Atrial and ventricular ejection force of the fetal heart: Which of the four chambers is the dominant?

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ABSTRACT

Background/Aim: **This study aimed to measure and compare the ejection force of the cardiac chambers in healthy singleton fetuses and to investigate the relationship of ejection force of cardiac chambers with gestational age, fetal sex, and fetal heart rate.**

Patients and Methods: **A prospective study was performed on 68 singleton fetuses with a gestational age of 17–34 weeks. Atrial and ventricular ejection force was measured. Measurements were repeated in 18 of the fetuses to assess intraobserver reliability.**

Results: **The right atrium had the highest ejection force of all the cardiac chambers. Ejection force of both atria and ventricles increased with gestational age.**

Conclusion: **The right atrium is the dominant chamber of the fetal heart in 17–34 weeks of gestation. Comparison of our values with previous studies indicates that left atrial ejection force almost doubles in the 1st month after birth. This study highlights the crucial role of the right atrium in the fetal cardiac function during 17–34 weeks of gestation.**

Keywords: Fetal cardiac function, fetal echocardiography, left atrial ejection force, left ventricular ejection force, normal values, right atrial ejection force, right ventricular ejection force

INTRODUCTION

Assessment of cardiac function is an important component of fetal echocardiography.[1] There are several methods of assessment of systolic and diastolic function of the fetal heart by two-dimensional, color Doppler, tissue Doppler, and three-dimensional echocardiography with spatiotemporal image correlation.[2-7] However, a method for routine clinical practice needs to be non-time-consuming, inexpensive, and applicable to all four chambers of the heart. Ejection force is a Doppler index which is based on the Newton's second law of motion and when compared with other Doppler indices, is less preload and afterload dependent.[8-10] Its measurement is easy and reproducible and does not require any special echocardiographic hardware or calculation software. Ejection force is expressed as millinewton or dynes and allows comparison of the function of all four cardiac chambers using a uniform metric.

There are only a few studies on ventricular ejection force in fetuses with normal and abnormal hearts, and the literature on fetal atrial ejection force is even scarcer.[11-15] To the best of our knowledge, measurement

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and comparison of the ejection force of the four cardiac chambers of the normal fetal heart has not been reported so far.

The aims of this prospective study on healthy fetuses were threefold: (1) to determine the normal values of ejection force of the right atrium, the left atrium, the right ventricle, and the left ventricle, (2) to compare the ejection forces of the four cardiac chambers, and (3) to investigate the relationship of ejection forces of the cardiac chambers with fetal gestational age, fetal sex, and fetal heart rate.

PATIENTS AND METHODS

We performed a prospective cross-sectional study on 68 consecutive healthy singleton fetuses referred for fetal echocardiography to the Fetal Cardiology Unit of Children's Medical Center from July 2017 to December 2017.

We defined the gestational age by the specific date of the last menstrual period and the ultrasound examination during the second trimester. The mothers had been referred by perinatologists and gynecologists with routine indications for fetal echocardiography.[1,16]

Inclusion criteria for mothers were singleton pregnancy; absence of maternal diabetes, hypertension, collagen vascular disease, and cardiovascular disorder; and absence of consumption of any drug which could potentially affect the fetal heart such as antihypertensive medications or corticosteroids.[17] Only healthy fetuses with no structural and chromosomal abnormality were included in the study. Fetuses with poor acoustic window were excluded from the study. Informed consent was obtained from all the participants. The study was approved by the Research Ethics Committee of Tehran University of Medical Sciences. The research was performed in accordance with the ethical principles of the Declaration of Helsinki.[18]

Echocardiography protocol

A single senior pediatric cardiologist performed all the fetal echocardiographic examinations using Affinity 70 Ultrasound system (Philips, Holland) and C9-2 curved array probe.

We adjusted the gain for each examination and set the sweep speed at the highest (264 mm/s) for Doppler measurements. The sample size was adjusted according to the size of the fetus. All measurements were done when the fetus was not moving. Measurements were repeated for five consecutive cardiac cycles and averaged. To obtain Doppler flow of the pulmonary and aortic valves, we inserted the ultrasound beam of the gated-pulsed wave Doppler in the main pulmonary artery and ascending aorta immediately above the respective valves. Tricuspid and mitral valve flow velocities were recorded immediately beyond the valves in the ventricle. The angle of insonation was <20°. The diameters of mitral and tricuspid valves (TVs) were measured in 4-chamber views in diastole. The diameters of pulmonary and aortic valves were measured in systole. The diameter of the pulmonary valve was measured in short-axis view of the right ventricle or sagittal approach to the ductal arch. The diameter of the aortic valve was measured in long-axis view of the left ventricle. To assess the intraobserver reliability, measurements were repeated in 18 of the fetuses.

Measurements and calculations

Atrial and ventricular ejection forces were measured using the following formulas:[11,12]

- Right atrial ejection force (RAEF) $=0.5\times \rho \times TVA \times (\text{peak A velocity})^2$
- Left atrial ejection force (LAEF) $=0.5\times \rho \times MVA \times (\text{peak A velocity})^2$
- Right ventricular ejection force (RVEF) $= (1.055 \times \text{pulmonary valve area} \times \text{TVI ac}) \times (PSV/TPV)$
- Left ventricular ejection force (LVEF) $= (1.055 \times \text{aortic valve area} \times \text{TVI ac}) \times (PSV/TPV)$

  1.055 = Density of blood (g/cm^3), ρ = The density of the blood = 1.06 g/cm^3; TVA = Tricuspid valve area $= \pi \times (\text{tricuspid valve radius})^2$ (cm^2); MVA = Mitral valve area $= \pi \times (\text{mitral valve radius})^2$ (cm^2); TVI ac = Flow time velocity integral during the acceleration time of the pulmonary/aortic blood flow; PSV = Peak systolic velocity (cm/s); TPV = Time to peak velocity (seconds).

The unit of atrial and ventricular ejection force can be expressed as dynes(g.cm/s^2) or milli newton (mN). Each 100 dynes is equal to one mN. One millinewton is the force needed to move one gram mass at an acceleration rate of one meter per second squared(g.m/s^2).

We also calculated the following parameters using these formulas:

- Total cardiac ejection force (TCEF) = RAEF + LAEF + RVEF + LVEF
- The ratio of ejection force of the atria to TCEF $= \frac{RAEF+LAEF}{TCEF}$
- The ratio of ejection force of the ventricles to TCEF $= \frac{RVEF+LVEF}{TCEF}$
- The ratio of ejection force of the right heart to TCEF $= \frac{RAEF+RVEF}{TCEF} <$
- The ratio of ejection force of the left heart to TCEF $= \frac{LAEF+LVEF}{TCEF}$
- The ratio of RAEF to TCEF $= \frac{RAEF}{TCEF}$

- The ratio of LAEF to TCEF $= \frac{LAEF}{TCEF}$
- The ratio of RVEF to TCEF $= \frac{RVEF}{TCEF}$
- The ratio of LVEF to TCEF $= \frac{LVEF}{TCEF}$

Statistical analysis

We performed a descriptive analysis for all parameters. Shapiro–Wilk test was used to determine the normality of distribution of data for each variable. Variables with normal distribution were analyzed using parametric tests and those with nonnormal distribution were analyzed using nonparametric tests. Kruskal–Wallis H-test was performed to compare nonparametric variables, using both a series of *post hoc* Mann–Whitney U-tests and pairwise comparisons with significant values adjusted by the Bonferroni correction for multiple tests. Independent *t*-tests, one-way analysis of variance, and Scheffe's *post hoc* tests were done for comparison of parametric variables.

Simple and multiple regression were used for the evaluation of the correlation between ejection forces of cardiac chambers and independent variables of fetal gestational age, fetal sex, and fetal heart rate. All data were analyzed using IBM SPSS Statistics for Windows, version 25 (IBM Corp., Armonk, N.Y., USA). $P < 0.01$ was considered statistically significant.

Fifth percentile and ninety-fifth percentile for RVEF and LVEF, according to fetal gestational age, were calculated using STATA 14 software (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP. USA).

RESULTS

We measured the ejection force of the atria and ventricle in the fetal heart of 68 singleton healthy fetuses of 17–34 weeks of gestation. In 18 cases in which the measurements were repeated by the same echocardiographer, the intraclass correlation coefficient was 0.911 (95% confidence interval [CI]: 0.876–0.946).

Ejection forces of the four cardiac chambers

Basic characteristics of the study population are shown in Table 1. The mean ± standard deviation (SD) and the median of ejection forces of the four cardiac chambers are shown in Table 2. The ratios and composite ratios of ejection force are displayed in Table 3. Figure 1 indicates the mean and 95% CI of the ejection force of cardiac chambers.

Comparison of the ejection forces of the four cardiac chambers

Kruskal–Wallis H-test, performed to compare the RAEF, LAEF, RVEF, and LVEF, showed a significant difference between ejection forces of the four cardiac chambers ($P = 0.011$). *Post hoc* pairwise comparison and also a series of *post hoc* Mann–Whitney U-tests showed that the ejection force of the right atrium was significantly higher than the left ventricle ($P = 0.002$).

Table 1: Basic characteristics of the study population

Variable	Value
Male sex, *n* (%)	45 (66)
Female sex, *n* (%)	23 (34)
Fetal gestational age in weeks, mean±SD (range)	21.14±3.21 (18-34)
Fetal heart rate as beats/min, mean±SD (range)	144±8 (119-161)
Maternal age in years, mean±SD	29.12±5.58

SD: Standard deviation

Table 2: Mean±standard deviation and median of ejection forces of cardiac chambers in 68 healthy and singleton fetuses from 17 to 34 weeks of gestational age

Variable	Mean±SD	Median
	(10^{-3}) newton (or mN)	
RAEF	4.96±4.04	4.22
LAEF	3.94±2.82	3.06
RVEF	4.35±3.84	3.86
LVEF	3.70±3.32	2.51
TCEF	16.91±11.61	12.57

RAEF: Right atrial ejection force, LAEF: Left atrial ejection force, RVEF: Right ventricular ejection force, LVEF: Left ventricular ejection force, TCEF: Total cardiac ejection force, SD: Standard deviation

The ratio of RAEF to total cardiac ejection force (RAEF/TCEF) was significantly higher than the ratio of other cardiac chambers (LAEF/TCEF: $P < 0.001$, RVEF/TCEF: $P = 0.003$, and LVEF/TCEF: $P < 0.001$). There was no significant difference between LAEF/TCEF and LVEF/TCEF ($P = 0.986$) [Figure 2].

Effect of fetal heart rate, fetal gestational age, and fetal sex on ejection force of fetal cardiac chambers

Simple and multiple linear regression showed a significant correlation between ejection force of atria and ventricles and fetal gestational age ($P < 0.001$). For each week increase in fetal gestational age, the ejection force of RA, LA, RV, and LV increased 1.07, 0.70, 0.62, and 0.81mN, respectively [Table 4 and Figure 3].

There was no significant correlation between fetal heart rate and ejection forces of the cardiac chambers (RA: adjusted $R^2 = 0.014$, $P = 0.165$; LA: adjusted $R^2 = 0.016$, $P = 0.156$; RV: adjusted $R^2 = -0.013$, $P = 0.668$; and LV: adjusted $R^2 = -0.015$, $P = 0.857$).

Furthermore, we found no significant correlation between fetal sex and ejection forces of the cardiac chambers (RA: adjusted $R^2 = -0.016$, $P = 0.938$; LA: adjusted $R^2 = -0.015$, $P = 0.836$; RV: adjusted

Table 3: Mean±standard deviation of ratios of ejection forces of cardiac chambers in 68 healthy and singleton fetuses from 17 to 34 weeks of gestational age

RHEF/TCEF	LHEF/TCEF	RHEF/LHEF	TAEF/TVEF	RAEF/TCEF	LAEF/TCEF	RVEF/TCEF	LVEF/TCEF	RAEF/LAEF	RAEF/RVEF	LAEF/LVEF	RVEF/LVEF
0.54±0.08	0.45±0.08	1.30±0.58	1.31±0.71	0.29±0.08	0.24±0.06	0.25±0.11	0.21±0.89	1.27±0.47	1.66±2.38	1.52±1.14	1.61±1.48

RAEF: Right atrial ejection force, RVEF: Right ventricular ejection force, RHEF: Right heart ejection force, i.e., the sum of the right atrial and right ventricular ejection force, LAEF: Left atrial ejection force, LVEF: Left ventricular ejection force, LHEF: Left heart ejection force, i.e., the sum of the left atrial and the left ventricular ejection force, TCEF: Total cardiac ejection force, i.e., the sum of the ejection forces of the right atrium, left atrium, right ventricle, and left ventricle

Table 4: Simple and multiple linear regression analysis of fetal gestational age, fetal sex and maternal age and ejection force of fetal cardiac chambers in 68 healthy and singleton fetuses from 17 to 34 weeks of gestational age

Dependent variable	Predictor variable	Unstandardized coefficient (B)	95% confidence interval (CI)		*P*	Unstandardized coefficient (B)	95% confidence interval (CI)		*P*
			Lower Bound	Upper Bound			Lower Bound	Upper Bound	
RAEF	Fetal gestational age	106.499	89.513	123.486	<0.001	107.327	89.664	129.99	<0.001
LAEF		70.925	57.822	84.027	<0.001	70.469	57.075	83.863	<0.001
RVEF		62.745	37.168	88.321	<0.001	62.150	36.44	87.861	<0.001
LVEF		81.520	65.358	97.681	<0.001	81.703	64.843	98.563	<0.001

*Predictor variables: Fetal gestational age, fetal sex, fetal heart rate, and maternal age, †Abbreviations: RAEF: right atrial ejection force, LAEF: left atrial ejection force, RVEF: right ventricular ejection force, LVEF: left ventricular ejection force

R^2 = −0.016, P = 0.9; and LV: adjusted R^2 = −0.008, P = 0.477).

Comparison of ejection force of the right heart and the left heart

Mann–Whitney U-test revealed that the sum of ejection force of the right heart, i.e., the sum of RAEF and RVEF, was significantly higher than that of the left heart, i.e., the sum of LAEF and LVEF ($P < 0.001$).

Comparison of peak A velocity and valve area of tricuspid and mitral valves

One sample *t*-test showed a significant difference between A velocity of the tricuspid and mitral valves (mean ± SD of 48.44 ± 6.56 cm/s vs. 47.42 ± 5.09 cm/s, respectively, $P < 0.001$). The TV area was also significantly larger than the mitral valve area (mean ± SD of 0.27 ± 0.09 cm^2 vs. 0.24 ± 0.08 cm^2, respectively, $P < 0.001$).

Comparison of peak velocity and valve area of pulmonary and aortic valves

Peak systolic velocity of pulmonary valve was significantly higher than the aortic valve (mean ± SD of 60.06 ± 10.54 cm/sec vs. 58.62.42 ± 13.98 cm/sec, respectively, $P < 0.001$). Thepulmonary valve area was also significantly larger than the aortic valve area (mean ± SD of 0.16 ± 0.09 cm^2 vs. 0.12 ± 0.06 cm^2, respectively, $P < 0.001$).

DISCUSSION

Our study showed that the right atrium is the dominant chamber of the heart in fetuses aged 17– 34 weeks of gestation.

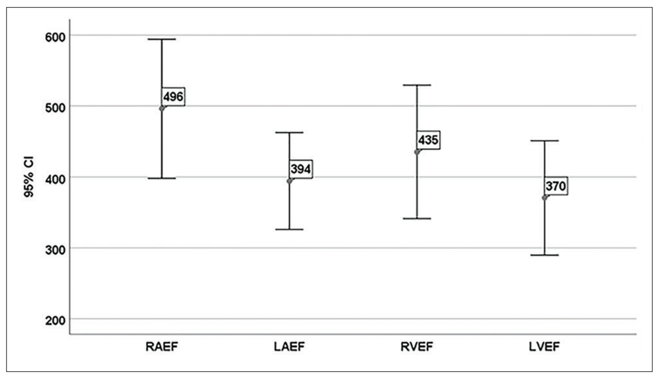

Figure 1: Error bar indicating mean and 95% confidence interval of the right atrial ejection force, left atrial ejection force, right ventricular ejection force, and left ventricular ejection force. RAEF: Right atrial ejection force, LAEF: Left atrial ejection force, RVEF: Right ventricular ejection force, LVEF: Left ventricular ejection force

There are several advantages for the measurement of ejection force for the evaluation of cardiac function. It can be easily applied to all the four cardiac chambers, including atria and ventricles. Comparison of cardiac chambers is easy because of a single unit or metric, i.e., mN. Compared with other Doppler indices, it is less dependent on preload and afterload, although there is controversy regarding the afterload dependency of LVEF.[10,19] It does not require any special echocardiographic hardware or calculation software. There is an acceptable positive correlation between ejection force of atria and ventricles with other echocardiographic parameters for the assessment of cardiac function, including atrial strain and reserve and booster-pump function of the atria and ventricular ejection fraction.[8,20]

To the best of our knowledge, there are five reports on reference values of ejection forces of the cardiac chambers in the fetal period.[11-15] In none of them, all the four cardiac chambers are simultaneously measured. Furthermore, there is no study on reference values of RAEF and LAEF during any week of gestation in healthy fetuses.

Wloch *et al.* studied ejection force of the atria in the embryos aged 6–10 weeks of gestation, but they did not define values for RAEF and LAEF separately.[11] They reported the ratio of atrial to ventricular ejection force to be more than 1. Similarly, in our study, atrial to ventricular ejection force was more than 1 in both the right and the left hearts.

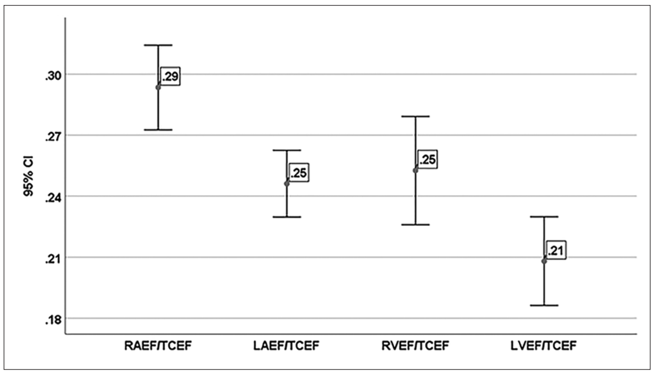

Figure 2: Error bar indicating mean and 95% confidence interval of ratios of the right atrial ejection force, left atrial ejection force, right ventricular ejection force, and left ventricular ejection force to total cardiac ejection force. RAEF: Right atrial ejection force, LAEF: Left atrial ejection force, RVEF: Right ventricular ejection force, LVEF: Left ventricular ejection force, TCEF: Total cardiac ejection force

Kiani *et al.* reported a mean ± SD of 10.11 ± 4.2 mN for normal LAEF in 47 neonates.[21] Zhong *et al.* measured LAEF in 102 healthy adult individuals. Similar to our findings, they showed that LAEF increases with age, but does not differ significantly with gender.[22]

Rizzo *et al.* studied RVEF and LVEF in 156 normal fetuses and 72 fetuses with intrauterine growth retardation (IUGR). They found that both RVEF and LVEF decrease in IUGR. These authors provided reference values for RVEF and LVEF as 5th–95th percentiles in normal fetuses aged 18–40 weeks.[12] Comparison of our findings with their results is tabulated in Table 5. Rasanen *et al.* studied ventricular ejection force in 73 normal and 41 abnormal fetal hearts of fetuses of 19–41 weeks of gestation. They showed that chronic volume overload increases RVEF and acute pressure overload decreases RVEF. None of these loading conditions changed LVEF.[13] They reported the mean ± SD of 12.7 ± 4.7 and 12.2 ± 4.9 mN for RVEF and LVEF, respectively. Szwas *et al.* measured RVEF and LVEF in 76 healthy fetuses aged 17–40 weeks and reported a range of values of 0.97–28.5 and 0.73–24.2 mN, respectively.[14] The range of RVEF and LVEF in our series was 1.43–26.45 and 0.44–17.5 mN, respectively. More than tenfold rise in ventricular ejection force during the second half of gestation and the fewer number of fetuses aged more than 30 weeks in our series explain our lower values.[12]

Parasuraman *et al.* studied RVEF and LVEF in 236 healthy fetuses with a gestational age of 12–40 weeks.[15] They reported their normative values for RVEF and LVEF as 3rd–97th percentiles and also as median values at 18, 30, and 37 weeks.

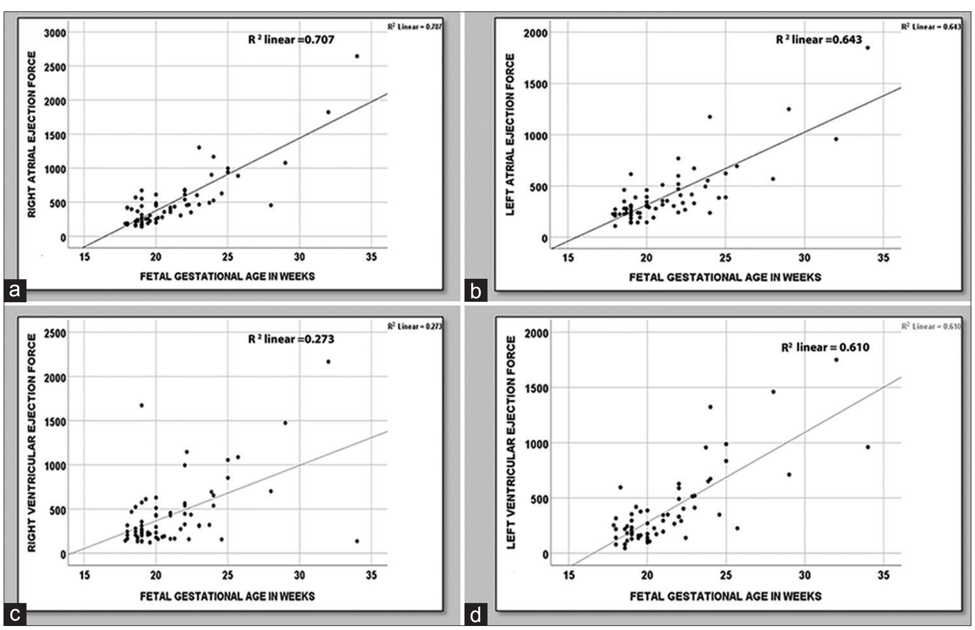

Figure 3: (a-d) Values of the right atrial ejection force, left atrial ejection force, right ventricular ejection force, and left ventricular ejection force in 68 singleton healthy fetuses according to fetal gestational age in weeks. (a) Right atrial ejection force, (b) Left atrial ejection force, (c) Right ventricular ejection force, and (d) Left ventricular ejection force

Valve area and peak velocity are the two components of the formula for ejection force. In our study, cross-sectional area of the TV was significantly larger than the mitral valve. We also found that the peak A velocity of the TV was significantly higher than the mitral valve. This raises the question of why peak A velocity is higher in the TV relative to the mitral valve? Is the vortex dynamics in the right atrium different from that of the left atrium? To explain the higher peak A velocity, we investigated the dynamics of flow entering into the RA from inferior vena cava (IVC) and superior vena cave (SVC). Interestingly, we found that the flow from superior vena cava and IVC enter into the RA with an angle of near 60° on both sides [Figure 4 and Videos 1 and 2]. The symmetrical and convergent entrance of flow from both sides through IVC and SVC into the RA may explain the increase in the peak A velocity of the diastolic blood flow across the TV. Doppler vortography is a new imaging modality in Doppler echocardiography, which may be helpful in understanding the importance of vortex dynamics in the fetal heart in future.[23,24] The increased volume of the fetal right atrium may also be contributive.[25] Currently, there is no study to objectively demonstrate the effect of changes in preload and afterload on the ejection force of fetal atria and ventricles.

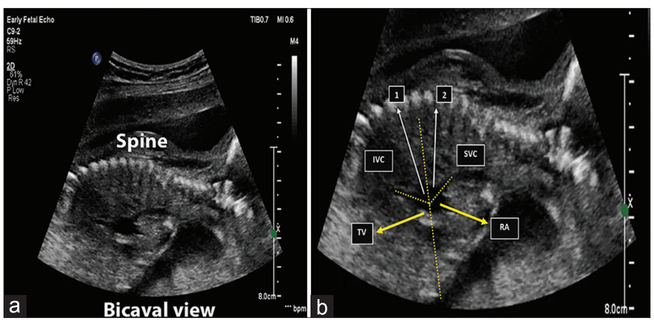

Figure 4: (a) Bicaval view. (b) Same as Figure (a), but with labels. The two angles: angle number 1 that is between the axis of inferior vena cava and the line passing through the tricuspid valve orifice and the angle number 2 that is between the axis of inferior vena cava and the line passing through the tricuspid valve orifice. The first angle is 60° and the second is 50°. Flow enters into the right atrium from the two sides with almost the same angle toward the tricuspid valve orifice. This can lead to augmentation of flow and increased A velocity

Practical clinical implications of ejection force of cardiac chambers in the fetal period and beyond

Abnormalities of ventricular ejection force of cardiac chambers are reported in a variety of cardiac pathologies in the fetuses, neonates, and adults.[12,14-29]

Atrial ejection force

Atrial ejection force not only indicates atrial systolic function but also provides information regarding ventricular diastolic function.[28,29] Abnormally reduced LAEF indicates decreased atrial systolic function, and abnormally increased LAEF is indicative of ventricular diastolic dysfunction.[26-33] Decreased LAEF has been reported in paroxysmal atrial fibrillation and sick sinus syndrome in adults and indicates poorer outcome after catheter ablation.[27,30]

Kiani *et al.* evaluated systolic and diastolic function in newborns with mild asphyxia. They showed that increased LAEF index can unveil latent abnormality in the left ventricular filling.[26] Similarly, in adults, increased LAEF has been shown to be as a manifestation of LV diastolic dysfunction patients with myocardial infarction and hypertrophic cardiomyopathy.[29,31] LAEF is increased in chronic heart failure and can be used as a helpful parameter for the optimization of treatment of adult patients with chronic heart failure.[32,33]

By extrapolation of the studies in adults, we may conclude that decreased LAEF may be helpful in the diagnosis of fetal atrial arrhythmias and increased LAEF may be

Table 5: Comparison of our findings on the right and left ventricular ejection force in 68 healthy singleton fetuses aged 17-34 weeks with the study of Rizzo *et al.* (including 156 fetuses aged 18 to 38 weeks) according to each week of gestation[12]

Gestational age (week)	RVEF (mN)		LVEF (mN)	
	Our study (5th to 95th percentile)	Rizzo *et al.* (5th to 95th percentile)	Our study (5th to 95th percentile)	Rizzo *et al.* (5th to 95th percentile)
17	1.21-2.96	-	0.41-1.27	-
18	1.44-4.66	2.07-3.33	0.45-2.14	0.88-1.89
19	1.51-4.81	2.36-3.80	1.08-3.28	1.01-3.32
20	2.21-4.96	2.69-4.33	1.38-3.95	1.16-3.82
21	2.61-5.46	3.07-4.94	1.71-3.98	1.33-4.38
22	3.56-6.45	3.50-5.63	1.78-5.19	1.53-5.03
23	4.06-6.91	3.99-6.42	3.10-5.80	1.76-5.78
24	4.19-6.96	4.55-7.32	3.34-7.84	2.02-6.63
25	5.11-9.86	5.19-8.35	3.58-8.87	2.32-7.62
26	6.18-10.14	5.92-9.52	5.42-9.08	2.66-8.74
28	8.09-10.98	7.69-12.37	7.63-10.86	3.51-11.53
29	11.06-13.97	8.77-14.12	8.68-11.56	4.02-13.23
32	17.62-24.41	13-20.92	10.95-13.54	6.09-20.0
34	21.46-26.12	16.90-27.20	12.41-18.15	8.03-26.41

*Rizzo *et al.* presented the normative values as percentiles. RVEF: Right ventricular ejection force, LVEF: Left ventricular ejection force[12] useful for the recognition of fetal ventricular diastolic dysfunction, particularly in the presence of hypertrophic cardiomyopathy in fetuses of diabetic mothers.

Ventricular ejection force

Both RVEF and LVEF are reduced in fetuses with IUGR.[12] IUGR occurs in 10%–15% of pregnancies and is an important cause of perinatal morbidity and mortality with significant short- and long-term adverse consequences including metabolic syndrome and neurologic disorders.[34]

Decreased ventricular ejection force to <5th percentile has been shown to portend poor prognosis in these fetuses.[12] Hence, early detection of abnormal ventricular ejection force in fetuses with IUGR may be helpful in timely management of this high-risk population. Increased RVEF is reported in fetuses with hypoplastic left heart syndrome.[14]

Avramides *et al*. reported decreased LVEF in patients with dilated cardiomyopathy.[20] They showed that patients with higher NYHA class had lower LVEF. Increased LVEF is reported in adults with hypertension.[35] Further investigations are needed to reliably extrapolate findings on ejection force of cardiac chambers in the adult population to the fetal period.

Limitations

The sample size of our study was small. Further studies with larger sample size and adequate number of fetuses in each gestational week are recommended. Geometrical assumption could be a source of bias in our calculations; however, we performed all our measurements according to the recommendations of the American Society of Echocardiography to minimize any potential error.[36]

CONCLUSION

We measured RAEF and LAEF and RVEF and LVEF in 68 healthy singleton fetuses between 17 and 34 weeks of gestation. The right atrium is the dominant cardiac chamber in healthy fetuses.

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Conflicts of interest

There are no conflicts of interest.

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