

Ultrasonography accompanied by genetic testing in feline polycystic kidney disease

Thao Phuong Vu^{1*} Thong Quang Le² Ha Nguyen Nhat Tran²

Khoa Hoang Dang Le¹ Anh Phu Nam Bui¹

Abstract

Autosomal dominant polycystic kidney disease (ADPKD), caused by the *PKD1* c.10063C>A mutation, is a prevalent inherited feline disorder, but its allele frequency in Vietnam remains unidentified. This study aimed to determine the carrier frequency of this variant in British Shorthair, Maine Coon, and Ragdoll cats in Ho Chi Minh City and to correlate genotype with ultrasonographic phenotype. Ninety-seven client-owned cats were genotyped for the *pkd1* mutation using PCR-RFLP. A subset of 47 cats also underwent abdominal ultrasonography to detect renal cysts. Genotypic results were correlated with sonographic findings, and risk factors were analyzed using chi-square tests and odds ratios (OR). Sixteen of 97 cats (16.5%) were heterozygous carriers, yielding an overall mutant-allele frequency of 0.08. No homozygous mutants were found. Breed-specific carrier frequencies were 56.3% in British shorthairs, 25% in Maine Coons, and 18.7% in ragdolls. Among the 47 ultrasonographically examined cats, there were nine (19.1%) had renal cysts, and eight of whom were mutation carriers. The sensitivity and specificity of the genetic test relative to ultrasound were 88.9% and 97.4%, respectively. A strong genotype-phenotype correlation was confirmed, where mutant carriers had significantly higher odds of having kidney cysts detected on ultrasound (OR = 296.0; $P < 0.001$). The *PKD1* c.10063C>A allele is present at a significant frequency in popular non-Persian breeds in Vietnam. In conclusion, PCR-RFLP is a rapid and accurate screening tool, supporting its integration into breeding programs and clinical practice to mitigate ADPKD incidence and improve feline health.

Keywords: feline ADPKD, genotype-phenotype correlation, PCR-RFLP genotyping, *PKD1* c.10063C>A, ultrasonography

¹Ho Chi Minh City Open University, Vietnam

²Nong Lam University Ho Chi Minh City, Vietnam

*Correspondence: 6770015431@student.chula.ac.th (T.P. Vu)

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Introduction

In Vietnam, cats have rapidly shifted from village animals to full-fledged family members. This shift has been reflected in commercial market analyses by Indochina Research (2025) and Petfair Vietnam (2025), which estimated that roughly 3 in 10 pet-owning households now keep at least one cat. These reports further forecast the national pet population to surpass 43 million by 2027, with dogs and cats together accounting for 43% of that total. This thriving “pet-humanization” trend drives demand for veterinary genetic screening, because several inherited disorders already recognized worldwide are now reported, or strongly suspected, in Vietnamese catteries.

Autosomal-dominant polycystic kidney disease (ADPKD), caused by the *PKD1* c.10063C>A mutation, remains one of the most common feline inherited disorders: global studies show a prevalence of approximately one-third in Persian-related breeds, and local diagnostic labs increasingly report the same pattern via ultrasound and PCR assays. Another common mutation is hypertrophic cardiomyopathy, which is linked to MYBPC3 missense variants (A31P in Maine Coons, R820W in Ragdolls), threatening an estimated 10-15% of pedigree cats imported into Southeast Asia, including Vietnam’s growing population (Grzeczka *et al.*, 2024). Drug-induced neurotoxicity arising from the ABCB1 1930_1931del TC deletion has also been confirmed in Maine Coon lines, highlighting the need for genotyping before ivermectin or other macrocyclic-lactone therapy (Nürnberg *et al.*, 2021). Moreover, recessive variants in the CMAH gene that determine blood type B persist in domestic shorthairs and pure breeds, making pre-breeding blood-group genotyping essential to prevent neonatal isoerythrolysis (Kehl *et al.*, 2019). Collectively, these data show that safeguarding feline welfare - and the rapidly growing companion-animal economy - in Vietnam now hinges on integrating routine genetic testing into both clinical practice and breeding programs.

ADPKD in the cat is almost universally produced by a nonsense C→A transversion at nucleotide 10 063 of exon 29 in *PKD1* (c.10063C>A), first cloned by Lyons *et al.* in 2004; the change introduces a premature stop-codon that truncates ~25% of polycystin-1, is lethal in homozygotes, and shows complete penetrance in heterozygotes (Lyons *et al.*, 2004; Nicholas *et al.*, 2025). Ultrasound surveys performed soon after that discovery found the allele in 38–50% of Persian cats in the USA, UK and Australia and at ~6 % in the global domestic population, establishing it as the most prevalent inherited feline disorder (Nicholas *et al.*, 2025). Subsequent molecular epidemiology has revealed marked regional variation: 23.1% of Persian-derived cats in western Mexico, 19.4% of mixed-breed samples in Thailand, and 62.5% of clinically nephropathic cases in a Turkish referral cohort carry the variant, while a 2023 Japanese survey of 1 281 clinical submissions detected it in only 1.8% of cats but confirmed strong enrichment in Persian, Scottish Fold and Exotic Shorthair lines (Bilgen *et al.*, 2020; Michel-Regalado *et al.*, 2022; Jaturanratsamee *et al.*, 2023; Shitamori *et al.*, 2023). The same Japanese project used targeted resequencing to describe four previously

unreported exon 15 variants - two missense and a frameshift among them - in cystic-kidney cats lacking the canonical mutation, demonstrating that *PKD1* heterogeneity in feline ADPKD is broader than once thought and parallels the mutational spectrum recognized in humans (Shitamori *et al.*, 2023). Long-term follow-up of 300 mutation-positive cats now places life expectancy at birth around 12.7 years, with renal-related mortality accelerating after six years, emphasizing the need for early screening (Enomoto *et al.*, 2025). Collectively, these data show that while the c.10063C>A allele remains the principal target for genetic tests, region-specific prevalence and emerging non-canonical *PKD1* variants justify combining sensitive PCR-based assays with next-generation sequencing in breeding and clinical programs worldwide.

Vietnam’s blooming companion-animal sector, with cats forming an increasingly prominent share, has promoted the demand for evidence-based veterinary care, including genetic screening for heritable diseases. Among the latter, ADPKD caused by the canonical *PKD1* c.10063C>A nonsense variant is the most prevalent feline monogenic disorder worldwide, with reported carrier frequencies ranging from ~20% to >60% in Persian-derived lineages and appreciable spill-over into mixed-breed populations (Lyons *et al.*, 2004; Bilgen *et al.*, 2020; Michel-Regalado *et al.*, 2022), and local ultrasound surveys in Vietnam have already implicated the same mutation in catteries. Despite the potential impacts of ADPKD on feline health and welfare, the true allele frequency across the country’s rapidly expanding pedigree and household-cat populations remains unknown. Determining this frequency is essential for three reasons: (i) it will quantify the genetic burden and thereby inform the scale of national screening programs; (ii) it will guide breed-specific breeding policies aimed at eliminating lethal homozygous conceptions while preserving genetic diversity; and (iii) it will provide baseline data against which emerging non-canonical *PKD1* variants can be monitored. Additionally, although uncommon, other non-Persian cat breeds such as Ragdoll and Maine Coon have also been genetically screened for this disease, and there is ultrasonographic evidence of renal cysts (Gendron *et al.*, 2013; Paeppe *et al.*, 2013). Therefore, it is also worthwhile to extend the genetic and ultrasonographic studies of these two breeds in Vietnam due to the lack of known data.

In general, these epidemiological insights will promote both feline welfare and the economic sustainability of Vietnam’s growing pet industry, ensuring that the benefits of “pet humanization” are not undermined by preventable renal morbidity and early mortality.

Materials and Methods

Animals: From September 2022 to April 2023, British shorthair, Maine Coon, and Ragdoll cats from multiple breeding catteries, veterinary clinics, and individual households within Ho Chi Minh City were included in this study. All cats were handled in accordance with the Vietnam Law on Animal Health (79/2015/QH13)

and the Law on Animal Husbandry (32/2018/QH14). After being informed about the proposed diagnostic procedures, the clients signed a consent form for study participation.

Prior to ultrasound examination and blood sample collection, all cats underwent detailed history-taking and a thorough physical examination to document their signalment (breed, age, and sex) and to assess their overall health status and detect any clinical signs potentially indicative of renal disease. All diagnostic and sampling procedures were refined to the lowest practicable level of invasiveness in accordance with internationally recognized best-practice guidelines for feline clinical research.

Blood sample collection: For genetic analysis, blood samples were collected from each cat via venipuncture using a 23-gauge needle. A minimum of 0.5 mL of whole blood was collected into EDTA-anticoagulated tubes for subsequent genomic DNA extraction and PCR-RFLP analysis.

DNA extraction: Genomic DNA was isolated from 200 μ L of anticoagulated feline whole blood using the FastPure Blood/Cell/Tissue/Bacteria DNA Isolation Mini Kit (Vazyme, cat. no. DC112). Following the manufacturer's protocol, leukocytes were lysed for 10 min at 56 °C in Buffer BL supplemented with proteinase K; ethanol was then added to promote nucleic-acid binding to the silica membrane. The spin column was washed twice with PW and PE buffers to remove heme, proteins, and other PCR inhibitors, and DNA was eluted in 50 μ L nuclease-free water. Typical yields were 4–6 μ g ($\approx$ 40–60 ng μ L⁻¹) with $A_{260}/_{280}$ ratios of 1.8–2.0, and agarose-gel analysis showed high-molecular-weight fragments > 20 kb, indicating minimal degradation. The solvent-free workflow is completed in < 40 min and produces DNA that is immediately amenable to downstream applications such as PCR-RFLP, making it well-suited for large-scale molecular screening of the *PKD1* allele.

PCR-RFLP analysis: To screen cats for the pathogenic c.10063C > A (p.L3284P) substitution in exon 29 of *PKD1*, we used primers that bracket the variant while yielding an amplicon large enough (559 bp) to display clearly resolved restriction fragments yet short enough for robust amplification from partially degraded genomic DNA. The forward primer 5'-CAGGTAGACGGGATAGACGA-3' and reverse primer 5'-TTCTTCCTGGTCAACGACTG-3' are each 20 nt, with GC contents of 55 % and 50 %, respectively. Thermal cycling on a Biorad T100 thermocycler comprised an initial denaturation at 94 °C for 3 min; 35 cycles of 94 °C for 1 min, 58 °C for 1 min and 72 °C for 1 min; followed by a terminal extension at 72 °C for 10 min. Amplicons were resolved on 1.5 % agarose, visualized with a Bio-Rad documentation system as single bands of the expected 558 bp, and stored at -20 °C pending sequence verification. In-silico digestion of the reference allele revealed no recognition site for the type IIS endonuclease MlyI (5'-GAGTC(N)5'-3') (New England Biolabs) within the 558 bp product, whereas the C > A transversion introduces this motif. Consequently, MlyI digestion leaves the wild-type

allele intact at 558 bp but cleaves the mutant allele into two diagnostic fragments of 316 bp and 243 bp. Heterozygous carriers thus exhibit all three bands (558 bp + 316 bp + 243 bp) on a 2.5 % agarose or 10 % polyacrylamide gel. This PCR-RFLP assay is cost-effective, rapid ($\leq$ 6 h from DNA to result), and readily scalable for population-level screening of felines at risk for ADPKD.

Abdominal ultrasonography: Abdominal ultrasound examinations were performed in 47/97 cats to confirm the presence of cystic lesions in both kidneys and other parenchymal organs. Cats were restrained on either lateral or dorsal recumbency without the use of sedatives. Bilateral regions on the flank were shaved to remove the fur and optimize image quality.

Examination was performed using an available ultrasound probe and machine. Both kidneys were systematically scanned on longitudinal and transverse views. A lesion will be considered 'cystic' if its structure is anechoic, round to oval, with a defined margin, and found within the renal parenchyma, most frequently in the cortical or cortico-medullary regions of the kidney. Color Doppler was used to differentiate between a cystic lesion with renal blood vessels. The ultrasonographic diagnosis of polycystic kidney disease was determined based on established age-based ultrasonographic criteria, as previously described (Guerra *et al.*, 2019).

Statistical analysis: Statistical analysis was performed by IBM SPSS (v28.0). Descriptive analysis was performed to present the characteristics of the study population. Percentages were calculated for categorical variables (breed, sex, age groups, ultrasound results, and genetic results). For the quantitative variable (age), mean value and standard deviation (mean $\pm$ SD) were presented. In addition, Chi-squared test or Fisher's exact test was used to evaluate the correlation of different risk factors – including the presence of *PKD1* mutation (negative/positive), breed (British shorthair/non-Persian), and age group (< 3 years/ $\geq$ 3 years), with the incidence of polycystic kidney disease (PKD) confirmed by the presence of cystic lesions on ultrasonography. Odds ratio (95% CI) was calculated to quantify the level of correlation. A factor was considered a risk factor if the OR was greater than 1 and its 95% CI did not include 1. Statistical significance was set at $P < 0.05$.

Results

Characteristics of the study population: A total of 97 cats of three breeds were included in the study. Ragdolls accounted for 38.1% (n=37, followed by British shorthair at 33.0% (n=32), and Maine Coons at 28.9% (n=28). Regarding sex, there were relatively equal percentages between females (51.5%) and males (48.5%). The mean age at examination was 2.3 $\pm$ 1.6 years, with cats < 3-year-old accounted for 63.9%, the youngest individual being 0.17 years-old (approximately 2 months-old) and the oldest being 7 years-old. Among 97 cats, 66.0% were recruited from catteries, and 34.0% were recruited from veterinary clinics/households with the permission of the owners.

Of the cases collected from veterinary clinics, there were three British shorthair cats diagnosed with PKD and chronic kidney disease.

Results of PCR-RFLP and sequencing for PKD1 mutation: The PCR-RFLP assay amplified a 558 bp fragment of exon 29 of the feline *PKD1* gene from all 97 genomic DNA samples analyzed. Subsequent restriction digestion produced genotype specific banding patterns that were readily distinguished on a 1 % agarose gel (Fig. 1). There were 81/97 (83.5 %) samples that displayed only the undigested 558 bp

fragment, confirming their wild-type status (CC). There were 16/97 (16.5%) samples yielded the heterozygous profile consisting of three bands (558, 316 and 243 bp), indicating the presence of one mutant allele (Table 1). No samples exhibited the 316 bp + 243 bp pattern expected for homozygous mutants, a finding consistent with the widely accepted view that the c.10063C>A *PKD1* mutation is embryonically lethal in the homozygous state. Distribution of carriers across breeds revealed 9/16 heterozygotes in British Shorthair cats (56.25%), 4/16 in Maine Coons (25.0%), and 3/16 in Ragdolls (18.75%).

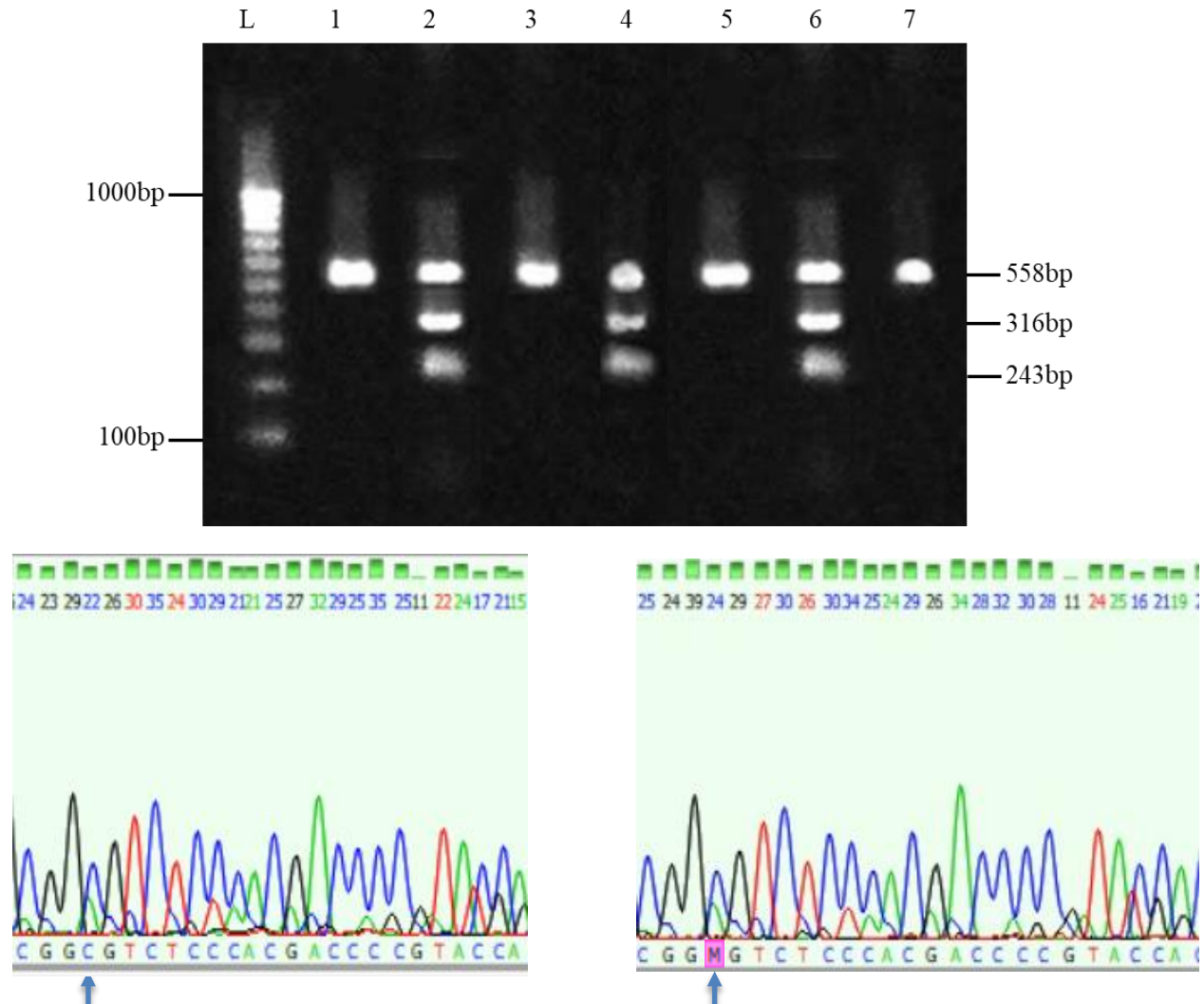


Figure 1 The image comprises two panels illustrating the molecular detection and genotyping of a single nucleotide polymorphism (SNP) using PCR-RFLP and Sanger sequencing. Top panel: An agarose gel electrophoresis image showing the results of PCR-RFLP analysis. A 100bp DNA ladder is present in the first lane for fragment size reference. Subsequent lanes contain digestion products representing three genotypes at a specific locus. Homozygous wild-type (Sample 1, 3, 5: homozygous wild-type cat for Ragdoll, Maine Coon, and British shorthair, respectively): characterized by a single undigested band (558bp). Heterozygous (Sample 2, 4, 6: heterozygous cat for Ragdoll, Maine Coon, and British shorthair, respectively): showing three bands corresponding to both undigested and digested fragments (558bp, 316bp, and 243bp). These distinct banding patterns confirm the presence or absence of the restriction site introduced or abolished by the SNP... Sample 7: undigested PCR product. Bottom panel: Electropherograms from Sanger sequencing. The left chromatogram displays a homozygous heterozygous genotype (allele C) with a single peak (arrow). The left-right chromatogram shows a heterozygote genotype (allele M = A/C), evident by the overlapping peaks at the polymorphic site, representing the mutant allele.

Table 1 Breed distribution of mutation carriers and wild-type individuals.

Breed	PKD1 mutation carriers	Wild-type
British shorthair	9 (56.3%)	23 (28.4%)
Maine Coon	4 (25.0%)	24 (29.6%)
Ragdoll	3 (18.7%)	34 (42.0%)
Total	16 (100%)	81 (100%)

Ultrasonographic findings: All cats underwent blood collection for genetic testing, while only 47/97 of them were given permission for ultrasound examination by the clients. Among them, 9/47 individuals (19.1%) were diagnosed with PKD (Table 2). All of the ultrasonographically PKD-positive cases were British shorthair cats, accounting for 36.0% (9/25) of the total of British shorthair in this group; no diagnosis of PKD was made in cats of other breeds.

Among 9 cases with PKD, unilateral cysts were reported in 6 individuals, accounting for 19.1% (9/47) of cats undergoing ultrasound examination and 66.7% of cats with PKD (4 cases had cysts only on the left kidney, and 2 cases had cysts on the right side) (Fig. 2). Bilateral cystic lesions were found in 8.1% (3/47) of cats undergoing ultrasound examination and 33.3% of the total affected cats (Table 3). None of the cats had cystic lesions in other organs, such as the liver or pancreas.

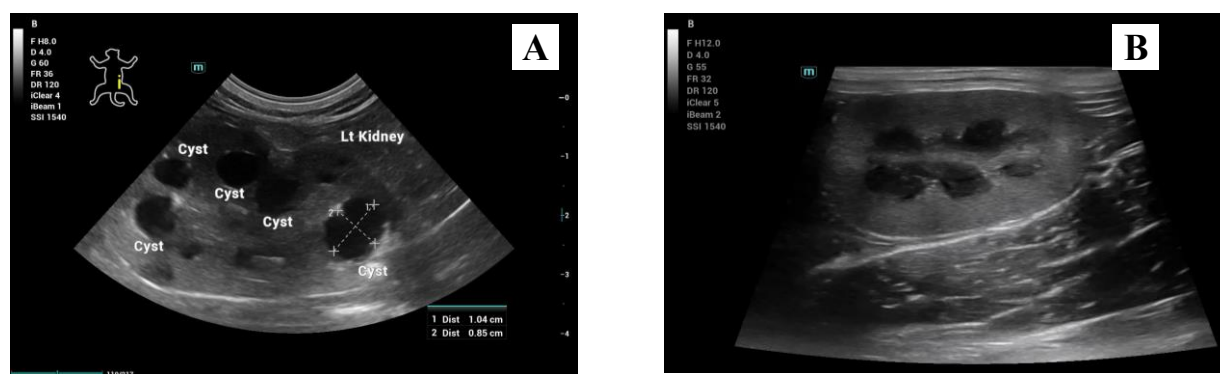


Figure 2 Longitudinal ultrasonographic images of a polycystic left kidney (A) and a normal kidney (B) from two different British shorthair cats. Multiple cystic lesions appeared as anechoic and well-defined at both cortical region and cortico-medullary junction (Courtesy: K9 Veterinary Clinic).

Table 2 Signalment and genotype of nine cats with sonographically-confirmed PKD.

Place of origin	Name/ID	Sex	Age (year)	Genotype
Veterinary Clinic/ Household	Xam	Male	3.0	Positive
	Dua	Male	2.0	Positive
	Tu	Female	4.0	Positive
	Hau	Male	2.0	Positive
	Bo	Male	4.5	Negative
Cattery	BSH-22	Male	3.0	Positive
	BSH-28	Male	4.0	Positive
	BSH-29	Male	3.0	Positive
	BSH-30	Female	1.0	Positive

Table 3 Frequencies and positions of polycystic lesions detected by ultrasonographic examination on 47 cats.

Ultrasound results	Position	Number of cats (n)	Percentage (%)
Without PKD	-	38	80.9
With PKD	Total	9	19.1
	Left kidney	4	8.5
	Right kidney	2	6.4
	Both kidneys	3	4.3

Correlation between PCR-RFLP and ultrasonographic results

Number of cats included for PCR-RFLP genotyping and/or ultrasonographic phenotyping: The ultrasonographic phenotypes of all 47 cats were compared with PKD1 genotypes. Sanger analysis identified eight carriers of the c.10063C > A allele (C/A), whereas the remaining 39 animals were homozygous wild type (C/C). Genotype correlated strongly with renal imaging findings: cystic lesions

were visualized in all eight cats, and every genetically affected individual belonged to the heterozygous group, yielding a highly significant difference in cyst prevalence between C/A and C/C cohorts. One male British shorthair, 4.5 years old, displayed renal cysts despite lacking the variant, indicating that non-PKD1 causes of cystic pathology can occur although infrequent. The distribution of mutation carriers and cyst-positive cases on ultrasonography is detailed in Table 4.

Correlation between PCR-RFLP genotyping and ultrasonographic phenotyping: A strong correlation was observed between the *PKD1* genotype and the sonographic phenotype (Table 5). Of the nine cats diagnosed with PKD via ultrasound, eight (88.9%) were tested positive for the *PKD1* mutation. On the other hand, of the 38 cats with no ultrasonographic evidence of PKD, only 1 were tested positive for the mutation. These results yield a sensitivity of 88.9% and a specificity of 97.4% for the PCR-RFLP test when using ultrasonography as the reference.

Table 4 Number of cats included for *PKD1* genotyping by PCR-RFLP and/or ultrasonographic examination.

Ultrasonography	<i>PKD1</i> genotyping		Total
	<i>PKD1</i> mutant	Wild-type	
No examination	7 (14.0%)	43 (86%)	50 (100%)
Examination	8 (17.0%)	39 (82.0%)	47 (100%)

Table 5 Correlation between *PKD1* genotype and the PKD phenotype on ultrasonography.

<i>PKD1</i> gene exon 29 genotyping	PKD phenotype on ultrasonography	
	Positive	Negative
Positive	8 (88.9%)	1 (2.6%)
Negative	1 (11.1%)	37 (97.4%)

Table 6 Analysis of risk factors associated with the PKD phenotype on 47 ultrasonographically examined cats.

Factor	Comparison	P-value	Odds Ratio	95% CI
<i>PKD1</i> Gene	Positive / Negative	< 0.001	296.0	16.69 – 5247.91
Breed	BSH / Non-Persian	< 0.001	Undefined	
Age	≥ 3 years / < 3 years	0.298	2.22	0.48 – 10.21
Sex	Male / Female	0.054	4.81	0.88 – 26.29

*The OR for breed could not be determined as there were no positive cases in the Non-Persian group. BSH = British shorthair.

Discussion

In this study, although absolute prevalence cannot be calculated without the denominator for each breed, the detection of carriers in all three groups emphasizes the diffusion of the Persian-derived *PKD1* allele into non-Persian lineages. The overall mutant allele frequency in this mixed cohort was 0.08 (8 mutant alleles out of 100), which is lower than that reported for Persians but exceeds estimates for the general cat population. The unexpectedly high proportion of carriers among the Ragdolls examined may reflect founder effects or undocumented outcrossing to affected lines, while the presence of positives in Maine Coons and British Shorthairs highlights the necessity of routine molecular testing even in breeds traditionally perceived as low risk.

Technical performance of the assay was exemplary: fragment boundaries were sharp, digestion was complete in all heterozygotes, and no spurious bands were observed, attesting to the assay's specificity and suitability for high-throughput cattery or shelter screening. Compared with sequencing or probe-based qPCR platforms, PCR RFLP offers a cost-effective alternative for laboratories with limited resources while still providing unambiguous genotype resolution.

It is noteworthy that one cat with sonographically-confirmed PKD lacked the common C > A mutation. This finding is consistent with previous reports and suggests that feline PKD may involve genetic heterogeneity, with other mutations potentially responsible for the disease (Lee *et al.*, 2010; Guerra *et*

Risk analysis of factors associated with the PKD phenotype on 47 ultrasonographically examined cats: Subsequent analysis identified the *PKD1* gene status ($P < 0.001$) and breed ($P < 0.001$), as statistically significant risk factors for the ultrasonographic detection of PKD (Table 6). The odds of detecting PKD in cats carrying the mutation were exceptionally high (OR = 296.0). No significant association was found for age or sex ($P > 0.05$).

al., 2015; Shitamori *et al.*, 2023). Consequently, a negative result from a targeted genetic test for the exon 29 mutation does not entirely exclude a diagnosis of PKD, and other causes for renal cysts, such as simple cysts or chronic renal failure, should be considered as differential diagnoses (Lee *et al.*, 2010). While some literature characterizes feline PKD as a typically bilateral disease (Sato *et al.*, 2019), our findings indicate a predominance of unilateral cysts (6/9 cases). This suggests that asymmetric expression is a common presentation, a possibility also reported in literature which describe PKD as having either unilateral or bilateral renal cyst formation (Schirrer *et al.*, 2021). This variability in phenotypic expression further complicates diagnosis based on imaging alone.

In the present study, PCR-RFLP results were highly consistent with cyst formation detected by ultrasonography. However, some inconsistencies were noted. One cat with renal cysts detected by ultrasonography was negative by genetic testing for the *PKD1* mutation, which was also observed in other studies where 3/14 affected cats (Lee *et al.*, 2010) and 33/159 affected cats (Sato *et al.*, 2019) were ultrasonographically positive but genetically negative for the specific mutation. This finding suggests that while the tested mutation is the primary cause, the possibility that another mutation exists at an unknown location cannot be excluded. In contrast, four cats diagnosed as having no cysts by ultrasonography were positive for the *PKD1* mutation, similar to 3/150 "false positive" cats reported previously (Sato *et al.*, 2019). It is difficult to investigate renal cysts in very young cats,

and it is possible that these cats were young carriers in whom cysts had not yet developed to a detectable size (Schirrer, 2021). These findings suggest that while there is a strong correlation, the results of ultrasonography can depend on the age of the cat, and a combined diagnostic approach is recommended.

The risk-analysis results confirmed that the *PKD1* c.10063C>A mutation is the main cause of the disease, as shown by the exceptionally high odds ratio. The wide 95% confidence interval (16.69 – 5247.91) is a statistical result of having only one conflicting case in our data, where a British shorthair cat tested negative for the mutation but had cysts on ultrasound. Furthermore, the significant association with the British Shorthair breed highlights its predisposition, which likely reflects the introduction of the mutation through previous outcrossing with Persian cats (Kurushima et al., 2013). Surprisingly, in this study, age did not show a statistically significant association with the diagnosis of PKD. This differs somewhat from the literature, which generally considers PKD to be progressive over time. This lack of statistical significance could be due to the specific age distribution within this study's sample size or the limited number of positive cases, which can make it more difficult to detect differences between age groups. On the other hand, the lack of association with sex is consistent with a dominant inheritance pattern and previous reports, which found no significant difference in mutation rate between male and female cats (Guerra et al., 2019; Sato et al., 2019). From a clinical and breeding perspective, identification of heterozygous *PKD1* carriers is critical because the mutation is dominant with full penetrance, leading to progressive renal cyst formation and eventual renal failure. Breeding strategies should therefore exclude carriers from mating programs or, at a minimum, avoid carrier-to-carrier pairings to prevent the production of lethal homozygous embryos. Moreover, integrating genetic testing with ultrasonographic screening is advisable, particularly in breeds such as Maine Coon, where cystic kidney disease can arise from other genetic etiologies.

The study's main limitations are its modest, small sample size and the lack of phenotypic follow-up data, both of which provide prevalence estimates and genotype-phenotype correlations. Future work should expand cohort size, document breed-specific denominators, and incorporate longitudinal clinical assessments to refine prognostic counselling and monitor potential emergence of additional *PKD1* variants or genetic modifiers. Nonetheless, the present findings demonstrate that the *PKD1* mutation remains a significant genetic health concern beyond Persian-related breeds and that PCR-RFLP is an effective tool for surveillance and eradication of feline PKD.

In conclusion, this study demonstrates that the canonical *PKD1* c.10063C>A mutation is prevalent among British Shorthair, Maine Coon, and Ragdoll cats in Ho Chi Minh City, with an overall mutant allele frequency of 8 %. The strong genotype-phenotype concordance (OR = 296.0, $P < 0.001$) and high sensitivity/specificity of the PCR-RFLP assay validate its utility for large-scale screening. Routine genetic testing, combined with ultrasonography, should be

adopted in Vietnamese catteries to guide breeding decisions, prevent lethal homozygous conceptions, and ultimately reduce the burden of ADPKD on feline welfare and the blooming companion-animal industry.

Conflicts of interest: There were no conflicts of interest that may have biased the work reported in this study.

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References

- Bilgen N, Bişkin Türkmen M, Çınar Kul B, Isparta S, Şen Y, Akkurt MY, Çıldır Ö and Bars Z 2020. Prevalence of *PKD1* gene mutation in cats in Turkey and pathogenesis of feline polycystic kidney disease. *J Vet Diagn Invest.* 32: 549-555.
- Enomoto T, Kobayashi S and Ishiguro N 2025. Life table analysis of feline polycystic kidney disease in Japan. *J Vet Med Sci.* 87: 791-797.
- Gendron K, Owczarek-Lipska M, Lang J and Leeb T 2013. Maine Coon renal screening: Ultrasonographical characterisation and preliminary genetic analysis for common genes in cats with renal cysts. *J Feline Med Surg.* 15: 1079-1085.
- Grzeczka A, Graczyk S, Pasławski R and Pasławska U 2024. Genetic basis of hypertrophic cardiomyopathy in cats. *Curr Issues Mol Biol.* 46: 8752-8766.
- Guerra JM, Daniel AGT, Cardoso NC, Grandi F, Queiroga F and Cogliati B 2015. Congenital hepatic fibrosis and polycystic kidney disease not linked to C>A mutation in exon 29 of *PKD1* in a Persian cat. *JFMS Open Rep.* 1: 2055116915619191.
- Guerra JM, Freitas MF, Daniel AG, Pellegrino A, Cardoso NC, de Castro I, Onuchic LF and Cogliati B 2019. Age-based ultrasonographic criteria for diagnosis of autosomal dominant polycystic kidney disease in Persian cats. *J Feline Med Surg.* 21: 156-164.
- Indochina Research 2025. "Vietnam's Pet Ownership Trends in 2025" [Online]. Available: <https://indochina-research.com/vietnams-pet-ownership-trends-in-2025/>. Accessed September 25, 2025.
- Jaturanratsamee K, Jiwaganont P, Sukumolanan P and Petchdee S 2023. *PKD1* gene mutation and ultrasonographic characterization in cats with renal cysts. *F1000Res.* 12: 760.
- Kehl A, Mueller E and Giger U 2019. CMAH genotyping survey for blood types A, B and C (AB) in purpose-bred cats. *Anim Genet.* 50: 303-306.
- Kurushima JD, Lipinski MJ, Gandolfi B, Froenicke L, Grahn JC, Grahn RA and Lyons LA 2013. Variation of cats under domestication: genetic assignment of

- domestic cats to breeds and worldwide random-bred populations. *Anim Genet.* 44: 311-324.
- Lee YJ, Chen HY, Hsu WL, Ou CM and Wong ML 2010. Diagnosis of feline polycystic kidney disease by a combination of ultrasonographic examination and *PKD1* gene analysis. *Vet Rec.* 167: 614-618.
- Lyons LA, Biller DS, Erdman CA, Lipinski MJ, Young AE, Roe BA, Qin B and Grahn RA 2004. Feline polycystic kidney disease mutation identified in *PKD1*. *J Am Soc Nephrol.* 15: 2548-2555.
- Michel-Regalado NG, Ayala-Valdovinos MA, Galindo-García J, Duifhuis-Rivera T and Virgen-Méndez A 2022. Prevalence of polycystic kidney disease in Persian and Persian-related cats in western Mexico. *J Feline Med Surg.* 24: 1305-1308.
- Nicholas FW, Tammen I and Sydney Informatics Hub 2025. "OMIA:000807-9685: Polycystic kidney disease in *Felis catus* (domestic cat)" [Online]. Available: <https://omia.org/OMIA000807/9685/>. Accessed September 25, 2025.
- Nürnberg D, Wagner L, Müller SF, Leiting S, Leidolf R, Alber J, Hamann M and Geyer J 2021. Detection of the *ABCB1* 1930_1931del TC mutation in two suspected ivermectin-sensitive cats and their relatives by a novel TaqMan Allelic Discrimination Assay. *Front Vet Sci.* 8: 808392.
- Paepe D, Bavegems V, Combes A, Saunders JH and Daminet S 2013. Prospective evaluation of healthy Ragdoll cats for chronic kidney disease by routine laboratory parameters and ultrasonography. *J Feline Med Surg.* 15: 849-857.
- Petfair Vietnam 2025. "Petfair Vietnam & Future growth trends in 2024-2029" [Online]. Available: <https://petfair-vietnam.com/petfair-vietnam-future-growth-trends-in-2024-2029-2/>. Accessed September 25, 2025.
- Sato R, Uchida N, Kawana Y, Tozuka M, Kobayashi S, Hanyu N, Konno Y, Iguchi A, Yamasaki Y, Kuramochi K and Yamasaki M 2019. Epidemiological evaluation of cats associated with feline polycystic kidney disease caused by the feline *PKD1* genetic mutation in Japan. *J Vet Med Sci.* 81: 1006-1011.
- Schirrer L, Marín-García PJ and Llobat L 2021. Feline polycystic kidney disease: An update. *Vet Sci.* 8: 269.
- Shitamori F, Nonogaki A, Motegi T, Matsumoto Y, Sakamoto M, Tanizawa Y, Nakamura Y, Yonezawa T, Momoi Y and Maeda S 2023. Large-scale epidemiological study on feline autosomal dominant polycystic kidney disease and identification of novel *PKD1* gene variants. *J Feline Med Surg.* 25: 1098612x231185393.