Original Article

Establishing Normal Range Of Fetal Renal Artery Resistivity And Pulsatility Index Values In Singleton Pregnancies During 18-38 Weeks Of Gestation

Beenish Nadeem[1], Naushaba Malik[2], Anam Zahoor[3]

[1] Consultant Radiologist, PESSI Hospital, Islamabad.
[2] Head of Radiology, PESSI Hospital, Islamabad
[3] Assistant Professor RMU and Allied Hospitals, Rawalpindi

Author's Contribution
[1] Conception of study
[1] Experimentation/Study conduction
[3] Analysis/Interpretation/Discussion
[1,3] Manuscript Writing
[2] Critical Review
[2] Facilitation and Material analysis

Corresponding Author
Dr. Beenish Nadeem
Consultant Radiologist
PESSI Hospital
Islamabad
Email: beenishnadeem15@yahoo.com

Article Processing
Received: 02/11/2022
Accepted: 13/03/2023

Cite this Article: *Nadeem, B., Malik, N., & Zahoor, A. (2023). Establishing Normal Range Of Fetal Renal Artery RI And PI Values In Singleton Pregnancies During 18-38 Weeks Of Gestation. Journal of Rawalpindi Medical College, 27(1).*
DOI: https://doi.org/10.37939/jrmc.v27i1.2061

Conflict of Interest: *Nil*
Funding Source: *Nil*

Abstract

Objective: Our study aims at establishing a normal reference range for fetal renal artery indices in a healthy Pakistani pregnant population which has not been done before.

Methodology: This is a nonprobability convenient study investigating 130 healthy pregnant women during 18-38 weeks of gestation. Resistivity and pulsatility indices (RI and PI) of the fetal renal arteries were evaluated by dividing the patients into four groups as per their gestational age. Normal reference ranges of RI and PI values were established. P values for RI and PI were also calculated.

Results: Mean values of the RI and PI of the fetal renal arteries were calculated. The p-value for RI is 0.05 and PI is 0.69. Hence the values remain unaltered with advancing gestational age.

Conclusions: These reference ranges demonstrate the minimal change of fetal renal hemodynamics during healthy pregnancies pertinent to our reference population. These may be applicable in antenatal practice to identify deviations from these reference ranges and will be beneficial in further studies related to the prediction of fetal renal function.

Keywords: Fetal renal artery; antenatal pulse wave doppler; pulsatility; resistivity; normal range.

Introduction

The human kidney constitutes an important organ during the period of embryogenesis. The development of fetal nephrons is a complex process that starts in early gestation and continues till term 1. The latter half of the second trimester and third trimester is considered the most crucial phase of renal development[2]. The use of regular ultrasound during antenatal follow-ups not only assesses structural aspects of the fetal body but can also evaluate the functional integrity of fetal organs[3].

The kidney is a vulnerable organ and gets affected by fetal growth restriction and hypoxia. In such cases, the continuous shifting of blood to organs like the brain and heart causes undetectable renal damage which is to be investigated upon [4]. Modern studies have used Sono graphically derived fetal Doppler waveforms for evaluating fetal circulation. These waveforms not only vary with fetal growth discrepancies but also affect the amount of amniotic fluid[6]. Evaluation of renal hemodynamics in a better way can also aid in sorting out different renal diseases like multicyclic dysplastic kidney and autosomal recessive polycystic kidney. However, this still marks a challenge and needs to be explored more[7].

Unfortunately, fetal renal hemodynamics has been studied more in Western populations which have better socio-economic status and good antenatal care, unlike developing countries.

Materials and Methods

This research is being conducted at the radiology department of Social Security Hospital Islamabad from 15-07-2022 to 15-10-2022. The sample size was calculated using the WHO sample size calculator taking the mean value of PI as 2.4 with +/- standard deviation of 0.29 with a confidence interval of 95% and a power of test of 80%[8] using SPSS version 23. This is a non-probability consecutive sampling that includes healthy pregnant females between 18 to 38 weeks of gestation. Patients with uncertain last menstrual period date, diagnosed fetal anomalies, multiple gestations, and other maternal co-morbid, and growth-restricted fetuses are excluded from our research.

Official approval from the ethical committee had been acquired (Certificate # SSR/Hospital 14). After obtaining written consent from patients, a questionnaire (Annexure A) was filled out. All pregnant females under study were evaluated by a senior radiologist to minimize the probability of technical errors. All patients were evaluated on a real-time ultrasound machine (GE Health care, LOGIC P6, USA) with a 3.75 MHz curvilinear probe. Using a coronal view, fetal kidneys were evaluated, fetal renal arteries were traced, and RI and PI values were evaluated by pulse wave Doppler ultrasound. Both right and left renal arteries were evaluated randomly and the data was collected and entered into SPSS (version 23). Other quantitative variables like the age of the mother, gestational age, and laterality of the fetal kidney were also analyzed and presented as mean ± standard deviation. A hypothesis was made presuming a change in RI and PI values with increasing gestational age. Student t-test was applied and the p-value for RI and PI was determined.

Results

In total 130 females were recruited in the study; ultrasound scans were performed between 18 and 38 weeks of gestational age according to the inclusion and exclusion criteria mentioned above. Four gestational age groups were made for study purposes. The mean age of the females was 28.7 years with SD of 5.17 years. (Table No. 1)

Table-1. Maternal age in years with respect to the gestational age in weeks

	Gestational Age in weeks						
		18 to 23	24 to 28	29 to 33	34 to 38	n	%
Age of patient in years	< 20	3	3	1	1	8	6.2
	21 to 30	20	14	23	16	73	56.2
	31 to 40	19	5	18	7	49	37.7
Total		42	22	42	24	130	100.0

When maternal age groups were compared with a number of previous pregnancies, the following data was obtained.

All females who were less than 20 years of age were primigravidae. There were 53 females in age group 21-30 years who were primigravida whereas 20 in the same group were multigravida. In the maternal age group 30-40, there were 38 females who were multi gravida and 11 were primigravida.

Table-2. Maternal age groups with respect to the number of previous pregnancies

Maternal age groups with respect to the number of previous pregnancies					
		Multigravida	**Primigravida**	**n**	%
Age Group	**< 20**	**0**	**8**	**8**	6.2
	21 to 30	20	53	73	56.2
	31 to 40	38	11	49	37.7
Total		**58**	**72**	**130**	**100**
		44.6%	55.4%		

In 50 cases right, the fetal kidney was taken as a reference while in 80 cases left, the kidney was taken into consideration for measurements. The mean RI of the fetal renal artery was 0.75 with the highest being 0.91 and lowest being 0.49 and SD 0.087. While the mean PI for the scans done was 1.63 where the highest being 2.90 and the lowest 1.01 and SD 0.34.

Details of RI and PI in our population for various gestational ages are shown in table no. 3.3. Data was stratified for various age groups and gestational age groups; the difference was significant for various age groups (p-value = 0.0001) and not significant for various gestational age groups (p-value = 0.99).

The p-value of mean RI was 0.05 0.69 and p-value of PI is 0.069 which is significant. Hence suggested that RI and PI values remain unaltered with increasing gestational age.

Table-3. Comparison of RI and PI with gestational groups in weeks

Descriptive Statistics (n = 130)							
Gestational Age groups		**N**	**Range**	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
18 to 23 wks	Age	42	20.00	19.00	39.00	29.3095	5.48385
	RI		0.41	0.49	0.90	0.7007	0.08696
	PI		1.52	1.08	2.60	1.5617	0.31721
	Gestation Age		5.00	18.00	23.00	20.3810	1.89932
24 to 28 wks	Age	22	20.00	19.00	39.00	27.0909	5.96744
	RI		0.30	0.60	0.90	0.7668	0.07840
	PI		0.70	1.20	1.90	1.5300	0.22213
	Gestation Age		4.00	24.00	28.00	25.6364	1.43246
29 to 33 wks	Age	42	20.00	18.00	38.00	29.8571	4.45887
	RI		0.35	0.55	0.90	0.7664	0.07470
	PI		1.80	1.10	2.90	1.6776	0.36254
	Gestation Age		4.00	29.00	33.00	31.0476	1.41339
34 to 38 wks	Age	24	15.00	19.00	34.00	27.2083	4.53948
	RI		0.26	0.65	0.91	0.7950	0.08054
	PI		1.69	1.01	2.70	1.7650	0.40388
	Gestation Age		4.00	34.00	38.00	35.5417	1.17877

The mean RI and PI values of the fetal renal artery in the four mentioned gestational age groups are also represented through a box plot diagram.

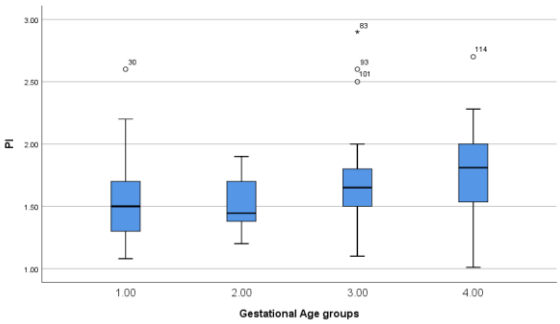

Figure-1: Plot and Whisker of PI and Gestational age groups

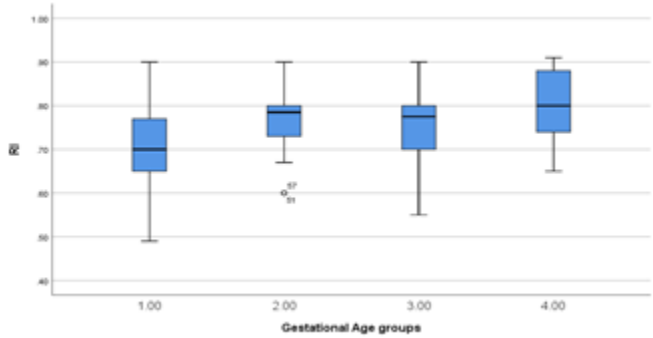

Figure-2: Plot and Whisker of RI and Gestational age groups

Discussion

We aimed to develop standard RI and PI values of fetal renal artery from 18 to 38 gestational weeks by making four gestation age groups. Our study showed that RI and PI values in normal singleton pregnancies are mildly increased with increasing gestation, however, do not show marked variability. Our study has assessed normal RI and PI values in a wide range of gestation so that a comprehensive normal range of fetal renal Doppler indices can be established in our reference population.

Most of the studies done so far on fetal renal artery indices had random inclusive and exclusive criteria hence making comparative evaluation more challenging[9,10].

We made four groups based on gestational age and established mean RI and PI values for each group. The overall RI and PI values show little variability which may be due to the restricted function of the fetal renal artery in prenatal life as the placenta is mostly responsible for fetal excretory functions. It is also important to mention that only 3-7 percent of fetal blood is distributed towards kidneys in prenatal life hence favoring less alteration of fetal renal artery Doppler indices[11].

There are some previous studies that showed a decreasing trend of RI and PI values with increasing gestational age however more data is required to make it an authentic statement[12.] In our study, the data were stratified for various maternal age groups and the difference was found significant for various age groups (p-value = 0.0001), to our knowledge no previous literature is available for comparison of these two variables. Further multicenter studies are needed to validate this point as our study is a single center and also being limited due to the small sample size.

Brennan et al have similar findings to our study. This was a longitudinal study on 155 patients and demonstrated standard normograms of PI and RI values of the fetal renal artery in a wide range of gestational ages, the mean PI was 2.4 while the mean RI was 0.9.[13]

A study conducted on the Thai population also established mean RI and PI values of the fetal renal artery in the otherwise normal pregnant cohort.[14] It is of pertinent importance that the mean RI and PI

Figure 2
The side of fetal kidney (right or left) was selected randomly, and mean RI and PI values were evaluated for each side respectively. (Table 4)

Table-4. RI and PI values with respect to the side of the fetal kidney

	Side of kidney	*N*	*Mean*	*Std. Deviation*	*Std Error Mean*
RI	L	50	.7618	.08448	.01195
	R	80	.7435	.08896	.00995
PI	L	50	1.6080	.39112	.05531
	R	80	1.6459	.31242	.03493

values in our study population demonstrated a relatively lower range as compared to the above studies. The comparatively lower range of doppler indices as compared to international studies can be due to different socio-economic backgrounds and racial characteristics. This further strengthened our idea of proposing normal fetal renal Doppler indices exclusive to our population.

It is also worth mentioning that there is an established variation in Doppler indices values due to inevitable factors like unpredicted fetal mobility, respiratory movements, and cardiac motion. Also, doppler values are highly dependent on the technique and expertise of the attending radiologists and it's not a mere two-dimensional fetal biometric measurement. Hence more refined Doppler techniques are needed to reduce observational errors[15-17].

An interesting study has been carried out by Barbero et al pregnant sheep, demonstrating early changes in fetal renal indices in malnourished cases as compared to those who had a healthy nutritious diet. Keeping in view the level of poverty and low socio-economic status of our country, this study can be helpful in the early detection of fetal hypoxia in the targeted population[18.]

A comparative study conducted in India evaluated fetal renal artery and umbilical artery Doppler indices in normal versus growth-restricted fetuses. The author established that fetal renal artery indices could be a reliable predictor for detecting adverse perinatal outcomes in growth-restricted fetuses[19].

Another study focused on the importance of establishing normograms of renal artery indices from the last three months of gestation until six months of post-natal life. The author predicted the importance of this research in the early detection of obstructed uropathies in the late antenatal and immediate post-natal phases. This study measured RI of the fetal renal artery in the late trimester which ranged from 0.67 to 0.88, also there was no difference among values of right or left kidney[20]. The result was quite similar to our study where no marked variability was noted between right and left-sided renal artery Doppler indices.

Another research studied fetal renal artery indices and established its relationship with fetal urinary output which directly affects the amount of liquor. More research studies are warranted to look for fetal renal artery indices with poly and oligohydromnios[21].

The main limitation of our study is that it's a pioneer study of our population with a small sample size which is not sufficient enough to represent whole community which has variable socio-economic characteristics. Further studies in this subject are thus necessary to check for the validity of the reference ranges established through our research work.

The main scope of our study is to introduce new doppler parameters for evaluating fetal status other than the routinely evaluated doppler indices like that of umbilical artery and middle cerebral artery. We intend to establish a normal range of fetal renal artery RI and PI values that will further help in evaluating fetal growth restriction keeping in mind the compensatory blood redistribution away from fetal kidneys in such cases.

Conclusion

These reference ranges demonstrate the minimal change of the fetal renal hemodynamics during healthy pregnancies pertinent to our reference population. These may be applicable in antenatal practice to identify deviations from these reference ranges and will be beneficial in further studies related to prediction of renal function.

References

1- Ryan D, Sutherland MR, Flores TJ, Kent AL, Dahlstrom JE, Puelles VG, Bertram JF, McMahon AP, Little MH, Moore L, Black MJ. Development of the Human Fetal Kidney from Mid to Late Gestation in Male and Female Infants. EBioMedicine. 2018 Jan;27:275-283. doi: 10.1016/j.ebiom.2017.12.016. Epub 2017 Dec 20.

2- Rosenblum S, Pal A, Reidy K. Renal development in the fetus and premature infant. Semin Fetal Neonatal Med. 2017 Apr;22(2):58-66. doi: 10.1016/j.siny.2017.01.001. Epub 2017 Feb 1.

3- Alia, N., Ahmed, I., Mahais, A.H., & Perveen, N. CONGENITAL ANOMALIES : PREVALENCE OF CONGENITAL ABNORMALITIES IN 2 ND TRIMESTER OF PREGNANCY IN MADINA TEACHING HOSPITAL , FAISALABAD ON GRAY SCALE ULTRASOUND. Journal of University Medical & Dental College.2012.

4- Montaldo P, Puzone S, Caredda E, Pugliese U, Inserra E, Cirillo G, Gicchino F, Campana G, Ursi D, Galdo F, Internicola M, Spagnuolo F, Carpentieri M, Capristo C, Marzuillo P, Del Giudice EM. Impact of intrauterine growth restriction on cerebral and renal oxygenation and perfusion during the first 3 days after birth. Sci Rep. 2022 Mar 24;12(1):5067. doi: 10.1038/s41598-022-09199-5.

5- Schrauben EM, Saini BS, Darby JRT, Soo JY, Lock MC, Stirrat E, Stortz G, Sled JG, Morrison JL, Seed M, Macgowan CK. Fetal hemodynamics and cardiac streaming assessed by 4D flow cardiovascular magnetic resonance in fetal sheep. J Cardiovasc Magn Reson. 2019 Jan 21;21(1):8. doi: 10.1186/s12968-018-0512-5.

6- Veille JC, Kanaan C. Duplex Doppler ultrasonographic evaluation of the fetal renal artery in normal and abnormal fetuses. Am J Obstet Gynecol. 1989 Dec;161(6 Pt 1):1502-7. doi: 10.1016/0002-9378(89)90913-7.

7- Polin RA, Abman SH, Rowitch DH, Benitz WE, Fox WW. Fetal and neonatal physiology. Fifth ed. Philadelphia, PA: Elsevier; 2017.
8- Brennan S, Watson D, Schneider M, Rudd D, Kandasamy Y. Fetal renal artery blood flow - Normal ranges. Ultrasound. 2022 Feb;30(1):62-71. doi: 10.1177/1742271X211022402. Epub 2021 Jun 15.
9- Vyas S, Nicolaides KH, Campbell S. Renal artery flow-velocity waveforms in normal and hypoxemic fetuses. Am J Obstet Gynecol. 1989 Jul;161(1):168-72. doi: 10.1016/0002-9378(89)90257-3.
10- Mari G, Kirshon B, Abuhamad A. Fetal renal artery flow velocity waveforms in normal pregnancies and pregnancies complicated by polyhydramnios and oligohydramnios. Obstet Gynecol. 1993 Apr;81(4):560-4.
11- Doherty TM, Hu A, Salik I. Physiology, Neonatal. 2022 Apr 28. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan.
12- Mari G, Kirshon B, Abuhamad A. Fetal Renal Artery Flow Velocity Waveforms in Normal Pregnancies and Pregnancies Complicated by Polyhydramnios and Oligohydramnios. Obstet Gynecol. 1993;81(4):560-4.
13- Brennan S. The renal parenchyma – evaluation of a novel ultrasound measurement to assess fetal renal development. PhD Thesis, James Cook University.2020.
14- Ponglopisit S, Hanprasertpong T, Geater A, Petpichetchian C, Kor-anantakula O, Leetanaporn R, Suntharasaj T, Suwanrath C, Pruksanusak N, Pranpanus S, Jitpiboon W. Doppler waveform patterns and reference ranges of fetal renal artery blood flow indices in normal Thai fetuses during the second trimester. Asian Biomedicine. 2015;9(2): 217-224. https://doi.org/10.5372/1905-7415.0902.390
15- Doro GF, Senra JC, Rodrigues AS, Miyadahira S, Ribeiro RL, Francisco RPV, et al. Renal vascularization indexes and fetal hemodynamics in fetuses with growth restriction. Prenat Diagn. 2017;37(8):837-42.
16- Tsai P-Y, Chang C-H. Assessment of the blood flow in kidneys of growth-restricted fetuses using quantitative three-dimensional power Doppler ultrasound. Taiwan J Obstet Gynecol. 2018;57(5):665-7.
17- Ali A, Addley S, Ong S. Three-dimensional indices of renal perfusion in normal pregnancy and pre-eclampsia. Ir J Med Sci. 2019;188(1):173-7.
18- Barbero A, Porcu C, Spezzigu A, Succu S, Dattena M, Gallus M, Molle G, Naitana S, Gonzalez-Bulnes A, Berlinguer F. Changes in renal hemodynamics of undernourished fetuses appear earlier than IUGR evidences. J Dev Orig Health Dis. 2018 Jun;9(3):338-343. doi: 10.1017/S204017441800003X. Epub 2018 Jan 28.
19- Mundkur A, Paladugu S, Yedlapalli S, Vasudeva A, Shivananda RP, Hegde N. Performance of Fetal Renal Artery Doppler Compared with Umbilical Artery Doppler in Mild and Moderate Fetal Growth Restriction: An Observational Study in a Tertiary Care Hospital. Int J Infertil Fetal Med 2020; 11 (1):1-4.
20- Andriani G, Persico A, Tursini S, Ballone E, Cirotti D, Lelli Chiesa P. The renal-resistive index from the last 3 months of pregnancy to 6 months old. BJU Int. 2001 Apr;87(6):562-4. doi: 10.1046/j.1464-410x.2001.00085.x.
21- Azpurua H, Dulay AT, Buhimschi IA, Bahtiyar MO, Funai E, Abdel-Razeq SS, Luo G, Bhandari V, Copel JA, Buhimschi CS. Fetal renal artery impedance as assessed by Doppler ultrasound in pregnancies complicated by intraamniotic inflammation and preterm birth. Am J Obstet Gynecol. 2009 Feb;200(2):203.e1-11. doi: 10.1016/j.ajog.2008.11.001