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Radiographic Morphometry of Radio-ulna Bone in Red Sokoto Goat

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Abstract:
Fifty-seven (57) Red Sokoto goats of both sexes from Sokoto metropolis of different age groups were used for the study, the forearm was radiographed and the image of the radiograph captured. The aim of the research was to evaluate radiographic morphometry of radio-ulna bone in Red Sokoto goat, and thus to provide data on the postnatal developmental pattern of the radio-ulna bone, which will serve as a guide for the estimation of age by radiography and in selection of different sizes of intramedullary pin during fracture reduction in orthopedic surgery, and also as a guide for Veterinarians in diagnosis, prognosis and surgical procedures. The parameters considered were the radiographic mean lengths and widths of the radio-ulna bones. The radius and ulna bones had lowest mean lengths of 58.23±0.78mm and 60.09±0.21mm respectively at 1st week and highest mean length of 148.07±0.35mm and 149.72±0.53mm respectively at 144th week. The Radius and ulna bones had lowest mean widths of 5.76±0.06 and 1.96±0.07 respectively at 1st week and highest mean width of 12.04±0.01mm and 8.71±0.07mm respectively at 144th week. Statistical significance (P<0.05), was seen across all the groups for the radio-ulna bone lengths and no significant difference was seen for the radio-ulna bone widths except for groups B and D in ulna bone width. It was concluded that the radio-ulna bones increased in lengths and widths as the animal age increased, though the radius was shorter but wider than the ulna and longitudinal growth has a faster rate compared to transverse growth in radio-ulna bones.

Keywords: *goat, epiphyseal plate, week, radius, ulna, fusion, Radiography*

1. Introduction

Red Sokoto Goat (RSG) has five different ecotypes based on their colour coats (brown, dark red, light brown, black and variegated) and 19% of the total population of Red Sokoto goat in Sokoto State are classified as Dark Red Sokoto goat (Umar *et al*., 2013).Ozung *et al*. (2011) reported that goats contribute 16.0% of total domestically produced meat in Nigeria. Goat and other animal products, such as bones can be used for making bone meal, fertilizer, food, weapons, medicine, divination tool, shovels, construction materials, buttons, plastic and flutes (Ubua, 2011; Jenn, 2013).

Bones are generally classified into five categories; including the long bones, short bones, flat bones, irregular bones, and sesamoid bones (Evans and De Lahunta, 2012). Long bones are bones that are longer than they are wide. They are characterized by an elongated shaft and somewhat enlarged extremities (proximal and distal) that bear articular surfaces (Colville and Bassert, 2002). They include the humerus, radius, femur, tibia, metacarpals, and metatarsals (Konig and Liebich, 2004).

Each bone consists of outer compact part (dense or cortical bone) and inner cancellous part (spongy bone) (Evans and De Lahunta, 2012). According to Das *et al*. (2009) five major events occur during endochondral ossification (bone formation); these include: bone collar formation, cavity formation, vascular invasion, elongation and epiphyseal ossification.

Dyce *et al*. (2010) stated that epiphyseal growth plates at each end of the long bones are composed of four zones of cells, whose activities are responsible for the longitudinal growth of the long bones; the zones of reserve zone, proliferative, maturation and hypertrophy, calcified matrix and the zone of ossification respectively from the epiphyseal end to the diaphyseal end of the epiphyseal growth plate (Chaurasia, 2006).

Although some works have been conducted on the long bones of different animal species; A Radiographic study of growth plate closure compared with age in the Korean native goat (Choi*et al*., 2006), Macro-Anatomy of the Bones of the Forelimb of Black Bengal Goat (Siddiqui *et al.*,2008), Medicolegal importance of radiographic images of humerus in determination of age in sheep and goat (Youssef *et al*., 2016), Morphologic and Morphometric Studies of Long Bones of One Humped Camel Foetuses by Sonfada *et al.* (2015),assessment of calcium and phosphorus contents of the calvaria of one-humped camel fetuses (Hena *et al*., 2012), Comparative Osteometric Study of Long Bones in Yankasa Sheep and Red Sokoto Goats (Salami *et al.*, 2011; Salami *et al.* 2010). However, there is lack of information on the radiographic morphometry of the radio-ulna bone and other skeletal structures of the Red Sokoto goat.

This study will provide radiographic morphometric data on the longitudinal and transverse growth of the radio-ulna bone of the Red Sokoto goat, which will serve as a guide for the estimation of age by radiography hence reducing the problem of inadequate birth record keeping among farmers, it will further serve as a guide in the selection of different sizes of intramedullary pin during fracture reduction in orthopedic surgery. Understanding the anatomy of longitudinal and transverse bone growth will also help practicing Veterinarians in diagnosis, prognosis and surgical procedures **(**Summerlee, 2002; Boskey, 2002).

The study is generally aimed at evaluating the radiographic morphometry of the radio-ulna bones in Red Sokoto goat across there chronological age groups.

2. Methodology

Fifty-seven (57) Red Sokoto goat of both sexes were randomly obtained from three different small ruminant farms with birth record within Sokoto metropolis Nigeria. Their ages ranged from weeks 1 to 144 and they were classified into different age groups and subgroups (Table 1).

Physical and clinical investigations were performed to select apparently healthy animals and exclude those with skeletal deformities and injuries. They were then transported to Veterinary Radiology laboratory, Department of Veterinary Surgery and Radiology, Usmanu Danfodiyo University, Sokoto.

The forearm region of each animals were groomed using a brush to remove any dirt particles that maybe radiopaque on the radiograph. Physical restrain was used to place each animal on a right lateral recumbences on the X-ray table, with the right limb down and the upper left limb retracted and restrained backwards, the right forearms were slightly extended and allowed to rest on the radiographic film cassette (Dr Goos Suprema® Germany, size 35x43cm and 24x30cm) and a digital dry medical X-ray films (AGFA DT2B India and FUJI Japan Tokyo, size 35x43cm and 24x30cm) were used. The x-ray beam was directed vertically from the focal spot to the center of the forearm.

Two radiographic shots per goat with an exposure of 60kV and 10mAs for the kids and 65kv and 12mAs for adult goats. A film-to-focus distance of 97cm were used, giving the total of 114 shots.

The X-ray films were processed in the dark room using a method described by Sirois and Anthony (2009). The processed X-ray films were then illuminated and scrutinized with the aid of an X-ray film illuminator (Techmel and Techmel Texas U.S.A). The radiographic images on the illuminator were captured using a Panasonic Lumix Digital Camera (7.2 Megapixels, DMC-FX07 Model) and transferred to a PC (Personal Computer).

The following radiographic morphometric measurements were obtained with the aid of an illuminator, A4 paper, thread and electronic digital caliper (Raider®) RDDC 706 model to the nearest 0.01mm (modifications), the A4 paper was placed across the width of the radius and ulna bone on the processed X-ray film and the landmarks were marked on the A4 paper for measurement of the widths, the thread was placed across the curved length of the radius and ulna bones on the exposed X-ray film and the landmarks were also marked on the thread for measurement lengths, using the digital caliper, the landmarks are:

i. Radial Bone length (RBL): measured from the proximal diaphyseal end to the distal diaphyseal end of the radius shaft.
ii. Ulna Bone length (UBL): measured from the proximal diaphyseal end to the distal diaphyseal end of the ulna shaft.
iii. Radial Bone Width (RBW): measured from the left and right lateral ends of the radius shaft, and the average of the proximal, mid and distal third radius shaft was used for the measurement.
iv. Ulna Bone Width (UBW): measured from the left and right lateral ends of the ulna shaft, and the average of the proximal, mid and distal third ulna shaft was used for the measurement.

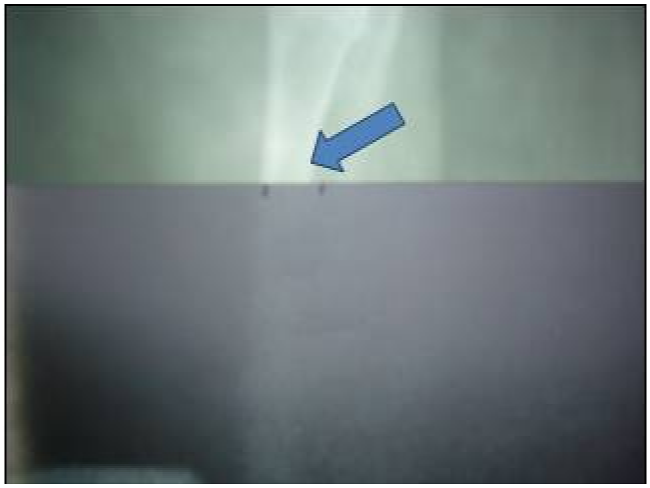

Figure 1: A photograph of an A4 paper on an illuminated radiograph showing how the landmarks were marked on the A4 paper for Radial Bone width (RBW) (Arrow)

Figure 2: A photograph of an A4 paper, a digital caliper showing how the landmarks were marked (from the radiograph) and measured with the caliper

2.1. Statistical Analysis

The data obtained were tabulated and presented as means ± SEM (standard error of the mean). The mean differences were compared for statistical significance by one-way ANOVA. Difference was considered significant at $P<0.05$. The statistical analysis was performed using GraphPad InStat statistical software version 3.0.

3. Result

3.1. Radiographic Radio-Ulna Bone Length Findings

Generally, the radius and ulna bones appeared longer than they are wide. They were characterized by an elongated shaft and somewhat enlarged extremities (proximal and distal) with articular surfaces across all the age groups.

The shaft of each bone has a radiopaque left and right lateral portions (dense or cortical bone) and a middle radiolucent portion (spongy bone). The ulna was caudal to the radius in the proximal part of the forearm but lateral in the distal part. Radio-ulna bones articulates at their extremities, leaving an interosseous space between their shafts. The transversely wide proximal extremity of the radio-ulna bones articulates with the humerus. Their shafts was convex cranially and concaved caudally. However, the ulna has a strong curvature than the radius. The radius bones extend distally to form a styloid process and corresponding lateral extension is formed by the ulna bones.

There was chronological increase in the radiographic mean lengths and widths of the radio-ulna bone across all the age groups. The radius and ulna bone had lowest mean length of 58.23±0.78mm and 60.09±0.21mm respectively at 1st (Table 2 and Figure 3) week and highest mean length of 148.07±0.35mm and 149.72±0.53mm respectively at 144th week. Furthermore, the radius and ulna bone had lowest mean width of 5.76±0.06mm and 1.96±0.07mm respectively at 1st week and highest mean width of 12.04±0.01mm and 8.71±0.07mm respectively at 144th week.

In group A, there was significant difference within all the subgroups for the radiographic mean length of the radial bone, except for weeks 2 (62.84±0.28mm) and 3 (66.22±0.24mm) and the radiographic mean length of the ulna bones was statistically significant ($P<0.05$) among all the subgroups (from weeks 1 and 4), though, there is a continuous increase in length for both radius and ulna, the ulna bones appeared consistently longer than the radius bone within the group (Table 2).
In group B, the radial bone length showed significant difference ($P<0.05$) only within the subgroups of weeks 8 and 16, whereas the ulna bone length showed significant difference across the subgroups, except between weeks 12 and 16, though, the ulna bones were still longer than the radius across the subgroups.
In group C, the radiographic mean lengths of the radius bones had significant difference ($P<0.05$) within the subgroups (weeks 20-28), more so, the subgroups of weeks 24 and 28 showed that radius bone was longer than the ulna bone. Between 24th to 28th weeks there was sudden increase in the length of radial bone, at this age, the radius was slightly longer than the ulna bone; radiographic mean lengths of radius and ulna bones at weeks 24 and 28 were 104.20±3.06mm and 101.05±0.01mm and 111.85±0.23mm and 104.71±1.41mm respectively.
In group D, there was significant difference ($P<0.05$) in the radiographic mean lengths of the ulna bones within each bones of the group, and the ulna bone lengths were consistently longer than the radius bones.
In group E, there was significant difference within the subgroups (weeks 48-144) for both radiographic mean lengths of the radius and ulna bones across their columns. However, the ulna bones were longer than the radius across each subgroup (Table 1).

Age group (weeks)	**Subgroups (weeks) (n=57)**	**Length (mm)**	
		Radial bone	Ulna bone
A (1-4)	1	58.23±0.78^{ab}	60.09±0.21^{a}
	2	62.84±0.28^{c}	63.14±0.14^{a}
	3	66.22±0.24^{ad}	68.25±0.56^{a}
	4	74.44±2.85^{bc}	79.43±0.28^{a}
B (8-16)	8	79.01±0.59^{a}	79.43±0.28^{ab}
	12	84.75±0.43	86.22±0.20^{a}
	16	88.76±0.14^{a}	90.42±0.31^{b}
C (20-28)	20	97.54±0.41^{a}	99.30±0.25^{b}
	24	104.20±3.06^{b}	101.05±0.01
	28	111.85±0.23^{ab}	104.71±1.41^{b}
D (32-44)	32	112.00±0.57^{ab}	115.41±0.58^{c}
	36	117.72±0.51	121.09±0.37^{c}
	40	120.59±0.36^{a}	125.87±2.27^{c}
	44	121.69±1.19^{b}	128.21±0.65^{c}
E (48-144)	48	122.88±0.80^{abcd}	128.21±1.18^{abcde}
	72	138.65±0.35^{aef}	142.77±1.12^{abfg}
	96	143.07±0.83^{bg}	146.31±0.33^{cfhi}
	120	145.41±0.02^{cegh}	148.06±1.22^{dgh}
	144	148.07±0.35^{dfh}	149.72±0.53^{ei}

Table 1: Radiographic mean length ±SEM of radius and ulna bones across different age groups
Means with the same superscript across the subgroups in the columns differ significantly at ($P<0.05$)

3.2. Radiographic Radio-Ulna Bone Width Findings

The radiographic mean widths of radius bones did not vary significantly ($P<0.05$) across all the subgroups of each group in the column. Furthermore, the radiographic mean widths of ulna bones for groups A, C and E showed no significant difference ($P<0.05$) in their respective subgroups. However statistical difference ($P<0.05$) were seen within the subgroups of groups B and D and the radius bones were wider than the ulna across all the groups (Table 2).

Age group (weeks)	Subgroups (weeks) (n=57)	Width (mm)	
		Radial bone	Ulna bone
A (1-4)	1	5.76±0.06	1.96±0.07
	2	6.01±0.01	2.03±0.15
	3	6.24±0.60	2.08±0.09
	4	6.74±0.31	2.09±0.09
B (8-16)	8	8.51±0.71	$2.24±0.07^{ab}$
	12	8.53±0.17	$3.24±0.04^{a}$
	16	9.08±0.04	$3.64±0.21^{b}$
C (20-28)	20	9.66±0.06	3.89±0.09
	24	10.12±0.13	4.14±0.28
	28	10.57±0.36	4.37±0.07
D (32-44)	32	11.05±0.12	$4.48±0.17^{ab}$
	36	11.46±0.27	$4.76±0.17^{cd}$
	40	11.56±0.12	$6.03±0.01^{ac}$
	44	11.79±0.07	$6.11±0.01^{bd}$
E (48-144)	48	11.79±0.06	6.16±0.04
	72	11.89±0.16	6.88±0.01
	96	11.91±0.32	7.79±0.02
	120	11.94±0.29	8.71±0.08
	144	12.04±0.01	8.71±0.07

Table 2: Radiographic mean width ±SEM of radius and ulna bones across different age groups
Means with the same superscript across the subgroups in the columns differ significantly at (P<0.05)

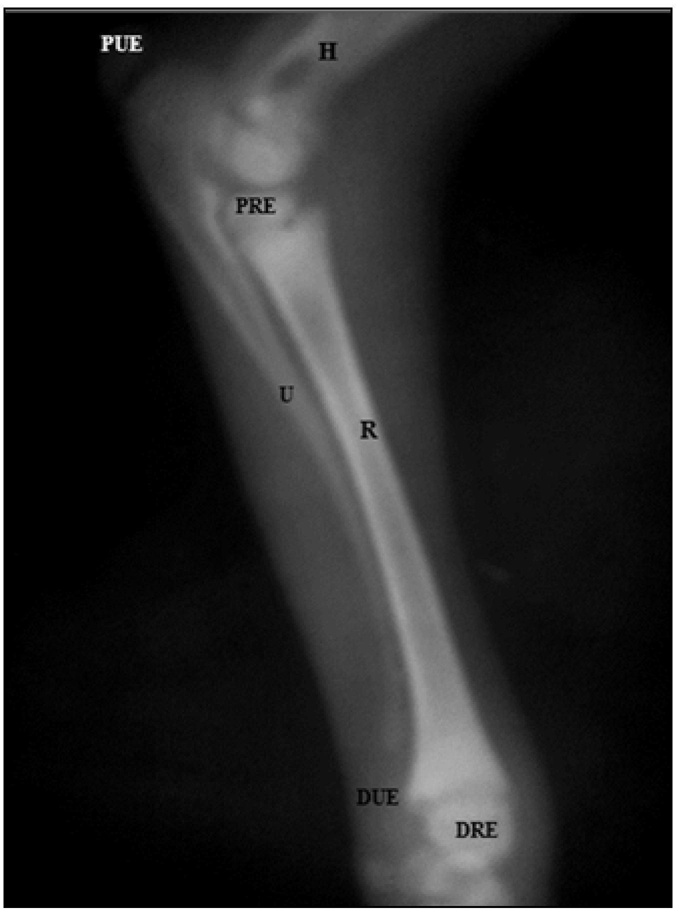

Figure 3: A right medial view of radio-ulna bone radiograph at week 1, of Red Sokoto goat showing the radius (R), Ulna (U), Humerus (H), Proximal Radius Epiphysis (PRE), Distal Radius Epiphysis (DRE), Proximal Ulna Epiphysis (PUE) and Distal Ulna Epiphysis (DUE)

Figure 4: A right medial view of radio-ulna bone radiograph at week 8, of Red Sokoto goat showing the radius (R), Ulna (U), Humerus (H), Proximal Radius Epiphysis (PRE), Distal Radius Epiphysis (DRE), Proximal Ulna Epiphysis (PUE) and Distal Ulna Epiphysis (DUE)

Figure 5: A right medial view of radio-ulna bone radiograph at week 20, of Red Sokoto goat showing the radius (R), Ulna (U), Humerus (H), Proximal Radius Epiphysis (PRE), Distal Radius Epiphysis (DRE), Proximal Ulna Epiphysis (PUE) and Distal Ulna Epiphysis (DUE)

Figure 6: A right medial view of radio-ulna bone radiograph at week 32, of Red Sokoto goat showing the radius (R), Ulna (U), Humerus (H), Proximal Radius Epiphysis (PRE), Distal Radius Epiphysis (DRE), Proximal Ulna Epiphysis (PUE) and Distal Ulna Epiphysis (DUE)

Figure 7: A right medial view of radio-ulna bone radiograph at week 48, of Red Sokoto goat showing the radius (R), Ulna (U), Humerus (H), Proximal Radial Epiphysis (PRE), Distal Radius Epiphysis (DRE), Proximal Ulna Epiphysis (PUE) and Distal Ulna Epiphysis (DUE)

4. Discussion

It has been reported by Richardson *et al.* (1976) that bone growth in width and length depends mainly on the amount of calcium salt deposited during ossification in the zone of ossification. Sivachelvan *et al.* (1996) further stated that this depends on the quantity of the mineral content of the feed and the ability of the animal to use the mineral for bone calcification. Hence, it is therefore, important to state that the nutritional status of animals from which the radiographs were obtained were unknown.

This research therefore revealed that ulna bones was longer than the radial bones. This is in agreement with the findings of Salami *et al.* (2010) in Red Sokoto goat and Siddiqui *et al.* (2008) in black Bengal goat. However, salami *et al.* (2010) reported a much higher radio-ulna length in Red Sokoto goat, this could be due to the difference in research design, since Salami *et al.* (2010) worked on the bone itself rather than the radiograph as performed in this research. We also noted that both the radius and ulna bones length increased with age, which was similar to the findings of Youssef *et al.* (2016) who reported that the length of humerus increases with age.

The results of this study however, showed that radio-ulna bone width increases with age and that the radius width is wider compared to the ulna. The differences in width of all the radial bones measured were not statistically significant ($P < 0.05$), which implies that, there is a slow transverse growth radius bone. However, Salami *et al*. (2011) reported a wider width measurement of radio-ulna bone, and this difference can be related to the different methodology adopted

Salami *et al.* (2011) reported that the ulna lengths is longer than the radius in Yankasa Sheep, which is similar to the findings of this work. However, Salami *et al*. (2011) reported a higher ulna length, this variation could be due to specie difference. The radius bone widths in this work was wider than the ulna, and they both increased across the age groups, this was in agreement with the report of Salami *et al*. (2011)

The cellular proliferation, maturation, calcification and ossification of the chondrocytes within four histological zones of the proximal and distal epiphyseal growth plate of the radio-ulna bones are responsible for the progressive increase in length (longitudinal growth) and width of these bones as seen in this work (Akers and Denbow, 2014).

5. Conclusion

The radio-ulna bones increased in length and width as the animal age increases, though the radius was shorter but wider than the ulna and longitudinal growth has a faster rate compared to transverse growth of radio-ulna bones.

6. Recommendation

The data obtained from this research should be used in the estimation of age and sizes of intramedullary pin orthopedic surgery in goat

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