Suez Canal University Medical Journal Vol. 25 (4), 2022
Pages 70-80

Assessment of Mitral Valve Apparatus in Children with Mitral Valve Prolapse: An Echocardiography Study

Abdel-Salam E. Abdel-Razek*, Ayman F. Sabry, Zainab A. Mohamed

Department of Pediatrics, Faculty of Medicine, Suez Canal University, Egypt

Abstract

Background: **Mitral valve prolapse is the most common anomaly of the mitral valve apparatus. Echocardiography plays a central role in the evaluation of the mitral valve. When a detailed evaluation of the mitral valve is required, transesophageal echocardiography is indicated with the advantage of better resolution and additional views.** ***Aim:*** **To evaluate mitral valve prolapse using trans-thoracic echocardiography.** ***Subjects and Methods:*** **A cross-sectional descriptive study design was done including 60 control and 60 patients with isolated mitral valve prolapse attending Suez Canal University hospital for echocardiographic evaluation, excluding children with other congenital heart diseases, rheumatic heart disease, cardiomyopathy, each participant was subjected to full medical history, general, cardiac examination, and investigations.** ***Results:*** **a significant difference was found between the patient and control regarding mitral leaflets long axis PML (P=0.012), mitral leaflets apical PML (P=0.000), coaptation length (P=0.000), triangle (P=0.000), chordea tendinea attached to posterior leaflet (apical parasternal view) (P=0.002), mitral regurge (P=0.000). A significant positive strong correlation was found between coaptation and mitral regurge in patients (r =0.716; P =0.001), the best critical value between mitral regurge (M1+M2) and absence of mitral regurge (Mo), to predict mitral regurge (m1+m2), the coaptation length is more than 4, the best critical value between moderate mitral regurge (M2) and mild(M1) + no regurge (Mo), to predict moderate mitral regurge (m2), coaptation length is more than 5.** ***Conclusion:*** **Trans-thoracic echocardiography is an effective imaging modality to evaluate mitral valve abnormalities and assess the severity and the hemodynamic consequences.**

Keywords: Leaflets, Parasternal, Chordea tendinea

Introduction

Mitral valve is a complex anatomical and functional structure. Mitral apparatus consists of three parts: mitral annulus, mitral valve leaflets and sub valvular apparatus (chordae tendinea and papillary muscles). For its function left atrial and ventricular myocardium is also important. Normal function of all parts of the mitral valve apparatus is essential for the normal function of the mitral valve[1,2]. Mitral annulus is a saddle shaped fibrous structure, which anteriorly borders to the aorta. Posterior annulus is close to circumflex coronary artery at the lateral side and to coronary sinus at the medial side. Mitral annulus is in a fibrous continuity with aortic and tricuspid valve[3]. Mitral leaflets consist of a larger and longer anterior (AMVL) and shorter posterior mitral valve leaflet (PMVL)[4]. Based on Carpentier's classification mitral

*Corresponding Author: Abdooooo2025@gmail.com

leaflets are divided in eight segments. Anterior and posterior leaflet have three scallops each: medial (A3, P3), middle (A2, P2) and lateral (A1, P1). The middle scallop is the largest. The leaflets are connected by two commissures: anterolateral, adjacent to left atrial appendage, and posteromedial commissure[5]. Sub valvular apparatus consists of chordae tendineae and papillary muscles. Chordae are thin filaments that connect the margins of the mitral leaflets to the papillary muscles. There are primary, secondary, and tertiary mitral chordae which are attached to two papillary muscles: posteromedial and anterolateral papillary muscle. Chordae from the medial part of both leaflets attach to the posteromedial papillary muscle and from the lateral part to the anterolateral papillary muscle[6]. Mitral valve prolapse is the most common anomaly of the mitral valve apparatus with an incidence of 2–6 per cent. Mitral valve prolapse is caused by progressive myxomatous degeneration of mitral valve leaflets and chordae tendins with a higher displacement of one or two mitral leaflets by more than 2 mm above the mitral annulus plane to the left atrium[7]. Mitral valve prolapse is a valve heart condition characterized by the abnormally thickened mitral valve leaflet being transferred to the left atrium during systole. Prolapsed mitral valves are classified into various subtypes depending on the thickness of the leaflet, the concavity, and the degree of contact with the mitral annulus. Subtypes may be classified as classical, non-classical, symmetrical, flail or non-flail. MVP has a low probability of complications in its non-classical form[8]. Mitral valve prolapse is normal with a recorded prevalence of 2–3 per cent. Some would continue to experience severe mitral regurgitation (MR) that would require action. However, the rate of disease progression remains elusive. MVP pathophysiology is thought to be a persistent pattern of frequent minor damage and repair occurring in a mitral valve with small congenital anatomical variations in the valve apparatus during the cardiac cycle. This can explain the age-based development and progression of prolapse[7]. This identifies two distinct types of "mitral valve prolapses (MVP)". Also known as mitral valve prolapse syndrome (MVPS), is the primary or classic form. It is associated with mitral valve leaflet defects, as well as perivalvular supporting tissue such as chordae tendinea and annulus. MVPS is also associated with additional cardiac symptoms such as skeletal, connective tissue, and characteristics of neuropsychiatry. The defect in the secondary or non-classical form is confined to the mitral valve without perivalvular or systemic manifestations[9]. Echocardiography plays a central role in the evaluation of the mitral valve. To enable the assessment of its morphology and function. The basic investigation is transthoracic echocardiography (TTE) which can routinely be used in everyday clinical practice. When detailed evaluation of the mitral valve is required, transesophageal echocardiography (TEE) is indicated with the advantage of better resolution and additional views[10]. Echo-Doppler studies is an essential tool to identify the presence and magnitude of mitral valve prolapse, the thickness of mitral valve leaflets, mitral annulus size, chordae tendineae length, and left ventricular and left atrial size and function. The test also reveals any associated heart diseases. Multiple views of the mitral valve annulus are essential, and the echo-Doppler findings have to be correlated with clinical data[11].

Subjects and Methods

Study setting and Study population

This study was carried out in the Pediatrics Department at Suez Canal University hospital in Ismailia, included 120 children as 60 control and 60 patients with mitral valve prolapse, attending to Suez Canal University hospital for echocardiographic evaluation. All children with isolated mitral valve prolapse were included. All children with other congenital heart disease, all_children with rheumatic heart disease, and all children with cardiomyopathy excluded by echocardiography were excluded.

Study design and Sample Size Justification
A cross-sectional descriptive study was conducted on infants with mitral valve prolapse presented to Suez Canal University Hospitals. Those fulfilled the inclusion criteria were enrolled in this study. Non-probability comprehensive sampling method will be conducted. Calculation of the sample size according to the formula [12,13] revealed 60 patients/group.

Data collection tool
A) History: The following data was collected: Age (by year), sex, age at diagnosis, history of rheumatic fever, congenital disease, and medications. *B) Examination:* Height, weight, and cardiac examination was done. *C) Investigations.*

Full trans-thoracic two-dimensional echocardiography study
Complete two dimensional, pulsed-wave, continuous wave and color-flow Doppler echocardiographic examinations were performed with a General Electric, echocardiographic evaluation using Philips cx50 equipped with 3-8MHZ transducer. frequency suitable for patient's age and size. Echocardiographic MVP has since been defined as single leaflet or bi leaflet prolapse of at least 2 mm into the left atrium during a systole beyond the long axis annular plane, with or without mitral leaflet thickening was considered the diagnostic criterion for mitral valve prolapse[14].

a. M-mode echocardiography
Measurement of the dimensions of cardiac chambers and vessels, thickness of the septum and free walls. LV systolic function including fractional shortening, ejection fraction. Normal FS is 36% (range 28% to 44%). Normal mean ejection fraction is 66% (range 56% to 78%).

b. Doppler
Assessment of right and left ventricular diastolic function using mitral valve (MV) inflow velocities.

C- Assessment of Mitral valve prolapse
Measure length of both AML& PML, measure area below AML& PML, measure both chordae tendinea of anterior and posterior leaflet in apical / long axis PSV, measure length of closure tip of mitral leaflet (coaptation length), and measure intra papillary muscle distance.

Results

Age of patients and control group
As shown in (table 1), there was statistical significance difference between patient and control regarding age p-value=0.042.

Posterior Mitral leaflet
(Long axis parasternal view)
There was a statistically significant difference between patient and control regarding Mitral leaflets long axis PML (increase in control group). P =0.012 (Figure 1)

3. Post. Mitral leaflet
(Apical parasternal view)
There is a statistically significant decrease in patients' group compared to control group regarding mitral leaflets apical PML P=0.000 (Table 2).

Table 1: Comparison between patients and control group as regard age				
Groups	Age		T-test	
	Range	Mean ± SD	t	P-value
Control group	3y - 16y	8.600 ± 3.468	-2.059	0.042*
Patients group	5y - 15y	9.833 ± 3.082		

.

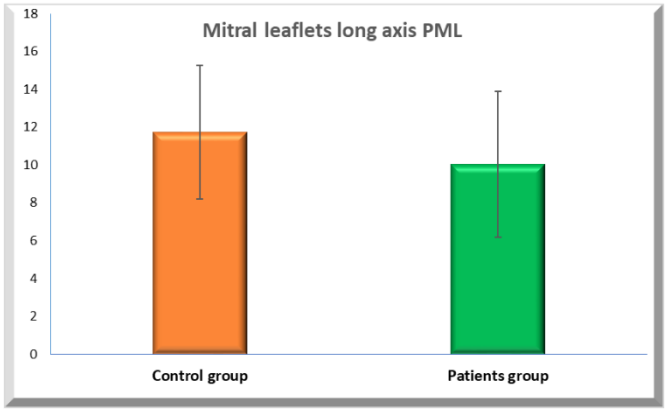


Figure 1: Posterior Mitral leaflet long axis parasternal view

4. Triangle measurement (apical parasternal view)
There was a statistically significant decrease in patients regarding Triangle and compared to control group, P =0.000 (Table 3).

5. Coaptation length and mitral leaflets closure: there is statistically significant difference between patient and control regarding Coaptation length "increased in patients' group than control group" P-value=0.000, (Figure 2).

6. Chordea tendinea attached to posterior leaflet (apical parasternal view):
There was a statistically significant increase in chordea tendinea attached to posterior leaflet in the control group compared to the patients' group (P=0.002, Fig. 3).

7. Mitral regurge
Table (4) shows a statistically significant difference between patients and controls group regarding mitral regurge. P-value=0.000.

Table 2: Comparison between patients and control group as regard Posterior Mitral leaflet (apical parasternal view).				
Groups	Mitral leaflets apical PML		T-test	
	Range	Mean ± SD	t	P-value
Control group	9 - 24	13.867 ± 4.131	4.590	0.000*
Patients group	5 - 16	10.667 ± 3.477		

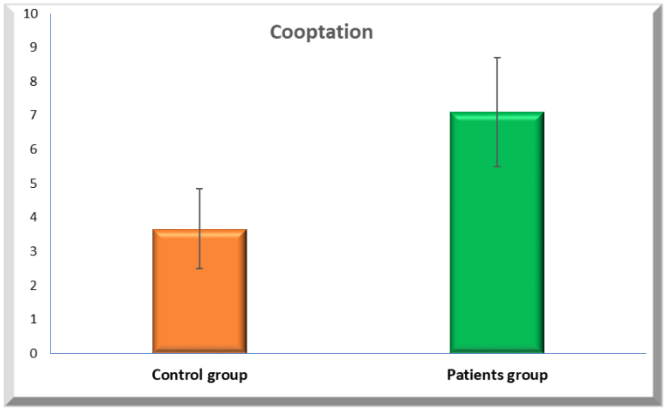


Figure 2: Coaptation length and mitral leaflets closure

Table 3: Comparison between patients and control group as regard Triangle measurement (apical parasternal view).				
Groups	Triangle		T-test	
	Range	Mean ± SD	t	P-value
Control group	17 - 37	24.900 ± 4.990	4.384	0.000*
Patients group	13 - 30	21.333 ± 3.847		

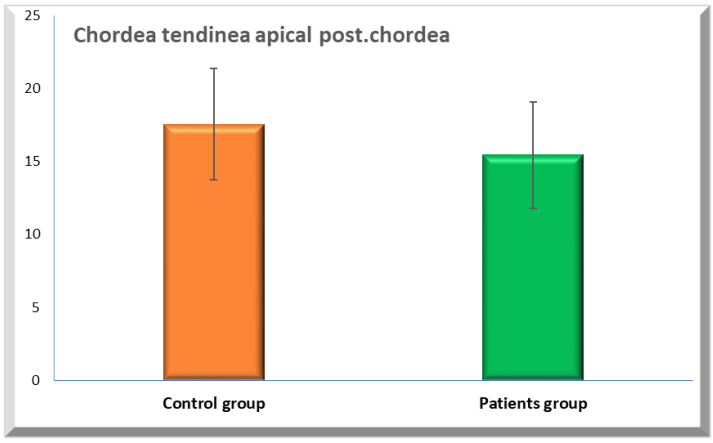


Figure 3: Chordea tendinea attached to posterior leaflet apical parasternal view.

Table 4: Comparison between patients and control group as regard Mitral regurge.				
		Groups		Total
		Control group	Patients group	
Mitral regurge	M0	60(100.0%)	12(20.0%)	72(60.0%)
	M1	0(0.0%)	32(53.3%)	32(26.7%)
	M2	0(0.0%)	16(26.7%)	16(13.3%)
Total		60(100.0%)	60(100.0%)	120(100.0%)
Chi-square	X^2	80.000		
	P-value	0.000*		

8. relation between coaptation length and mitral regurge: Figure (4) shows a significant positive strong correlation between coaptation and mitral regurge in patients where the correlation coefficient (r)=0.716 and P-value=0.001 (< 0.05).

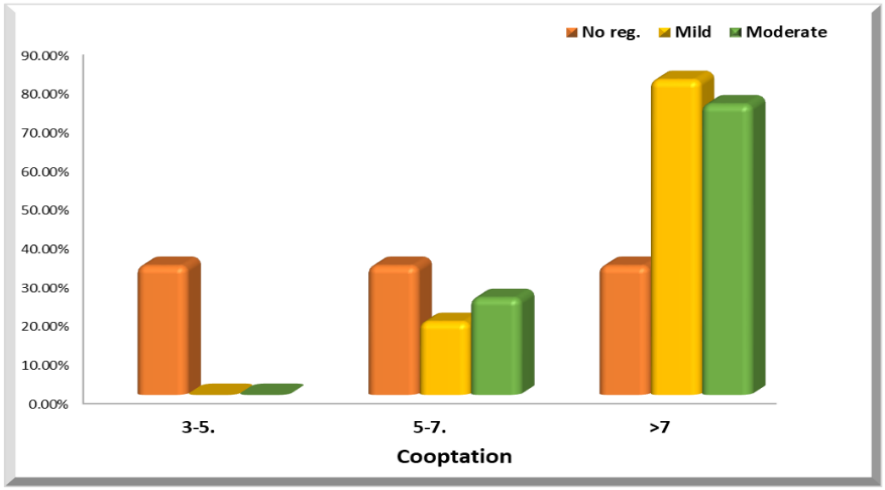


Figure 4: The relation between Coaptation length and Mitral regurge in patients

9. correlation between coaptation length and mitral regurge

Table (5) shows that the best critical value between mitral regurge (M1+M2) and absence of mitral regurge (Mo), to predict mitral regurge (m1+m2), the coaptation length is more than 4 with sensitivity 100%, specificity 72.2%, positive predictive value (PPV) 70.6, negative predictive value 100% and the accuracy was 92.2%.

Table 5: ROC curve between Coaptation length and Mitral regure (M1+M2 VS Mo).

ROC curve between Coaptation length and Mitral regure					
Cutoff	Sens.	Spec.	PPV	NPV	Accuracy
> 4 *	100.0	72.2	70.6	100.0	92.2

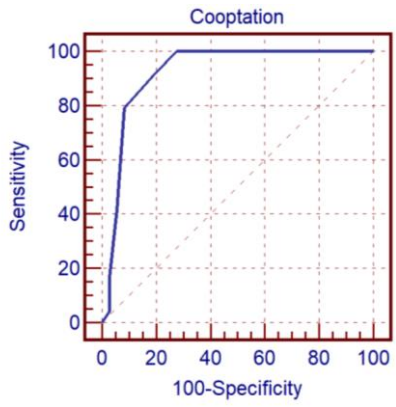
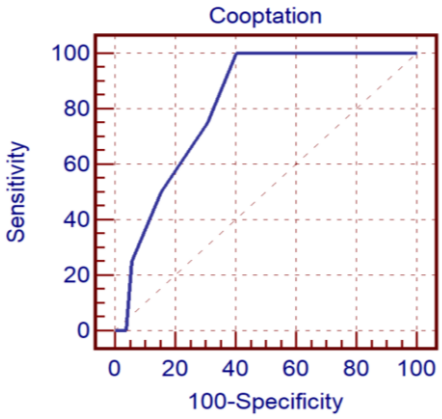


Table (6) shows that the best critical value between moderate mitral regurge (M2) and mild(M1) + no regurge (Mo), to predict moderate mitral regurge (m2), coaptation

length is more than 5, with sensitivity 100%, specifity 59.6%, positive predictive value (PPV) 27.6, negative predictive value 100% and the accuracy was 81.5%.

Table 6: ROC curve between Coaptation length and Mitral regurge (M2 VS M0+M1)					
ROC curve between Coaptation length and Mitral regurge					
Cut off	Sens.	Spec.	PPV	NPV	Accuracy
> 5 *	100.0	59.6	27.6	100.0	81.5



Discussion

Mitral valve is one of the four heart valves. It is located between the left atrium and the left ventricle, it is responsible for modulating blood flow between left atrium and left ventricle**,** not simply valve is a complex termed mitral apparatus. It receives its name due to its shape which resembles a bishop's miter with two peaks[15]. Mitral valve prolapses (MVP); is a valvular heart disease characterized by displacement of abnormally redundant thickened one or both leaflets into the left atrium during systole more than 2mm above mitral valve hinge points. It is generally a benign disease discovered accidentally during cardiac auscultation or by echocardiography[16]. Echocardiography has proved utility for the noninvasive diagnosis of mitral valve prolapse syndrome[3]. The echocardiographic features of mitral valve prolapse appear to be similar in children and adults. Although there are numerous theories about the basic abnormality in this disease, it is unclear whether an abnormality of the left ventricular contraction pattern or a primary abnormality of the mitral valve apparatus is the underlying cause[4]. A complex interrelation may exist between factors of ventricular shape and mitral valve structure in the etiology of the mitral valve prolapse syndrome[3]. An objective review of an echocardiographic material suggested that there was a spectrum of normal mitral valve motion in children with mitral valve prolapse and that the patterns of motion are likewise dependent up on the portion of the valve examined[17]. Further, it had encountered patterns mimicking mitral valve prolapse in patients with an enlarged left ventricle or sub aortic stenosis who have no evidence of prolapse on angiography. This cross-sectional study was conducted at Pediatrics Department at Suez Canal University hospital in Ismailia and included 120 children as 60 control and 60 patients with mitral valve prolapse, for

echocardiographic evaluation using philips cx50 equipped with 3-8MHZ transducer. In our study there was a significant comparison between patient and control regarding age P-value=0.042. In control group, the age ranged from 3 to 16 by Mean (8.600+3.468). And the aged ranged from 5 to 15 by mean (9.833+3.082). Regarding to sex distribution in our study we were found no statistical significance between male and female in control group (male=28 (46.7%), (female= 28(46.7%) and in patient group(male=24(40.0%), female=36(60.0%), where p-value=0.143. This agrees with previous studies [18-20] studies. These studies ascertained and reduced the sex incidence difference of mitral valve prolapse, which was 3 times in females more than in males according to old studies [21], to become equal between both sex groups. This correction was done by improved technology, community studies rather than hospital-based studies, better understanding of the 3-dimensional architecture of the mitral valve annulus and using new echocardiographic criteria for the diagnosis of mitral valve prolapse. This is in keeping with Toyono and Kestelli[22,23] who stated that there was no significant difference in sex value between patients with MVP. This is in agreement with Garfunkel et al.[24] who stated that MVP prevalence in children and adolescents: 6% to 11%. Mean age of presentation was 9.9 years; rare presentation before adolescent growth spurt in children without connective tissue disorders. Also, Mohamed Diab et al. [9] study found that the mean age of the study group (children with MVP) was 8.20±2.36, the majority of the studied group was in age group 6-9 years. Regarding to mitral leaflets diameter we found statistical significance in posterior mitral leaflet in (long axis and apical parasternal view) where p value =0.012 (long axis) and p-value=0.000(apical). But not statistical significance found with anterior mitral leaflet in both (long axis and apical view) where p-value=1.000(long axis) and p-value=0.890(apical). Comparing the techniques, it was our impression that the slightly greater incidence of abnormal studies with standard single crystal examinations could be related to atypical transducer angulations33which are less easily achieved with the larger multiple crystal transducer. In agreement with Atalay et al. [25] study which found that valvular thickening and chordal elongation were common in patients with MVP by echocardiography. Anterior leaflet and chordal lengths of the MV were closely related to the degree of valve regurgitation in the study. It was also observed that the patients with MVP had greater posterior leaflet thickness than patients without prolapse. Furthermore, other studies found the elongation of anterior and posterior mitral leaflets was demonstrated in patients with MVP. It also found elongation of both MV leaflets inpatients with MVP when compared to those without MVP[26]. Zhou et al.[27] had suggested that a rheumatic etiology should be suspected whenever anterior MVP exists, especially in young patients. Weissman et al. [28] demonstrated the high prevalence of abnormal leaflet thickening in patients with MVP by two-dimensional echocardiography. We demonstrated in our work that mitral regurge was statistical significance between patient and control p-value=0.000, we found in patient group 12 cases (20%) without mitral regurge, and 32 cases (53.3%) had mild mitral regurge and 16 cases (26.7%) had moderate mitral regurge. Like Mohamed Diab et al.[9] who found that, the majority of the studied group (88%) show normal 2D echocardiographic findings, the overall prevalence was 18 cases (12.0%), 17 cases (11.3%) had a mild MVR, only one case (0.7%) had

moderate MVR. We found the Coaptation length was statistical significance with mitral valve prolapse, although, and Coaptation length was statistical significance with mitral regurge where p-value =0.001, and we found when coaptation length (more than 4) is the best value to predict mitral regurge with sensitivity 100%, Specifity 72.2%, Positive predictive value (PPV) 70.6, Negative predictive value 100% and the accuracy was 92.2%. We found when coaptation length (more than 5) is the best value to predict moderate mitral regurge (table 18) with sensitivity 100%, specificity 59.6%, positive predictive value (PPV) 27.6, negative predictive value 100% and the accuracy was 81.5%. Regarding to chordae tendinea attached to anterior leaflet in (long axis and apical parasternal view) and chordae tendinea attached to the posterior mitral leaflet in (long axis parasternal view) we found no statistical significance between patient and control where p-value =0.168, 0.722, 0.096 respectively. And we found statistical significance in chordae tendinea attached to posterior mitral leaflet in (apical parasternal view) which increase in control group where p-value =0.002. This agrees with Ortiz et al.[29] who found that in MVP patients there was left atrioventricular valve with short chordae the leaflet attached near the apex of the left ventricle. Regarding to difference in chordea length between chordea tendinea attached to anterior mitral leaflet and chordea attached to posterior mitral leaflet we found no statistical significance in long axis and apical view p-value=0.363 and 0.124 respectively. we found statistical significance between mitral regurge and chordea length difference in apical view p-value=0.049. But we found no statistical significance be between mitral regurge and chordea length difference in along axis parasternal view p-value=0.103. Regarding to Intra papillary Muscle distance we found statistical significance between patient and control group as (increase in patient group) where p-value=0.023, and a significant positive correlation between Intra papillary Muscle distance and chordae tendinea attached to anterior mitral leaflet P-value=0.028 and a significant positive correlation between Intra papillary Muscle distance and chordae tendinea attached to posterior mitral leaflet in apical parasternal view (P=0.009. Regarding to triangle measurement in apical parasternal view we found statistical significance between patient and control group (decrease in patient group) where p-value=0.000. Clinical implications: It is likely that mitral valve prolapse represents a summation of motions of the mitral ring, the mitral leaflets, the papillary muscle apparatus, the left ventricular wall and, indeed, the whole heart. The abnormalities are probably related to, and occur at, the time of a specific ventricular size and shape. The M mode tracing thus represents an addition of structural motions and images obtained from different portions of the valve during its systolic descent. Therefore, prolapse may or may not be detectable in echocardiography in an individual patient. Further, the motion of prolapse may at times be outside the examining plane. It is therefore possible that echocardiography will fail to identify some mitral abnormalities of the prolapse type because mitral valve motion will appear within the normal spectrum. These cases, representing false negative diagnoses, will require diagnosis with previously utilized clinical methods. False positive diagnoses also occur and may cause psychologic damage or create non disease. Systematization of the criteria for mitral valve prolapse and the method of examination, as well as increased awareness of causes of false positive systolic motion abnormalities, should

lessen confusion regarding the incidence and meaning of mitral prolapse and reduce overdiagnosis in individual patients.

Conclusion

Trans-thoracic echocardiography is an effective imaging modality to evaluate mitral valve abnormalities and to assess the severity and the hemodynamic consequences.

References

1. Ho SY. Anatomy of the mitral valve. Heart. 2002 Nov 1;88(suppl 4): iv5-10.
2. McCarthy KP, Ring L, Rana BS. Anatomy of the mitral valve: understanding the mitral valve complex in mitral regurgitation. Euro J Echocardiography. 2010 Dec 1;11(10): i3-9.
3. Omran AS, Arifi AA, Mohamed AA. Echocardiography of the mitral valve. J Saudi Heart Assoc. 2010 Jul 1;22(3):165-70.
4. Prokšelj, K., 2017. Echocardiography of the mitral valve. *Posebna izdanja Akademije nauka i umjetnosti BiH*, (1), pp.26-41.
5. Dal-Bianco JP, Levine RA. Anatomy of the mitral valve apparatus: role of 2D and 3D echocardiography. Cardiol clinics. 2013 May 1;31(2):151-64.
6. Vahanian A, Baumgartner H, Bax J, et al. Guidelines on the management of valvular heart disease: The Task Force on the Management of Valvular Heart Disease of the European Society of Cardiology. Euro Heart J. 2007 Jan 1;28(2):230-68.
7. Delling FN, Vasan RS. Epidemiology and pathophysiology of mitral valve prolapse new insights into disease progression, genetics, and molecular basis. Circulation. 2014 May 27;129 (21):2158-70.
8. Hayek E, Gring CN, Griffin BP. Mitral valve prolapse. The Lancet. 2005 Feb 5;365(9458):507-18.
9. Mohamed Diab NA, El-Seheimy LA, Abd Elmohsen AM. Frequency of Mitral Valve Prolapse in Apparently Healthy Children in Alexandria Governorate. Int J Med Arts. 2020 Apr 1;2(2):462-8.
10. Mylotte D, Pilote L, Ionescu-Ittu R, Abrahamowicz M, Khairy P, Therrien J, Mackie AS, Marelli A. Specialized adult congenital heart disease care: the impact of policy on mortality. Circulation. 2014 May 6;129(18):1804-12.
11. Shah PM. Current concepts in mitral valve prolapse—diagnosis and management. J Cardiol. 2010 Sep 1;56(2):125-33.
12. Dawson et al. Basic & Clinical Biostatistics (LANGE Basic Science). 2004.
13. Lapenna E, De Bonis M, Sorrentino F, et al. Commissural closure for the treatment of commissural mitral valve prolapse or flail. J Heart Valve Dis. 2008 May 1;17(3):261.
14. Ghosh N, Al-Shehri H, Chan K, et al. Characterization of mitral valve prolapse with cardiac computed tomography: comparison to echocardiographic and intraoperative findings. Int J Cardiovasc Imaging. 2012 Apr;28(4):855-63.
15. Fishbein GA, Fishbein MC. Mitral valve pathology. Curr Cardiol Reports. 2019 Jul;21(7):1-8.
16. Boudoulas KD, Boudoulas H. Floppy mitral valve (FMV)/mitral valve prolapse (MVP) and the FMV/MVP syndrome: pathophysiologic mechanisms and pathogenesis of symptoms. Cardiology. 2013;126(2):69-80.
17. Kalangos A, Beghetti M, Vala D, et al.. Anterior mitral leaflet prolapse as a primary cause of pure rheumatic mitral insufficiency. Ann Thoracic Surg. 2000 Mar 1;69(3):755-61.
18. Sutton MS, Weyman AE. Mitral valve prolapse prevalence and complications: an ongoing dialogue. Circulation. 2002 Sep 10;106(11):1305-7.
19. Lawrence CH. Valvular Heart Disease. Proceeding of an NHLBI Conference on Cardiovascular Health and Disease in Women, 2007. Chap 52, Pp 335-39.

20. Avierinos JF, Inamo J, Grigioni F, et al. Sex differences in morphology and outcomes of mitral valve prolapse. Ann Intern Med. 2008 Dec 2;149(11):787-94.
21. Levy D, Savage D. Prevalence and clinical features of mitral valve prolapse. Am Heart J. 1987 May 1;113(5):1281-90.
22. Toyono M, Pettersson GB, Matsumura Y, et al. Preoperative and postoperative mitral valve prolapse and regurgitation in adult patients with secundum atrial septal defects. Echocardiography. 2008 Nov;25(10):1086-93.
23. Kestelli M. Mitral valve prolapse in atrial septal defect. Int J Cardiol. 2001; 1:1-4.
24. Garfunkel LC, Kaczorowski J, Christy C. Pediatric clinical advisor E-book: instant diagnosis and treatment. Elsevier Health Sci; 2007 Jul 5.
25. Atalay S, Uçar T, Ozcelik N, et al. Echocardiographic evaluation of mitral valve in patients with pure rheumatic mitral regurgitation. Turk J Pediatr. 2007 Apr 1;49(2):148.
26. Malkowski MJ, Boudoulas H, Wooley CF, et al. Spectrum of structural abnormalities in floppy mitral valve echocardiographic evaluation. Am Heart J. 1996 Jul 1;132(1):145-51.
27. Zhou LY, Lu K. Inflammatory valvular prolapse produced by acute rheumatic carditis: echocardiographic analysis of 66 cases of acute rheumatic carditis. Int J Cardiol. 1997 Jan 31;58(2):175-8.
28. Weissman NJ, Pini R, Roman MJ, et al. In vivo mitral valve morphology and motion in mitral valve prolapse. The Am J Cardiol. 1994 Jun 1;73(15):1080-8.
29. Ortiz ED, Somerville JA. Assessment by cross sectional echocardiography of surgical" mitral valve" disease in children and adolescents. Heart. 1986 Sep 1;56(3):267-71.