ORIGINAL ARTICLE

Echocardiographic findings before and after surgical repair of Tetralogy of Fallot

Noor Mohammad Noori,[1] Maziar Mahjoubifard,[2] Seyed Mostafa Alavi,[3] Alireza Teimouri[4]

Abstract

Objective: To compare echocardiographic findings before and after surgical repair of Tetralogy of Fallot.

Methods: The interventional study was conducted in Ali-ebne-Abitaleb Hospital, Zahedan, Iran, from September 2008 to March 2010, and comprised patients undergoing surgical repair of Tetralogy of Fallot. Physical examination, chest radiography and electrocardiography were done before echocardiography. Data were analysed by using SPSS 20.

Results: Of the 30 patients, 10(33.3%) were girls and 20(66.6%) boys, with an overall pre-surgery mean age of 47.40±21.34 months and 74.46±20.63 months post-surgery (p=0.001). The mean duration of post-operative period was 37.86±18.27 months. The results for right heart showed that Z scores for peak E velocity, peak A velocity, pre-ejection period, isovolumic relaxation time, myocardial performance index and isovolumic contraction time were significantly different (p<0.05). In the left heart, aortic, left atrium, left ventricular end-systolic dimension, left ventricular end-diastolic dimension, deceleration time, Peak E velocity/Peak A velocity, Peak E velocity, Peak A velocity, pre-ejection period/ejection time, pre-ejection period, shortening fraction and ejection fraction had significant difference (p<0.05).

Conclusion: Right ventricular performance indices can serve as valuable parameters in assessing cardiac performance.

Keywords: Echocardiography, Tetralogy of Fallot, Myocardial performance index, Children. (JPMA 65: 921; 2015)

Introduction

Tetralogy of Fallot (TOF) is one of the most common cyanotic congenital heart diseases (CHDs) with a prevalence of 0.26-0.8 in 1000 live births. TOF constitutes 10 per cent of CHDs. The severity of right ventricular (RV) outflow obstruction determines the onset of symptoms, degree of cyanosis and amount of right ventricular hypertrophy. The best age for surgical correction is 4-12 months. Most patients enjoy a symptom-free and normal life with good function. However, there is long-term morbidity with potentially lethal complications like arrhythmia and sudden death. It is necessary to follow patients who undergo surgical repair of TOF by imaging to obtain adequate information about residual anatomical problems, degree of pulmonary stenosis or regurgitation and systolic and diastolic function of both ventricles.[1,2]

Echocardiography is a suitable tool to assess myocardial performance index (MPI). MPI is calculated by dividing the sum of isovolumic contraction time (ICT) and isovolumic relaxation time (IRT) by ejection time (ET). Cardiac function may change following complete surgical correction of TOF.

[1]Pediatric Cardiology, [2,3]Cardiac Anesthesiology Fellowship, [4]Dempgrapher, Children and Adolescent Health Research Center, Zahedan University of Medical Sciences, Zahedan, Iran.

Correspondence: Maziar Mahjoubifard. Email: m_mahgoobifard@yahoo.com

Although assessment of RV function is important in management of children with CHD, but imaging techniques are limited by the special geometric shape of the RV.[3] In earlier studies, myocardial systolic and diastolic function was measured using Tei Index or MPI.[4,5] One study in patients with transposition of great vessels stated that in a systemic RV, MPI can assess the global function of the ventricle and estimate its ejection fraction (EF) with acceptable accuracy.[6] Another study used a multivariate regression analysis and reported that MPI is not affected by degree of pulmonary insufficiency, presence of tricuspid insufficiency, or duration of QRS complex in electrocardiogram (ECG) and concluded that MPI is a simple and reliable index for assessment of RV function after complete surgical correction of TOF.[7] One study found that following surgical correction of TOF, tissue Doppler echocardiography can measure exertional MPI and predict patients at high risk of ventricular arrhythmia.[8] Another study reported that increased MPI reflects decreased RV EF and exertional capacity in patients after surgical correction of TOF.[9] A study mentioned that following surgical correction of TOF, increased RV volume load can negatively affect left ventricular (LV) function through creating global mechanical dyssynchrony.[10] Yet another study showed that measurement of MPI using a tissue method can rapidly identify changes in the contraction quality of LV, but this is influenced by changes in both preload and afterload.[11]

The hypothesis of the current study was that the findings of echocardiography before and after correction of TOF in the left and right heart do not change. This is the first study of its kind in Iran, and similar studies are few in other countries. It aimed at comparing echocardiographic findings before and after surgical correction of TOF, and investigated the use of Doppler echocardiography as a simple, inexpensive and reproducible method for assessment of cardiac function.

Patients and Methods

The interventional study was conducted in Ali-ebne-Abitaleb Hospital, Zahedan, Iran, from September 2008 to March 2010, and comprised patients undergoing surgical repair of TOF. The study was approved by the research ethics committee of Zahedan University of Medical Sciences, and informed consent was obtained from parents before enrolment in the study. All participants underwent physical examination, chest radiography and ECG before echocardiography. Patients who had surgical repair at least 6 months earlier were included in the study. Echocardiography was performed using the same device (Challenge 7000, made in Italy using 2.5, 3.5 and 5 MHZ transducers) by one paediatric cardiologist. Echocardiography was performed in supine position and without breath holding by 2D, M-Mode and Doppler methods and the average value of each parameter was calculated in three cardiac cycles. M-Mode images were obtained at the level of the tips of mitral valve cusps at the parasternal line. Using the M-Mode inter-ventricular septum and LV posterior wall thickness were measured in systole and diastole as well as left ventricular end-systolic diameter (LVESD), left ventricular end-diastolic diameter (LVEDD), EF and shortening fraction (SF). Pulsed-Doppler was used to measure velocity of blood through valves and E-velocity, A-velocity, ET and pre-ejection period (PEP), E/A, PEP/ET ratios and IRT. M-Mode and Doppler views were recorded on a paper at a speed of 50mm/sec. For measurement of MPI, the sample volume locating at the tips of tricuspid and mitral valve leaflets in the apical 4-chamber view enabled measurement of A, which is the time of interval between the end and the start of trans-mitral and trans-tricuspid flow. The sample volume then was repositioned to the left ventricular outflow tract (LVOT) just below the aortic (AO) valve (apical five-chamber view) for measurement of B, the LV ET. RV outflow velocity pattern was also recorded from the parasternal short axis view with the Doppler sample volume positioned just distal to the pulmonary valve for measurement of B. MPI or Tie index was calculated as: a-b/b = (IRT+ICT)/ET.[12,13]

Data was analysed using SPSS 20 and normality test to identify the type of data distribution based on the basic variable was applied. If normality was observed, the analysis was done by paired t-test; if not, non-parametric test such as Wilcoxon signed-rank test was used.

Results

Of the 30 patients, 10(33.3%) were girls and 20(66.6%) were boys. The mean age of patients before surgery was 47.40±21.34 months and after the surgery it was 74.46±20.63 months (p=0.001). The average duration of post-operative period was 37.86±18.27 months.

Left heart data showed that in the case of left atrium(LA)/AO, 19(63.3%) patients had higher score after the surgery.

For the left heart, factors of AO, LA, LVESD, LVEDD,

Table-1: Parameters measured in left ventricle before and after surgery.

Pairs		N	Mean Rank	Sum of Ranks	Z	two tailed p value
LA/AO_a - LA/AO_b	NR*	10	20.2	202	-0.34	0.737
	PR**	19	12.26	233		
	Ties	1				
	Total	30				
Ao_a-Ao_b	NR	20	15.98	319.5	-2.21	0.027
	PR	9	12.83	115.5		
	Ties	1				
	Total	30				
LA_a-LA_b	NR	30	15.5	465	-4.78	0.000
	PR	0	0	0		
	Ties	0				
	Total	30				
$LVDESD_a$- $LVDESD_b$	NR	30	15.5	465	-4.78	0.000
	PR	0	0	0		
	Ties	0				
	Total	30				

$LVEDD_a$- $LVEDD_b$	NR	30	15.5	465	-4.78	0.000
	PR	0	0	0		
	Ties	0				
	Total	30				
MPI_a-MPI_b	NR	16	18.63	298	-1.74	0.082
	PR	13	10.54	137		
	Ties	1				
	Total	30				
ICT_a-ICT_b	NR	15	14.07	211	-0.44	0.658
	PR	15	16.93	254		
	Ties	0				
	Total	30				
IRT_a-IRT_b	NR	14	15.46	216.5	-0.33	0.742
	PR	16	15.53	248.5		
	Ties	0				
	Total	30				
DT_a-DT_b	NR	6	9.08	54.5	-2.92	0.004
	PR	19	14.24	270.5		
	Ties	5				
	Total	30				
E/A_a-E/A_b	NR	19	18.05	343	-2.71	0.007
	PR	10	9.2	92		
	Ties	1				
	Total	30				
A_a-A_b	NR	7	12.79	89.5	-2.77	0.006
	PR	22	15.70	345.5		
	Ties	1				
	Total	30				
E_a-E_b	NR	11	12.59	138.5	-1.93	0.053
	PR	19	17.18	326.5		
	Ties	0				
	Total	30				
PEP/ET_a-PEP/ET_b	NR	23	18.35	422	-3.9	0.000
	PR	7	6.14	43		
	Ties	0				
	Total	30				
PEP_a-PEP_b	NR	26	15.79	410.5	-4.17	0.000
	PR	3	8.17	24.5		
	Ties	1				
	Total	30				
ET_a-ET_b	NR	19	16.11	306	-1.51	0.13
	PR	11	14.45	159		
	Ties	0				
	Total	30				
FS_a-FS_b	NR	2	14.50	29	-4.09	0.000
	PR	27	15.04	406		
	Ties	1				
	Total	30				
EF_a-EF_b	NR	2	10.75	21.5	-4.34	0.000
	PR	28	15.84	443.5		
	Ties	0				
	Total	30				

NR*, Negative Ranks; PR**, Positive Ranks.

AO, Aortic ; LA, Left atrium ; MPI, Myocardial performance index; IRT, Isovolumic relaxation time; ICT, Isovolumic contraction time; DT, Deceleration time; E, Peak E velocity; A, Peak A velocity; PEP, Pre-ejection period; ET, Ejection time EF, Ejection fraction; SF, Shortening fraction; LVESD, Left ventricular end-systolic dimension; LVEDD, Left ventricular end-diastolic dimension.

Table-2: Parameters measured in right ventricle before and after surgery.

Paires		N	Mean Rank	Sum of Ranks	Z	two tailed p value
Ea-Eb	NR*	3	7.50	22.5	-4.32	0.000
	PR**	27	16.39	442.5		
	Ties	0				
	Total	30				
Aa-Ab	NR	6	12.08	72.5	-3.29	0.001
	PR	24	16.35	392.5		
	Ties	0				
	Total	30				
E/Aa-E/Ab	NR	12	15.67	188	-0.92	0.36
	PR	18	15.39	277		
	Ties	0				
	Total	30				
PEPa-PEPb	NR	30	15.50	465	-4.78	0.000
	PR	0	0.00	0		
	Ties	0				
	Total	30				
ETa- ETb	NR	19	14.74	280	-0.98	0.33
	PR	11	16.82	185		
	Ties	0				
	Total	30				
PEP/ETa- PEP/ETb	NR	30	15.5	465	-4.78	0.000
	PR	0	0	0		
	Ties	0				
	Total	30				
DTa-DTb	NR	16	12.72	203.5	-0.01	0.991
	PR	12	16.88	202.5		
	Ties	2				
	Total	30				
IRTa-IRTb	NR	24	15.83	380	-3.52	0.000
	PR	5	11.00	55		
	Ties	1				
	Total	30				
MPIa-MPIb	NR	27	16.93	457	-4.62	0.000
	PR	3	2.67	8		
	Ties	0				
	Total	30				
ICTa-ICTb	NR	26	16.46	428	-4.02	0.000
	PR	4	9.25	37		
	Ties	0				
	Total	30				

NR*, Negative Ranks; PR**, Positive Ranks

IRT: Isovolumic relaxation time; ICT: Isovolumic contraction time; MPI: Myocardial performance index; DT: Deceleration time; E: Peak E velocity; A: Peak A velocity; PEP: Pre-ejection period; ET: Ejection time.

deceleration time (DT), E/A, A, PEP/ET, PEP, SF and EF had a significant difference after surgical repair (Table-1).

For the right heart, factors E, A, PEP, IRT, MPI and ICT revealed significant difference ($p<0.05$) (Table-2).

Discussion

Most methods that are used to assess changes in cardiac function following surgical correction for TOF are either invasive or very costly. This study was carried out to assess the cardiac function using echocardiography that is simple, inexpensive and reproducible. MPI has been increasingly used to assess both systolic and diastolic function of ventricles and is defined as the sum of isovolumetric cardiac activity divided by ET and could be measured for right and left heart separately.[12-14]

In a study on LV MPI in patients treated with doxorubicin, MPI was higher in cases than controls, mainly due to increased IRT and decreased ET (ICT remained relatively constant).[13,15] A study on the value of MPI in assessment of cardiac function following surgical repair of TOF showed that right and left ventricular function changes such that RV MPI was unexpectedly below normal range (76.5%), resulting from reduced IRT; a finding that contradicts those of the present study. In the same study, LV MPI was also observed to be less than normal due to reduced ICT, but in our study, LV ICT increased following surgery.[3] In another study on the relation between LV asynchrony and right bundle branch block following surgery for TOF, patients with right bundle branch block evidenced by ECG showed significantly higher MPI associated with regional and global LV dysfunction. This can explain the increased MPI in our study since majority of our patients had evidence of bundle branch block.[16] One study assessed the relation between RV function and QRS duration in patients with TOF whose pulmonary regurgitation was completely corrected surgically.[5] It found that MPI increased more significantly in patients with severe pulmonary regurgitation compared with patients with mild or moderate pulmonary regurgitation. This was due to reduced RV EF. It also observed a relationship between the size of the RV and the QRS duration. In our study there was only one case with severe pulmonary regurgitation. Following surgical repair of TOF brain natriuretic peptide (BNP) may increase in relation to the size of right heart chambers and severity of pulmonary insufficiency.[17] In the same study, echocardiographic parameters of the patients increased much like our study. Some studies on repaired TOF patients using Cardiovascular Magnetic Resonance (CMR) give clues with regard to ventricular mechanisms and clinical effects in such patients.[18,19] Quite a few authors have proved that the degree of PR and RV diastolic dimensions and stroke volume are closely related. Akin to LV role in rigorous chronic AO regurgitation, once the compensatory mechanisms of the RV fail, mass-to-volume ratio lessens, end-systolic volume raises, and EF reduces.[18]

A study showed that an increase in RV wall stress, a reduction in RV EF, and symptoms in patients with repaired TOF could be correlated.[20] There are some other factors seriously influencing RV mechanisms. They involve the spatial extent and magnitude of duskiness of the outflow patch,[19] RV fibrosis,[21] impaired RV diastolic function[22] and LV dysfunction.[18]

It is probable that lengthened conduction time and dyssynchrony of RV contraction play an additional part to RV dysfunction. Like the natural history of rigorous AO regurgitation, in which irreversible myocardial damage appears after a period of reversible ventricular dysfunction, evidence shows that the same happens late after TOF repair.[18-20]

One study[19] concluded that an obvious slow response to dobutamine stress for both the RV and LV implies that LV function is adversely affected by impaired RV mechanisms. A clinical research exists that applied CMR in patients with repaired TOF revealing a near-linear connection between RV EF and LV EF.[18]

One study showed that in adults with delayed correction for TOF, RV myocardial dysfunction exists despite normal Doppler echocardiography findings. In these patients tissue Doppler echocardiography can be highly valuable in predicting serious response and long-term assessment of cardiac reserve function.[8]

Another study showed that major diagnostic errors by echocardiography only was 0.2% to 2% in infants. Also, it demonstrated that echocardiography has easy availability and portability, has no radiation risk, low sedation, and requirements in young children. Also, this equipment is useful in evaluation of intracardiac morphology, regional functional assessment, diastolic function, assessment of pressure gradient, stress imaging and foetal imaging is superior form another imaging modalities.[23]

CMR in assessment of ventricular function quantification, flow quantification, quantification of valve regurgitation, tissue characterisation, myocardial viability and first pass perfusion is better than other imaging modalities.[23] Cardiac computed tomography (CCT) in assessment of intracardiac morphology [ungated], extra-cardiac vasculature [gated], coronary artery imaging, and trachea and main stem bronchi is greater from other imaging modalities.[23] Nuclear Scintigraphy in assessment of myocardial viability and first pass perfusion and stress imaging is better than other imaging modalities.[23] Another research illustrated that echocardiography [TTE, TEE] remained the first-line cardiovascular imaging modality in patients with CHD, although suboptimal sound can be problematic after previous cardiac surgery.[24] Echocardiography is superior to CMR for diagnosis of patent foramen ovale, structural abnormalities of valve leaflets and their suspensory apparatus and infective endocardial vegetations. CCT offers excellent spatial resolution and relatively unrestricted access in much shorter acquirement times than CMR. CCT is well suited for imaging the epicardial coronary arteries and their relationships to adjacent structures or conduits. In patients with a pacemaker or implantable cardioverter defibrillator, CT offers an alternative to CMR.[19,24]

CMR has important contributions to make in the assessment and follow-up of patients with repaired TOF. CMR with contrast angiography has a role in the selection of the patients for such procedures, but also has CT, which allows the visualisation of calcium and the clear delineation of coronary arteries relative to previously-placed conduits. In the end, the evaluation of repaired TOF requires through assessment of left and right heart, extending to the branch pulmonary arteries and ascending aorta.[17,22] Another study illustrated that CMR to echocardiography is better imaging modality for assessment of pulmonary artery and RV function following total correction of TOF.[25]

Another study reported that RV function declined after cardiac surgery in CHD due to three mechanisms: acute ischaemia or air emboli; cytokines release; and peri-operative temperature variations. The harmful effects of pericardial disruption on RV filling and function were reasonable.[19,26] In addition, this study showed that no association was observed between the declined right ventricular function (RVF) and frequency of RVF, stay in hours, in tropes dependence and fluid balance in the first 24 hour on the intensive care unit (ICU). Also, this study demonstrated that patients with CHD have a decline in RVF directly subsequent to cardiac surgery, not considering the side of surgery.[26]

One study showed that patients with TOF more often than not have LV dysfunction previous to cardiac surgery and there is no additional worsening subsequent to surgery. On other hand, RV volume increases and EF decreases following cardiac surgery. These post-operative changes have been reported to pulmonary insufficiency, pre-operative hypoxia and ventriculotomy.[17,23,24] CMR and radionuclide ventriculography are choice methods for assessment of the ventricular function; also, they are expensive and prolonged in duration.[19,25,27]

Other studies demonstrated that echocardiography, especially via Doppler tissue imaging, is useful for evaluation of right and left ventricular function after cardiac surgery, for example TOF, as it is inexpensive and of short duration.[27-31]

Conclusion

Echocardiographic findings indicated that in patients with TOF after surgical correction, the impaired function of both RV and LV might be similar to earlier studies due to dyskinesis of the outflow patch, RV fibrosis, diminished RV diastolic function, and LV dysfunction.

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