Al-Qadisiyah J. Vet. Med. Sci. 2026; 25 (1): 94-100. doi.org/10.29079/qjvms.2026.169617.1171

ISSN P: 1818-5746
E: 2313-4429
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Comparative Morphometric Characterization of Renal Development in Sheep

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Submitted: February 24, 2026
Revised: March 03, 2026
Accepted: March 08, 2026

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Abstract The study examined growth and morphological alterations of the kidneys in Awassi sheep at two critical developmental stages; pre-birth (3–4 months of gestation) and post-birth (3–4 months after birth). The findings indicated that the kidneys of embryos gestating for 3 -4 months were diminutive and slender, encased in a removable fibrous capsule. The brains were pale, and the renal pyramids were just beginning to take shape. It is typical for the right kidney to be higher than the left. The right and left kidneys were about the same dimensions (length, width, thickness, and weight) at this point. But when they were born, the kidneys of lambs increased a lot in all morphometric metrics, making them look like beans since they got bigger, thicker, and smoother. The fibrous capsule was more securely attached to the renal parenchyma, and the cortex and medulla were clearly different from each other. The renal pyramids were well-formed, and the renal pelvis was easy to see, which meant that the kidney was getting bigger. The data suggest that the growth of sheep's kidneys remains proportionate bilaterally, with significant alterations occurring pre- and postnatally due to inherent growth processes. This study provides valuable insights into the morphology and dimensions of the kidneys in Awassi sheep during their growth. It can be used as a reference for research that looks at the anatomy of different animals, how they grow, or birth problems in tiny ruminants.

Key words: Morphological analysis, Nephrogenesis, Prenatal development, Postnatal development.

Introduction The Awassi sheep (Ovis aries Awassi) are essential domesticated animals known for their adaptability, high reproductive rates, and minimal management requirements. Their domestication aids livestock breeding, offering economic benefits (1, 2, 3, and 4). The kidney plays a key role in regulating fluid balance and waste excretion. A thorough understanding of kidney development is vital for identifying abnormalities in domestic ruminants. The urinary tract develops in stages, with nephrogenesis completed by week thirty-two, while disruptions in embryonic tissue interactions may result in congenital disorders. Renal organogenesis involves precise spatial and temporal processes crucial for nephron

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formation, emphasizing the significance of this knowledge for veterinary practices (5). The study aims to investigate kidney morphology at prenatal and postnatal stages in sheep to enhance understanding of embryonal development and associated anomalies.

Material and Methods

Ethical approval

The current study procedures were approved by the College of Veterinary Medicine, University of AlQadisiyah.

Study area and Sample Collection

The present study was conducted in the Department of Anatomy and Histology College of Veterinary Medicine, University of Al-Qadisiyah. All kidney samples were collected at Qadisiyah modern slaughterhouse, Qadisiyah City, Iraq. Ten kidney samples were collected from young lambs aged 3–4 months, and ten kidneys were obtained from ovine fetuses at 3–4 months of gestation. The samples were collected from clinically healthy animals of local breed Awassi sheep (*Ovis aries*) at different developmental stages (prenatal and postnatal) immediately after slaughter, during the period from September 2025 to November 2026. As soon as the animals were slaughtered, fresh kidney organs were taken, put in a labeled nylon bag then put in an ice-filled container, and shipped directly to the laboratory.

Determination of Study Ages

The ages selected for the study were determined according to the key developmental stages of renal growth in fetal and postnatal sheep. These stages were chosen to represent critical morphometric, histological, and molecular transitions during kidney development. The selection was based on literature describing the chronological pattern of renal development in sheep. For fetus's, the age is determined by using the (CRL) formula $Y = 2.1 (X + 17)$, (Y) is the fetus's age, and (X) is the fetus's length from crown to anus in cm Figure (3-1). In some cases, the estimated age was also confirmed based on the available information provided by the breeder or the slaughterhouse records (6). Regarding the postnatal age of lambs was estimated based on their external morphological characteristics, including body size, weight, and other physical features.

Exclusion Criteria

The following criteria were excluded from the study: Other breeds of sheep; animals below the required age for the study; Unhealthy animals; Irregular kidneys (extra-large, too small); Damaged kidneys (kidneys that contain abnormal lesions, hematomas, trauma, cysts, or tumors).

Morphology and Morphometric Study of kidney

The gravid uterine wall was opened along the greater curvature of the dorsal surface to expose the fetuses at a gestational age ranging between 3 and 4 months. The fetuses were gently cleaned using cotton soaked in water to remove the amniotic fluid, and the mean fetal crown–rump length (CRL) was measured. In fetuses, the kidneys were carefully dissected in situ by opening the abdominal cavity and gently reflecting the visceral organs laterally to expose the paired kidneys in the sub lumbar region. The kidneys were then separated with their associated vessels and ureters intact. In postnatal specimens, the abdominal cavity was opened through a midline incision from the xiphoid cartilage to the pelvic. The visceral organs were reflected to visualize the kidneys in their normal position. Each kidney was dissected free from the surrounding fascia and fat, preserving the renal artery, vein, and ureter as much as possible (15). The morphology and morphometric study of each kidney in both age groups (prenatal and postnatal) included observations of its shape, color, and location (position in situ and anatomical connections). While parameters were recorded:

1- Kidney length: distance between the cranial and caudal poles of the kidney measured along the longitudinal axis using electronic digital vernier caliper (cm)
2- Kidney width: was measured as the maximum transverse distance from the lateral to the medial border across the hilum, using electronic digital vernier caliper (cm).
3- Kidney thickness: was measured as the maximum vertical distance from the dorsal to the ventral surface at the mid-transverse

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section of the kidney using electronic digital vernier caliper (cm)

4- Kidney weight using a sensitive electronic balance (Sartorius B154, ± 0.001 gm, China) (g).

Result

Fetal Kidneys (3–4 Months of Gestation)

At 3–4 months of gestation, the fetal kidneys (metanephros) of sheep appeared that it has taken a more definite shape to appear migrated forward to reset relatively among the sacral and sub lumber region relatively with the right kidney being slightly higher than the left. The left kidney was in contact with the primitive stomach on its craniolateral aspect; while approximately half of the ventral surface of the right kidney was in contact with the elongated caudate process of the liver (figure, 1). The posterolateral surfaces of both metanephros were attached to the respective testes. The posterior extremities of the adrenal glands were anteriorly attached to their corresponding sides of each kidney. Both kidneys exhibited distinct dorsal and ventral surfaces, medial and lateral borders, and cranial and caudal poles.

The right kidney appeared triangular with a broad posterior extremity, while the left kidney was slightly curved and bean-shaped. Both kidneys exhibited reddish – brown pale in color (figure, 2). The medial border was compressed and concave, while the lateral border was relatively thick in the cranial region and thinner toward the caudal end. The cranial extremity was broad, whereas the caudal extremity was narrow and flattened (figure, 3). The kidneys were enveloped by a thick layer of perirenal fat, and their color showed a marked change to brown.

The thin fibrous capsule could be easily detached from the underlying parenchyma. The cortex appeared pale, and relatively thick, whereas the medulla was darker, striated, and organized into developing renal pyramids that converged toward the primitive renal pelvis (figure, 4). Both kidneys displayed a well-defined hilus containing the developing renal vessels and ureter. The overall morphology indicated progressive maturation of the renal parenchyma with advancing gestational age. There were no significant differences in the dimension and weight between right and left kidney at this stage of the development. The mean length, width, thickness and weight of right kidney (34.15±0.62) mm, (23.49±0.41) mm, (15.29±0.16) mm and (7.57±0.28) g respectively Table (1and 2). In comparison, mean length, width, thickness and weight of left kidney (32.83±0.49) mm, (24.34±0.31) mm, (15.41±0.13) mm and (7.71±0.28) g respectively Table (1&2).

Lamb Kidneys (3–4 after birth)

At two months after birth, both kidneys were located in the sublumbar region on either side of the vertebral column, with the right kidney positioned slightly more cranially than the left, and both partially covered by the last ribs. Their location and relation with the adjacent organ did not differ markedly from that observed in the 3–4 months of gestation. Both kidneys exhibited a uniform bean-shaped appearance with smooth surfaces and well-balanced margins. They were enclosed by a thin but distinct fibrous capsule that was slightly more adherent to the underlying parenchyma compared with the fetal stage (figure, 5). Grossly, the kidneys exhibited a reddish-brown color that was more intense than in the fetal stage, reflecting increased vascularity and functional activity. The renal surface was smooth and devoid of lobulations, indicating complete fusion of the fetal lobes (figure, 5).

The cortex appeared pale brown and relatively thick, while the darker, striated medulla formed distinct renal pyramids converging toward a clear renal pelvis. The hilus contained the renal vessels and pelvis in their typical postnatal arrangement. No marked morphological differences were noted compared to the previous stage, except for the more distinct appearance of the cortex and medulla (figure,6). There were no significant differences in the dimension and weight between right and left kidney at this stage of the development. The mean length, width, thickness and weight of right kidney (61.60±0.44) mm, (43.50±0.25) mm, (31.02±0.07) mm and (49.58±0.75) g respectively Table (1and 2). In comparison, mean length, width, thickness and weight of left kidney (63.53±0.43) mm, (46.28±0.36) mm, (30.06±0.12) mm and (51.33±0.54) g respectively Table (1&2).

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(Table. 1): Morphological parameters of the right & left kidney in fetal (3–4) months of gestation & lamb (3–4 after birth)

Groups	Length of kidney(m)		Width of kidney(m)	
	Left	Right	Left	Right
Fetal sheep	32.83±0.49 Aa	34.15±0.62 Aa	24.34±0.31 Aa	23.49±0.41 Aa
Lamb sheep	63.53±0.43 Ba	61.60±0.44 Ba	46.28±0.36 Ba	43.50±0.25 Ba
LSD	9.56		6.60	

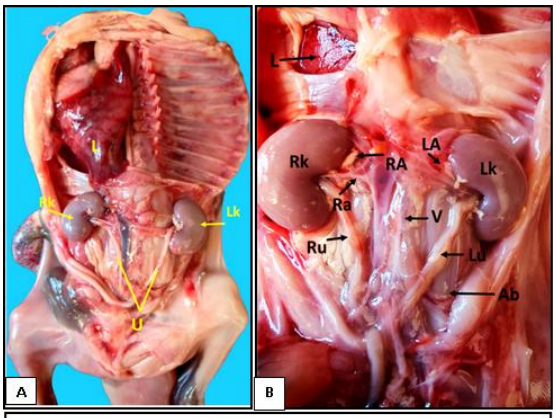

Figure (1 A, B) Macrograph of fetus ageing 3-4 month of gestation showing: Rk.Right kidney, Lk. Left kidney, L. Liver, R. Rumen, U.ureters , Ru.Right ureter, Lu. Left ureter, Ra. Renal artery, RA. Right adrenal gland, LA. Left adrenal gland, V. vena cava, Ab. Abdominal cavity.

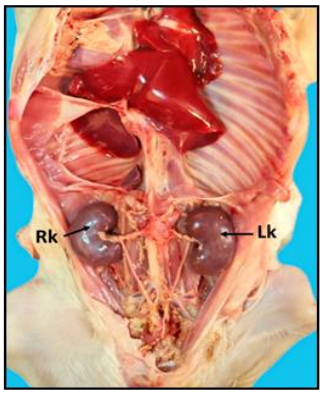

Figure (2) Macrograph of fetus ageing 3-4 month showing: Rk.Right kidney, Lk. Left

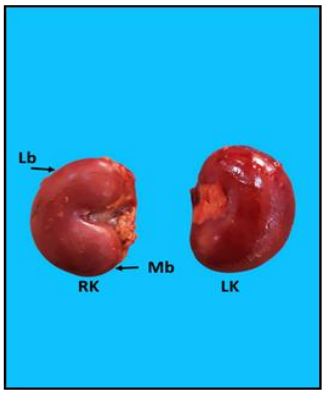

Figure (3) Macrograph of kidney showing: Lb. Lateral border, Mb. Medial border

(Table .2): Morphological parameters of the right left kidney in fetal (3–4) months of gestation & lamb (3–4)

Groups	Thickness of kidney(m)		Weight of kidney(m)	
	Left	Right	Left	Right
Fetal sheep	15.41±0.13 Aa	15.29±0.16 Aa	7.71±0.28 Aa	7.57±0.28 Aa
Lamb sheep	30.06±0.12 Ba	31.02±0.07 Ba	51.33±0.54 Ba	49.58±0.75 Ba
LSD	2.34		10.75	

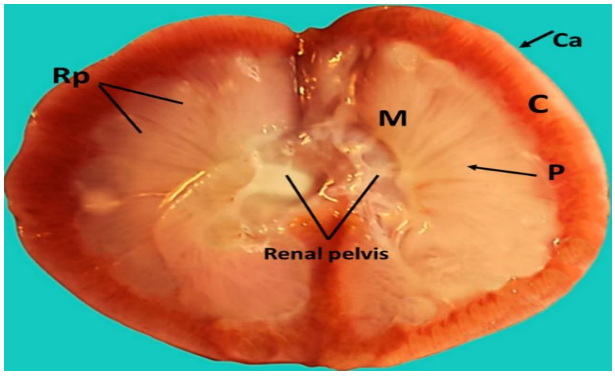

Figure (4) Macrograph of kidney of fetus ageing 3-4 month showing: Ca. Capsule, C. Cortex, M. medulla,

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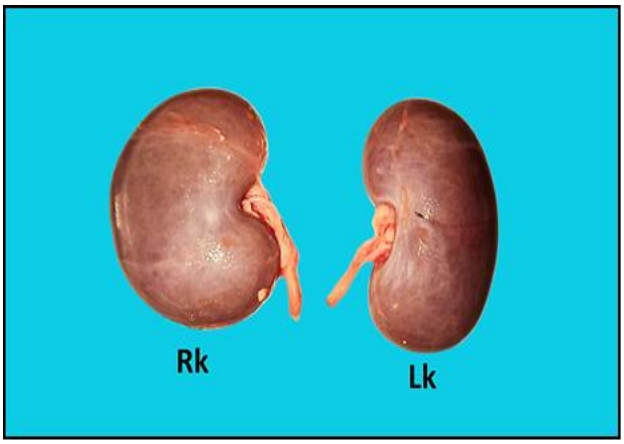

Figure (5) Macrograph of kidney of limb ageing 3-4 month showing: Rk. Right kidney, Lk. Left kidney

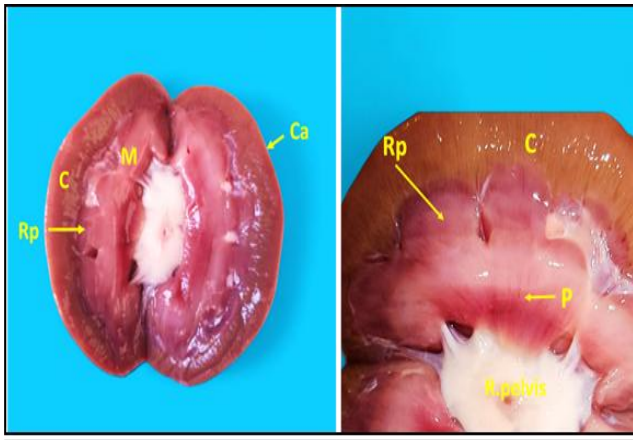

Figure (6) Macrograph of kidney of limb ageing 3-4 month showing: Ca. Capsule, C. Cortex, M medulla, Rp. Renal pyramid, P. papilla.

Discussion

The present study demonstrated distinct morphological differences between the developing kidneys (metanephros) of sheep fetuses at 3–4 months of gestation and the postnatal kidneys of lambs aged 3–4 months. These changes reflect the continuous process of renal growth, differentiation, and maturation that occurs from the prenatal to the postnatal period as reported by. The increase in size and compactness reflects the postnatal hypertrophy of nephrons and interstitial tissue, which accompanies the establishment of full renal functionality.

In addition, slight morphological variations were observed between the right and left kidneys at each developmental stage. These variations were mainly related to differences in shape and anatomical orientation, particularly during the 3–4 months of gestation. In this stage the right kidney in sheep is typically positioned being slightly higher than the left and tends to be more elongated or flattened, whereas the left kidney is often slightly curved or bean-shaped. The present findings are consistent with (7) in dogs.

The recent study revealed that both kidneys at 3–4 months of gestation and at 3–4 months after birth were smooth in texture and appeared pale reddish-brown in color, the present results correspond with the findings of (8), who explained that the dark brown coloration of the kidneys during this stage of gestation is associated with increased vascularization and a high blood supply.

Importantly, despite these subtle morphological differences, no significant differences were detected in the morphometric parameters between the right and left kidneys within each developmental age group, these observations are consistent with the findings of (8) in sheep. This finding suggests that paired renal structures undergo coordinated bilateral growth and morphogenesis throughout fetal development. In mammals, the paired metanephric kidneys arise from symmetrical intermediate mesoderm on both sides of the body, and their development is regulated by conserved genetic and molecular signaling pathways that ensure lateral symmetry in organ formation and growth. This bilateral coordination is considered a hallmark of normal renal organogenesis, as both kidneys are patterned simultaneously under similar developmental cues, resulting in comparable sizes at equivalent gestational stages (9).

In contrast, the significant differences observed between the studied developmental ages reflect the normal pattern of developmental progression. As gestational age advances, the kidney undergoes continuous growth and maturation driven by ongoing nephrogenesis, branching

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morphogenesis of the ureteric bud, increases in nephron number, and expansion of both the renal cortex and medulla. Consequently, this age-dependent increase in renal size, weight, and structural complexity is a well-described feature of fetal renal development, with morphometric parameters showing a direct correlation with gestational age and overall body growth across many mammalian species, including sheep and humans (10). Therefore, the lack of a significant lateral difference within each age group indicates that side-to-side symmetry is maintained during renal development, whereas the significant differences observed between developmental ages represent the normal trajectory of renal growth with increasing gestational time rather than any inherent asymmetry between the right and left kidneys.

At 3–4 months of gestation, the kidneys appeared relatively small, smooth, and less compact, with a thin capsule that could be easily separated from the underlying parenchyma. The cortex was pale and finely granular, while the medulla was darker but lacked a distinct corticomedullary demarcation. These findings agree with those of (11), who reported that during fetal life, the sheep kidney exhibits incomplete differentiation, with ongoing nephrogenesis and less distinct renal pyramids.

The distinct corticomedullary demarcation and well-developed renal pyramids observed in the postnatal kidneys indicate the cessation of the nephrogenic phase and the beginning of full renal functionality. Functionally, this morphological maturation supports the kidney's transition from a developing organ to a fully functional excretory organ capable of maintaining homeostasis independently of the placenta. These findings align with the concept of "renal developmental programming, which suggests that structural and molecular events during prenatal and early postnatal life determine long-term renal health and function (12 and 13). Environmental or nutritional disturbances during these stages can therefore affect nephron endowment and predispose the animal to renal dysfunction later in life.

Conflict of interest

Authors declare no conflict of interest.

Funding source

This research had no specific fund; however, it was self-funded by the authors

Acknowledgment

I want to express my gratitude to all those who assisted me throughout this project. I want to express my gratitude to all those who aided me in meeting the criteria for this research.

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