BRIEF REPORT

Echocardiographic Evaluation of Right Ventricular Function in Healthy Full-term Neonates during First Week of Life

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ABSTRACT

Background: To study echocardiographic parameters of right ventricular function in healthy full-term neonates during first week of life.

Materials and Method: Detailed echocardiographic evaluation of right ventricular function was performed in 25 healthy full-term neonates during first week of life.

Results: Inferior vena cava showed inspiratory collapse of around 50% suggesting normal respiratory change in right atrial filling. Systolic wave velocity was more than diastolic wave velocity in hepatic vein and superior vena cava suggesting normal filling pattern of right atrium. Right ventricular outflow tract fractional shortening was more than 50% suggesting normal systolic function of right ventricle. Pulmonary artery flow acceleration time was 88.5±17.6 msec suggesting higher pulmonary vascular resistance. Systolic excursion and slope of lateral tricuspid annulus were more than those of medial tricuspid annulus suggesting greater systolic shortening of lateral wall of right ventricle. Pulsed Doppler evaluation of tricuspid flow revealed A-wave velocity more than E-wave velocity suggesting impaired relaxation pattern. Velocity of propogation of late diastolic tricuspid flow was more than that of early diastolic flow suggesting impaired relaxation with rapid filling during atrial systole. Tissue Doppler imaging of tricuspid annulus also revealed greater velocity in late diastole than in early diastole. These findings also suggest impaired relaxation pattern of right ventricle in neonates during first week of life.

Conclusions: Our data provide preliminary information for various echocardiographic parameters of right ventricular function in healthy full-term neonates during first week of life. Right ventricle shows impaired relaxation pattern in this age group. This could be due to only partial regression of right ventricular dominance of fetal circulation. (J Clin Prev Cardiol. 2013;2(4)195-201)

Keywords: echocardiography; neonates; right ventricle; tissue Doppler imaging

Introduction

Evaluation of right ventricular function is important in neonates with congenital heart disease (1). Most of the neonates with suspected heart disease undergo echocardiographic evaluation during first week of life. Echocardiographers mostly look at structural defects. Importance of ventricular function in this age group is not widely appreciated. With similar structural defect, prognosis and postoperative results are likely to depend on myocardial function. There is no literature about detailed echocardiographic evaluation of right ventricular function in this age group (2–9). We, therefore, performed detailed echocardiographic evaluation of right ventricular function in healthy full-term neonates during first week of life to find normal pattern in this age group.

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Material and Methods

The study was approved by institutional ethical committee. Informed consent was obtained from all parents. Twenty-five healthy full-term neonates were studied during first week of life. They had no cardiorespiratory or systemic disease. They were not receiving any drugs and were breathing room air. They did not have any abnormality on two-dimensional or Doppler echocardiography. Sixteen were males and nine were females. Mean age was 4.8±2.8 days. Mean heart rate was 121±17/min. Mean weight was 2.8±0.7 kg.

Exclusion Criteria

Neonates with history of asphyxia were excluded as even mild asphyxia can affect myocardial function (10). Neonates with patent ductus arteriosus were excluded to avoid any possible impact of increased pulmonary flow and left ventricular volume overload on right ventricular function. Neonates with any atrial septal defect or those with any evidence of pulmonary artery hypertension were excluded to avoid effect of right ventricular volume or pressure overload on right ventricular function. Neonates with any valvular lesion were excluded. Neonates with any rhythm disorder or conduction defect were excluded. Neonates of diabetic mothers were excluded as such neonates are known to have myocardial dysfunction (11). Preterm neonates, those with intrauterine growth retardation and those with chromosomal abnormalities/syndromes were also excluded as such neonates are likely to have cardiac function abnormalities (12,13).

Echocardiography

It was performed on Siemens Acuson X300 with facility for tissue Doppler imaging. Phased array transducer with frequency of 4–8 MHz was used. Dimensions of inferior vena cava (IVC) and flow pattern in hepatic vein (HV) and superior vena cava (SVC) were evaluated in supine position. Rest of the examination was performed in slight right anterior oblique position. Dimensions of IVC were measured at a point distal to the joining of HV. M-mode cursor was used. Maximum expiratory and minimum inspiratory dimensions were measured and percentage of inspiratory collapse was calculated (Fig. 1a). SVC flow pattern was recorded by placing transducer in right supraclavicular region (14). Representative tracing is shown in Figure 1b. HV flow pattern was recorded from subcostal long axis view with sample volume in right superior HV just proximal to its connection to IVC (14). Representative tracing is shown in Figure 1c. Velocity and velocity time integral of systolic wave, diastolic wave and atrial reversal wave were analyzed in SVC and HV flow. Tricuspid flow A-wave duration minus HV flow A-wave reversal duration was calculated.

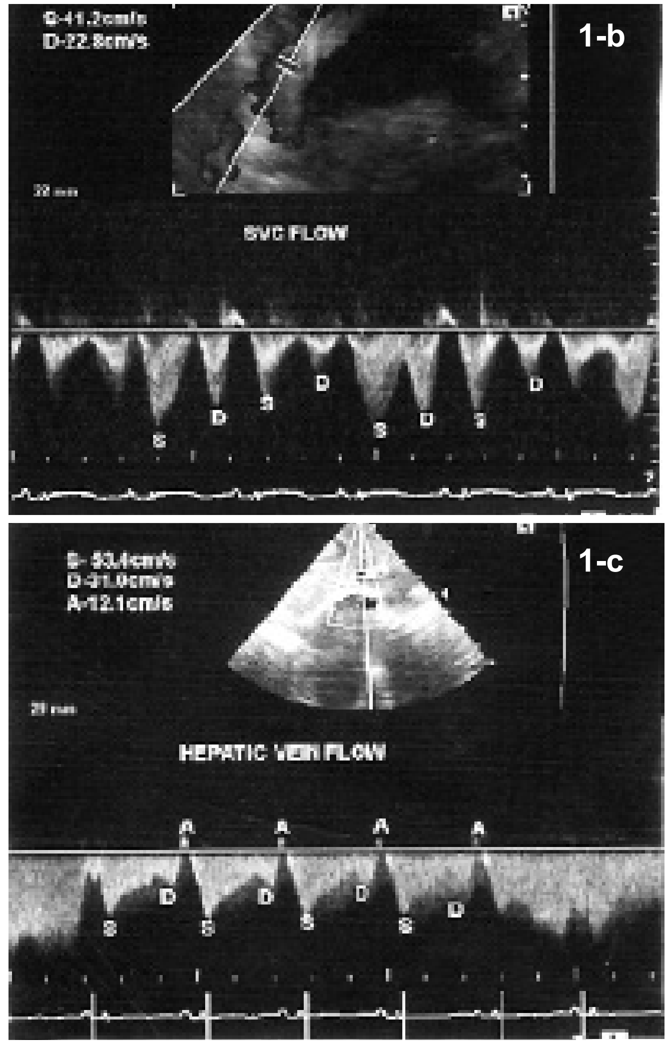
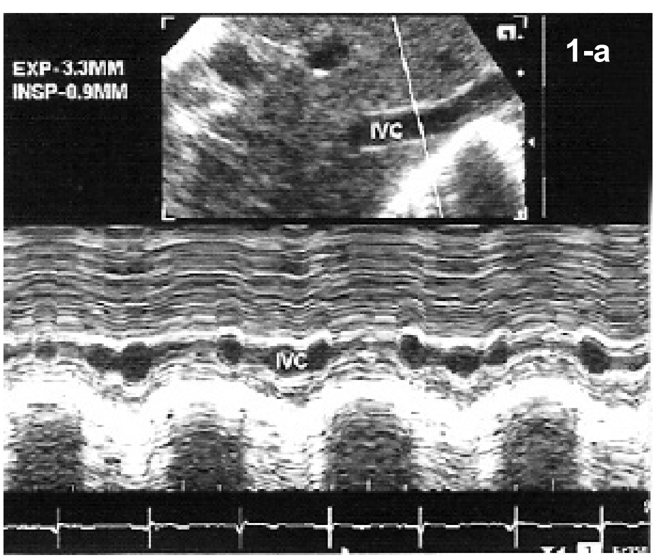


Figure 1. (a) M-mode tracing showing inspiratory collapse of inferior vena cava. (b) Pulsed Doppler flow of superior vena cava showing systolic wave velocity more than diastolic wave velocity. (c) Pulsed Doppler flow of hepatic vein showing prominent systolic wave and minimal atrial reversal wave.



Right ventricular outflow tract (RVOT) dimensions were recorded from left parasternal short axis view at the level of aortic root (15). M-mode cursor was used. RVOT anterior wall thickness and cavity dimensions were measured in end-diastole and end-systole (Fig. 2a). Fractional shortening was calculated. Pulsed Doppler evaluation of pulmonary artery flow was performed in left parasternal short axis view at the level of aortic root. Sample volume was kept just distal to pulmonary valve. Peak velocity and acceleration time were analyzed (Fig. 2b).

Tricuspid annulus plane systolic excursion was measured using M-mode cursor in apical four-chamber view (16). Lateral and septal parts of annulus were evaluated (Fig. 2c & d). Systolic excursion and slope were analyzed. Tricuspid flow velocities were recorded by pulsed Doppler method. Sample volume was placed at the level of tip of tricuspid leaflets in diastole. Early (E) and late (A) diastolic velocities were recorded (Fig. 3a). Velocity time integral (VTI) of E- and A-wave were analyzed. E/A ratio was calculated. Deceleration time of E-wave and duration of A-wave were analyzed. When A-wave started before end of E-wave, deceleration time of E-wave was calculated by extrapolation of initial slope to base line. Tricuspid flow propogation velocity (Vp) was recorded in the same view using color Doppler and keeping M-mode cursor in the tricuspid flow. Slopes of early and late diastolic flow were measured (Fig. 3b). Tissue Doppler imaging was also performed in apical four-chamber view (9). Sample volume was kept over medial and lateral part of tricuspid annulus (Fig. 4a & b). Ultrasound beam was kept perpendicular to the plane of the annulus to minimize angle of incidence. Systolic velocity (Sa), early diastolic velocity (Ea), late diastolic velocity (Aa), their VTI, isovolumic contraction time (IVCT), isovolumic relaxation time (IVRT) and ejection time were analyzed and myocardial performance index (MPI) was calculated.

Due to fast heart rate and respiratory rate, effect of single respiratory cycle is much less in neonates (6). Further, any phase lag between respiration and ventricular filling is difficult to discern at fast heart and respiratory rates (6). Therefore, average of consecutive five cardiac cycles was taken for each parameter to minimize the effect of respiration (7). Data are presented as mean±SD.

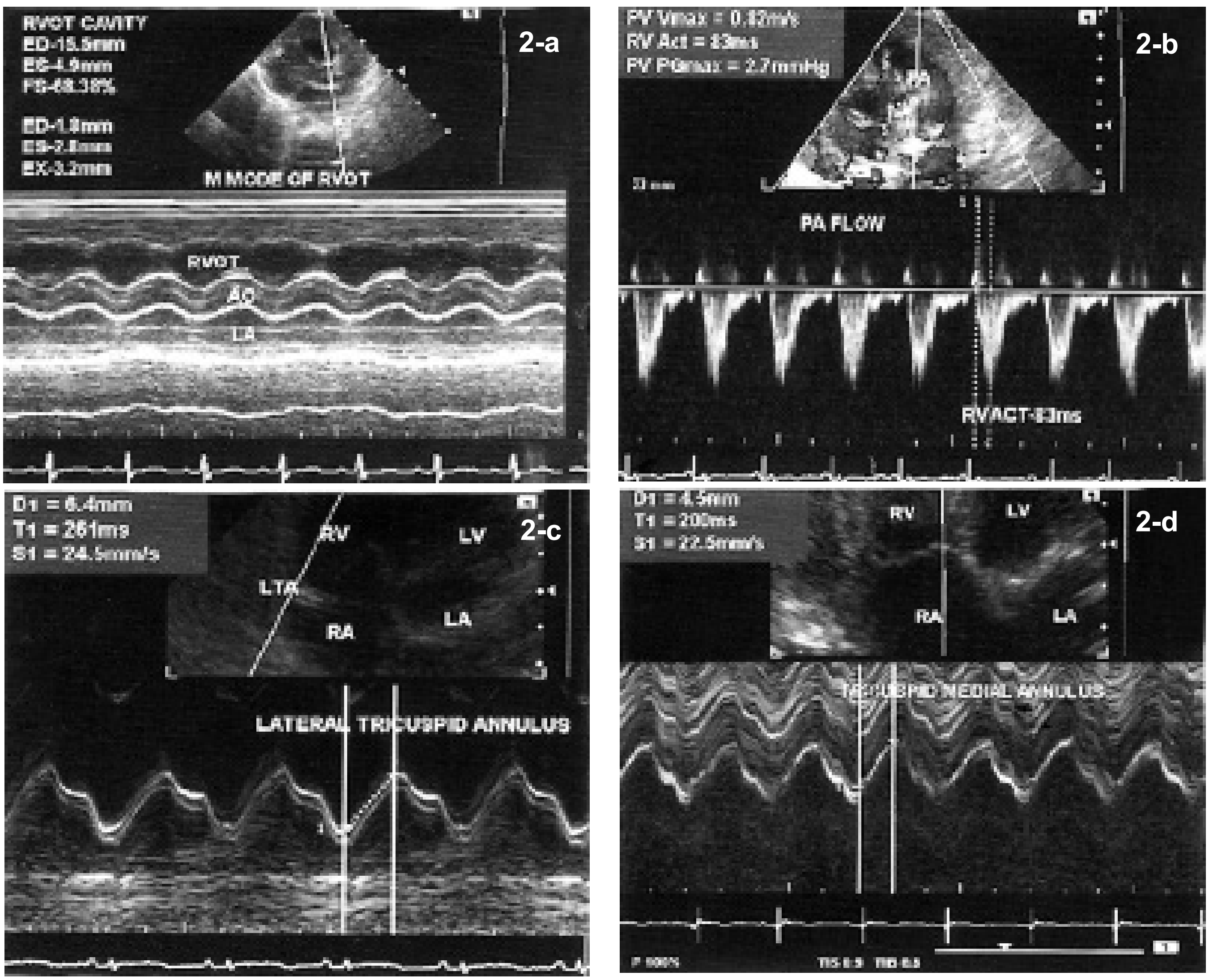


Figure 2. (a) M-mode tracing of right ventricular outflow tract showing systolic reduction in right ventricular outflow tract dimensions. (b) Pulsed Doppler of pulmonary artery showing normal flow. (c) M-mode tracing of lateral tricuspid annulus showing systolic excursion and slope. (d) M-mode tracing of medial tricuspid annulus showing systolic excursion and slope.

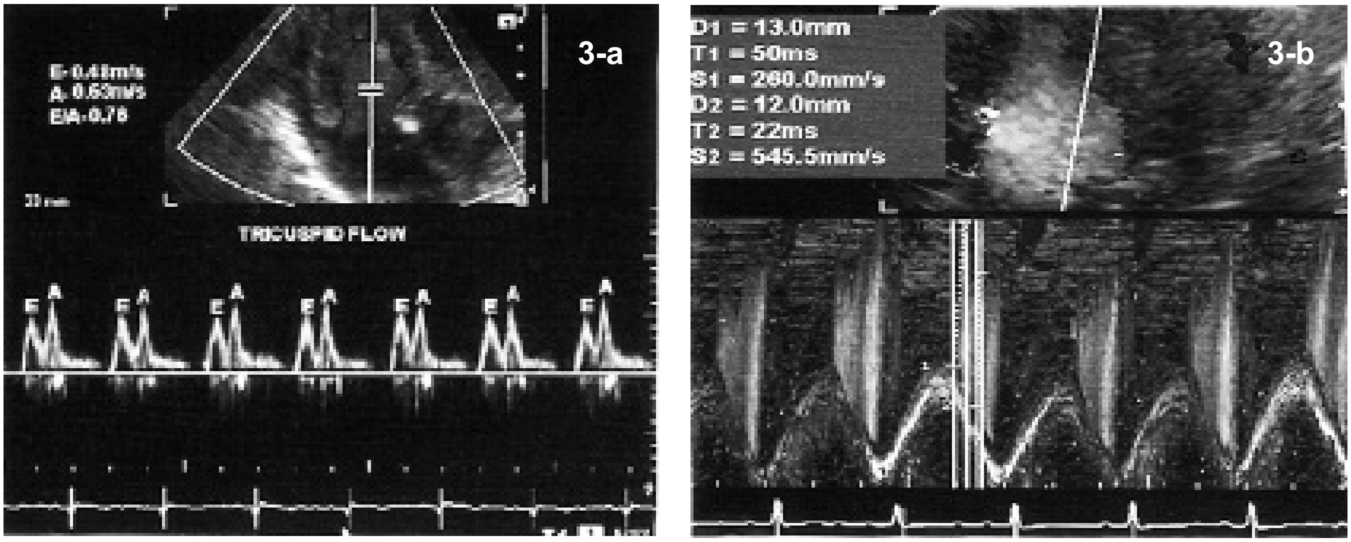


Figure 3. (a) Pulsed Doppler evaluation of tricuspid flow showing E & A waves. (b) Color M-mode of tricuspid flow showing measurement of velocity of propogation.

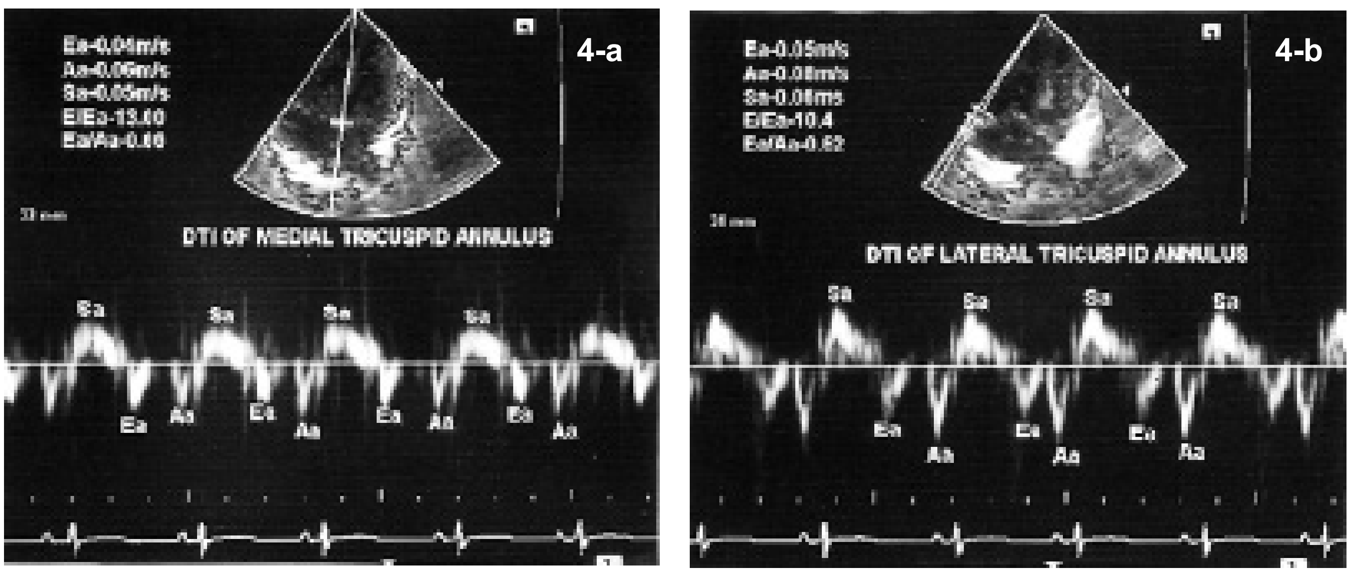


Figure 4. (a) Tissue Doppler imaging of medial tricuspid annulus showing Aa velocity more than Ea velocity. (b) Tissue Doppler imaging of lateral tricuspid annulus showing Aa velocity more than Ea velocity.

Results

IVC dimension was 4.4±1.0 mm in expiration and 1.8±0.6 mm in inspiration. Inspiratory collapse was 66.5±13.5%. HV size was 4.6±1.1 mm. HV and SVC flow patterns are shown in Table 1. Systolic wave velocity was more than diastolic wave velocity. Atrial reversal wave had minimum velocity and VTI. Velocities were more in HV than in SVC. Tricuspid flow A-wave duration was more than duration of atrial reversal wave in HV. RVOT anterior wall thickness was 2.2±0.5 mm in end diastole and 3.2±0.8 mm in end systole. Systolic excursion was 3.9±0.8 mm. RVOT cavity dimensions were 10.8±1.9 mm in end diastole and 4.0±1.0 mm in end systole. Fractional shortening was 63.1±6.7%. Pulmonary artery flow peak velocity was 0.7±0.2 cm/sec. Acceleration time was 88.5±17.6 msec. Medial tricuspid annulus plane systolic excursion was 6.1±1.0 mm with a slope of 27.6±6.2 cm/sec. Lateral tricuspid annulus plane systolic excursion was 8.3±1.6 mm with a slope of 37.1±9.0 cm/sec. Pulsed Doppler parameters of tricuspid flow are shown in Table 2. A wave velocity and VTI were more than respective values of E-wave. E/A ratio was less than 1. Velocity of propogation of early tricuspid flow was 44.5±11.9 cm/sec. Vp of late tricuspid flow was 211.1±105.1 cm/sec. E/Vp was 3.2±1.6. Slope of late diastolic flow was rapid than slope of early diastolic flow. Tissue Doppler imaging velocities of medial and lateral part of tricuspid annulus are shown in Table 3. All velocities were more along lateral part of tricuspid annulus. Late diastolic velocity (Aa) was more than early diastolic velocity (Ea).

Table 1.

Pulsed Doppler evaluation of hepatic vein and SVC flow

Parameter	Hepatic vein (mean±SD)	Superior vena cava (mean±SD)
Systolic wave		
Velocity (cm/sec)	54.4±20.7	39.4±12.7
VTI (cm)	9.5±4.9	6.5±2.2
Diastolic wave		
Velocity (cm/sec)	40.6±18.6	25.5±10.9
VTI (cm)	5.9±3.1	3.3±1.9
Atrial reversal wave		
Velocity (cm/sec)	18.7±9.4	17.4±5.4
VTI (cm)	1.6±1.0	1.4±0.6
Duration (msec)	65.2±14.7	
TVA-HVA	35.1±19.2	

VTI, velocity time integral; TVA, tricuspid valve Doppler flow A-wave duration; HVA, hepatic vein atrial reversal flow duration.

Table 2.

Doppler evaluation of tricuspid flow

Parameter	Mean±SD
E-wave	
Velocity (cm/sec)	44.4±11.6
VTI (cm)	4.2±1.1
DT (ms)	144.6±123.0
A-wave	
Velocity (cm/sec)	50.6±14.9
VTI (cm)	4.3±1.2
Duration (msec)	100.3±14.0
E/A (velocity)	0.9±0.3

VTI, velocity time integral; DT, deceleration time.

Table 3.

Tissue Doppler imaging of tricuspid annulus

Parameter	Mean±SD	
	MTA	LTA
Ea		
Velocity (cm/sec)	4.5±1.3	6.6±1.6
VTI (cm)	0.4±0.1	0.5±0.2
Aa		
Velocity (cm/sec)	5.9±1.3	8.1±1.9
VTI (cm)	0.5±1.1	0.6±0.1
Sa		
Velocity (cm/sec)	4.5±0.9	6.4±1.0
VTI (cm)	0.7±0.1	1.1±0.2
E/Ea	10.4±3.2	7.1±2.3
Ea/Aa	0.8±0.2	0.8±0.2
IVCT (m.sec)	55.3±19.3	44.8±13.2
IVRT (m.sec)	49.4±17.7	45.3±14.9
MPI	0.5±0.2	0.4±0.1

MTA, medial tricuspid annulus; LTA, lateral tricuspid annulus; Ea, early diastolic velocity; Aa, late diastolic velocity; Sa, systolic velocity; E, velocity of early diastolic flow of tricuspid valve; IVCT, isovolumic contraction time; IVRT, isovolumic relaxation time; MPI, myocardial performance index.

Discussion

IVC showed inspiratory collapse of more than 50%. This reflects normal inspiratory fall in right ventricular and right atrial pressure (17,18).There is no previous literature about this parameter in neonates. In SVC and HV flow, systolic velocity was more than diastolic velocity with small reversal wave during atrial contraction. This suggests normal filling pattern of right atrium with greater filling in systole than in diastole (19,20). Flow velocities were greater in HV than in SVC. This could be because of closer proximity of HV to right atrium and also because of relatively less compliance of HV (21). Tricuspid flow A-wave duration was more than the duration of atrial reversal wave in HV. There is no previous literature on this parameter. This finding correlates with greater A-wave duration of mitral flow than duration of atrial reversal flow in pulmonary vein (PVa) in normal persons (22).

Evaluation of RVOT revealed good systolic thickening of anterior wall and fractional shortening of more than 50%. These findings are considered suggestive of normal RV systolic function (15). Pulmonary artery flow peak velocity was normal. Pulmonary flow acceleration time is the time interval between beginning of the flow and its peak velocity (23). It was slightly lower in neonates. It could be due to increased afterload caused by physiological pulmonary hypertension. Tricuspid annular excursion reflects longitudinal shortening of the right ventricle (24). Greater excursion of lateral part of the annulus is because the lateral wall of right ventricle is rich in longitudinal fibers. Interventricular septum has more of circumferencial fibers (16,25). Koestenberger *et al*. (26) evaluated lateral tricuspid annulus plane systolic excursion in infants, children and adolescents. They reported a mean value of 0.91 cm for lateral tricuspid annulus in neonates as a whole (0–30 days). Our observation during first week of life is 0.8±0.2 cm. Slight difference could be due to the effect of maturation with advancing age (7, 11). There is no literature about systolic excursion of medial tricuspid annulus in neonates. We observed a relatively lower value 0.6±0.1 cm for medial tricuspid annulus. This is understable because interventricular septum has less longitudinal fibers (25).

Doppler evaluation of tricuspid flow revealed that late diastolic flow (A) velocity was more than early diastolic (E) flow velocity. E/A ratio was less than 1. Increased A-wave velocity suggests impaired relaxation of right ventricle resulting in forceful right atrial contraction. This finding is in agreement with observation of previous workers (6–9). These observations suggest impaired relaxation of right ventricle in first week of life. This could be because of only partial regression of right ventricular dominance of fetal circulation. Velocity of propogation of late diastolic tricuspid flow was more than that of early diastolic flow suggesting impaired relaxation with rapid filling of RV during right atrial contraction.

Tissue Doppler imaging velocities revealed that all velocities were more along lateral part of tricuspid annulus. Late diastolic velocity (Aa) was more than early diastolic velocity (Ea). Previous studies on lateral tricuspid annulus in neonates had similar observations (9,27). These observations also suggest impaired relaxation of right ventricle during neonatal period. Systolic velocity (Sa) observed by us (6.4±1.0 cm/sec) is similar to values observed by Mori *et al*. (9) (6.2±1.1 cm/sec) and Alp *et al*. (6.5±1.4 cm/sec) (27) in neonates. Ea/Aa ratio (0.9±0.2) and E/Ea ratio (7.1±2.3) of lateral tricuspid annulus are similar to values observed by Alp *et al*. on first day of life (Ea/Aa 0.72±0.14, E/Ea 7.9±1.6) (27). There is no literature about tissue Doppler imaging velocities of medial tricuspid annulus in neonates. Tissue Doppler imaging of medial tricuspid annulus is also important in evaluation of right ventricular function (28).We observed that Ea/Aa ratio of medial as well as lateral tricuspid annulus was less than 1. This finding also supports impaired relaxation of right ventricle in early neonatal period. We observed that IVRT of lateral tricuspid annulus was 45.3±14.9 msec in neonates. Right ventricular isovolumic relaxation time correlates with pulmonary artery pressure (29). IVCT in our subjects was 44.8±13.2 msec. There is no literature on this parameter in neonates. IVCT corelates with rate of systolic shortening of RV (30). Right ventricular MPI (Tei index) was 0.42±0.13 in our subjects. This could be due to prolonged IVRT. Tei index gives an overall impression about systolic and diastolic performance of RV(31).

Conclusion

At present, there is paucity of data on normal values of various echocardiographic parameters of right ventricular systolic and diastolic function in healthy neonates during first week of life. Right ventricle shows impaired relaxation pattern during this period. This could be due to only partial regression of right ventricular dominance of fetal circulation. Our data provide preliminary information on this topic.

Limitations

Sample size is small. This was because we strictly followed exclusion criteria. Getting well-informed written concent from parents of healthy asymptomatic neonates was another difficulty. Study of larger number of neonates can priovide more information and reference values. Long-term follow-up of same neonates can provide more information about progressive changes in right ventricular function. Comparison with neonates with right ventricular overload, their long-term follow-up and post-operative results is needed to find clinical utility of our observations.

Source of Funding

Nil

Conflict of Interest

Nil

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