DOI: 10.37990/medr.1511470 Med Records 2024;6(3):376-81

MEDICAL RECORDS-International Medical Journal

Research Article

Does Fetal Renal Disease Have a Hemodynamic Effect in the Prenatal Period? A Detailed Analysis Method with Fetal Echocardiography

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Abstract

Aim: Is there a change in the circulatory system in fetuses with renal disease in the prenatal period to make hemodynamic assessments. In addition, fetal cardiac functions in the same patients will be studied in detail using fetal echocardiography.

Material and Method: Thirty-one fetuses with renal disease were included in the study; 4 with polycystic kidneys, 4 with bilateral hydronephrosis, 12 with unilateral hydronephrosis, and 28 with pelvicalyceal ectasia. In the control group, there were 30 fetuses of the same gestational week without renal disease. The circulatory system and hemodynamic status were examined in detail by fetal echocardiography in both groups.

Results: High umbilical artery pulsatility index (PI) values were observed in 2 fetuses with bilateral hydronephrosis and 2 fetuses with unilateral hydronephrosis. The PI values of the middle cerebral artery were high in 2 fetuses with bilateral hydronephrosis and 2 cases with isolated pelvicalyceal ectasia. When the right and left myocardial performance index values of fetuses with renal disease were compared with normal fetuses, no significant results were observed, but the tricuspid valve pulse Doppler was abnormal in fetuses with fetal kidney disease. In addition, the right spherical index was higher in fetuses with renal disease than in the control group.

Conclusion: Although there is no functional change, morphologic findings of right ventricular overload can be observed in fetuses with fetal renal disease.

Keywords: Fetal renal disease, hydronephrosis, polycystic kidney disease, fetal echocardiography, myocardial performance index

INTRODUCTION

If renal disease (such as polycystic kidney or hydronephrosis) develops in the fetus during the prenatal period, knowledge of the hemodynamic effects on the cardiovascular system will help the physician determine the appropriate time of delivery and plan postnatal treatment (1, 2). It provides information about the presence of hemodynamic effects in the prenatal period and also whether renal dysfunction is present in oligohydromnios. Previously, the Doppler findings of the renal arteries have been evaluated to assess renal function, but the parameters of the fetal heart and other flow indices of the fetal arteries have not been used together (3,4). The fetal heart and fetal arteries should be examined by fetal echocardiography and color Doppler. These are noninvasive methods that provide information about the hemodynamic status of the fetal circulatory system (5).

Myocardial performance index (MPI), systolic excursion of the mitral anular plane (MAPSE), systolic excursion of the tricuspid anular plane (TAPSE), and sphericity index (SI) for cardiac function and morphologic changes are different ultrasound indices that provide information about fetal hemodynamic changes. In addition, Doppler velocity parameters of the major arteries in the fetal circulation such as the renal artery, middle cerebral artery (MCA), and umbilical artery are commonly used for hemodynamic assessment of the fetal circulation (6-8).

MATERIAL AND METHOD

A prospective cohort study was conducted in pregnant women with polycystic kidney, hydronephrosis, and pelvicalyceal ectasia. Thirty-one pregnant women with polycystic kidney, hydronephrosis, and pelvic ectasia were enrolled between January 2021 and May 2022 at 2nd and

CITATION
Yilmaz Ergani S, Yilmaz O. Does Fetal Renal Disease Have a Hemodynamic Effect in the Prenatal Period? A Detailed Analysis Method with Fetal Echocardiography. Med Records. 2024;6(3):376-81. DOI:1037990/medr.1511470

Received: 06.07.2024 **Accepted:** 30.07.2024 **Published:** 12.09.2024
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3rd trimester. Informed consent was obtained from all pregnant women who participated in the study. The study protocol was approved by the hospital's Department of Medical Research Ethics. The authors have confirmed that they have complied with the World Medical Association Declaration of Helsinki regarding the ethical conduct of research involving human subjects.

In the perinatology clinic, 31 fetuses were diagnosed with renal disease by abdominal ultrasonography. Among the fetuses with renal disease included in this study, polycystic kidney disease was present in 4 fetuses, bilateral hydronephrosis in 4 fetuses, unilateral hydronephrosis in 12 fetuses, and pelvicalyceal ectasia in 28 fetuses. A polycystic kidney was defined as a kidney with cysts 7 mm or more in diameter in at least two locations. We defined a hydronephrotic kidney as one with an anteroposterior pelvic diameter of 7 mm or more (9-11). 30 fetuses without renal disease were also included in the study as a control group.

Twenty fetuses at the same week of gestation (2nd and 3rd trimesters) without abnormal kidneys and other congenital additional anomalies were studied. Informed consent was obtained. Exclusion criteria included multiple pregnancy, premature rupture of membranes, chorioamnionitis, placental abruption, severe fetal growth restriction, fetal congenital heart diseases, preeclampsia, oligohydramnios, and maternal diabetes.

During the evaluation of the study group and the control group: Voluson 730 Ultrasound (GE Healthcare, Zipf, Austria), the kidneys were examined by a specialist in perinatology. Vivid S6 fetal echocardiography device (GE Healthcare, Zipf, Austria) was used by a pediatric cardiologist for measurement of fetal cardiac structure, cardiac functions, and pulse Doppler, umbilical artery pulsatility index (PI), fetal renal artery PI, and MCA PI. To obtain an effective wave analysis during Doppler measurements, it was attempted to obtain them at the lowest point of uterine contractions and fetal activity and at an angle of less than 30°. Spectral recording was performed with at least six pulse streams. PI pulse Doppler measurements were used to evaluate the waveforms of the umbilical artery, fetal MCA, and renal artery (12-15).

We studied the functions and morphological changes of the fetal heart using the following methods (5,6,8,16-18).

1. Diastolic functions of the left and right ventricles: Early diastolic ventricular filling (E), active contractility of the atria (A), mitral and tricuspid valves E/A. Pulse Doppler spectra were obtained for E-, A-, and S-wave velocities and MPI measurements. In the apical four-chamber section, the cursor of the device was placed near the anterior leaflet of the mitral valve in the left ventricle and near the posterior leaflet of the tricuspid valve in the right ventricle. Velocities were recorded as metres per second (m/s) values. For the left and right ventricles, the time from artioventricular (AV) valve closure to semilunar valve opening was measured as isovolumic contraction time (IVCT) and the time from semilunar valve closure to AV valve opening was measured as isovolumic relaxation time (IVRT). Ejection time (ET) is the time from opening to closing of both semilunar valves. Times were expressed in millisecond (ms). MPI was calculated using the following equation: IVCT+IVRT/ ET (Figure 1).

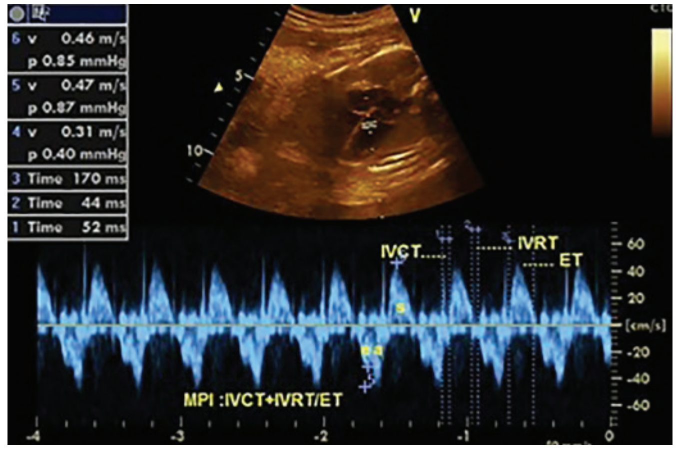

Figure 1. Illustration of myocardial performance index (MPI) assessment by spectral Doppler. Placing the Doppler sample volume on the medial wall of the ascending aorta in a four-chamber view, biphasic mitral inflow (e and a-waveforms) and aortic outflow (s-waveform) are displayed in the same spectral image. MPI is calculated by measuring the following time intervals: isovolumic contraction time (IVCT) from closure of the mitral valve to opening of the aortic valve; ejection time (ET) from opening to closure of the aorta; and isovolumic relaxation time (IVRT) from closure of the aortic valve to opening of the mitral valve

2. Systolic functions of the left and right ventricles were measured: Ventricular contractility per minute (Heart rate), mitral valve S velocity, tricuspid valve S velocity, TAPSE for the right ventricle, MAPSE for the left ventricle. It is the representation and measurement of the displacement of the mitral and tricuspid valves in the systolic phase in the M-mode spectra. It is referred to as MAPSE for the left ventricle and TAPSE for the right ventricle (Figure 2).

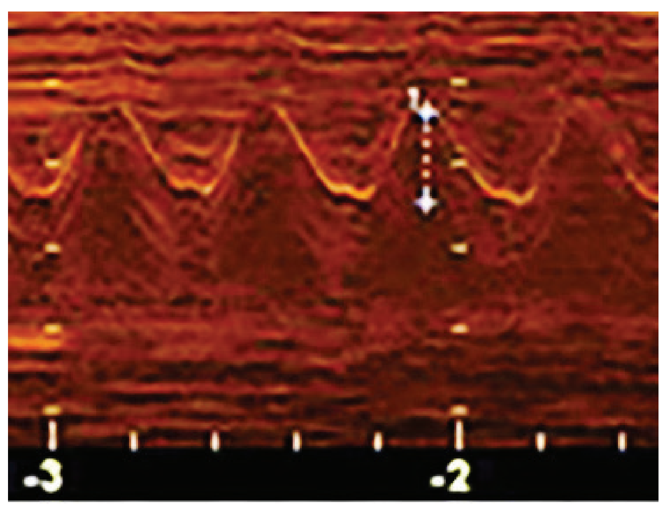

Figure 2. MAPSE M-mode spectra image

3. Morphologic features of the left ventricle and right ventricle: Cardio-thoracic ratio (CTR) was calculated, and left spherical index and right spherical index were evaluated. CTR is the ratio of the circumference of the heart to the circumference of the chest. SI is the ratio of the apical length of the AV valve planes to the basal length of the valves in diastole.

SPSS was used for all statistical analyzes (23.0; SPSS Chicago, USA). Statistics were expressed as mean±standard deviation, and variables were expressed as percentages. Student's t test was used to evaluate normally distributed groups, and Mann Whitney U test was used to compare nonnormally distributed groups. The Kolmogorov-Smirnov test was used to show whether the groups had a normal distribution. Statistical Results: At 95% confidence interval, p values <0.05 were considered significant.

RESULTS

Thirty-one women were included in this study. The mean maternal age was 27.3 years (range, 21.4-42.5 years), and the mean gestational age of women with fetal kidney disease was 28±1.8 weeks. The mean estimated fetal weight was 1.81 g (range: 760-2,460 g). There were no fetal deaths or preterm births.

Renal diseases were unilateral hydronephrosis (n=12), bilateral hydronephrosis (n=4), polycystic kidney disease (n=4), and pelvicalyceal ectasia (n=28) (Table 1 and Figure 3). The mean PI values of the renal artery, umbilical artery, and middle cerebral artery are summarized in graphs 1, 2, 3. The umbilical artery PI values of all cases, high PI values were observed in 2 bilateral hydronephrosis cases and in 2 unilateral hydronephrosis cases. Values close to the 95% percentile limit were observed in 2 isolated cases of pelvicalyceal ectasia. For MCA pulsatility indices, PI values were high in 2 cases of bilateral hydronephrosis and 2 cases of isolated pelvicalyceal ectasia. MCA PI -values were in the 50-95th percentile range in most patients with renal disease. The PI graphics of umbilical artery, renal artery and MCA was shown in Figure 4.

Table 1. Distribution of renal diseases

Renal diseases	Unilateral hydronephrosis	Bilateral hydronephrosis	Polycystic kidney	Pelvicalyceal ectasia
Unilateral hydronephrosis	1	-	1	10
Bilateral hydronephrosis	-	-	-	4
Polycystic kidney	1	1	-	2
Pelvicalyceal ectasia	10	4	2	12

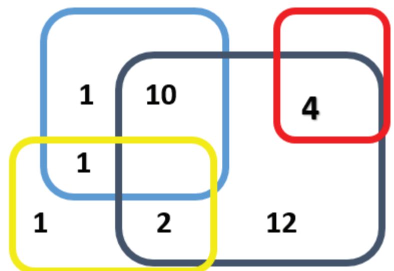

Figure 3. Blue color: unilateral hydronephrosis, Red color: bilateral hydronephrosis, Yellow color: polycystic kidney, Black color: pelvicalyceal ectasia

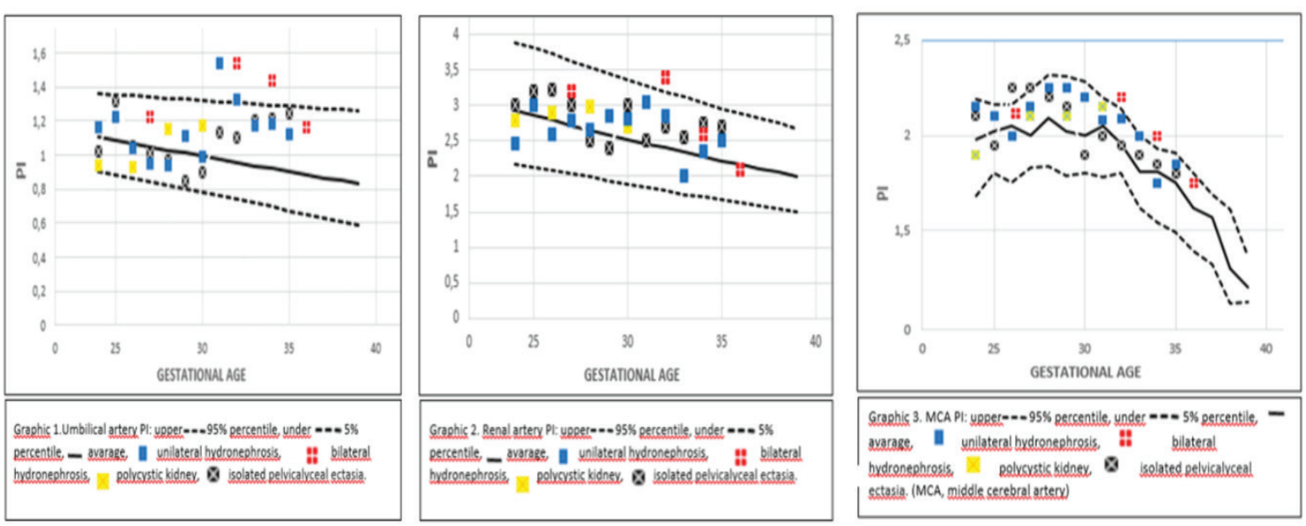

Figure 4. The PI graphics of umbilical artery, renal artery and MCA

Diastolic, systolic, and diastolic-systolic functional parameters and morphometric values of the fetal heart of the study group and the control group were compared in Table 2.

The right and left MPI values of the fetuses with renal disease were compared with those of normal fetuses. The E and A values of the tricuspid valve were higher than those of the normal fetuses (p<0.05). Right spherical index was found to be statistically significantly higher in renal disease (p=0.048).

The results of TAPSE, MAPSE, mitral S, and tricuspid S to evaluate systolic functions of fetuses with renal disease were compared with normal fetuses, and no significant difference was found between cytolic functions in both groups. Similarly, the results of cardiothoracic ratio, left spherical index, and right spherical index were compared between the two groups to compare the morphological characteristics of the heart, and no significant difference was found (Table 2).

Table 2. Diastolic, systolic and diastolic-systolic function parameters and morphometric values of fetal heart in fetal kidney disease and control group

	Renal disease (n=31)	Control (n=30)	p
Diastolic function			
Left ventricle MPI[a]	0.51±0.01	0.54±0.01	0.09
Mitral maximum E wave velocity (m/s)	39±2.14	41±1.95	0.18
Mitral maximum A wave velocity (m/s)	61±3.22	62±2.65	0.64
Mitral E/A	0.64±1.16	0.66±0.21	0.09
Right ventricle MPI[a]	0.53±0.02	0.55±0.01	0.1
Tricuspid maximum E wave velocity (m/s)	48±2.14	44±1.95	**0.044**
Tricuspid maximum A wave velocity (m/s)	66±2.21	62±1.32	**0.046**
Tricuspid E/A	0.73±2.12	0.71±1.28	0.09
Systolic function			
Heart rate, bpm	142	140	0.14
MAPSE[b] (mm)	7.28±0.98	7.02±0.80	0.28
TAPSE[b] (mm)	7.68±0.98	7.22±0.80	0.26
Mitral S (cm/sn)	6.6±0.56	6.5±0.8	0.40
Tricuspid S (cm/sn)	7.9±0.56	7.2±0.8	0.22
Cardiac morphometry			
Cardiothoracic ratio	0.31±0.2	0.30±0.2	0.35
Left spherical index	1.95±0.04	1.85±0.06	0.09
Right spherical index	0.77±0.08	0.68±1.28	**0.048**

Mann Whitney U test was performed; a: myocardial performance index, b: mitral annular plane systolic excursion, c: tricuspid annular plane systolic excursion; results were accepted as 95% confidence interval and p value <0.05 significant

DISCUSSION

The most frequently detected renal diseases in the fetal period: fetal hydronephrosis, polycystic kidney disease, pelvicalyceal ectasia. Fetal hydronephrosis may be unilateral or bilateral. Fetal renal disease is easily detected here with fetal ultrasound. We included the cases of unilateral hydronephrosis, bilateral hydronephrosis, polycystic kidney and pelvicalyceal ectasia (2,19,20). The fact that the functional parameters were normal and the right spherical index was higher in the fetal renal disease than in the control group suggests that early-onset cardiac overload may be present morphologically, if not functionally.

Studies have shown that diagnosed fetal renal disease may have hemodynamic effects. The studies used hemodynamic effects in fetal renal artery and descending aorta Doppler parameters. However, the studies investigating the cardiac functions and renal hemodynamic effects in fetal renal disease in the fetal period are insufficient (3,21-23). In this study, we investigated the umbilical artery, MCA Doppler parameters of fetuses with renal disease in the fetal term, fetal renal arteries, and also showed the systolic and diastolic functional parameters of the heart and the results of the morphological structure of the heart. The cases with fetal renal disease included in the study were compared with normal fetuses at the same gestational week.

Wladimiroff et al. studied the PI of renal arteries in patients with bilateral hydronephrosis, unilateral hydronephrosis, and unilateral multicystic kidney. In this study, the majority values of the renal artery PI did not differ from normal values in both bilateral and unilateral obstructive uropathy (4). Gudmundsson et al. obtained similar results in their studies (24). In two studies by Lura, the use of PI in renal disease showed little change with gestational age and no statistically significant difference was found (2,3). However, Wladimiroff et al. showed a positive correlation between renal artery PI and severe hydronephrosis. In patients with multicystic kidneys, the renal artery PI was found to be above the normal range in two quarters (4). Among the fetuses in our study, only one case with bilateral hydronephrosis had a high renal artery value PI. When we consider the umbilical artery values PI of all cases, high PI values were observed in 2 bilateral hydronephrosis cases and in 2 unilateral hydronephrosis cases. Values close to the 95% percentile limit were observed in 2 isolated cases of pelvicalyceal ectasia. For MCA pulsatility indices, PI values were high in 2 cases of bilateral hydronephrosis and 2 cases of isolated pelvicalyceal ectasia. MCA PI -Values were in the 50-95th percentile range in most patients with renal disease. Apart from renal artery values PI, it should be noted that umbilical artery and MCA PI values can also provide valuable results in renal disease.

In previous studies, fetal MPI has been increasingly used as an indicator of fetal cardiac function in various pathologies, including intrauterine growth retardation and twin-to-twin transfusion syndrome. as well as in diabetic pregnancies (16,17). In our study, when the right and left MPI values of fetuses with renal disease were compared with normal fetuses, there was no significant result, but the E and A values of the tricuspid valve were higher than normal values (p<0.05). The difference between E/A values of the tricuspid valve was insignificant. The E wave is caused by the pressure in the ventricles falling below the pressure in the atria during the cardiac cycle, and therefore atrial pressure is affected by ventricular compliance and the rate of relaxation of the ventricles. The A wave or wave of atrial contraction is located immediately after the E wave in Doppler flow analysis. It is influenced by ventricular compliance, atrial pressure, and atrial contraction rate. The E and A waves are influenced by preload and afterload. In the fetal period, the A velocity is greater than the E velocity. Flow, preload, and heart rate (including arrhythmias) change with age (25,26). The proportional increase in E and A velocities of tricuspid flow in the group with renal disease may actually be related to increased preload rather than diastolic dysfunction. The fact that the functional parameters were normal in the fetal renal disease detected in our study and the right spherical index was higher than in the control group supports this situation.

When TAPSE, MAPSE, mitral S, and tricuspid S results were compared to evaluate systolic functions of fetuses with renal disease with normal fetuses, no significant difference was found between cytolic functions in both groups. In fact, in fetuses with renal disease, except for the abnormally high values in bilateral hydrops fetalis, there were no major changes in umbilical artery, renal artery, and MCA Doppler data, and cardiac morphology and systolic and diastolic functions were hardly affected. There may be volume loading on the right side of the heart that does not affect cardiac functions. The fact that MCA PI values are above the mean in most patients with renal pathology may be explained by a volume load that is higher than expected hemodynamically (25).

Limitations

Our study has some limitations. First of all, our sample size is partially small. Although prenatal ultrasound has revolutionized the management of renal anomalies by providing definitive, early intervention, it also reveals the vast majority of clinically and literally "not sick" newborns.

CONCLUSION

In summary, we can use fetal echocardiography analysis methods to reveal the hemodynamic influence and cardiac function in the prenatal period with sensitive measurements. In contrast to previous studies, it may be useful to use other criteria that indicate hemodynamic changes. In particular, in fetuses with renal disease, the PI values of the renal artery, umbilical artery, and MCA, as well as the E and A velocity values of the tricuspid valve, may be evaluated differently than in normal fetuses. In addition, the high right spherical index indicates that there may be a morphological burden on the right heart in fetal kidney disease that does not affect the functional parameters. However, to make the results more meaningful and reliable, more comprehensive studies are needed that include cases with multiple fetal kidney diseases.

Financial disclosures: *The authors declared that this study has received no financial support.*

Conflict of interest: *The authors have no conflicts of interest to declare.*

Ethical approval: *The study protocol was approved by Ankara Etlik Zubeyde Hanim Women's Health Training and Research Hospital Ethical Committee Approval with the decision number of 05/01/2022/3. The authors have confirmed that they have complied with the World Medical Association Declaration of Helsinki regarding the ethical conduct of research involving human subjects.*

REFERENCES

1. Chittty LS, Pembrey ME, Chudleigh PM, Campbell S. Multicenter study of antenatal calyceal dilatation detected by ultrasound. The Lancet. 1990;336:p875.
2. Iura T, Makinoda S, Miyazaki S, et al. Prenatal diagnosis of the hemodynamics of fetal renal disease by color Doppler ultrasound. Fetal Diagn Ther. 2003;18:148-53.
3. Iura T, Makinoda S, Tomizawa H, et al. Hemodynamics of the renal artery and descending aorta in fetuses with renal disease using color Doppler ultrasound–longitudinal comparison to normal fetuses. J Perinat Med. 2005;33:226-31.
4. Wladimiroff J, Heydanus R, Stewart P, et al. Fetal renal artery flow velocity waveforms in the presence of congenital renal tract anomalies. Prenat Diagn. 1993;13:545-9.
5. Valenzuela-Alcaraz B, Crispi F, Cruz-Lemini M, et al. Differential effect of assisted reproductive technology and small-for-gestational age on fetal cardiac remodeling. Ultrasound Obstet Gynecol. 2017;50:63-70.
6. Crispi F, Valenzuela-Alcaraz B, Cruz-Lemini M, Gratacós E. Ultrasound assessment of fetal cardiac function. Australas J Ultrasound Med. 2013;16:158-67.
7. Wosiak A, Niewiadomska-Jarosik K, Zamojska J, et al. Myocardial dysfunction in children with intrauterine growth restriction: an echocardiographic study. Cardiovasc J Afr. 2017;28:36-9.
8. DeVore G, Zaretsky M, Gumina D, Hobbins J. Right and left ventricular 24-segment sphericity index is abnormal in small-for-gestational-age fetuses. Ultrasound Obstet Gynecol. 2018;52:243-9.
9. Wisser J, Hebisch G, Froster U, et al. Prenatal sonographic diagnosis of autosomal recessive polycystic kidney disease (ARPKD) during the early second trimester. Prenat Diagn. 1995;15:868-71.
10. Zerres K, Mücher G, Becker J, et al. Prenatal diagnosis

of autosomal recessive polycystic kidney disease (ARPKD): molecular genetics, clinical experience, and fetal morphology. Am J Med Genet. 1998;76:137-44.

11. Roth JA, Diamond DA. Prenatal hydronephrosis. Curr Opin Pediatr. 2001;13:138-41.
12. Thompson R, Trudinger B, Cook C. A comparison of Doppler ultrasound waveform indices in the umbilical artery—I. Indices derived from the maximum velocity waveform. Ultrasound Med Biol. 1986;12:835-44.
13. Acharya G, Wilsgaard T, Berntsen GKR, et al. Reference ranges for serial measurements of umbilical artery Doppler indices in the second half of pregnancy. Am J Obstet Gynecol. 2005;192:937-44.
14. Srikumar S, Debnath J, Ravikumar R, et al. Doppler indices of the umbilical and fetal middle cerebral artery at 18–40 weeks of normal gestation: a pilot study. Med J Armed Forces India. 2017;73:232-41.
15. Zimmermann R, Eichhorn K, Huch A, Huch R. Doppler ultrasound examination of fetal renal arteries. Ultrasound Obstet Gynecol. 1992;2:420-3.
16. Zanardini C, Prefumo F, Fichera A, et al. Fetal cardiac parameters for prediction of twin-to-twin transfusion syndrome. Ultrasound Obstet Gynecol. 2014;44:434-40.
17. Sanhal CY, Daglar HK, Kara O, et al. Assessment of fetal myocardial performance index in women with pregestational and gestational diabetes mellitus. J Obstet Gynaecol Res. 2017;43:65-72.
18. Paladini D, Chita S, Allan L. Prenatal measurement of cardiothoracic ratio in evaluation of heart disease. Arch Dis Child. 1990;65:20-3.
19. Gunn TR, Mora JD, Pease P. Antenatal diagnosis of urinary tract abnormalities by ultrasonography after 28 weeks' gestation: incidence and outcome. Am J Obstet Gynecol. 1995;172:479-86.
20. Dias T, Sairam S, Kumarasiri S. Ultrasound diagnosis of fetal renal abnormalities. Best Pract Res Clin Obstet Gynaecol. 2014;28:403-15.
21. Rotmensch S, Liberati M, Celentano C, et al. The effect of betamethasone on fetal biophysical activities and Doppler velocimetry of umbilical and middle cerebral arteries. Acta Obstet Gynecol Scand. 1999;78:768-73.
22. Sepulveda W, Dezerega V, Carstens E, Gutierrez J. Fused umbilical arteries: prenatal sonographic diagnosis and clinical significance. J Ultrasound Med. 2001;20:59-62.
23. Wladimiroff JW, vd Wijngaard JA, Degani S, et al. Cerebral and umbilical artery blood flow velocity waveforms in normal and growth-retarded pregnancies. Obstet Gynecol. 1987;69:705-9.
24. Gudmundsson S, Neerhof M, Weinert S, et al. Fetal hydronephrosis and renal artery blood velocity. Ultrasound in Obstetrics and Gynecology: Ultrasound Obstet Gynecol. 1991;1:413-6.
25. Tissot C, Singh Y, Sekarski N. Echocardiographic evaluation of ventricular function—for the neonatologist and pediatric intensivist. Front Pediatr. 2018;6:79.
26. Lopez L, Colan SD, Frommelt PC, et al. Recommendations for quantification methods during the performance of a pediatric echocardiogram: a report from the Pediatric Measurements Writing Group of the American Society of Echocardiography Pediatric and Congenital Heart Disease Council. J Am Soc Echocardiogr. 2010;23:465-95.