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Original Article

The Association between Fetal Renal Artery Doppler Flow with Hourly Urine Output and Amniotic Fluid Volume of Fetuses with a Gestational Age of 30 to 34 Weeks

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ABSTRACT

Background: The present study investigated the association between fetal renal artery Doppler flow, hourly urine output, and amniotic fluid volume in fetuses with a gestational age of 30 to 34 weeks in normal pregnancies.

Methods: This cross-sectional study was conducted on 95 eligible pregnant women referred for their routine third-trimester care from March 2022 to March 2023. Each fetus's amniotic fluid volume, kidney size, and hourly urine output were recorded in resistance (RI) and plausibility (PI) indexes of the umbilical and renal arteries. The hourly urine production was calculated by considering bladder volume differences at a 30-minute duration.

Results: With gestational age increasing, amniotic fluid volume (p-value=0.005) and the hourly urine output (p-value=0.005) increased significantly. RI of umbilical (p-value=0.022), right (p-value<0.001), and left (p-value=0.001) renal arteries and PI of right (p-value=0.042) and left (p-value=0.001) renal arteries decreased significantly through the pregnancy. There was a negative linear association between RI and PI of the renal arteries with hourly urine output. The results showed that the mean of renal artery Doppler indices, including right and left RI (0.87 ± 0.08 vs. 0.88 ± 0.07, p-value=0.274) and right and left PI (2.52 ± 0.59 vs. 2.56 ± 0.64, p-value=0.614) was similar in both sides. In adjusted linear regression analysis, two variables of gestational age and renal artery RI were (p-value<0.001) significantly associated with hourly urine output.

Conclusion: The fetus's renal artery Doppler findings and urine outputs seem to represent fetal renal function, warning the physicians about post-natal evaluation after birth.

Keywords: Doppler, Umbilical arteries, Ultrasonography

Introduction

Ultrasound is a simple and accessible method regarding fetus evaluation (1). Real-time and Doppler Ultrasound is a non-invasive method of assessing fetal organ status and circulation (4). Amniotic fluid characteristics, assessed by ultrasound, can be one of the indicators of fetal health, especially after the 20th week of pregnancy (2). After about 20 weeks of pregnancy, the fetus's urine makes up most of the amniotic fluid volume, and the amniotic fluid volume remains almost constant between 28 and 34 weeks of pregnancy (3).

Since fetal renal blood supply can be effective in fetal urine production, examining the kidney blood supply by Doppler measurement of the fetal renal artery can be helpful in this field (5). Fetal blood supply is checked by measuring fetal umbilical artery Doppler. In this way, the

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relationship between umbilical artery Doppler and fetal urine production and the amount of amniotic fluid is investigated (5, 6).

Due to the low sensitivity of Doppler examinations, assessing other fetal arteries in addition to the umbilical and cerebral arteries can help better evaluate the fetus's condition. Otherwise, Renal artery Doppler seems to be useful in indirectly evaluating urine output and amniotic fluid level (7). Hence, the present study was conducted to evaluate the association between fetal renal artery Doppler indices with hourly urine output and amniotic fluid volume in fetuses with a gestational age of 30 to 34 weeks.

Methods

This cross-sectional study was conducted on 95 eligible pregnant women referred for routine prenatal care to Shariati Hospital affiliated with Tehran University of Medical Sciences from March 2022 to March 2023.

Inclusion criteria were singleton uncomplicated pregnancies with gestational ages of 30 to 34 weeks. Exclusion criteria were having underlying diseases such as diabetes, hypertension, and collagen vascular diseases or major anomalies in the fetus, as well as unwillingness to participate. A convenience sampling method was used.

In each fetus, the amniotic fluid volume, kidney size, renal, umbilical, and cerebral artery resistance (RI), and plausibility (PI) indexes were measured with real-time and Doppler ultrasound (Philips affinity 70) with a C_9/2 convex probe. According to the Subhash et al. study (1), the hourly urine production was calculated by considering bladder volume differences at a 30-minute duration.

A unique perinatologist performed all Doppler ultrasounds at the time the fetus had minimum movements. At first, the pregnant woman was placed in the left lateral decubitus. The angle between the ultrasound probe and the fetus's blood flow direction was below 30 degrees. The renal artery blood flow was recorded at the level of origin, which is separated from the abdominal aorta. The umbilical artery blood flow was recorded in a free loop of the umbilical cord, far from the fetus and placenta. Three consecutive waveforms were used to calculate the PI and RI.

The Chi-square test (for association between qualitative variables) and T-test (for comparison between quantitative variables) were used for data analysis. Pearson Correlation coefficient and linear regression were also applied for complementary analysis. All analyses were performed using SPSS (Statistical Package for Social Science) version 26 software at a significant level of less than 0.05.

Ethical approval of the study was obtained from the Shariati Hospital ethical board (IR.TUMS.SHARIATI.REC.1402.004) based on the Declaration of Helsinki. All participants signed written informed consent. Before enrolling in the study, the aim of the study was described for all the participants. No additional costs were imposed on the subjects, and their right to stop the study was guaranteed.

According to Subhash et al.'s study (1), the correlation between fetal hourly urine volume and RI of the umbilical artery has been reported as 0.4. using G*Power software under the correlation subgroup, the sample size is considered 88 with a significance level of 5%, power of 90%, and attrition risk of 30%.

Ethical approval

Ethical approval of the study was obtained from the Shariati Hospital ethical board (IR.TUMS.SHARIATI.REC.1402.004) based on the Declaration of Helsinki.

Results

The mean age of participants was 31.2 ± 6.6 years, the mean number of pregnancies was 2.1 ± 1.1 times, and the average gestational age was 32.2 ± 1.3 weeks. About half of the fetuses were boys, with a mean weight of 1995.43±359.87 grams (Table 1).

With gestational age increasing, amniotic fluid volume (p-value=0.005) and the hourly

Table 1. The demographic and clinical history of the mothers and fetuses

Variable	Mean±SD or Number (%)
Number of pregnant women	95
Age (years)	31.2±6.6
Number of pregnancies (times)	2.1±1.1
Gravida (times)	
1-2	66 (69.5)
3-4	25 (26.3)
>4	4 (4.2)
Gestational age (week)	32.2±1.3
Body mass index (km/m^2)	28.4±2.2
Hemoglobin (mg/dl)	12.2±1.4
Hematocrit (%)	36.7±3.8
Fetus sex	
Boy	46 (48.4)
Girl	49 (51.6)
Fetus weight (gram)	1995.43±359.87

Table 2. Doppler ultrasound results of uterine volume, umbilical artery, fetal kidney artery, fetal middle cerebral artery and amniotic fluid amount according to gestational age

Variable	Gestational age < = 32 w (N=46)	Gestational age > 32 w (N=49)	Total (N=98)	p-value
Placenta thickness	4.04±0.62	4.30±0.75	4.17±0.70	0.070
Amniotic fluid volume	13.62±3.27	15.26±2.16	14.46±2.86	0.005
Umbilical artery RI	0.64±0.05	0.61±0.05	0.62±0.05	0.022
Umbilical artery PI	1.01±0.10	0.97±0.12	0.99±0.11	0.123
Cerebral artery PSV	42.08±7.33	47.39±8.72	44.82±8.46	0.002
Cerebral artery RI	0.89±0.09	0.90±0.09	0.89±0.09	0.586
Cerebral artery PI	2.36±0.62	2.27±0.49	2.31±0.56	0.438
RK RI	0.90±0.07	0.83±0.08	0.86±0.08	<0.001
RK PI	2.65±0.71	2.39±0.41	2.52±0.59	0.042
RK length	3.84±0.33	3.96±0.49	3.89±0.42	0.160
RK width	1.99±0.31	2.08±0.30	2.03±0.31	0.163
RK calis	0.34±0.07	0.37±0.11	0.35±0.09	0.129
LK RI	0.91±0.07	0.89±0.07	0.88±0.07	0.001
LK PI	2.79±0.76	2.35±0.40	۴±0.6۴2.5	۱0.00
LK length	3.96±0.43	4.09±0.46	4.02±0.44	0.143
LK width	2.15±0.40	2.18±0.28	2.17±0.34	0.745
LK calis	0.34±0.09	0.35±0.07	0.34±0.08	0.496
Hourly urine output	18.38±4.50	26.79±8.08	22.72±7.80	< 0.001

RI: resistance index, PI: plausibility index, PSV: Peak systolic velocity, RK: right kidney, LK: left kidney

urine output (p-value=0.005) were increasing significantly. RI of umbilical (p-value=0.022), right (p-value<0.001), and left kidneys (p-value=0.001) and PI of right (p-value=0.042) and left kidneys (p-value=0.001) decreased significantly with the gestational age advanced (Table 2).

There was a negative linear association between RI and PI of the renal arteries with hourly urine output. No significant association existed between these indexes and amniotic fluid volume (Table 3).

The results showed that the mean of renal artery Doppler indices, including right and left RI (0.87 ± 0.08 vs. 0.88 ± 0.07, p-value=0.274) and right and left PI (2.52 ± 0.59 vs. 2.56 ± 0.64, p-value=0.614) was similar in both sides. In adjusted linear regression analysis, two variables of gestational age and renal artery RI were (p-value<0.001) associated with hourly urine output significantly (Table 4).

Table 3. Correlation between infant's renal artery indices with the amniotic fluid volume and the one-hour urine output of the fetus

Variables		Right renal artery RI	Right renal artery PI	Left renal artery RI	Left renal artery PI
Amniotic fluid volume	r	-0.007	0.053	-0.067	0.099
	p-value	0.947	0.609	0.520	0.340
One-hour urine output	r	-0.541	-0.395	-0.455	-0.443
	p-value	<0.001	<0.001	<0.001	<0.001

RI: resistance index, PI: plausibility index

Table 4. The crude and adjusted logistic regression for estimating urine output

Variables	Univariate regression		Multivariable regression	
	B	P-value	B	P-value
Gestational age	0.01	<0.001	2.16	<0.001
Umbilical artery RI	-24.76	0.059	-3.28	0.814
Umbilical artery PI	-10.39	0.079	-5.74	0.359
Renal artery RI	-51.10	<0.001	-30.20	<0.001
Renal artery PI	-5.19	<0.001	-1.92	0.093

RI: resistance index, PI: plausibility index

Discussion

The results of the present study showed that there was a negative linear association between RI and PI of the renal artery with hourly urine output. These findings are largely consistent with the results of studies by Suban (1) and Seravalli (3) et al. Suban et al.'s study (1), which was done on 110 fetuses aged 19-40 weeks, confirmed the relationship between renal artery RI and fetal urine production (1). In Seravalli et al.'s study (3), the relationship between renal artery PI and amniotic fluid reduction in fetuses aged 17 to 38 weeks was detected.

In Brennan et al.'s study (9), it was confirmed that standard graphs of renal artery RI and fetal renal artery PI can be used to examine the clinical

function of the renal artery and, as a result, the normal function of the fetal kidney, but this measurement is necessary to be done continuously and accurately. Shoari et al. (10) showed that the color Doppler of the umbilical artery has no significant relationship with the state of the fetal kidney artery, especially the PI of the renal artery, and the ultrasound findings of the umbilical artery cannot be used to determine the state of the fetal kidneys. It is necessary to perform an ultrasound of the renal artery itself. The findings of the above two studies have emphasized the importance of examining the renal artery of newborns in assessing their health, which is completely consistent with the present findings.

The value of the Amniotic fluid index (AFI) varies according to the gestational age. In general, after the 30th week of pregnancy, the normal value of AFI is between 10 and 20 centimeters (cm). A value of less than 5 cm is defined as oligohydramnios, and more than 24 cm is hydramnios. hydramnios significantly increases perinatal mortality whenever AFI is defined as more than 24-25 cm (11, 12).

Many studies have stated that the renal vascular index of the fetus, and subsequently, the amount of urine produced by the fetus (which changes the volume of amniotic fluid) is one of the most important criteria for evaluating the fetus's health. In fetuses that suffer intrauterine growth delay for any reason, indicators of renal vessels and amniotic fluid volume change significantly (13, 14).

A study by Doro et al. aimed to identify the relationship between renal vascular index (PI and RI), amniotic fluid index, and hemodynamics of the placenta and fetus stated that the renal vascular indices decreased in fetuses that show hemodynamic disorders, but the amniotic fluid index usually has not a significant change (15).

Evaluating blood flow in the renal artery, especially the PI pulse index, is one of the most important indicators of fetal health evaluation. This index shows the mechanisms of concentration of blood circulation in case of fetal distress. Assessment of blood flow in fetal vessels is an important element in prenatal diagnosis. Amniotic fluid volume can also help in this field, but it is not as useful as renal artery indices (16, 17). All the results of the above studies align with our study's findings and show the importance of renal vascular indices and the measurement of amniotic fluid volume in the assessment of fetal health.

Today, using various vascular indicators, especially the umbilical and renal vessels and even the middle cerebral vessels, which are usually checked with Doppler ultrasound, is vital in evaluating the fetus's health and in different months of pregnancy and is usually used. Correct and timely use of these indicators can detect a large number of fetal, placental, and maternal disorders, even in the early stages (18, 19).

One of our study limitations was the lack of applying 3D ultrasound in the urine output measurements and the long follow-up of the neonate, which are suggested to be considered in future studies.

Conclusion

Finally, the results of this research showed a negative linear association between the renal artery RI and PI and hourly urine output. The mean renal artery Doppler indices, including right and left RI and PI, were similar and possibly used interchangeably. The fetus's renal artery Doppler findings and urine outputs seem to represent fetal renal function, warning physicians about post-natal evaluation after birth.

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Authors' contribution

MNa conceptualized this study, MNo supervised the project, provided important intelligence input, and critically revised the manuscript. NN and NT performed computational studies and analyzed the data. NN and LM drafted the manuscript; all authors read and approved the final version of the manuscript before submission.

Conflicts of interest

The authors declare there is no conflict of interest.

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