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Original Article

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Determining the location and position of renal arteries on the aorta during the second-trimester ultrasound examination of non-anomalous fetuses: A cross-sectional study

Serhat Altınkaya[1], Ümran Kılınçdemir Turgut[1], Raziye Narin[1]

[1]University of Health Sciences, Adana City Training and Research Center, Department of Obstetrics and Gynecology, Adana, Turkiye

Abstract

Objective: The evaluation of the angle between the renal artery and the aorta, as well as the determination of the distance of renal arteries from the aortic bifurcation, was carried out in fetuses without anomalies during the second-trimester ultrasound examination.

Methods: Between 18+0 and 23+6 gestational weeks, 100 singleton fetuses without anomalies were evaluated. Demographic parameters and obstetric examination findings of the participants were recorded. During the ultrasound examination, the angles of the renal arteries were measured by determining the angle formed between the long axis of the right/left renal arteries and the long axis of the descending aorta, with the point of intersection located inferiorly (rRA-Ao°, lRA-Ao°). The location of the right/left renal arteries on the aorta and the distance from the midpoint of where the renal arteries originate from the aorta to the aortic bifurcation were also determined (rRA-Ab, lRA-Ab). Intra-observer and inter-observer evaluations were performed, and intraclass correlation analysis (ICC) analysis was conducted.

Results: The rRA-Ao° remains constant with gestational weeks, while lRA-Ao° increases with gestational weeks ($p = 0.746$; $p = 0.048$, respectively). The rRA-Ab and lRA-Ab increase with gestational weeks ($p < 0.001$). Intraobserver and interobserver agreement for rRA-Ao° and lRA-Ao° were moderate (intraobserver ICC, 0.641; 0.643; interobserver ICC, 0.612; 0.624 respectively) and for rRA-Ab and lRA-Ab were good (intraobserver ICC, 0.823; 0.769, interobserver ICC, 0.760; 0.778 respectively).

Conclusion: During the second trimester fetal ultrasound examination, rRA-Ao° remains constant regardless of the gestational week, while lRA-Ao°, rRA-Ab and lRA-Ab increase with gestational age.

Keywords: Fetal ultrasound examination, renal artery variations, fetal urogenital system examination, and perinatology

Introduction

The renal arteries are the largest lateral branches of the abdominal aorta, and the frequency of variations in them is notably high.[1] Multiple renal artery variations have been identified in the normal population at a rate of 12% and the artery variations are the most frequent variations.[2-3] Studies on renal artery variations in fetuses are limited. In cadaver studies, the level of the renal artery is typically determined based on the vertebral level.[4] Similarly, the vertebral level is used in evaluating renal vein variations.[5]

In cadaver studies, it may be practical to evaluate the level of the renal artery or vein relative to the vertebral level. However, determining the level and variations of the renal artery in a fetus during the intrauterine period may not always be possible. The first reason for this is that there may be inaccuracies in anatomical evaluation due to the fetal position. The second reason is that assessing the renal artery relative to the vertebral level remains a subjective evaluation.

The awareness of renal artery variations is important prior to surgical procedures and renal

Correspondence: Ümran Kılınçdemir Turgut, University of Health Sciences, Adana City Training and Research Center, Department of Obstetrics and Gynecology, Adana, Turkiye, **e-mail:** umrankilincdemiritf@hotmail.com, **Received:** May 22, 2024 **Accepted:** October, 03, 2024

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ORCID ID: S Altınkaya 0000-0003-3143-0903 ; Ü Kılınçdemir Turgut 0000-0003-2513-5297; R Narin 0000-0001-5352-878X

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transplantation.[6-7] It is known that abnormalities in the location of fetal kidneys, such as horseshoe kidney and pelvic kidney, may coexist with variations in the renal artery.[8-9] Additionally, their association with genetic disorders is emphasized, highlighting the necessity of focusing on studies regarding their genetic origins.[10-11]

The objective of this study is to determine the position of renal arteries in the aorta during the second-trimester fetal ultrasound examination. This objective perspective can assist in obtaining prenatal diagnosis in renal artery variations. Additionally, it may contribute to the prenatal diagnosis of fetal kidney placement anomalies.

Methods

This study was conducted after obtaining approval from the local ethics committee with the reference number 2178 between 01.10.2022 and 01.01.2023 at the tertiary center. Patients were informed about the study, and informed consent was obtained from those who volunteered.

A total of 100 singleton pregnancies between 18+0 - 23+6 gestational weeks were included in the study. The inclusion criteria for participation in the research were low-risk prenatal screening test results, singleton pregnancies, fetal position suitable for evaluating the renal artery, and no congenital malformations detected in the fetal kidney or any other system. Exclusion criteria included high maternal abdominal fat tissue, multiple pregnancies, high-risk results in prenatal aneuploidy screening tests, and the presence of major or minor anomalies detected in the fetal renal system or other system examinations.

Demographic parameters of the pregnant, including age, date of last menstrual period (adjusted if there was a difference of more than 1 week between the last menstrual period and fetal biometry on the first-trimester sonographic examination), gravidity-parity, body mass index (BMI), maternal abdominal fat tissue thickness, history of previous births, and presence of congenital kidney disease in previous children, were recorded. Fetal information included aneuploidy screening results, second-trimester sonographic examination findings, biparietal diameter (BPD), head circumference (HC), abdominal circumference (AC),femur length (FL), estimated fetal weight (EFW), placental location in addition to fetal kidney examination. All measurements were performed using the Samsung RS85 Prestige ultrasound system (Samsung Medison Co., Ltd.,-Gangwon, Korean) using a convex 1e5-MHz probe and evaluated by a perinatology specialist. Coronal plane views were obtained to visualize the renal arteries and the descending aorta in their entirety. The angles of the renal arteries were measured as follows: the angle formed between the long axis of the right and left renal arteries and the long axis of the descending aorta, with the point of intersection located inferiorly (rRA-Ao°, lRA-Ao°). The location of the right and left renal arteries on the aorta and the distance from the midpoint of where the renal arteries originate from the aorta to the aortic bifurcation were determined (rRA-Ab, lRA-Ab) (Figure 1).

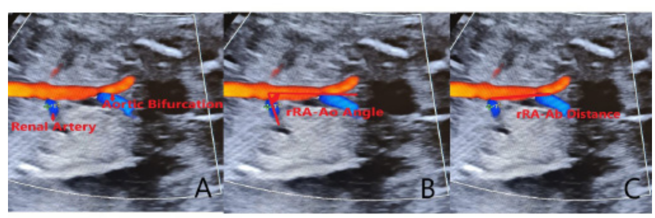

Fig 1. (A) Illustration of the fetal renal artery over the descending aorta in the coronal plane. (B) Illustration of the angle between the right renal artery and the descending aorta (rRA-Ao°). (C) Illustration of the distance of the right renal artery to the aortic bifurcation (rRA-Ab).

The selection of patients for the study and the sonographic evaluations were carried out by a perinatology specialist (Ü.K.T.). All measurements were performed by the same perinatology specialist. The images were archived. Thirty days after the completion of data collection for the study, 20 images were randomly selected from among the participants listed by the same perinatology specialist. These 20 images were re-evaluated by the perinatology specialist to complete the intraobserver assessment. Subsequently, a gynecology and obstetrics specialist

(S.S) was asked to evaluate the selected 20 images. These data were also recorded and compared with those of the perinatology specialist to complete the interobserver assessment.

The data were analyzed using IBM SPSS version 23 (IBM Inc., Chicago, IL, USA). Prior to statistical analysis, data entry errors were checked to ensure data accuracy, and checks were performed to determine whether parameters were within the expected range. Normality assumptions of continuous variables were assessed using the Kolmogorov-Smirnov test, and homogeneity of variances was examined using Levene's test. Descriptive statistics including mean and standard deviation values were provided for continuous variables. Spearman's rho correlation test was used for correlation analysis of continuous variables. A significance level of $p < 0.05$ was considered for all analyses. ANOVA test was used to evaluate subgroup analysis. The formula for the estimation of the variables was determined using the linear model.

Results

A total of 100 singleton pregnant women meeting the inclusion criteria were enrolled in the study. The angles between the right/left renal artery and the aorta, as well as the distance between the right/left renal artery to the aortic bifurcation, were recorded. The demographic parameters are presented in Table 1. Maternal age was 30.66±5.96 years, and gestational age was 21.03±1.6 weeks (Table 1.). Correlation analysis was conducted between the measured renal artery parameters and BPD, HC, AC, FL, EFW, and gestational age. It was demonstrated that the rRA-Ao° remained unchanged, measuring 80.63±7.38°, irrespective of BPD, HC, AC, FL, EFW, and gestational age. No statistically significant correlation was found between the lRA-Ao° and HC, FL or EFW (p=0.102;p=0.308; p=118, respectively). However, a weak positive correlation was observed between BPD, AC and gestational age (p=0.042;p=0.031; p=0.042, respectively). The lRA-Ao° was determined to be 80.16±6.9° (Table 2).

Table 1. Identification of demographic characteristics of participants and examination findings

	Mean	SD
Age (years)	30.66	5.96
Gravida	2.44	1.26
Parity	1.22	1.19
Maternal Height (cm)	160.67	5.41
Maternal Weight (kg)	70.19	9.74
Maternal Abdominal Fat Tissue Thickness (mm)	41.16	12.50
Gestational Age (weeks)	21.03	1.6
EFW (g)	416.85	131.26
BPD (mm)	49.87	5.62
HC (mm)	185.45	20.90
AC (mm)	160.96	20.53
FL (mm)	34.02	4.98
Right Renal Artery-Aortic Angle (°) (rRA-Ao°)	80.63	7.38
Distance from Right Renal Artery-Aortic Bifurcation (mm) (rRA-Ab)	15.88	2.86
Left Renal Artery-Aortic Angle (°) (lRA-Ao°)	80.16	6.9
Distance from Left Renal Artery-Aortic Bifurcation (mm) (lRA-Ab)	15.67	2.62

EFW. Estimated Fetal Weight; BPD. Biparietal Diameter; HC. head circumference; AC. abdominal circumference; FL. Femur Length; SD. Standard Deviatio

Furthermore, a moderate positive correlation was identified rRA-Ab, lRA-Ab and BPD, HC, AC FL, EFW, and gestational age (Table 2). Additionally, the correlation graph of fetal renal artery measurements according to gestational weeks is shown in figure 2. The measurements were re-evaluated by categorizing them according to gestational weeks (Table 3).

Table 2. Correlation analysis of fetal renal artery measurements with fetal biometry and gestational age

n=100		rRA-Ao°	rRA-Ab (mm)	lRA-Ao°	lRA-Ab (mm)
Gestational Age (weeks)	R	.009	.555**	.204*	.590**
	P	.927	.000	.042	.000
EFW (g)	R	-.005	.528**	.157	.577**
	P	.958	.000	.118	.000
BDP(mm)	R	.036	.582**	.204*	.585**
	P	.722	.000	.042	.000
HC(mm)	R	.016	.605**	.164	.637**
	P	.878	.000	.102	.000
AC(mm)	R	.022	.524**	.216*	.564**
	P	.826	.000	.031	.000
FL(mm)	R	-.034	.553**	.103	.596**
	P	.735	.000	.308	.000
rRA-Ao°	R	1	-.042	.219*	.008
	P		.682	.029	.940
rRA-Ab(mm)	R		1	.049	.891**
	P			.630	.000
lRA-Ao°	R			1	.010
	P				.922
lRA-Ab(mm)	R				1
	P				

EFW. Estimated Fetal Weight; BPD. Biparietal Diameter; HC. Head circumference; AC. Abdominal Circumference; FL. Femur Length; rRA-Ao°. Right Renal Artery Aortic Angle (°); rRA-Ab. Distance from Right Renal Artery-Aortic Bifurcation (mm); lRA-Ao°.Left Renal Artery Aortic Angle (°). lRA-Ab. Distance from Left Renal Artery-Aortic Bifurcation (mm)

**. Correlation is significant at the 0.01 level

*. Correlation is significant at the 0.05 level

Linear models were constructed for the estimation of rRA-Ab, lRA-Ab and lRA-Ao° between them (dependent variables) based on fetal gestational weeks (independent variables) such as rRA-Ab= -3.97+0.135(gestational weeks (days)), lRA-Ab = -3.74+0.13(gestational weeks (days)), lRA-Ao°=62.53+0.12 (gestational weeks (days)). For example, linear regression model of lRA-Ab = -3.74+0.13(gestational weeks (days)) was obtained. If the gestational weeks (days) increases by 1 unit, the lRA-Ab is expected to increase by 0.13 units. Intraobserver and interobserver agreement for rRA-Ao° and lRA-Ao° were moderate (intraobserver ICC, 0.641; 0.643; interobserver ICC, 0.612; 0.624 respectively) and for rRA-Ab and lRA-Ab were good (intraobserver ICC, 0.823; 0.769, interobserver ICC, 0.760; 0.778 respectively) (Table 4).

Table 3. Reference intervals for renal artery measurements considering gestational age

	GW	n	Mean±SD	Range	P
Right Renal Artery-Aortic Angle (°) (rRA-Ao°)	18+	13	82.3±4.6	69-87	0.274
	19+	17	78.2±8.2	61-89	
	20+	22	81.9±7.6	60-89	
	21+	15	79.0±7.8	61-87	
	22+	21	81.6±7.5	61-89	
	23+	12	79.9±7.2	62-87	
Distance from Right Renal Artery-Aortic Bifurcation (mm) (rRA-Ab)	18+	13	12.0±1.5	8-14	<0.001*
	19+	17	15.2±2.2	12-20	
	20+	22	15.9±2.5	12-20	
	21+	15	16.5±3.1	12-23	
	22+	21	17.4±2.0	13-21	
	23+	12	17.4±2.3	14-21	
Left Renal Artery-Aortic Angle (°) (lRA-Ao°)	18+	13	75.9±7.4	61-85	0.075
	19+	17	79.9±6.7	66-88	
	20+	22	79.3±7.3	66-89	
	21+	15	83.0±5.6	72-89	
	22+	21	81.9±6.6	66-89	
	23+	12	79.8±5.9	67-89	
Distance from Left Renal Artery-Aortic Bifurcation (mm) (lRA-Ab)	18+	13	12.4±1.6	10-16	<0.001**
	19+	17	14.7±2.1	10-19	
	20+	22	15.6±2.4	12-20	
	21+	15	15.9±2.5	13-21	
	22+	21	17.3±1.8	14-20	
	23+	12	17.4±2.2	15-21	

+denotes the corresponding gestational week. For example. 18+ denotes 18 0/7 to 18 6/7 weeks of gestation; GW. gestational week; SD. standard deviation;

*p value is significant between 18+ and 19+.20+.21+.22+.23+ .also 19+ and 22+ by Tukey HSD. p value is not significant between other than these.

**p value is significant between 18+ and 19+.20+.21+.22+.23+ .also 19+ and 22+.23+ by Tukey HSD. p value is not significant between other than these.

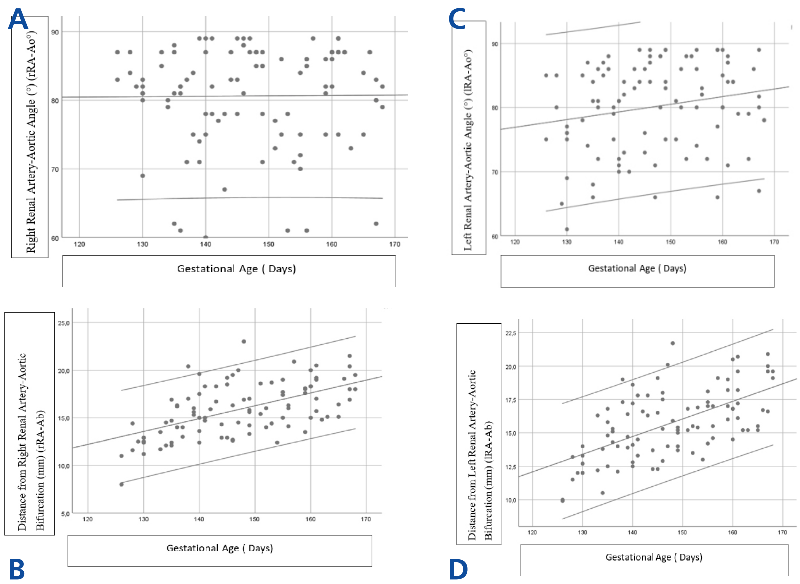

Fig 2. Correlation analysis chart of fetal renal artery measurements according to gestational age (days), A; Correlation graph between rRA-Ao° and gestational age. B; Correlation graph between rRA-Ab and gestational age. C; Correlation graph between lRA-Ao° and gestational age. D; Correlation graph between lRA-Ab and gestational age

Table 4. Intraobserver and interobserver intraclass correlation analysis

	Intraobserver Evaluation	Interobserver Evaluation
Right Renal Artery-Aortic Angle (°) (rRA-Ao°)	0.641 (0.622-0.661)	0.612 (0.571-0.644)
Distance from Right Renal Artery-Aortic Bifurcation (mm) (rRA-Ab)	0.823 (0.712-0.891)	0.760 (0.603-0.871)
Left Renal Artery-Aortic Angle (°) (lRA-Ao°)	0.643 (0.551-0.699)	0.624 (0.502-0.791)
Distance from Left Renal Artery-Aortic Bifurcation (mm) (lRA-Ab)	0.796 (0.638-0.899)	0.778 (0.621-0.897)

Discussion

The main finding of this study is that the angle of the right renal artery remains unchanged throughout gestational age, staying within a narrow range, while the distance from the right renal artery to the aortic bifurcation increases with gestational age. Additionally, the angle between the left renal artery and the aorta increases in correlation with gestational age, and the distance from the left renal artery to the aortic bifurcation also increases with gestational age. The positions of both renal arteries along the aorta were determined in millimeters. Additionally, in this study, the determination of the position of the renal artery relative to the aortic bifurcation and the description of the angle formed between the aorta and the renal arteries is significant as it is the first in the literature. Knowing the normal values can facilitate the recognition of variations or abnormal development.

Studies have been conducted in the literature on fetal renal artery variations, and furthermore, the origins of renal arteries have been evaluated by Doppler ultrasound and compared with the contralateral renal artery.[12] In this case, errors in comparison are inevitable in the presence of a possible renal contra-renal artery variation.The most significant finding of current study is the determination of the renal artery's position in the aorta independently of the contralateral renal artery. In a study conducted on renal artery variations diagnosed with renal angiography, a 24% renal artery variation rate was reported.[13] During the embryonic stage, as fetal kidneys ascend from the pelvis to the lumbar region in their developmental phases, new renal arteries form. Consequently, although a single renal artery originating from the aorta is common, variations are frequent[14] Interestingly, approximately 20% bilateralism was reported in the presence of renal artery variations.[13] Therefore, evaluating based on the contralateral renal artery may lead to diagnostic inaccuracies. Hence, selecting a fixed origin and evaluating based on this origin would be more objective. Consequently, vertebral levels are often used in the literature for this purpose.[15] However, ensuring fetal anatomical position may not always be possible. Therefore, a different origin is proposed in this study. Evaluating based on aortic bifurcation and determining the position of renal arteries according to gestational weeks can provide an objective perspective. Studies focusing on renal artery variations have been added to the literature. Similarly, a study emphasizes that renal artery variations may accompany fetal kidney pathologies[12] However, a precise value indicating the position of the renal artery on the aorta has not been established for these variations. The aim of the current study is to evaluate the detection of renal artery variations more objectively. For this purpose, the distance of the renal artery from the aortic bifurcation was used. This approach can provide accurate information about the exact localization of the renal artery.

Another significant finding in this study is the constant angle between the right renal artery and the aorta from 18+0 to 23+6 gestational weeks, whereas the angle between the left renal artery and the aorta continues to increase. This is indicative of the ongoing ascent of the left kidney within the abdominal cavity during these gestational weeks. Fetal kidney development involves three embryological stages, during which the kidneys ascend within the fetal abdomen and ultimately settle into their final positions within the renal fossae.[16] The metanephros represents the mature form of the fetal kidneys. A key finding in this study is the continued ascent of the left kidney, albeit to a small degree, into the second trimester. The absence of ascent in the right kidneys and the stable angle between the renal artery and the aorta may be attributed primarily to the presence of the fetal liver.

In this study, it was found that the left renal artery originates more distally than the right renal artery. No statistically significant difference was detected when comparing their distances to the aortic bifurcation. Similarly, cadaver studies have shown that the right renal artery originates at the same level as or higher than the left renal artery.[4] The right renal artery originating more distally than the left renal artery in renal artery anomalies may raise suspicion of renal abnormalities. However, determining the position of the renal artery on the aorta can provide an objective perspective.

An interesting finding is the strong correlation observed between the angles of the right and left renal arteries with the aorta. This reflects the symmetry of the right/left renal arteries. Although not as symmetrical as a mirror image, fetal renal arteries are expected to have a certain degree of symmetry. This finding suggests that asymmetry in renal arteries may raise suspicion of renal artery variations and/or congenital malformations. It may prompt the obstetrician to conduct further investigations.

The limitations of the study include the inability to make prenatal diagnoses, especially when renal artery variations occur anterior or posterior to the aorta, due to the sections we used. This limitation stems from all sections being in the coronal plane and the absence of 3D ultrasound in the study. Past studies have shown an increase in the detectability of renal artery variations with the use of 3D ultrasound applied by experienced clinical physicians with an appropriate learning curve.[17]

Conclusion

As a result, the position and location of renal arteries in fetuses without anomalies were evaluated between 18+0 and 23+6 gestational weeks. The angle between the right renal artery and the aorta remained constant without changing with gestational weeks. Additionally, the distance of the right renal artery from the aortic bifurcation increased with gestational weeks. On the other hand, the angle of the left renal artery with the aorta continued to increase proportionally with gestational weeks, and similarly, the distance of the left renal artery from the aortic bifurcation also increased proportionally with gestational weeks.

References

1. Gautam A, Khan GA, Timilsina S, Dhungel D, Sah SK. Variation in formation of renal artery. J. Coll. Med. Sci. Nep, vol. 16, pp. 41–43, 2020. [CrossRef]
2. Tardo DT, Briggs C, Ahern G, Pitman A, Sinha S. Anatomical variations of the renal arterial vasculature: An Australian perspective. J. Med. Imaging Radiat. Oncol., vol. 61, no. 5, pp. 643–649, 2017. [PubMed][CrossRef]
3. Salih MA, Hasan MA. Renal artery morphology and anatomical variations among Sudanese subjects. Anat. J. Africa, vol. 7, no. 1, pp. 1103–1112, 2018. [CrossRef]
4. Çiçekcibaşi AE, Ziylan T, Salbacak A, Şeker M, Büyükmumcu M, Tuncer I. An investigation of the origin, location and variations of the renal arteries in human fetuses and their clinical relevance. Ann. Anatomy-Anatomischer Anzeiger, vol. 187, no. 4, pp. 421–427, 2005. [PubMed][CrossRef]
5. Gupta A, Gupta R, Singal R. Congenital variations of renal veins: embryological background and clinical implications. J Clin Diagn Res, vol. 5, no. 6, pp. 1140–1143, 2011.
6. Shigueoka DC. Anatomic variations of the renal arteries, as characterized by computed tomography angiography: rule or exception? Its usefulness in surgical plannning. Radiologia brasileira, vol. 49. SciELO Brasil, pp. VII–VIII, 2016. [PubMed][CrossRef]
7. Coen LD, Raftery AT. Anatomical variations of the renal arteries and renal transplantation. Clin. Anat. Off. J. Am. Assoc. Clin. Anat. Br. Assoc. Clin. Anat., vol. 5, no. 6, pp. 425–432, 1992. [CrossRef]
8. Eid S, Iwanaga J, Loukas M, Oskouian RJ, Tubbs RS. Pelvic kidney: a review of the literature.Cureus, vol. 10, no. 6, 2018. [PubMed] [CrossRef]
9. Natsis K, Piagkou M, Skotsimara A, Protogerou V, Tsitouridis I, Skandalakis P. Horseshoe kidney: a review of anatomy and pathology. Surg. Radiol. Anat., vol. 36, pp. 517–526, 2014. [PubMed][CrossRef]
10. Uy N, Reidy K. Developmental genetics and congenital anomalies of the kidney and urinary tract. J. Pediatr. Genet., pp. 51–60, 2015. [PubMed][CrossRef]
11. Humphries A, Speroni S, Eden K, Nolan M, Gilbert C, McNamara J. Horseshoe kidney: morphologic features, embryologic and genetic etiologies, and surgical implications. Clin. Anat., 2023. [PubMed][CrossRef]
12. Degani S, Leibovitz Z, Shapiro I, Ohel G. Variations of the origin of renal arteries in the fetus identified on power Doppler and 3D sonography. J. Clin. Ultrasound, vol. 38, no. 2, pp. 59–65, 2010. [PubMed][CrossRef]
13. Özkan U, Oguzkurt L, Tercan F, Kizilkilic O, Koç Z, Koca N. Renal artery origins and variations: angiographic evaluation of 855 consecutive patients. Diagnostic Interv. Radiol., vol. 12, no. 4, p. 183, 2006.
14. Contag S. Fetal Renal Artery. in Doppler Ultrasound in Obstetrics and Gynecology, Springer, 2023, pp. 181–196. [CrossRef]
15. Gümüş H. et al.. Variations of renal artery in 820 patients using 64-detector CT-angiography. Ren. Fail., vol. 34, no. 3, pp. 286–290, 2012. [PubMed][CrossRef]
16. Raissian Y, Grande JP. Embryology and Normal Anatomy of the Kidney. Pract. Ren. Pathol. A Diagnostic Approach E-b. A Vol. Pattern Recognit. Ser., p. 1, 2012. [CrossRef]
17. Gindes L. et al.. Three-dimensional ultrasonographic depiction of fetal abdominal blood vessels. J. Ultrasound Med., vol. 28, no. 8, pp. 977–988, 2009. [PubMed][CrossRef]