The Journal of Veterinary Medical **Science**

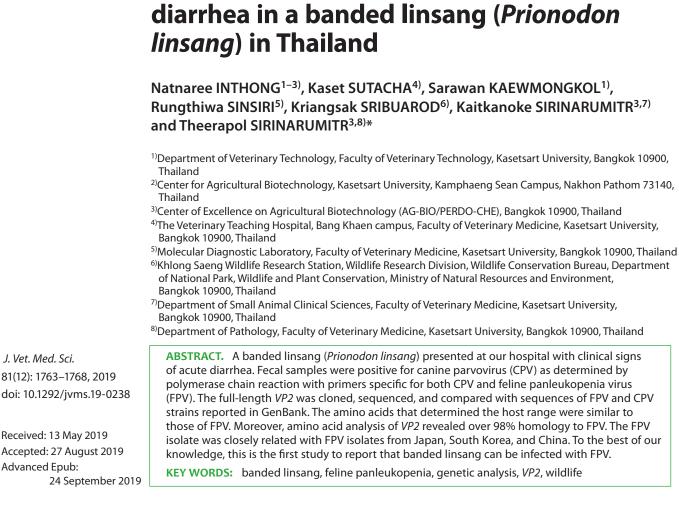


J. Vet. Med. Sci.

Advanced Epub:

Wildlife Science

NOTE



Feline panleukopenia virus as the cause of

Feline panleukopenia virus (FPV) is a small, nonenveloped single-stranded DNA virus that usually infects domestic cats and other Felidae, such as those in the families Mustelidae, Procyonidae, and Viverridae, which include raccoons and minks. FPV is highly contagious and is associated with a high mortality and morbidity in young animals. FPV usually causes acute gastroenteritis and leukopenia [4, 17, 18]. The virus is very closely related to canine parvovirus type 2 (CPV-2), with a genomic homology of greater than 98%. These viruses are grouped with other viruses, including mink enteritis virus, raccoon parvovirus (RPV), raccoon dog parvovirus (RDPV), and blue fox parvovirus (BFPV) [16]. Certain amino acids of the VP2 protein of the parvovirus are very important for determining the host range differences between FPV and CPV, including amino acid positions 80 (Lys to Arg), 93 (Lys to Asn), 103 (Val to Ala), 232 (Val to Ile), 323 (Asp to Asn), 564 (Asn to Ser), and 568 (Ala to Gly) (Table 1) [3, 9, 13, 14, 16, 17, 19].

There have been several reports of FPV infection in wild animals, including an Eurasian lynx (Lynx lynx) and European wildcat (Felis silvestris) [20], lions (Panthera leo) [6, 7], a tiger (Panthera tigris) [7] and a monkey [21]. There have been two reports of FPV infection in the Asian palm civet, a member of the family Viverridae [6, 10].

A banded linsang (Prionodon linsang) presented at the Veterinary Teaching Hospital, Kasetsart University, Bangkok, Thailand, with clinical signs of acute diarrhea. We wanted to determine whether the banded linsang was infected with parvovirus and to determine whether this parvovirus was CPV or FPV by comparing the complete amino acid sequence of the VP2 gene of the parvovirus in this case with those of other FPV and CPV strains reported in GenBank.

A fecal sample tested positive for CPV with the screening test kit (Vet-smart Canine CPV/CCV Antigen Duo Test, Pacific Biotech Co., Ltd., Bangkok, Thailand). To confirm the screening test, a multiplex polymerase chain reaction (M-PCR) was

*Correspondence to: Sirinarumitr, T.: fvettps@yahoo.com

©2019 The Japanese Society of Veterinary Science



This is an open-access article distributed under the terms of the Creative Commons Attribution Non-Commercial No Derivatives (by-nc-nd) License. (CC-BY-NC-ND 4.0: https://creativecommons.org/licenses/by-nc-nd/4.0/)

Amino acid position (VP2)	Comparison	Function	References
80	FPV and CPV	Antigenicity and feline host range	[2, 13, 14, 16]
87	CPV-2 and CPV-2a/2b	Antigenicity	[13, 14, 16]
93	FPV and CPV	Antigenicity and feline host range	[2, 7, 13, 14, 16]
103	FPV and CPV	Viability in the presence of changes of residues 93 and 323	[2, 13, 14, 16]
232	FPV and CPV	Antigenicity and feline host range	[16]
300	CPV-2 and CPV-2a/2b	Antigenicity	[10, 11, 13, 14]
305	CPV-2 and CPV-2a/2b	Antigenicity	[10, 11, 13, 14]
323	FPV and CPV	Antigenicity and canine host range	[2, 7, 13, 14]
426	CPV-2 and CPV-2a/2b	Antigenicity	[11, 14, 16]
564	FPV and CPV	Feline host range	[2, 13, 14, 16]
568	FPV and CPV	Feline host range	[2, 13, 14, 16]

Table 1. Important functions of amino acids at different positions in the VP2 gene of parvoviruses

FPV, Feline panleukopenia virus; CPV, canine parvovirus; CPV-2, canine parvovirus type 2; CPV-2a/2b, canine parvovirus type 2a/2b.

Name of set primer	Sequence of primer (5'-3')	PCR product (bp)	References
F 2a/2b R 2a/2b	GAA GAG TGG TTG TAA ATA ATT CCTATATAACCAAAGTTAGTAC	681	[12]
Fp Rp	TATGGTCCTTTAACTGCATTAAA TTAATATAATTTTCTAGGTGCTAG	404	-
Fw Rw	ATGAGTGATGGAGCAGTTCA TTAATATAATTT TCTAGGTGCTAGTTG	1,755	-

Table 2. Primers used in this study

performed using two set of primers (Table 2) for the detection of CPV-2 (Fp and Rp) and CPV-2a/2b (F2a/2b and R2a/2b) [15]. Briefly, the PCR mixture (100 μ l) was composed of 10 μ l of 10 × buffer (20 mM Tris-HCl (pH 8.4), 50 mM KCl₂), 2 μ l of 10 mM dNTPs, 5 μ l of 50 mM MgCl₂, 1 μ l of 100 pmol of each of the forward and reverse primers, 0.5 μ l of 5 units/ μ l of Taq DNA polymerase (Invitrogen, Carlsbad, CA, U.S.A.), 10 μ l of DNA template, and distilled water to make the total volume 100 μ l. After an initial denaturing at 94°C for 7 min, the amplification was performed using 35 cycles at 94°C for 1 min, annealing at 55°C for 90 sec, extension at 72°C for 90 sec, and a final extension at 72°C for 5 min. The M-PCR products showed a single band of approximately 400 bp in size. This result showed that the banded linsang might be infected with CPV-2.

To determine whether this banded linsang was infected with CPV or FPV, a set of primers was designed for the amplification of the full-length *VP2* genes of both FPV and CPV (Fw and Rw) (Table 2). After an initial denaturing at 94°C for 5 min, the amplification was performed using 35 cycles at 94°C for 40 sec, annealing at 50°C for 40 sec, extension at 72°C for 90 sec, and a final extension at 72°C for 10 min. The PCR products were expectedly 1,755 base pairs in size. The PCR products were purified using an UltraClean®15DNA purification kit (MO BIO Laboratories, Inc., Carlsbad, CA, U.S.A.) and cloned into plasmid pGEM-T easy (Promega Corporation, Madison, WI, U.S.A.). The sequence of the cloned full-length *VP2* was determined at First BASE Laboratories Sdn Bhd, Selangor, Malaysia.

The nucleotide sequences of the full-length *VP2* were translated, and multiple alignments of the amino acid sequences were identified using the Bioedit biological sequence alignment editor computer package (version 7.1.3; Ibis Biosciences, Carlsbad, CA, U.S.A.). The amino acid sequence of the cloned full-length *VP2* in this study showed more than 98% homology with the *VP2* gene from FPV. The amino acids at positions 80, 93, 103, 232, 323, 564, and 568 were similar to FPVs (Fig. 1).

For performing phylogenetic analysis, the amino acid sequence of the full-length *VP2* in this study was compared with 39 reference FPV and CPV strains available in the GenBank database (Table 3). The amino acid phylogenetic analysis was created using MEGA (version 6.0; The Bio Design Institute, Tempe, AZ, U.S.A.), and a phylogenetic tree was constructed using the neighbor-joining method and by running 1,000 replicates in the bootstrap to test the reliability of the phylogenetic tree for the *VP2* region. The phylogenetic analysis of the full-length *VP2* amino acid sequence was closely related to FPV from cats in Japan (AB000056) and South Korea (HQ184198), mink enteritis virus (KJ186148), and FPV isolated from a tiger (FJ405225) (Fig. 2). Based on these results, the banded linsang in the current study was infected with FPV.

In this study, the fecal sample of the banded linsang was found to be positive for CPV by both screening and PCR analysis. The amino acids of this cloned *VP2* at positions 80, 93, 103, 232, 323, 564, and 568 were similar to FPV but not CPV. These results indicated that the banded linsang in this study was infected with FPV. Currently, it is unclear whether the banded linsang is also susceptible to CPV. It is possible that the banded linsang may be infected with CPV, since this virus can infect both canine and feline cells with similar efficiency by binding to both canine and feline transferrin receptors (TfR) [2]. The *TFCR* gene, which encodes TfR, of carnivore species has up to a 10% difference in DNA sequence, with the changes distributed throughout

	10	20	30 40	50	60 70	80 90 100
DQ099431 FPV Cat China	MSDGAVQPDGGQPAVRN	IERATGSGNGSG	GGGGGGSGGVGI		VEITANSSRLVHLNMP	ESENYKRVVVNNMDKTSVKGNMALDD
FJ231389 FPV Monkey China FJ405225 FPV Tiger China						
EU145593 FPV Asian Palm Civet KJ813893 FPV Bobcat USA	т					
KJ813895 FPV Raccoon USA FPV Prionodon linsang Thailand						
M38245 CPV2 VP2 FJ435343 CPV 2a China	. G					
KP715668 CPV2a Thailand KF482468 CPV 2b Cat China						R L A . N
KP715695 CPV2b Thailand AY869724 CPV2b Taiwan						
EU009205 CPV2b Dog South kore FJ005236 CPV2c Dog USA	• • • • • • • • • • • • • • • • • • • •					
FJ222821 CPV2c Dog Italy						
	110	120	130 140	0 150 	160 170 .	180 190 200
DQ099431 FPV Cat China FJ231389 FPV Monkey China	THVQIVTPWSLVDANAW	GVWFNPGDWQL				VALDSNNTMPFTPAAMRSETLGFYPW
FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet						
KJ813893 FPV Bobcat USA KJ813895 FPV Raccoon USA						
FPV Prionodon linsang Thailand						
M38245 CPV2 VP2 FJ435343 CPV 2a China						
KP715668 CPV2a Thailand KF482468 CPV 2b Cat China						G.T
KP715695 CPV2b Thailand AY869724 CPV2b Taiwan	A					
EU009205 CPV2b Dog South kore FJ005236 CPV2c Dog USA	a A					
FJ222821 CPV2c Dog Italy	A					
	210 	220				280 290 300
DQ099431 FPV Cat China FJ231389 FPV Monkey China	KPTIPTPWRYYFQWDRT	LIPSHTGTSGT	PTNVYHGTDPDD	VQFYTIENSVPVHLLRTG	DEFATGTFFFDCKPCR	LTHTWQTNRALGLPPFLNSLPQSEGA
FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet						
KJ813893 FPV Bobcat USA KJ813895 FPV Raccoon USA						
FPV Prionodon linsang Thailand M38245 CPV2 VP2						ŝ
FJ435343 CPV 2a China KP715668 CPV2a Thailand						
KF482468 CPV 2b Cat China KP715695 CPV2b Thailand					· · · · · · · · · · · · · · · · · · ·	
AY869724 CPV2b Taiwan EU009205 CPV2b Dog South kore						
FJ005236 CPV2c Dog USA FJ222821 CPV2c Dog Italy						
	310	320	330 340	350	360 370	380 390 400
DQ099431 FPV Cat China	310 TNFGDIGVQQDKRRGVT	320 QMGNTDYITEA				380 390 400
FJ231389 FPV Monkey China FJ405225 FPV Tiger China	310 TNFGDIGVQQDKRRGVT					380 390 400
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813893 FPV Bobcat USA	310 TNFGDIGVQQDKRRGVT		IMRPAEVGYSA	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG	380 390 400
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813893 FPV Bobcat USA KJ813895 FPV Raccoon USA FPV Prionodon linsang Thailand	310 		TIMRPAEVGYSA	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG	380 390 400
FJ331389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813893 FPV Bobcat USA KJ813895 FPV Raccon USA FPV Prionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China	310 TNFGD I GVQODKRRGVT		TIMRPAEVGYSA	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG	380 290 400 DPRYAFGRQHGQKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA FPV Priondon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV2 a China KP715668 CPV2a Thailand KF482486 CPV2 bC at China	310 TNFGD I GVQODKRRGVT VQODKRRGVT VQODKRRGVT		TIMRPAEVGYSA	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG	380 290 400 DPRYAFGRQHGQKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Raccoon USA FPV Prionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP715668 CPV2a Thailand KF482468 CPV2 Ab Cat China KP15695 CPV2b Thailand AY680724 CPV2b Tailwan	Y R Y Y Y Y Y		TIMRPAEVGYSA	PYYS FEASTQG PF KTP I A	AGRGGAQTDENQAADG	380 290 400 DPRYAFGRQHGQKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Shain Palm Civet KJ813895 FPV Bobact USA KJ813895 FPV Raccoon USA FPV Prionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP15668 CPV2a Thailand KF482468 CPV2 A China KP15695 CPV2b Thailand AY680724 CPV2b Thailand AY680724 CPV2b Taivan EU009205 CPV2b Dog South kore FJ005236 CPV2c Dog USA	Y R Y Y Y Y Y		TIMRPAEVGYSA	PYYS FEASTQG PF KTP I A	AGRGGAQTDENQAADG	380 290 400 DPRYAFGRQHGQKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813893 FPV Bohcet USA KJ813895 FPV Raccoon USA FPV Prionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP115686 CPV2 Thailand KF482468 CPV2 Thailand KP1689724 CPV2b Thailand AY869724 CPV2b Thailand	Y R Y Y Y Y Y		TIMRPAEVGYSA	PYYS FEASTQG PF KTP I A	AGRGGAQTDENQAADG	380 290 400 DPRYAFGRQHGQKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bocat USA FPV Prionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP715668 CPV2a Thailand KF482486 CPV2 A China KP15695 CPV2b Thailand AY869724 CPV2b Taivan EU009205 CPV2b Dog South kore FJ005236 CPV2c Dog USA FJ222821 CPV2c Dog Italy	Y R Y Y Y Y Y		TIMRPAEVGYSA	PYYS FEASTQG PF KTP I A	AGRGGAQTDENQAADG	380 290 400 DPRYAFGRQHGQKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA FPV Priondon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP715668 CPV2a Thailand KF482486 CPV2 A China KP15695 CPV2b Thailand AY869724 CPV2b Taivan EU009205 CPV2b Dog South kore FJ005236 CPV2c Dog USA FJ222821 CPV2c Dog Italy DQ099431 FPV Cat China FJ231389 FPV Monkey China	Y R Y Y Y Y Y		TIMRPAEVGYSA	PYYS FEASTQG PF KTP I A	AGRGGAQTDENQAADG	380 290 400 DPRYAFGRQHGQKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ812805 CPV2 PD2 FJ435343 CPV2 AD2 KJ812805 CPV2 DC KJ812805 CPV2 DC KJ812805 FJ202821 CPV2 CD KJ812805 FJ202821 CPV2 CD KJ812805 FJ202821 CPV2 CD KJ812805 FV Monkey China FJ405225 FPV Monkey China FJ405225 FPV Monkey China FJ405225 FPV Monkey China FJ405225 FPV Kaiper China	Y R Y Y Y Y Y		TIMRPAEVGYSA	PYYS FEASTQG PF KTP I A	AGRGGAQTDENQAADG	380 290 400 DPRYAFGRQHGQKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ812895 CPV2 PP2 FJ435343 CPV2 PP2 TJ45543 CPV2 PP2 FJ435434 CPV2 DC At China KP715695 CPV25 Dag South kore FJ005236 FPV Toger Othan FJ231389 FPV Monkey China FJ405225 FPV Tiger China FJ405225 FPV Tager China FJ405225 FPV Tager China FJ45525 FPV Asian Palm Civet KJ813893 FPV Bobcat USA	Y R Y Y Y Y Y		TIMRPAEVGYSA	PYYS FEASTQG PF KTP I A	AGRGGAQTDENQAADG	380 290 400 DPRYAFGRQHGQKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Siger USA KJ813895 FPV Bobed USA KJ813895 FPV Bobed USA KJ813895 FPV Raccoon USA FPV Prionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP15695 CPV25 Drail KP15695 CPV25 Drail KP15695 CPV25 Drail FJ425285 CPV25 Drail KP15695 CPV25 Drail KP15695 CPV25 Drail KP15695 CPV25 Drail KP15695 CPV25 Drail KP15695 CPV25 Drail KP15695 CPV25 Drail KP156555 FPV Tager China FJ231389 FPV Monkey China FJ4513893 FPV Monkey China FJ455225 FPV Tiger China FJ455225 FPV Tiger China FJ455255 FPV Tager China FJ455255 FPV Tager China FJ455255 FPV Tager China FPV Prionodon USA FPV Prionodon USA FPV Prionodon USA	Y R Y Y Y Y Y Y Y I AHQD TGR Y PEGDWI ON	CMGNTD V I TEA N.N.TEA N.N.N. N.N.N. N.N. N.N. N.N. N.N. N.N	1 MRPAEVGYSA 430 444 1 LPTDPI GGKT	PYYSFEASTQGPFKTPIA 	AGRGGAQTDENQAADG 460 470 NVPPVYPNGQIWDKEF	380 390 400 DPRYAFGROHGQKTTTTGETPERFTY N 400 400 500 DTDLKPRLHVNAPFVCQNNCPGQLFV
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ8245 CPV2 VP2 FJ435343 CPV2 AD KF482486 CPV2a Thailand KP715695 CPV2b Thailand KP715695 CPV2b Thailand KP715695 CPV2b Thailand KP715695 CPV2b Thailand KP715695 CPV2b Thailand KP715695 FPV Taccoon USA FJ222821 CPV2c Dog Stuth kore KJ813893 FPV Monkey China FJ405225 FPV Tiger China FJ405225 FPV Tager China KJ813893 FPV Monkey China FJ405225 FPV Tager China KJ813893 FPV Monkey China FPV Prionodon USA FPV Prionodon USA FPV Prionodon USA FPV Prionodon Chinang Thailand M38245 CPV2 VP2	Y . R Y . Y Y . Y Y . Y Y . Y I A HQD T GR Y P E G D W I O N	CMGNTD V I TEA N.N.TEA N.N.N. N.N.N. N.N. N.N. N.N. N.N. N.N	1 MRPAEVGYSA 430 441 1 LLPTDP1 GGKT	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG 460 470 NVPPVYPNGQIWDKEF	380 390 400 DPRYAFGROHGQKTTTTGETPERFTY N
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ8245 CPV2 VP2 FJ435343 CPV 2a China KP715695 CPV25 Dai KJ82468 CPV2 China KP715695 CPV25 Dai KJ82468 CPV2 China FJ205205 CPV25 Dai SOUth kore FJ205205 CPV25 Dai SOUTh KAN KJ813895 FPV Monkey China FJ405225 FPV Tiger China FJ405225 FPV Tiger China FJ405225 FPV Monkey China FJ405225 FPV Monkey China FJ431389 FPV Monkey China FJ405225 FPV Tiger China FPV Prionodon Iinsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP15695 CPV25 VP3	Y . R Y	CMGNTD V I TEA N.N.TEA N.N.N. N.N.N. N.N. N.N. N.N. N.N. N. N.	1 MRPAEVGYSA 430 441 1 LLPTDP1 GGKT	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG 460 470 NVPPVYPNGQIWDKEF	380 390 400 DPRVAFGROHGOKTTTTGETPERFTY N 400 400 500 DTDLKPRLHVNAPFVCQNNCPGQLFV
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ8245 CPV2 VP2 TJ45543 CPV2 DC Thailand KP715695 CPV25 Dail KJ82456 CPV25 Dail KJ82456 CPV25 Dail KJ8256 CPV25 Dail KJ8256 CPV25 Dail KJ8256 CPV25 Dail KJ8257 FPV Tail KJ813893 FPV Monkey China FJ231389 FPV Monkey China FJ231387 FPV Bobcat USA FPV Prionedon	Y . R Y	GMGNTD V I TEA N. N D. D. D. D. D	I MRPAEVGYSA	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG 460 470 NVPPVYPNGQIWDKEF	380 390 400 DPRYAFGROHGOKTTTTGETPERFTY N 400 400 500 DTDLKPRLHVNAPFVCONNCPGOLFV
FJ231389 FPV Monkey China FJ40523 FPV Tige China EU145593 FPV Tige China EU145593 FPV Sobact USA KJ813895 FPV Bobact USA KJ813895 FPV Raccon USA FPV Pionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV2 a China KF482486 CPV2 a China KF482486 CPV2 b Cat China KF482486 CPV2 b Cat China KP15695 CPV2b Dog South kore FJ005236 CPV2c Dog USA FJ222821 CPV2c Dog USA FJ222821 CPV2c Dog Italy DQ099431 FPV Cat China FJ231389 FPV Monkey China FJ405235 FPV Tige China EU145593 FPV Sabar USA KJ813895 FPV Raccon USA KJ813895 FPV Raccon USA KJ813895 FPV Raccon USA KJ813895 FPV Raccon USA KJ813895 CPV2 DC2 FJ435343 CPV2 A China KP175698 CPV2 Thailand KF482486 CPV2 CP1a KF482486 CPV2 CP1a KF482486 CPV2 CP2 KF482468 CPV2 CP1a KF482486 CPV2 CP1a KF482486 CPV2 CP1a KF482486 CPV2 CP1a KF482486 CPV2 CP2 KF482468 CPV2 CP1a KF482486 CPV2 CP1a KF482486 CPV2 CP1a KF482486 CPV2 CP12 KF482486 CPV2 CP12 KF48246 CPV2 CP12 KF48246 CPV2 CP2 KF48246 CPV2 CP12 KF48246 CPV2 CPV2 CP12 KF48246 CPV2 CP12 KF48246 CPV2 CPV2 CP12 KF48246 CPV2 CP12 KF4847 KF48246 CPV2 CP12 KF48246 CPV2 CP12 KF4847 KF48246 CPV2 CP	Y R Y A Y A Y A A A A A A A A A A A A A A A	CMGNTD Y I TEA N. N. N. N. N. N. N. N. N. N. N. N. N.	1 MR PAE V G Y SA	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG	380 390 400 DPRYAFGROHGOKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405235 FPV Tiger China EU145593 FPV Siger China EU145593 FPV Shaer USA KJ813995 FPV Bobcet USA KJ813995 FPV Bobcet USA FPV Priondon linsang Thailand M38245 CPV2 VP2 FJ435543 CPV2 A China KF482468 CPV2 A Thailand XF882764 CPV2 Dog South kore FJ005236 CPV2 Dog USA FJ222821 CPV2c Dog USA FJ222821 CPV2c Dog USA FJ4252821 CPV2c Dog Italy DQ099431 FPV Cat China FJ231389 FPV Shotet USA KJ813995 FPV Flager China EU145593 FPV Salan Palm Civet KJ813895 FPV Raccon USA FPV Priondon linsang Thailand M38245 CPV2 VP2 FJ43533 CPV2 A China KP15685 CPV2 DP2 FJ435343 CPV2 A China KP15685 CPV2 DP2 FJ435343 CPV2 A China KP15685 CPV2 DP3 FJ43543 CPV2 A China KP15685 CPV2 DP3 FJ43543 CPV2 A China KP15685 CPV2 DP3 FJ43543 CPV2 A China KP15695 CPV2 Dp3 South kore FJ005236 CPV2 Dp3 South kore	410 1 A HQD T GR Y P E GDW I QN	GMGNTD V I TEA N N N N N N N N N N N N N	1 MRPAEVGYSA 430 441 1 1 1 1 L L PT DP I GGKT 1 L PT DP I GGKT A 500 644	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG	380 390 400 DPRYAFGROHGOKTTTTGETPERFTY
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Siger USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ8245 CPV2 VP2 FJ435343 CPV 2a China KP715695 CPV2b Thailand KP715695 CPV2b Thailand AY869724 CPV2b Taivan EU009205 CPV2b Dog South kore FJ2232821 CPV2c Dog Italy DQ099431 FPV Cat China FJ231389 FPV Monkey China FJ435255 FPV Tiger China FJ435255 FPV Tiger China FJ435255 FPV Tiger China FJ435333 CPV 2a China KP15695 FPV Br2 Coop USA FPV Prionodon Iinsang Thailand KF482468 CPV2 Dr2 China KP15695 CPV2b Thailand KF482468 CPV2 CP2 China KP15695 CPV2b Thailand KF482468 CPV2 CP2 China KP15695 CPV2b Thailand KF482468 CPV2b Cat China KP15695 CPV2b Thailand	Y . R Y . Y Y . Y Y . Y A . Y	GMGNTDVITEA N.N. N.N. N.N. N.N. N.N. INFNLPVTNDN INFNLPVTNDN D. D. D. D. D. D. D. D. D. D. D. D. D.	430 444 	PYYSFEASTQGPFKTPIA 6 460 6 1 460 7 1 7 1 7 1 7 1 7 1 7 1 7 1 7 1 7 1 7 1	AGRGGAQTDENQAADG 460 470 NVPPVYPNGQIWDKEF 560 570 FNYVPNIGAMKIVYE	380 390 400 D P R Y A F G R O H G Q K T T T T G E T P E R F T Y N 480 490 500 D T D L K P R L H Y N A P F V C Q N N C P G Q L F Y 580 A
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813995 FPV Bobcat USA KJ813995 FPV Bobcat USA KJ813995 FPV Bobcat USA KJ812895 CPV2 DP2 FJ435343 CPV 2a China KP715695 CPV25 Dailor KP15695 CPV25 Dailor KJ915695 FPV Tiger China FJ405225 FPV Tiger China FJ405225 FPV Tailor Disand Thailand KJ915695 FPV Saccon USA FPV Prionedon USA FPV Dailand KF482468 CPV 2b Cat China KF482468 CPV 2b Cat China FJ0252821 CPV2c Dog USA FJ222821 CPV2c Dog USA FJ2231389 FPV Monkey China FJ405225 FPV Tiger China	Y . R Y	GMGNTD V I TEA N. N D. D. D D. D. D Station J. V. V. V. V. S Station J. S.	1 MR PAEVGYSA	PYYSFEASTQGPFKTPIA 6 450 GINYTNIFNTYGPLTALN 9 550 ASHTWNPIQQMSINVDNG	AGRGGAQTDENQAADG	390 390 400 D P R VA F G R O H G O K T T T T G E T P E R F T Y N N 490 490 500 D T D L K P R L H V N A P F V C O N N C P G O L F V A K S O L A P R K L Y P
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Raccoon USA FPV Prionodon linsang Thailand KP15685 CPV22 PD2 TJ6585 CPV22 DD3 South kore FJ005236 CPV22 DD3 South kore FJ005236 CPV22 DD3 South kore FJ005236 CPV22 DD3 South kore FJ005236 CPV22 DD3 South kore FJ231389 FPV Monkey China FJ231389 FPV Monkey China FJ435331 SPV Sabotat USA FJ22821 CPV2C DD3 Ball KJ813893 FPV Bobcat USA FPV Prionodon linsang Thailand KF15695 CPV22 DD3 China KP15695 CPV22 DD3 China KP15695 CPV2 DD3 China KF15422821 CPV2 CD3 USA FJ222821 CPV2 CD3 USA FJ223389 FPV Monkey China FJ405225 FPV Tiger China FJ405225 FPV Tiger China FJ405225 FPV Tiger China FJ405257 FPV Tiger China FJ405537 FPV Sobcat USA	Y . R Y	GMGNTD V I TEA N. N N N N N N N N N N N N N N N N D	1 MRPAEVGYSA 430 444 1 ALLPTDPI GGKT 1 ALLPTDPI GGKT 530 544 1 KGKLVFKAKLR	PYYSFEASTQGPFKTPIA 6 450 GINYTNIFNTYGPLTALN 5 550 ASHTWNPIQQMSINVDNG	AGRGGAQTDENQAADG 460 470 1 1 1 NVPPVYPNGQ I WDKEF 560 570 FNYVPNN I GAMK I VYE S.	390 390 400 D PR VA F G R OH G OK TT TT G E T P E R F T Y N N 490 490 500 D T D L K P R L H V NA P F V C ON NC P G OL F V D T D L K P R L H V NA P F V C ON NC P G OL F V A K S OL A P R K L Y P
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ812895 CPV2 DP2 TJ45534 CPV2 DP2 TJ45543 CPV2 DP2 TJ45545 CPV2 DP2 TJ45555 CPV2 DP3 CPV2 DP3 FJ222821 CPV2 D03 SOUth kore FJ22389 FPV Monkey China FJ451389 FPV Monkey China FJ451389 FPV Monkey China FJ451389 FPV Monkey China FJ45525 FPV Tiger China FJ45525 FPV Tiger China FJ455353 FPV Monkey China FJ45535 FPV Asian Palm Civet KJ813893 FPV Bobcat USA FPV Prionedon USA FPV Prionedon USA FPV Prionedon USA FPV Prionedon USA FJ252821 CPV22 D03 South kore FJ005236 FPV Tiger China FJ405225 FPV Tiger China FJ405225 FPV Tiger Dina	Y	GMGNTD V I TEA N N N N N N N N N N N N N	1 MR PAEVGYSA	PYYSFEASTQGPFKTPIA 6 480 GINYTNIFNTYGPLTALN 5 550 ASHTWNPIQQMSINVDNG	AGRGGAQTDENQAADG 460 470 1 1 1 NVPPVYPNGQIWDKEF 560 570 FNYVPNIGAMKIVYE S.	390 390 400 D PR VA F G R OH G OK TT TT G E T PE R F T Y N N 490 490 500 D T D L K PR L H V NA PF V C ON NC P G OL F V D T D L K PR L H V NA PF V C ON NC P G OL F V A A A A A
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ813895 FPV Bobcat USA KJ812895 CPV2 DP2 TJ435343 CPV 2a China KP715695 CPV2b Thailand KP715695 CPV2b Thailand KP715695 CPV2b Thailand KP715695 CPV2b Thailand FJ405225 CPV2b Dog South kore FJ203139 FPV Monkey China FJ405225 FPV Tiger China FJ405225 FPV Tiger China FJ405225 FPV Toger China FJ405225 CPV2b Tog South kore FJ405235 CPV2b Tog South kore FJ405235 CPV2b Tog South kore FJ005236 CPV2b Dg South kore FJ005236 FPV Tiger China FJ405225 FPV Tiger China FJ405235 FPV Saian Palm Civet KJ813895 FPV Raccoon USA KJ813895 FPV Raccoon USA FPV Pionodon Inisang Thailand M38245 CPV2 P2	410 410 1 A HQD T GR Y P E G DW I ON 510 K V A P N L T N E Y D P D A S A N	GMGNTD V I TEA N. N N N N N N N N N N N N N N D	1 MRPAEVGYSA	PYYSFEASTQGPFKTPIA 6 450 G I NYTNIFNTYGPLTALN 5 550 ASHTWNPIQQMSINVDNG	AGRGGAQTDENQAADG 460 470 1 1 1 NVPPVYPNGQIWDKEF 560 570 FNYVPNIGAMKIVYE S.S.G.S.G.	390 390 400 D PR VA F G R O H G O K T T T T G E T P E R F T Y N N 490 490 500 D T D L K P R L H V N A P F V C O N N C P G O L F V A A A A S90 S90 S90 S90 S90 S90 S90 S90
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813995 FPV Raccoon USA FPV Prionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP715695 CPV2b Thailand KP715695 CPV2b Thailand AY869724 CPV2b Taivan EU009205 CPV2b Dog South kore FJ2232821 CPV2c Dog USA FJ222821 CPV2c Dog Italy DQ099431 FPV Cat China FJ435389 FPV Monkey China FJ435389 FPV Monkey China FJ435389 FPV Monkey China FJ435339 FPV Bobcat USA KJ813993 FPV Bobcat USA FPV Prionodon linsang Thailand M38245 CPV2 PV2 FJ435343 CPV2a China KP15695 CPV2b Taivan EU009205 CPV2b Dog South kore FJ005236 CPV2c Dog USA FJ222821 CPV2c Dog USA FJ222821 CPV2c Dog South KP15695 CPV2b Taivan EU009205 CPV2b Dog South kore FJ005236 CPV2c Dog USA FJ222821 CPV2c Dog Italy DQ099431 FPV Cat China KF145959 FPV Taiccon USA FJ2231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Saian Palm Civet KJ813895 FPV Raccon USA KJ813995 FPV Raccon USA	Y	GMGNTDY I TEA N	1 MR PAE VGYSA 430 444 1 4 1 1 L L PT DP I GGKT 1 L L PT DP I GGKT 4 4 530 544 1 4 1 1 KGKL V F KAKL R	PYYSFEASTQGPFKTPIA 9 460 GINYTNIFNTYGPLTALN 9 550 ASHTWNPIQQMSINVDNC	AGRGGAQTDENGAADG 460 470 NVPPVYPNGQIWDKEF 560 570 FNYVPNNIGAMKIVYE S. S. S. S. S. G. S. G. S. G. S. G.	390 390 400 DPRYAFGROHGQKTTTTGETPERFTY A90 400 500 A90 500 DTDLKPRLHVNAPFVCQNNCPGQLFV A90 A90 500 DTDLKPRLHVNAPFVCQNNCPGQLFV A S90 A00 A
FJ231389 FPV Monkey China FJ405225 FPV Tiger China EU145593 FPV Asian Palm Civet KJ813895 FPV Bobcat USA KJ813895 FPV Raccoon USA FPV Prionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP15695 CPV2b Thailand KP15695 CPV2b Thailand KF42488 CPV 2b Cat China KP15695 CPV2b Thailand KF42468 CPV2 Cat China KP15695 CPV2b Thailand KF42468 CPV2b Cat China KP15695 CPV2b Thailand KF42468 CPV2b Cat China KP15695 CPV2b Thailand KF42468 CPV2b Cat China KP15695 CPV2b Thailand KF42578 FPV Tiger China FJ405225 FPV Tiger China FJ405225 FPV Tiger China FJ405225 FPV Tiger China FJ405225 FPV Tiger China KJ415939 FPV Cat China KJ41593 FPV Cat China KJ41593 FPV Scat China KJ41593 FPV Scat China KJ41593 FPV Scat China KJ41593 FPV Scat China KJ41595 FPV Taccon USA KJ813995 FPV Raccon USA KJ813995 FPV Raccon USA KJ813995 FPV Thailand KP15695 CPV2b Thailand	Y	GMGNTDY I TEA N	430 444 	PYYSFEASTQGPFKTPIA 6 460 G INYTNIFNTYGPLTALN 5 550 ASHTWNPIQQMSINVDNC	AGRGGAQTDENGAADG	390 390 400 D PR VA F G R O H G O K T T T T G E T P E R F T Y N N 490 490 500 D T D L K P R L H V N A P F V C O N N C P G O L F V D T D L K P R L H V N A P F V C O N N C P G O L F V A S90 A A S90 A A A
FJ231389 FPV Monkey China FJ405235 FPV Tige China EU145593 FPV Siger USA KJ813995 FPV Roccon USA KJ813995 FPV Roccon USA FPV Prionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV2 A China KP15695 CPV2b Thailand KP15695 CPV2b Thailand KF42468 CPV2 A China KP15695 CPV2b Thailand KF42468 CPV2 A China KP15695 CPV2b Thailand KF42468 CPV2b Cat China KP15695 CPV2b Thailand KF42468 CPV2b Cat China KP15695 CPV2b Thailand KF42468 CPV2b Cat China KP15695 CPV2b Thailand KF42574 CPV2b Taiwan EU009205 CPV2b Dog South kore FJ005236 CPV2c Dog USA FJ222821 CPV2c Dog Italy DQ09431 FPV Cat China KJ435303 CPV2a China KJ435305 CPV2b Thailand KF482468 CPV2b Cat China KJ415593 FPV Aaccon USA KJ813995 FPV Raccon USA KJ813995 FPV Raccon USA KJ813995 FPV Raccon USA KJ813995 FPV Taiwan EU00205 CPV2b Dog South kore FJ005236 CPV2c DDg USA KJ813995 FPV Taiwan EU00205 CPV2b DDg South kore KP15665 CPV2b Thailand KP15665 CPV2b Thailand KP15655	410 I AHQD T GRY PEGDW I QN 1 AHQD T GRY PEGDW I QN 510 K V AP NLT NEYD PD A SAN	CMGNTDY I TEA N. N. N. N. N. N. N. N. N. N. N. N. N. N. N. N	1 MR PAE VG Y SA	PYYSFEASTQGPFKTPIA	AGRGGAQTDENQAADG	380 390 400 DPRYAFGRQHGQKTTTTGETPERFTY N N 480 400 500 DTDLKPRLHVNAPFVCQNNCPGQLFV 590
FJ231389 FPV Monkey China FJ405235 FPV Tige China EU145593 FPV Siger USA KJ813895 FPV Siger USA KJ813895 FPV Raccon USA FPV Pionodon linsang Thailand M38245 CPV2 VP2 FJ435343 CPV 2a China KP715665 CPV2b Thailand KF824868 CPV2b Cat China FJ205236 CPV2b Dog South kore FJ005236 CPV2b Dog South kore FJ005236 CPV2b Dog South kore FJ005235 CPV2b Thailand KP1715695 CPV2b Thailand KP1715695 CPV2b Thailand KP1715695 CPV2b Thailand KP1715695 CPV2b Thailand KP1715695 CPV2b Thailand KP1715695 CPV2b Thailand FJ005235 CPV2b Dog South kore EU145593 FPV Monkey China FJ005235 CPV2b Dog South kore EU145593 FPV Monkey China FJ231389 FPV SaiaP Thailand M38245 CPV2 VP2 FJ435333 CPV 2a China KPT15695 CPV2 VP2 FJ435333 CPV 2a China KP15695 CPV2 VP2 FJ435345 CPV2 VP2 FJ45555 CP2 FJ45555 CP2 FJ45 LP2 FJ45555 FJ45 LP2 FJ45555 CP2 FJ45 LP2	Y	GMGNTDY I TEA N	1 MR PAE VG YSA	PYYSFEASTQGPFKTPIA 6 460 G INYTNIFNTYGPLTALN 5 550 ASHTWNPIQQMSINVDNC	AGRGGAQTDENGAADG 460 470 NVPPVYPNGQIWDKEF 560 570 FNYVPNNIGAMKIVYE FNYVPNNIGAMKIVYE S. S. S. G. S. G. S. G. S. G. S. G. S. G.	390 390 400 DPRYAFGROHGOKTTTTGETPERFTY 490 490 500 DTDLKPRLHVNAPFVCONNCPGOLFV 590 A

Fig. 1. The full-length *VP2* amino acid sequence of the banded linsang compared with 15 other isolates of feline panleukopenia virus (FPV), canine parvovirus type 2 (CPV-2), canine parvovirus type 2a (CPV-2a), canine parvovirus type 2b (CPV-2b), and canine parvovirus type 2c (CPV-2c).

01 111			
No.	Isolate	Origin	GenBank accession No.
1	FPV/ARG07	Argentina	FJ440713
2	FPV/ARG08	Argentina	FJ440714
3	FPV/Tiger	China	FJ405225
4	FPV 389/07 Asian Palm Civet	Hungary	EU145593
5	FPV strain 42/06-G10/Cat	Italy	EU498705
6	FPV strain 143/04/Cat	Italy	EU498692
7	FPV, Obihiro/Cat	Japan	AB000056
8	FPV/Cat	Japan	AB000061
9	FPV strain:V211/Cat	Japan	AB054227
10	FPV isolate PT271/14/Cat	Portugal	KT240136
11	FPV PT210/13/Cat	Portugal	KT240134
12	FPV strain KS2/Cat	South Korea	HQ184204
13	FPV, KS18/Cat	South Korea	HQ184198
14	FPV Cat	Taiwan	AF015223
15	FPV Prionodon linsang	Thailand	MH669800 (present study)
16	FPV strain 97/06-11/Cat	U.K.	EU498714
17	FPV strain 490/07/Cat	U.K.	EU498719
18	FPV/ND/979/2013/Bobcat	U.S.A.	KJ813893
19	FPV isolate Raccoon	U.S.A.	KJ813895
20	Purevax vaccine	-	EU498680
21	Felocell vaccine	-	EU498681
22	Mink enteritis virus/mink	China	KJ186148
23	CPV 2	U.S.A.	M38245
24	CPV 2a Dog	China	FJ435343
25	CPV 2a Dog	South Korea	FJ197834
26	CPV 2a Dog	Taiwan	U72698
27	CPV 2a Dog	Thailand	KP715668
28	CPV 2a Dog	Thailand	KP715675
29	CPV 2a Dog	Thailand	KP715684
30	CPV 2a Dog	Thailand	GQ379047
31	CPV 2a Dog	Thailand	GQ379048
32	CPV 2a Dog	Thailand	GQ379049
33	CPV 2b Dog	China	KF482468
34	CPV 2b Dog	Thailand	KP715695
35	CPV 2b Dog	Thailand	FJ869122
36	CPV 2b Dog	Thailand	FJ869123
37	CPV 2b Dog	Thailand	FJ869124
38	CPV2c Cat	Italy	HQ025913
39	CPV2c Dog	Italy	FJ222821
40	CPV2c Dog	Germany	FJ005202

 Table 3. Canine parvovirus and feline panleukopenia virus strains used for construction of the phylogenetic tree

the gene, including the apical domain region that is associated with parvovirus binding [11]. A single amino acid change or new glycosylation site in the apical domain of TfR, especially at amino acid position 384, may reduce or eliminate both parvovirus binding and infection [8, 11, 12]. If such a change in the TfR of the banded linsang is present, CPV infection may not occur. Whether the absence of CPV infection in the banded linsang is due to a lack of clinical cases or natural resistance to infection remains to be determined. There have been reports of FPV infection in members of the family Viverridae, such as the Asian palm civet (*Paradoxurus hermaphrodites*) [5] and Formosan gem-faced civets (*Paguma larvata taivana*) [10]. However, there has been no report of FPV infection in the banded linsang (*Prionodon linsang*), a member of the family Prionodontidae, which is closely related to the family Viverridae [2]. According to molecular phylogenetics, Prionodontidae has a sister relationship with Viverridae [1]. Thus, the *TFCR* gene of Prionodontidae might have minimal or no variation from that of the family Viverridae. This might be the reason why the banded linsang can be infected with FPV, as other feliform species have also been infected with FPV. Thus, to the best of our knowledge, this is the first report of FPV infection in the banded linsang (*Prionodon linsang*), demonstrating that parvoviruses have been continuously expanding their host range. Based on the findings of this study, it is important to undertake effective biosecurity measures and vaccination to prevent interspecies transmission of FPV in the zoo.

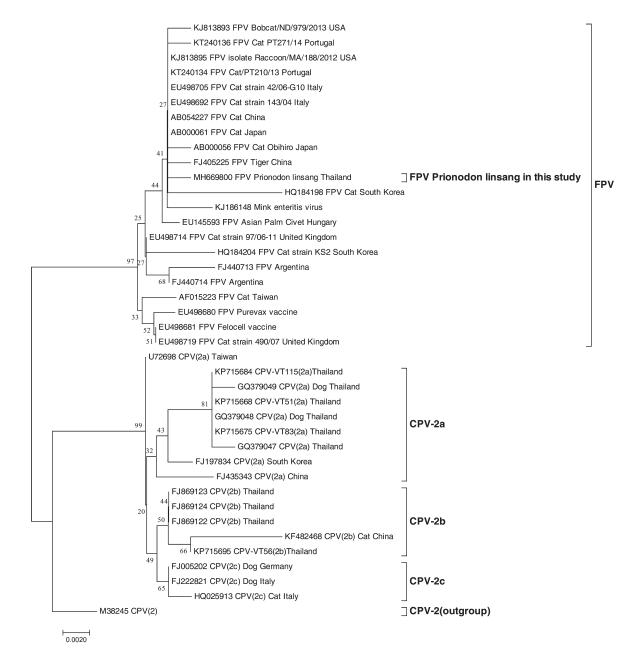


Fig. 2. Phylogenetic analysis based on the entire *VP2* gene amino acid sequence of feline panleukopenia virus (FPV) isolated in this study compared with canine parvovirus and feline panleukopenia virus strains obtained from the GenBank database. A phylogenetic tree was constructed using the MEGA6 program with the neighbor-joining method.

ACKNOWLEDGMENTS. This research was supported by a grant from the Center of Excellence on Agricultural Biotechnology, Science and Technology Postgraduate Education and Research Development Office, Office of Higher Education Commission, Ministry of Education, Science, Research and Innovation (AG-BIO/PERDO-CHE), Bangkok, Thailand.

REFERENCES

- 1. Agnarsson, I., Kuntner, M. and May-Collado, L. J. 2010. Dogs, cats, and kin: a molecular species-level phylogeny of Carnivora. *Mol. Phylogenet. Evol.* **54**: 726–745. [Medline] [CrossRef]
- Allison, A. B. and Parrish, C. R. 2014. Chapter 3-parvoviruses of carnivores: their transmission and the variation of viral host range. pp. 39–61. In: The Role of Animals in Emerging Viral Diseases. Academic Press, Boston.
- 3. An, D. J., Jeoung, W., Jeoung, H. Y., Yoon, S. H., Kim, H. J., Park, J. Y. and Park, B. K. 2011. Phylogenetic analysis of feline panleukopenia virus (FPLV) strains in Korean cats. *Res. Vet. Sci.* **90**: 163–167. [Medline] [CrossRef]
- 4. Barker, I. K., Povey, R. C. and Voigt, D. R. 1983. Response of mink, skunk, red fox and raccoon to inoculation with mink virus enteritis, feline panleukopenia and canine parvovirus and prevalence of antibody to parvovirus in wild carnivores in Ontario. *Can. J. Comp. Med.* **47**: 188–197.

[Medline]

- Demeter, Z., Gál, J., Palade, E. A. and Rusvai, M. 2009. Feline parvovirus infection in an Asian palm civet (*Paradoxurus hermaphroditus*). *Vet. Rec.* 164: 213–216. [Medline] [CrossRef]
- Demeter, Z., Palade, E. A. and Rusvai, M. 2010. Feline panleukopenla virus infection in various species from Hungary. *Lucr. St. Med. Vet. Timisoara* 43: 73–81.
- 7. Duarte, M. D., Barros, S. C., Henriques, M., Fernandes, T. L., Bernardino, R., Monteiro, M. and Fevereiro, M. 2009. Fatal infection with feline panleukopenia virus in two captive wild carnivores (*Panthera tigris* and *Panthera leo*). J. Zoo Wildl. Med. 40: 354–359. [Medline] [CrossRef]
- 8. Goodman, L. B., Lyi, S. M., Johnson, N. C., Cifuente, J. O., Hafenstein, S. L. and Parrish, C. R. 2010. Binding site on the transferrin receptor for the parvovirus capsid and effects of altered affinity on cell uptake and infection. *J. Virol.* **84**: 4969–4978. [Medline] [CrossRef]
- 9. Hueffer, K., Govindasamy, L., Agbandje-McKenna, M. and Parrish, C. R. 2003. Combinations of two capsid regions controlling canine host range determine canine transferrin receptor binding by canine and feline parvoviruses. *J. Virol.* **77**: 10099–10105. [Medline] [CrossRef]
- 10. Ikeda, Y., Miyazawa, T., Nakamura, K., Naito, R., Inoshima, Y., Tung, K. C., Lee, W. M., Chen, M. C., Kuo, T. F., Lin, J. A. and Mikami, T. 1999. Serosurvey for selected virus infections of wild carnivores in Taiwan and Vietnam. *J. Wildl. Dis.* **35**: 578–581. [Medline] [CrossRef]
- Kaelber, J. T., Demogines, A., Harbison, C. E., Allison, A. B., Goodman, L. B., Ortega, A. N., Sawyer, S. L. and Parrish, C. R. 2012. Evolutionary reconstructions of the transferrin receptor of Caniforms supports canine parvovirus being a re-emerged and not a novel pathogen in dogs. *PLoS Pathog.* 8: e1002666. [Medline] [CrossRef]
- 12. Palermo, L. M., Hueffer, K. and Parrish, C. R. 2003. Residues in the apical domain of the feline and canine transferrin receptors control hostspecific binding and cell infection of canine and feline parvoviruses. *J. Virol.* **77**: 8915–8923. [Medline] [CrossRef]
- 13. Parrish, C. R., Aquadro, C. F. and Carmichael, L. E. 1988. Canine host range and a specific epitope map along with variant sequences in the capsid protein gene of canine parvovirus and related feline, mink, and raccoon parvoviruses. *Virology* **166**: 293–307. [Medline] [CrossRef]
- 14. Parrish, C. R., Aquadro, C. F., Strassheim, M. L., Evermann, J. F., Sgro, J. Y. and Mohammed, H. O. 1991. Rapid antigenic-type replacement and DNA sequence evolution of canine parvovirus. *J. Virol.* **65**: 6544–6552. [Medline]
- 15. Senda, M., Parrish, C. R., Harasawa, R., Gamoh, K., Muramatsu, M., Hirayama, N. and Itoh, O. 1995. Detection by PCR of wild-type canine parvovirus which contaminates dog vaccines. *J. Clin. Microbiol.* **33**: 110–113. [Medline]
- Steinel, A., Munson, L., van Vuuren, M. and Truyen, U. 2000. Genetic characterization of feline parvovirus sequences from various carnivores. J. Gen. Virol. 81: 345–350. [Medline] [CrossRef]
- 17. Steinel, A., Parrish, C. R., Bloom, M. E. and Truyen, U. 2001. Parvovirus infections in wild carnivores. J. Wildl. Dis. 37: 594–607. [Medline] [CrossRef]
- 18. Stuetzer, B. and Hartmann, K. 2014. Feline parvovirus infection and associated diseases. Vet. J. 201: 150-155. [Medline] [CrossRef]
- 19. Truyen, U., Gruenberg, A., Chang, S. F., Obermaier, B., Veijalainen, P. and Parrish, C. R. 1995. Evolution of the feline-subgroup parvoviruses and the control of canine host range in vivo. J. Virol. 69: 4702–4710. [Medline]
- 20. Wasieri, J., Schmiedeknecht, G., Förster, C., König, M. and Reinacher, M. 2009. Parvovirus infection in a Eurasian lynx (*Lynx lynx*) and in a European wildcat (*Felis silvestris silvestris*). J. Comp. Pathol. 140: 203–207. [Medline] [CrossRef]
- 21. Yang, S., Wang, S., Feng, H., Zeng, L., Xia, Z., Zhang, R., Zou, X., Wang, C., Liu, Q. and Xia, X. 2010. Isolation and characterization of feline panleukopenia virus from a diarrheic monkey. *Vet. Microbiol.* **143**: 155–159. [Medline] [CrossRef]