Norovirus infection is a major cause of endemic and epidemic acute gastroenteritis. These viruses have been classified into 7 genogroups on the basis of the major capsid protein, VP1. Noroviruses GI, GII, and GIV can infect humans, GII pigs, GIII and GV ruminants and mice, and GVI and GVII dogs (1). The evolutionary mechanism and typing of noroviruses can be analyzed on the basis of recombination between the genes for RNA-dependent RNA polymerase and VP1 (2). Newly emerged norovirus strains might lead to increasing incidence of infection worldwide (3). The predominant genotype of noroviruses in humans is GII.4. Genetic diversity of noroviruses has been reported in a wide range of animals (e.g., pigs, cattle, and dogs).

In 2007, canine noroviruses in Italy were reported to have the GIV.2 genotype (4). Subsequently, these viruses have been reported to cause diseases in dogs in Asia and Europe (5–8). The seroprevalence of human noroviruses in dogs in the United Kingdom was reported to be 13% (6). The GII.4 genotype (variants GII.4-2006b and GII.4-2008) was reported in dogs in Finland, indicating that human noroviruses could be transmitted to and cause diarrhea in dogs (9). In humans, antibodies against canine norovirus were also reported in veterinarians, who experienced high risk of exposure (10). However, only a few reports describe human norovirus infections in dogs, and limited numbers of complete genomes of canine noroviruses are available in GenBank. We report evidence of human norovirus infection in dogs from a kennel and children on the same premises in Thailand.

The Study
On July 27, 2018, we investigated acute gastroenteritis in dogs in a dog kennel. An outbreak occurred in a small-scale dog kennel that contained 18 adult dogs in Suphanburi, central Thailand. Clinical signs in bitches and puppies were fever, acute watery diarrhea, and mild dehydration (Appendix Figure 1, https://wwwnc.cdc.gov/EID/article/26/2/19-1151-App1.pdf). Information for the outbreak investigation indicated that 2 weeks earlier (July 18), 2 children (8 months and 2 years of age) who lived on the kennel premises were hospitalized because of vomiting and watery diarrhea. These children recovered within 1 week. During hospitalization, human cases were diagnosed and confirmed as norovirus infection by using a rapid test kit (RIDA QUICK Norovirus, https://clinical.r-biopharm.com). Five adults, 2 children, and 18 adult dogs were living on the premises. All dogs were housed in the kennel; only 2 apparently pregnant dogs (CU21939 and CU21952) were moved into the house of the owner. The 2 apparently pregnant dogs were kept in close contact with children.

On August 2, 2018, a pregnant dog gave birth to 6 puppies, and the other bitch was found to have a false pregnancy. During the 6 weeks (July 27–September 5) of the norovirus outbreak, 2 (11.11%) of 18 dogs (the 2 apparently pregnant dogs kept in the house of the owner) and 5 (83.33%) of 6 puppies showed clinical signs of infection (Appendix Table 1). After treatment and hygiene management, including separation of dogs, frequent cleaning, and disinfection, all dogs recovered, and no deaths occurred.

Animal samples were collected and examined at the Center of Excellence for Emerging and...
Re-emerging Infectious Diseases in Animals, Chulalongkorn University (Bangkok, Thailand). Studies were approved by the Institutional Animal Care and Use Committee (approval no. 1731074). Human samples were collected and submitted to the Center of Excellence for Clinical Virology under the institutional review board of Chulalongkorn University (Institutional Review Board no. 634/59).

During the 4 visits in the study, we examined 75 samples (4 stool samples from 2 children, 71 rectal swab specimens from 18 adult dogs and 6 puppies). We detected norovirus by using a reverse transcription PCR specific for the RNA-dependent RNA polymerase gene as described (11,12) (Appendix). We detected norovirus in samples from children (4/4), adult dogs (2/53), and puppies (10/18) (Appendix Table 1). All human samples were positive for norovirus at the first (July 27) and third (August 25) visits. The 2 bitches with clinical signs were positive for norovirus at the first visit (July 27). Their puppies (5/6) were positive at the second (August 18) and third (August 25) visits. Our findings are consistent with a previous report that animals can shed noroviruses for a long period (4). All samples were also tested for canine parvovirus type 2, rotavirus A, canine coronavirus, and canine distemper virus to rule out other canine enteric diseases; all showed negative results (Appendix Table 1).

We selected 4 of the noroviruses, 2 from humans (CU21953 and CU21954) and 2 from dogs (CU21939 and CU21952), for whole-genome sequencing by using oligonucleotide primer sets (Appendix). We then submitted nucleotide sequences for these viruses (GenBank accession nos. MK928496–9) (Table). Phylogenetic analysis showed that the noroviruses in this investigation clustered in genotype GII.4. In general, canine noroviruses are commonly grouped into genogroups GIV, GVI, and GVII. In contrast, noroviruses from these dogs were closely related to human noroviruses and viruses in genogroup GII (Figure 1). Phylogenetic analysis of partial open reading frame 1 (ORF1) and ORF2 showed that all noroviruses from this investigation clustered with norovirus GII.Pe-GII.4 Sydney 2012, which were reported to be

![Figure 1. Phylogenetic tree of whole-genome sequences of canine noroviruses (red dots) and human noroviruses (blue triangles) from Thailand and reference sequences. Genogroups GI–GVII are indicated by red oval and blue ovals. The tree was constructed by using MEGA version 7.026 (https://www.megasoftware.net) with the neighbor-joining algorithm and bootstrap analysis with 1,000 replications. Numbers along branches are bootstrap values. Scale bar indicates nucleotide substitutions per site.](image-url)
circulating worldwide (Figure 2; Appendix Figure 2) (3). Noroviruses from dogs in this study (GII.4 Sydney) were in different clusters from canine noroviruses 3–09 (GII.4 DenHaag) and 261–10 and 1C-09 (GII.4 unclassified) reported in Finland (9).

We compared nucleotide and deduced amino acids of the noroviruses from this investigation with reference canine and human noroviruses. On the basis of antigenic epitopes (A–E) of major capsid protein that correlate with blockade of neutralization antibodies, the noroviruses from Thailand had specific amino acids in specific positions consistent with those for human norovirus GII.Pe-GII.4 Sydney, which were not observed in human norovirus genogroups GI and GIV and canine norovirus genogroups GIV and GVII (Appendix Table 2).

Pairwise comparisons of whole-genome sequences showed that the viruses had 99.90% nt identities (only 3 nt differences in ORF2; T1176C [silent mutation 392G], C1354T [silent mutation 452L] and...
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in ORF3; T803A [V268E] to each other and highest nucleotide identities to human norovirus from China [99.00%; JN0110] and the human norovirus reference Sydney strain [97.6%; NSW0514]). On the basis of partial ORF2 sequences, we showed that the canine noroviruses from this investigation were different from canine noroviruses GI.4 (3-09, 1C-09, and 261-10; 91.6% nt identities) and GIV, GVI, and GVII (52.90%–55.50% nt identities) (Appendix Table 3).

Conclusions

We report infection of dogs with human norovirus GI.4 Sydney. Human noroviruses have been reported in dogs in Finland (GI.4 Denhaag and GI.4 unclassified) (9). Dogs showed mild clinical signs of acute watery diarrhea, similar to that for human norovirus infection, and low levels of illness and death. Similar observations have also been reported in other studies (8,13). In this study, children had been hospitalized 2 weeks before the investigation. Disease developed in dogs and puppies after they shared the same premises and possible direct contact with the children. This observation suggests potential human-to-dog transmission of human noroviruses. Genetic and phylogenetic analyses confirmed that whole genomes of canine and human noroviruses were closely related to human norovirus GI. Pe-GII.4 Sydney, suggesting that a common strain is circulating in Thailand and worldwide (14,15). However, in our study, it is not clear how and when the viruses were introduced to children and dogs.

In summary, we demonstrated evidence of norovirus GI. Pe-GI.4 infection in humans and dogs in Thailand. Dog owners and veterinarians should pay more attention to norovirus infection as a potential zoonotic and reverse zoonotic disease in households, animal hospitals, and shelters. Expanded surveillance for norovirus is needed to determine its status and distribution in human and dog populations.

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Appendix

Infection in Dogs

During July–September 2018, the Center of Excellence for Emerging and Re-emerging Diseases in Animals at Chulalongkorn University (Bangkok, Thailand) investigated a suspected outbreak of norovirus infection in dogs that had fever, acute vomiting, and watery diarrhea in a small-scale dog kennel. Epidemiologic investigation, sample collection, and laboratory diagnosis were conducted to determine the cause of the outbreak. Information from the outbreak investigation showed that 2 weeks before reporting of cases in animals, 2 children (8 months and 2 years of age) who lived on the kennel premises had been hospitalized on July 18, 2018 because of vomiting and watery diarrhea. These children recovered within 1 week. During hospitalization, human cases were diagnosed and confirmed as norovirus infection by using a rapid test kit. Animal sample collection and testing were performed under the Chulalongkorn University Animal Care and Use Committee Protocol (Institutional Animal Care and Use Committee no. 1731074). Human sample collection and testing were performed at the Center of Excellence for Clinical Virology under the Institutional Review Board of Chulalongkorn University Hospital protocol for human study (Institutional Review Board no. 634/59).

Identification of Viruses

Over 4 visits during July–September 2018, we collected 75 samples: 4 stool samples from 2 children (8 months and 2 years of age) and 71 rectal swab samples from 18 adult dogs and 6 puppies. We identified noroviruses by using an RT-PCR specific for the RNA dependent RNA polymerase gene (1,2). Because dogs showed clinical signs similar to those for canine enteric diseases, all samples were also examined for canine parvovirus type 2, rotavirus A, canine coronavirus, and canine distemper to rule out other canine enteric diseases (3–7). We extracted virus RNAs from 10% stool suspensions in phosphate-buffered saline, pH 7.2, and from rectal swab samples by using the QIAsymphony DSP Viral/Pathogen Mini Kit (QIAGEN,
https://www.qiagen.com) following the manufacturer’s instructions. The virus RNA was stored at −80°C until use.

A PCR for norovirus identification was conducted as described (1,2). We use a set of oligonucleotide primers (Appendix Table 4). A 1-step reverse transcription PCR (RT-PCR) (Invitrogen, https://www.thermofisher.com) was conducted in a final volume of 25 µL containing 3 µL of template RNA, 12.5 µL of 2× reaction mixture, 0.6 µL of 10 µmol/L of forward (F4895) and reverse (R5591) primers, 1.2 µL of SuperScript III reverse transcriptase (Invitrogen), and distilled water. The RT-PCR procedure included a reverse transcription step at 55°C for 30 min; an initial denaturation step at 94°C for 2 min; followed by 40 cycles of denaturation at 94°C for 30 s, annealing at 50°C for 30 s, and extension at 68°C for 1 min; and final extension step at 68°C for 6 min. To confirm the presence of noroviruses, 4 µL PCR product was subjected to electrophoresis on a 1.5% agarose gel, with RedSafe dye (Bulldog Bio, https://www.bulldog-bio.com), at 100 V for 45 min. The amplification product was visualized on a UV transilluminator. The expected size of the norovirus-positive amplified product was 493 bp.

We conducted a 1-step real-time RT-PCR for norovirus identification as described (8,9). This real-time RT-PCR was conducted by using the TaqMan Fast Virus 1-step real-time RT-PCR (Thermo Fisher Scientific, https://www.thermofisher.com) with specific primers and probe to GI and GII noroviruses was conducted in a final volume of 25 µL containing 5 µL of template RNA, 1× Master Mix, 0.25 µmol/L GI forward and reverse primers, 0.125 µmol/L of GI-JOE labeled probe, 0.25 µmol/L GII forward and reverse primers, 0.125 µmol/L of GII-FAM labeled probe, and distilled. This real-time RT-PCR included a reverse transcription step at 50°C for 10 min; an enzyme activation step at 95°C for 20 s; followed by 45 cycles of denaturation at 95°C for 3 s and annealing at 60°C for 30 s. A cycle threshold value <40 was considered as indicating GI and GII positive.

**Characterization of Viruses**

In this study, we selected 4 noroviruses from Thailand: including 2 from humans (CU21953 and CU21954) and 2 from dogs (CU21939 and CU21952) for whole-genome sequencing. Whole norovirus genomes were sequenced by using oligonucleotide primer sets previously described and new primer sets designed with Primer 3 Plus (Appendix Table 4)
A 25 µL RT-PCR mixture contained 3 µL of template RNA, 12.5 µL of 2× reaction mixture, 0.6 µL of 10 µmol/L forward and reverse primers, 1.2 µL of SuperScript III reverse transcriptase, and distilled water. The RT-PCR procedure included a reverse transcription step at 55°C for 30 min; an initial denaturation step at 94°C for 2 min; followed by 40 cycles of denaturation at 94°C for 30 s, annealing at 48–55°C for 30 s, and extension at 68°C for 2 min; and a final extension step at 68°C for 6 min. Amplicons were gel-purified and sequenced (First Base Laboratories, http://www.firstbaselab.com). Nucleotide sequences were assembled and validated by using SeqMan software version 5.03 (DNASTAR Inc., https://www.dnastar.com). Whole-genome sequences of noroviruses from Thailand were submitted to GenBank under accession nos. MK928496–9.

For pairwise comparisons and genetic analysis of noroviruses from Thailand, we aligned nucleotide sequences and deduced amino acids of noroviruses with reference noroviruses from GenBank by using MEGA version 7.026 (https://www.megasoftware.net) and MegAlign version 5.03 (DNASTAR Inc.) software. For phylogenetic analysis, we compared complete genome sequences of noroviruses from Thailand with those of reference noroviruses, including genogroups GI (n = 2), GII (n = 5), GIII (n = 3), GIV (n = 4), GV (n = 2), GVI (n = 2), and GVII (n = 2). We analyzed the partial open reading frame 1 of noroviruses from Thailand NoVs by comparison with reference GII noroviruses, including GII.P1 (n = 2; United States), GII.P4 (n = 25; Australia, Japan, Georgia, South Korea, the Netherlands, Taiwan, United Kingdom and United States), GII.P5 (n = 1; Japan), GII.P6 (n = 2; Japan and United States), GII.P7 (n = 5; Japan, the Netherlands, and United States), GII.P8 (n = 1; Japan), GII.P11 (n = 1; China), GII.P12 (n = 7; China, South Korea, and Japan), GII.P16 (n = 6; Germany, Japan, Russia, and United States), GII.P17 (n = 1; Hong Kong), GII.P18 (n = 1; United States), GII.P20 (n = 1; Germany), GII.P22 (n = 2; Japan), GII.P21 (n = 2; Japan and the Netherlands), GII.Pc (n = 1; United States), GII.Pe (n = 10; Australia, China, Japan, and Thailand), GII.Pg (n = 2; Australia and China), and outer group GI.P1 (n = 1; United States). We compared the partial open reading frame 2 ORF2 of noroviruses from Thailand with those of reference of GII noroviruses, including genogroups GII.1 (n = 1; United States), GII.2 (n = 1; United Kingdom), GII.3 (n = 3; Argentina, Canada, and the Netherlands), GII.4 (n = 40; Australia, Canada, China, Finland, Ireland, Japan, Netherlands, Thailand, United Kingdom, and United States), GII.5 (n = 1; United Kingdom), GII.6 (n = 22; China, Japan, Italy, Taiwan, United Kingdom, and United States),
GII.7 (n = 12; Japan, Netherlands, Germany, Italy, United Kingdom, and United States), GII.8 (n = 4; China, the Netherlands, and Russia), GII.9 (n = 1; United States), GII.10 (n = 1; Germany), GII.11 (n = 1; Japan), GII.12 (n = 1; United Kingdom), GII.13 (n = 18; China, Nepal, and United States), GII.14 (n = 14; Germany, Japan, and United States), GII.16 (n = 1; United States), GII.17 (n = 1; United States), GII.18 (n = 1; United States), GII.19 (n = 1; United States), GII.20 (n = 1; Germany), GII.21 (n = 18; Bhutan, China, Cambodia, Hong Kong, India, Iraq, Japan, South Korea, Russia, United Kingdom, and United States), GII.22 (n = 1; Japan), and outer groups; GI (n = 1; United States) and GVII (n = 1; Hong Kong). Phylogenetic analysis was performed using MEGA version 7.026 with the neighbor-joining algorithm and bootstrap analysis of 1,000 replications.

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Appendix Table 1. Characteristics of samples collected and examined from a dog kennel, Thailand, 2018*

| Sample name   | Sample ID  | Collection date | Sex | Age     | Breed               | Sample | Clinical sign       | NoV RT-PCR | NoV real-time RT-PCR | CPV2 | RVA | CaCoV | CDV |
|---------------|------------|-----------------|-----|---------|---------------------|--------|---------------------|------------|----------------------|------|-----|-------|-----|
| First visit, n = 19 |
| Human 1       | CU21953†   | Jul 27          | M   | 2 y     | Not applicable      | Feces  | Soft stool          | +          | + (27.3)             | –    | –   | NA    | NA  |
| Human 2       | CU21954†   | Jul 27          | M   | 8 mo    | Not applicable      | Feces  | Soft stool          | +          | + (20.5)             | –    | –   | NA    | NA  |
| Dog 1         | CU21936    | Jul 27          | F   | 6 mo    | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 2         | CU21937†   | Jul 27          | M   | 6 mo    | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 3         | CU21938    | Jul 27          | F   | 2 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 4         | CU21939†   | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Watery diarrhea | +          | + (29.7)             | –    | –   | –     | –   |
| Dog 5         | CU21940    | Jul 27          | F   | 3 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 6         | CU21941†   | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 7         | CU21942    | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 8         | CU21943    | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 9         | CU21944    | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 10        | CU21945†   | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 11        | CU21946    | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 12        | CU21947    | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 13        | CU21948†   | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 14        | CU21949†   | Jul 27          | M   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 15        | CU21950†   | Jul 27          | M   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 16        | CU21951†   | Jul 27          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 17‡       | CU21952†   | Jul 27          | F   | 3 y     | French bulldog      | Rectal swab | Watery diarrhea | +          | + (29.6)             | –    | –   | –     | –   |
| Second visit, n = 24 |
| Puppy 1‡      | CU22011    | Aug 18          | M   | 2 wk    | French bulldog      | Rectal swab | Watery diarrhea | +          | + (30.5)             | –    | –   | –     | –   |
| Puppy 2       | CU22012    | Aug 18          | M   | 2 wk    | French bulldog      | Rectal swab | Watery diarrhea | +          | + (30.1)             | –    | –   | –     | –   |
| Puppy 3       | CU22013†   | Aug 18          | F   | 2 wk    | French bulldog      | Rectal swab | Watery diarrhea | +          | + (31.4)             | –    | –   | –     | –   |
| Puppy 4       | CU22014†   | Aug 18          | F   | 2 wk    | French bulldog      | Rectal swab | Watery diarrhea | +          | + (30.7)             | –    | –   | –     | –   |
| Puppy 5       | CU22015†   | Aug 18          | F   | 2 wk    | French bulldog      | Rectal swab | Watery diarrhea | +          | + (31.8)             | –    | –   | –     | –   |
| Puppy 6       | CU22016†   | Aug 18          | F   | 2 wk    | French bulldog      | Rectal swab | Watery diarrhea | –          | –                   | –    | –   | –     | –   |
| Dog 1         | CU22020‡   | Aug 18          | F   | 6 mo    | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 2         | CU22019‡   | Aug 18          | M   | 6 mo    | French bulldog      | Rectal swab | Asymptomatic | –          | + (36.0)             | –    | –   | –     | –   |
| Dog 3         | CU22018‡   | Aug 18          | F   | 2 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 4         | CU22034‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 5         | CU22022‡   | Aug 18          | F   | 3 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 6         | CU22026‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 7         | CU22021‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 8         | CU22025‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 9         | CU22023‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 10        | CU22029‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 11        | CU22030‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 12        | CU22024‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 13        | CU22031‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 14        | CU22028‡   | Aug 18          | M   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 15        | CU22032‡   | Aug 18          | M   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 16        | CU22027‡   | Aug 18          | F   | 1 y     | French bulldog      | Rectal swab | Asymptomatic | –          | + (37.0)             | –    | –   | –     | –   |
| Dog 17‡       | CU22033‡   | Aug 18          | F   | 3 y     | French bulldog      | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Dog 18        | CU22017‡   | Aug 18          | F   | 5 y     | Miniature pinscher | Rectal swab | Asymptomatic | –          | –                   | –    | –   | –     | –   |
| Sample name | Sample ID | Collection date | Sex | Age | Breed | Sample | Clinical sign | NoV RT-PCR | NoV real-time | CPV2 | RVA | CaCoV | CDV |
|-------------|-----------|-----------------|-----|-----|-------|--------|---------------|------------|---------------|------|------|-------|------|
| Third visit, n = 9 |
| Human 1     | CU22080   | Aug 25          | M   | 2 y | Not applicable | Feces | Asymptomatic  | +           | S (40.0)      | –    | –    | NA    | NA   |
| Human 2     | CU22081   | Aug 25          | M   | 8 mo| Not applicable | Feces | Asymptomatic  | +           | + (33.4)     | –    | –    | NA    | NA   |
| Puppy 1     | CU22072   | Aug 25          | M   | 3 wk| French bulldog | Rectal swab | Watery diarrhea | +           | + (32.3)     | –    | –    | –     | –    |
| Puppy 2     | CU22073   | Aug 25          | M   | 3 wk| French bulldog | Rectal swab | Watery diarrhea | +           | + (33.2)     | –    | –    | –     | –    |
| Puppy 3     | CU22074   | Aug 25          | F   | 3 wk| French bulldog | Rectal swab | Watery diarrhea | +           | + (31.9)     | –    | –    | –     | –    |
| Puppy 4     | CU22075   | Aug 25          | F   | 3 wk| French bulldog | Rectal swab | Watery diarrhea | +           | + (32.5)     | –    | –    | –     | –    |
| Puppy 5     | CU22076   | Aug 25          | F   | 3 wk| French bulldog | Rectal swab | Watery diarrhea | +           | + (32.5)     | –    | –    | –     | –    |
| Puppy 6     | CU22078   | Aug 25          | F   | 3 wk| French bulldog | Rectal swab | Watery diarrhea | –           | –            | –    | –    | –     | –    |
| Dog 11      | CU22079   | Aug 25          | F   | 3 y | French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Fourth visit, n = 23 |
| Puppy 1††  | CU22143   | Sep 5           | M   | 1 mo| French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Puppy 2     | CU22144   | Sep 5           | M   | 1 mo| French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Puppy 3     | CU22145   | Sep 5           | F   | 1 mo| French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Puppy 4     | CU22146   | Sep 5           | F   | 1 mo| French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Puppy 5     | CU22147   | Sep 5           | F   | 1 mo| French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Puppy 6     | CU22148   | Sep 5           | F   | 1 mo| French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Dog 1       | CU22151   | Sep 5           | F   | 7 mo| French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Dog 2       | CU22150   | Sep 5           | M   | 7 mo| French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Dog 3       | CU22153   | Sep 5           | F   | 2 y | French bulldog | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |
| Dog 5       | CU22155   | Sep 5           | F   | 3 y | French bulldog | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |
| Dog 6       | CU22161   | Sep 5           | F   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |
| Dog 7       | CU22166   | Sep 5           | F   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Dog 8       | CU22152   | Sep 5           | F   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Dog 9       | CU22157   | Sep 5           | F   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Dog 10      | CU22154   | Sep 5           | F   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Dog 11      | CU22158   | Sep 5           | F   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | –            | –    | –    | –     | –    |
| Dog 12      | CU22163   | Sep 5           | F   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |
| Dog 13      | CU22164   | Sep 5           | F   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |
| Dog 14      | CU22149   | Sep 5           | M   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |
| Dog 15      | CU22159   | Sep 5           | M   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |
| Dog 16      | CU22162   | Sep 5           | F   | 1 y | French bulldog | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |
| Dog 17†     | CU22160   | Sep 5           | F   | 3 y | French bulldog | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |
| Dog 18      | CU22165   | Sep 5           | F   | 5 y | Miniature pinscher | Rectal swab | Asymptomatic   | –           | NA           | –    | –    | –     | –    |

*Numbers in parentheses are cycle threshold values. CaCoV, canine coronavirus; CDV, canine distemper virus; CPV2, canine parvovirus 2; ID, identification; NA, not available; NoV, norovirus; RT-PCR, reverse transcription PCR; RVA, rotavirus A; +, positive; –, negative. 
†Samples were subjected to whole-genome sequencing. 
††Dog 17 was a bitch with 6 puppies. 
§Puppies 1–6 were from the same litter of dog 17.
### Appendix Table 2. Genetic analysis of nucleotide sequences of canine and human noroviruses from Thailand for antigenic epitopes (A–E) major capsid protein compared with those for other noroviruses*

| Virus          | County/year | GenBank accession no. | Variant               | Antigenic epitopes       |
|----------------|-------------|-----------------------|-----------------------|--------------------------|
|                |             |                       |                       | A           | B           | C           | D           | E           |
|                |             |                       |                       | 294 | 296 | 297 | 298 | 368 | 372 | 382 | 340 | 376 | 393 | 395 | 407 | 412 | 413 |
| Human          |             |                       |                       |                | A | S | H | D | T | N | L | K | A | Q | D | –† | H | N | T | G |
| Lordsdale      | UK/1993     | X86557                | Bristol 1993          |                | A | T | H | N | N | N | M | K | G | E | N | G | T | S | T | G |
| Camberwell     | AU/1994     | AF145896              | Camberwell 1994       |                | V | S | H | D | T | N | L | K | A | Q | D | –† | H | N | T | G |
| Farmington Hills | USA/2002   | AY502023              | Farmington Hills 2002 |                | A | T | Q | N | S | S | V | R | R | E | S | T | T | D | D | S |
| Hunter504D/04O | AU/2004     | DQ078814              | Hunter 2004           |                | A | T | Q | N | S | S | V | R | R | E | S | T | T | D | D | S |
| CGMH09         | TW/2006     | JN400607              | Den Haag 2006b        |                | A | S | R | N | S | E | V | K | G | E | S | T | T | S | N | V |
| JB-15          | KOR/2015    | HQ009513              | Apeldoorn 2008        |                | T | S | R | N | A | D | V | K | A | D | N | T | A | S | N | S |
| New Orleans1805 | USA/2009   | GU445325              | New Orleans 2009      |                | P | S | R | N | A | D | V | K | T | E | S | T | T | S | N | I |
| NSW0514        | AU/2012     | JX459906              | Sydney 2012           |                | T | S | R | N | E | D | V | K | T | E | G | T | T | S | N | T |
| JN010          | CHN/2017    | MG214988              | Sydney 2012           |                | T | S | H | N | E | N | M | K | T | E | G | T | T | S | N | T |
| DBM15–156      | THA/2015    | MG786781              | Sydney 2012           |                | T | S | R | N | E | D | M | K | T | E | S | T | T | S | N | T |
| HuNoV/CU21953  | THA/2018    | This study            | Sydney 2012           |                | T | S | H | N | E | N | M | K | T | E | G | T | T | S | N | T |
| HuNoV/CU21954  | THA/2018    | This study            | Sydney 2012           |                | T | S | H | N | E | N | M | K | T | E | G | T | T | S | N | T |
| Canine         |             |                       |                       |                | A | S | H | N | E | N | M | K | T | E | G | T | T | S | N | T |
| CaNoV/CU21952  | THA/2018    | This study            | Sydney 2012           |                | T | S | H | N | E | N | M | K | T | E | G | T | T | S | N | T |
| CaNoV/CU21939  | THA/2018    | This study            | Sydney 2012           |                | T | S | H | N | E | N | M | K | T | E | G | T | T | S | N | T |

*AU, Australia; CaNoV, canine norovirus; HuNoV, human norovirus; KOR, South Korea; THA, Thailand; TW, Taiwan.

†, Gap at position 394.
### Appendix Table 3. Pairwise comparisons of nucleotides and amino acids of canine norovirus CU21939 from Thailand with those of reference noroviruses*

| Virus | Host | Genotype † | Country/year | GenBank accession no. | Variant † | Nucleotide (amino acid) identity, % |
|-------|------|------------|--------------|-----------------------|-----------|-----------------------------------|
|       |      |            |              |                       |           | WGS 1–756‡ ORF1 5–5104‡ ORF2 5085–6707‡ ORF3 6707–7513‡ |
| Canine |      |            |              |                       |           |                                   |
| AN843 | Dog  | GIV.2      | USA/2011     | MK067289 NA           | NA        | 62.20 (47.80)§ 55.30 (38.80) 50.90 (41.40) |
| 170/07 | Dog  | GIV.2      | Italy/2007   | EU224456 NA           | NA        | 64.50 (71.20)§ 54.20 (36.50) 51.40 (42.90) |
| AN1610| Dog  | GIV.2      | USA/2017     | MK067288 NA           | NA        | 62.30 (47.80)§ 55.20 (38.10) 51.20 (40.02) |
| AN1663| Dog  | GIV.2      | USA/2017     | MK067291 NA           | NA        | 62.30 (47.80)§ 55.10 (38.30) 51.20 (41.70) |
| AN1638| Dog  | GIV.2      | USA/2017     | MK067290 NA           | NA        | 62.60 (48.40)§ 55.10 (38.30) 51.20 (41.70) |
| C33/Viseu | Dog | GIV.2     | Portugal/2007| GQ443611 NA          | NA        | 64.90 (72.10) 53.90 (39.10) 53.90 (46.50) |
| FD53  | Dog  | GIV.2      | UK/2007      | JF930689 NA           | NA        | 64.20 (71.20)¶ 54.40 (39.10) 54.20 (46.50) |
| FD210 | Dog  | GIV.1      | Italy/2007   | JF939046 NA           | NA        | 65.10 (70.80)§ 54.30 (38.60) 54.20 (44.10) |
| AN1633| Dog  | GIV.1      | USA/2017     | MK067293 NA           | NA        | 62.60 (48.40)§ 55.50 (40.60) 53.10 (43.50) |
| AN1632| Dog  | GIV.1      | USA/2017     | MK067292 NA           | NA        | 62.40 (47.80)§ 55.50 (40.60) 53.10 (43.50) |
| ITA/91| Dog  | GIV.1      | Italy/2007   | FJ875027 NA           | NA        | 65.10 (71.20)¶ 55.00 (39.90) 53.40 (43.80) |
| 63.15 | Dog  | GIV.2      | Italy/2015   | KY486329 NA           | NA        | 65.10 (72.10)¶ 54.20 (38.80) 55.20 (46.20) |
| AN1640| Dog  | GIV.2      | USA/2017     | MK067295 NA           | NA        | 62.40 (47.80)§ 54.20 (38.90) 54.55 (44.70) |
| HKU Ca026F | Dog | GIVII     | China/2007   | JF692500 NA           | 58.50 (47.20) 62.20 (55.00) 52.90 (37.90) 43.80 (33.00) |
| HKU Ca035F | Dog | GIVII     | China/2007   | JF692501 NA           | 58.50 (47.20) 62.20 (55.00) 52.90 (38.10) 43.80 (33.00) |
| 1C-09 | Dog  | GII.4      | Finland/2009 | JF746890 Unclassified | NA        | 91.60 (91.60)# NA |
| 261–10 | Dog  | GII.4     | Finland/2010 | JF746891 Unclassified | NA        | 91.60 (91.60)# NA |
| 3–09  | Dog  | GII.4      | Finland/2009 | JF746892 Den Haag 2006b | NA        | 91.60 (97.40)# NA |

| Human |      |            |              |                       |           |                                   |
|-------|------|------------|--------------|-----------------------|-----------|                                   |
| HuNoV/OC07138 | Human | GII.Pe-GII.4 | Japan/2007   | AB434770 Osaka 2007   | NA        | 94.80 (98.50)** 89.60 (94.60) 99.00 (98.90) |
| HuNoV/NSW01P | Human | GII.Pe-GII.4 | USA/2008     | GQ843567 New Orleans 89.10 (94.50) 94.50 (86.50) 94.10 (93.90) 93.60 (96.30) |
| HuNoV/New Orleans | Human | GII.P4-GII.4 | USA/2009     | GU445325 New Orleans 89.00 (94.70) 94.70 (86.70) 94.30 (93.70) 93.7 (96.10) |
| HuNoV/NSW0514 | Human | GII.P4-GII.4 | Australia/2012 | JX459908 Sydney 2012 97.6 (98.70) 98.70 (97.70) 99.20 (97.40) 97.00 (98.00) |
| HuNoV/UCHK3630 | Human | GII.P4-GII.4 | China/2012   | KC175323 Sydney 2012 98.20 (99.20) 99.20 (98.20) 99.50 (98.10) 98.00 (98.50) |
| HuNoV/JN010 | Human | GII.P4-GII.4 | China/2017   | MG214988 Sydney 2012 99.00 (99.50) 99.50 (99.00) 99.60 (99.00) 99.80 (99.80) |
| HuNoV/DBM15–156 | Human | GII.P4-GII.4 | Thailand/2015 | MG786781 Sydney 2012 97.40 (98.80) 97.50 (99.50) 97.50 (98.50) 95.90 (95.20) |
| HuNoV/CU21953 | Human | GII.P4-GII.4 | Thailand/2018 | This study Sydney 2012 99.90 (99.80) 99.80 (100) 99.90 (100) 99.90 (99.80) |
| HuNoV/CU21954 | Human | GII.P4-GII.4 | Thailand/2018 | This study Sydney 2012 99.90 (99.80) 99.80 (100) 99.90 (100) 99.90 (99.80) |
| CaNoV/CU21952 | Dog  | GII.P4-GII.4 | Thailand/2018 | This study Sydney 2012 99.90 (99.80) 99.80 (100) 99.80 (100) 99.80 (99.80) |
| CaNoV/CU21939 | Dog  | GII.P4-GII.4 | Thailand/2018 | This study Sydney 2012 100.00 (100) 100.00 (100) 100.00 (100) 100.00 (100) |

*CaNoV, canine norovirus; HuNoV, human norovirus; NA, not available; ORF, open reading frame; WGS, whole-genome sequencing.
†Genotype classification by the Norovirus Genotype Tool (https://www.nrm.nl/mpf/typingtool/norovir).
‡Norovirus strain NSW0514 (JX459908) was used as a reference. Values are baselines.
§Size of the ORF1 gene for genetic comparison is 5,088 bp.
¶Size of the ORF1 gene for genetic comparison is 699 bp.
#Size of the ORF2 gene for genetic comparison is 228 bp.
**Size of the ORF1 gene for genetic comparison is 805 bp.
### Appendix Table 4. Primers for identification and sequencing of noroviruses, Thailand*

| Primer       | Sequence, 5′→3′ | Position | Target     | Reference |
|--------------|-----------------|----------|------------|-----------|
| F4895        | GATTAGGTGACACTATAGYDSTTYTCTTTYAYGGKGAYGATGA | 4585     | RdRp       | (1)       |
| R5591        | ATCGGCGCAGACATCGGAGTC | 5078     | RdRp       |           |
| G2S KR       | CCRCNGCATRHCRTTNTACTAT | 5389     | VP1        | (2)       |
| NOV-ORF1–1F  | GTGAATGAAGATGCGCTAAG | 1        | ORF1       | This study|
| NOV-ORF1–1R  | CTTCTCCAATCTGGATACG | 705      | ORF1       | This study|
| NOV-ORF1–2F  | GCATTCTCGATGCGYCTCAC | 1233     | ORF1       | This study|
| NOV-ORF1–2R  | TAGGTTTTGGTCATAGGTTAC | 1065     | ORF1       | This study|
| NOV-ORF1–3F  | CTTTTTCTCAATCTGT GTC | 1740     | ORF1       | This study|
| NOV-ORF1–3R  | CAGGGTGTRGCTGCTTATCC | 1580     | ORF1       | This study|
| NOV-ORF1–4F  | TCACATRGGTCTCGACATCCTT | 2208     | ORF1       | This study|
| NOV-ORF1–4R  | GAGCATCAGGTTACTCCATG | 2066     | ORF1       | This study|
| NOV-ORF1–5F  | CTCTTTTACTCTCTGATCTCCTCATT | 2700 | ORF1       | This study|
| NOV-ORF1–5R  | CACAGAAGAGATGGCCAAACA | 2561     | ORF1       | This study|
| NOV-ORF1–6F  | CTGAAATCATGCGCTCAGATC | 3227     | ORF1       | This study|
| NOV-ORF1–6R  | GCCTGTCGCGATGATGCTCACT | 3062     | ORF1       | This study|
| NOV-ORF1–7F  | TTTTTCTCTCTCCTAACATTAGG | 4038     | ORF1       | This study|
| NOV-ORF1–7R  | TCAGGTGCGCTCTCATTG | 3726     | ORF1       | This study|
| NOV-ORF1–8F  | AAGGGAGTTGGGCCTGATGATC | 4561     | ORF1       | This study|
| NOV-ORF1–8R  | CAGAACCACACTCGGCCAG | 4371     | ORF1       | This study|
| NOV-ORF1–9F  | GCTAAATCATTTTGTGCGCCCGC | 5210     | ORF1       | This study|
| NOV-ORF1–9R  | AGCAAGAAGCTCATGTCACG | 5004     | ORF2       | This study|
| NOV-ORF2–1F  | GTACGCTCGACGACCATCAGG | 5887     | ORF2       | This study|
| NOV-ORF2–1R  | TGAAGGAGATGCAATCAGAGA | 5787     | ORF2       | This study|
| NOV-ORF2–2F  | AGTCCGAAAGGATGCTACAG | 6709     | ORF2       | This study|
| NOV-ORF2–2R  | AGGTTTATCCTGCGGTAYACCAG | 6630     | ORF3       | This study|
| NOV-ORF3–1F  | CGTGACTCCCGGCTTACG | 7487     | ORF3       | This study|
| NOV-ORF3–1R  | GAGTGACCGCGCCGCTG20 | Poly A    | (10)       |           |

*NOV, norovirus; ORF, open reading frame; RdRp, RNA-dependent RNA polymerase; VP, viral protein.
Appendix Figure 1. Human norovirus infection in dogs, Thailand. A) Diarrhea. B) Collection of fecal sample.
Appendix Figure 2. A) Phylogenetic tree of ORF2 of noroviruses. B) Phylogenetic tree of ORF2 of GII.4 noroviruses. Red circles indicate canine noroviruses from Thailand, green triangles indicate canine noroviruses from Finland, and blue squares indicate human noroviruses from Thailand. Trees were constructed by using MEGA version 7.026 (https://www.megasoftware.net) with the neighbor-joining algorithm and bootstrap analysis with 1,000 replications. Numbers along branches are bootstrap values, and numbers on the right of panel A indicate genogroups. Scale bars indicate nucleotide substitutions per site. ORF, open reading frame.