomyopathy or liver disease (3). Involved diagnostic examinations may include echocardiography, Computed Tomography (CT)-scan, Magnetic Resonance Imaging (MRI), cardiac catheterization, and surgical endometrial biopsy as the final step (4).

**Corresponding author:* Maryam Mohammadzadeh, Department of Radiology, Amiralalm Hospital, Tehran University of Medical Sciences, Tehran, Iran, Cellphone: +98-9113386324, E-mail: mm1361@yahoo.com.

Non-invasive imaging techniques, such as echocardiography, are the initial diagnostic step for assessment of patients with suspected CP (5). Echocardiographic findings that suggest the diagnosis are pericardial thickening, dilatation of the superior and inferior vena cava, flattening of the posterior ventricular wall in diastole, and early diastolic interruption of ventricular dimension change (6). However, echocardiography is unable to distinguish CP from Restrictive Cardiomyopathy (RCM) (1). It is also associated with other limitations like poor acoustic window, operator dependency, and poor tissue characterizations (7).

Cross-sectional imaging modalities like MRI can directly delineate the pericardium and show increase in pericardial thickness, a common finding in CP. MRI also yields functional and anatomical findings like pericardial inflammatory changes or distortion of the cardiac chambers, which help diagnose CP (8). Other MRI findings of CP include late gadolinium enhancement, abnormal septal motion myocardial restainment in tagging (adherence), and abnormal Short TI Inversion Recovery (STIR) signal of myocardium or pericardium (4, 8).

2. Objectives

This study aims to assess the diagnostic accuracy of various MRI and echocardiography variables and compare these two imaging modalities with regard to diagnosis of CP.

3. Patients and Methods

3.1. Patients Enrollment

This study was conducted on 45 patients at Shahid Rajaie Cardiovascular, Medical, and Research Center from 2011 to 2017. Among these patients, 36 were clinically suspected for CP and nine showed the symptoms of pericarditis without the clinical findings of pericardial constriction [non-constrictive pericarditis]. Among the 36 patients clinically suspected for CP, 20 underwent surgical pericardiectomy (that is the gold standard). Among these patients, 19 were proved to have CP after assessment of the pathological criteria in histopathological evaluation and one patient was pathologically negative for CP. Therefore, there were 19 pathologically proven CP patients and were considered as the CP-positive group. There were also 10 CP-negative patients, including one negative patient after surgery and nine patients clinically suggestive for non-constrictive pericarditis (these patients were gathered as disease negative patients for calculating the diagnostic efficacy indices as they had the most similar pathological condition to CP clinically. Considering the point that there was only one case of negative CP after surgical pathology, the diagnostic efficacy study could not be carried out). The remaining 16 patients with clinical suspicion of CP did not undergo surgery as the gold standard. Thus, they were not included in diagnostic efficacy assessment. Yet, their MRI and echocardiographic findings have been presented in Table 1. All 45 patients underwent echocardiography and MRI (Figure 1).

3.2. Imaging Assessments

MRI, echocardiographic, and clinical findings were obtained from the hospital digital archive. All patients were provided with an informed consent form, which included a

Table 1. MRI and Echocardiographic Findings in Different Groups and Their Comparison between CP-Positive and CP-Negative Groups

Imaging Method	Imaging Minding	Proved CP, (N = 19), No. (%)	Proved Non-CP (N = 10), No. (%)	Clinically Suspicious for CP, (Non-Proved CP) (N = 16) No. (%)	P-value (Proved CP vs. Proved Non-CP)	P-value (Proved CP vs. Non-Proved Suspicious CP)
MRI	Pericardial effusion	8 (42.1)	5 (50)	6 (37.5)	0.7	0.78
	Increased pericardial thickness	19 (100)	2 (20)	13 (81.3)	< 0.001	0.086
	Pericardial thickness extent (circumferential/local/normal)	16 (84.2)/ 3(15.8)/0	1 (10)/ 0/9 (90)	9 (56.3)/4 (25)/3 (18.8)	< 0.001	0.07
	Pericardial calcification	4 (21.1)	0	3 (18.8)	0.27	0.99
	Late gadolinium enhancement	7 (36.8)	8 (80)	6 (37.5)	0.05	0.99
	Abnormal septal motion	19 (100)	0	14 (87.5)	< 0.001	0.2
	Myocardial restainment in tagging (adherence)	5 (26.3)	1 (10)	2 (12.5)	0.63	0.42
	Abnormal pericardial signal in STIR	1 (5.3)	2 (20)	2 (12.5)	0.27	0.58
	Abnormal myocardial signal in STIR	0	0	4 (25)	-	0.035
	Increased right atrium size	13 (68.4)	2 (20)	12 (75)	0.021	0.72
	Increased left atrium size	11 (57.9)	4 (40)	11 (68.8)	0.45	0.51
	Dilated IVC	12 (63.2)	1 (10)	6 (37.5)	0.008	0.13
	Tubular shaped ventricle	2 (10.5)	0	2 (12.5)	0.53	0.99
Echocardiography	Increased pericardial thickness	14 (73.7)	0	3 (18.8)	< 0.001	0.002
	Abnormal septal motion	16 (84.2)	0	9 (56.3)	< 0.001	0.13
	Dilated IVC	16 (84.2)	3 (30)	9 (56.3)	0.011	0.13
	Diastolic reversal flow in hepatic vein	1 (5.3)	0	1 (6.3)	0.99	0.99
	Respiratory variation in MV and TV inflow velocity	15 (78.9)	0	7 (43.8)	< 0.001	0.032
	Flattening of the left ventricular posterior wall	3 (15.8)	1 (10)	3 (18.8)	0.99	0.99

Abbreviations: CP, constrictive pericarditis; IVC, inferior vena cava; MV, mitral valve; TV, tricuspid valve; MRI, magnetic resonance imaging

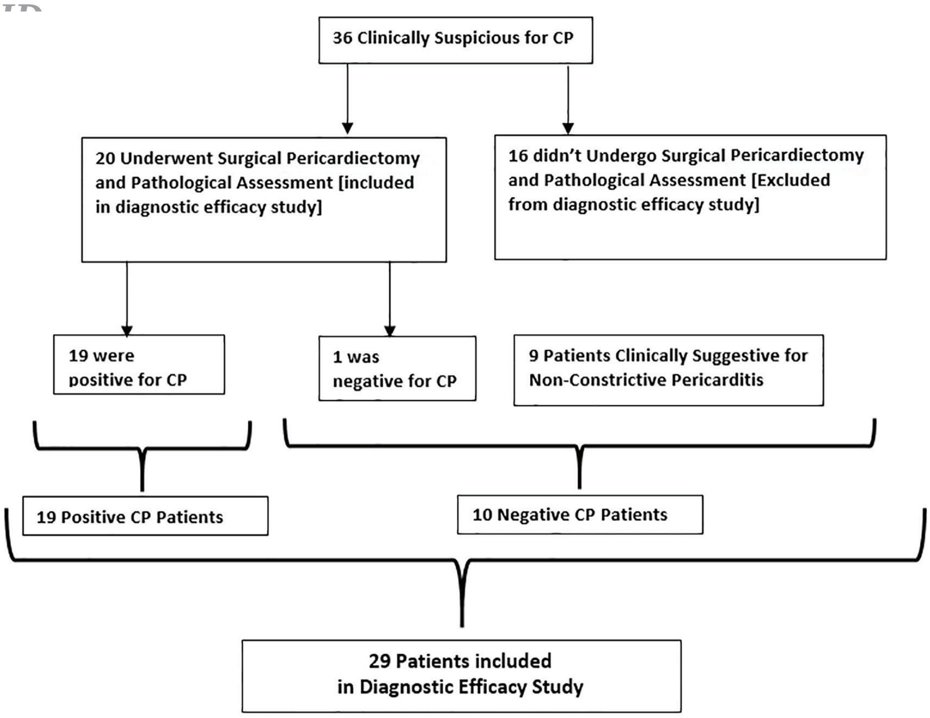


Figure 1. Flowchart of Patients' Enrollment

brief description of the study design and objectives. Indeed, the study protocol was approved by the Ethics Committee of Iran University of Medical Sciences (code: 2204).

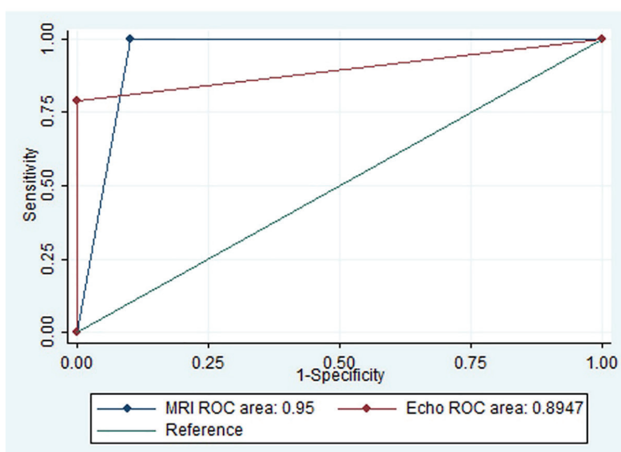
All patients had undergone echocardiography using a single echocardiographic machine (Siemens Acuson C512). Echocardiographic diagnosis of CP was made on the basis of thickened pericardium and exaggerated septal bounce. Other used echocardiographic diagnostic criteria included dilated Inferior Vena Cava (IVC) with expiratory hepatic venous flow reversal and inspiratory decrease of transmitral early diastolic flow.

All patients had undergone MRI on a 1.5 Tesla Avanto magnetic resonance scanner (Siemens Medical Systems, Munich, Germany) with breath-holding and free-breathing respiratory gated imaging and with electrocardiographic triggering. First, survey imaging was acquired in transverse, coronal, and sagittal planes. Black-blood T1-weighted spin-echo sequence was used to visualize pericardial thickness (≥ 4 mm was considered to be pathological) (Figure 2a). Half-Fourier Acquisition Single-shot Turbo Spin-echo (HASTE) sequence was used for assessment of morphological abnormalities, such as tubular shaped ventricles (Figure 2d). Cardiac Magnetic Resonance (CMR) tagging technique was also performed to detect the adhesions of pericardial layers. Moreover, STIR sequences were used to depict pericardial edema and gradient echo sequences were acquired 5-10 min after gadolinium (Omniscan, GE Healthcare injection) to detect Late Gadolinium Enhancement (LGE) (Figure 2c). Finally, Breath-hold cine sequence was performed to study the dynamic changes in CP, such as septal bounce (Figure 3). Diagnosis of CP was based on the demonstration of pericardial thickening > 4 mm along with morphological and hemodynamic abnormalities.

3.3. Statistical Analysis

All data were analyzed using the SPSS software, version 18 (SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago, Il) and STATA, version 11 (StataCorp. 2009. Stata Statistical Software: Release 11. College Station, TX: StataCorp LP.). In order to compare the two groups in terms of MRI and echocardiographic findings, at first, the normality of the data was checked by

Figure 2. A. Black Blood Heavily T2w HASTE Image



The image represents pericardial thickening in the RV anterior wall (6.095 mm) and the posterior LV wall (6.447 mm). B: Black blood heavily T2w HASTE image. The image represents pericardial effusion around the RV anterior wall (7.004) and the posterior LV wall (11.410 mm). C: True fast Imaging with Steady Precession-Phase Sensitive Inversion Recovery (FISP-PSIR) late gadolinium enhancement image. The four chamber view represents circumferential pericardial enhancement around the ventricles (white arrow). D: Bright blood 4-chamber T2/T1w true FISP image. The image depicts the tubular deformity of both ventricles (A) and loculated pericardial effusion over the posterior aspect of LV (B) and around the RV anterior wall (C). E: 2D echocardiography of a patient with constrictive pericarditis in the short axis view showed pericardial thickening around the LV.

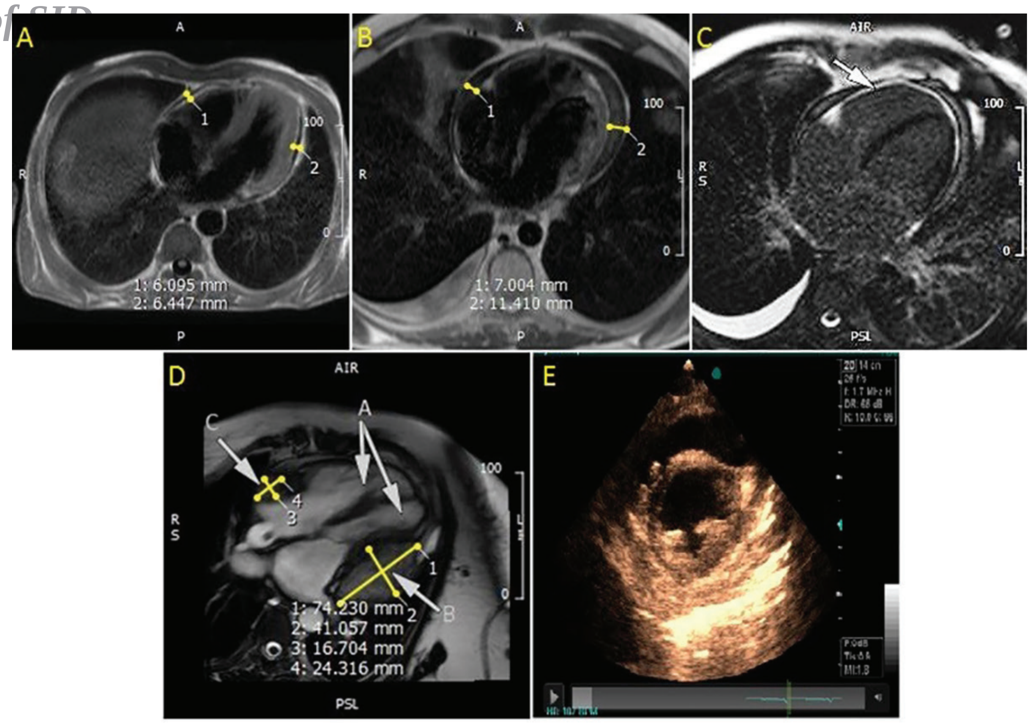


Figure 3. A: Real Time Free-Breathing T1w Fast Low Angle Shot (FLASH) Image at the End Expiratory Phase. Septal Bounce with Leftward Deviation of the Interventricular Septum Can Be Seen (White Arrow). B: 2D Echocardiography Showed Septal Bounce. C: M-Mode Echocardiography Depicted Typical Septal Bounce (Diastolic Double Component Motion of the Interventricular Septum).

Kolmogorov-Smirnov test. The two groups were compared using t-test for normally distributed data and Mann-Whitney test for non-normally distributed data. Additionally, the two groups were compared with respect to ordinal data via Mann-Whitney test. Considering nominal data, chi-square or Fisher's exact test were used as appropriated. In order to assess the diagnostic accuracy of MRI and echocardiography (and their different findings) in diagnosis of CP, cross tables were employed. Indeed, Receiver Operating Characteristic (ROC) curves and Area Under the ROC Curve (AUC) were considered as the indicators for diagnostic accuracy of the imaging methods. Based on the cross tables drawn for the dichotomous variables, all diagnostic accuracy indices, including sensitivity, specificity, Positive Predictive Value (PPV), Negative Predictive Value (NPV), Positive Likelihood Ratio (PLR), Negative Likelihood Ratio (NLR), and accuracy, and their 95% Confidence Intervals (CI) were calculated. P-values lower than 0.05 were considered to be statistically significant.

4. Results

As mentioned above, among the 36 patients with clinical impression of CP, 20 underwent surgical assessment (pericardiectomy). Among these patients, 19 were confirmed as having CP. The mean age of the patients with proved CP and those without CP was 48.1 ± 20.7 (12 - 77) and 50.6 ± 115.3 (25 - 72) years, respectively. Among the proved CP patients, 15 were male (78.9%), while six patients were male (60%) in the CP-negative group. Different echocardiographic and MRI findings in CP have been mentioned in Table 1. The results in terms of different groups have been presented, as well. Comparisons were also made between the patients with proved CP and proved non-CP patients as well as between proved CP and suspicious CP groups. The mean pericardial thickness was 7.2 ± 3.3 mm in the patients with proved CP, 5.2 ± 1.3 mm in the suspicious CP patients, and 2.8 ± 0.8 mm in the proved non-CP patients ($P < 0.001$ for CP-positive group vs. CP-negative group and $P = 0.022$ for CP positive vs. CP suspicious cases). Among different MRI findings, pericardial thickness and abnormal septal motion were positive in all CP patients, while abnormal pericardial signal in STIR sequence was positive in only one patient. Besides, abnormal myocardial signal in STIR sequence was negative in all CP proved patients. Additionally, abnormal septal motion and dilated IVC in echocardiography were seen more frequently in comparison to other echocardiographic findings (each one in 16 patients). Moreover, respiratory variation in Mitral Valve (MV) and Tricuspid Valve (TV) inflow velocity was positive in 15 patients and increased pericardial thickness was seen in 14 patients, while diastolic reversal flow in hepatic veins was seen in one patient. The results showed that the two groups were significantly different with respect to MRI and echocardiographic findings (all P-values < 0.05) (Table 1).

Diagnostic indices of all MRI variables have been presented in Table 2. Accordingly, abnormal septal motion was equivalent to the gold standard, and the sensitivity of increased pericardial thickness was found to be 100%. Most MRI variables were found to have good to excellent specificity. The sensitivity and specificity of final MRI results were equal to 100% and 90%, respectively (Table 2).

Diagnostic indices of echocardiographic assessments have been presented in Table 3. As the table depicts, the sensitivity of abnormal septal motion and dilated IVC was 84%. Most echocardiography variables had good to excellent specificity (70 - 100%). The sensitivity and

Table 2. Diagnostic Indices of MRI Findings in Constrictive Pericarditis

MRI Findings	TP	FN	TN	FP	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	PLR (95% CI)	NLR (95% CI)	Accuracy (95% CI)
Pericardial effusion	8	11	5	5	42 (20 - 67)	50 (19 - 81)	62 (32 - 86)	31 (11 - 59)	0.84 (0.37 - 1.9)	0.86 (0.42 - 1.8)	0.45 (0.26 - 0.64)
Increased pericardial thickness	19	0	8	2	100 (82 - 100)	80 (44 - 97)	90 (70 - 99)	100 (63 - 100)	5 (1.4 - 17.3)	------	93 (77 - 99)
Pericardial calcification	4	15	10	0	21 (6 - 46)	100 (69 - 100)	100 (40 - 100)	40 (21 - 61)	-----	1.3 (1 - 1.6)	48 (29 - 67)
Late gadolinium enhancement	7	12	2	8	37 (16 - 62)	20 (3 - 56)	47 (21 - 73)	14 (2 - 43)	0.46 (0.24 - 0.9)	0.32 (0.09 - 1.15)	31 (15 - 51)
Abnormal septal motion	19	0	10	0	100 (82 - 100)	100 (69 - 100)	100 (82 - 100)	100 (69 - 100)	-----	------	100 (88 - 100)
Myocardial restainment in tagging (adherence)	5	14	9	1	26 (9 - 51)	90 (56 - 99)	83 (36 - 99)	39 (20 - 61)	2.6 (0.35 - 19.6)	1.2 (0.87 - 1.7)	48 (29 - 67)
Abnormal pericardial signal in STIR	1	18	8	2	5 (0.1 - 26)	80 (44 - 97)	33 (1 - 91)	31 (14 - 52)	0.26 (0.03 - 2.6)	0.84 (0.61 - 1.2)	31 (15 - 51)
Abnormal myocardial signal in STIR	0	19	10	0	0 (0 - 17)	100 (69 - 100)	-----	34 (18 - 54)	-----	1 (1 - 1)	34 (18 - 54)
Increased right atrial size	13	6	8	2	68 (43 - 87)	80 (44 - 97)	87 (60 - 98)	57 (29 - 82)	3.4 (0.95 - 12.3)	2.5 (1.2 - 5.3)	72 (53 - 87)
Increased left atrial size	11	8	6	4	58 (34 - 80)	60 (26 - 88)	73 (45 - 92)	43 (18 - 71)	1.4 (0.62 - 3.4)	1.4 (0.68 - 3)	59 (39 - 76)
Dilated IVC	12	7	9	1	63 (38 - 83)	90 (56 - 99)	92 (64 - 99)	56 (30 - 80)	6.3 (0.95 - 41.8)	2.4 (1.3 - 4.6)	72 (53 - 87)
Tubular shaped ventricle	2	17	10	0	11 (1 - 33)	100 (69 - 100)	100 (16 - 100)	37 (19 - 58)	-----	1.1 (0.96 - 1.3)	41 (24 - 61)
Final MRI result	19	0	9	1	100 (82 - 100)	90 (56 - 99)	95 (75 - 99)	100 (66 - 100)	10 (1.6 - 64.2)	-----	97 (82 - 99)

Abbreviations: TP, true positive; FN, false negative; TN, true negative; FP, false positive; PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; STIR, short TI inversion recovery; IVC, inferior vena cava

Table 3. Diagnostic Indices of Echocardiographic Findings in Constrictive Pericarditis

	TP	FN	TN	FP	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	PLR (95% CI)	NLR (95% CI)	Accuracy (95% CI)
Increased pericardial thickness	14	5	10	1	74 (49 - 91)	100 (69 - 100)	100 (77 - 100)	67 (38 - 88)	----	3.8 (1.8 - 8.1)	83 (64 - 94)
Abnormal septal motion	16	3	10	0	84 (60 - 97)	100 (69 - 100)	100 (79 - 100)	77 (46 - 95)	-----	6.3 (2.2 - 17.9)	90 (73 - 98)
Dilated IVC	16	3	7	3	84 (60 - 97)	70 (35 - 93)	84 (60 - 97)	70 (35 - 93)	2.8 (1.1 - 7.4)	4.4 (1.5 - 13.5)	79 (60 - 92)
Diastolic reversal flow in HV	1	18	10	0	5 (1 - 26)	100 (69 - 100)	100 (3 - 100)	36 (19 - 56)	-----	1.1 (0.95 - 1.2)	38 (21 - 58)
Respiratory variation in MV and TV inflow velocity	15	4	10	0	79 (54 - 94)	100 (69 - 100)	100 (78 - 100)	71 (42 - 92)	------	4.8 (2 - 11.3)	86 (68 - 96)
Flattening of the left ventricular posterior wall	3	16	9	1	16 (3 - 40)	90 (56 - 99)	75 (19 - 99)	36 (18 - 57)	1.6 (0.19 - 13.3)	1.1 (0.8 - 1.4)	41 (24 - 61)
Final echocardiography result	15	4	10	0	79 (54 - 94)	100 (78 - 100)	100 (78 - 100)	71 (42 - 92)	------	4.8 (2 - 11.3)	86 (68 - 96)

Abbreviations: PPV, positive predictive value; NPV, negative predictive value; PLR, positive likelihood ratio; NLR, negative likelihood ratio; IVC, inferior vena cava; MV, mitral valve; TV, tricuspid valve

specificity of the final echocardiographic results were 79% and 100%, respectively (Table 3).

In order to compare the diagnostic accuracy of MRI and echocardiography, ROC curve was used and the AUCs of the imaging methods were compared. The AUCs of MRI and echocardiography were 0.95 (95% CI = 0.85 - 1) and 0.89 (95% CI = 0.80 - 0.99), respectively (P = 0.43) (Figure 4). Additionally, the sensitivity of MRI and echocardiography in diagnosis of CP was 100% and 78.9%, respectively that showed a better sensitivity for MRI (P = 0.045). However, no significant difference was observed between the two methods with regard to specificity (90% vs. 100%, P = 0.32).

In order to determine the agreement between MRI and echocardiography in similar assessments, Kappa coefficient of agreement was used among all 45 patients. The best agreement (0.53) was for abnormal septal motion (Table 4).

5. Discussion

CP is a rare medical condition characterized by a thick fibrotic pericardium, which leads to diastolic dysfunction (1) and should always be taken into account in patients with predominant symptoms of right heart failure (8). Differentiation of CP from other entities that can also result in right-sided heart failure, such as left ventricular

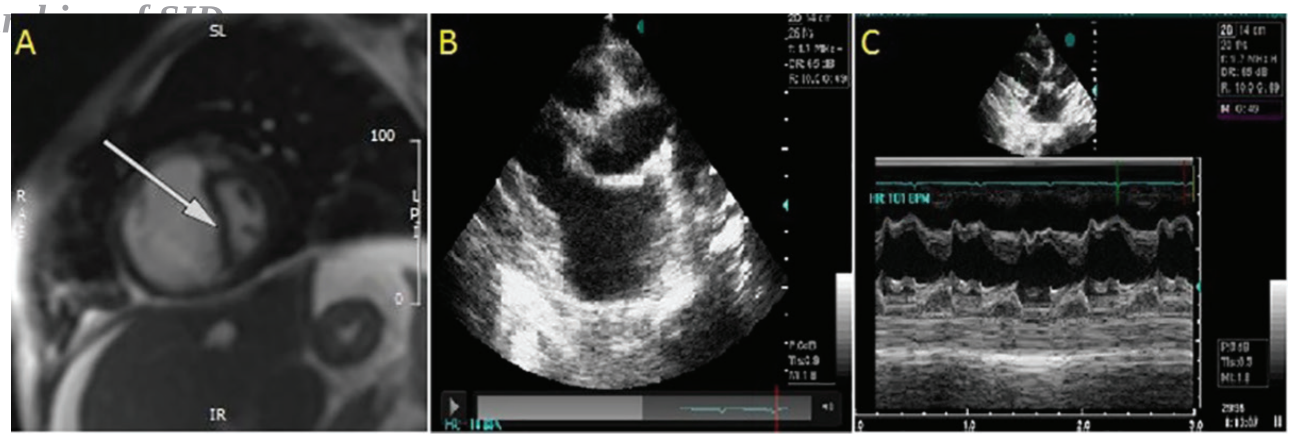


Figure 4. ROC Curves of the Final MRI and Echocardiography Results for Diagnosis of Constrictive Pericarditis

Table 4. Kappa Agreements between Similar Assessments of MRI and Echocardiography

Index	Estimate	95% CI
Increased pericardial thickness	0.33	0.14 - 0.51
Abnormal septal motion	0.53	0.29 - 0.77
Final result	0.41	0.20 - 0.63

systolic dysfunction, pulmonary embolism, pulmonary hypertension, right ventricular infarction, and mitral stenosis, is of prime importance in management of these patients. Nowadays, echocardiography can be employed in excluding or diagnosis of the above-mentioned other causes of right-sided heart failure (9). Cross-sectional imaging modalities, such as CT and MR scanning, can evaluate pericardial thickness, which is consistently increased in patients with CP. However, in the past few decades, the etiology of CP has changed mainly from tuberculous pericarditis to chest radiation induced CP and cardiac surgical procedures that involve the opening of the pericardium (8). Following chest radiation therapy or an open heart surgery, CP, restrictive cardiomyopathy, or a combination of both may occur. Previously, many patients with CP showed heavy calcification of the entire pericardium most often as a result of tuberculous pericarditis. Today, diffuse calcification of the pericardium is present notably less in patients with CP and sometimes the pericardial thickness is even within the normal limits (10).

Imaging for diagnosis of pericardial inflammation may detect early reversible CP, allowing medical therapy that may decrease the need for surgery (11). Several researchers have investigated non-invasive diagnostic methods in assessment of pericardium. Ultrafast CT, cine-gated CT, and MRI are the most widely used cross-sectional imaging modalities for non-invasive evaluation of CP (12, 13). Echocardiography is another non-invasive method that has been employed to estimate pericardial thickness. Even though echocardiography results are operator-dependent and high gain settings can potentially result in false-positive assessments, increased pericardial thickness can frequently be recognized with reasonable correlation to pathological findings after surgical periocardiectomy (12, 13). The main limitation of imaging modalities is that these tests present anatomical data and do not necessarily show the underlying pathophysiological abnormality (10). Moreover, CP can develop in patients with normal pericardial thickness and, as shown in multiple studies, patients with surgically proven CP might have a normal-appearing pericardium on non-invasive imaging modalities like CT or MRI (10).

It has been reported that CP originates most commonly from idiopathic or viral causes (42 – 49%), post-cardiac surgery (11 – 37%), chest radiotherapy (9 – 31%) (mostly for Hodgkin's disease or breast cancer), connective tissue disorder (3 – 7%), post-infectious causes (tuberculosis or purulent pericarditis in 3 – 6%), and miscellaneous causes (malignancy, trauma, drug-induced causes, asbestosis, sarcoidosis, and uremic pericarditis in < 10%) (13). In the present study, the most common etiologies of CP were found to be idiopathic and postsurgical.

The current study results indicated that both echocardiography and MRI were acceptable methods for diagnosis of CP. Although MRI was more sensitive, a point should be taken into account in this regard. Enrollment of mostly severe cases in a diagnostic test study would accentuate differences and could lead to overestimation of diagnostic indices. In the present study, there were 16 suspicious CP cases who did not undergo surgery. These cases might have had the milder forms of CP that did not fulfill the treatment indications of pericardiectomy (performing this operation only for research objectives is not ethical). Thus, if they were confirmed as CP by the gold standard, the diagnostic indices would decrease. According to the results presented in Table 1, no significant difference was found between this group and the CP-positive patients regarding MRI and echocardiography findings. Hence, if these patients had milder CP, adding their data to all cases would not cause a significant change in diagnostic indices. Of course, some of these cases might have not been CP. In this regard, a precise remark on this group is not simply possible. However, the patients under the present investigation might have had more severe forms of CP. Therefore, generalization of the findings to all CP patients (including those with milder forms) could be incorrect. Unfortunately, as mentioned above, all CP suspicious patients could not be operated (this task is not ethical). Hence, the milder forms of CP might be missed, resulting in the inability to assess the real diagnostic indices of imaging modalities among all CP patients.

5.1. Conclusion

The study results demonstrated that MRI septal bounce had the best diagnostic accuracy for diagnosis of CP. Indeed, MRI was found to be more sensitive than echocardiography in diagnosis of CP.

5.2. Ethical Considerations

This study was approved by the Ethics Committee of Rajaie Cardiovascular Medical and Research Center (code: 2204).

Acknowledgements

There is no acknowledgements.

Authors' Contribution

Study concept and design: A.M., analysis and interpretation of data: A.M., data acquisition and gathering: S.T., drafting of the manuscript: M.M., critical revision of the manuscript: A.B., statistical analysis: M.S.

Funding/Support

This research was supported in part by Iran University of Medical Sciences.

Financial Disclosure

The authors have no financial interests related to the material in the manuscript.

References

1. Lachhab A, Doghmi N, Zouhairi A, Seghrouchni A, Wahid FA, Boulahya A, *et al*. Use of magnetic resonance imaging in assessment of constrictive pericarditis: a Moroccan center experience. *Int Arch Med*. 2011;**4**:36.
2. Bogaert J, Francone M. Cardiovascular magnetic resonance in pericardial diseases. *J Cardiovasc Magn Reson*. 2009;**11**:14.
3. Bolen MA, Rajiah P, Kusunose K, Collier P, Klein A, Popovic ZB, *et al*. Cardiac MR imaging in constrictive pericarditis: multiparametric assessment in patients with surgically proven constriction. *Int J Cardiovasc Imaging*. 2015;**31**(4):859-66.
4. Bertog SC, Thambidorai SK, Parakh K, Schoenhagen P, Ozduran V, Houghtaling PL, *et al*. Constrictive pericarditis: etiology and cause-specific survival after pericardiectomy. *J Am Coll Cardiol*. 2004;**43**(8):1445-52.
5. Cremer PC, Kwon DH. Multimodality imaging of pericardial disease. *Curr Cardiol Rep*. 2015;**17**(4):24.
6. Oh JK, Hatle LK, Seward JB, Danielson GK, Schaff HV, Reeder GS, *et al*. Diagnostic role of Doppler echocardiography in constrictive pericarditis. *J Am Coll Cardiol*. 1994;**23**(1):154-62.
7. Verhaert D, Gabriel RS, Johnston D, Lytle BW, Desai MY, Klein AL. The role of multimodality imaging in the management of pericardial disease. *Circulation: Cardiovascular Imaging*. 2010;**3**(3):333-43.
8. Nishimura RA. Constrictive pericarditis in the modern era: a diagnostic dilemma. *Heart*. 2001;**86**(6):619-23.
9. Welch TD, Ling LH, Espinosa RE, Anavekar NS, Wiste HJ, Lahr BD, *et al*. Echocardiographic diagnosis of constrictive pericarditis: Mayo Clinic criteria. *Circulation: Cardiovascular Imaging*. 2014;**7**(3):526-34.
10. Talreja DR, Edwards WD, Danielson GK, Schaff HV, Tajik AJ, Tazelaar HD, *et al*. Constrictive pericarditis in 26 patients with histologically normal pericardial thickness. *Circulation*. 2003;**108**(15):1852-7.
11. Chowdhury UK, Subramaniam GK, Kumar AS, Airan B, Singh R, Talwar S, *et al*. Pericardiectomy for constrictive pericarditis: a clinical, echocardiographic, and hemodynamic evaluation of two surgical techniques. *Ann Thorac Surg*. 2006;**81**(2):522-9.
12. Ling LH, Oh JK, Tei C, Click RL, Breen JF, Seward JB, *et al*. Pericardial thickness measured with transesophageal echocardiography: feasibility and potential clinical usefulness. *J Am Coll Cardiol*. 1997;**29**(6):1317-23.
13. Nagueh SF, Bierig SM, Budoff MJ, Desai M, Dilsizian V, Eidem B, *et al*. American Society of Echocardiography clinical recommendations for multimodality cardiovascular imaging of patients with hypertrophic cardiomyopathy: Endorsed by the American Society of Nuclear Cardiology, Society for Cardiovascular Magnetic Resonance, and Society of Cardiovascular Computed Tomography. *J Am Soc Echocardiogr*. 2011;**24**(5):473-98.