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Prevalence, Risk Factors, and Clinicopathological Characterization of Ocular and Renal Complications of Diabetes Mellitus in Dogs

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ABSTRACT

Canine diabetes mellitus (DM) is an endocrinopathy in dogs, which can lead to diabetic complications in the patient's eyes and kidneys. The present study aimed to describe the prevalence, risk factors, hematologic and serum biochemical findings, and incidence of ocular and renal complications of DM in dogs at veterinary clinics in Ho Chi Minh City, Vietnam. Dogs brought to veterinary clinics with clinical signs of polyuria, polydipsia, polyphagia, and weight loss were examined for DM, including hematology, serum biochemical, and urine analyses, from January to December 2025. Dogs confirmed with DM had hyperglycemia after at least 8 hours of fasting and concomitant glycosuria. The incidence of ocular and renal complications of diabetic dogs was recorded by using slit-lamp and urine parameters (elevated serum creatinine, blood urea nitrogen, microalbuminuria, and urine protein-to-creatinine ratio), respectively. Twenty canine DM cases were identified, accounting for 1.43% of the total dogs brought to veterinary clinics during the study. The mean age of diabetic dogs was 6.35 ± 3.65 years. The highest prevalence of DM was in the 3-8 years old group, the overweight group, and the male-neutered group among male dogs; however, female-entire dogs had the highest overall prevalence (3.36%). Diabetic dogs demonstrated elevated mean corpuscular volume, mean corpuscular hemoglobin, alanine aminotransferase, aspartate transaminase, alkaline phosphatase, creatinine, blood urea nitrogen, and cholesterol, and decreased Lymphocytes, red blood cells, hemoglobin, and hematocrit–in hematology and serum biochemical analyses. Urinalysis results of diabetic dogs demonstrated an increase in creatinine, microalbuminuria, and proteinuria, which could be used to diagnose diabetic renal complications in dogs. Cataract formation was the only ocular complication recorded in the present study, which was recorded in 5 diabetic dogs, and all diagnosed dogs had cataracts in both eyes. Renal failure was observed in 5 diabetic dogs, including 4 dogs with stage 4 renal failure and 1 dog with stage 3 renal failure. No dogs had both ocular and renal complications at the same time. In the current study, dogs that were older, overweight, or male-neutered had higher DM prevalence, with cataracts and stage 4 renal failure being the most common diabetic complications.

Keywords: Diabetes mellitus, Dog, Hematology, Ocular complication, Renal complication

INTRODUCTION

Canine diabetes mellitus (DM) is a common endocrine disease in dogs, which is characterized by persistent hyperglycemia resulting from insulin deficiency in production, action, or both (Ettinger et al., 2017). Depending on the mechanism causing hyperglycemia, canine DM is divided into insulin-dependent and non-insulin-dependent (Vaitaitis et al., 2024). Insulin-dependent diabetes (type I DM) is characterized by the destruction of pancreatic beta cells by immune-mediated mechanisms, usually leading to insulin deficiency (Ettinger et al., 2017; Vaitaitis et al., 2024). Most diabetic dogs are thought to have insulin-dependent DM (Feldman et al., 2015). In previous studies in North America and Europe, the prevalence of canine DM was approximately 0.32% to 1.33% of total dogs brought to veterinary clinics (Guptill et al., 2003; Fracassi et al., 2004; Mattin et al., 2014). Risk factors associated with canine DM were breed, sex, neuter status, age, and body condition (Mattin et al., 2014). Breeds at high risk for DM included Bichon Frise, Australian Terrier, Siberian Husky, Standard Schnauzer, Samoyed, Poodle, and Yorkshire Terrier (Guptill et al., 2003; Fracassi et al., 2004). These breeds had genetic factors that increased the risk of developing DM (Catchpole et al., 2013). Gender was reported to be one of the risk factors for DM in previous studies (Fall et al., 2007). Furthermore, neuter status was reported to be a risk factor for DM in female dogs, as progesterone-induced diabetes occurs during pregnancy (Fall et al., 2007). Previous studies showed that age was one of the risk factors for DM, as DM was most commonly diagnosed in dogs above 10 years old (Guptill et al., 2003; Fall et al., 2007). Overweight was also associated with DM in dogs (Mattin et al., 2014).

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New management strategies and therapies for canine DM might alter the outcome of diabetic patients and increase their lifespan (Mattin et al., 2014). As a result, ocular and renal complications of DM in dogs have also become more common (Miller and Brines, 2018; Priyanka et al., 2018). Cataract formation is one of the most common diabetic complications in dogs (Miller and Brines, 2018). Diabetic cataract, due to the accumulation of sorbitol and galactitol in the lens, is irreversible, which can eventually lead to blindness (Cantero et al., 2023). Diabetic nephropathy is a chronic complication that takes years to progress to renal failure, which (Bloom and Rand, 2013). Consequently, diabetic renal complications were rarely reported in dogs with DM. However, there have been only a few studies on the prevalence of canine DM, as well as ocular and renal complications of diabetes in dogs in Vietnam. Therefore, the present study aimed to investigate the prevalence and risk factors of DM in dogs and the incidence of ocular and renal complications in diabetic dogs in Ho Chi Minh City, Vietnam.

MATERIALS AND METHODS

Ethical approval

Ethics approval was provided by the Animal Ethics Committee, Nong Lam University, Ho Chi Minh City, Vietnam.

Hematology, serum biochemistry, and urine analyses

A total of 1,390 dogs were examined for DM from January to December 2025 at two veterinary clinics in Ho Chi Minh City, Vietnam. Dogs with clinical signs of canine DM, such as polyuria, polydipsia, polyphagia, and weight loss, were examined for DM by veterinarians. A total of 20 blood samples, with 2 mL of blood for each sample, were collected from the cephalic vein and analyzed by an automated biochemistry analyzer (Pointcare V3, MNChip, China) for serum biochemistry analysis and an automated hematology analyzer (DH36Vet, Dymind, China) for hematology analysis. Approximately 5-10 mL of urine was collected and analyzed by urine test strips (Vet11AC, DFI, Korea) and a urine reader (UriDoctor Vet, DFI, Korea). Dogs with at least 8 hours of fasting before blood sampling, confirmed with DM, had persistent fasting hyperglycemia (blood glucose above 6.6 mmol/L) and concomitant glycosuria (Ettinger et al., 2017). Dogs with fasting status less than 8 hours at the time of blood collection were excluded from the study. The recorded data included breed group (domestic, foreign), sex (male, female), neuter status (neutered, entire), age categories (1-3 years, 3-8 years, over 8 years), and body condition, which was determined using the Body Condition Score by The World Small Animal Veterinary Association (WSAVA, 2025).

Ocular and renal complications

Dogs previously diagnosed with DM or newly diagnosed with DM in the study were screened for cataract formation. A slit lamp (PSL One Portable Slit Lamp, Keeler, USA) was used by veterinarians to confirm and determine the stages of cataracts (Cantero et al., 2023). Cataracts were divided into five stages, including initial, immature, mature, hypermature, and intumescent. Diabetic dogs were also tested for renal complications. Diabetic dogs confirmed with renal complications had elevated serum creatinine (> 176.8 µmol/L), blood urea nitrogen (> 10.4 mmol/L), microalbuminuria (or proteinuria), and elevated urine protein-to-creatinine ratio (> 0.5; Bloom and Rand, 2013). The severity of kidney disease was determined by International Renal Interest Society (IRIS) references (IRIS, 2023).

Statistical analysis

Data were collected and analyzed with Minitab statistical software (Minitab 17, Minitab LLC, USA), with statistical significance determined by a p-value less than 0.05. Multiple regression was used to assess the risk factors for diabetes in dogs by breed, sex, and neuter status. Chi-square and Fisher's tests were used to compare the prevalence of diabetes across age groups, body condition, and neuter status within the same sex.

RESULTS AND DISCUSSION

Prevalence of diabetes mellitus

In a total of 1,390 dogs brought to veterinary clinics in this study, there were 20 dogs diagnosed with DM, which accounted for 1.43% of the total cases. The prevalence of DM in dogs was influenced by sample size, population of each dog breed, geographical location, duration of the study, and the care habits of the owners. Previous studies showed that the prevalence of DM in dogs was from 0.34% to 1.33% of total dogs brought to veterinary hospitals (Guptill et al., 2003; Fracassi et al., 2004; Mattin et al., 2014). Diabetes mellitus in dogs can be discovered incidentally when the patients are brought to the veterinary clinics due to other diseases. In the study by Mattin et al. (2014), approximately 47% of DM dogs were incidentally diagnosed with diabetes during veterinary hospital visits for other diseases.

The prevalence of DM in a domestic dog breed (Phu Quoc Ridgeback) and foreign dog breeds (one French Bull, one Golden Retriever, two Labrador Retrievers, two Pugs, two Alaskas, three Poodles) was 1.37% (9/658) and 1.50% (11/732), respectively (Table 1). The results of the current study showed that dog breed did not significantly increase the risk of DM in dogs ($p > 0.05$). However, according to previous studies, dog breed was one of the risk factors for canine diabetes (Catchpole et al., 2013; Feldman et al., 2015). The breeds with a high possibility of DM were Samoyed, Poodle, and Cairn Terrier (Ettinger et al., 2017). Furthermore, Irish and English Setters were proven to have a 2-4 times higher risk of developing diabetes compared to mixed breeds (Fracassi et al., 2004). Differences in the prevalence of diabetes in dog breeds are also influenced by the breed's geographical distribution (Fracassi et al., 2004). Previous studies on diabetes-related genes in dogs have been conducted on certain breeds (Catchpole et al., 2013; Short et al., 2014). However, the number of experimental samples in diabetes-related genetic studies was still relatively low, and the genes selected for veterinary studies were primarily based on human studies (Denyer et al., 2021).

Table 1. Breed, sex, and neuter status of dogs with diabetes mellitus presented to veterinary clinics in Ho Chi Minh City, Vietnam, from January to December 2025

Parameters	Surveyed dogs	Diabetic dogs	Prevalence	P-value
Breed				
Domestic	658	9	1.37[a]	0.833
Foreign	732	11	1.50[a]	
Sex				
Male	774	8	1.03	0.155
Female	616	12	1.95	
Neuter status				
Neutered	588	14	2.38[a]	< 0.05
Entire	802	6	0.75[b]	

[a,b] Mean different superscript letters indicated a significant difference among groups in the same column ($p < 0.05$)

The prevalence of DM in female dogs recorded at the clinic during the survey period was 1.95% (12/616), and in male dogs it was 1.03% (8/774; Table 1). The prevalence of diabetes in neutered dogs was 2.38% (14/588), higher than the prevalence of diabetes in entire dogs, which was 0.77% (6/802; $p < 0.05$). In the current study, the result showed that the prevalence of DM in male dogs (1.05%) was lower than in female dogs (1.95%), but statistical analysis showed no significant difference. The study of Mattin et al. (2014) also showed that sex was not a risk factor for DM in dogs. However, a previous study by Fall et al. (2007) indicated that female dogs were more susceptible to DM than male dogs. In male dogs of the present study, the prevalence of diabetic neutered dogs was 2.32%, which was higher than diabetic male-entire dogs (0.21%; Table 2; $p < 0.05$). Sex hormones are thought to play a significant role in the risk of diabetes in dogs; for instance, male sex hormones help reduce the risk, while female sex hormones increase the risk of DM (Feldman et al., 2015). Hormonal changes in female dogs during pregnancy were considered to be the main cause of increased DM risk in female dogs, while male sex hormones were thought to be the reason why male dogs were less obese than female dogs, which resulted in a lower incidence of DM in male dogs (Mattin et al., 2014). The trend of spaying female dogs to avoid unwanted pregnancies has changed over time, which might also influence the sex-associated incidence of diabetes in dogs (Fall et al., 2007). Therefore, neuter status may affect the prevalence of DM in dogs.

The mean age of diabetic dogs was 6.35 ± 3.65 years. Dogs aged 3-8 years had the highest percentage of DM (1.66%), followed by the above 8 years old group (1.66%), and the 1-3 years old group (0.29%; Table 2; $p > 0.05$). Geriatric dogs are more likely to develop diseases such as DM. In a study by Mattin et al. (2014), dogs in the 8-11 years old group accounted for about 40% of diabetic dogs, followed by the 11-13 years old group (27.3%), 3-8 years old group (19.6%), and the over 13 years old group (12.4%). Another study by Guptill et al. (2003) also indicated that dogs aged 8-15 years had the highest percentage of diabetic dogs, which was approximately 75% of diabetic dogs. The mean age of diabetic dogs in the current study was relatively low (about 6 years old), which indicated a lack of awareness of nutrition and canine DM control in the area.

The overweight group had a diabetic prevalence of 2.60% (13/500), higher than the under ideal (1/412) and ideal (6/478) groups ($p < 0.05$). All female dogs were confirmed not to be pregnant at the time of survey. Neutered male dogs had a prevalence of diabetes of 2.32%, higher than entire male dogs (0.21%; $p < 0.05$). The incidence of diabetes in neutered female dogs was 1.28%, and the incidence of diabetes in entire female dogs was 3.36%. Dogs with DM can have either ideal, under ideal, or over ideal body condition (Ettinger et al., 2017). Untreated DM in dogs over a long period may lead to weight loss; however, severe loss of muscle mass is rare unless there is another underlying disease, such as exocrine pancreatic insufficiency (Feldman et al., 2015). However, obesity is considered one of the risk factors of DM in dogs (Feldman et al., 2015). A study by Mattin et al. (2014) indicated that overweight dogs were shown to have a higher risk of developing the disease compared to non-overweight dogs. Approximately 15% of diabetic dogs were obese, according to a study by Thao et al. (2015). Dogs diagnosed with diabetes are usually given regular check-ups, and their body weight can be appropriately controlled.

Table 2. Age, body condition, and sex-neuter status of dogs with diabetes mellitus presented to the veterinary clinics in Ho Chi Minh City, Vietnam from January to December 2025

Parameters	Surveyed dogs	Diabetic dogs	Prevalence	P-value
Age group				
1-3 years old	350	1	0.29^{a}	
3-8 years old	678	13	1.92^{b}	0.105
Above 8 years old	362	6	1.66^{b}	
Body conditions				
Under ideal	412	1	0.24^{a}	
Ideal	478	6	1.26^{ab}	0.011
Overweight	500	13	2.60^{b}	
Sex-neuter status				
Male-neuter	302	7	2.32^{a}	0.007
Male-entire	472	1	0.21^{b}	
Female-neuter	286	7	2.45	0.147
Female-entire	330	5	1.52	

[a,b] Mean different superscript letters indicated a significant difference among groups in the same column ($p < 0.05$)

Hematology, serum biochemistry, and urine results

In the current study, most diabetic dogs had normal hematology results within the reference range. The average results for mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) were higher than the reference range, while lymphocyte percentage (Lym%) was below the reference range (Table 3). There were 15 diabetic dogs with elevated MCV, and 13 dogs with elevated MCH. The percentage of diabetic dogs with decreased red blood cells (RBC), hematocrit (HCT), and hemoglobin (HGB) was 30%, 40%, and 40%, respectively. Hematological abnormalities could affect other tissues and organs, which could lead to complications such as cataracts and kidney disease in diabetic dogs (Mansour et al., 2023). However, there are not many studies on the relationship between hematological abnormalities and DM in dogs. In the present study, diabetic dogs had Lym, RBC, HGB, HCT, MCV, and MCHC outside the reference ranges reported by Vaden (2009). High blood glucose levels lead to the non-enzymatic binding of glucose to red blood cell protein (HbA1c), causing red blood cells to bind more tightly to oxygen, making it difficult to release oxygen to tissues and resulting in localized tissue hypoxia (Mansour et al., 2023). In cases of inflammation or pancreatitis, neutrophil counts could be elevated (Peter, 2017). A study conducted by Slead et al. (2022) on hematological analysis and blood smears in diabetic dogs showed that RBC, HGB, and HCT counts were lower, and WBC counts in diabetic dogs were higher than the reference range. Furthermore, diabetic ketoacidosis is often found in diabetic dogs with an overproduction of codocytes (Slead et al., 2022).

In the present study, the average values of aspartate aminotransferase (AST), alkaline phosphatase (ALP), creatinine (Crea), blood urea nitrogen (BUN), and cholesterol (CHOL) were higher than the reference range (Table 3). The results showed that approximately 25% of diabetic dogs might have liver diseases, with elevated AST and ALP. In the present study, there were 5 diabetic dogs that showed elevated Crea and BUN, suggesting that diabetes in dogs ~~may~~ be associated with urinary diseases. Elevated CHOL was also observed in 5 dogs, which accounted for 25% of the total number of diabetic cases. Other serum biochemistry parameters were recorded within the reference range in most diabetic dogs. In the study, a proportion of diabetic dogs showed abnormalities in liver and kidney functions. In diabetic dogs, hypovolemia could occur, which leads to hepatocellular damage and elevated serum AST, ALP, and ALT in the serum biochemistry analysis panel (Babazadeh et al., 2022). An increase in serum creatinine and BUN could indicate kidney disease or diabetic renal complications (O'Brien, 2010). Dogs with DM often exhibit hyperketonemia, which eventually could lead to ketoacidosis (Slead et al., 2022). Diabetic ketoacidosis occurs when the body increases ketone production to compensate for inefficient glucose utilization in the blood (Feldman et al., 2015). A previous study demonstrated the potential of HbA1c and fructosamine in canine DM diagnosis (Baldo et al., 2020). However, elevated serum fructosamine levels within the reference range can still occur in dogs with newly diagnosed diabetes shortly before veterinary clinic admission (Ettinger et al., 2017; Norris and Schermerhorn, 2022).

In the present study, there were 7 dogs recorded with hyperketoneuria, and 11 dogs also showed hyperalbuminuria (Table 4). An elevated protein/creatinine ratio was also observed in 5 dogs. Urinalysis is one of the tests that should be performed in cases of diabetic dogs (Ettinger et al., 2017). A study by Mazzi et al. (2008) showed that approximately 25% of diabetic dogs had albuminuria, which could also be an indicator for detecting diabetic kidney damage. In the same study, the percentage of dogs with elevated protein/creatinine and albumin/creatinine levels was 71%. Glucosuria may increase the risk of urinary tract infections (Ettinger et al., 2017). Therefore, bacterial culture and isolation in urine can be performed to assess the presence of urinary tract infections.

Table 3. Hematology and serum biochemistry analysis of diabetic dogs presented to veterinary clinics in Ho Chi Minh City, Vietnam from January to December 2025

Parameter	Unit	Reference range*	Average result	Below reference range	Within reference range	Above reference range
Hematology analysis						
WBC	10^3/µL	6-17	15.61	10%	75%	15%
Lym	10^3/µL	1-5	1.93	15%	80%	5%
Lym percentage	%	24-26	14.57	65%	25%	10%
RBC	10^6/µL	5.4-7.8	6.22	30%	65%	5%
HGB	g/dL	13-20	13.72	40%	60%	-
HCT	%	40-60	40.09	40%	60%	-
MCV	fL	39-52	64.56	-	25%	75%
MCH	pg	13-21	22.01	-	35%	65%
MCHC	g/dL	30-38	34.16	-	95%	5%
PLT	10^3/µL	170-575	337	15%	70%	15%
Serum biochemistry analysis						
ALB	g/L	22-44	34.72	-	100%	-
TP	g/L	57-89	70.94	5%	90%	5%
GLOB	g/L	23-52	38.23	-	90%	10%
A/G			1.5			
TBIL	µmol/L	0-15	7.39	-	100%	-
ALT	U/L	5-130	108.52	-	95%	5%
AST	U/L	0-48	56.33	-	75%	25%
ALP	U/L	14-111	178.34	-	75%	25%
Crea	µmol/L	53-177	254.98	10%	65%	25%
BUN	mmol/L	2.9-10.4	12.00	-	75%	25%
BUN/Crea			19.02			
GLU	mmol/L	3.89-6.66	10.27	-	-	100%
CHOL	mmol/L	1.68-5.81	6.07	-	75%	25%

WBC: White blood cells, Lym: Lymphocytes, RBC: Red blood cells, HGB: Hemoglobin, HCT: Hematocrit, MCV: Mean corpuscular volume, MCH: Mean corpuscular hemoglobin, MCHC: Mean corpuscular hemoglobin concentration, PLT: Platelets, ALB: Albumin, TP: Total protein, GLOB: Globulin, A/G: Albumin/globulin ratio, TBIL: Total bilirubin, ALT: Alanine aminotransferase, AST: Aspartate transaminase, ALP: Alkaline phosphatase, Crea: Creatinine, BUN: Blood urea nitrogen, GLU: Blood glucose, CHOL: Cholesterol. The source of the reference ranges was Vaden (2009).

Ocular and renal complications

In the current study, the incidence of cataract complications in diabetic dogs was 25% (5/20 cases; Table 5). However, cataract was the only ocular complication recorded in diabetic dogs. All cases of diabetic dogs with cataracts in the study were observed in both eyes. There was one case of immature, one case of mature, and three cases of hypermature cataract. There was one case of incipient and intimescent cataracts recorded. The duration of DM and the time of cataract onset were not recorded in any of the cataract cases. Cataract formation is one of the most common eye complications in diabetic dogs (Miller and Brines, 2018). A study by Beam et al. (1999) showed that 14% of dogs diagnosed with DM already had cataract formation. Over 65% of diabetic dogs had cataracts, and approximately 80% of diabetic dogs developed cataracts after about 16 months (Beam et al., 1999). The incidence of cataract in diabetic dogs in the current study was lower than in a previous study, which might be due to the low mean age of diabetic dogs. In a study of cataract formation in dogs by Donzel et al. (2017), the average age of diabetic dogs with cataracts was about 10 years old. While it was hypothesized that glycemic control prolongs the time to cataract development, a recent study by

Arad et al. (2025) indicated that dogs with hyperglycemia and increased glycemic variability had diabetic cataracts develop rapidly.

Table 4. Urinalysis of diabetic dogs presented to the veterinary clinics in Ho Chi Minh City, Vietnam from January to December 2025

Parameter	Unit	Reference range*	Below reference range	Within reference range	Above reference range
GLU	mg/dL	Negative	-	-	100%
Bilirubin		Negative	-	80%	20%
Ketone	mg/dL	Negative	-	65%	35%
USG		1.015-1.025	-	15%	85%
RBC	cells/hpf	< 2-5	-	100%	-
pH		6-7.5	25%	75%	-
Protein	mg/dL	Negative	-	55%	45%
Nitrite		Negative	-	90%	10%
WBC	cells/hpf	< 2-5	-	80%	20%
Microalbumin	mg/L	0-1	-	45%	55%
Creatinine	mg/dL	0-0.5	-	25%	75%
P/C		0-0.5	-	75%	25%

USG: Urine specific gravity, Ketone: Urine ketone, Creatinine: Urine creatinine, P/C: Urine protein/creatinine ratio, RBC: Urine red blood cells, WBC: Urine white blood cells, hpf: High-power field. Source: Vaden (2009)

Table 5. Incidence of cataracts of diabetic dogs presented to veterinary clinics in Ho Chi Minh City, Vietnam from January to December 2025

Stage of cataracts	Number of cases	Percentage
Incipient cataract	-	-
Immature cataract	1	5
Mature cataract	1	5
Hypermature cataract	3	15
Intumescent cataract	-	-
Total	5	25

The incidence of renal complications in dogs was 25% of the total number of diabetic dogs (5/20 cases). Based on the IRIS classification of chronic kidney disease stages in dogs, there were 4 cases classified as stage 4 chronic kidney disease, and 1 case as stage 3. None of the dogs with renal complications also developed cataracts during the study period. Urinalysis for microalbuminuria is a method to detect renal complications due to diabetes. Microalbuminuria occurs in diabetic dogs, and the albumin/creatinine ratio in urine increases before the urine protein and creatinine ratio in urine increases (Mazzi et al., 2008). According to a study by Mazzi et al. (2008), over 50% of diabetic dogs have an elevated albumin/creatinine ratio in their urine.

CONCLUSION

Cataract formation was the most common diabetic ocular disease in dogs. Most diabetic dogs with renal complications had stage 4 chronic kidney disease. However, the associations between diabetic complications and DM in dogs still need more investigation. More studies are needed to investigate the associations between microalbuminuria and renal complications in diabetic dogs. The present study had certain limitations, as only 20 diabetic dogs were recorded, which may not reflect actual clinical effects, despite the statistical difference observed between the groups compared. Additionally, the study did not record or analyze data on dogs' dietary intake and daily exercise, which could influence the risk of developing DM. More studies are needed to investigate the associations between microalbuminuria and renal complications in diabetic dogs.

DECLARATIONS

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Authors' contributions

Thuong Thi Nguyen and Khanh Nguyen Dinh carried out conceptualization, methodology, formal analysis, original draft preparation, review, and editing. Tan Nhat Nguyen participated in formal analysis, original draft preparation, review, and editing of the study. Linh Ngoc Thuy Bui and Tuyen Thi Kim Le participated in original draft preparation. All authors have read and approved the final edition of the manuscript before publication in the present journal.

Availability of data and materials

The authors of the present study confirm that all data supporting the findings of the present study are available upon reasonable request from the corresponding author.

Competing interests

The authors declare no conflict of interest.

Ethical considerations

This article was written originally without any copying from data of published articles and books. The authors used NotebookLM to find appropriate articles for citation in the study. The authors take full responsibility for all use of artificial intelligence (NotebookLM) for identifying suggested citations. All suggested citations have been verified and reviewed by the authors. The authors are solely responsible for the accuracy, originality, and integrity of the final manuscript before submission, during the revision and publication of the article.

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