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ORIGINAL ARTICLE

Gross and Morphometric Anatomical Changes of the Thyroid Gland in the West African Dwarf Goat (*Capra hircus*) During the Foetal and Post-Natal Periods of Development

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SUMMARY

The thyroid gland morphology of West African Dwarf goat was investigated in the foetal, pre-pubertal and pubertal age of development in an attempt to evaluate the changes that take place during these periods. It was studied by gross dissection and morphometric determination of size. The results showed that the location of the thyroid gland on the larynx and trachea varied between the cricoid cartilage of larynx and 12th tracheal cartilage as the age progressed. The right lobe was more cranially located on the larynx and trachea than the left lobe in all age groups. Thyroid isthmus was absent in few foetal thyroid but was consistent in the postnatal thyroids. It became a mere thin fibrous tissue in the older pubertal goats. Accessory thyroid was not observed in all age groups. There were significant differences ($p<0.05$) in the mean weight, length, width and thickness of thyroids of the studied age groups. All measured gross parameters increased with advancing foetal and postnatal age. The study demonstrated the variability of location, size and presence of isthmus during development of thyroid in WAD goats.

Key words: Thyroid gland, anatomy, morphometry, development, Goats.

INTRODUCTION

The thyroid gland is a highly vascularised endocrine organ and it is normally made up of two lobes. These lobes are asymmetrically situated on either side of the trachea close to the thyroid cartilage of the larynx (Venzke 1975; Franson *et al*., 2003). In rare cases, the lobes are situated symmetrically on either side of the trachea (Hamad, 2008). An accessory lobe is sometimes seen in the dog, sheep, goat and camel (Habel, 1989; Taha and Abdel-Magied, 1994).

Remarkable variations in the location colour, shape and other gross features of thyroid in different vertebrates have been observed; even during the developmental period in a particular species (Roy *et al.*, 1975; Dyce *et al*., 2002; Hajovska, 2002).The colour of the thyroid varies in domestic animals and with age of the animal. It is dark red in the camel and sheep

(Venzke, 1975; Taha and Abdel-Magied, 1984). In the pig, the thyroid lobes are reddish brown, while the colour in bovine varies from dark red in calves, to pale or brick red in adult (Venzke, 1975; Dyce *et al*., 2002). Variations in shape are also noted in different animals. In the horse and dog the lobes are irregularly triangular in outline, while they are elongated in the sheep and goat (May, 1970; Habel, 1989). The thyroid weight varies amongst domestic and wild animals depending on the diet, size and weight of the animal (Little, 1991). There are also variations relating to the presence or absence of thyroid isthmus in domestic animals. In the sheep and goat, the isthmus may be reduced to a fibrous connective tissue strand or completely absent especially in the sheep (May, 1970; Hajovska, 2002). In horse, the paired lobes are widely dissociated but connected by an insubstantial isthmus; in cattle, the lobes are connected by a wide isthmus of parenchymal tissue (Dyce *et al*., 2002).

Thyroid develops from a ventral epithelial thickening in the pharyngeal portion of the foregut. This thickening invades the surrounding mesenchyme forming the thyroglossal duct; the distal end of this duct forms a horseshoe-shaped lobe that moves caudally to the beginning of the trachea. The duct is lost and further development of the thyroid is accomplished with formation of two lobes, joined by an isthmus and caudal movement on the larynx (Hyttel *et al*., 2010).

Thyroid hormones produced by the thyroid gland are essential for normal growth and development in young animals, while calcitonin secreted by parafollicular cells regulate calcium level in blood (Norris, 2007).

Goat provides products that are important for man throughout the world. In developed countries goats are valued for their milk, fibre, and meat; while in developing countries they are valued mainly for meat followed by milk, fibre and skin. Goat also meets the socioeconomic, cultural and recreation needs in developing countries of West Africa (Solaiman, 2010).

The responses of thyroid structure and function to nutritional, environmental and climatic factors differ amongst animal species and with age of their development (Buffenstein *et al*., 2001). The size of thyroid varies depending on the iodine content of the diet. When iodine content is deficient, an enlargement of the thyroid (goitre) may develop. Iodine is incorporated into thyroid hormones that have multiple functions as regulators of cell activity (Capen and Martin, 2003).

Most of the available information on the gross anatomy of the thyroid gland comes mainly from murines (mouse and rat), reptiles, birds, zebra fish and human beings as reviewed extensively by Fujita (1975) and Van Vliet and Polak, (2007). Few published articles available on gross morphology are mainly on exotic breeds of goats, particularly Indian, Nubian and Pakistani goats (Roy *et al.*, 1975; 1978; Baishya *et al*., 1986; Adhikary *et al*., 2003; Hamad, 2008). Moreover the earlier study of thyroid gland of West African dwarf goat (Osuagwu and Aire, 1992), focused only on morphometric parameters of foetal thyroids.

The present study is aimed at investigating the gross and morphometric anatomical changes of the thyroid gland of West African dwarf (WAD) goat during the foetal and postnatal periods. It is expected that this report will provide baseline information that will be useful in interpreting radiographs, ultrasonographs and pathological conditions of the thyroid gland during the foetal and postnatal stages of development.

MATERIALS AND METHODS

Experimental Animals

Thyroid glands used were harvested from ten (pubertal) and 10 prepubertal male goats

purchased from markets around the University of Nigeria, Nsukka and maintained for about two weeks in order to ascertain that they were in good health condition for the study. A total of sixty (60) paired foetal thyroid lobes were obtained from male foetuses of pregnant goats unknowingly slaughtered for meat in the local abattoirs in Nsukka and Obollo-Afor, Enugu State, Nigeria, just before singeing of the carcass. The foetal age for WAD were determined by prediction formula (Richardson, 1980) and visual observation of developmental features. Prediction formula: Y= (CRL+17)2.1, where Y is the age (days) and CRL = Crown to Rump Length (cm). The age of the prepubertal and pubertal goats were determined by dentition (Dyce *et al*., 2002; Chibuzo, 2006; Solaiman, 2010). The experimental animals were grouped following the estimated age as follows: foetal age (50-70 days; 75-90 days; 95-125 days), prepubertal, pubertal (1-2 years) and pubertal (3 years and above).Their body weights ranged as follows:50-70 days (15.5-85.5g), 75-90 days (134.5-360.7g), 95-125 (540.7-1148.8g), pre-pubertal (1.5-3.5kg), pubertal 1-2 years (4.6-6.2kg), pubertal over 3years (7.5-10.2 kg).

Experimental Procedure

Before sacrifice, the animals were weighed; the foetuses were weighed with Ohaus® Heavy Duty Double Beam Balance (Thomas Scientific, UK) in the laboratory, Department of Veterinary Anatomy, UNN, while the prepubertal and pubertal goats were weighed with Avery® weighing balance (Pacific Industrial Scale, USA) in the Veterinary Teaching Hospital, UNN and Mobile weighing scale (UK).The postnatal goats (prepubertal and pubertal) were sacrificed under anaesthesia using pentobarbitone sodium solution at dosage of 1-2ml/kg/body mass by intravenous injection (Kyron Laboratories, Benrose , South Africa). Following death in all study age groups, the skin and superficial fascia on the ventral midline of the neck were excised to expose the laryngeal muscles, divisions of sternocephalicus, cartilages, tracheal rings and the right and left lobes of thyroid gland. The topographical relationships of the two thyroid lobes with surrounding structures were noted and photographed with 10.0 Samsung digital camera (China Hifi, Corp.). Thereafter, the left and right thyroid lobes were carefully harvested and weighed separately with Mettler balance (Mettler Group, UK).The colour and shape of thyroid lobes were noted. The positions of the two lobes along the laryngeal-tracheal cartilage tube were noted. Length, width and thickness of each lobe were measured with Vernier calliper. Length was measured between the cranial and caudal poles of each lobe; width and thickness were taken from the middle of the lobes.

(i) Length (longitudinal/long axis –cranial to caudal pole) (cm)

(ii) Width (transverse/short axis diameter) (cm)

(iii) Thickness (height/dorso-ventral axis) (cm)

Photographs of the various ages of development were taken. Measured parameters were analysed statistically using analysis of variance. Duncan's multiple range test was used to separate variant means, and significance was accepted at $p< 0.05$.

RESULTS

The dorso-lateral aspect of each lobe was covered by sternothyroideus, sternomandibularis and sternomastoideus muscles. The dorsal aspect was related to the common carotid artery, internal jugular vein, vago-sympathetic trunk, external jugular vein and oesophagus. The cranial border was in contact with cricopharyngeus and cricothyrodeus. These anatomical relationships were maintained in all age groups of development (Plates 1-8).

Generally, from foetal to pubertal goats (Plates 1-8), the thyroid possessed two lobes

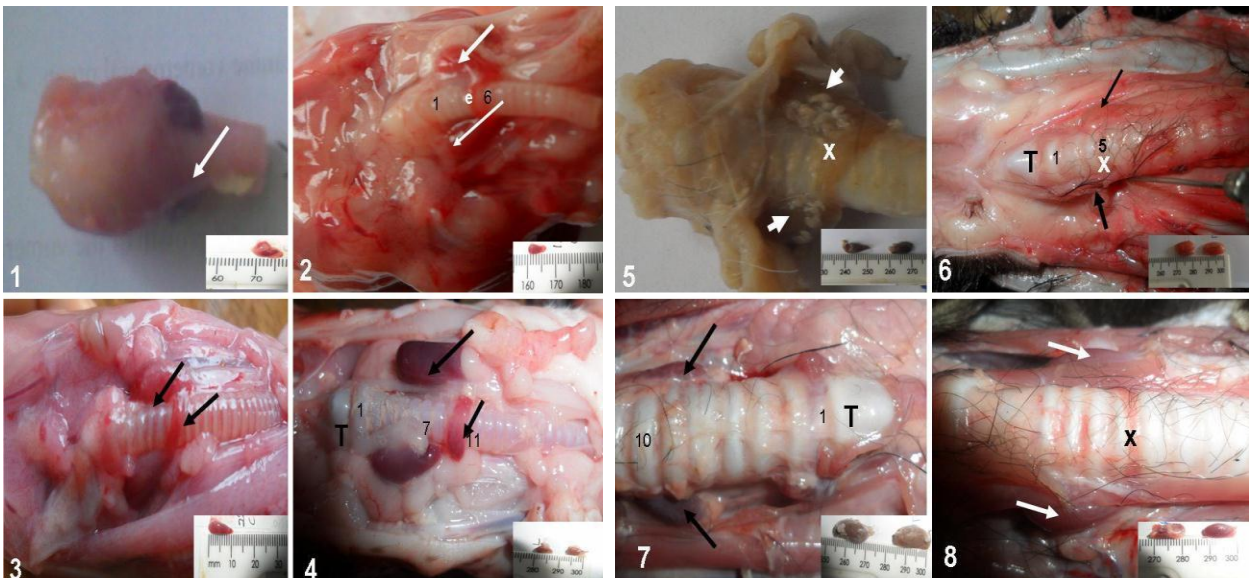

Plate 1: Gross photograph of ventral region of WAD goat foetus (50-70 days) showing developing lobes -right thyroid lobe (arrow) apposed on the laryngeal cartilages and contacted the 1st-3rd tracheal ring. Inset **(a**) is the length of each lobe). The isthmus was not quite distinct at this age. **Plate 2**: Gross photograph of ventral neck region of the WAD goat foetus of about 70 days with distinct lobes of thyroid (arrows) and isthmus (X). Note the symmetrical position of these lobes to each other with the straight isthmus (**e**) joining. Inset (a) is the length of each lobe. The number of tracheal ring is represented by (1, 6). **Plate 3**: Gross photograph of ventral neck region WAD goat foetuses (75-90 days) , showing the developing thyroid lobes (white arrows), brick-red in colour and placed asymmetrically to each other, joined by the diagonally-placed isthmus (black arrow). Inset (a) showing increased length of each lobe at this age of development. **Plate 4:** Gross photograph showing maturation of the thyroid gland of WAD goat foetuses of 95-125 days with distinct elliptical lobes (white arrow), dark-red in colour and showed a distinct isthmus (black arrow). Note the position of thyroid between the 1st to the 10th or 12th tracheal cartilage. Insert (a) showed further increase in length at this stage of development. The number of tracheal ring is shown by (1, 7, 11). **Plate 5:** Gross photograph of formalin –fixed of thyroid gland of near term foetus of WAD goat (140-150 days) with distinct isthmus (X) and thyroid lobes (arrowheads). Inset (**a**) showing further increase in length of lobes. **Plate 6**: Gross photograph of the thyroid gland of prepubertal WAD goat with symmetrical lobes (black arrows), and indistinct fibrous isthmus(x) in between the lobes on 5th tracheal ring (**5**). Inset **(a**) showing further increase in length of lobes. **Plate 7:** Gross photograph showing further development of the thyroid lobes of pubertal WAD goat (1-2 yrs), with symmetrically placed lobes (arrows), indistinct fibrous isthmus (x) and thyroid cartilage (T). Inset **(a),** shows further increase in length. Note the relationship of the thyroid lobes with other structures such sternomastoideus and sternomandibularis. The tracheal ring number is shown by (1, 10). **Plate 8:** Gross photograph showing the thyroid of older pubertal goats (<3yrs) that did not differ in the features previously seen in the age of 1-2 yrs. Inset (a) shows further increase in length of the lobes. Note the thin fibrous isthmus (X) connecting the two lobes (arrows). Insert (a) indicating length of each lobe.

that were located laterally and asymmetrically on the larynx and tracheal cartilages. Its position varied between the larynx (cricoid cartilage) and tracheal rings (12th tracheal ring) as the age progressed. Accessory thyroid tissue was not encountered in any the studied age groups. The right lobe was more cranially located along the larynx and tracheal rings than the left lobe in all age groups studied. In addition to the above, a very thing strand of isthmus connected the two lobes diagonally crossing the ventral surface of tracheal rings at varying positions, connecting the caudal end of the lobes. However, the isthmus was not observed in thyroid lobes of few foetuses (less than 5%). The isthmus were present, was always located between the second and fourth tracheal ring in most of the foetuses (Plates 1 to 5), but increased in size and thickness such that in older pubertal goats of about 3 years, they were found between the 4th to the seventh tracheal ring (Plate 8). Also the texture of the gland was firm and the colour was dark-red in fresh samples, and brownish in fixed samples with minor variations. Generally the shape of the thyroid lobes in all age group was elongated and elliptical in outline. The left lobe varied in shape in some adult goats, while the right lobe maintained the elongated elliptical shape in most samples examined. The cranial pole of each lobe was enlarged, thick and rounded, while the caudal pole was relatively reduced in mass and thinned-out forming a tapering narrow end to join the isthmus from opposite lobe. In the foetuses and following further maturation of thyroid of pubertal and pubertal goats, the thyroid lobes were observed to be in contact with the lateral surface of the cricoid cartilage.

Specifically, in the younger foetuses of about 50-70 days of gestation, the thyroid lobes were more cranial, symmetrically positioned on both sides of the neck, lying between 1st and 6th tracheal rings and were in close contact with the thyroid cartilage (Plates.1&2). The same relationship and features were presented by the foetuses of 75-90 days (Plate 3). There were few variations in the position of the thyroid lobes along the tracheal rings amongst foetuses of even the same developmental age and this resulted in slight asymmetry of the lobes in the older foetuses. In foetuses of 95-125 days, the thyroid lobes were located between the 1st and 10th or 12thtracheal ring with some few exceptions (Plate 4).

The left lobe extended between the 1st and the 5th tracheal rings, while the right lobe was positioned from about the 5th to the 10 or 12th tracheal ring. There were no significant changes from the previous age in near term foetuses of about 140-150 days (Plate5). The thyroid lobes showed symmetrical positioning in most of the late foetal and postnatal goats. In the prepubertal WAD goat (2-4 months) (Plate 6), the thyroid lobes maintained a symmetrical position on the latero-ventral aspect of the neck with increased size and were in most cases located between the 5th and 7th tracheal ring and the thyroid isthmus was present on the 4th-5th tracheal ring. In most pubertal WAD goat (Plates 7 & 8) the symmetrically positioned lobes always extended between the first tracheal to 4th or 5th tracheal rings on both sides of the neck. The isthmus was always located between the 2nd and 4th tracheal ring in foetuses and increased in size such that in older pubertal goats, they were present between 4th to 7th tracheal rings. In some cases the isthmus was connected to the thyroid lobes horizontally in younger foetuses below 74 days and diagonally placed in some foetuses of about 95-125 days (Plate 4). In the near term foetuses (140-150 days) (Plate 5) and postnatal goats (Plates. 6 to 8), the isthmus of the thyroid, maintained a direct horizontally (straight isthmus) connection between the two lobes of the thyroid and were symmetrically positioned between the caudal ends of the lobes. The isthmus was

TABLE 1: Gross morphometry of the thyroid gland of WAD goat during development

Dev. Age (days/yrs)	Wt. thyroid (g)	Length (cm)	Width (cm)	Thickness (cm)
50-70d	0.05 ±0.001[a]	0.42±0.004[a]	0.22±0.001[a]	0.22±0.01[a]
75-90d	0.22±0.001[b]	0.88±0.02[b]	0.53±0.09[b]	0.43±0.08[b]
95-125d	0.38±0.04[c]	0.90±0.02[b]	0.61±0.01[c]	0.53±0.01[c]
Prepubertal	0.49±0.01[d]	1.11±0.03[c]	0.62±0.01[c]	0.56±0.01[c,d]
Pubertal (1-2yrs)	0.54±0.02[e]	1.88±0.02[d]	0.89±0.02[d]	0.54±0.02[c,d]
Pubertal (<3 yrs)	0.85±0.01[f]	2.14±0.04[e]	1.12±0.03[e]	0.57±0.02[d]

Note: a,b,c,d,e,f = Means with different superscripts across columns are significantly different ($p<0.05$)

mere indistinct fibrous connective tissue in older pubertal goats (Plate 8).

The thyroid weight increased with age. For instance, the two lobes weighed about 0.05g in 50-70 days foetuses, while in the pubertal goats, it weighed 0.85g. Also other morphometric parameters relating to size (dimensions), including length, width and thickness of each lobe, showed that all parameters increased with advancing age (Table 1). These differences were significant at $p<0.05$.

DISCUSSION

The present study showed variations of thyroid location as the developmental age progressed and its location also differs from other domestic animals investigated including camel, cattle, pig and sheep (Venzke 1975; Hajovska, 2002; Dyce *et al*., 2002). It was attached dorsolaterally to the larynx in all age groups studied. Its position varied between cricoid cartilage of larynx and 12th tracheal rings during the developmental period. The two lobes were between the 4th to 5th tracheal rings in pubertal goats. Unlike in the adult camel where it is located caudal to the larynx from the level of the 1st to 10th tracheal rings (Taha and Abdel-Magied, 1994). In the horse, it is related to the first three or four tracheal rings (Venzke, 1975). In the ox, the thyroid is closely attached to the cricoid cartilage of the larynx and in the sheep; it extends from 2nd to the 7th tracheal rings (May, 1970).In the present study, the gross morphological study of the thyroid gland during the foetal and postnatal period of development generally showed that the gland was related to the cricoid cartilage and the dorso-lateral part of the first three tracheal cartilages in development, but there were some variations in the location of the thyroid gland amongst the age groups. These variations in position of the thyroid on the laryngo-tracheal tube may be due to species differences in morphogenetic mechanisms that are involved in migration of thyroid anlagen in the neck and mouth that determine the final location of the mature thyroid. In addition, the number of tracheal rings is not constant in domestic animals even within species of the same age (Dyce *et al*., 2002). The present finding in foetal and postnatal goats is supported by earlier gross description of location of adult thyroid in goat by Venzke (1975), and Budras and Habel (2003). Comparative studies on foetal thyroid positions were not readily available.

The present report is also consistent with gross description of the thyroid in goat by some authors (Venzke, 1975; Dyce *et al*., 2002; Budras and Habel, 2003; Bhardwaj *et al.,* 2006; Hammad, 2008; Hussain, 2010). However the study showed a consistent thyroid isthmus across the ventral aspect of tracheal ring in pubertal goat. Its presence

was inconsistent in foetal goats. The absence of thyroid isthmus can be associated with several thyroid developmental anomalies (Duh *et al*., 1994) and is therefore a mal-developmental finding in this report of foetal thyroid. The present observation of isthmus is similar to the findings of some authors who failed to find thyroid isthmus in all goats studied (Roy et al., 1975) and sheep foetuses (Hajovska, 2002). The colour of the thyroid lobes in all age group was dark-red in fresh samples, similar to that of camel and sheep (Taha and Abdel-Magied, 1994); Venzke, 1975). It is redish brown in porcine and in bovines, it varies from dark-red in calves to pale in the adult (Venzke, 1975). It may also be reddish brown adult sheep (May, 1970). The variation in colour may be due to genetic differences and nutritional variations that may be related to availability of iodine. Generally the shape of thyroid lobes in all age group of the present study was elongated and elliptical in outline, with minor variation of shape of left lobe in some pubertal goats. Comparatively, the lobes are irregularly triangular in porcine, horse and dog (Venzke, 1975). In the sheep (Habel, 1989), they are ovoid and elongated in outline almost similar to the present finding in pubertal goat.

Regarding thyroid size, the present finding followed the pattern of growth of most organs in animal which normally increase in size and weight as the animal matured. The mass and volume of the thyroid depend on animal breed, body weight, nutrition, physiological status, and season of the year, geographical and climatic region (Hamad, 2008). The significant variability in weight of thyroids during development may be caused by the above factors in addition to the nomadic pastoral management of some goats in most parts of Nigeria. The relationship between weights of the thyroid to body weight was not considered in this study, mainly because the factors that influence thyroid/body weight relationship such as sex and body weight were not available because of the abattoir-origin of many of the study samples. However the absolute weight of thyroid gland showed a significant increase with age of development.

As far as the thyroid weight, length, thickness and width are concerned, the present study is consistent with the earlier findings of Roy *et al*., (1975) in postnatal goats and in swine (Das, 1971). In addition, Baishya et al., (1985) showed no significant difference in weight, length, width and thickness of thyroid of various age groups of postnatal Assam goat from zero to ninety days. However, Islam (1993) found differences in weight, length, width and thickness between the thyroid gland of young and adult dwarf goats in Pakistan. The present observations on variations of parameters related to size are in agreement with those of Das (1971) in the dog, Kausar and Shahid (2006) in camel.

Roy *et al.,* (1975) stressed a greater variability of the weight of the thyroid gland in comparison with the weight of other endocrine glands. A comparison of absolute weights of thyroid gland obtained in the present study to that of exotic breeds showed that the thyroid weight of our indigenous goats were generally smaller in weight. For instance the mean absolute weight of thyroid lobes in pubertal WAD goat was 0.85 ± 0.01 g, while that of Nubian goats weighed approximately 1g from kids to adult goats (Hamad, 2008). Similarly the each lobe of Nubian goat thyroid measured from 1.5 cm to 3cm in length, 1 cm- 1.5 cm in width (Hamad, 2008). This value is greater than what was obtained in the present study. This may be related to nutrition and type of herd-management of these animals amongst other factors. However, the gross size of thyroid gland does not always reflect its functionality. The size and shape of thyroid gland is important in differential diagnosis of hypothyroidism, hyperthyroidism, and

hyperplasia of thyroid follicular cells (goitre), colloid goitre, iodide-excess goitre in domestic animals.

The increase in fibrous connective tissue with advancing age observed in the study is similar to the report of Andrew (1971) and Roy *et al.,* (1975). The presence of isthmus on some but not all foetuses of goat is similar to the report of Hájovská (2002) in foetal sheep, in which glandular isthmus was present in only 8 cases from 18 foetuses studied. The present result showed isthmus on all pubertal goat species, different from the study of Roy *et al.,* (1975), that revealed its absence in 9% of postnatal goats examined. Similarly, Karski (1964) noticed absence of isthmus in 14.7% of lateral lobes of adult monkey studied. The presence of consistent thyroid isthmus in all pubertal specimen of goat examined contrary to the report of some investigators (Roy *et al*., 1975; Hamad 2008), may be due to the number of goat thyroid studied. It may be also be a peculiar anatomical feature of the thyroid of our indigenous goat. The absence of isthmus in some foetuses of WAD goat examined in the present study can be explained as an anomaly of embryological development. The absence of an isthmus can be associated with other types of dysorganogenesis, such as the absence of a thyroid lobe or the presence of ectopic tissue (Duh *et al*., 1994). The isthmus may be missing in amphibians, birds and among mammals- monotremes, certain marsupials, cetaceans, carnivores and rodents. In rhesus monkey (*Macacus rhesus*), the thyroid glands are normal in position but the isthmus is not present (Pastor-Varquez *et al*., 2006). In dogs, the presence or absence of a glandular isthmus depends upon the age and breed of the dog. A glandular isthmus is present in the larger breeds of dogs, but is absent in the smaller breeds of dogs (Hoskins *et al.,* 1962).

The work showed the position of the thyroid isthmus in relation to the tracheal rings varied with advancing age in the goats species studied. This finding concurs with the studies of Roy et al., (1975) in postnatal goats and May (1970) in the sheep. The thin isthmus and the thyroid lobes appeared not to shift in position relation to tracheal rings during development. It was in contact with cricoid cartilage, muscles, oesophagus and the first to third tracheal ring. A functional and glandular thyroid isthmus as seen in foetal and young pubertal goat in this study would apparently increase thyroid hormone production as well as relative weight of the gland. It has been shown in dogs that female dogs more frequently possessed a glandular and functional isthmus due to needs arising from oestrus and pregnancy (Booth, 1975).

In the present study, accessory thyroid tissue was not observed in any stage of development in goats. This finding suggests that accessory thyroid tissue is not a common developmental anomaly in the local WAD goat studied as in the dog (Booth, 1975). Carcangiu (2007) described that accessory thyroid tissue can be found in the vicinity of the thyroid gland, in the region of the hyoid bone, within the thymus, along the entire cervical portion of the trachea, between the mediastinal pleurae, within the pericardium in aortic arch region, embedded in the periaortic fat, and suspended cardially in the conus arteriosus. Roy *et al*., (1975) observed accessory tissue in one specimen, out of eleven goats, age ranging from one month to six months. The presence of accessory thyroids in sheep, horse and dog has been mentioned by Venzke (1975). Karski (1964) found accessory glands in 4% of the monkey. Sanson (1967) found accessory glands in 23.5% of the adult goats and Roy (1971); found it in 5% of the buffaloes studied. Accessory thyroid tissue is common in dogs; about 50% of adult dogs have 1 to 5 accessory nodules of thyroid tissue embedded in fat on the intrapericardial aorta. Based on the present study it may be concluded that accessory

gland tissue may not be a common developmental anomaly amongst The WAD goat used in this study and further study involving screening of larger number of animals may be required. Accessory thyroid tissue may undergo neoplastic transformation in the adult animal (Scarlet, 1994).

CONCLUSION

The study has shown the variability of location, size and presence of isthmus during the development of the thyroid gland from the foetal to the pubertal period. This finding should be considered in the diagnostic interpretation of pathological specimen and ultrasonography of the neck region in WAD goat.

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