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Renal Artery Doppler Studies in Intrauterine Growth Restriction Fetuses

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Abstract:

Intrauterine growth restriction (IUGR) is a condition in which the fetus fails to achieve its genetically determined growth potential and is associated with increased perinatal morbidity and mortality. Doppler ultrasonography has become a crucial non-invasive tool for monitoring fetoplacental and fetal circulations, providing valuable information on hemodynamic adaptation. Among these, renal artery Doppler studies offer insights into fetal redistribution of blood flow and kidney perfusion, which may reflect the severity of growth restriction.

Keywords: IUGR; Fetal growth restriction; Renal artery Doppler; Umbilical artery; Middle cerebral artery; Fetal circulation; Perinatal outcome.

Introduction:

Intrauterine growth restriction is a major obstetric problem, affecting 5–10% of pregnancies, and is strongly associated with adverse perinatal outcomes **(1).**

Doppler studies of the umbilical and middle cerebral arteries are widely used to assess fetoplacental circulation, but they may not always fully reflect redistribution of blood flow to vital and non-vital organs **(2).**

Renal artery Doppler has been proposed as a useful adjunct, as changes in resistance index and pulsatility index may indicate decreased renal perfusion and preferential shunting of blood to the brain in IUGR fetuses **(3).**

Abnormal renal artery Doppler indices have also been correlated with oligohydramnios and adverse neonatal outcomes, highlighting their potential value in clinical practice **(4).**

The renal arteries arise directly from the aorta just below the projection of the 12th rib and below the superior mesenteric artery. The left renal artery is usually a little higher and longer than that on the right. Close to the renal hilum the renal arteries divide into multiple branches with large anterior and posterior branches. These branches in turn divide into large segment arteries, which eventually terminate in arcuate arteries (**5**)**.**

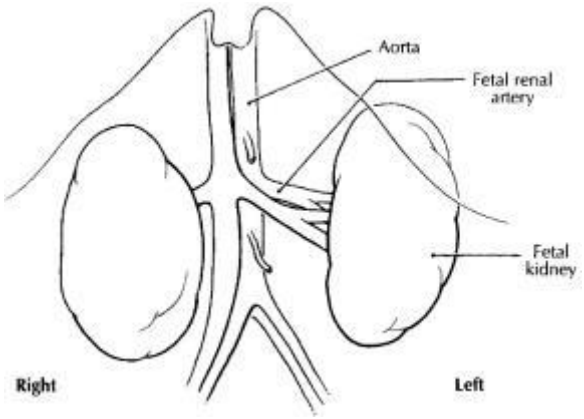

Figure (**1**)**:** Fetal Renal Artery **(6)**

The best way to assess the renal arteries is to find the abdominal aorta and the renal hilum using a coronal axis view. The renal arteries are usually seen arising from the lateral aspect of the abdominal aorta. The superior artery is often difficult to visualize in the fetus compared to that in the adult, but the renal artery can be seen using a multipurpose midfrequency scanhead (35 MHz)(**5**)**.**

The abdominal aorta and fetal kidney should be localized first using a two-dimensional examination. The Doppler cursor is placed in the area where the ultrasonographer suspects the renal artery to be, with the Doppler sample volume and Doppler angle adjusted prior to turning on the Doppler instrument **(Fig. 2)** so Doppler ultrasound exposure is minimized (**7**)**.**

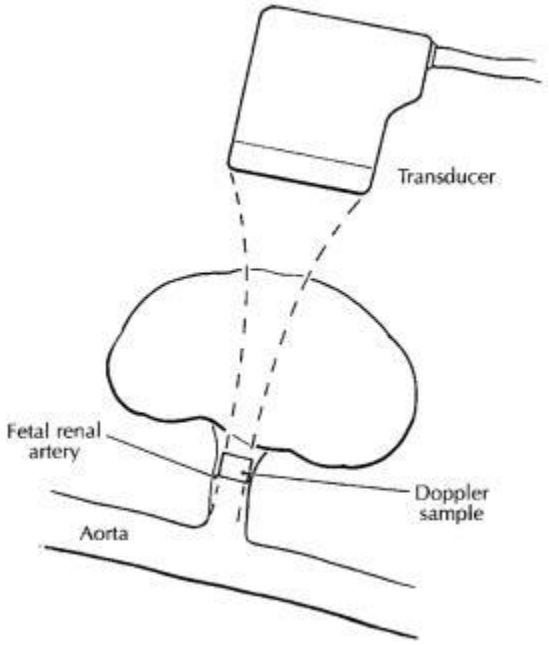

Figure (2)**:** Doppler sample is placed on the area of the fetal renal artery **(6)**

The renal artery Doppler waveform has a characteristically high peak forward velocity and low but continuous forward flow during diastole that is easily differentiated from the adjacent fetal abdominal aorta. Like any other Doppler examination, the renal velocity waveforms should be obtained during a period of fetal quiescence. The velocity waveforms should be recorded at a fast speed, with the lowest pass filter. Using these guidelines, most ultrasonographers can obtain adequate Doppler waveforms from these small renal vessels. It is of the utmost importance to minimize Doppler and color exposure, as the safety of such techniques on human fetuses has not been fully evaluated (**7**)**.**

The diastolic flow of the fetal renal artery is a low-impedance/low-resistance flow, the diastolic flows are not as high as those observed in the umbilical artery. Diastolic flow of this vascular bed has always been present in normal fetuses at gestational ages of less than 16 weeks. Absent or reverse diastolic flows of this vascular bed in the fetus should be considered abnormal. It is imperative to keep the wall filter at a minimum to avoid causing artifacts that may have serious clinical implications. When this circulation is quantitatively assessed, in addition to the problems associated with signal acquisition it is important to understand the Doppler waveform **(8).**

Clinical Application: Fetal Renal Artery Doppler Assessment:

The first report on noninvasive measurement of human circulation using ultrasound was published in 1977 by FitzGerald and Drumm. Since then, numerous papers have emerged in the literature describing application of the technique to the study of maternal, placental, and fetal circulations (**9**)**.**

Renal Artery Doppler Studies in the Normal Fetus:

Vyas et al. established reference ranges for the PI of the fetal renal artery in a cross-sectional study done on 114 human fetuses between weeks 17 and 43 of gestation. In the normal human fetus, impedance to flow in the renal artery decreased with advancing gestational age. In more than 54% of these normal fetuses the renal artery had an absent end-diastolic Doppler velocity. A high-pass filter of 125 Hz was used which may have obstructed low levels of end-diastolic flow (**10**).

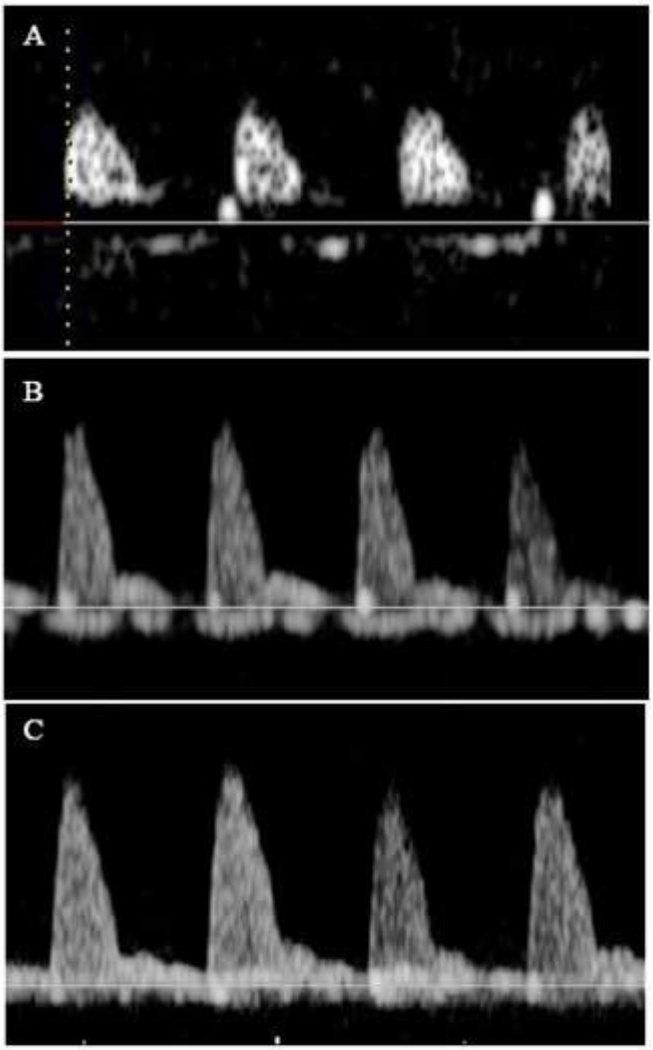

Figure (3)**:** Flow-velocity waveforms in the fetal renal artery. A: Type I (absence of diastolic flow in the entire cardiac cycle) at 15 weeks (systolic waveform is visualized). B: Type II (absence of diastolic flow at the end of cardiac cycle) at 20 weeks (the systolic waveform is present, and the diastolic waveform is absent). C: Type III at 24 weeks (systolic waveform is present and the diastolic waveform progresses into the following systolic waveform) **(11).**

In one study describing the development of uteroplacental and fetal blood flow during the third trimester in 393 uncomplicated pregnancies with uncomplicated term delivery, maximum systolic, mean, and maximum end-diastolic velocity after correcting the angle were studied in a cross-sectional study. Quantiles such as quantitative Doppler indices for the maximum systolic, mean time averaged maximum velocity (TAMX), and maximum end-diastolic velocity were calculated and published. Certain conclusions can be drawn because of these studies:

1. Resistance to the blood flow in the maternal portion of the placenta does not change during the third trimester

2. Resistance to the blood flow on the fetal side of the placenta decreases up to week 42 of gestation.
3. Cerebral vascular resistance decreases constantly up to gestational week 42.
4. Vascular resistance to the blood flow of the kidney decreases only slightly during the third trimester **(12).**

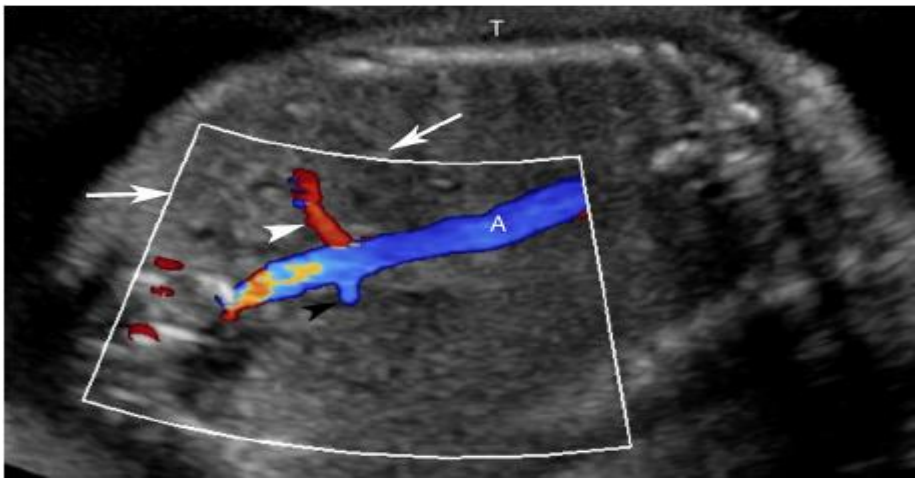

Figure (4)**:** Renal arteries in fetus. Color Doppler. Coronal plane. This obliqued en face view of the fetus shows the aorta (A) with 2 vessels coming off it and extending to the kidneys. White arrows mark off the better-seen right kidney. The red Doppler signal in the right renal artery (white arrowhead) is consistent with flow toward the transducer and the periphery of the right kidney. The blue color in the technically less well seen left renal artery indicates flow toward the left kidney and away from the transducer **(13).**

Konje et al. (14) used color angiography to longitudinally quantify blood flow volume in renal arteries during gestation. They followed 81 appropriately grown fetuses from 24 to 38 weeks of gestation. When flow was adjusted to the estimated fetal weight, there was an initial and significant fall in the blood flow in all the vessels to a minimal level at 30 weeks of gestation.

Blood flow rose thereafter until term. The ratios of flow volume in the ascending aorta to those in the other vessels increased with gestation, with the highest ratio being that between the ascending aorta and the renal arteries (**15**)**.**

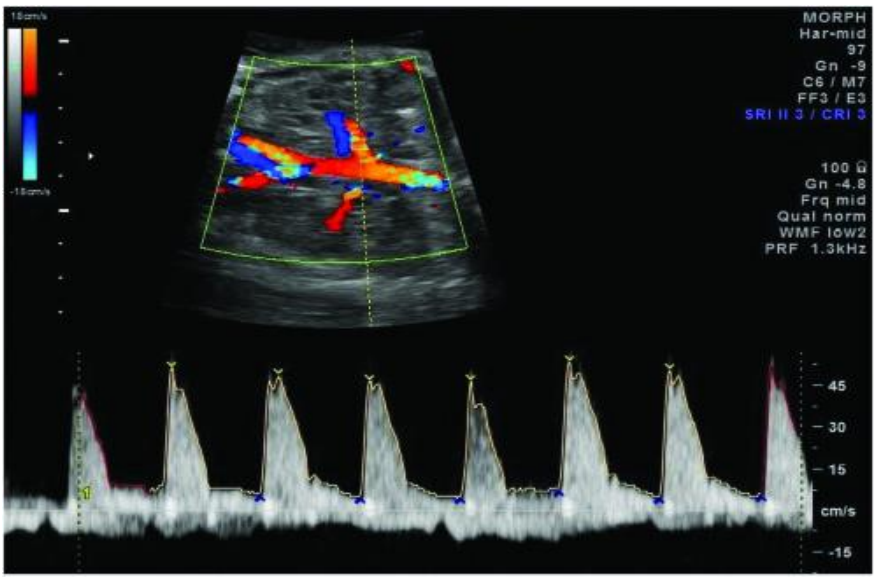

Figure (5)**:** Left renal artery mid-trunk colour and pulse wave Doppler (28 weeks' gestational age) **(16).**

Andriani et al. measured the renal RI, an estimate of renal vascular resistance, from the last trimester of pregnancy to the sixth month of life in a large series of healthy subjects. Ninety-three subjects were studied, 32 were fetuses in the last trimester of pregnancy (group 1) and 61 were children, 30 aged 0-1 month, 20 aged 1-3 months and 11 aged 3-6 months. All subjects underwent color Doppler ultrasonography, and the RI of the renal artery was measured for each kidney. The RI was very high in the "fetal group" but decreased noticeably during the first 6 months of life, reaching values like those in adults after the third month. The variability in RI continuously declined with age and there were no statistically significant differences between the left and right kidneys (**17**)**.**

Renal Artery Doppler Studies in IUGR Fetuses:

Using duplex Doppler ultrasound and a low wall filter (50 Hz). Veille and Kanaan could not demonstrate absent end-diastolic flow of the fetal renal artery in a group of asymmetric fetuses who were suffering intrauterine growth restriction (IUGR). The P in the IUGR fetuses was significantly higher than in normally grown fetuses. Among the IUGR group, fetuses with signs of hypoxia had an even higher S/D ratio than the fetuses without signs of hypoxia. These investigators suggested that local mechanisms are operational in the fetal kidneys that may in turn influence renal blood flow **(18).**

Vyas and Campbell found that 64% of small-for-gestational-age (SGA) human fetuses had a PI higher than the 10^{th} percentile confidence interval of the reference range for gestation. They found no association between the change in PI and a change in umbilical cord PO, concentration. In this group of SGA fetuses, 20 of 48 (429) had oligohydramnios. The PI of 16 of 20 fetuses with oligohydramnios (8096) were above the 95^{th} percentile of their normal reference range. The authors concluded that as the impedance to fetal renal blood flow increases, which indicates a higher PI, it is associated with a decrease in fetal urine production (**6).**

In another study, the renal volume in fetuses with IUGR fetuses was 31% (95% CI, 20%-40%), which was less than the renal volume obtained in the group of non-IUGR fetuses after adjusting for gestational age. The ratio of renal volume to estimated fetal weight was 15% (95% CI 19-26%), which was less than the same ratio in the non-IUGR fetuses. No differences were seen in the renal artery Doppler measurements.

These authors concluded that IUGR appears to be associated with a decrease in fetal renal volume. Because renal volume is a likely proxy for nephron number, this study supports the hypothesis that IUGR may be linked to congenital oligonephropathy and potentially to hypertension in later life and other related vascular diseases Some authors have determined the fetal blood flow redistribution and the amount of amniotic fluid in appropriate for gestational-age (AGA) fetuses and growth-restricted fetuses (**19**)**.**

In one study, Yoshimura determined the blood flow velocity waveforms of the umbilical artery, descending aorta, middle cerebral artery, renal artery, and uterine artery using pulsed Doppler ultrasonography in 100 AGA fetuses and 39 growth-restricted fetuses. The Pl values and the amount of amniotic fluid were compared between the two groups. The PI values of the umbilical artery and renal artery were significantly higher in AGA fetuses with oligohydramnios than in fetuses with an adequate amount of amniotic fluid **(18).**

Thus, most of the published studies on fetal renal artery waveforms support the concept that IUGR fetuses with oligohydramnios have a PI above the established values for the 95th percentile. The combination of IUGR, oligohydramnios, and elevated PI of the fetal renal artery seems to be associated with an increase in perinatal morbidity and mortality (**20**)**.**

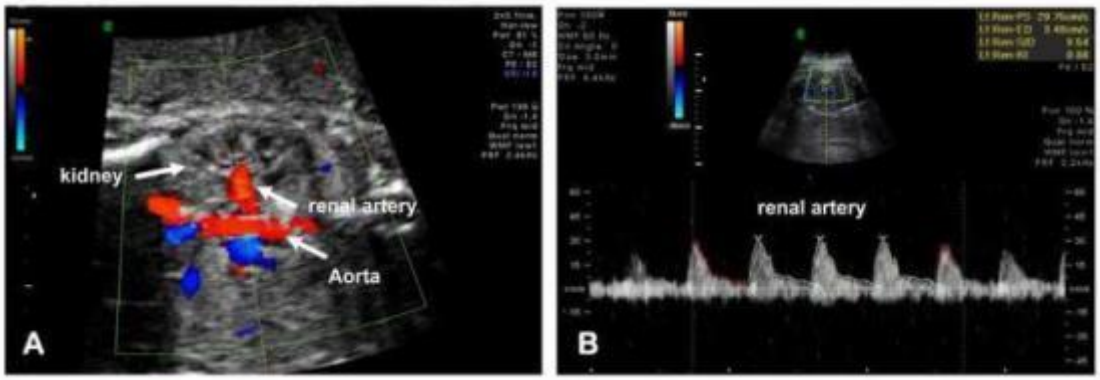

Figure (6)**:** (A) A frontal plane image of the fetal abdomen to allow identification of the abdominal aorta and its bifurcation at the level of the fetal kidneys. Renal artery blood flow was sampled within the lumen of the renal artery away from the aorta and before any emergent branches. The velocity waveform was recorded at fast speed with a low pass filter. (B) Representative Doppler flow tracing of the renal artery in a patient with intra-amniotic inflammation **(21).**

These Doppler studies support an intrarenal increase in impedance, which in turn affects renal perfusion and urine production Akita et al. evaluated renal blood flow in 102 normal human fetuses between weeks 20 and 40 of gestation and compared these normative results to those of 11 IUGR fetuses with normal amniotic fluid, 15 fetuses with oligohydramnios, and 10 IUGR fetuses with oligohydramnios (**21**)**.**

Hypoxia caused the fetal carotids to contract, whereas the same degree of hypoxia caused the fetal renal arteries to relax. In vivo studies suggest that the same vessel responds differently within its length. For example, the proximal carotid of the fetal guinea pig constricts, whereas the distal carotid relaxes under the same hypoxic conditions. Such regional differences are supported by observations in the fetal circulation of normal human fetuses. Normal women during the third trimester of pregnancy were asked to inhale a gas mixture containing 3% (**22**)**.**

The responses of the umbilical, middle cerebral, and renal arteries were analyzed before and during the 15-min CO challenge. A significant decrease in the SVD velocity ratio occurred in the fetal middle cerebral artery but not in the fetal renal artery or the umbilical artery. The authors concluded that human fetal vessels can selectively vary their resistance with the same stimulus, supporting the vascular differences previously reported for guinea pigs (**23**)**.**

One study looked at two groups of pregnancies resulting in intrauterine chronic hypoxia in the third trimester. Group comprised 120 pregnant women with pregnancy-associated hypertension and/or proteinuria. Group 2 consisted of 87 pregnancies with IUGR. Both study groups included pregnant women in the third trimester. Hyperechogenic renal medullae were detected in 15 out of 120 cases with pregnancy associated hypertension and/or proteinuria, and in 22 fetuses of the 87 pregnancies involving IUGR Fetal renal hyperechogenicity appears to be an indicator of fetal arterial circulatory depression, correlated with pathological changes in the RI for the fetal renal arteries. The fetal renal arterial blood flow RI was significantly lower in hyperechogenic cases. The authors concluded that these findings may represent an indication of subsequent intrauterine and neonatal complications. In such fetuses cesarean section was increased because of intrauterine hypoxia (**24**)**.**

In those with fetal renal hyperechogenicity there was an increase in fetal distress (43%), admission to a neonatal intensive care unit (519), and an increase in perinatal mortality (5.4%, as compared with 0.8%-1.0% in the normal population). They concluded that a detailed ultrasound and Doppler examination of renal parenchyma and arteries may be a useful method prenatally to diagnosis fetal reduced renal perfusion (**25**)**.**

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