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Solitary exophytic renal cysts in dogs: A retrospective case series of nine dogs with clinicopathological, diagnostic imaging and 12-month outcome data following unilateral nephrectomy

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Abstract

Solitary exophytic renal cysts are uncommon in dogs, and information regarding their clinical characteristics, diagnostic imaging findings, and outcomes following surgical treatment is limited. This retrospective case series describes the clinicopathological, imaging, and histopathological findings and 12-month outcomes of nine dogs with solitary exophytic renal cysts treated by unilateral nephrectomy. Medical records from May 2023 to December 2024 were reviewed. Clinical examination, hematology, serum biochemistry, serum symmetric dimethylarginine (SDMA), urinalysis, urine culture, ultrasonography, contrast-enhanced computed tomography (CT), histopathology, and postoperative follow-up data were evaluated. Six cysts involved the right kidney, and three the left, with dimensions ranging from 32 × 30 to 61 × 56 mm. Seven cysts originated from the cranial pole and two from the mid-pole. Ultrasonography and CT demonstrated well-circumscribed, thin-walled, fluid-filled exophytic lesions without septations, mural nodules, mineralization, or contrast-enhancing solid components. Four cysts compressed the adjacent renal cortex. Urine cultures were positive in three dogs. Histopathology confirmed benign renal cystic lesions with variable tubular ectasia, fibrosis, and chronic inflammatory changes. During 12 months of follow-up, urinary erythrocyte and leukocyte counts and serum creatinine and SDMA concentrations decreased significantly. No recurrence or clinically apparent renal insufficiency was identified. In this selected population, unilateral nephrectomy was associated with favorable clinical and clinicopathological outcomes; however, these findings do not establish nephrectomy as routine treatment for uncomplicated renal cysts, and renal-sparing approaches should remain a consideration in appropriately selected cases.

Key words: canine kidney; renal cyst; nephrectomy; ultrasonography; computed tomography; symmetric dimethylarginine

Abbreviations: CT, computed tomography; SDMA, serum symmetric dimethylarginine.

1. Introduction

Renal cysts are uncommon lesions in dogs and may occur as solitary or multiple cystic structures within the renal parenchyma. Histologically, renal cysts are typically epithelial-lined cavities containing fluid and may be incidentally identified during abdominal imaging. In dogs, renal cystic lesions encompass a heterogeneous group of conditions, including solitary renal cysts, cystic lesions associated with chronic renal disease, polycystic kidney disease, perinephric pseudocysts, and cystic renal neoplasia, each of which has different diagnostic and therapeutic implications (Wisner et al. 2002; Orioles et al. 2014; Van Dyck et al. 2018; Vagias et al. 2022). In a recent multicenter retrospective study of 18 dogs with intrarenal cystic lesions, renal cysts were histologically confirmed in seven dogs, whereas neoplasia was identified in six, highlighting the heterogeneous biological nature of apparently cystic renal lesions in dogs (Vagias et al. 2022).

The clinical significance of a solitary renal cyst depends on its size, anatomical location, degree of renal parenchymal involvement, and associated complications. Small, uncomplicated lesions may be detected incidentally and can be monitored using serial diagnostic imaging, whereas larger or complicated cysts may cause abdominal discomfort, hematuria, urinary tract obstruction, infection, polyuria, polydipsia, or other nonspecific clinical signs (Zatelli et al. 2005, 2007; Agut et al. 2008; Park et al. 2019; Vagias et al. 2022). Ultrasonography is the most frequently described imaging modality for canine renal cysts and typically demonstrates a well-defined, round or oval, anechoic lesion with a thin wall and distal acoustic enhancement. Contrast-enhanced computed tomography (CT) can provide additional information regarding lesion morphology, the extent of renal parenchymal involvement, and the relationship of the cyst to adjacent structures. Features such as septations, altered wall characteristics, mineralization, solid components, or contrast enhancement may increase concern for a complicated or neoplastic lesion (Agut et al. 2008; Dennis et al. 2010; Vagias et al. 2022).

When intervention is indicated, preservation of functional renal parenchyma is an important therapeutic consideration. Several renal-sparing techniques have been described in dogs, including ultrasound-guided aspiration with ethanol sclerotherapy, surgical fenestration or deroofing, and omentalisation (Zatelli et al. 2005, 2007; Agut et al. 2008; Van Dyck et al. 2018; Park et al. 2019; Dekerle et al. 2022; Vagias et al. 2022). Ultrasound-guided drainage and ethanol sclerotherapy have been successfully used for symptomatic or obstructive renal cysts in individual dogs, although recurrence or the need for repeated intervention may occur (Zatelli et al. 2005, 2007; Van Dyck et al. 2018). Surgical fenestration combined with omentalisation has also been reported to achieve sustained regression of renal cysts while preserving renal parenchyma, including in dogs treated using laparoscopic approaches (Park et al. 2019). Similarly, long-term resolution has been reported following laparoscopic deroofing, fulguration, and omentalisation of a simple renal cyst in a dog (Dekerle et al. 2022).

Despite these renal-sparing options, accurate preoperative classification of a cystic renal lesion may be challenging. In the 18-dog study by Vagias et al. (2022), histopathology identified both benign and neoplastic intrarenal cystic lesions, and cytological examination of cystic fluid failed to identify neoplastic cells in dogs subsequently diagnosed histologically with neoplasia. Moreover, a canine renal cystic adenoma has been reported in a lesion that initially appeared as a thin-walled cystic mass on diagnostic imaging and had previously been treated by percutaneous drainage and ethanol sclerotherapy, with recurrence of the lesion and clinical signs before laparoscopic deroofing and omentalisation (Dekerle et al. 2020). These findings emphasize that apparently simple imaging characteristics and cyst fluid examination may not always establish the biological nature of a renal cystic lesion.

Therefore, unilateral nephrectomy remains an option in selected dogs when renal-sparing treatment is considered unsuitable because of substantial renal parenchymal involvement, obstruction, persistent or recurrent clinical or urinary abnormalities, recurrence following minimally invasive treatment, or uncertainty regarding the biological nature of the lesion (Tobias and Tillson 2018; Vagias et al. 2022). In a dog with a unilateral renal cyst associated with a perinephric pseudocyst, nephrectomy resulted in

resolution of the clinical signs, with histopathology confirming an epithelial-lined renal cyst (Orioles et al. 2014). However, the decision to remove a kidney should consider the structural and functional status of the contralateral kidney because adequate compensatory renal function is essential following unilateral nephrectomy.

Although renal cystic lesions have been described in individual dogs and in a recent retrospective multicentre series, information specifically concerning solitary exophytic renal cysts managed by unilateral nephrectomy remains limited, particularly regarding their integrated ultrasonographic and CT characteristics, histopathological findings and longitudinal clinicopathological outcomes. Existing veterinary reports have primarily focused on renal-sparing procedures, individual case reports, or heterogeneous populations of intrarenal cystic lesions rather than a defined group of dogs undergoing nephrectomy (Park et al. 2019; Dekerle et al. 2022; Vagias et al. 2022).

Therefore, the objectives of this retrospective case series were to describe the clinical presentation, ultrasonographic and CT characteristics, histopathological findings, and postoperative outcomes of dogs with solitary exophytic renal cysts treated by unilateral nephrectomy, and to evaluate longitudinal changes in selected haematological, serum biochemical, and urinary parameters during 12 months of follow-up.

2. Materials and Methods

2.1 Study design and case selection

This retrospective case series was conducted at the Referral Veterinary Polyclinic of the ICAR–Indian Veterinary Research Institute (ICAR-IVRI) in Izatnagar, Uttar Pradesh, India. The medical records of dogs evaluated between May 2023 and December 2024 were retrospectively reviewed to identify cases with solitary exophytic renal cystic lesions that underwent unilateral nephrectomy.

Dogs were eligible for inclusion if they met all of the following criteria: (1) solitary exophytic renal cystic lesion identified on abdominal ultrasonography; (2) further evaluation with contrast-enhanced computed tomography (CT); (3) unilateral nephrectomy of the affected kidney; (4) histopathological examination of the resected kidney confirming a benign renal cystic lesion; and (5) availability of postoperative follow-up data for at least 12 months. Dogs with polycystic kidney disease, perinephric pseudocysts, congenital renal dysplasia, multiple renal cysts, or incomplete medical records were excluded from the study.

The following information was retrieved from the medical records: signalment, body weight, presenting complaint, relevant previous clinical history, physical examination findings, haematological and serum biochemical variables, serum symmetric dimethylarginine (SDMA) concentration, urinalysis, urine bacterial culture and antimicrobial susceptibility results, ultrasonographic and CT findings, intraoperative findings, histopathological diagnosis, perioperative complications, and postoperative clinical outcomes. Longitudinal clinicopathological and urinary data were recorded for preoperative assessment and for follow-up examinations performed at approximately 1, 3, and 12 months after surgery. When hospital-based follow-up was not available, outcome information was obtained from owners or referring veterinarians.

2.2 Clinicopathological evaluation

Complete blood count (CBC), serum biochemical analysis, and serum symmetric dimethylarginine (SDMA) concentration were evaluated before surgery. The haematological assessment included erythrocyte indices, leukocyte and differential leukocyte counts, platelet count, and related erythrocyte and platelet indices. Serum biochemical analysis included selected renal and hepatobiliary variables and serum electrolyte concentrations.

Urinalysis was performed on urine samples collected by urethral catheterization. Physical characteristics, chemical parameters, and urinary sediment were evaluated using routine laboratory procedures. The parameters recorded included urine specific gravity, pH, protein concentration, color, appearance, and microscopic erythrocyte and leukocyte counts per high-power field. When a urinary tract infection was suspected based on clinical findings or urinalysis, urine samples collected by ultrasound-guided cystocentesis were submitted for aerobic bacterial culture and antimicrobial susceptibility testing. Bacterial isolates were identified using routine diagnostic laboratory procedures, and antimicrobial treatment was selected based on antimicrobial susceptibility results when available.

Clinicopathological and urinary evaluations were repeated at approximately 1, 3, and 12 months after unilateral nephrectomy. The same variables evaluated preoperatively were recorded during follow-up when samples were available, permitting longitudinal assessment of haematological, biochemical, and urinary changes following surgery.

2.3 Diagnostic imaging

2.3.1 Abdominal ultrasonography

Abdominal ultrasonography was performed on all dogs using a Samsung diagnostic ultrasound system equipped with a sector transducer. The abdominal hair over the region of interest was clipped/shaved, and ultrasonographic examination was performed with the dogs positioned in the dorsoventral recumbency.

Both kidneys were systematically examined for size, shape, corticomedullary differentiation, and echogenicity. The cystic lesion was evaluated for laterality, anatomical location, maximum dimensions, wall characteristics, internal echogenicity, presence of septations, mural nodules, mineralization, or internal debris, and distal acoustic enhancement. The relationship between the lesion and the surrounding renal parenchyma and the degree of renal cortical compression were also assessed. The dimensions of each cystic lesion are presented in Table 1.

All dogs had unilateral renal involvement. The contralateral kidney was examined in each dog and was considered apparently normal on ultrasonographic examination, with no obvious structural abnormalities identified. The lesions were characterized ultrasonographically as predominantly fluid-filled cystic structures with well-defined margins and predominantly anechoic contents.

2.3.2 Contrast-enhanced computed tomography

Contrast-enhanced computed tomography (CT) was subsequently performed in all dogs to further characterize the renal cystic lesions and assess the affected and contralateral kidneys.

For the CT examination, dogs were chemically restrained with midazolam (0.2 mg/kg, IV) and butorphanol (X mg/kg, IV), followed by the induction of general anesthesia with propofol (4 mg/kg, IV). A single dose of propofol was sufficient to complete the CT examination in all dogs.

Contrast-enhanced CT was performed using iohexol (300 mg iodine/mL) administered intravenously at a dose of 2 mL/kg. Pre- and postcontrast images were evaluated for the size and location of the cystic lesion, attenuation characteristics, wall thickness and regularity, internal septations, mineralization, mural nodules, contrast enhancement, relationship with adjacent renal parenchyma, and evidence of compression or invasion of surrounding structures. The contralateral kidney was also evaluated for abnormalities that could influence the suitability of unilateral nephrectomy.

2.4 Preoperative ultrasound-guided cystic lesion sampling

In four dogs, ultrasound-guided percutaneous Tru-Cut biopsy of the renal cystic lesion was performed preoperatively because of diagnostic uncertainty regarding the nature of the lesion. Dogs were

premedicated with midazolam (0.2 mg/kg, IM) and xylazine (1 mg/kg, IM), followed by induction of general anaesthesia with propofol (3 mg/kg, IV).

Following ultrasonographic localization and characterization of the lesion, the skin over the selected biopsy site was aseptically prepared. Under real-time ultrasonographic guidance, an 18-gauge Tru-Cut biopsy needle was advanced through the abdominal wall into the accessible portion of the cyst wall or associated renal tissue while avoiding major renal vessels and the renal pelvis. Needle placement and tissue acquisition were continuously monitored using ultrasonography. Following withdrawal of the needle, the biopsy site was examined ultrasonographically for evidence of hemorrhage or perirenal hematoma.

The biopsy specimens were immediately placed in 10% neutral-buffered formalin and submitted for histopathological examination. Histopathological evaluation included assessment of the cyst lining, epithelial morphology, stromal tissue, inflammatory changes, cellular atypia, and evidence of neoplasia. The ultrasound-guided renal biopsy was performed according to the standard renal biopsy principles described for dogs (Vaden, 2005).

2.5 Surgical management and histopathology

The decision to perform unilateral nephrectomy was based on clinical signs, urinary abnormalities, cyst size and location, involvement or compression of the renal parenchyma, imaging findings, and the structural and functional status of the contralateral kidney. Particular consideration was given to lesions for which cystic neoplasia could not be definitively excluded.

Dogs were fasted for 12 h and underwent general anesthesia using a balanced protocol, with intravenous crystalloid therapy and multimodal analgesia. Ventral midline celiotomy was performed, and the affected kidney was mobilized following blunt dissection. The renal artery and vein were individually isolated and ligated using absorbable suture and/or vascular clips, and the ureter was double ligated and transected (Figure 1). The kidney with the intact cystic lesion was removed and histopathologically examined. The abdomen was routinely closed in three layers using absorbable suture material.

Postoperatively, dogs received intravenous fluids, opioid analgesia, and antimicrobial therapy when indicated by perioperative protocols and urine culture results. Dogs were hospitalized for 2–3 days and discharged following clinical stabilization.

Resected kidneys were fixed in 10% neutral-buffered formalin, routinely processed, and paraffin embedded. Sections (4–5 μ m) were stained with hematoxylin and eosin and examined histopathologically for cyst lining, renal parenchymal changes, inflammation, fibrosis, atypia, and neoplasia.

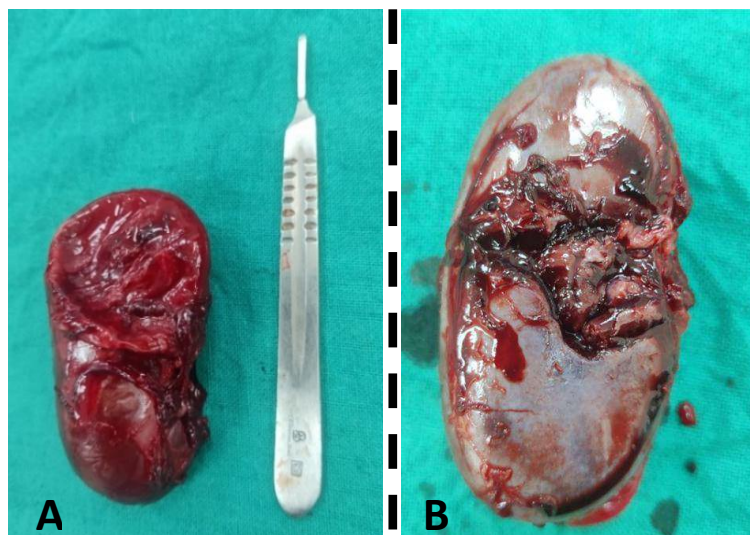


Figure 1. Intraoperative appearance of solitary exophytic renal cysts in two dogs. **(A)** Large cyst located at the cranial pole of the right kidney. **(B)** Exophytic cyst located at the mid-pole of the kidney in a different dog, viewed from the caudal aspect of the kidney.

2.6 Statistical analysis

Longitudinal clinicopathological and urinalysis data were analyzed at four assessment time points: preoperatively and at 1, 3, and 12 months postoperatively, with individual dogs treated as repeated subjects. Data distribution was assessed using the Shapiro–Wilk test.

Variables meeting parametric assumptions were analysed using linear mixed-effects models, with time as a fixed effect and dog as a random intercept. Estimated marginal means were compared using Holm-adjusted pairwise comparisons. Variables not meeting parametric assumptions were analysed using the LD-F1 procedure, followed by paired Wilcoxon signed-rank tests with Holm adjustment for pairwise comparisons. Ordinal variables, including urine colour and appearance scores, were analysed using the Friedman test followed by Holm-adjusted paired Wilcoxon signed-rank tests, where appropriate.

Continuous variables are presented as mean $\pm$ standard error (SE), and ordinal variables are presented as medians (interquartile range). Statistical significance was set at $P < 0.05$. Where the overall time effect was significant but no Holm-adjusted pairwise comparison was significant, the result was interpreted as an overall temporal effect without assigning significance to individual time-point comparisons.

3. Results

3.1 Case characteristics and clinical presentation

Nine dogs met the predefined inclusion criteria. The dogs ranged from 5 to 10 years of age and weighed 16–42 kg. Unilateral cystic renal lesions involved the right kidney in six dogs and the left kidney in three dogs. The clinical presentations included inappetence, weight loss, hematuria, polyuria/polydipsia, vomiting, and abdominal discomfort. In one dog, the renal cystic lesion was detected incidentally during the diagnostic evaluation for an unrelated clinical complaint.

Preoperative haematological abnormalities were characterized predominantly by leukocytosis and neutrophilia. Serum biochemical abnormalities included variable increases in blood urea nitrogen (BUN), creatinine, serum symmetric dimethylarginine (SDMA), alkaline phosphatase (ALP), and aspartate aminotransferase (AST), together with hypoalbuminemia in individual dogs. Urinalysis revealed variable urinary abnormalities, including hyposthenuria, pyuria, hematuria, and proteinuria. Aerobic urine culture was positive in three of nine dogs, with *Staphylococcus aureus*, *Escherichia coli*, and *Staphylococcus pseudintermedius* isolated in individual cases.

3.2 Diagnostic imaging

Abdominal ultrasonography revealed a solitary exophytic cystic renal lesion in each of the nine dogs. The lesion dimensions ranged from 32×30 mm to 61×56 mm. Seven lesions were located at the cranial pole of the affected kidney and two at the mid-pole (Figure 2). All lesions were well-defined, thin-walled, and predominantly anechoic, with distal acoustic enhancement. No internal septations, mural nodules, mineralization, or echogenic debris were identified in any case. Mild to moderate compression of the adjacent renal cortex was observed in four dogs, particularly in association with larger lesions.

Contrast-enhanced CT confirmed a solitary, well-circumscribed, hypoattenuating exophytic cystic lesion arising from the renal cortex in each dog. No lesion demonstrated mural enhancement, internal septation, mineralization, or a solid soft-tissue component. Corticomedullary differentiation was

preserved in the remaining renal parenchyma. The contralateral kidney was structurally normal on CT examination in all nine dogs (Figure 3: case1-9).

The mean lesion length was 47.00 ± 3.12 mm and the mean breadth was 42.56 ± 2.74 mm. The length-to-breadth differences were not normally distributed (Shapiro–Wilk $W = 0.816$, $P = 0.031$); therefore, a paired Wilcoxon signed-rank test was used. The lesion length was significantly greater than the breadth ($V = 0$, $P = 0.0039$), with all nine lesions showing a positive length-to-breadth difference. Lesion length and breadth were strongly positively correlated (Spearman's $\rho = 0.983$, $P < 0.001$).

Preoperative biopsy of the cystic lesion in four dogs yielded myxomatous/myxoid tissue, which increased diagnostic uncertainty regarding the biological nature of the lesion and contributed to the decision to perform a definitive surgical excision.

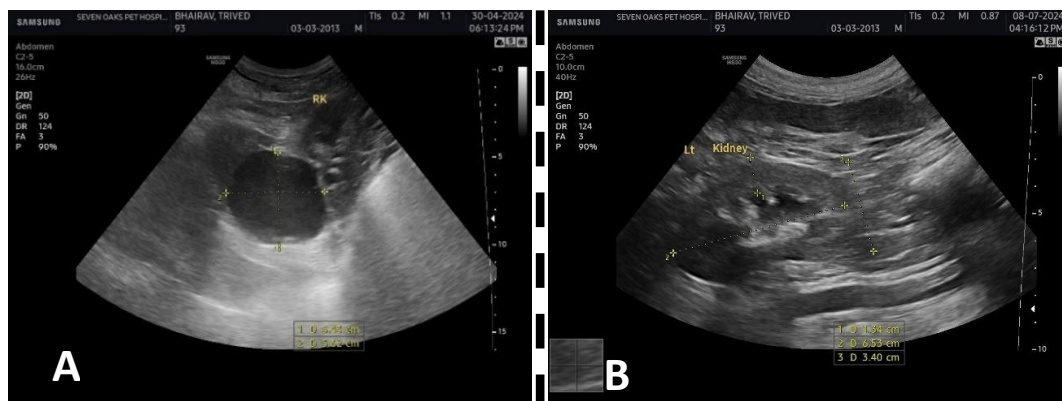


Figure 2. Abdominal ultrasonographic appearance of a solitary exophytic renal cyst in a dog. (A) Large exophytic cyst arising from the right kidney, measuring 54×50 mm in size. (B) Contralateral left kidney with preserved size and architecture.

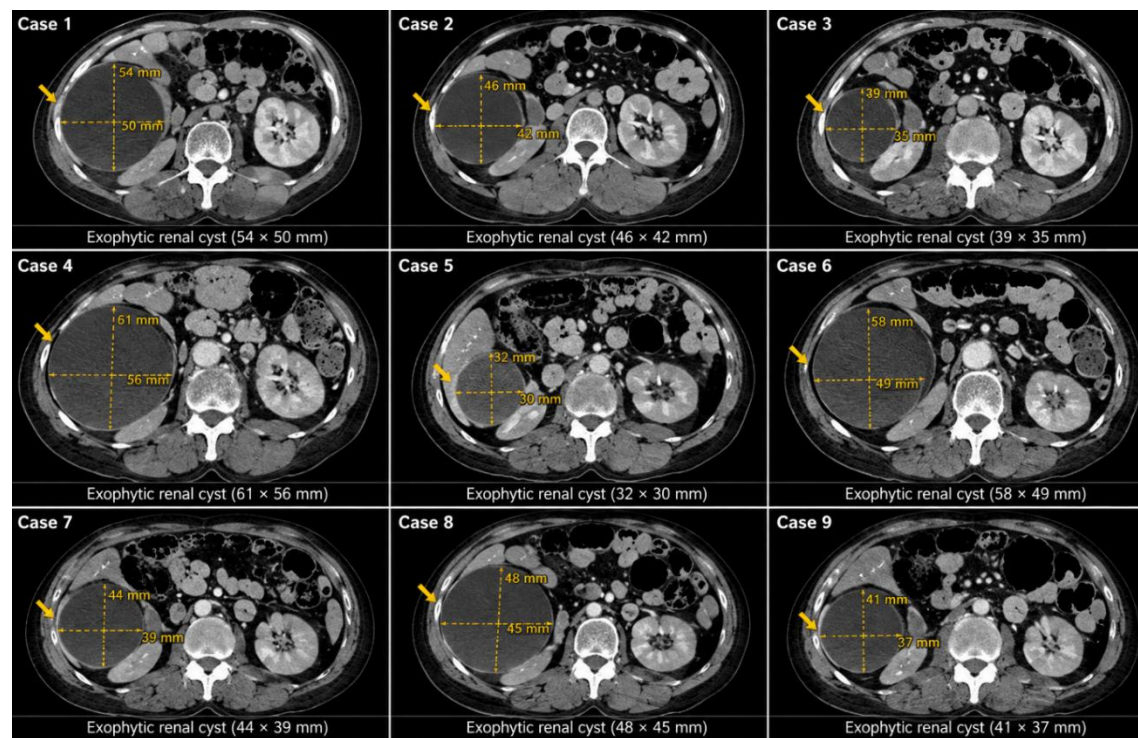


Figure 3. Contrast-enhanced computed tomography (CT) images of solitary exophytic renal cysts in nine dogs. Axial CT images show well-defined, rounded-to-oval, thin-walled, fluid-attenuating cystic lesions arising exophytically from the renal cortex (yellow arrows). The maximum longitudinal $\times$

transverse dimensions of the cysts were 54 × 50 mm (Case 1), 46 × 42 mm (Case 2), 39 × 35 mm (Case 3), 61 × 56 mm (Case 4), 32 × 30 mm (Case 5), 58 × 49 mm (Case 6), 44 × 39 mm (Case 7), 48 × 45 mm (Case 8), and 41 × 37 mm (Case 9).

Case	Affected kidney	Cyst location	Maximum cyst size (mm)	Ultrasonographic appearance	Cortical compression	Contralateral kidney
1	Right	Cranial pole	54 × 50	Well-defined anechoic exophytic cyst with distal acoustic enhancement	Mild	Normal (6.53 × 3.40 cm)
2	Right	Cranial pole	46 × 42	Thin-walled anechoic cyst with smooth margins	No	Normal
3	Left	Mid-pole	39 × 35	Well-circumscribed cortical cyst with distal enhancement	No	Normal
4	Right	Cranial pole	61 × 56	Large exophytic anechoic cyst causing cortical compression	Moderate	Normal
5	Left	Cranial pole	32 × 30	Solitary thin-walled cortical cyst	No	Normal
6	Right	Cranial pole	58 × 49	Large exophytic cyst with marked distal enhancement	Mild	Normal
7	Right	Mid-pole	44 × 39	Anechoic cortical cyst with smooth wall	No	Normal
8	Left	Cranial pole	48 × 45	Well-defined exophytic cyst with distal acoustic enhancement	Mild	Normal
9	Right	Cranial pole	41 × 37	Simple exophytic renal cyst with smooth margins	No	Normal

Table 1. Ultrasonographic characteristics and morphometric measurements of solitary renal cyst

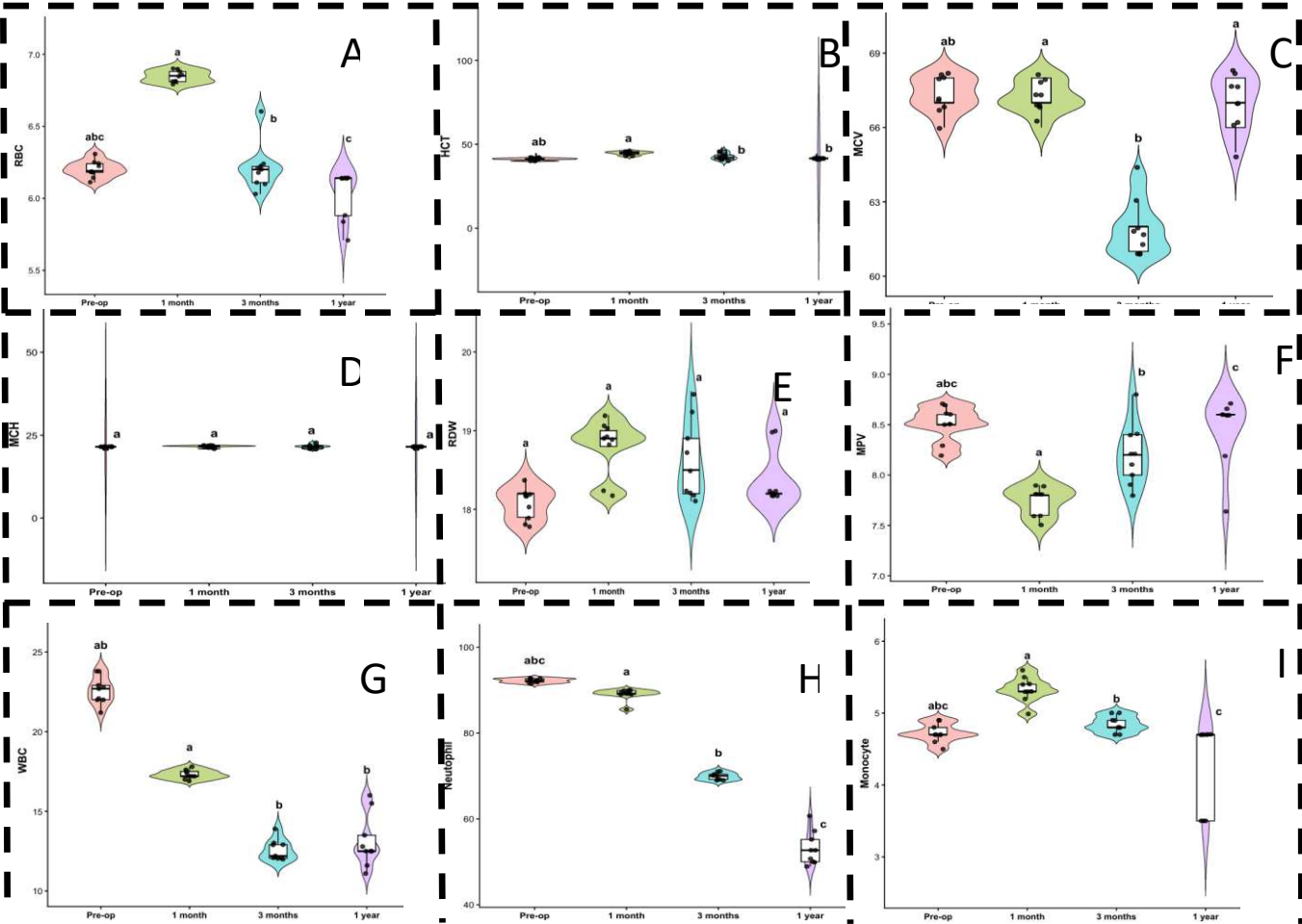
Abbreviations: mm, millimeters. All cysts were solitary, thin-walled, anechoic lesions exhibiting distal acoustic enhancement. No internal septations, mural nodules, mineralization, or echogenic debris were identified in any case.

3.3 Haematological and serum biochemical changes

Significant temporal variations were observed in several haematological variables during the 12-month follow-up period (Table 2a; Figure 4). RBC count, HCT, MCV, and MCHC differed significantly among the four assessment time points ($P < 0.001$), whereas MCH did not show a significant temporal change ($P = 0.827$). WBC and neutrophil counts decreased significantly during follow-up ($P < 0.001$). Monocyte and eosinophil counts also showed significant temporal variations. Hemoglobin, platelet, and lymphocyte counts differed significantly among the time points, with increases at 1 month followed by

values approaching preoperative concentrations by 1 year. Detailed values and multiplicity-adjusted pairwise comparisons are presented in Table 2a.

Renal-associated serum biochemical variables also showed significant temporal variation (Tables 2a and 2b; Figures 4 and 5). BUN and serum creatinine concentrations decreased significantly over the follow-up period ($P < 0.001$). Serum SDMA concentration decreased from 23.23 ± 0.61 preoperatively to 20.18 ± 0.43 at 1 year ($P < 0.001$). Significant temporal differences were also observed for ALT, ALP, AST, total bilirubin, calcium, sodium, and potassium ($P \leq 0.0219$). Among the variables analyzed using the non-parametric model, total protein decreased significantly by 1 year, whereas albumin increased during follow-up ($P < 0.001$). Glucose also decreased significantly over time ($P < 0.001$). Chloride showed a significant overall time effect ($P = 0.0099$); however, none of the Holm-adjusted pairwise comparisons reached statistical significance.



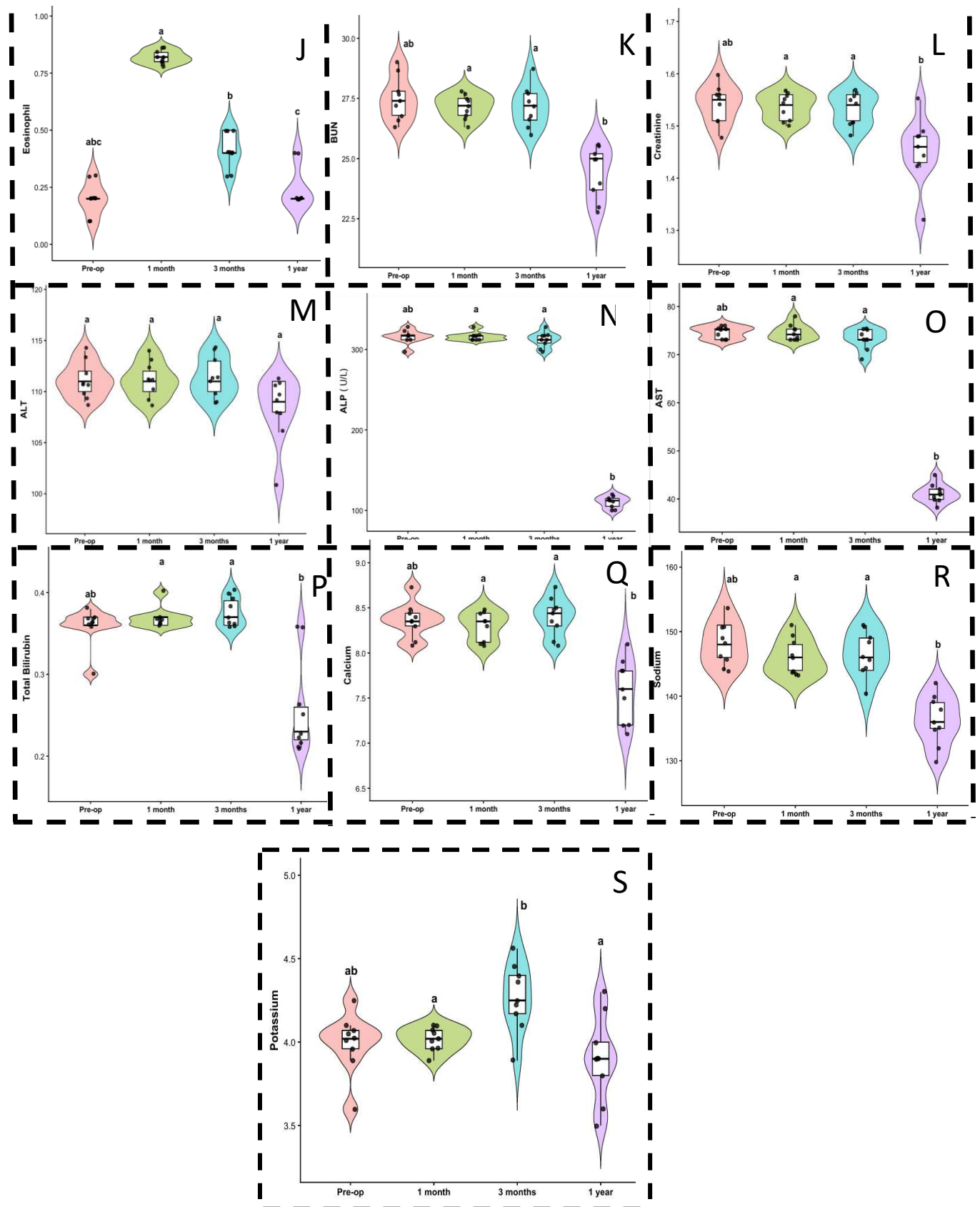


Figure 4. Violin plots showing the longitudinal distribution of haematological and serum biochemical variables in nine dogs before unilateral nephrectomy and at 1, 3, and 12 months after surgery. Violin plots represent the distribution of individual observations, and box plots indicate the median and

interquartile range. Different superscript letters indicate significant differences between time points following Holm-adjusted pairwise comparisons ($P < 0.05$).

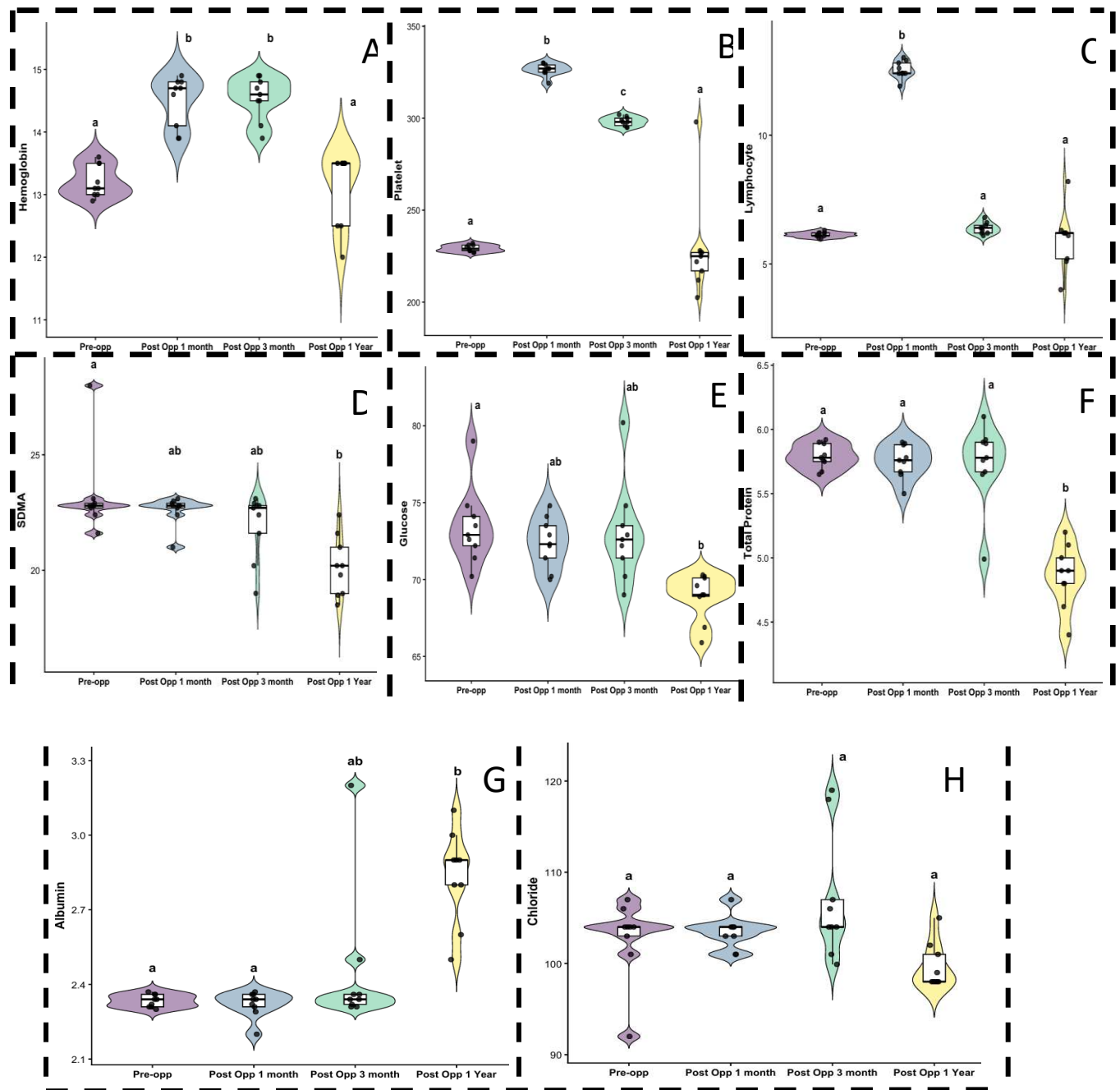


Figure 5. Violin plots showing the longitudinal distribution of non-normally distributed haematological and serum biochemical variables in nine dogs before unilateral nephrectomy and at 1, 3, and 12 months after unilateral nephrectomy. Violin plots represent the distribution of individual observations, and box plots indicate the median and interquartile range. Different superscript letters indicate significant differences between time points following Holm-adjusted pairwise comparisons ($P < 0.05$).

3.4 Urinalysis and urine culture

Urinalysis showed significant temporal changes in several urinary variables during the 12-month follow-up (Table 3). The urine specific gravity increased from 1.0048 ± 0.0004 preoperatively to 1.0446 ± 0.0008 at 1 month, followed by values comparable to the preoperative measurement at 3 months and 1 year (Friedman $\chi^2(3) = 27.00$, $P < 0.001$). Urine pH decreased progressively from 8.48 ± 0.02 preoperatively to 7.12 ± 0.08 at 1 year ($\chi^2(3) = 20.10$, $P < 0.001$). The urinary WBC/pus cell counts

decreased from 7.00 ± 0.24 preoperatively to 2.56 ± 0.44 at 1 year, while the urinary RBC counts decreased from 10.33 ± 0.33 to 1.67 ± 0.24 over the same period ($P < 0.001$ for both variables). All Holm-adjusted pairwise comparisons of the urinary RBC counts were statistically significant.

Urinary protein concentration showed a significant overall temporal effect ($\chi^2(3) = 12.10$, $P = 0.007$); however, none of the Holm-adjusted pairwise comparisons remained statistically significant. Urine color scores also differed significantly over time (Friedman $\chi^2(3) = 18.56$, $P < 0.001$), whereas urine appearance showed a significant overall time effect ($\chi^2(3) = 12.60$, $P = 0.0056$) without significant individual pairwise differences following Holm adjustment.

Aerobic urine culture was positive in three of nine dogs. *Staphylococcus aureus*, *Escherichia coli*, and *Staphylococcus pseudintermedius* were isolated in individual cases. Antimicrobial treatment was selected according to the reported susceptibility results (Table 4).

Parameter	Preoperative	Post operative (1 month)	Post operative (3 months)	Post operative (1 year)	Overall result
RBC	6.20 ± 0.02^{abc}	6.85 ± 0.01^a	6.21 ± 0.05^b	6.03 ± 0.06^c	F(3,32)=76.37, P<0.001
HCT	41.09 ± 0.23^{ab}	44.61 ± 0.35^a	42.58 ± 0.66^b	41.55 ± 0.00^b	F(3,32)=16.27, P<0.001
MCV	67.33 ± 0.24^{ab}	67.22 ± 0.22^a	61.89 ± 0.35^b	67.00 ± 0.37^a	F(3,32)=76.58, P<0.001
MCH	21.50 ± 0.00^a	21.62 ± 0.10^a	21.53 ± 0.19^a	21.50 ± 0.00^a	F(3,24)=0.30, P=0.827
MCHC	31.32 ± 0.17^{ab}	32.10 ± 0.00^a	31.92 ± 0.18^a	30.95 ± 0.28^b	F(3,32)=8.31, P<0.001
RDW	18.08 ± 0.07^a	18.80 ± 0.12^a	18.61 ± 0.17^a	18.38 ± 0.12^a	F(3,24)=6.71, P=0.0019
MPV	8.51 ± 0.06^{abc}	7.74 ± 0.05^a	8.20 ± 0.10^b	8.47 ± 0.11^c	F(3,24)=23.26, P<0.001
WBC	22.58 ± 0.29^{ab}	17.31 ± 0.10^a	12.57 ± 0.22^b	13.11 ± 0.55^b	F(3,24)=233.52, P<0.001
Neutrophil	92.23 ± 0.16^{abc}	89.05 ± 0.46^a	69.90 ± 0.28^b	53.11 ± 1.30^c	F(3,32)=656.09, P<0.001
Monocyte	4.72 ± 0.04^{abc}	5.33 ± 0.06^a	4.84 ± 0.04^b	4.30 ± 0.20^c	F(3,24)=17.64, P<0.001
Eosinophil	0.20 ± 0.02^{abc}	0.82 ± 0.01^a	0.41 ± 0.03^b	0.24 ± 0.03^c	F(3,24)=172.28, P<0.001
BUN	27.50 ± 0.30^{ab}	27.14 ± 0.17^a	27.17 ± 0.28^a	24.42 ± 0.36^b	F(3,24)=25.74, P<0.001
Creatinine	1.54 ± 0.01^{ab}	1.54 ± 0.01^a	1.53 ± 0.01^a	1.45 ± 0.02^b	F(3,24)=9.92, P<0.001
ALT	111.11 ± 0.56^a	111.11 ± 0.56^a	111.33 ± 0.65^a	108.33 ± 1.08^a	F(3,32)=3.68, P=0.0219
ALP	315.67 ± 2.87^{ab}	316.11 ± 1.73^a	312.11 ± 3.18^a	110.48 ± 2.41^b	F(3,24)=1803.17, P<0.001
AST	74.60 ± 0.41^{ab}	74.62 ± 0.56^a	73.27 ± 0.71^a	41.14 ± 0.66^b	F(3,24)=866.13, P<0.001
Total Bilirubin	0.36 ± 0.01^{ab}	0.37 ± 0.00^a	0.38 ± 0.01^a	0.26 ± 0.02^b	F(3,32)=23.81, P<0.001
Calcium	8.36 ± 0.06^{ab}	8.30 ± 0.05^a	8.40 ± 0.07^a	7.58 ± 0.12^b	F(3,24)=30.42, P<0.001

Sodium	148.11 ± 1.15 ^{ab}	146.00 ± 0.94 ^a	146.56 ± 1.20 ^a	136.33 ± 1.28 ^b	F(3,32)=21.65, P<0.001
Potassium	3.99 ± 0.06 ^{ab}	4.02 ± 0.02 ^a	4.27 ± 0.07 ^b	3.90 ± 0.08 ^a	F(3,24)=6.74, P=0.0019

Table 2. a. Haematological and serum biochemical variables in nine dogs before unilateral nephrectomy and during 12-month postoperative follow-up.

Parameter	Preoperative	Post operative (1 month)	Post operative (3 months)	Post operative (1 year)	Overall result
Hemoglobin	13.21 ± 0.09 ^a	14.49 ± 0.13 ^b	14.54 ± 0.12 ^b	13.11 ± 0.20 ^a	ATS=33.44, df=2.37, P<0.001
Platelet	229.22 ± 0.62 ^a	326.44 ± 1.13 ^b	298.22 ± 0.85 ^c	228.72 ± 9.11 ^a	ATS=67.53, df=2.24, P<0.001
Lymphocyte	6.13 ± 0.03 ^a	12.53 ± 0.11 ^b	6.39 ± 0.07 ^a	5.94 ± 0.38 ^a	ATS=23.43, df=2.39, P<0.001
SDMA	23.23 ± 0.61 ^a	22.61 ± 0.21 ^{ab}	21.94 ± 0.48 ^{ab}	20.18 ± 0.43 ^b	ATS=9.74, df=1.68, P<0.001
Glucose	73.41 ± 0.84 ^a	72.38 ± 0.55 ^{ab}	72.98 ± 1.07 ^{ab}	68.88 ± 0.51 ^b	ATS=8.84, df=1.71, P<0.001
Total Protein	5.79 ± 0.03 ^a	5.75 ± 0.04 ^a	5.74 ± 0.10 ^a	4.86 ± 0.08 ^b	ATS=14.48, df=1.65, P<0.001
Albumin	2.33 ± 0.01 ^a	2.32 ± 0.02 ^a	2.45 ± 0.10 ^{ab}	2.83 ± 0.06 ^b	ATS=11.66, df=1.25, P<0.001
Chloride	102.78 ± 1.46 ^a	103.44 ± 0.60 ^a	106.99 ± 2.30 ^a	99.67 ± 0.83 ^a	ATS=4.85, df=1.81, P=0.0099

Table 2. b. Non-normally distributed haematological and serum biochemical variables in nine dogs before unilateral nephrectomy and during 12-month postoperative follow-up.

Values are presented as mean ± standard error of the mean. Different superscript letters within a row indicate significant differences between time points following Holm's adjustment ($P < 0.05$); shared superscript letters indicate no significant difference. The overall time effect is reported in the final column.

Abbreviations: BUN, blood urea nitrogen; ALT, alanine transaminase; ALP, alkaline phosphatase; AST, aspartate aminotransferase; serum symmetric dimethylarginine (SDMA); H, high; L, low.

Parameter	Preoperative	Post operative (1 month)	Post operative (3 months)	Post operative (1 year)	Overall result
Specific gravity	1.0048 ± 0.0004 ^a	1.0446 ± 0.0008 ^b	1.0048 ± 0.0004 ^a	1.0048 ± 0.0004 ^a	$\chi^2(3)=27.00$, P<0.001
pH	8.4778 ± 0.0222 ^a	7.5889 ± 0.0904 ^b	7.1889 ± 0.0676 ^b	7.1222 ± 0.0846 ^b	$\chi^2(3)=20.10$, P<0.001
Urine Protein	0.000311 ± 0.000026 ^a	0.000278 ± 0.000028 ^a	0.000222 ± 0.000022 ^a	0.000167 ± 0.000024 ^a	$\chi^2(3)=12.10$, P=0.007
WBC/Pus cells	7.00 ± 0.236 ^a	5.44 ± 0.294 ^b	4.33 ± 0.167 ^c	2.56 ± 0.444 ^d	$\chi^2(3)=24.11$, P<0.001
RBC	10.33 ± 0.333 ^a	7.00 ± 0.236 ^b	3.44 ± 0.377 ^c	1.67 ± 0.236 ^d	$\chi^2(3)=26.73$, P<0.001
Physical examination	Preoperative	Post operative (1 month)	Post operative (3 months)	Post operative (1 year)	Overall result

Colour	3.00 (3.00–4.00) ^a	2.00 (2.00–3.00) ^b	2.00 (2.00–3.00) ^{ab}	2.00 (2.00–2.00) ^b	Friedman $\chi^2(3)=18.56$, $P<0.001$
Appearance	1.00 (0.00–1.00) ^a	0.00 (0.00–0.00) ^a	0.00 (0.00–0.00) ^a	0.00 (0.00–0.00) ^a	Friedman $\chi^2(3)=12.60$, $P=0.0056$

Table 3. Urinalysis findings in nine dogs before unilateral nephrectomy and during 12-month post operative follow-up

Case	Culture result	Organism isolated	Antimicrobial susceptibility
1	Positive	<i>Staphylococcus aureus</i>	Sensitive to amoxicillin-clavulanate
2	Negative	—	—
3	Negative	—	—
4	Positive	<i>Escherichia coli</i>	Sensitive to enrofloxacin
5	Negative	—	—
6	Negative	—	—
7	Positive	<i>Staphylococcus pseudintermedius</i>	Sensitive to cephalixin
8	Negative	—	—
9	Negative	—	—

Table 4. Urine culture results, bacterial isolates, and antimicrobial susceptibility in nine dogs with solitary exophytic renal cystic lesions

Values are presented as mean $\pm$ standard error for continuous variables and as median (interquartile range) for ordinal variables. Different superscript letters within a row indicate significant differences between time points following Holm's adjustment ($P < 0.05$); shared superscript letters indicate no significant difference.

3.5 Surgical management and perioperative outcome

All nine dogs underwent unilateral nephrectomy of the affected kidney. The cystic lesions were removed intact and submitted for histopathological examination. No major intraoperative complications were observed.

3.5.1 Histopathological findings

Histopathological examination of the resected kidneys confirmed benign renal cystic lesions in all nine dogs. The lesions were characterized by variable degrees of renal tubular dilatation and ectasia, interstitial fibrosis, and chronic inflammatory changes (Figure 6). In representative sections, moderate-to-severe multifocal tubular dilatation and ectasia with mild interstitial fibrosis were observed. The dilated tubular and cystic spaces were lined by epithelium ranging from squamous to cuboidal and columnar and occasionally contained pale amphophilic material admixed with necrotic cellular debris, macrophages, and/or degenerate neutrophils. The intervening interstitium contained variable amounts of loose connective tissue and multifocal mixed inflammatory cell infiltrates. Mild thickening of the glomerular basement membrane and urothelium was observed in occasional sections. No epithelial dysplasia or malignant neoplasia was identified in any of the nine dogs.

3.5.2 Preoperative biopsy and definitive histopathological diagnosis

Preoperative ultrasound-guided Tru-Cut biopsy was performed in four of the nine dogs because of diagnostic uncertainty regarding the nature of the renal cystic lesions. Histopathological examination of the limited biopsy specimens revealed predominantly myxomatous tissue, which was interpreted as

benign renal fibroma. However, the biopsy findings did not definitively characterize the cystic lesions identified on imaging and represented only a limited portion of the lesions. Definitive histopathological examination of the entire affected kidneys following unilateral nephrectomy confirmed benign renal cystic lesions characterized by tubular dilatation and ectasia, variable interstitial fibrosis, and chronic inflammatory changes, with no evidence of epithelial dysplasia or malignant neoplasia.

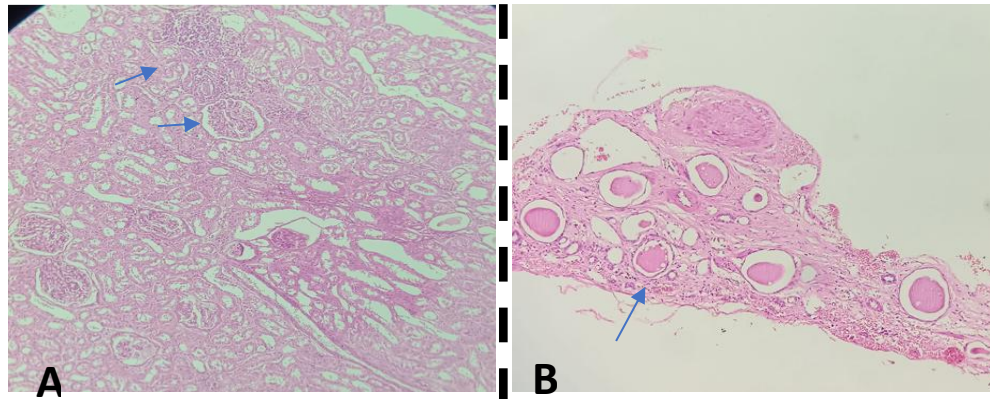


Figure 6. Histopathological features of renal cysts. **(A)** Renal cystic lesion containing a mixed inflammatory cell infiltrate and cellular debris. **(B)** Moderate-to-severe multifocal renal tubular dilatation and ectasia with mild interstitial fibrosis.

4. Discussion

The present retrospective case series describes the clinical, imaging, histopathological, and 12-month postoperative findings in nine dogs with solitary exophytic renal cystic lesions managed by unilateral nephrectomy. The lesions were unilateral and relatively large, with variable clinical and urinary abnormalities. Ultrasonography and contrast-enhanced computed tomography (CT) consistently demonstrated well-defined, predominantly cystic lesions without overtly aggressive imaging features, whereas histopathological examination confirmed benign renal cystic lesions in all dogs. No major intraoperative complications or clinically apparent renal insufficiency were recorded during the 12-month follow-up. However, these findings should be interpreted in the context of case selection, as nephrectomy was performed in dogs in which clinical abnormalities, renal parenchymal involvement, urinary abnormalities, or diagnostic uncertainty influenced the decision for definitive surgical treatment rather than renal-sparing management.

The clinical presentation was variable, ranging from incidental identification to inappetence, weight loss, hematuria, polyuria/polydipsia, vomiting, and abdominal discomfort. Such variability has been reported in dogs with solitary renal cysts, which may remain clinically silent or become clinically relevant when associated with enlargement, inflammation, infection, or compression of adjacent structures (Zatelli et al. 2005; Orioles et al. 2014; Park et al. 2019). In the present series, lesion dimensions ranged from 32 × 30 to 61 × 56 mm, and mild to moderate compression of the adjacent renal cortex was identified in four dogs. The relatively large size and exophytic location of the lesions may have contributed to the clinical signs in some dogs; however, a direct causal relationship could not be established from this retrospective study. This distinction is important because the clinical manifestations of renal cystic disease are influenced by lesion location, associated renal changes, and concurrent urinary or systemic diseases rather than cyst size alone.

Ultrasonography and CT provided complementary information for lesion characterization and surgical planning. Ultrasonography revealed that all lesions were well-defined, thin-walled, and predominantly anechoic, with distal acoustic enhancement. CT further demonstrated well-circumscribed, fluid-attenuating exophytic lesions without septations, mineralization, mural nodules, or contrast-enhancing

solid components. These findings are compatible with the typical imaging appearance of simple renal cysts in dogs (Paskalev et al. 2012; Van Dyck et al. 2018). CT additionally allowed assessment of the cortical origin and extent of the lesions, residual renal parenchyma, and contralateral kidney. The structurally normal appearance of the contralateral kidney in all dogs was particularly relevant when unilateral nephrectomy was considered.

Nevertheless, the imaging appearance did not establish the biological nature of the lesions. Cystic renal neoplasia may mimic apparently uncomplicated renal cysts, and cystic renal neoplasms have been reported in dogs (Cicarelli et al. 2019; Vagias et al. 2022). Therefore, the absence of septations, mural nodules, or contrast-enhancing solid tissue should be regarded as supportive of a benign-appearing lesion rather than definitive evidence of benignity. This was particularly relevant in the present study because preoperative ultrasound-guided sampling in four dogs yielded myxomatous or myxoid tissue and did not provide a definitive diagnosis. Limited percutaneous sampling may not adequately represent the entire cyst wall or focal pathological areas. Histopathological examination of the resected kidneys subsequently confirmed benign renal cystic lesions characterized by tubular ectasia, variable interstitial fibrosis, and chronic inflammatory changes, with no epithelial dysplasia or malignant neoplasia. Thus, the histopathological findings provided definitive lesion characterization in this selected population, while also highlighting the limitations of relying exclusively on imaging or limited biopsy specimens.

Urinary abnormalities were observed in several dogs, including hematuria, pyuria, hyposthenuria, and proteinuria. Bacterial infection was identified by urine culture in three dogs, with antimicrobial treatment selected according to susceptibility results. The decrease in urinary erythrocyte and leukocyte counts during follow-up, together with changes in urine pH and color, indicates temporal improvement in several urinary abnormalities. However, these changes cannot be attributed exclusively to nephrectomy because antimicrobial treatment and resolution of concurrent urinary inflammation or infection may have contributed. Previous reports have also documented renal cyst-associated infection as a clinically relevant complication that may require antimicrobial treatment and, in selected cases, definitive intervention (Khan et al. 2022; Suwabe et al. 2021). Accordingly, urine culture and antimicrobial susceptibility testing may provide useful complementary information when urinary infection is suspected.

Serum renal biomarkers showed significant temporal variation during the 12-month follow-up. Blood urea nitrogen and creatinine concentrations decreased, while SDMA decreased from 23.23 ± 0.61 preoperatively to 20.18 ± 0.43 at 12 months. These findings, together with the absence of clinically apparent postoperative renal insufficiency, indicate that unilateral nephrectomy was well tolerated in the dogs included in this series. However, the decrease in serum renal biomarkers should not be interpreted as evidence of improved renal function attributable to nephrectomy. Serum creatinine and SDMA are indirect markers of renal filtration and may be influenced by hydration status, systemic health, muscle mass, and other factors. Therefore, assessment of renal function is best interpreted using multiple clinical, biochemical, and urinary parameters (Paepe & Daminet 2013). Direct measurement of GFR was not performed in the present study and would have provided a more direct assessment of functional adaptation of the remaining kidney.

The management of renal cystic lesions should be individualized according to clinical status, lesion characteristics, and the amount of functional renal parenchyma that can be preserved. Renal-sparing approaches, including percutaneous aspiration with or without sclerotherapy, surgical deroofting, fenestration, and omentalization, have been described for selected renal cystic lesions in dogs (Zatelli et al. 2007; Van Dyck et al. 2018; Park et al. 2019; Dekerle et al. 2022; Tobias & Tillson 2018). These approaches have the potential advantage of preserving functional renal tissue and may be appropriate when the lesion is confidently characterised as benign and adequate renal parenchyma can be maintained. Recurrence following drainage or sclerotherapy is also an important consideration when selecting treatment, particularly for larger lesions.

In the present series, nephrectomy was selected on the basis of the overall clinical and diagnostic assessment rather than cyst size alone. Several dogs had clinical or urinary abnormalities, four had adjacent cortical compression, three had positive urine cultures, and four had inconclusive preoperative tissue sampling. Although the imaging findings were compatible with simple cysts, they could not definitively exclude a cystic neoplasm. Definitive excision therefore provided both therapeutic management and complete histopathological assessment of the lesion and surrounding renal tissue. These findings should not be interpreted as evidence that nephrectomy is preferable to renal-sparing procedures for uncomplicated renal cysts; rather, they illustrate a clinical situation in which definitive excision was selected because complete lesion characterization and treatment were considered important.

The principal limitations of this study were its retrospective design, small sample size, and absence of a comparison group. All nine dogs underwent nephrectomy; therefore, outcomes could not be directly compared with those following aspiration, sclerotherapy, deroofting, fenestration, or omentalisation. Selection bias is also likely because dogs considered suitable for renal-sparing treatment were not represented. Furthermore, direct measurement of the GFR was not performed, which limited the interpretation of postoperative renal functional adaptation. Concurrent treatment of urinary infections also prevented the attribution of changes in urinalysis solely to surgical treatment. Although 12 months of follow-up provides useful medium-term information, longer-term monitoring would be required to determine the persistence of renal functional compensation.

Conclusion

Unilateral nephrectomy was associated with favorable 12-month clinical and clinicopathological outcomes in this selected series of dogs with solitary exophytic renal cysts and structurally normal contralateral kidneys. Ultrasonography and contrast-enhanced CT were useful for lesion characterization and surgical planning, although benign-appearing imaging features did not definitively establish benign biological behavior. Histopathological examination confirmed benign cystic lesions in all nine dogs. These findings support individualized case selection rather than routine nephrectomy, with renal-sparing treatment remaining an appropriate consideration when preservation of functional renal parenchyma is feasible.

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Author's Contribution

Prarthana R.: Conceptualization, literature review, study design, clinical case management, data acquisition, patient follow-up, data analysis, interpretation of results, original manuscript draft, and preparation of figures and tables. Rohit Kumar: Surgical planning, supervision of clinical procedures, interpretation of findings, and critical revision of the manuscript. A. Gopinathan and A. C. Saxena: Diagnostic imaging, radiographic and ultrasonographic interpretation, and review of the manuscript. Kiranjeet Singh: Surgical assistance, interpretation of results, manuscript editing, and critical revision for important intellectual content. Vinodh Kumar: Statistical analysis and data interpretation; Pawan Kumar: Histopathological examinations and cytology reading with photographic recording with documentation; Purushotham RV: Antimicrobial susceptibility testing (ABST), interpretation of microbiological findings, and manuscript editing. A. S. Patil: Manuscript proofreading, language editing, and critical review. All authors contributed to the interpretation of the data, reviewed and approved the final version of the manuscript, and agree to be accountable for all aspects of the work, ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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600 **Data availability:** The clinical data supporting the findings of this study are available from the
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602 confidentiality restrictions.

603 **Declaration**

604 Formal ethical approval was not required for this retrospective study, which analyzed clinical data from
605 client-owned dogs that underwent diagnostic and therapeutic procedures as part of routine veterinary
606 care. No experimental procedures were performed for research purposes.

607 **Consent for publication** Written informed consent was obtained for the use of clinical data and images
608 for scientific publication.

609 The authors declare no conflicts of interest.

610 **5. Reference**

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