

## Anatomic Characteristics and Locations of Nutrient Foramen in Humerus of Domestic Animals

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### ABSTRACT

**Objective:** This study aimed to determine the numbers, directions, localizations, diameters, morphometric values of the nutrient foramina (NF) in humerus of domestic mammals and to reveal the differences between the right and left humerus in animal species.

**Materials and methods:** In the study, a total of 223 humerus, large ruminants (56), small ruminants (60), equidae (29), sus (24), carnivora-dog (42), and carnivora-cat (12), were examined in the Department of Anatomy, Faculty of Veterinary Medicine, Van Yuzuncu Yil University. The numbers, shapes, directions, localization sites and localized surfaces of the NF's were observed with the naked eye, and recorded. The locations of the NF's were confirmed by calculating the Foraminal Index (FI). The diameters of the NF's were measured using 1.2 mm (18 Gauge: G), 0.9 mm (20 G), 0.7 mm (22 G), 0.55 mm (24 G), and 0.1 mm (34 G) needles. In animal species, morphometric measurements were taken such as total length of the humerus (TLH), distance between the NF with the proximal end of the humerus (NFP), distance between the NF with the distal end of the humerus (NFD), FI and performed statistical analysis of the measured values.

**Results:** There was found a single NF in 99% of the examined humerus in the study. In general, it was seen that the NF's were directed downwards, and located in the middle 1/3 with lower 1/3 segments. NF's were determined to be localized to the facies caudalis in 100% of sus, in 93% of large ruminants and carnivora-dogs, and in 85% of small ruminants; however, in equidae and carnivora-cats were all localized to the margo medialis. According to the statistics, no statistically significant difference ( $p>0.05$ ) was observed between the right and left humerus NF measurement values in terms of morphometric properties. But only, the diameter of the NF in the small ruminants was statistically significant ( $p<0.05$ ).

**Conclusion:** It was found that the morphological and morphometric differences of NF's in right and left humerus of domestic mammals. Moreover, in these animals, it is thought that the study may help veterinary clinicians and surgeons in evaluating of the pathological conditions related to humeral NF and planning of the operative applications to be performed in this region.

**Keywords:** Anatomy, Foraminal indeks, Humerus, Nutrient foramen

### INTRODUCTION

The humerus, one of the bones that make up the ossa membri thoracici, is a long and thick bone that connects to the scapula with the articulatio humeri in the proximally and also the extremity by means of the articulatio cubiti with the antebrachium

(radius-ulna) in the distally (Dursun, 2002; Dyce et al., 2002; Bahadır and Yıldız, 2008).

Foramen nutricium, which is one of the important anatomical features of long bones such as humerus, is clinically important as it is the site of entry into the feeding vessels of the bone and guiding the

identification of weak areas sensitive to bone fractures (Uzuner et al., 2018; Zahra et al., 2018).

In general, there is an nutrient artery and vein that enters and leaves the diaphysis of the long bone from a nutrient foramen (NF). The nutrient artery (arteria nutricia; NA), which enter the bone through the NF and nutrient canal (NC), is divided into proximal and distal branches when they reach to the medullar cavity (cavum medullare), and these separated branches that provides feeding of the bone marrow and the adjacent cortical bone regions in both during the embryonic phase and the normal growth period (Rhineland, 1968; Martini et al., 2015; Zahra et al., 2018). NA's are responsible for 70-80% of the blood supply of the bones. When this blood supply is restricted in various interventional procedures such as any surgical or operative procedures applied to the region, it may result in necrosis, especially bone ischemia, of the bone marrow and cortex (Shim et al., 1968).

Knowing the localization of NF in long bones is important in applications requiring evaluation of bone development and preservation of blood circulation (Campos et al., 1987). Foraminal Index (FI), used to describe the localization of NF's, is obtained by dividing the distance between the proximal end of the bone and the NF to the total bone length (Hughes, 1952; Gümüşburun et al., 1994; Kizilkanat et al., 2007; Kara et al., 2011). In addition, knowing the morphological features of NF is clinically critical importance for the evaluation of various pathological conditions such as developmental abnormalities and hematogenic osteomyelitis in these bones (Skawina and Wyczolkowski, 1987), and the planning of surgical and orthopedic applications such as bone fracture, bone graft and bone implant applications (Piermattei et al., 2006; Kizilkanat et al., 2007; Kara et al., 2011; Sim and Ahn, 2014; Zahra et al., 2018). Furthermore, in the development of new techniques in the field of bone transplantation and resection, it is of great benefit to know the position of the foramen nutricium and arteria nutricia that supply blood to the bone (Kizilkanat et al., 2007; Xue et al., 2016).

When considering the importance of the clinical and morphological of NF, It is important medically to investigate the characteristics of NF in domestic mammals. This study aimed to determine the numbers, directions, localizations, diameters, morphometric values of the nutrient foramina (NF) in humerus of domestic mammals, and to reveal the

differences between the right and left humerus in animal species.

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## MATERIALS and METHODS

In the study, a total of 223 humerus, large ruminants (56), small ruminants (60), equidae (29), sus (24), carnivora-dog (42), and carnivora-cat (12), were examined in the Department of Anatomy, Faculty of Veterinary Medicine, Van Yuzuncu Yil University. The bones were chosen so that they did not have any anatomical disorder. Age and sex characteristics of the examined bones were not known. The foramen nutricium on the bone was observed with the naked eye. Only well-defined the NF's were accepted in the diaphysis of the bone. The foramina nutricium at both ends of the bone were ignored.

### Morphological and Morphometric Evaluation of the NF's in Humerus Diaphysis

Foramen nutricium in the diaphysis of the humerus in domestic mammals (Figure 1.) was evaluated using the following measurements:

**Direction of the bone:** Right and left directions of the humerus were determined first.

**Number of NF's:** The NF's in the diaphysis of the bones were counted.

**Direction of NF's:** It was separated downwards, upwards and horizontally.

**Localizations of NF's:** Localizations of NF's were calculated using FI. To calculate the localization of all the NF's; The formula  $FI = (NFP / TLH) \times 100$  was used. TLH: total length of the humerus, NFP: distance between the NF and the proximal end of the humerus (Hughes, 1952; Gümüşburun et al., 1994; Kizilkanat et al., 2007; Kara et al., 2011).

**According to the FI, the locations of the NF's were determined as follows:** The proximal 1/3-Type1 (FI up to 33.33), the middle 1/3-Type2 (FI from 33.33 up to 66.66), and the distal 1/3-Type3 (FI above 66.66).

**Localized surfaces of the NF's were divided into four types as follow:** Facies cranialis, facies caudalis, margo lateralis, and margo medialis.

**Diameters of NF's (FD):** It was measured using 1.2 mm (18 Gauge: G), 0.9 mm (20 G), 0.7 mm (22 G), 0.55 mm (24 G), and 0.1 mm (34 G) needles.

**Total length of the humerus (TLH):** The distance between the proximal end and the distal end of the humerus.

**NFP:** Distance between the NF and the proximal end of the humerus.

**NFD:** Distance between the NF and the distal end of the humerus.

Nomina Anatomica Veterinaria (2017) was used as terminology in the study. Morphometric measurements were made by using digital caliper. Pictures of the study materials were taken with the Sony Digital DSC-W830.

### Statistical Analysis

Descriptive statistics for studied variables were presented as median, mean, standard deviation, minimum and maximum values. In the study, categorical variables were expressed as numbers and percentages. Shapiro-Wilk ( $n < 50$ ) was used to determine whether the continuous variables in the study were normally distributed or not. In general, nonparametric tests were performed because these variables were not normally distributed. The Mann-Whitney U test was used to compare the measurements according to right-left groups. Statistical significance levels were considered as 1% and 5%. The SPSS (IBM SPSS Statistics for Windows, Ver. 23) was used for all statistical computations.

## RESULTS

### Direction of the humerus and Number of NF's

The number of the right and left humerus of domestic mammal in animal species and the number of NF's in the diaphysis of this bone are given in Table 1. According to this, it was observed that the NF's were the only one in 98% of the humerus of large and small ruminants; in the all of the equidae, sus, and carnivora. In general, there was found a single NF in 99% of the examined humerus in the study. However, NF was not found in only 1% of the examined bones.

### Direction of NF's

The directions of the NF in the diaphysis of the examined humerus by animal species are given in Table 2. According to this, it was seen that the NF's were directed downwards in 93% of large ruminants; in the all of small ruminants, equidae, sus, and carnivora. Nevertheless, in 7% of large ruminants was detected that the horizontal direction. In domestic mammals, no humerus was found with the upward direction of the NF's.

### According to the FI, the locations of the NF's

According to the FI, the locations of the NF's in the diaphysis of the examined humerus by animal species are given in Table 3. In general, it was seen that the NF's were located in the middle 1/3 with

lower 1/3 segments. NF's were determined to be localized to the middle 1/3- type 2 in 91% of large ruminants, in 88% of small ruminants, in 34% of equidae, in 96% of sus, in 98% carnivora-dogs, and in 75% of carnivora-cats; the distal 1/3-type 3 in 9% of large ruminants, in 12% of small ruminants, in 66% of equidae, in 4% of sus, in 2% of carnivora-dogs, and in 25% of carnivora-cats.

**Table 1.** Numbers observed NF in the diaphysis of the humerus.

Animal	Direction	n	Numbers of the NF (%)	
Large ruminant	Left	29	1	28
	Right	27	0	27
	Total	56	1 (2)	55 (98)
Small ruminant	Left	31	1	30
	Right	29	0	29
	Total	60	1 (2)	59 (98)
Equidae	Left	14	0	14
	Right	15	0	15
	Total	29	0 (0)	29 (100)
Sus	Left	11	0	11
	Right	13	0	13
	Total	24	0 (0)	24 (100)
Carnivora-dog	Left	22	0	22
	Right	20	0	20
	Total	42	0 (0)	42 (10)
Carnivora-cat	Left	6	0	6
	Right	6	0	6
	Total	12	0	12 (100)
Grand total (all bones)		223	2 (1)	221 (99)

NF: Nutrient Foramen, n: Number

### Localized surfaces of the NF's

Localized surfaces of the NF's in the diaphysis of the examined humerus by animal species are given in Table 4. According to this, NF's were determined to be localized to the facies caudalis in 100% of sus, in 93% of large ruminants and carnivora-dogs, and in 85% of small ruminants; however, in equidae and carnivora-cats were all localized to the margo medialis.

### Diameters of NF's (FD)

The diameters of the NF's in the diaphysis of the examined humerus by animal species are given in Table 5. According to this, the diameters of the examined NF's were observed to be 1.2 mm in 76%, and 0.9 mm in 24% of large ruminants; 0.9 mm in 2%, 0.7 mm in 22%, and 0.55 mm in 76% of small ruminants; 1.2 mm in 79%, and 0.9 mm in 21% of equidae; 1.2 mm in 83%, and 0.9 mm in 17% of sus; 1.2 mm in 24%, 0.7 mm in 43%, and 0.55 mm in 33% of carnivora-dogs; 0.1 mm in 100% of carnivora-cats.

**Table 2.** Direction of NF's

Animal	Direction	n	Direction of NF's n (%)		
			Downwards	Upward	Horizontal
Large ruminant	Left	28	24 (86)	0 (0)	4 (14)
	Right	27	27 (100)	0 (0)	0 (0)
	Total	55	51 (93)	0 (0)	4 (7)
Small ruminant	Left	30	31 (100)	0 (0)	0 (0)
	Right	29	29 (100)	0 (0)	0 (0)
	Total	59	60 (100)	0 (0)	0 (0)
Equidae	Left	14	14 (100)	0 (0)	0 (0)
	Right	15	15 (100)	0 (0)	0 (0)
	Total	29	29 (100)	0 (0)	0 (0)
Sus	Left	11	11 (100)	0 (0)	0 (0)
	Right	13	13 (100)	0 (0)	0 (0)
	Total	24	24 (100)	0 (0)	0 (0)
Carnivora-dog	Left	22	22 (100)	0 (0)	0 (0)
	Right	20	20 (100)	0 (0)	0 (0)
	Total	42	42 (100)	0 (0)	0 (0)
Carnivora-cat	Left	6	6 (100)	0 (0)	0 (0)
	Right	6	6 (100)	0 (0)	0 (0)
	Total	12	12 (100)	0 (0)	0 (0)

**Table 3.** According to the FI, the Locations of the NF's.

Animal	Direction	n	Locations of the NF's n (%)		
			Proximal 1/3- Type 1	Middle 1/3- Type 2	Distal 1/3- Type 3
Large ruminant	Left	28	0	25	3
	Right	27	0	25	2
	Total	55	0 (0)	50 (91)	5 (9)
Small ruminant	Left	30	0	27	3
	Right	29	0	25	4
	Total	59	0 (0)	52 (88)	7 (12)
Equidae	Left	14	0	5	9
	Right	15	0	5	10
	Total	29	0 (0)	10 (34)	19 (66)
Sus	Left	11	0	10	1
	Right	13	0	13	0
	Total	24	0 (0)	23 (96)	1 (4)
Carnivora-dog	Left	22	0	21	1
	Right	20	0	20	0
	Total	42	0 (0)	41 (98)	1 (2)
Carnivora-cat	Left	6	0	5	1
	Right	6	0	4	2
	Total	12	0 (0)	9 (75)	3 (25)

FI: Foraminal Index;

**Table 4.** Localized Surfaces of the NF's

Animal	Direction	n	Localized Surfaces of the NF's n (%)			
			Facies cranialis	Facies caudalis	Margo lateralis	Margo medialis
Large ruminant	Left	28	2	25	1	0
	Right	27	0	26	1	0
	Total	55	2 (3.5)	51 (93)	2 (3.5)	0 (0)
Small ruminant	Left	30	0	24	6	0
	Right	29	1	26	2	0
	Total	59	1 (2)	50 (85)	8 (13)	0 (0)
Equidae	Left	14	0	0	0	14
	Right	15	0	0	0	15
	Total	29	0 (0)	0 (0)	0 (0)	29 (100)
Sus	Left	11	0	11	0	0
	Right	13	0	13	0	0
	Total	24	0 (0)	24 (100)	0 (0)	0 (0)
Carnivora-dog	Left	22	1	20	0	1
	Right	20	0	19	0	1
	Total	42	1 (2)	39 (93)	0 (0)	2 (5)
Carnivora-cat	Left	6	0	0	0	6
	Right	6	0	0	0	6
	Total	12	0 (0)	0 (0)	0 (0)	12 (100)

**Table 5.** Diameters of NF's (mm)

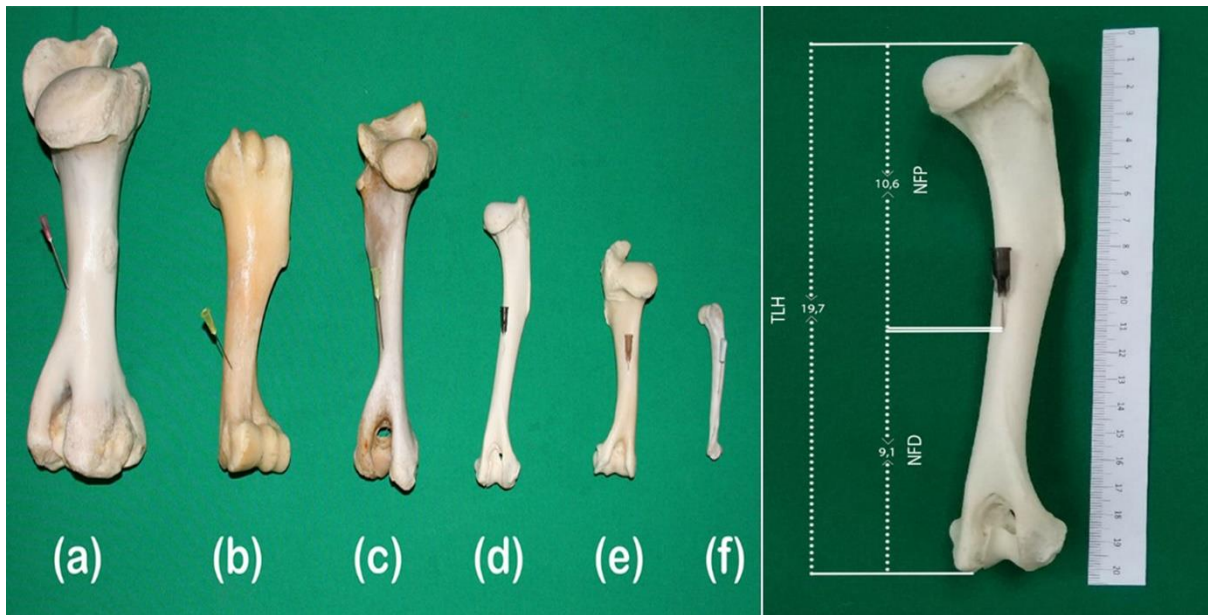
Animal	Direction	n	Diameters of NF's n (%)				
			1.2 (18G)	0.9 (20G)	0.7 (22G)	0.55 (24G)	0.1 (34G)
Large ruminant	L	28	20	8	0	0	0
	R	27	22	5	0	0	0
	T	55	42 (76)	13 (24)	0 (0)	0 (0)	0 (0)
Small ruminant	L	30	0	0	3	27	0
	R	29	0	1	10	18	0
	T	59	0 (0)	1 (2)	13 (22)	45 (76)	0 (0)
Equidae	L	14	11	3	0	0	0
	R	15	12	3	0	0	0
	T	29	23 (79)	6 (21)	0 (0)	0 (0)	0 (0)
Sus	L	11	9	2	0	0	0
	R	13	11	2	0	0	0
	T	24	20 (83)	4 (17)	0 (0)	0 (0)	0 (0)
Carnivora-dog	L	22	0	7	8	7	0
	R	20	0	3	10	7	0
	T	42	0 (24)	10 (0)	18 (43)	14 (33)	0 (0)
Carnivora-cat	L	6	0	0	0	0	6
	R	6	0	0	0	0	6
	T	12	0 (0)	0 (0)	0 (0)	0 (0)	12 (100)

G: Gauge; D: Direction; n: Number; L: Left; R: Right; T: Total.

**Table 6.** Descriptive Statistics and Comparison of Characteristics of the NF's

Animal	Parameter	Direction	Mean	Median	Std. Dev.	Min.	Max.	*p.
Large ruminant	TLH	L	28.53	28.85	2.03	24.10	32.30	0.076
		R	29.80	29.80	2.42	25.10	35.00	
	NFP	L	17.20	16.95	2.37	13.60	22.10	0.209
		R	17.84	17.90	1.73	14.50	20.60	
	NFD	L	11.33	11.85	2.18	5.70	15.90	0.341
		R	11.96	12.10	1.55	9.40	14.90	
	FI	L	60.29	59.88	7.19	48.87	79.50	0.840
		R	59.89	59.67	3.79	52.92	67.02	
FD	L	1.11	1.20	0.14	0.90	1.20	0.385	
	R	1.14	1.20	0.12	0.90	1.20		
Small ruminant	TLH	L	16.39	16.40	1.74	13.50	21.10	0.903
		R	16.49	16.50	1.94	12.50	21.00	
	NFP	L	10.11	9.80	1.49	7.60	14.60	0.347
		R	9.81	9.60	1.82	6.40	15.10	
	NFD	L	6.29	6.30	0.78	4.80	8.10	0.108
		R	6.67	6.60	1.00	4.30	9.10	
	FI	L	61.51	61.29	4.23	52.41	69.23	0.071
		R	59.27	59.03	5.84	49.35	71.90	
FD	L	0.56	0.55	0.05	0.45	0.70	0.033	
	R	0.61	0.55	0.10	0.45	0.90		
Equidae	TLH	L	27.61	29.20	3.73	21.40	33.00	0.631
		R	27.51	28.70	3.51	21.50	33.00	
	NFP	L	18.54	19.15	2.34	14.30	23.00	0.965
		R	18.55	18.30	2.36	14.50	23.20	
	NFD	L	9.08	9.55	1.81	5.90	11.90	0.793
		R	8.96	9.50	1.81	5.60	11.60	
	FI	L	67.31	67.56	3.54	60.42	72.81	0.827
		R	67.59	67.44	4.19	59.58	74.07	
FD	L	1.14	1.20	0.13	0.90	1.20	0.926	
	R	1.14	1.20	0.12	0.90	1.20		
Sus	TLH	L	23.03	24.00	3.00	15.20	26.00	0.283
		R	21.95	22.30	3.01	15.40	26.30	
	NFP	L	13.67	13.90	2.33	9.00	18.10	0.643
		R	13.08	14.10	1.87	9.40	15.80	
	NFD	L	9.35	9.30	2.06	6.20	13.80	0.324
		R	8.86	8.80	2.18	6.00	15.10	
	FI	L	59.43	60.00	6.43	45.02	69.62	0.685
		R	59.88	60.73	5.64	42.59	66.36	
FD	L	1.12	1.20	0.14	0.90	1.20	0.484	
	R	1.15	1.20	0.11	0.90	1.20		
Carnivora-dog	TLH	L	17.62	18.00	3.20	12.10	23.80	0.830
		R	17.80	18.50	3.09	12.10	22.20	
	NFP	L	10.01	9.90	2.35	6.70	15.70	0.480
		R	10.17	10.30	1.88	6.00	13.90	
	NFD	L	7.61	8.00	1.34	4.90	9.50	0.890
		R	7.63	7.65	1.72	4.60	11.20	
	FI	L	56.53	57.05	4.85	48.05	71.36	0.378
		R	57.24	57.64	5.32	46.88	65.48	
FD	L	0.72	0.70	0.14	0.55	0.90	0.418	
	R	0.68	0.70	0.12	0.55	0.90		
Carnivora-cat	TLH	L	10.00	10.00	0.68	8.90	10.80	0.998
		R	10.00	10.05	0.72	8.80	10.80	
	NFP	L	6.27	6.30	0.66	5.50	7.10	0.809
		R	6.32	6.40	0.52	5.60	6.80	
	NFD	L	3.73	3.60	0.62	2.90	4.60	0.936
		R	3.68	3.60	0.62	3.00	4.70	
	FI	L	62.69	63.57	5.42	56.57	70.10	0.997
		R	63.27	63.30	4.61	55.66	69.07	
FD	L	0.10	0.10	0.00	0.10	0.10	1.000	
	R	0.10	0.10	0.00	0.10	0.10		

Mann-Whitney U Test Results, \* p<0.05: Statistically significant; TLH: Total length of the humerus; NFP: Distance between the NF and the proximal end of the humerus; NFD: Distance between the NF and the distal end of the humerus; FI: Foramina Index; FD: Diameters of NF's.



**Figure 1.** The diaphyseal foramen nutricium in the humerus of domestic mammals (a: Large ruminant, b: Equidae, c: Sus, d: Carnivora-dog, e: Small ruminant, f: Carnivora-cat, TLH: Total length of the humerus, NFP: Distance between the NF and the proximal end of the humerus, NFD: Distance between the NF and the distal end of the humerus)

### Descriptive statistics and comparison of characteristics of the NF's

The descriptive statistics of the NF's in the diaphysis of the examined humerus by animal species are given in Table 6. According to the statistics, no statistically significant difference ( $p > 0.05$ ) was observed between the right and left humerus NF measurement values in terms of morphometric properties. But only, the diameter of the NF in the small ruminants was statistically significant ( $p < 0.05$ ).

### DISCUSSION

It is important to know the distribution and location of foramen nutricium and canalis nutricium in long bones such as humerus, so as not to cause any damage to the nutritional vessels of the bone during surgical procedures (Kumar et al., 2013). In operative interventions to the long bones require vascularization or protection of these vessels to improve healing more quickly (Wavreille et al., 2006). Moreover, knowing the number and position of NF's in these bones plays an important role in orthopedic surgery such as bone grafting, humeral diaphyseal transplantation, bone fracture repair, microvascular bone surgery, and joint replacement therapy (Kizilkanat et al., 2007).

While there are many studies on anatomical characterization and localization of NF's in human long bones (Shulman, 1959; Kawahara et al., 1967; Mysorekar, 1967; Longia et al., 1980; Ajmani, 1982;

Campos et al., 1987; Skawina and Wyczolkowski, 1987; Gümüşburun et al., 1994; Kizilkanat et al., 2007; Kumar et al., 2013; Xue et al., 2016; Uzuner et al., 2018; Zahra et al., 2018; Sukumar, 2019); this issue has so far attracted little attention or has been studied without going into much detail in domestic mammals. In the veterinary field, Hughes (2016) on the directions of NF and NC in the long bones of various birds and mammals, Payton (1934) on the direction, development and position of NF's in pigs, Daniel et al. (2008) on the relationship between NF's and diseases in sesame bones of hounds, Ahn (2013), Evans and de Lahunta (2013), Sim and Ahn (2014) studied the localization, direction and localization of NF's and the vessels passing through them in the long bones of the forelimb and hindlimb of the dogs. In addition, Garita and Rapoff (2003), Bassage and Ross (1998) on equidea bones, Siddiqui et al. (2008) on goat bones, Rohlan et al. (2018) on bull bones was mentioned about the NF's in their studies. Moreover, in the study performed by Johnson et al. (2017) the differences between the morphological and morphometric characteristics of NF's in the humerus and femur bones of human, sheep and pigs were revealed. This study is very important for forensic anthropology.

In general, there was found a single NF in 99% of the examined humerus in the our study. Compatibility with literature information shows that the NF's in the diaphyseal part of humerus are often singularity (Hughes, 1952; McLeod et al.,

1958; Getty, 1975; Kizilkanat et al., 2007; Sim and Ahn, 2014; Xue et al., 2016).

Generally, the NF's on the humerus were reported to be localized to the facies medialis, and the lower 1/3 segments of the bone in the horses (Getty, 1975); the facies caudalis, and the middle 1/3 segments of the bone in the sheeps (Getty, 1975) and the black bengal goats (Siddiqui et al., 2008); the margo lateralis, and the lower 1/3 segments of the bone in the cattle (McLeod et al., 1958) and blue bull (Rohlan et al., 2018); the facies caudalis, and the junction of the middle and lower 1/3 of the bone in the pigs (Payton, 1934); the facies caudalis, and the lower 1/3 segments of the bone in the elephant (Ahasan et al., 2016), Indian Blackbuck (Choudhary and Singh, 2016), Ox (Raghavan, 1964), and dogs (Miller et al., 1964; Sim and Ahn, 2014). In our study, NF's were determined to be localized to the facies caudalis in 100% of sus, in 93% of large ruminants and carnivora-dogs, and in 85% of small ruminants; however, in equidae and carnivora-cats were all localized to the margo medialis. Moreover, the localizations of NF's were calculated using FI. In general, it was seen that the NF's were located in the middle 1/3 with lower 1/3 segments. NF's were determined to be localized to the middle 1/3- type 2 in 91% of large ruminants, in 88% of small ruminants, in 34% of equidae, in 96% of sus, in 98% carnivora-dogs, and in 75% of carnivora-cats; the distal 1/3-type 3 in 66% of equidae.

Literature shows that the growing end of the long bone grows twice as fast as the other end. Therefore, obliquity of NF's and NC's is directed away from the growing end. This can be explained by the 'Berard's rule' or growing end theory which suggests that the nutrient artery or NC is directed away from the growing end (Mysorekar, 1967; Longia et al., 1980). In general, this theory is mostly valid for the NF's in the diaphysis of long bones such as the humerus, and the direction of the NF or CN's is directed towards the elbow joint (downward-distal) (Hughes, 1952). In this study, in accordance with this information, it was seen that the NF's in the diaphysis of the examined humerus were directed downwards in 93% of large ruminants; in the all of small ruminants, equidae, sus, and carnivora.

Xue et al. (2016) reported that the diameter of the NF's on the humerus is approximately  $1.11 \pm 0.32$  mm in human. Also, Sim and Ahn (2014) determined that this value was between 0.5-1.0 mm in their study on German Shepherd Dogs. However, in the literature review, no study was

found to clearly identify the diameters of NF's in other animal species. In our study, the diameters of the examined NF's were observed to be 1.2 mm in 76%, and 0.9 mm in 24% of large ruminants; 0.9 mm in 2%, 0.7 mm in 22%, and 0.55 mm in 76% of small ruminants; 1.2 mm in 79%, and 0.9 mm in 21% of equidae; 1.2 mm in 83%, and 0.9 mm in 17% of sus; 1.2 mm in 24%, 0.7 mm in 43%, and 0.55 mm in 33% of carnivora-dogs; 0.1 mm in 100% of carnivora-cats. According to the statistics, no statistically significant difference ( $p>0.05$ ) was observed between the right and left humerus NF measurement values in terms of morphometric properties. But only, the diameter of the NF in the small ruminants was statistically significant ( $p<0.05$ ).

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## CONCLUSION

In conclusion, it was found that the morphological and morphometric differences of NF's in right and left humerus of domestic mammals. Moreover, in these animals, it is thought that the study may help veterinary clinicians and surgeons in evaluating of the pathological conditions related to humeral NF and planning of the operative applications to be performed in this region.

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