VOLUME-7, ISSUE-1, JANUARY-2018 • PRINT ISSN No 2277 - 8160

Original Research Paper | Paediatrics

FUNCTIONAL ECHOCARDIOGRAPHY IN CRITICALLY ILL CHILDREN

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ABSTRACT The purpose of this study was to evaluate the cardiac functions by bedside 2D Echocardiogram/Color Doppler in critically ill children. Design: Descriptive, observational, prospective case control study. Setting: Tertiary care Children's Hospital. Methods: 83/100critically ill PICU children who fulfilled the study criteria were included. Initial Echocardiogram was done within 48 hours of admission and repeat echocardiograms if necessary. Cardiac dimensions, functions and cardiac output were assessed by standard methods and compared to Pediatric norms for age and Body Surface area (BSA). Volume status was assessed by inferior venacaval (IVC) collapsing index (IVC-CI) and IVC distensibility index (IVC-DI). Results: LV systolic functions were normal in (n=62/83; 74.7%) patients, dysfunction in (n=16/83; 19.27%), hyper contractile in (n=5/83; 6.0 %). Left ventricular hypertrophy (LVH) was noted in 22.9% and high LVMI was noted in children with abnormal renal profile, hypertension and hypocalcaemia [p<0.05]. LV systolic dysfunction was significant in sepsis group patients (32.5%) [p=0.0063] and those who had a PICU stay more than 10 days duration [p=0.013]. Total number of mortality during study period was ten (12%) and transferred out from PICU were 73 patients (87.9%). Conclusion: Cardiac dysfunction more prevalent in sepsis group patients and those required prolonged ventilation. Evaluation of Cardiac functions and volume status by functional echocardiography helps to tailor fluids and inotropes timely and support hemodynamics in critically ill children.

KEYWORDS : Bed-side point of care, 2D Echocardiography, PICU, critically ill.

Functional Echocardiography in critically ill children

Critically ill children need accurate assessment and monitoring of various organ functions so as to reduce morbidity and mortality[1,2]. Functional Echocardiography is emerging as a standard non-invasive modality to detect cardiac dysfunction early and at the bedside point –of –care. It has also shown to have a significant impact on medical decision-making in adult ICU[3,4]. The purpose of study was to evaluate the cardiac functions by functional 2 D Echocardiogram/Color Doppler.

Materials and Methods

Aims and objectives:

1. To estimate the cardiac functions by bedside 2 D Echocardiogram/ Color Doppler and to evaluate factors affecting the outcome.

The study was conducted from February 2012 to October 2012. 100 patients admitted in PICU were selected for the study of which 83 children fulfilled the study criteria

Inclusion criteria-

1. All children admitted in the PICU.

Exclusion criteria-

1. Neonates < 28 days old.
2. Those with Congenital Heart diseases (CHD).
3. Those with acquired heart diseases.
4. Post-operative patients

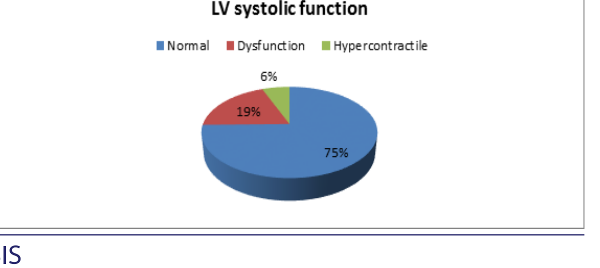
Initial functional Echocardiogram was done within 48 hours of admission into PICU by a trained Pediatric cardiologist and repeat functional echocardiograms done in patients having ventricular dysfunction and/or when the child was not improving. LV systolic functions was assessed by ejection fraction (EF), fractional shortening (FS) by noting the left ventricular end diastolic dimension (LVIDd), left ventricular end systolic dimension (LVIDs). LV diastolic function was studied by Doppler imaging by noting the mitral inflow (MV) tracing such as MV E velocity and MV A velocity and MV E/A ratio and pulmonary venous tracings (PV) such as PV S (systolic) velocity, PV D (diastolic) velocity and S/D ratio[5,6,7]. Left-ventricular mass (LVM) was calculated using the Devereux formula[8] and LVM index (LVMI) was calculated by dividing LVM by Body surface area (BSA) to minimize effects of age, gender, and weight status. Right Ventricle function was assessed by tricuspid annular plane systolic excursion (TAPSE), RV area in diastole and RV fractional area changes (FAC). CO-index was calculated by dividing the CO by body surface area (BSA)[9]. Volume status was assessed by inferior vena cava (IVC) collapsing index (IVC-CI) and IVC distensibility index (IVC-DI). IVC-DI value exceeding 18% predict fluid responsiveness in mechanically ventilated patients[10]. IVC-CI with greater than 55% collapsibility is indicative of hypovolemia in spontaneous breathing patient[11]. All measured values obtained were compared to standard Pediatric Echocardiographic values available in literature and remaining with adult norms.[12,13,14,15,16]

Treatment strategies: The study children were managed as per standard treatment protocol of PICU. Myocardial functions and fluid status evaluated by functional 2D echocardiography were followed by necessary interventions. Follow up functional 2D Echocardiography was done in those who had LV systolic dysfunction on initial evaluation or if there was a deterioration of hemodynamic status or the child needed change in inotropes.

Outcome: Outcome in study was noted as transfer out from PICU or death.

Statistical analysis: Descriptive statistics of continuous variables were expressed as means and standard deviation. Discrete variables were presented as frequencies and group percentage. All continuous variables were tested for normal distribution by D'Agostino-Pearson normality test. Categorical data were tested using the chi-square test. All statistical tests were 2-tailed, and a p value of <0.05 was considered statistically significant. Data were analysed using SPSS 17.0 software for Windows.

Graph.1 : Number of patients with Normal and abnormal LV systolic function.



Graph.2: Distribution of diastolic function.

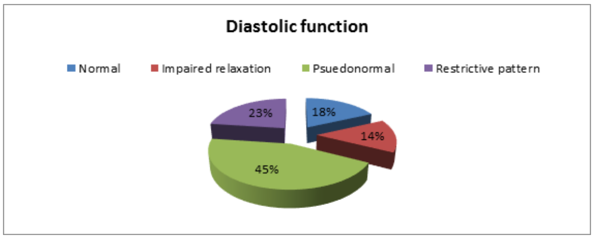


Table 1: Statistics of various variables among the cases

variables	Number	Mean	SD	Mini	Max
Age(months)	83	50.89	52.16	1.50	168.00
BSA (M2)	83	0.59	0.32	0.17	1.50
LVIDd (cm)	83	2.78	0.97	1.01	5.10
LVIDs(cm)	83	1.84	0.73	0.60	4.10
FS	83	0.33	0.08	0.14	0.54
EF	83	0.63	0.12	0.26	0.86
LV mass/BSA(LVMI)	83	60.87	41.94	15.00	219.74
E-velocity(m/s)	83	0.86	0.21	0.46	1.32
A-velocity(m/s)	83	0.70	0.23	0.30	1.25
E/A ratio	83	1.33	0.42	0.60	2.30
S/D ratio	83	1.18	0.34	0.60	2.41
RV area D(cm2)	83	10.66	5.96	2.10	35.60
FAC	83	0.29	0.16	0.05	0.92
TAPSE(cm)	83	1.51	0.41	0.20	2.40
LV CO-index	83	4.01	2.19	0.32	11.41
RV CO- index	83	4.55	3.00	0.71	17.74
IVC-CI	83	0.42	0.19	0.05	0.80
IVC-DI	83	0.97	0.81	0.05	4.00

Results: Normal Echocardiography in first evaluation was found in (n=7/83; 8.4%) and abnormal functional Echocardiography (including systolic and diastolic dysfunction) in (n=76/83; 91.5%). Left ventricular dilatation was noted in 5 patients (6.0%). The mean LVIDd was 2.78±0.97 cm (1.01cm to 5.10cm)[Table.1]. Left ventricular hypertrophy (LVH)-was found in (n=19; 22.9%) patients, mean LVMI was 60.82gm/m^2 (15.00 to 219.24gm/m^2)[Table.1]. When FS and /or EF values higher than normal was considered to have hyper contractile heart and below normal as LV dysfunction. LV systolic functions were normal in (n=62/83; 74.7%) patients, dysfunction in (n=16/83; 19.27%), hyper contractile in (n=5/83; 6.0 %)[graph 1]. In the study diastolic function was abnormal in (n=68/83; 81.9%) patients and in abnormal diastolic function impaired relaxation was found in 14.46%, pseudo normalization in 44.58% and restrictive pattern in 22.89% [graph 2]. Right ventricle (RV) functions- was considered abnormal if tricuspid annular plane systolic excursion (TAPSE) was low or RV area in diastole was increased or RV fractional area changes (FAC) were decreased /increased[13,14,15]. The mean TAPSE value was 4.01±3 mm (0.32 to 11.41 mm). Low TAPSE was found in (n=8/83; 9.6%), mean RV volume in diastole was 10.66 ±5.96 cm^2(2.1 to 35.60 cm^2). Increased RV volume in diastole was found in (n=15/83; 18.1%), mean FAC was 0.29±0.16 (0.05 to 0.92) decreased FAC was found in (n=50/83; 60.2%), while increased FAC was present in (n=3/82; 3.6%). In the study abnormal RV function was prevalent in (n=57/83; 68.7%).

Cardiac (CO) index- CO-index is defined as CO divided by body surface area (BSA), and normal values ranges from (3.5–5.5 l/min/m^2) regardless of patient age and size[16]. In the study mean LVCO-index was 4.01±2.19 l/min/m^2 (0.32 to 11.41 l/min/m^2) and RVCO-index mean was 4.55±3l/min/m^2 (0.17 to 17.74 l/min/m^2) [Table.1]. In the study low LVCO-index was found in (n=38/83; 45.0%) patients, and high in (n=18/83; 21.7%). RVCO-index was low in (n=38/83; 45.0%), and high in (n=22/83; 26.5%). LV -CO index was low in (n=6/11; 54.5%) of hypotensive patients, in (n=26/57; 45.6%) of normotensive patients, and in (n=7/15; 46.6%) of hypertensive patients while high LV CO-index was found in (n=1/11;9.09%) of hypotensive patients, in (n=15/57; 26.36%) of normotensive patients, and in (n=2/15; 13.3%) of hypertensive patients[p=0.618].

High LV CO-index was noted in 18 patients and (n=12/18; 66.7%) of these patients had Hb below 10gm%.

Assessing volume status based on Inferior vena caval (IVC) collapsibility-IVC collapsibility noted in IVC collapsibility index (IVC-CI) and IVC distensibility index (IVC-DI).The mean IVC-CI was 42±19 % (5to 80%) and IVC-DI was 97±81% (5 to 400%) [Table.1]. The IVC-CI more than 55% was found in 22/83 patients (26.5%) and IVC-DI more than 18 % in 76/83 patients (91.6%).

Table.2: Association between LV mass/BSA(LVMI) and BUN, Creatinine, hypertension and number of inotropes .

Parameter	variables	LV mass/BSA(LVMI)		P-value (chi-square test)
		increased	Normal	
BUN	Increased	10	10	0.00093
	Normal	9	54	
Creatinine	Increased	14	18	0.00034
	Normal	5	46	
Hypertension	Yes	7	8	0.015
	No	12	56	
Calcium	Hypocalcaemia	10	12	0.0033
	Normal	9	52	

Table.3: Association variables with LV diastolic function (P value significant at <0.05).

Parameter	Variables	Diastolic function				P-value
		Pseudo normal	Restrictive pattern	Impaired relaxation	Normal	
LV systolic function	Dysfunction	6	2	3	5	0.089
	Hyper contractile	1	1	0	3	
	Normal	30	16	9	7	
LV systolic function	Abnormal	13			8	**0.0058**
	Normal	55			7	
RV function	Abnormal	27	13	8	9	0.834
	Normal	10	6	4	6	
MODS	Yes	19	11	5	10	0.588
	No	18	8	7	5	
Diagnosis	Sepsis	18	10	6	6	0.903
	Non Sepsis	19	9	6	9	
Sr.Calcium level	Hypocalcaemia	8	5	5	4	0.600
	normal	29	14	7	11	
Electrolyte	Abnormal	4	8	2	3	0.053
	Normal	33	11	10	12	

Follow up echocardiography: was done before transfer to ward. Echocardiography was normal in (n=69/74; 93.2%) patients and (n=5/74; 6.7%) patients still showed mild systolic dysfunction.

Discussion: In the study, significant proportion of patients with high creatinine or high BUN had LVH (n=14/32; 43.8%) [**p=0.00034**] and [**p=0.0093**] respectively [table 2]. Hypocalcaemia patients had significant LVH (n=10/22; 45.5%) [**p=0.0033**] and hypertensive patients had higher prevalence of LVH (n=7/15; 46.7%)[**p=0.015**][table2]. Thus significant LVH correlated with high BUN, high creatinine and hypertension is consistent with study by " MarkMitsnefes et al[18] and other Pediatric and adult studies. In the present study significant LV hypertrophy represents compensatory chronic changes made by heart due to chronic kidney disease and chronic hypertension [**p=0.037**]. However more studies would be necessary to correlate acute cardiac changes with hypertrophy and hyper contractile heart with LVMI.

LV systolic dysfunction was noted more commonly in patients with sepsis (n=13/40; 32.5%) as compared to non-sepsis patients (n=3/43; 6.9%)[**p=0.0063**] this finding is consistent with study by "MichaMaeder et al"[19]. In a study byVieillard-Baron et al[20] LV dysfunction in sepsis was 18% on day 1 while in another study by Etchecopar-Chevreuil et al[21] it was 46% these are consistent with the present study. 47.1% (n=8/17) of children with LV systolic dysfunction need more than 10 days of PICU stay. Tailoring of inotropes and adjustments of fluids can be easily done on quantification of LV function[22,23].

LV diastolic dysfunction was found in 88.7% (n=55/62) patients with preserved LV systolic function as compared to abnormal LV systolic function with LV diastolic dysfunction (n=13/21; 61.9%)[**p=0.0058**]. No such correlation was found in literature between LV systolic dysfunction and diastolic dysfunction. There are increasing evidence in literature on importance of diastolic dysfunction in adults though not much studies are done in children. Diastolic dysfunctions precedes systolic heart failure and are always due to minor hemodynamics disturbances and are generally correctable by improving electrolyte and metabolic parameters like hypokalemia, hypocalcemia, acidosis and treating sepsis[5,24,25].

LV CO index was low in (n=11/26; 42.3%) patients with 2 organ dysfunction, In patients with 3 or 4 organ dysfunction low and high LV CO index was equally prevalent that is (n=4/9; 44.4%) patients each, while only a single (1/9) patient had a normal LV CO index. The only patient having 5 organ dysfunction had low LV CO index value 3.1L/min/m^2. This indicates increasing organ dysfunction is associated with abnormal LV CO-index [p=0.187]. Non-invasive CO measurements can be easily quantified by echocardiography and critically ill children especially in shock could be divided into low and high CO state. This assessment becomes more important in children with sepsis and timely interventions such as fluid or inotropes can be used to improve CO which would improve hemodynamics and survival.

Intervention was needed in (n=51/76; 67.1%) patients with IVC-DI >18% and (n=7/7; 100%) patients with IVC-DI <18% and Intervention in relation to ICV-CI was needed in (n=11/22; 50%) patients with IVC-CI >55% and in (n=47/61; 77.0%) patients with IVC-CI <55%[**p=0.035**]. Interventions were done in the form of intravenous fluid bolus/restriction or change in inotropes or blood product or intravenous furosemide. In the study by Michelle S et al[26] IVC-CI more than 55% in non-ventilated and IVC-DI more than 18% in ventilated patients predicted fluid responsiveness. Easily assessed and measured by echocardiography IVC collapsibility and distensibility is the true reflection of fluid status in non-ventilated and ventilated patients respectively. It helps in gauging the filling pressure so that timely interventions such as fluid bolus or restriction of fluid and /or use of inotropes could be timely instituted. Fluid resuscitation in septic shock with a positive fluid balance and elevated central venous pressure are associated with increased mortality[16].

Outcome- LV systolic dysfunction was in (n=16/83; 19.27%), and diastolic dysfunction was in (n=68/83; 81.9%) patients. Total death (12%; n=10/83) were noted and rest patients transferred out from PICU (71/83; 85%).

Conclusion

In Critically ill children

1. LV dysfunction was noted more in those with associated sepsis and on prolong ventilator support.
2. LV hypertrophy observed commonly in children with deranged renal function tests, hypertension and hypocalcaemia.
3. LV diastolic dysfunction is more common than systolic dysfunction.
4. Functional bedside Echocardiography in the PICU helps to assess cardiac dysfunction early and timely interventions definitely has a better outcome in these critically ill children.

Limitations of Study:

1. Limited sample size
2. Area of coverage was single center study.

Future research is required to further delineate and characterize the prevalence, frequency, and cardiovascular dysfunction in critically ill children. Future prospect study should be developed in cooperating large sample size and multi-centric study with appropriate methodology to capture the frequency and prevalence of cardiovascular dysfunction in critically ill children.

Abbreviations

TVI = Time velocity integral
MV A_{vmax} = Mitral valve atrial filling phase peak velocity
MV E_{vmax} = Mitral valve early filling phase peak velocity

MV E/A_{vmax} = Mitral valve ratio of early to atrial filling phase peak velocities

PV S = Peakantegrade pulmonary venous flow velocity during ventricularsystole

PV D velocity = Pulmonary valve peak anterograde diastolic (D) velocity,

PV S/D ratio = Mitral valve ratio of systolic (S) velocity to peak anterograde diastolic (D) velocity

SV =Stroke volume
CO = Cardiac output
LV =Left ventricle
RV =Right ventricle
LV CO- index =Left ventricle cardiac output index
RV CO-index = Right ventricle cardiac output indext
RVOT = Right ventricle outflow tract
LVOT =Left ventricle outflow tract
LVIDd =Left ventricle inner diameter in diastole
LVIDs = Left ventricle inner diameter in systole
IVC-CI = Inferior veinacaval collapsing index
IVC-DI = Inferior veinacavaldistensibility index
TAPSE = Tricuspid annular plane systolic excursion
FAC = Right ventricle fractional area changes
LVH = Left ventricle hypertrophy
LVMI = Left ventricle mass index
BSA = Body surface area

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