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Postnatal developmental morphology of the kidney in Black Bengal goats (*Capra hircus*) from birth to maturity

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Abstract

Background: Postnatal kidney development in goats follows a predictable growth trajectory influenced by genetic, nutritional, and environmental factors. Establishing age-specific kidney morphometric norms is critical for distinguishing pathological changes from normal developmental variation in clinical and forensic veterinary contexts.

Objectives: This research investigated the postnatal developmental trajectory of kidney morphology in Black Bengal goats from birth through maturity at the University of Veterinary Science, Myanmar, during 2025-2026.

Methods: Kidneys from 36 Black Bengal goats across six age groups (birth, 1, 3, 6, 12 months, and adult >24 months; n=6 per group, equal sex distribution) were subjected to gross morphometric analysis including weight, length, width, volume, cortex thickness, medulla thickness, and capsule thickness.

Results: Kidney weight increased 8.3-fold from 5.8 ± 0.4 g at birth to 47.9 ± 3.6 g at maturity. The most rapid growth phase occurred between birth and 3 months, accounting for 47.4% of total weight gain. Kidney length showed a 2.8-fold increase from 2.1 to 5.9 cm. Cortex and medulla growth was proportional, maintaining a stable cortex-to-medulla ratio.

Conclusion: Kidney development in Black Bengal goats follows a triphasic postnatal growth pattern. These age-specific morphometric baselines provide essential reference standards for clinical diagnosis and pathological evaluation.

Keywords: Black Bengal goat, kidney development, postnatal morphology, morphometry, *Capra hircus*, growth

Introduction

Postnatal organ development in domestic animals follows predictable growth trajectories governed by genetic programming, nutritional adequacy, and environmental influences [1]. The kidney, as a vital organ responsible for homeostatic regulation, electrolyte balance, acid-base maintenance, and metabolic waste elimination, undergoes substantial morphological and functional maturation from birth through adulthood in small ruminants [2].

Gross morphological documentation of the Barbari goat kidney established important baseline parameters including organ dimensions, shape characteristics, and surface features in adult specimens [3]. However, the temporal progression of kidney development across postnatal life stages in goat breeds has received limited attention, particularly for the Black Bengal breed [4]. The Black Bengal, a prolific meat-type breed native to South and Southeast Asia, exhibits compact body size and early maturity characteristics that may influence the pattern and rate of visceral organ development.

Understanding age-specific kidney morphometric norms is essential for veterinary practitioners to accurately distinguish pathological renal changes from normal developmental variation at different life stages [5]. This research was designed to characterise the complete postnatal developmental trajectory of kidney morphology in Black Bengal goats from birth through maturity, providing age-specific reference standards for clinical and forensic veterinary applications.

Furthermore, age-specific reference standards enable forensic veterinary practitioners to estimate the approximate age of goat carcasses or isolated kidneys based on organ

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dimensions, which may be relevant in cases involving illegal slaughter, wildlife crime investigations, or insurance assessments. Systematic documentation of the complete postnatal developmental trajectory thus serves multiple practical and academic purposes across veterinary disciplines [6].

Material and Methods

Material

The research was conducted at the Department of Anatomy, University of Veterinary Science, Yezin, Myanmar, from January 2025 to March 2026. Animals were sourced from the university teaching and research farm where Black Bengal goats have been maintained under standardised management for over a decade.

A total of 36 Black Bengal goats were assigned to six age groups with equal sex distribution: birth (day 0, n=6), 1 month (n=6), 3 months (n=6), 6 months (n=6), 12 months (n=6), and adult (>24 months, n=6). Animals were maintained under standard institutional management with access to natural grazing, concentrate supplementation, and clean water. All animals were clinically healthy and free from renal pathology at the time of examination.

Methods

Kidneys were harvested following humane slaughter conducted in accordance with institutional ethical guidelines, freed of perinephric fat, and processed within one hour of collection. Gross morphometric parameters measured included total weight (digital balance, 0.01 g accuracy), length, width, and thickness (digital vernier callipers, 0.01 mm accuracy), and volume (water displacement method).

Mid-sagittal sections were prepared for measurement of cortex thickness, medulla thickness, hilus length, and capsule thickness. Growth rate between consecutive age groups was calculated as percentage increase per parameter. One-way ANOVA with post-hoc Tukey HSD test was used for multiple age-group comparisons. Nonlinear regression was applied to fit growth curves. All analyses were performed using GraphPad Prism version 10 with significance at $P<0.05$.

Results

Kidney weight demonstrated a continuous progressive increase across all age groups, from 5.8 ± 0.4 g at birth to 47.9 ± 3.6 g at maturity, representing an 8.3-fold total increase over the postnatal growth period (Table 1). The most rapid growth phase occurred between birth and 3 months, with kidney weight increasing from 5.8 g to 22.7 g, a 3.9-fold increase accounting for 47.4% of total weight gain.

The growth trajectory displayed three distinct phases: rapid growth from birth to 3 months, moderate growth from 3 to 12 months, and plateau from 12 months to adulthood (Figure 1). Kidney length followed a parallel trajectory with a 2.8-fold increase from 2.1 ± 0.2 cm at birth to 5.9 ± 0.3 cm in adults.

Width and thickness followed parallel growth trajectories, with width increasing 2.8-fold (1.2 to 3.4 cm) and thickness 2.5-fold (0.9 to 2.3 cm) over the postnatal period. The length-to-width ratio remained relatively stable across all age groups (range 1.71-1.75), indicating isometric growth patterns with proportional expansion along all three anatomical axes.

Table 1: Postnatal kidney morphometric parameters across age groups in Black Bengal goats

Parameter	Birth	1 month	3 months	6 months	12 months	Adult
Weight (g)	5.8 ± 0.4	12.4 ± 1.1	22.7 ± 2.0	33.5 ± 2.8	41.2 ± 3.2	47.9 ± 3.6
Length (cm)	2.1 ± 0.2	3.2 ± 0.3	4.1 ± 0.3	4.9 ± 0.3	5.5 ± 0.3	5.9 ± 0.3
Width (cm)	1.2 ± 0.1	1.9 ± 0.2	2.5 ± 0.2	2.9 ± 0.2	3.2 ± 0.2	3.4 ± 0.2
Volume (mL)	5.1 ± 0.4	11.2 ± 1.0	20.5 ± 1.8	30.1 ± 2.5	37.8 ± 3.0	43.5 ± 3.4

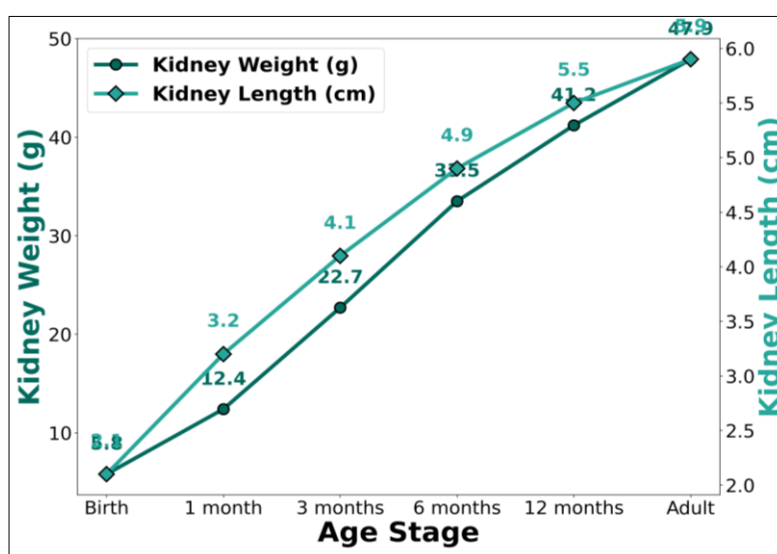


Fig 1: Postnatal growth trajectory of kidney weight and length in Black Bengal goats from birth to maturity

Regional morphometric analysis revealed differential but proportional growth patterns between cortex and medulla (Table 2, Figure 2). Cortex thickness increased 2.0-fold

from 2.8 mm at birth to 5.6 mm in adults, while medulla thickness showed a 1.9-fold increase from 4.1 mm to 7.9 mm. The cortex-to-medulla thickness ratio remained

relatively stable, ranging from 0.68 at birth to 0.71 at maturity.

Capsule thickness increased from 0.21 ± 0.03 mm at birth to 0.38 ± 0.04 mm at maturity (1.8-fold increase). All morphometric parameters showed statistically significant

increases between birth and 3-month age groups ($P < 0.001$), with non-significant changes between 12-month and adult groups for most parameters ($P > 0.05$), confirming attainment of near-mature kidney dimensions by one year of age.

Table 2: Regional kidney measurements (mm) across age groups in Black Bengal goats

Parameter	Birth	1 month	3 months	6 months	12 months	Adult
Cortex thickness	2.8 ± 0.3	3.5 ± 0.3	4.2 ± 0.3	4.8 ± 0.4	5.3 ± 0.4	5.6 ± 0.4
Medulla thickness	4.1 ± 0.4	5.2 ± 0.4	6.1 ± 0.4	6.8 ± 0.5	7.4 ± 0.5	7.9 ± 0.5
Hilus length	1.5 ± 0.2	2.0 ± 0.2	2.4 ± 0.2	2.7 ± 0.3	3.0 ± 0.3	3.2 ± 0.3
Capsule thickness	0.21 ± 0.03	0.25 ± 0.03	0.28 ± 0.03	0.32 ± 0.04	0.35 ± 0.04	0.38 ± 0.04

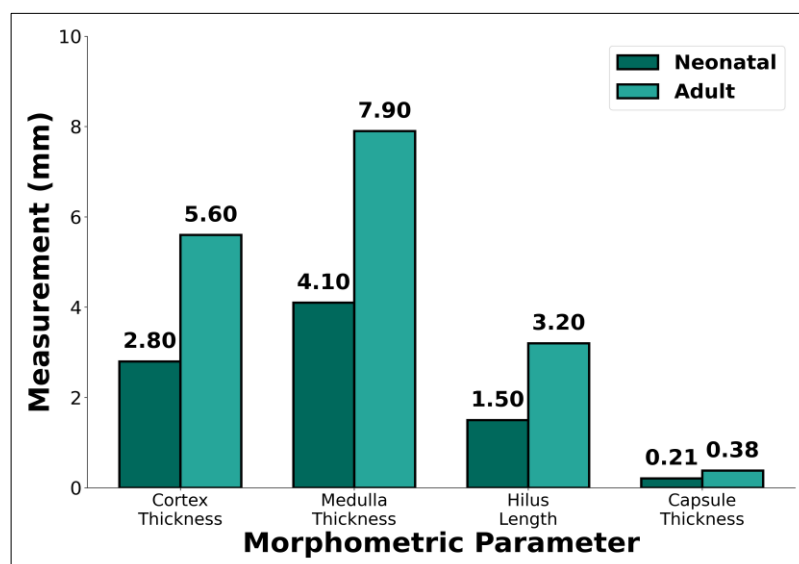


Fig 2: Comparative regional kidney measurements between neonatal and adult Black Bengal goats

Discussion

The postnatal kidney growth pattern observed in Black Bengal goats follows the characteristic sigmoidal trajectory documented in other domestic ruminant species, with rapid early growth reflecting the intensive functional demands placed on developing kidneys during the transition from colostral to solid feed nutrition [6]. The concentration of 47.4% of total kidney weight gain within the first three months of life corresponds to the period of most rapid whole-body growth and increasing metabolic demands on renal excretory capacity.

The proportional growth of cortex and medulla, maintaining a stable cortex-to-medulla ratio throughout postnatal development, suggests coordinated developmental programming of both functional regions [7]. This finding has practical significance for veterinary pathologists, as deviations from this ratio at any given age may indicate pathological changes in cortical or medullary tissue.

The plateau in kidney growth beyond 12 months coincides with the attainment of physiological maturity in Black Bengal goats [8], suggesting that kidney maturation tracks closely with overall somatic growth cessation. These age-specific morphometric data fill an important gap in the comparative veterinary anatomy literature and provide clinicians with essential reference values for evaluating renal morphology across the lifespan of Black Bengal goats. From a clinical standpoint, the attainment of near-mature kidney dimensions by 12 months carries practical implications for veterinary diagnostic imaging. Ultrasonographic reference values established in adult

animals may be applied with reasonable confidence to animals older than 12 months, but significant adjustment is necessary for younger age groups, particularly those under three months of age where kidney dimensions are less than half of adult values [9]. The growth curve equations derived from this research provide a quantitative framework for such age-specific adjustments in clinical practice.

Conclusion

Kidney development in Black Bengal goats follows a triphasic postnatal growth pattern characterised by rapid growth from birth to 3 months, moderate growth through 12 months, and subsequent plateau toward adult dimensions. The 8.3-fold increase in kidney weight with proportional cortical and medullary expansion demonstrates coordinated organ maturation aligned with whole-body growth.

These age-specific morphometric baselines provide essential reference standards for clinical diagnosis, pathological evaluation, and forensic age estimation of renal tissue in Black Bengal goats, and contribute to the comparative developmental anatomy database for *Capra hircus* breeds.

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