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Research Article

Normal Amount of Pericardial Fluid in Neonates, Infants and Children

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Abstract

Background: Pericardial effusion though rare is very important to diagnose and if severe like pericardial tamponade can cause impending death. In a healthy adult there is usually 15 - 50 ml of straw-coloured fluid. There is little data on the normal amount of pericardial fluid in neonates and children to serve as a reference. Measuring normal pericardial fluid in newborns and children is challenging and several formulae have been used to estimate the amount of fluid, but are not totally accurate.

Objectives and Design: A prospective study to measure the amount of pericardial fluid in infants. The study was conducted from February 2014 to September 2015.

Setting: Tertiary Care Maternity and Neonatal center, and Advanced Diagnostic and Research center, Bangalore.

Study Methodology: Neonates and children aged from a few hours after birth to 15 yrs who needed an echocardiogram for various reasons were prospectively studied. We used GE Vivid i and Vivid S5. Pericardial space dimension was measured in late diastole at the maximum point measurable posterior to LV and anterior to RV outflow tract. We measured mid LV-RV level pericardial and epicardial diameters in end diastole in the same axis. Cubing these diameters gives the pericardial and cardiac volumes and the difference is the volume of the pericardial fluid.

Results: We studied neonates and children total of 208, with newborns including gestational age ranging from 27 weeks to 40 weeks , infants and children till 15yrs. About 134 (64%) were in the age group less than 1 year and rest 74 (36%) were of 1 - 15 years age group. Average volume range for newborns to less than 1 year age group varied from 3 ml to 6.87 ml, and more than 1 year ranged from 8.5 ml to 37 ml. When weight was taken into consideration the volume per kg ranged from 1.5 ml per kg in newborns to 0.98 ml per kg in 10 - 15 years age group. None of them had significant cardiac lesions.

Conclusion: A semi quantitative method can be used to assess the amount of pericardial fluid in infants. Neonates have a higher amount of pericardial fluid per kilogram body weight compared to infants.

***Keywords:** Neonates; Infants; Children; Normal Pericardial Fluid; Pericardial Effusion*

Introduction

The normal amount of pericardial fluid present in the pericardial space around the heart has been mentioned in several sources of reference (See table 1) but no attention is paid to the fact that from neonates to adolescents there is a great variability in size and weight. Before the advent of echocardiography (ECHO) there was no way one could have estimated this in living children. Large amount of Pericardial effusion could be predicted by clinical examination like enlarged area of cardiac dullness with the apex beat well within it, muffled heart sounds, hypotension, raised venous pressure, paradoxical pulses or by chest X-ray showing water bottle appearance of the cardiac silhouette [1]. But issues of large pericardial tumours, excessive pericardial fat, or a huge thymic mass would have to be considered in the differential diagnosis. There was no accurate way of estimating this in live patients though, large amounts of pericardial effusion with signs of tamponade when pericardiocentesis was done, amount of fluid drawn out would be known. Even at postmortem studies pathologists would mention accumulated fluids in large serous cavities (like pleural and peritoneal cavities) but how could they measure the normal amount of pericardial fluid unless there was a significant effusion. Hence the numbers given by these various sources have to be arbitrary, not supported by experimental data.

Source	Age	Normal amount of Pericardial Fluid
Gray's Anatomy [2]	-	15 - 20 ml
Pathological Basis of Disease, Robbin [3]	Adult	30 - 50 ml
Comprehensive Text Book of Echocardiography, Nanda [4]	Adult	Echo Free space < 10 mm = Small effusion 10 - 20 mm = Mod Effusion > 20 mm = Large Effusion > 25 mm = Very large effusion
Heart Disease in Infants Children and Adolescents, Moss and Adams [5]	Adults and Child	20 - 30 ml in adults, considerably less in children
Ped Clin North Amer 1978, Gersony, Hordof [6]	Healthy Child	No more than 10 - 15 ml
Wilson E Sadoh., *et al*. [7]	Child	Mild up to 5 mm, Moderate- 5 - 10 mm, Severe > 10 mm
Randolf Martin., *et al*. [8]	-	Small- Mostly below AV Grove, Mod-More uniform distribution, Large- Apically, Posteromedially and Anteriorly
ASE Clinical Recommendation for multimodality CV imaging of patients with CV diseases- A consensus statement [9]	-	Posterior Echo free space. Trivial- seen only in systole, small < 10 mm, Moderate- 10 - 20 mm, Large > 20 mm, Very large > 25 mm

Table 1: *Normal amount of pericardial fluid.*

After the advent of echocardiography, one of the most useful applications of it was in detecting pericardial effusions, small or large. There may be some authenticity for estimates given by echocardiography by applying some mathematical formulas, but it is not absolute as this technique makes some assumptions and cannot account for the fluids in the crevices around the heart and great vessels, oblique sinus of the pericardium etc. Loculated effusions cannot be estimated by using these formulas [7-9,19-21].

Many echocardiographic estimates such as ejection fraction, fractional shortening, end diastolic volume (EDV), end systolic volume (ESV), stroke volume (SV), cardiac output (CO), and even the weight of the heart are estimated by echocardiography making several assumptions. These estimations are not necessarily equal to the absolute values. Some parameters can be verified by comparison with other more accurate methods using doppler echocardiography, CT, MRI Scan, but normal amount of pericardial fluid cannot be estimated by these techniques and they are expensive [10].

Invasive methods using cardiac catheterization [11] have been attempted in the past but not without risk. This at best is an indication of a large effusion and cannot estimate the amount. Perhaps it is not very critical to know the normal amount of pericardial fluid in children. But it is very crucial to recognize echocardiographic signs of tamponade when immediate action has to be taken. Tamponade does not depend only on the amount of fluid, but on various factors influencing intrapericardial pressure such as rapidity of effusion, pericardial stiffness or elasticity, intrathoracic pressure and cardiac chamber pressures [12,13].

Aim of the Study

The present study is aimed to measure the normal amount of pericardial fluid in infants and children echocardiographically. Even though this at best is a semi quantitative estimate, it is as close as we can be to the absolute value.

Materials and Methods

Neonates and children aged from a few hours after birth to 15 yrs who needed an echocardiogram for various reasons were prospectively studied with attention to the amount of pericardial fluid by the method described below from 11.02.2014 to 24.09.2015. When a clear line of echo free pericardial space was present around the heart an estimate was made. The pericardial space dimension was measured in late diastole at the maximum point measurable posterior to left ventricle (LV) and anterior to right ventricle (RV) out flow tract either in the PLAX view, apical or sub costal four chamber view whichever was optimal. same formula used for measuring ejection fraction [14] was used with the same mathematical assumptions made therein. The end systolic and end diastolic volumes are assumed to be equal to the cube of the end systolic and end diastolic diameters of M - mode of LV in PLAX view, at mid LV level, below the mitral valve but above the posterior papillary muscle. This is on the assumption that the long axis dimension of the LV is approximately equal to twice the short axis dimension of the LV, which may not always be true in children.

In the context of the pericardial volume study, the mid LV- RV level pericardial diameter and the epicardial diameter are measured in the same axis in end diastole. Cubing these diameters will give the pericardial volume and cardiac volume and the difference halved, is equal to the volume of the fluid in between. In case of Ejection fraction of LV, the shape of LV Cavity resembles a narrow prolate ellipse and in case of pericardial study the shape is a prolate ellipse but with a larger short axis diameter, the shape tending more towards a sphere than a narrow prolate ellipse (In the former it is a pear with chopped off top and in the latter a tender coconut with chopped off top see figure 1).

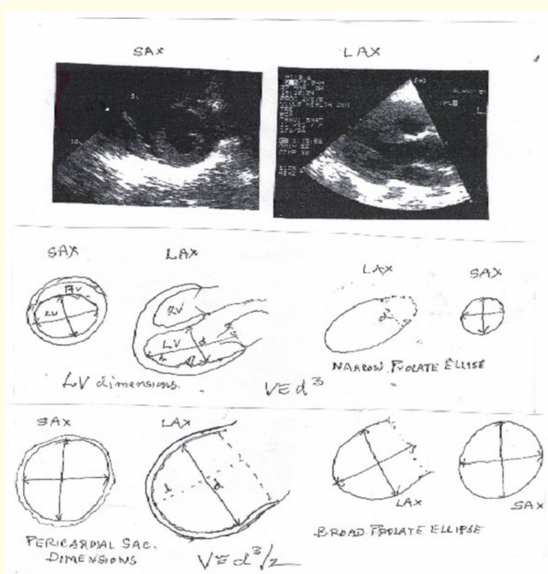

Figure 1: *Echo image and prolate ellipse pictures of heart and pericardial sac.*

In case of a narrow prolate ellipse with the length about twice the diameter the formula Volume = d^3 holds good. But in case of a broad prolate ellipse the formula has to be modified where the length is nearly equal to the diameter, the Volume = $d^3/2$ as shown below in table 2.

1. LV cavity resembles a *prolate ellipse* with a diameter d shorter than the length (approximately L=2 d). The following mathematical formula for the volume of a narrow prolate ellipse is used to calculate the volume of of LV in diastole and systole and there by the ejection fraction

$V = \pi \times 4/3 \times \frac{L}{2} \times d_1/2 \times d_2/2$, (L=Length,

$d_1\ d_2$ = diameters in short axis of the narrow prolate Ellipse shaped LV cavity where *it is asssumed* $d_1 = d_2 \quad \therefore L = 2d_1$

$$\therefore V = \pi \times \frac{4}{3} \text{ x } 2d_1/2 \text{ x } d_1/2 \text{ x } d_1/2$$

$$\therefore V = \pi \text{ x } \frac{4}{3} \text{ x } d^3/4 \text{ x } 2$$

$$\therefore V = \pi \text{ x } d^3/3 \text{ x} 2 = \pi/3 \text{ x } d^3/2$$

$(\pi = 22/7 = 3.14) \quad \pi/3 = 1.046)$

$$\therefore V \cong d^3 \text{x } 1.046$$

$$\therefore V \cong d^3 (ignoring\ 1.046)$$

Here d^3 is measured in end diastole and end systole gives the End Diastolic Volume (EDV) and End Systolic Volume (ESV) of LV. The difference gives the Stroke Volume (SV). Ejection Fraction (EF) = EDV- ESV/ EDV %. This is widely used as an index of LV Systolic Function by Echocardiography.

2. In this study the same principle is used with modification for the Volume of the Pericardial Sac (Vp) and that of the Heart (Vc). Vd- Vc = Vpf (Pericardial Fluid Volume) . But in this case the Pericardial Sac which includes the LV, RV, Atria and proximal roots of Aorta and Pulmonary artery with a diameter almost equal to the length, instead of a narrow prolate ellipse as in LV Cavity. Using the same formula $V = 4/3 \times \pi \times L/2 \times d_1/2 \times d_2/2$, (L=Length, $d_1\ d_2$ = diameters in short axis of the broad prolate ellipse shaped pericardial sac, tending towards a spherical shape where *it is asssumed* $d_1 = d_2\ (L = d_1\ \ say\ \ d1 = d2 = d)$

$$\therefore V = \pi \text{ x } 4/3 \text{ x } d/2 \text{ x } d/2 \text{ x } d/2 = \pi d^3/3 \text{ x } 2 \quad (\pi = 22/7 = 3.14)$$

$$\therefore V = \pi/3 \text{ x } d^3/2$$

$$\therefore V = 1.046\ d^3/2$$

Table 2: *Mathematical basis for pericardial volume estimation.*

Results

Total of 208 patients (Table 3) were studied over a period of 19 months in two institutions, one a tertiary care maternal and neonatal center (115), Bangalore and other a Diagnostic and Research Center (93). Standard Echocardiographic equipment (GE Vivid I, Acuson Sieman's 300) were used.

About 134 (64%) were in the age group less than 1 year and rest 74 (36%) were of 1 - 15 years age group (Table 4). Among newborns the most common reason for referral was foetal tachycardia followed by echogenic foci on prenatal echo, preterm infants with respiratory

Sl no	Age	Sex	Weight	Reason for ECHO	PE in ml	PE in ml/kg	Lesions on ECHO
1	2.5m	M	4.6	Murmur	8.78	1.9	PFO
2	5y	M	22	Murmur	52	2.36	PFO
3	8y	M	28	Chest Pain	50.5	1.8	Normal
4	2w	M	2.5	Murmur, Tachycardia	4.84	1.94	SVT 250/m
5	9m	M	8.4	ASD/VSD F/u	5.52	0.66	Normal
6	1y	F	9	Downs Syn to R/o CHD	4.38	0.48	Normal
7	2.5y	F	12	Tachycardia	11	0.92	Normal
8	13d	M	2.3	Pre-adoption	2.3	1	PFO
9	1.5m	M	4.5	Murmur	3.61	0.81	PFO
10	7.5y	F	34.5	Kawasaki F/u	43.42	1.26	Normal
11	4y	M	13	Murmur	21	1.61	Normal
12	5m	F	5.4	Echogenic Foci LV	9.52	1.76	Echogen Foci on MV Chordae
13	7y	M	21	Recurrent LRTI	23.87	1.14	Normal
14	3.5m	M	6.3	ASD/PFO F/u	8.44	1.34	PFO
15	4y	M	15	Murmur	7.70	0.5	Normal
16	8y	M	20	Seizures	17.5	0.87	Normal
17	17m	F	8.2	Arthralgia, Vasculitis	7.17	0.87	Normal
18	3.5y	F	17	Neonatal Seizures, CP	10.27	0.6	Normal
19	8y	M	23	Chest Pain	10.60	0.45	Normal
20	14 y	M	35	Chest Pain	38.12	1.09	Norml
21	3.25y	M	11	Murmur	6.44	0.58	Normal
22	16d	M	3.56	GDM	2.03	0.57	Normal
23	2m	F	3	Murmur	2.26	0.75	Musc VSD, PFO
24	2m	F	4.8	Murmur	3.34	0.69	ASD/PFO
25	7y	M	25	Chest Pain	12.5	0.50	Normal
26	20m	M	8.6	Murmur	3.09	0.36	RSOV AV dilaited
27	1y	F	8.5	PFO, RPA Stent F/u	9.47	1.11	IAS intact, RPA psg 12 mm
28	13m	M	7.6	Downs syn, murmur	9.23	1.21	PDA psg 62mm
29	1.5y	F	7.75	Murmur	4.55	0.59	Large ASD II, TR ps22
30	9y	F	28	Chest Pain	27.91	0.99	Normal
31	1m	F	3	Murmur	5.8	1.87	PFO, Pul Br Flow murmur
32	2y 4m	M	10.6	Murmur	6.85	0.64	Normal
33	20d	M	4.5	IDM	4.27	0.95	Normal
34	7w	F	3.7	Murmur	6.68	1.8	Echo-SVPS, PSG 22mm
35	5.5y	F	20	Lipodystrophy Synd	23.87	1.19	MVP+ MR+TVP+TR+ PG 30 Dil Aort Sinuses
36	1.3y	F	8	ASD II/PFO F/u	9.64	1.2	Tiny PFO L-R
37	9m	M	6.3	F/u PFO	6.04	0.96	Normal
38	9m	F	8.5	F/u Ap Mus VSD	8.52	1.00	Tiny Ap M VSD PG 59

39	22m	M	10	Breath holding spells	10.71	1.07	Normal
40	1y	M	9	Murmur	7.74	0.86	Normal
41	7m	M	8.9	Murmur	8.58	0.96	Normal
42	8m	M	9	Murmur	7.73	0.86	Normal
43	18d	F	2.5	IDM	3.0	1.2	PFO
44	6y	F	18.5	IDM	17.49	0.94	Normal
45	19m	F	9.6	Murmur	7.0	0.73	Normal
46	15d	M	3	Murmur	4.25	1.42	PDA LR psg 41 ASD II LR
47	8y	M	20	Chest Pain	17.35	0.87	Normal
48	6m	F	6	Syndactyly fingers	2.91	0.48	Normal
49	4y	F	14	Recurrent LRTI,	13.71	0.98	Normal
50	8d	F	2.5	Echogenic Foci LV in prenatal scan	1.33	0.53	Echogenic foci MV Chordae
51	7m	F	6.7	Murmur	6.77	1.01	Tiny Apical Muscular VSD
52	4.5m	F	6.2	Sibling had CoA. Echo genic Foci LV In prenatal scan	3.16	0.51	Echogen MV Chordae
53	9m	M	8.7	Echogenic Foci LV	7.33	0.84	Echogen Mitral chordae
54	4y	F	13	Murmur	13.51	1.04	Tiny Midmuscular VSD, PFO
55	4y	F	13	Murmur	8.88	0.68	Normal
56	10m	M	7.1	Murmur	7.53	1.06	Small ASD/PFO
57	4m	F	5.2	Murmur	5.59	1.07	Small ASD/PFO L-R
58	13y	M	60	Limb girdle muscular dystrophy to R/o cardiomyopathy	38.58	0.64	Normal
59	3y	F	12.7	Murmur	10.43	0.82	Normal
60	10y	M	24	Syncope	22.12	0.92	Mild PAH 30 TRmm, No CHD Wide Split S2. ECG normal
61	1.5m	M	2.8	Murmur	3.10	1.11	Small Musc VSD, Mild Aort St psg 37mm
62	3.5m	F	6.5	Murmur	4.22	0.65	Aort St psg 27mm
63	1.25m	F	4	Cyanotic spells with cough	5.10	1.29	Normal
64	2.75y	F	5	Murmur	5.42	1.06	ASD / PFO
65	7y	M	25	Murmur	23.37	0.92	Normal
66	1y	F	7.5	Murmur	9.15	1.22	Ao St psg 37
67	6y	F	21.4	Syncopal episodes	21.04	0.98	Normal
68	4y	F	11.8	VSD, AS F/u	10.64	0.90	Ao St Pg 58, No VSD
69	6m	F	5.7	Murmur	4.9	0.85	Normal
70	22m	F	8.5	Murmur	14.33	1.68	Large ASD2
71	2m	F	3.24	Murmur	2.91	0.90	Musc VSD psg 69
72	11y	M	28	Chest Pain	25.92	0.93	Normal
73	3y	F	14	Post op VSD	17.84	1.27	Echo Normal, VSD patch intact

74	4y	F	11	Kawasaki Disease	10.94	0.99	Normal
75	2.5y	F	13.5	Murmur	12.1	0.89	Normal
76	8.5y	F	30	Syncope	27.40	0.91	Normal
77	13y	F	24	Poor weigt gain, murmur	31.85	1.32	Normal
78	22m	F	6.6	ASD 2 F/u	6.90	1.04	ASD 2 L-R
79	6m	M	7.4	Echogenic foci preinatal scan	8.30	1.12	Echogenic Foci Mitral Chordee
80	4.75y	F	13	Palpitation	15.48	1.19	Normal
81	2m	M	4.2	Preadoption echo	4.63	1.1	Normal
82	13m	M	10	Persistent cough	9.49	0.95	Normal
83	5.5y	M	17	Murmur	15.86	0.93	Normal
84	13y	M	55	Palpitations	50.05	0.91	Normal
85	1m	M	4.3	Noisy breathing	5.44	1.26	Normal
86	3m	F	4	Birth asphyxia, seizures, stridor	7.78	1.94	Normal
87	4y	M	10.5	Precordial bulge	19.29	1.84	Normal
88	10m	M	8.3	Deformity fingers and toes to R/o CHD	7.41	0.89	Normal
89	45d	M	4	Murmur	5.95	1.43	Normal
90	18m	M	9.5	Murmur PDA F/u	13.90	1.46	Tiny PDA by CF
91	2y	M	9.5	F/u ASD/PFO	13.57	1.42	Normal
92	8wk	M	4.3	Stridor	7.29	1.69	Normal
93	5y	F	22.5	Chest pain	24.05	1.07	Normal
94	2H	M	2.24	Murmur, Echogenic Foci LV prenatal scan	6.5	2.9	PFO, PDA, Echogen Foci LV
95*	7d	M	2.24	F/u	8.7	3.63	PFO, PDA
96	6H	M	2.99	Murmur	7.70	2.57	PDA, PFO
97*	2d	M	2.99	Murmur	6.38	2.13	PDA, PFO
98	2d	F	2.76	Murmur	5.53	2.00	PDA, PFO
99	1d	F	1.25	Murmur	2.89	2.31	PDA, PFO
100	6d	M	3.6	Murmur	8.79	2.44	ASD, FPPS
101	2y	M	14.5	Murmur	10.89	0.75	Mild PS, PFO
102	12d	F	3.4	Murmur	7.85	2.3	PFO, RPA21mm LPA, 17 mm
103	1m	M	1.5	RDS on CPAP	4.15	2.76	PDA, PFO
104	4y	M	16	Recurrent LRTI	23.5	1.46	Normal
105	7m	F	7.6	Murmur	8.15	1.07	Normal
106	2H	M	3.2	Echogenic Foci LVin prenatal scan	5.52	1.73	PFO, PDA, Echgenic Foc iLV
107	2y	M	13.2	Murmur	32.33	2.45	Normal
108	5m	M	7	Echgenic Foci LV in prenatal scan	4.8	0.68	ASD/PFO, Echogeniv Foci MV chordae

109	33d	M	1.5	Recurrent Apnoea	1.32	0.88	HNOCM
110	20d	M	2.3	Murmur with LRTI	3.67	1.59	ASD/PFO
111	5.5m	F	6	F/u ASD, PDA	12.93	2.12	ASD, No PDA
112	2m	M	2	F/u HNOCM	4.04	1.98	HNOCM mainly IVSH
113	4H	F	1.66	Duodenal Atresia Preop to R/o CHD	3.66	2.20	PDA, PFO, CoA
114	5d	M	1.28	Mild RDS, tachycardia	1.13	0.88	Tachycardia Echo normal
115	1d	M	3	IDM	5.74	1.85	PDA, PFO, TR 53mm
116	3d	M	1.67	Duodenal Atresia Preop to R/O CHD	3.26	1.95	PFO
117	3d	F	2	IDM, Single Umbilical artery	2.68	1.31	ASD/PFO, PDA
118	6w	M	4.4	Murmur	3.87	0.88	ASD/PFO
119	18d	M	1.73	Postop Duodenal Atresia, Bradycardia	1.41	0.81	Normal
120	3d	F	1.49	Murmur	1.33	0.89	Large PDA LR
121	2d	M	2.9	Downs syn	2.23	0.77	Normal
122	16d	M	3.17	Cyanosis	3.01	0.95	Normal
123	9m	F	7.16	PFO, RPA Stenosis F/u	2.02	0.28	PFO L-R, RPA psg 23 mm
124	1.5m	M	3.4	VSD, PDA, PFO F/u	6.90	2.03	Perimembranous VSD, PFO
125	2.25m	M	1.9	To R/o CHD	0.43	0.23	PFO, Mild PAH
126	3d	M	1.67	Duodenal Atresia preop	3.26	1.95	Normal
127	1d	F	3.85	IDM	3.37	0.87	IVSH, RVH, PDA, PFO
128	3.5m	M	3.85	Murmur, poor feeding	5.30	1.38	Lge VSD, PSG 9 mm, PAH, Early decomp
129	2y	M	10.2	?Kawasaki	11.47	1.12	Normal
130	3.8y	F	14	Murmur, F/u ASD	6.58	0.47	Large ASD II, L-R, TR-PSG 26mm
131	6m	M	5.6	Murmur, F/u ASD Echogenic Foci LV	5.44	0.97	Echogenic MV chordae, No ASD
132	13d	F	1.64	Murmur	0.72	0.44	Perimembranous VSD, L-R, PSG-22mm, PFO L-R
133	3.5m	F	5.3	Cleft Lip-Palate Preop	2.93	0.55	Normal
134	4d	F	2.7	Murmur	3.04	1.12	PGO, RPA psg 15 FPPS
135	4.8y	M	16.3	Murmur	5.56	0.34	Normal
136	1d	M	3.34	Mild RDS	2.52	0.75	Echo: ASD/PFO, PDA LR 10 mm psg, TR 43 mm psg
137	6m	M	5.16	HCM F/u	5.54	1.07	Neonatal HCM, Resolving IVS/LVPW= 1.3
138	6d	M	1.32	Murmur	3.29	2.49	Large PDA, TR-32 mm, ASD/PFO

139	1d	M	1.89	Murmur	1.5	0.79	ASD/PFO, TR psg 43
140	4m	M	5.9	Murmur F/u VSD	4.44	0.75	Appical VSD, psg 57mm ASD/ PFO
141	4d	M	1.96	Mild RDS	1.20	0.61	ASD/PFO, Non comp Myo gr 1-2, No dysfn
142	20m	F	11	LRI, CXR PA seg increased	13.14	1.19	ASD II /PFO
143	1d	F	1.15	Meningomyelocele to R/o CHD	0.74	0.64	PDA, PFO L-R
144	6m	F	6.4	Murmur	3.24	0.50	ASD/PFO, Muscular VSD
145	1d	M	2.76	Mild RDS	2.55	0.92	DXP, ASD/PFO, PDA, TR 28mm
146	14.5m	M	11.9	Kawasaki F/u	8.06	0.68	f/u Kawasaki Dis Normal
147	4d	M	2.44	RDS on ventilator	3.17	1.30	ASD/PFO, Aneurysm LSOV no rupture
148	28m	F	10.3	Fever for 10d to R/o IE	10.65	1.03	Normal
149	3d	M	2.85	Murmur	2.74	0.96	Muscular VSD psg 42
150	3d	F	2.2	?Rt arch on X ray	2.50	1.14	ASD/PFO. Left Arch
151	3d	F	2	?Rt Arch on Fetal echo	2.49	1.24	ASD/PFO, Left Arch
152	1.25m	M	4.48	Murmur, Tachypnoea	6.12	1.37	VSD, psg 25 TR psg 64, LA / LV ++
153	4m	F	6	Preop Ano-Vulvar fistula	6.82	1.14	ASD/PFO L- R
154	7d	M	1.89	Skeletal Deformities to R/o CHD	2.24	1.19	ASD/PFO, PDA psg 22
155	6.5y	M	12.6	Chest pain, FTT	10.89	0.86	Normal
156	6.5m	F	7	ASD F/u	2.64	0.38	ASD 2 L R TR psg 26
157	1m	M	1.9	O2 dependent	2.31	1.22	ASD-2, L-R
158	6.5m	F	7.3	ASD, VSD F/u	7.45	1.02	Ap VSD psg 58, PFO
159	7d	F	2.44	Cleft Lip/Palate Preop	2.43	0.99	ASD/PFO
160	2.5m	M	5	VSD F/u	5.36	1.07	V Lge VSD, CCF PSG 65mm
161	1d	M	2.63	RDS	2.88	1.09	PFO, TR psg 14
162	3d	F	1.86	RDS	3.17	1.7	PDA L-R, TR 45m, ASD/PFO L-R
163	6w	M	3.64	Echogenic Foci Pre natal scan	4.86	1.33	Echogenic Foci MV, TV Chordae
164	9d	F	12.6	Seizures	2.56	0.97	ASD/PFO, PDA psg 24mm
165	7m	F	6	F/u ASD/PFO	8.06	1.32	Normal
166	2.75m	F	4.4	Fetal echo-VSD	4.48	1.02	Normal
167	13m	F	11.2	F/u ASD/PFO, Ds Ao psg 16mm	11.53	1.03	Normal
168	33d	M	1.64	Apnoeic Spells	2.27	1.38	PFO, TR 21mm

169	12d	M	1.24	Murmur, Tachycardia	1.60	1.29	Echo Lrge PDA, psg 23, TR psg 37, ASD/PFO L-R
170	12d	M	1.42	Bradycardia, Desaturation, murmur	2.03	1.43	Large PDA, psag 24, TR psg 36, ASD/PFO L-R
171	2d	F	2.14	RDS on CPAP, murmur	3.23	1.51	Large PDA psg 17, TR psg 39, ASD/PFO L-R
172	12d	M	2.2	Fetal Echo VSD F/u murmur	4.13	1.91	Perim VSD, psg 56mm no PAH, ASD/PFO L-R
173*	16d	M	1.4	Bradycardia, Desaturation, murmur	2.44	1.74	Large PDA psg 34 TR psg 24 Small PFP L-R
174	7.4m	M	7.8	Breath Holding Spells	7.19	0.92	Normal
175	2d	F	2	Previous Sibling died of CHD	2.39	1.16	Small ASD/PFO L-R
176	7y	M	22.6	Murmur, Recurrent LRTI	29.15	1.29	Normal
177	4d	M	2.26	Murmur, IDM	1.98	0.87	Supra TAPVC, Restr ASD, IVSH
178*	17d	M	1.3	Post op PDA ligation	3.50	2.69	No PDA, psg LPA 17 mm Small ASD/PFO
179	6y	F	17.6	Fatigue, Sleepines, Snoring	21.43	1.22	Normal
180	1d	F	2.99	Bradycardia	5.07	1.69	ASD/PFO
181	3m	F	4.2	ASD/PFO F/U ? Rt Ao Arch	9.80	2.34	Normal
182	3m	F	3.8	ASD?PFO F/U ?Rt Ao Arch	6.10	1.6	Normal
183	4.25y	1.56	15	ASD F/u	23.58	1.56	Large ASD 2, 1.2 cm, L-r Qp/Qs 2.27, TR pag 28mm
184	2d	1.49	1.95	RDS on CPAP, murmur	2.91	1.49	Small PFO
185	18d	0.89	1.24	IDM, murmur	1.11	0.89	PDA L-R pg 45, Tiny Muscular VSD, TR 17mm.
186	1d	0.76	2.97	IDM	2.26	0.76	PDA L- psg 45 TR sg 17, PFO L-R
187	25d	0.91	1.28	?DXC on Xray, Hypospadias	1.17	0.91	Levocardia, PFO
188	13h	2.04	2.76	TE Fistula, Preop	5.64	2.04	PDA psg 12, TR psg 69, PFO, LSVC to CS
189	7d	2.03	3.76	IDM	7.64	2.03	ASD/PFO, IVSH nonobstr, TR 16mm IVSH/PWD 1.75
190	3.25y	1.06	13	?Kawasaki Disease	13.79	1.06	Normal
191	1w	1.53	2.64	Post op TEF. LSVC to CS, PFO	4.04	1.53	LSVC-CS, PFO Contrast Study No CS to LA communication
192	2d	1.70	3.3	1 sibling died of CHD	5.59	1.70	Echogenic Foci MV/TV Chordae, ASD/PFO
193	1.5m	1.72	3	Preterm PDA F/u	5.35	1.72	Normal
194	1.5m	1.47	3.3	Preterm PDA F/u	4.84	1.47	Small ASD/PFO
195	1.5m	1.52	1.44	PDA on medications for F/u	2.19	1.52	Echo PFO no flow, TR 57mm PAH No vegns or thrombi

196	2m	1.29	2.6	Fever 5 d, to R/o IE	3.36	1.29	ASD/PFO
197	1w	0.94	3.06	Echogenic Foci in Fetal Echo	2.88	0.94	Echogenic Thickening MV/TV ASD/PFO
198	9d	1.53	2.72	Murmur	4.17	1.53	Small muscle VSD, psg 31, PFO
199	4y	1.60	16.7	Murmur	26.67	1.60	Normal
200	5y	1.04	15.5	Recurrent LRTI	16.1	1.04	Normal
201	37d	1.67	1.48	Klebsiella Sepsis to R/o IE	2.47	1.67	PFO
202	18m	1.33	9.7	Murmur	12.88	1.33	Normal
203	3.25y	1.61	13	Kawasaki F/u	21.01	1.61	Normal
204	3d	1.34	1.65	Tachypnoea	2.22	1.34	PFO
205	6h	M	3.47	IDM	6.65	1.91	ASD, PFO, PDA, IVSH
206	6y	M	19	Kawasaki Disease	24.29	1.28	Normal
207	6y	F	17.9	Acute Rheumatic Fever	21.61	1.20	Normal
208	1.5m	M	4.92	Murmur	8.09	1.64	ASD/PFO, Pul Br murmur

Table 3: *Data of 208 patients.*

distress, murmurs. None of the neonates were on ventilator. In older infants and children most common reason of referral for ECHO was murmurs, suspected CHD, follow up of CHD noted earlier, recurrent respiratory infections, chest pain, dyspnoea, failure to thrive, syncopal episode, palpitations, breath holding spells, pre adoption screening etc. None of them had any clinical condition contributing to pericardial effusion. Most echocardiography's done were normal, and the commonest finding was Patent Foramen ovale (PFO), followed by non significant patent dictus arteriosus (PDA) and atrial septal defect (ASD). Even on ECHO none of them had significant heart disease contributing to pericardial effusion.

Average volume range for newborns to less than 1 year age group varied from 3 ml to 6.87 ml, and more than 1 year ranged from 8.5 ml to 37 ml. When weight was taken into consideration the volume per kg ranged from 1.5 ml per kg in newborns to 0.98 ml per kg in 10 - 15 years age group (Table 4). Thus the data in this study indicates that on volume/kg basis, neonates have a larger amount of pericardial fluid normally which gradually decreases with advancing age.

Age	**0-7d**	**8 d-1m**	**1m-3m**	**3m-6m**	**6m-1y**	**1y-2y**	**2y-3y**	**3y-5y**	**5y-10y**	**10y-15y**
Number of Patients	44	24	30	18	18	17	10	21	21	5
Weight Range (Average in Kg)	1.25-3.76 (2.42)	1.24-4.8 (2.29)	1.44-4.92 (3.48)	1.19-6.3 (5.51)	6.1-8.9 (7.64)	6.6-12.01 (9.1)	5.75-14.5 (11.26)	10.5-22.5 (14.51)	15.5-34.5 (22.18)	24-60 (33.4)
Pericardial Fluid Volume Range (Average in ml)	1.13-8.79 (3.75)	0.72-5.8 (3.06)	0.43-8.78 (4.72)	2.31-12.93 (5.87)	2.02-9.47 (6.87)	4.38-31.52 (8.53)	5.42-32.33 (12.81)	5.56-52 (16.62)	12.6-50.5 (22.83)	25.92-50.5 (36.9)
Pericardial Fluid range in ml/ kg (Average)	0.64-3.63 (1.53)	0.44-2.76 (1.37)	0.23-2.34 (1.35)	0.48-1.93 (1.08)	0.29-1.35 (0.90)	0.48-1.68 (1.0)	0.64-2.44 (1.13)	0.34-3.6 (1.12)	0.5-1.29 (0.99)	0.64-1.32 (0.98)

Table 4: *Age and weight wise data of 208 patients.*

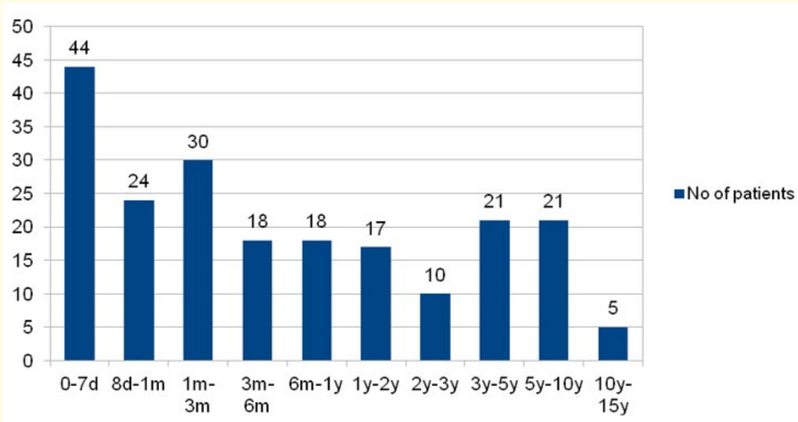

Figure 2: *Demonstration of number of patients age wise.*

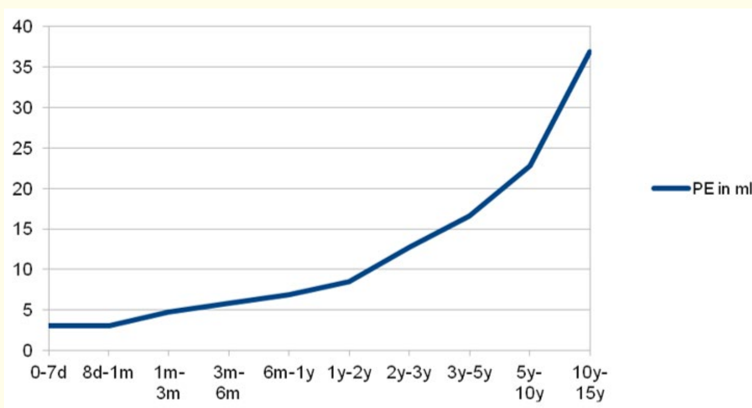

Figure 3: *Demonstration of total amount of pericardial fluid, age wise.*

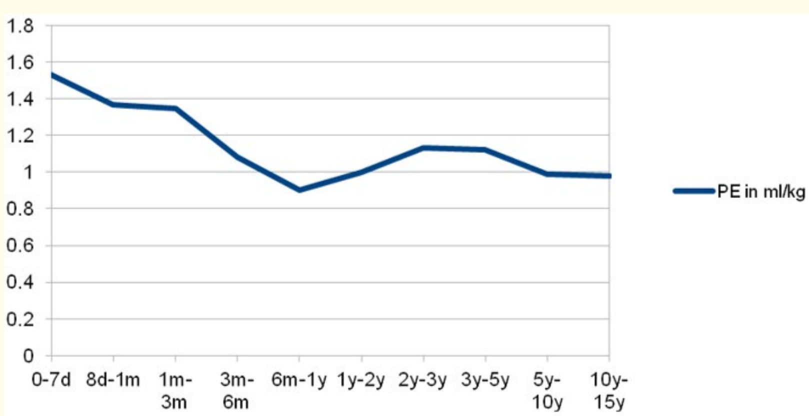

Figure 4: *Demonstration of pericardial fluid in ml/kg, age wise.*

Discussion

There is paucity of studies quantitating normal amount of pericardial fluid and data available is arbitrary without the methodology mentioned (Table 1). Echocardiographic data available is mostly regarding large effusions needing pericardiocentesis, correlating estimated amount of fluid drawn with echocardiographically estimated volume in adults [15-18]. Ours is the first systematic estimation by Echocardiography of normal amount of pericardial effusion in neonates upto 15 years of age.

Echocardiography is a well-validated technique for assessing pericardial effusion [7,8]. There are no specific data for differentiation of volume of physiological pericardial fluid from pathological effusion. Attempts to estimate the quantity of pericardial fluid from the M mode echocardiogram by cubing the widths of the pericardial sac and of the heart and then subtracting the heart volume from the pericardial sac have yielded conflicting results [19-21]. Data regarding normal amount of pericardial fluid in children is almost nil. Ours is the first largest study to estimate the actual pericardial fluid volume in children by echocardiography using the formula similar to the one used to calculate ejection fraction.

In this study we found that the estimated volume of pericardial fluid by echocardiography, increased with age, but on a per kg/wt basis it was higher in neonates and gradually decreased with age up to adolescence. A study done by Cruz and Hoffman [22] using the prolate ellipse formula showed that, the volumes of pericardial fluid drained had good correlation with the volumes estimated by echocardiography. However, it was a small study and was done in adults with clinical evidence of tamponade. The short comings were also that they had rounded off the volumes almost by 50 ml which cannot be done in children. A retrospective study by Leibowitz., *et al*. [23] have measured the pericardial effusion volume by applying the same formula for volume of prolate ellipse and found that measurements made by both ECHO and CT images had good correlation with amount of fluid drained by pericardiocentesis. However, this was also a small study including only age group above 15 years.

In our study the same prolate ellipse formula was used with some modification as shown before and the patients included were few hours old neonates, to children and adolescents of 15 year age group.

One limitation of this study was that echocardiogram was done only on patients referred because of suspected cardiac problems. But none had any condition or cardiac problems that would affect pericardial fluid volume such as cardiac failure. The volume measured was also not confirmed by CT/MRI as it would be an unnecessary and extra investigation, which would involve cost and radiation exposure. But previous studies have shown that sensitivity of ECHO to detect pericardial fluid is very high and almost similar to or better than those obtained with CT [24]. During estimation we have ignored the multiplication factor of 1.046 (π x 4/3) creating an underestimation error of 4.6%.

This study documents the normal amount of pericardial fluid in neonates, children and adolescents referred for cardiac problems. The criteria used to signify large effusions threatening tamponade by the width of the echo free space or volume by echocardiography, are very vague and variable and pediatric data is scanty. But Echo criteria to assess the severity of cardiac tamponade like right atrial wall collapse, right ventricular wall collapse and posterior LV wall collapse in diastole, are very well described in the literature [12,13].

Considering the variable amount of pericardial fluid volume in different age groups, and the importance of detecting life threatening pericardial tamponade, it would be worthwhile if a larger screening study be done in normal neonates and children to document the normal range of amount of pericardial fluid volume.

Conclusion

A semi quantitative data based on the amount of pericardial fluid normally present in neonates, infants and children is provided. Neonates and infants have a higher amount of pericardial fluid per kilogram body weight. In neonates Infants and Children, lower age and weight tend to have higher amounts of pericardial fluid normally. Preterm infants and LBW infants for gestational age tend to have larger amount of pericardial fluid per kilogram weight compared to term infants.

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