Echocardiographic Assessment of Right Ventricular Diastolic Function After Tetralogy of Fallot Correction

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Background --- Literature has shown that there is a development of right ventricular dysfunction in some patients after the total repair of Tetralogy of Fallot. Right ventricular diastolic function has been recently observed to show signs of impairment with a diverse behavior in different phases of the postoperative follow-up. The incidence of right diastolic dysfunction in literature after TOF repair ranges from 28 to 52%. This study was aimed to quantitate right ventricular diastolic dysfunction in early postoperative phase of tetralogy of fallot and to correlate it with the type of surgical procedure and clinical parameters.

Methods --- This was a prospective cohort study involving Tetralogy of Fallot patients who underwent total repair from May to November 2006 at the Philippine Heart Center. Clinico-demographics as well as echocardiographic studies with emphasis on the right ventricular function were obtained. RV diastolic indices, such as Tricuspid Inflow E Velocity, A velocity, E/A ratio, Tricuspid deceleration Time, Isovolumic relaxation time and Superior Vena Cavae velocities, were obtained from the study population and compared with normal values. Post-operative clinical parameters were then correlated with the RV diastolic indices.

Results --- There were 10 patients included in the study. The mean age of the patients was 9.78 +/- 5.3 years old There were six male and four female. There were seven patients who had VSD closure with RVOT patching while the remaining three patients had VSD closure with infundibulectomy. All the above RV diastolic indices measured from the patients have a significant difference as compared to normal values (P value < 0.05) except to E wave velocity of tricuspid inflow during inspiration. This means that most of the patients developed RV diastolic dysfunction in early postoperative period.

Conclusion --- Right ventricular diastolic dysfunction can develop in early post-operative period after TOF correction. The RV diastolic indices such as Tricuspid E wave velocity, Tricuspid E/A ratio, deceleration time, isovolumic relaxation time and Superior Vena Cavae Velocities are good parameters to determine the RV diastolic dysfunction. Age prior to surgery, ECG findings, and O2 saturation are good predictors of outcome of TOF correction. Surgical technique and duration of bypass time did not show significant correlation with our results in patients who had RV diastolic dysfunction. Almost all patients who developed right ventricular dysfunction have elevated central venous pressure, prolonged ICU stay and prolonged inotropic supports. ***Phil Heart Center J 2007;13(2):124-129.***

Key Words: Congenital Heart Disease ■Tetralogy of Fallot ■ Echocardiography ■ Right Ventricle, Diastolic Dysfunction

Diastole is a period of ventricular relaxation incorporating periods of isovolumetric relaxation and early and late diastolic filling. Impaired diastolic function with relative preservation of systolic function is an early feature of right and left ventricular disease.

The literature has shown that there is a development of right ventricular dysfunction in some patients after the total repair of tetralogy of fallot. Right ventricular diastolic function has been recently observed to show signs of impairment with a diverse behavior in different phases of the postoperative follow-up. The incidence of right diastolic dysfunction in literature after TOF repair ranges from 28 to 52%.[6]

In the study of Cardoso et al, restrictive right ventricular physiology was detected on the follow-up of most patients who underwent repair of tetralogy of Fallot.[8] A significant number of their patients(63.3%) with restrictive physiology had a longer post-operative period, a longer duration of QRS complex, and a lower E/A ratio in inspiration.

In our institution, there were some of patients who underwent TOF repair had a complicated post-operative course. In order to give optimal patient management perioperatively, we would like to objectively assess the right ventricular diastolic function after Tetralogy of Fallot repair. This can be of clinical use and can provide accurate prognostic information.

This study was conducted to identify right ventricular diastolic dysfunction in early postoperative phase of tetralogy of fallot and to correlate it with the type of

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surgical procedure and clinical parameters.

Methods

This was a prospective cohort study involving children less than 19 y/o that underwent TOF correction from May to November 2006. TOF patients with pulmonary arteries are confluent and good sized (Mcgoons: >/= 1.5) and with good RV and LV systolic function were included. Exclusion Criteria are as follows: presence of pulmonary valve atresia with ventricular septal defect (VSD), double-outlet right ventricle (DORV), associated complex congenital heart disease such as TOF with atrio-ventricular septal defect (AVSD), TOF with absent pulmonic valve, Coronary abnormalities, Malposition of great arteries, Genetic abnormalities(Down's Syndrome), and Cardiomyopathy.

Selected patients were identified and informed consent was obtained from all the parents. Clinical data was taken from their medical chart. We also recorded the age, sex, oxygen saturation, pertinent pre-operative ECG finding, surgical technique used for TOF correction, bypass time, central venous pressure, ICU stay and duration of inotropic support. These clinical parameters were recorded to correlate with the RV diastolic indices of the patients.

Echocardiogram was done at Non-invasive Cardiovascular Medicine Division of Philippine Heart Center from May 2006- November 2006. Detailed echocardiogram, which was done after a week or more postoperatively (when the patient was discharged from ICU), was obtained by one adult echo technologist who is well-trained in diastology. After doing the echocardiogram, patients were group into two:

Group 1 – Good Outcome (those who have normal right ventricular diastolic function indices post-operatively)

Group 2- Poor Outcome (those who have abnormal right ventricular diastolic function indices post-operatively)

The ICU stay and prolonged inotropic support was not used as a basis of good and poor outcome because patients were managed by different doctors.

Echocardiography

Transthoracic echocardiography was performed with an Acuson machine using 3.5 MHz transducer. Spectral Doppler recordings were obtained from the pulmonary artery (PA), Tricuspid valve, and Superior Venue Cavae inflow. These are the following techniques to measure Right Ventricular Diastolic Indices (by pulsed doppler study using apical four-chamber view):

1. Tricuspid Peak E velocity – a peak velocity during rapid right ventricular early filling; by using a pulse wave Doppler, place the cursor just below the tricuspid valves opening and when the E wave and A wave are identified, we can measure the peak E velocity by measuring the height of the E wave.
2. Tricuspid Peak A velocity – a peak velocity during rapid right ventricular late filling; by using a pulse wave Doppler, place the cursor just below the tricuspid valves opening and when the E wave and A wave are identified, we can measure the peak A velocity by measuring the height of the A wave.
3. E/A ratio- ratio of the Peak E velocity and Peak A velocity
4. Right Ventricular Isovolumic relaxation time- can be measured from the pulmonic closing component of the second heart sound to the onset of flow on the tricuspid Doppler tracings.
5. Deceleration Time can be measured as the slope of a straight line drawn from the peak E velocity to the point where peak E decreases by half of the descending limb of the early diastolic inflow. Ten tricuspid peak E wave velocities (inspiratory and expiratory) were recorded in every study and we got the average and compared it with the normal.

Other RV diastolic indices

1. Superior vena cavae velocity can be recorded from the suprasternal notch or subcostal positions. From the suprasternal position, forward flow in the superior vena cava is directed away from the transducer. (Suprasternal approach was used in our study). Normal superior vena caval flow is characterized by three distinct waveforms. The largest waveform is the S wave, which represents forward flow in the superior vena cava caused by relaxation of the right atrium and descent of the tricuspid annulus during right ventricular systole. The D wave, a second forward flow, occurs during rapid ventricular filling when the tricuspid valve opens. A third waveform is the A wave represents the reverse flow associated with right atrial contraction.
2. Diastolic Pulmonary Artery forward flow can be investigated by pulsed-wave doppler using parasternal short axis view. Velocities of PA systolic and diastolic forward flow were measured. Diastolic pulmonary artery forward flow is a premature opening of the pulmonic valve. It is believed to occur when RV diastolic pressure equals or exceeds diastolic pulmonary artery pressure. Recordings were made with simultaneous ECG, phonocardiogram, and a respiratory tracing. All patients were in sinus rhythm and without inotropic support during the doppler recordings.

Results

There were 10 patients included in the study. The age of the patients in the study is 9.78 +/- 5.3 years old (Table 1) Four patients were above 10 years old and the rest were below 10 years old. Among the ten, 6 were male and 4 were female. The ECG findings of these patients showed that those with prolonged PR interval and ST depression on right chest leads were ages 12 years old and above.

And those below 10 years old did not have prolonged PR or ST depression. Those patients with ST depression on ECG also have oxygen saturation of 85% and below. These same group of patients have increased hematocrit (>/= 0.58) as compared to those below 10 years old.

Table 1. Pre-operative clinical data of TOF patients included in the study.

Patient	Age/Sex	CLINICAL FINDINGS		
		O2 Sat	Hematocrit	ECG findings
1	3 / M	92%	0.50	(-) ST depression on R chest leads
2	9 / M	83%	0.52	(-) ST depression on R chest leads
3	12 / M	74%	0.60	PR: prolonged
4	5 / F	88%	0.59	(-) ST depression on R chest leads
5	15 / F	83%	0.58	(+) ST depression on R chest leads
6	16 / M	76%	0.74	(+) ST depression on R chest leads
7	9 / M	89%	0.56	(-) ST depression on R chest leads
8	3 / F	88 %	0.50	(-) ST depression on R chest leads
9	16 / M	85%	0.63	(+) ST depression on R chest leads
10	5 / F	87%	0.52	(-) ST depression on R chest leads

The operative and post-operative characteristics of the patients are presented in Table 2. There were seven patients who had VSD closure with RVOT patching while the remaining three patients had VSD closure with infundibulectomy. Five patients had a bypass time of 1'30" or more while the remaining had a bypass time of <1'30." Perioperatively, among the ten patients, six of them have elevated central venous pressure. Three of these patients with elevated CVP were above 10 years of age. Six patients stayed in the ICU more than seven days while the remaining four stayed in the ICU less than seven days.

Table 3.1 showed the statistical analysis done on each of the echocardiographic parameters of the patients. These standard Normal Values was done by Snider. All the above RV diastolic indices measured from the patients have a significant difference as compared to normal values (P value < 0.05) except to E wave velocity of tricuspid inflow during inspiration. This means that most of the patients developed RV diastolic dysfunction in early postoperative period.

Table 2. Operative and Post-Operative Characteristics of Included Patients

Patients	Surgical Procedure	Bypass time	Central Venous Pressure	ICU stay	Duration of Inotropic Supports
1	VSD patch closure w/ savage; transannular patching with pericardium and monocusp	1' 50"	13 mmHg	18 days	15 days
2	VSD patch closure, Infundibulectomy and MPA patching	1' 51"	14 mmHg	7 days	3 days
3	VSD patch closure and RVOT patching	2" 11'	13 mmHg	11 days	8 days
4	VSD patch closure and Infundibulectomy	1" 16'	10 mmHg	6 days	4 days
5	VSD closure and RVOT patching	1" 50'	15 mmHg	10 days	9 days
6	VSD patch closure and RVOT patching	1' 45"	9 mmHg	9 days	7 days
7	VSD patch closure and RVOT patching	1' 20"	8 mmHg	6 days	5 days
8	VSD closure and RVOT patching	1' 10"	9 mmHg	5 days	4 days
9	VSD patch closure and RVOT patching	1'01"	19 mmHg	9 days	9 days
10	VSD closure and Infundibulectomy	1" 40'	8 mmHg	5 days	4 days

Table 3. Post-operative Right Ventricular Diastolic Indices by Doppler Echocardiography

Patient	1	2	3	4	5	6	7	8	9	10
Tricuspid inflow E wave (inspiration)	0.584	0.924	0.64	1.06	0.574	0.413	0.67	0.94	0.59	0.83
Tricuspid inflow E wave (expiration)	0.924	0.826	0.528	0.99	0.565	0.407	0.58	0.854	0.442	0.66
E/A ratio	0.596	0.832	0.45	3.87	0.843	1.387	1.09	2.2	0.81	1.4
Tricuspid deceleration time	0.239	0.239	0.218	0.143	0.266	0.160	0.201	0.167	0.253	0.14
SVC										
S	0.42	0.27	0.25	0.54	0.20	0.28	0.64	0.27	0.57	0.15
D	0.73	0.26	0.15	0.18	0.34	0.25	0.75	0.53	1.17	0.63
A	0.112	0.120	0.080	0.10	0.088	0.191	0.116	0.140	0.112	0.072
IVRT	112	96	56	80	104	80	88	104	128	72
DPAFF	(-)	(-)	(-)	(-)	(-)	(+)	(-)	(-)	(+)	(-)

SVC = Superior venae cava velocity S,
D, A= Superior Vena Cava waveforms
IVRT = Isovolumic Relaxation Time
DPAFF = Diastolic Pulmonary Artery Forward Flow

Table 3.1. Doppler Echocardiography of Patients After TOF repair

PARAMETER	OBSERVED (PATIENTS) Mean +/- SD	NORMAL VALUE	P VALUE
E WAVE (Inspiration)	0.722 +/- 0.204	0.62 +/- 0.13	NS
E WAVE (Expiration)	0.628 +/- 0.202	0.49 +/- 0.12	0.031
E/A ratio	1.351 +/- 1.021	2.56 +/- 1.29	0.000
Isovolumic Relaxation Time	89.78 +/- 21.08	55 +/- 10	0.000
Deceleration Time	0.208 +/- 0.055	0.14 +/- 0.02	0.000
SVC			
S	0.305 +/- 0.118	0.532 +/- 0.097	0.000
D	0.383 +/- 0.194	0.337 +/- 0.086	0.453
R	0.115 +/- 0.035	0.337 +/- 0.86	0.000

Note: Refer to Normal Values on Table 3.1. All the results of RV diastolic indices of these 3 patients were normal or almost near the normal values. This means that they did not develop Right Ventricular Diastolic Dysfunction.

Table 3.2. Group II Bad Outcome (No RV Diastolic Dysfunction)

Group II	E wave(exp)	E/A	IVRT	DT	SVC S	SVC D	SVC R
Patient							
1	0.427	0.596	80	0.239	0.42	0.73	0.112
2	0.826	0.832	96	0.297	0.27	0.26	0.120
3	0.528	0.45	56	0.218	0.25	0.15	0.80
5	0.565	0.843	104	0.266	0.20	0.34	0.088
6	0.407	1.387	80	0.160	0.28	0.25	0.191
7	0.576	1.088	88	0.201	0.42	0.43	0.112
9	0.442	0.81	128	0.253	0.25	0.33	0.136

Note: Refer to Normal Values on Table 3.1. All the patients in this group have abnormal RV diastolic indices. This means that they developed Right Ventricular Diastolic Dysfunction.

Discussion

Surgical repair of tetralogy of fallot in our center (Philippine Heart Center) has markedly improved and our concern now is to decrease the early and late morbidity of TOF repair. There are many studies done by different regarding right ventricular diastolic function in TOF by showing diverse results. We therefore want to present the results and outcome of our surgical repair of tetralogy of fallot.

Clinical Characteristics

Demographic data was presented in Table 1. It showed that those patients' ages 12 years old and above (4 out of 10) manifested ischemic changes in preoperative ECG, most likely secondary to prolonged hypoxemia and chronic pressure overload. These same patients have an oxygen saturation below 85% and increased in hematocrit (>0.56) as compared with those below 12 years old with oxygen saturation of above 85% and hematocrit of below 0.56. With regards to our operative and perioperative characteristics of the TOF patients, there was no correlation between the surgical technique done and the development of RV diastolic dysfunction after repair. In the study of Gunnar et al (9), transannular patching (TAP) or without transannular patching of RVOT can have restrictive RV physiology. Similarly, our results showed that not all who underwent TAP (7 out of 10 patients) had RV diastolic dysfunction or restrictive RV physiology Five

patients have a cardiopulmonary bypass time of > 1' 30" and the rest were less than 1' 30". Correlating the bypass time with the RV diastolic indices of the respective patients, there is no significant correlation between the bypass time and development of RV diastolic dysfunction after TOF repair. There was a patient with shorter bypass time (patient 9 with bypass time of 1' 01") and still developed RV diastolic dysfunction. And some of the patients with prolonged bypass time didn't developed RV diastolic dysfunction. (Table 2)

Echocardiographic Findings (Table 3 – 3.1, 3.2)

We grouped the patients into two groups. The group 1 has a good outcome which means that there was no development of RV diastolic dysfunction after TOF repair, while group 2 has a bad outcome which means that there was a development of RV diastolic dysfunction after the surgical procedure (Table 3.2).

Following our criteria in grouping the patients, we compared the RV diastolic indices of each patient with the standard normal value by Snider (2). Those with good outcome were patient 4, 8 and 10. These three patients were ages 3 to 5 years old, with good oxygen saturation of 87-88% and no ischemic changes on ECG (Table 1). This indicates that age at the time of surgery , oxygen saturation and ECG findings are good preoperative clinical parameters that can predict the outcome of the TOF correction. These group of patients also have normal central venous pressure perioperatively, shorter ICU stay (5-6 days) and shorter duration of inotropic supports (4 days) (Table 2).

There was an exception in one patient (Patient 1) aged 3 years old who still developed RV diastolic dysfunction. This is probably because the patient underwent TOF correction with transannular patching and monocusp and therefore the bypass time was prolonged. There are no other clinical findings that can contribute to the development of RV diastolic dysfunction. The patient had good oxygen saturation (92%) prior to surgery; with no signs of ischemic changes on ECG and no increased in hematocrit. Patient 1 had also elevated central venous pressure perioperatively. The ICU stay and duration of inotropic supports of this patient were prolonged.

Those with bad outcome (w/ RV diastolic dysfunction after TOF correction) were patient 1,2,3, 5,6, 7 and 9(Table 3-3.2). Patient 1 was discussed above, then patient 3, 5, 6 and 9 were aged 12 years old up to 16 years old. These four patients have signs of ischemic changes on ECG prior to surgery and with increased hematocrit (>/= 0.58) (Table 1). Perioperatively, they have elevated central venous pressure (> 12 mmHg), prolonged ICU stay (>/= 9 days) and prolonged inotropic supports (>/= 7 days) (Table 2). Other patients who developed RV diastolic dysfunction after TOF repair were patient 2 and 7. Both of them were 9 years of age but they didn't have ischemic changes on ECG. Patient 2 had an oxygen saturation of 83%. This could be one of the factors for the development of RV diastolic dysfunction, a prolonged ischemia other than an older age prior to surgery (9 years old). Patient 7 had a good oxygen saturation of 89% but age prior to surgery was his risk factor (9 years old).

Among those who developed RV diastolic dysfunction, there were two patients (Patient 6 and 9) who had restrictive physiology on doppler study. They have diastolic pulmonary artery forward flow on echocardiogram post-operatively. Both patients were 16 years of age. The mechanism of the diastolic pulmonary artery forward flow is speculated to occur when the RV pressure equals or exceeds the diastolic PA pressure. The right ventricle appeared to be fairly non-compliant or non-distensible in these patients probably because of the chronic myocardial hypertrophy or pressure overload. These decreased RV compliance and increased RV diastolic volume (after surgery) created diastolic forward flow.[10]

Conclusion

We therefore conclude that right ventricular diastolic dysfunction can develop in early post-operative period after TOF correction. The RV diastolic indices such as Tricuspid E wave velocity, Tricuspid E/A ratio, deceleration time, isovolumic relaxation time and Superior Vena Cavae Velocities are good parameters to determine the RV diastolic dysfunction. Age prior to surgery, ECG findings, and O2 saturation are good predictors of outcome of TOF correction. Surgical technique and duration of bypass time did not show significant correlation with our results in patients who had RV diastolic dysfunction. Almost all patients who developed right ventricular dysfunction have elevated central venous pressure, prolonged ICU stay and prolonged inotropic supports.

Recommendation

We recommend to further study on the preoperative echocardiographic assessment of RV diastolic function in all tetralogy of fallot and correlate with the post-operative echocardiographic findings.

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