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Color Doppler Ultrasonographic Assessment of Renal Arteries Parameters in German Shepherd Dogs

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ABSTRACT

The purpose of this study was to establish the normal renal artery parameters in German Shepherd dogs. Consequently, the acquired values can be applied to the subsequent clinical research and the interpretation of the findings. Doppler ultrasound was used in this study to assess 24 healthy German shepherd dogs, including 11 female dogs (45.8%) and 13 male dogs (54.2%). The mean age of the dogs was 2.7 years (minimum age of 9 months and maximum age of 15 years) with a standard deviation of 1.07. The Doppler parameters in the renal arteries were evaluated in each case together with their normal values. The mean PSV and EDV in the major renal arteries were 84.07 cm/s and 44.46 cm/s, respectively. Mean PSV, EDV, RI, and AT for intrarenal arteries were 64.81 cm/s, 33.03 cm/s, 0.54 cm/s, and 36.53 m/s, respectively. The findings of the current study represent the typical renal artery parameters in healthy German Shepherd dogs that can be applied to clinical examinations and the interpretation of test results.

Introduction

Doppler ultrasonography is now recognized as a good alternative to angiography in many situations because it is noninvasive, free of side effects, and less expensive. In addition to showing us the vascular anatomy, it also provides us with important information about hemodynamic that is helpful in the diagnosis of various diseases.[1,2] A sonologist needs to be aware of the size and pattern of normal and abnormal blood flow speed while making a diagnosis.[3] Resistance index (RI) and pulsative index are the two most popular indicators calculated by pulsed Doppler ultrasound to determine blood flow speed (IP). These two measures are useful for evaluating vascular resistance.[4]

One of the earliest symptoms of kidney dysfunction is decreased renal blood flow which a Doppler ultrasound can detect. Reduced diastolic blood flow indicates an overall rise in renal vascular resistance that elevates the resistance index.[5] It has been noted that cats with obstructive renal disorders, acute and chronic kidney diseases, congenital dysplasia, and acute tubular necrosis as well as dogs with ureteral obstruction had higher resistance indices.[6] Vascular stenosis, obstruction, and constriction can all raise

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vascular resistance as well.[7] The diastolic blood flow rate typically declines more dramatically than the systolic blood flow rate when vascular resistance rises leading to an increase in Doppler indices.[8] It is helpful to evaluate the renal artery using Doppler ultrasonography to diagnose a variety of illnesses, such as renal artery stenosis, renal vein thrombosis, and renal parenchymal disease, and to distinguish between obstructive and nonobstructive hydronephrosis, among others.[9,10] Peak systolic (PS), acceleration time (AT), resistive index (RI), end diastolic velocity (EDV), renal/aortic ratio (RAR), acceleration index (AI), and pulsative index (PI) are the most significant measurements made in numerous investigations of renal arteries using Doppler ultrasonography (PSV).[11,12] The normal values in each case must first be known to interpret the data acquired from the ultrasonography of patients. The authors concluded after reading some books and papers. Firstly, no fixed amounts of Doppler criteria were mentioned in any of the resources.[13,14] Secondly, it is also advised that Doppler ultrasonography centers follow standards for their preparation and interpretation of the data.[15] Thirdly, a number of researches suggest that the majority of biological criteria vary between dog breeds and certain criteria cannot be generalized to all dogs.[16]

Due to the lack of thorough research on the natural renal artery parameters in dogs and the significant discrepancies in the results of earlier studies, it was necessary to study healthy German shepherd dogs and collect various renal artery Doppler measurements and normalized data sets for use in clinical trials and the interpretation of the results from these values.

Materials and Methods

In this cross-sectional study, Doppler ultrasound was used to assess 24 healthy German shepherd dogs, including 11 female (45.8%) and 13 male dogs (54.2%). The mean age of the dogs was 2.7 years (minimum age of 9 months and maximum age of 15 years) with a standard deviation of 1.07. In each case, the Doppler parameters in the renal arteries were measured along with their normal values. Considering that the main variables of this research were quantitative and referring to the results obtained from other articles regarding Doppler criteria.

Processing and Ultrasound Examination

First, a thorough medical history regarding renal illnesses and diabetes was obtained from the owners of the dogs who were referred to the ultrasound department. If there was a history of the disease, the case was eliminated from the study. The dogs that had no prior history of the desired diseases underwent physical examinations. The kidneys were examined in B mode if no abnormal results were found and if the disease was found, the case was withdrawn from the study. Doppler ultrasonography and spectrum drawing were done on the dogs that were identified as healthy. The device was set up to produce the largest and clearest wave possible, therefore; the following factors were taken into account: Maximum power pulsed Doppler, minimal velocity scale range, minimal wall filter (100 Hz), sweep time = 2″, sweep speed = 40-50 mm/s, sample volume = 3 mm and Doppler angle less than 60 degrees. The ultrasound machine used for color Doppler ultrasonography was EUB-525, Hitachi, Japan. It employed multi-frequency probes with convex 8–12 MHz bands.

PSV and EDV criteria in three areas-proximal, medial, and distal were established on both sides to investigate the origin of renal arteries from the aorta began and continued to distal renal arteries. When it was not possible to find all or part of the renal artery, the criteria AT, RI, EDV, and PSV were estimated in the upper, middle, and lower poles of the kidneys using Doppler ultrasonography of the renal arteries (segmental and interlobar). To get the best view of the artery and the closest distance feasible to the probe, each case was examined in the ventrodorsal position with left and right lateral recumbence. The results were then recorded in the corresponding tables. The veterinary radiologist did all of the ultrasonography. Doppler criteria were assessed in the upper, lower, and middle portions of the kidneys as well as in the three main renal artery regions (proximal, medial, and distal). After the completion of the sample size, all data contained in the table were averaged. Then, the obtained average and deviation criteria were recorded as a standard size.

Descriptive statistical techniques were utilized to present the results, including frequently distributed tables, graphs, and distributional indices. Similarly, the normal range was also determined using the confidence interval technique and SPSS statistical software (version 21) was utilized to analyze the data. The owners of the dogs were initially informed of the purpose and procedure of conducting the research, and they were reassured that ultrasonography would not endanger them. Following this, a consent form was obtained to comply with ethical requirements.

Results

The Sex distribution of the samples in Table 1 and sample separation in age groups are given in Table 2. As Tables 1 and 2 show, the renal arteries were visible in all 24 of the dogs that underwent ultrasonography (100%) and Doppler parameters could be measured. All parts of renal arteries were visible in 22 dogs (92.18%), although the central portion was only fully visible in three dogs (7.82%). Table 3 lists the Doppler parameters calculated in the major artery of the left kidney, while Table 4 lists the Doppler parameters measured in the main artery of the right kidney.

Tables 5 and 7 indicate the calculated Doppler parameters for the intrarenal arteries in the right and left kidneys, as well as these parameters for both kidneys. Table 8 lists the derived Doppler parameters by gender. The t-test findings for the comparison of the Doppler criteria by gender are shown in Table 9. The t-test shows that only two variables, PSV and EDV, have a significant difference between the male and female sexes, whereas there is no significant difference in the remaining variables. Table 10 indicates Doppler parameters broken down by age groups. The analysis of the variance test based on the aforementioned factors reveals that there is no significant difference between the age groups.

Table 1. Frequency distribution of dogs according to sex.

Sex	Frequency	Percent	Cumulative frequency percentage
Female	126	49.2	49.2
Male	130	50.8	50.8
Total	256	100	100

Table 2. Frequency distribution of dogs according to age.

Age group (years)	Prevalence	Percent	The cumulative percentage
< 3	2	8.3	8.3
3-6	9	37.5	45.8
6-9	8	33.3	79.2
9-12	3	12.5	91.7
12-15	2	8.3	100.0
Total	24	100.0	-
Minimum = 1	Maximum = 5	Standard deviation = 1.07339	Average = 2.75

Table 3. Statistical analyses of Doppler parameters in the renal artery of the left kidney.

Doppler parameters	Enrollment	Minimum	Maximum	Mean	Standard deviation	Limit of confidence 95%
PSV-proximal-LRA(cm/s)	239	57	120	87.12	13.61	85.07 and 88.65
EDV-Proximal-LRA(cm/s)	239	19	75	40.35	9.97	38.87 and 41.49
PSV-middle-LRA(cm/s)	234	57	118	86.54	13.53	84.54 and 88.14
EDV-middle-LRA(cm/s)	236	18	74	39.47	10.07	38.12 and 40.77
PSV-Distal-LRA(cm/s)	247	53	118	85.14	13.35	83.20 and 86.78
EDV-Distal-LRA(cm/s)	247	15	67	37.93	9.63	36.80 and 39.40

Table 4. Statistical analyses of Doppler parameters in the renal artery of the right kidney.

Doppler parameters	Enrollment	Minimum	Maximum	Mean	Standard deviation	Limit of confidence 95%
PSV-proximal-LRA(cm/s)	22	54	100	76.4167	14.16952	85.14 and 88.74
EDV-Proximal-RRA(cm/s)	22	16	77	40.6667	18.85797	38.63 and 41.31
PSV-middle-RRA(cm/s)	21	56	121	81.3750	17.44510	84.41 and 88.01
EDV-middle-RRA(cm/s)	21	16	80	50.5833	21.29282	37.72 and 40.36
PSV-Distal-RRA(cm/s)	22	45	120	79.4167	22.43622	82.96 and 38.87
EDV-Distal-RRA(cm/s)	22	14	71	41.8333	17.94355	36.34 and 38.87

Table 5. Statistical analyses of Doppler parameters in the interarenal artery of right kidney.

Doppler parameters	Enrollment	Minimum	Maximum	Mean	Standard deviation	Limit of confidence 95%
PSV-proximal-LRA(cm/S)	24	22.00	110.00	68.7500	27.15695	73.28 and 77.27)
EDV-upper-RK(cm/s)	24	12	59	39.9167	12.55221	31.51 and 33.29
RI-upper-RK	24	0.31	0.88	0.5929	0.17427	0.54 and 0.56
AT-upper-RK(ms)	24	0.31	67.00	21.6533	24.08171	28.14 and 30.45
PSV-Middle-RK(cm/s)	24	23	110.00	57.2917	27.24363	73.24 and 77.22
EDV-Middle-RK(cm/s)	24	13	59.00	40.9167	13.95931	31.36 and 33.14
RI-Middle-RK	24	0.44	0.88	0.6117	0.15293	0.54 and 0.56
AT-Middle-RK(ms)	24	7	66	35.0417	20.15263	27.94 and 30.28
PSV-Lower-RK(cm/s)	24	22	110	71.5833	28.04952	73.25 and 77.24
EDV-Lower-RK(cm/s)	24	12	59	39.7500	12.91864	31.29 and 33.06
RI-Lower-RK	24	0.31	0.88	0.5746	0.16569	0.54 and 0.56
AT-Lower-RK(ms)	24	8	59	33.8333	15.90643	28.31 and 30.60

Table 6. Statistical analyses of Doppler parameters in the interarenal artery of left kidney.

Doppler parameters	Enrollment	Minimum	Maximum	Mean	Standard deviation	Limit of confidence 95%
PSV-upper-LK(cm/s)	24	24	112.00	62.2917	27.97278	73.47 and 77.39
EDV-upper-LK(cm/s)	24	12	59	37.0417	13.28444	31.38 and 33.11
RI-upper-LK	24	0.29	0.88	0.56	0.17468	0.54 and 0.56
AT-upper-LK(ms)	24	8	67	26.8333	19.64836	28.47 and 30.88
PSV-Middle-LK(cm/s)	24	23	112.00	62.3750	27.78929	73.36 and 77.34
EDV-Middle-LK(cm/s)	24	13.00	59	37.8750	12.74606	31.31 and33.1
RI-Middle-LK	24	0.34	0.88	0.5863	0.14172	0.54 and 0.56
AT-Middle-LK(ms)	24	7	66	36.6250	19.18517	27.94 and 30.22
PSV-Lower-LK(cm/s)	24	22	112.00	69.4167	28.55341	73.20 and 77.29
EDV-Lower-LK(cm/s)	24	12.00	59	34.8750	13.58168	31.29 and 33.07
RI-Lower-LK	24	0.34	0.88	0.5983	0.15747	0.54 and 0.56
AT-Lower-LK(ms)	24	8	65	33.7917	18.00719	28.46 and 30.66

Table 7. Statistical analyses of Doppler parameters in both kidneys.

Doppler parameters	Enrollment	Minimum	Maximum	Mean	Standard deviation	Limit of confidence 95%
PSV(cm/s) of renal artery	21	55.84	120	84.0792	21.76735	84.25 and 87.80
EDV(cm/s)) of renal artery	21	17.53	65.84	44.4654	20.22716	38.80 and 40.40
PSV(cm/s) of interarenal artery	24	17.53	109.00	64.8183	27.09942	72.89 and 77.12
EDV(cm/s) of interarenal artery	24	12.98	65.84	33.0396	19.26807	31.45 and 33.41
RI of interarenal artery	24	0.29	0.88	0.5460	0.15717	0.54 and 0.56
AT(ms) of interarenal artery	24	7	65.00	36.5338	19.04386	28.35 and 30.75

Table 8. Statistical analyses of Doppler parameters according to gender.

Doppler parameters	Sex	Minimum	Maximum	Mean	Standard deviation	Limit of confidence 95%
PSV(cm/s) of renal artery	famale	59.83	119	88	13.18	85.44 and 90.55
	male	56.83	117	84	13.40	81.63 and 86.6
EDV(cm/s)) of renal artery	famale	18.5	69.83	40.45	10.08	42.40 and 38.50
	male	18.33	64	37.83	9.23	39.56 and 63.1
PSV(cm/s) of interarenal artery	famale	30.67	106.33	76.60	14.83	79.47 and 73.73
	male	24.17	108.17	73.52	16.60	76.63 and 70.41
EDV(cm/s) of interarenal artery	famale	18.67	58.33	33.15	7.11	34.53 and 31.77
	male	13.33	56.33	31.75	7.44	33.15 and 30.36
RI of interarenal artery	famale	0.35	0.72	0.55	8.20	0.57 and 0.53
	male	0.3	0.72	0.55	9.73	0.56 and 0.53
AT(ms) of interarenal artery	famale	8	56.67	30.01	8.48	31.65 and 28.37
	male	8	64.67	29.12	9.38	30.88 and 27.36

Table 9*.* Statistical analysis T for Comparison of Doppler criteria in both sexes.

Doppler parameters	Sex	Enrollment	Mean	Standard deviation	T test
PSV (cm/s) of renal artery	famale	11	84.8709	24.21082	*p** = 0.874 and T =.160
	male	13	83.4092	20.46020	
EDV (cm/s)) of renal artery	famale	11	37.9000	21.00365	*p** = 0.147 and T = -1.502
	male	13	50.0208	18.53663	
PSV (cm/s) of interarenal artery	famale	11	52.5118	24.97871	*p** = 0.038 and T =- 2.213
	male	13	75.2315	25.12591	
EDV (cm/s) of interarenal artery	famale	11	36.3600	19.30233	*p** = 0.450 and T = 0.770
	male	13	30.2300	19.55601	
RI of interarenal artery	famale	11	0.5213	0.19527	*p** = 0.491 and T = 0.179
	male	13	0.5669	0.12058	
AT (ms) of interarenal artery	famale	11	27.7273	20.71275	*p** = 0.034 and T = 0.073
	male	13	43.9854	14.36505	

*p** obtained are significant.

Discussion

In this study, the Doppler criteria were calculated in all parts of the kidney and renal arteries. However, categorization based on anatomic location has not been done and only a few Doppler criteria have been cited in reference books and several papers.[17] The findings demonstrated that there was no significant difference in the Doppler criterion across all age groups and that these criteria were applicable to all age groups.

Additionally, it was found that there is a significant difference between PSV and EDV when evaluating the Doppler criterion in both sexes. However, other criteria did not show any significant differences. Therefore, PSV and EDV should be evaluated using the usual values for each gender in the Doppler examination. The mean PSV in the intrarenal arteries was measured to be 76.32 cm/s in females and 74.35 cm/s in males, with other values in the major renal artery being the same for both sexes at 88 cm/s (SD = 13.18) and 84.17 cm/s (SD = 13.34). Additionally, the mean EDV in the main renal artery was found to be 40.45 cm/s in females and 37.68 cm/s in males. The mean EDV in the intrarenal arteries was measured to be 32.74 cm/s in females and 31.73 cm/s in males.

Veille and Kanaan in 1989 used ultrasonography to investigate changes in renal artery blood flow in dogs with obstructive hydronephrosis. The results of their evaluations showed that renal artery duplex Doppler ultrasonography could detect changes in renal perfusion as a result of urinary obstruction and this change could be detected as early as 24 hours after obstruction. However, high false-positive and false-negative rates may constrain the ability of this method

Table 10. Statistical indicators of Doppler parameters according to age groups

Doppler parameters	Age groups (years)	Enrollment	Mean (cm/s)	Standard deviation	Limit of confidence 95% for the average		ANOVA test
					High value	Low value	
PSV(cm/s) of renal artery	<3	21	87.11	14.91	93.90	80.31	F = 1.236 and *p* = 0.297
	3-6	93	87.96	13.15	90.67	85.25	
	6-9	86	83.60	12.84	86.35	80.85	
	9-12	14	86.15	14	94.24	87.06	
	12-15	4	86.29	18.14	115.7	57.41	
	Total	218	86.01	13.37	87.80	84.23	
EDV(cm/s)) of renal artery	<3	21	37.71	9.88	42.21	33.21	F = 0.306 and *p* = 0.874
	3-6	93	39.34	9.56	41.31	37.37	
	6-9	87	38.90	9.87	41.01	36.80	
	9-12	14	38.25	9.20	43.56	32.93	
	12-15	4	42.95	14.46	56.98	19.93	
	Total	219	39.01	9.72	40.30	37.71	
PSV(cm/s) of interarenal artery	<3	21	75.30	15.09	82.17	68.43	F = 0.800 and *p* = 0.526
	3-6	103	77.15	16.60	80.39	73.90	
	6-9	99	74.42	14.92	77.39	71.44	
	9-12	26	73.12	18.03	80.40	65.83	
	12-15	6	68.52	20.55	90.10	46.95	
	Total	25	75.32	16.06	77.30	73.34	
EDV(cm/s) of interarenal artery	<3	21	31.12	5.93	33.82	28.42	F = 0.898 and *p* = 0.466
	3-6	103	33.05	7.72	34.56	31.54	
	6-9	99	32.15	7.05	34.56	30.74	
	9-12	26	30.51	5.80	32.85	28.16	
	12-15	6	30.83	8.11	39.34	22.32	
	Total	25	32.23	7.16	33.11	31.35	
RI of interarenal artery	<3	21	0.57	7.69	0.60	0.53	F = 0.420 and *p* = 0.794
	3-6	102	0.55	9.33	0.57	0.53	
	6-9	99	0.55	8.46	0.57	0.53	
	9-12	26	0.55	0.11	0.60	0.51	
	12-15	2	0.52	0.10	0.63	0.41	
	Total	254	0.55	9.05	0.56	0.54	
AT(ms) of interarenal artery	<3	21	28.20	10.53	33	23.41	F = 0.531 and *p* = 0.713
	3-6	103	29.07	8.56	30.74	27.39	
	6-9	99	29.28	9.14	31.10	27.46	
	9-12	26	31.62	9.24	35.36	24.60	
	12-15	6	29.66	4.82	34.73	24.60	
	Total	256	29.35	8.94	30.46	28.25	

to accurately distinguish obstructive from nonobstructive collecting system dilatation.[18]

In a study conducted by Lee *et al*. in 2014 on Beagle dogs, they reported that overhydration of dogs caused a significant reduction in RI and PI before clinical overhydration symptoms were noticed. Ultrasound determination of renal arteries RI and PI appears to be a non-invasive and sensitive method to assess overhydration in dogs.[19]

Another study by Koma *et al*. in 2021 reported that acute and severe normovolaemic anemia significantly altered left renal artery Doppler parameters in resting dogs without influencing the interlobar artery. They concluded that moderate or mild chronic anemia did not affect any renal Doppler parameter.[20] In some studies by Constantinescu *et al*. (2015), Dodd *et al*. (2022), Platt and Rubin (1989), and Terry *et al*. (1992) the renal artery PSV was measured at 60-140 cm/s, 130-40cm/s, 140-340 cm/s, and 260 cm/s, respectively.[21-24] In this study, the mean PSV in the main renal arteries was 86.01 cm/s (87.80 and 84.25), while the mean PSV in the intrarenal arteries was 75.32 cm/s (77.12 and 72.89). The Acceleration Time of the renal artery in Platt *et al*. (1989), Dodd *et al*. (2022), and Terry *et al*.'s (1992) studies were 42-57 ms, 40-120 ms, and 37 ms, respectively. However, in this study, the mean acceleration time of intrarenal arteries was 29.35 ms (30.75 and 28.35). The application of the Acceleration Time is in the intrarenal arteries and if there is an increase, renal artery stenosis should be suspected. This is particularly important when the main renal artery is not visible due to technical reasons; in this case, the proposed increase in the Acceleration Time represents the stenosis that is not visible on ultrasonography, therefore, there is no need to measure the Acceleration in the main renal.

RI in the renal artery in Platt *et al*.'s study in 1989 was 0.56 to 0.7 and 0.6 (0.47 and 0.80) in Dodd *et al*.'s (2022), and in Terry *et al*.'s (1992) studies the intrarenal artery was 0.66, whereas in this study the mean RI in the intrarenal arteries was 0.55 (0.56 and 0.54).

In many cases RI is frequently utilized to distinguish between obstructive and non-obstructive hydronephrosis therefore, its measurement is crucial in the intrarenal arteries. The results obtained in this study are the normal parameters of renal arteries in healthy German Shepherd dogs, which can be used in clinical examinations and interpretation of the results.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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