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GROSS ANATOMY OF RADIUS AND ULNA IN ROYAL BENGAL TIGER (*Panthera tigris*)

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ABSTRACT

Present study was carried out on the radius and ulna bones of five adult royal Bengal tiger skeleton to notice the characteristic features from other carnivores. The radius was slightly twisted bone with an antero-posteriorly flattened shaft and two extremities. The bicipital tuberosity was present on the proximal part posterior surface. On the distal aspect of posterior surface eight faint oblique lines were present. Proximal extremity had concave facet circumscribed by a bony rim which was sharp and prominent on its lateral part and blunt towards the medial side. Distal extremity was expanded and was about twice the size of proximal extremity. It had a large concave facet that extended medially and ventrally. Ulna was longer than the radius and was fattened medio-laterally. Proximal extremity had olecranon process, anconeus process and facet for humerus. Olecranon process possessed three tubercles. The caudal one was largest (trifid) and lateral tubercle was prominent and smooth and placed cranial to the medial one. Distal extremity was much smaller than the proximal extremity and had rounded facet towards the medial side which articulated with the distal extremity of radius. During morphometry of radius and ulna bones, a non-significant difference was noticed between the bones of two fore limbs which may be of biomechanical importance.

Key words: Biomechanics, osteology, radius, tiger, ulna

INTRODUCTION

The tiger occupies the highest rank in food web in Indian forests which may be considered as the indicator species of Indian wildlife. In recent years, the population of tigers, India's national animal, has shown continuous decline due to poaching, diseases and destruction of their habitats, in which poaching is considered as one of the most important cause for reduction of their population and bringing them at the verge of extinction (Tomar *et al.,* 2018).

Being a member of family Felidae with carnivorous feeding habit, tigers have almost similar anatomical features as other domestic felines with some specie-specific parameters. The anatomical studies on domestic felines and canines have been conducted (Sisson, 1975) and some information is available on a few bones of leopard (Kale *et al*., 1999; Kumar, 2008), panther (Patil *et al*., 1998) and Asiatic lion (Pandey *et al*., 2004). Some of the osteological studies have been reported on *ossa-coxarum* of tiger and leopard and scapula of tiger and leopard (Tomar *et al.,* 2012a,b), on humerus of tiger (Tomar *et al.,* 2014) and on scapula of tiger (Tomar *et al.,* 2018) but there is paucity of

literature on the systematic information of characteristic anatomical and radiographic features of radius and ulna bones of tigers. The current study was designed with the aim to record gross morphological features and morphometry of radius and ulna in royal Bengal tiger.

MATERIALS AND METHODS

Gross anatomical and radiographic studies were conducted on radius and ulna of 5 adult royal Bengal tigers of either sexes, two procured from the Department of Wildlife Health and Management, Jabalpur, Madhya Pradesh and three from the Department of Veterinary Anatomy and Histology, College of Veterinary Sciences and Animal Husbandry, Madhya Pradesh Pashu Chikitsa Vigyan Vishwavidyalaya, Jabalpur (India). All the terminologies were adopted as per Boyd *et al*. (2001). The morphometrical data were recorded with a thread and scale having calibration in millimetres. These all measurements included all the elevations, depressions and curvatures present on the bones to understand the biomechanics of tiger skeleton. The collected data was subjected to the calculation of arithmetic mean and standard error by Microsoft excel 2007. The morphometrical data were also subjected to unpaired 't' test for any significant difference using the same software.

RESULTS AND DISCUSSION

Radius

The radius of tiger comprised of shaft and proximal and distal extremities, the typical features of a long bone with a narrow interosseous space in its whole length It was directed cranio-lateral to ulna by leaving a narrow interosseous space in its whole length. The right radius weighed 148.92±2.59 g and was 27.66±0.29 cm long. The mean circumference at its upper, middle and lower part of radius was 7.68±0.21, 8.12±0.14 and 9.80±0.22 cm, respectively (Table 1). It was slightly twisted thus articulated with ulna proximally at medial side and distally at lateral side.

The shaft of radius was antero-posteriorly flat with convex anterior and flattened posterior surfaces. The anterior surface was wide at the middle and in its center displayed one small crest and a depression just lateral to it. There was also a rough area just below the depression (Fig. 1 & 2). A

Table 1: The range, mean and standard error for various parameters of radius of tiger

S. No.	Parameters	Range		Mean		Standard error	
		Right	Left	Right	Left	Right	Left
1.	Weight (g)	141.0-155.0	142.0-156.5	148.92	150.34	2.59	2.48
2.	Length (cm)	26.9-28.4	26.7-28.1	27.66	27.46	0.29	0.27
3.	Shaft (cm)						
	- Length	19.7-20.3	19.5-20.1	20.00	19.84	0.11	0.12
	- Circumference						
	Upper part	6.9-8.1	6.8-8.0	7.68	7.42	0.21	0.20
	Middle part	7.6-8.4	7.3-8.0	8.12	7.80	0.14	0.13
	Lower part	9.1-10.4	9.0-10.1	9.80	9.58	0.22	0.19
4.	Proximal extremity (cm)						
	- Circumference	9.8-10.8	9.7-10.6	10.34	10.24	0.18	0.16
	- Width	5.0-5.6	5.0-5.5	5.04	5.00	0.26	0.25
5.	Distal extremity (cm)						
	- Circumference	13.2-14.7	13.1-14.4	14.02	13.96	0.27	0.23
	- Width	5.9-7.1	5.9-7.2	6.50	6.58	0.22	0.25

tuberosity was present below neck towards the lateral side. Semi-lunar/kidney shaped/ quadrangular bicipital tuberosity was present on proximal part of posterior surface towards the lateral border. The presence of bicipital tuberosity has been reported by Boyd *et al.* (2001) in domestic cat. Below the bicipital tuberosity a crest was observed which traversed obliquely towards the lateral border. This surface presented another oblique crest commenced from bicipital tuberosity and ended on upper third of medial border. On the distal aspect of posterior surface eight faint oblique lines were present. Medial border was curved, smooth, rounded and concave at its upper one fourth, which became convex and sharp in its middle and then straight in rest of the part; whereas lateral border was concave and thick (Fig. 1 & 2).

Proximal extremity had concave facet circumscribed by a bony rim which was sharp, notched centrally, and prominent in its lateral part and blunt towards the medial side. Similar findings have been reported by Podhade (2007) in leopard. Bony rim was notched anteriorly. The circumference and width of the proximal extremity were 10.34±0.18 and 5.04±0.26 cm, respectively (Table 1).

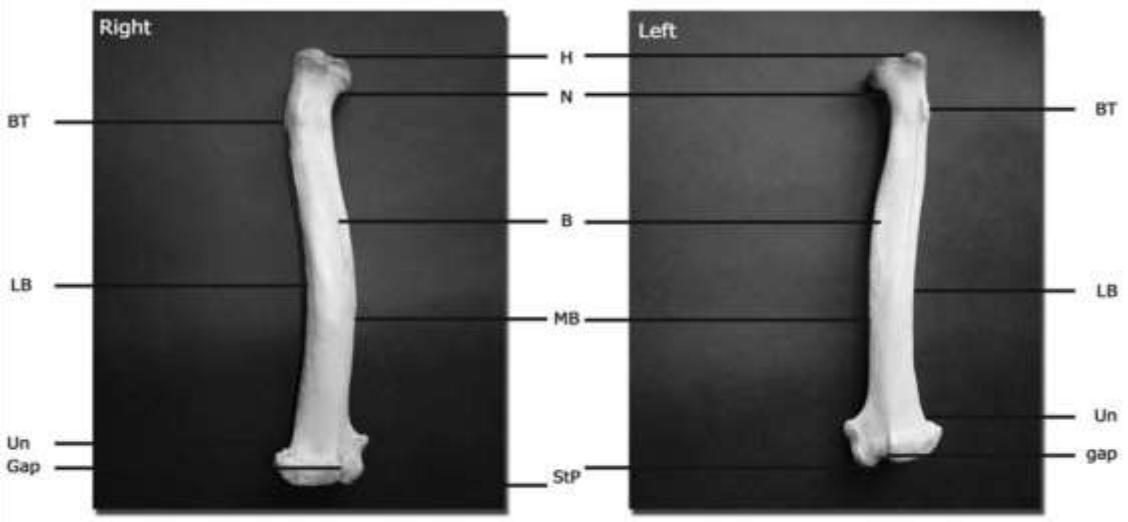

Fig. 1: Anterior aspect of right and left radius showing head (H), neck (N), body (B) groove for abductor pollicis longus (Gap), styloid process of radius (StP), ulnar notch (Un), lateral border (LB) and bicipital tuberosity (BT)

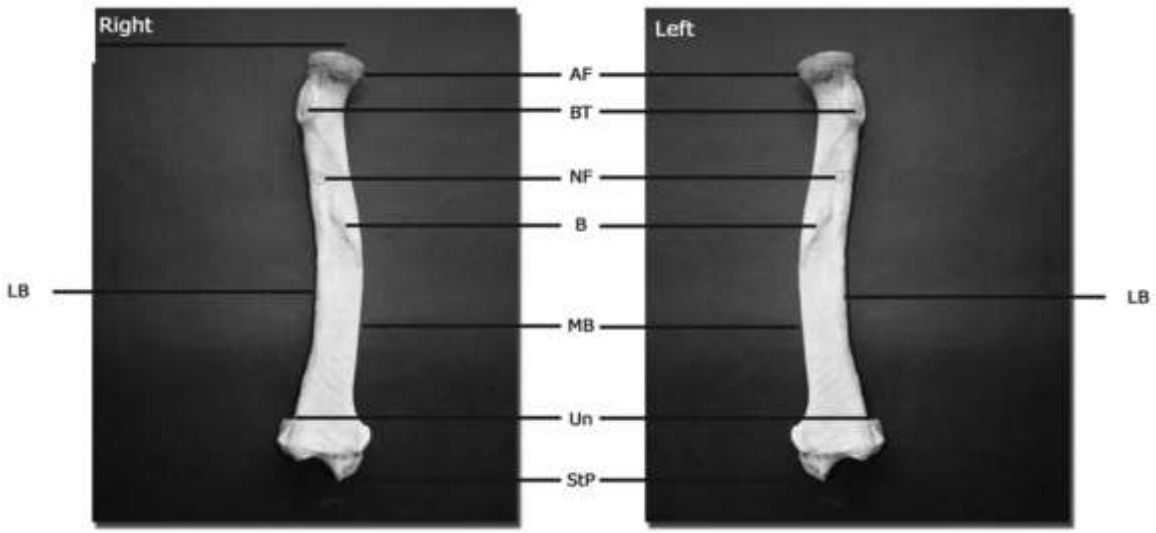

Fig. 2: Posterior aspect of right and left radius showing articular fovea (AF), nutrient foremen (NF), body (B), medial border (MB), styloid process of radius (StP), ulnar notch (Un), lateral border (LB) and bicipital tuberisity (BT)

Distal extremity was expanded and about twice to that of the proximal extremity. It had a large concave facet that extended medio-ventrally. Laterally this extremity had a transversally elongated facet that articulated with the distal extremity of ulna. Medially, the prominent styloid process was observed, which had a rough tuberous medial surface was present. This observation is in agreement with the findings of Pandit (1994) in tiger and Podhade (2007) in leopard. Just above the styloid process, there was a thin flattened projection/process. The distal extremity at the middle of its anterior aspect presented a prominent tubercle.

There was no difference in the morphology of left radius but it differed in morphometrical parameters; however, the differences were non-significant. It weighed 150.34±2.48 g and was 27.46±0.27 cm long with mean circumference at its upper, middle and lower part as 7.42±0.20, 7.80±0.13 and 9.58±0.19 cm, respectively. The mean circumference and width of proximal extremity was 10.24±0.16 and 5.00±0.25 cm, respectively. The mean circumference and width of distal extremity was 13.96±0.23 and 6.58±0.25 cm, respectively (Table 1). The morphometrical difference were also noticed in other appendicular bones of tiger by Tomar *et al*. (2014) and Tomar *et al*. (2018).

Ulna

In this study, ulna was longer than radius and was fattened medio-laterally. It possessed shaft and two extremities, which has also been reported by Pandit (1994) in tiger and Podhade (2007) in leopard. Right ulna weighed 207.56±2.06 g with a length of 34.02±0.32 cm. The cranial surface coursed along the caudo-medial surface of radius leaving a very narrow interosseous space which ran throughout the length of bones. This surface was wider above and gradually narrowed down (Fig. 3 & 4). It was rough, except at its upper one third which was smooth and slightly concave. Caudal border was thick in its upper part then gradually became thinner and terminated as caudal border of styloid process. Cranial border started below the facet for medial condyle of humerus and terminated just above facet for radius bones. The mean circumference of shaft at its upper, middle and lower part was 10.68±0.24, 7.82±0.20 and 5.94±0.08 cm, respectively (Table 2).

Proximal extremity had olecranon process, anconeus process and facet for humerus. Olecranon process possessed three tubercles. The caudal one was largest (trifid) and lateral tubercle was prominent and smooth and placed cranial to the medial one. These observations are in agreement with Sisson (1975) in dog and domestic cat. Medial tubercle of olecranon process was rough. The lateral surface of olecranon process was rough and elevated; whereas the medial surface was smooth and concave. Anconeus process had a large saddle shaped articular surface for

Table 2: The range, mean and standard error for various parameters of ulna of tiger

S. No.	Parameters	Range		Mean		Standard error	
		Right	Left	Right	Left	Right	Left
1.	Weight (g)	200.0-211.9	199.0-209.5	207.56	203.92	2.06	1.74
2.	Length (cm)	33.2-34.8	33.0-34.5	34.02	33.68	0.32	0.32
3.	Shaft (cm)						
	-Length	21.0-22.5	20.7-22.3	21.70	21.44	0.29	0.30
	- Circumference						
	Upper part	10.1-11.3	9.9-11.2	10.68	10.52	0.24	0.26
	Middle part	7.2-8.3	7.0-8.0	7.82	7.58	0.20	0.20
	Lower part	5.7-6.2	5.5-6.1	5.94	5.80	0.08	0.10
4.	Proximal extremity (cm)						
	- Circumference	14.8-15.9	14.4-15.7	15.44	15.22	0.21	0.24
	- Width	4.0-4.6	3.8-4.2	4.28	4.02	0.10	0.07
5.	Distal extremity (cm)						
	- Circumference	7.2-8.1	7.1-7.8	7.66	7.46	0.16	0.14
	- Width	4.1-4.3	3.9-4.3	4.40	4.16	0.09	0.07

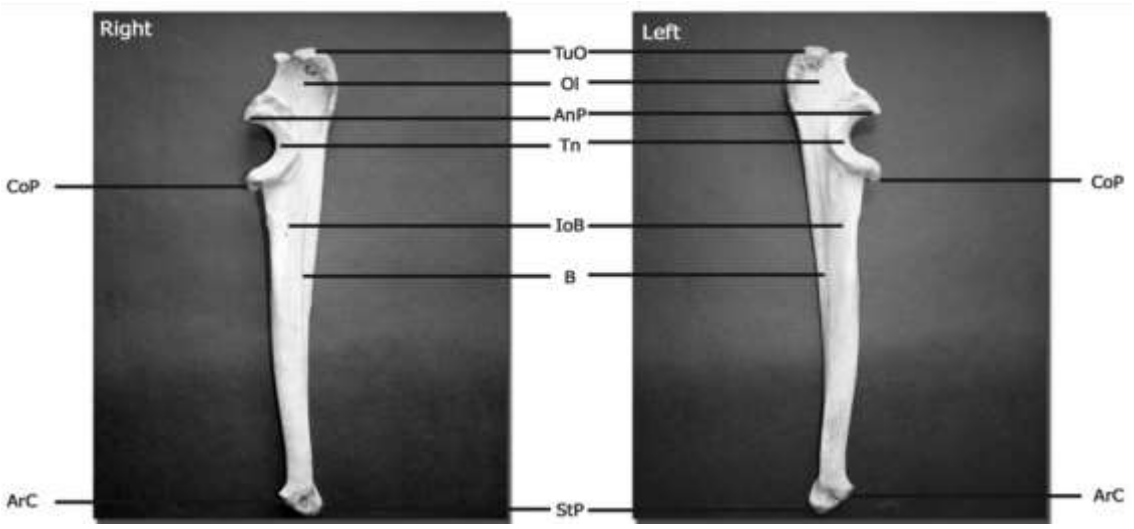

Fig. 3: Medial aspect of right and left ulnae showing tuber olecrani (TuO), olecranon process (OI), body (B), anconeal process (AnP), trochlear notch (Tn), interosseous border (IoB), articular circumference (ArC), styloid process (StP) and coronoid process (CoP)

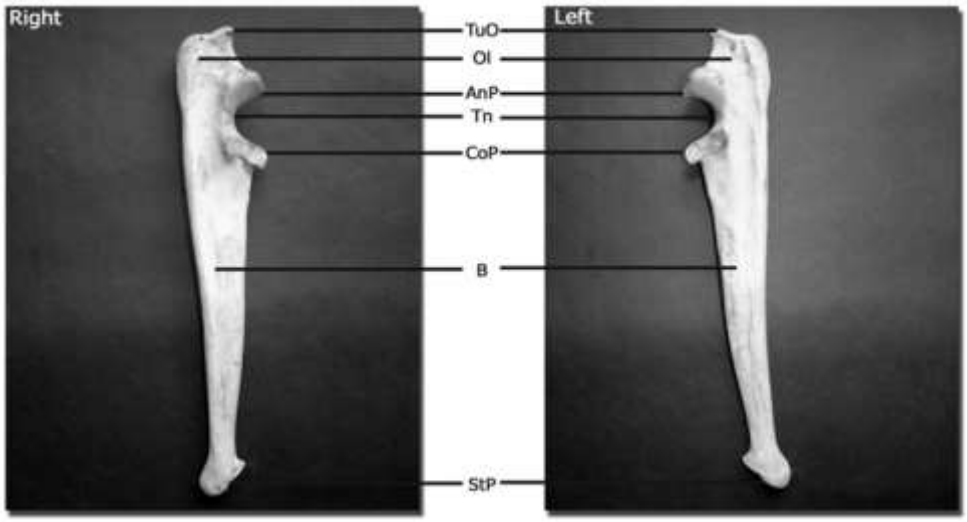

Fig. 4: Lateral aspect of right and left ulnae showing tuber olecrani (TuO), olecranon process (OI), body (B), anconeal process (AnP), trochlear notch (Tn), styloid process (StP) and coronoid process (CoP)

with the medial condyle of humerus. The distal part of anconeal process was smooth, slightly concave and articulated with the medial condyle of humerus. Laterally, the transversely elongated facet, which was narrow in middle and wide towards ends, was present. This facet was meant for articulation with the proximal extremity of radius. The trochlear (semilunar) notch was smooth, half-moon shaped concavity which faced cranially (Fig. 3 & 4) as also reported by Evans and Christenson (1964) in dog. The mean circumference and width of proximal extremity was 15.44±0.21 and 4.28±0.10 cm, respectively (Table 2).

Distal extremity was much smaller than the proximal extremity and had a rounded facet towards the medial side, which articulated with the distal extremity of radius. This information was in accordance with the information provided by Budras *et al.* (2007) in dog. The mean circumference and width of distal extremity was 7.66±0.16 and 4.40±0.09 cm, respectively (Table 2). Laterally, the ventrally directed blunt projection, the styloid process was present (Fig. 3 & 4).

Morphologically, the left ulna was similar to that of right ulna. However, there were non-significant numerical differences in morphometrical parameters between the two ulna. It weighed 203.92±1.74 g with mean length of bone as 33.68±0.32 cm. The mean circumference of shaft at its upper, middle and lower part was 10.52±0.26, 7.58±0.20 and 5.80±0.10 cm, respectively. The mean circumference and width of the proximal extremity was 15.22±0.24 and 4.02±0.07 cm, respectively. The mean circumference and width of distal extremity was 7.66±0.14 and 4.16±0.07 cm, respectively (Table 2). This morphometrical difference may be of biomechanical significance as observed by Tomar *et al.* (2014, 2018) in other appendicular bones in tiger.

Conclusion: During morphometry of radius and ulna bones of royal Bengal tigers, a difference was noticed in the bones of two fore limbs. However, the difference was non-significant but observed in all the specimen in present study which shows certain significance in the biomechanics of skeleton system of tiger.

Conflict of interest: Authors do not have any conflict of interest.

Ethical statement: This study was carried out on the bones collected from the Museum Stock of the Forest Department, Government of Madhya Pradesh, Jabalpur (India), after seeking official permission, which were later was transferred to the Department of Wildlife Health and Management, Jabalpur, Madhya Pradesh and the Department of Veterinary Anatomy and Histology, College of Veterinary Science and Animal Husbandry Madhya Pradesh Pashu Chikitsa Vigyan Vishwavidyalaya, Jabalpur (India).

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