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Krisztian Banyai

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Diverse origin of P[19] rotaviruses in children with acute diarrhea in Taiwan: detection of novel lineages of the G3, G5, and G9 VP7 genes

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9 4 novel lineages of the G3, G5, and G9 VP7 genes
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14 7 Fang-Tzy Wu^{1,2}, Krisztián Bányai³, Jason C. Huang², Ho-Sheng Wu^{1,4*}, Feng-Yee Chang¹,
15 8 Jyh-Yuan Yang¹, Chao Agnes Hsiung⁵, Yhu-Chering Huang⁶, Jen-Shiou Lin⁷, Kao-Pin
16 9 Hwang^{8,9}, Baoming Jiang¹⁰, and Jon R. Gentsch¹⁰
17
18
19 10
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22
23 12 ¹ Center for Research and Diagnostics, Centers for Disease Control, Department of Health,
24 13 Taiwan
25

26 14 ² Department of Biotechnology and Laboratory Science in Medicine, National Yang-Ming
27 15 University, Taipei, Taiwan
28

29 16 ³ Veterinary Medical Research Institute, Budapest, Hungary
30

31 17 ⁴ School of Medical Laboratory Science and Biotechnology, Taipei Medical University,
32 18 Taipei, Taiwan.
33

34 19 ⁵ Institute of Population Health Sciences, National Health Research Institutes, Zhunan,
35 20 Taiwan
36

37 21 ⁶ Division of Pediatric Infectious Disease, Chang Gung Children's Hospital, Chang Gung
38 22 University College of Medicine, Taoyuan, Taiwan
39

40 23 ⁷ Division of Pediatric Infectious Disease and Department of Laboratory Medicine, Changhua
41 24 Christian Hospital, Changhua, Taiwan
42

43 25 ⁸ Division of Pediatric Infectious Disease, Department of Pediatrics, Chang Gung Memorial
44 26 Hospital, Kaohsiung Medical Center, Chang Gung University College of Medicine,
45 27 Kaohsiung, Taiwan
46

47 28 ⁹ School of Medicine, Children's Hospital, China Medical University & Hospitals, Taichung,
48 29 Taiwan
49

50 30 ¹⁰ Division of Viral Diseases, Centers for Disease Control and Prevention, Atlanta, USA
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60 33 *Corresponding author. Tel: 886 2 26531377; Fax: 886 2 27837779. Email: wuhs@cdc.gov.tw
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35 Running head: Novel P[19] rotavirus strains in Taiwanese children

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37 Disclaimer: The findings and conclusions in this report are those of the authors and do not
38 necessarily represent the views of the CDC.

For Peer Review

Abstract

We previously reported the detection of genotype P[19] rotavirus strains from children hospitalized with acute dehydrating diarrhea during a 5-year surveillance period in Taiwan. The characterization of 5 P[19] strains (0.4% of all typed), including 3 G3P[19], a novel G5P[19] and a unique G9P[19] genotype is described in this study. Phylogenetic analysis of the VP4, VP7, VP6, and NSP4 genes was performed, which demonstrated novel lineages for respective genotypes of the VP4 and the VP7 genes. The sequence similarities of the P[19] VP4 gene among Taiwanese human strains was higher (nt, 91.5%-96.2%; aa, 93.7%-97.6%) than to other P[19] strains (nt, 83.5%-86.6%; aa, 89.4%-94.1%) from different regions of the world. The VP7 gene of the 3 G3P[19] Taiwanese strains shared up to 93.4% nt and 97.5% aa identity to each other but had lower similarity to reference strain sequences available in GenBank (nt, < 90.1%; aa, < 95.6%). Similarly, the VP7 gene of the novel G5P[19] strain was only moderately related to the VP7 gene of reference G5 strains (nt, 82.2%-87.3%; aa, 87.0%-93.1%), while the VP7 gene of the single G9P[19] strain was genetically distinct from other known human and animal G9 rotavirus strains (nt, ≤92.0%; aa, ≤95.7%). Together, these findings suggest that the Taiwanese P[19] strains originated by independent interspecies transmission events. Synchronized surveillance of human and animal rotaviruses in Taiwan should identify possible hosts of these uncommon human rotavirus strains.

Key words

phylogenetic analysis, VP7, VP4, VP6, NSP4

Introduction

Group A rotaviruses are the leading cause of severe dehydrating gastroenteritis in young children worldwide. Globally, rotavirus infections account for an estimated 611,000 deaths each year among children < 5 years of age [Parashar et al., 2006]. Rotavirus particles are

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2
3 65 icosahedral, 70-75 nm in diameter and contain 11 genomic segments of double-stranded
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5 66 RNA. The two outer-layer proteins VP7 and VP4 form the basis of the dual classification
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8 67 system of group A rotavirus into G and P types [Estes and Kapikian, 2007]. Of the 24 G and
9
10 68 31 P genotypes currently known, at least 11 G types and 12 P types, in at least 70 different
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12 69 antigen combinations have been identified in humans [Matthijnsens et al., 2009]. Of these, 5
13
14 70 are globally common (G1P[8], G2P[4], G3P[8], G4P[8], and G9P[8]), while others are
15
16 71 unusual combinations of these common antigen types and may be only regionally important.
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18 72 Rare strains include mainly those antigen specificities that originate from periodic occurrence
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20 73 of animal-to-human interspecies transmission events. Examples for such strains include G5,
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22 74 G6, G8, and G11 VP7 genes or P[3], P[7], P[11], and P[19] VP4 genes, as well as rare genetic
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24 75 variants of common antigen types, such as G3 VP7 genes of porcine, feline, or lapine origin
25
26 76 or genetically diverse porcine-like P[6] or feline-like P[9] VP4 genes [De Grazia et al., 2010;
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28 77 Bányai et al., 2003, 2009a; 2009b, 2009c; Matthijnsens et al., 2006, 2009; Esona et al., 2009;
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30 78 Martella et al., 2006, 2008; Khamrin et al., 2006; Chitambar et al., 2009; Steyer et al., 2008].
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36 79 Based on sequence similarities, recently a new classification system has been
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38 80 proposed, which designates independent genotypes for each genome segment [Matthijnsens
39
40 81 et al., 2008a, 2008b]. This system is being appreciably adopted by the scientific community
41
42 82 and several research groups initiated partial or whole genome based strain characterization
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44 83 studies to extend information on features of circulating rotavirus strains. For example, among
45
46 84 the 9 non-serotype genes, the VP6 and NSP4 genes have been studied extensively due to their
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48 85 recognized relative genetic linkage and their potential use in determining the original host
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50 86 species for unusual strains with suspected heterologous origin [De Grazia et al., 2007, 2008,
51
52 87 2009; Chitambar et al., 2009; Bányai et al., 2009; Khamrin et al., 2009; Martella et al., 2008;
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54 88 Li et al., 2008; Araujo et al., 2007; Khamrin et al., 2006, 2007; Ghosh et al., 2007; Iturriza-
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56 89 Gomara et al., 2003].
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3 90 In Taiwan, rotavirus strain surveillance started in 2001 [Chen et al., 2005]. Studies
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5 91 have identified the globally common strains, although the predominant antigen types seem to
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7 92 change over time. We have recently reported strain prevalence data over a 3-year period from
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10 93 3 sentinel hospitals located in northern, central and southern Taiwan [Wu et al., 2009]. That
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12 94 study utilized a nucleotide sequence-based genotyping assay, in which type common PCR
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14 95 primers were employed to amplify full-length or partial outer capsid genes. In total 829
15
16 96 strains were genotyped. Among these strains we identified G1P[8] strains to be predominant,
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18 97 followed by G3P[8], G9P[8] and G2P[4] strains as additional medically important strains,
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20 98 while 11 further antigen combinations represented minority strains. Unexpectedly, among
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22 99 these minority combinations we detected 2 P[19] strains associated with a G3 and a G9 VP7
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25 100 gene. In subsequent extended surveillance, we detected 3 additional P[19] strains in 2008 and
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27 101 2009 seasons; 2 associated with G3 and 1 with G5 VP7 gene. In an attempt to better
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29 102 understand the origin and relationship of these strains to one another and the few hitherto
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31 103 characterized human and animal P[19] strains, we determined and analyzed the full length or
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33 104 nearly full length VP7 genes, the variable VP8* fragment of the VP4 gene, and the genotype
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35 105 diversity and potential genetic linkage among the NSP4 and the VP6 genes.
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43 **Materials and Methods**

44 *Case definition and data collection*

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46 108 From January 2005 to December 2009, a total of 6,346 stool specimens were collected from
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48 109 children less than 5 years old who were hospitalized for treatment of acute gastroenteritis
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50 110 (AGE) in 3 sentinel hospitals located in northern, central and southern Taiwan. AGE was
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52 111 defined as three or more episodes of watery diarrhoea or looser-than-normal stool in the 24 h
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54 112 before presentation.
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3 115 *Laboratory testing*
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5 116 Stool specimens were collected and screened for rotavirus VP6 antigen using an EIA kit
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8 117 (RIDASCREEN® Rotavirus, R-Biopharm AG, Germany) at each hospital. Rotavirus EIA-
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10 118 positive specimens were shipped to Rotavirus Reference Laboratory at Taiwan CDC for G-
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12 and P-genotyping.
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17 121 *RT-PCR and Polyacrylamide Gel Electrophoresis*
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20 122 Viral RNA was extracted from 10% (wt/v) fecal supernatants by MagNA Pure LC DNA
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22 123 isolation kit (Roche Diagnostics GmbH, Germany) according to the manufacturer's
23
24 124 instructions. The extracted RNAs were used as the template for RT-PCR with random primers
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26 125 [Wu et al., 2009]. Viral VP4, VP6, VP7 and NSP4 genes were amplified with primers sets
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28 126 Con3/Con2, JRG7/JRG8 or GEN-VP6F/GEN-VP6R, Beg9-End9, and JRG30/JRG31 as
29
30 127 described [Gentsch et al, 1992; Luan et al, 2009; Matthijssens et al, 2006; Gouvea et al, 1990;
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32 128 Esona et al; 2009]. Viral RNA samples were also analyzed by a 10% polyacrylamide gel and
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34 129 silver staining according to the manufacturer's protocol (Bio-Rad, Hercules, CA, USA).
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41 131 *Sequencing and phylogenetic analysis*
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43 132 PCR amplicons were directly sequenced with primers sets Con3/Con2, JRG7/JRG8 or GEN-
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45 133 VP6F/GEN-VP6R, Beg9-End9, and JRG30/JRG31 on a ABI 3130 sequencer (Applied
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47 134 Biosystems, CA, US). Rotavirus genotypes were determined using the RotaC software [Maes
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49 135 et al., 2009]. Multiple nucleotide sequences were aligned and the phylogenetic analysis was
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51 136 performed using MEGA 4.0 software [Tamura et al., 2007].
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56 138 **Results**
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59 139 *Genetic analysis of the VP4 genes.* A 831 bp fragment of the VP4 gene (corresponding to nt
60
140 34-864, strain Mc345) of 5 Taiwanese P[19] strains was sequenced. Along a shorter stretch

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3 141 (750 bp and 250 aa), these strains shared 91.5%-96.2% (nt) and 93.7-97.6% (aa) identities
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5 142 among each other and a lower similarity to 16 other P[19] strains detected in mainland Asia
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8 143 (range, nt, 83.5-86.6%; aa, 89.4-94.1%). In our phylogenetic analysis, both nt (Fig. 1A) and
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10 144 aa (not shown) trees demonstrated that Taiwanese P[19] strains fell into a discrete genetic
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12 145 lineage. An aa alignment of the VP8* fragment revealed 5 aa substitutions in the VP8*
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15 146 fragment of the protein, which were unique for the Taiwanese P[19] strains (Fig. 1B).
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20 148 *Genetic analysis of the VP7 genes.* As determined by nucleotide sequence based genotyping,
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22 149 the 5 Taiwanese P[19] strains exhibited 3 different VP7 specificities: G3 (03-98s185, 07-
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24 150 94s126, 07-97s684), G5 (04-97s51), and G9 (07-96s1118) (Fig. 2).
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26
27 151 The full or nearly full length coding region was determined for the G3 strains. These 3
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29 152 strains shared 92.8% - 93.4% nt (and 96.3% - 97.5% aa) similarities along a 972 bp long
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31 153 fragment to each other, and a lesser similarity to 183 reference G3 strains (nt, < 90.1%; aa, <
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33 154 95.6%). They are most closely related to porcine isolates (e.g., CP-1). Along the antigenic
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35 155 region these 3 Taiwanese strains shared high similarities, although 1 to 4 aa substitutions were
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37 156 seen (Fig. 3). Phylogenetic analysis found that these 3 strains clustered on a separate branch,
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39 157 distinct from other strains suggesting they represent a new lineage of the G3 VP7 gene (Fig.
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46 159 Identification of a G5P[19] strain in our sample collection was unexpected, as this
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48 160 antigen combination was not identified previously in humans. Sequence analysis of a 828 bp
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50 161 stretch of the VP7 gene of strain 04-97s51 revealed moderate sequence identity to 98
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52 162 reference G5 strains of both animal and human origin (range: nt, 82.2-87.3%; aa, 87.0-
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54 163 93.1%). Similar divergence was seen in the neutralization epitopes between 04-97s51 and
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56 164 selected G5 strains. Overall, these similarity ranges together with results of phylogenetic
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3 165 analysis suggested that this Taiwanese G5 strain fell into a new lineage of the G5 VP7 gene
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5 166 (Fig. 2).
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8 167 A fifth Taiwanese P[19] strain contained a G9 VP7 gene. Because this specificity was
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10 168 seen in both human and porcine strains in South-East Asia, it was interesting to see whether
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12 169 the Taiwanese isolate clustered with these human or animal rotavirus strains. Of note, the 07-
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14 170 96s1118 strain displayed limited sequence similarity with other G9 strains detected in Taiwan
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16 171 or other parts of the world. Overall, this Taiwanese G9 strain shared $\leq 92.0\%$ nt (and $\leq 95.7\%$
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18 172 aa) identity to any known G9 VP7 gene along the full coding region, including both human
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20 173 and porcine strains, and shared particularly lower similarity to the globally emerging variant
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22 174 of G9 VP7 gene (nt, $< 90\%$). The closest relatives were among the unique US OM46-like G9
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24 175 strains that were detected during 1997-1998 in Omaha (nt, 92%; aa, 95.1%). The
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26 176 neutralization epitopes of this novel Taiwanese G9 strain also suggested extensive divergence
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28 177 from other G9 strains. All these data demonstrated that 07-96s1118 is not only highly
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30 178 divergent from the globally emerging variant of G9 VP7 gene, but also divergent from all
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32 179 other G9 VP7 genes identified in surveillance studies over the last 30 years (Fig. 2, 3).
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41 181 *Genetic analysis of the VP6 and NSP4 genes.* The full or partial coding regions of the VP6
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43 182 and NSP4 genes were determined to further characterize the 5 identified Taiwanese P[19]
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45 183 strains. For the VP6 gene, the RotaC [Maes et al., 2009] online genotyping software that was
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47 184 developed to predict rotavirus A genotype specificities identified 2 VP6 genotypes among
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49 185 Taiwanese P[19] strains (Fig. 4). Four strains were classified as genotype I1, a common
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51 186 human VP6 specificity, while 07-96s1118, the unique Taiwanese G9P[19] strain shared only
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53 187 moderate sequence identity to other genotypes. The automated genotyping platform
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55 188 recommended validating the VP6 gene specificity of this strain through the RCWG, whose
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57 189 opinion was that this gene falls within the newly described I12 VP6 genotype. This genotype
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3 190 is currently represented by 2 strains, the reference human Bangladeshi G11P[25] strain,
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5 191 KTM368, and the Taiwanese G9P[19] strain, 07-96s1118. Phylogenetic analysis suggested
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8 192 this genotype is intermediate between genotype II ($\leq 85\%$) and I5 VP6 ($\leq 86\%$) genotypes and
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10 193 even its representative strains share only marginal nt identities to one another (87.6% nt). The
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12 194 other 4 P[19] strains shared ~90-98% nt identities among each other, and were most closely
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14
15 195 related to 2 porcine strains (i.e., 04-97s51-like P[19] strains vs. CN86, 97.8-97.9% nt
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17 196 identities and 03-98s185 vs. JL94, 91.1% nt identity).

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20 197 RotaC clustered all five Taiwanese P[19] strains into a single E1 NSP4 genotype with
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22 198 $\leq 93.4\%$ identity to reference strains (Fig. 4). The P[19] strains shared 93.0%-96.0% nt
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24 199 similarities among one another. Among the reference strains, the rare human-porcine
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26 200 reassortant strains (e.g., LL4260) were most closely related to these Taiwanese P[19] strains
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29 201 (range: nt, 91.7%-93.4%).

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31 202 Three of the 5 Taiwanese P[19] rotavirus strains with adequate amount of RNA were
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33 203 further examined for their RNA profiles by polyacrylamide gel electrophoresis (Fig. 5). The 2
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35 204 strains with G5P[19] and G9P[19] genotypes had long RNA electropherotypes similar to that
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37 205 of the reference Wa strain, whereas one G3P[19] strain, 03-98s185, had a super-short
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39 206 electropherotype as indicated by its rearranged gene segment 11.
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46 208 **Discussion**

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48 209 This study reports new findings of unusual P[19] rotavirus strains from our sentinel hospital
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50 210 based-surveillance during 2004 to 2009. Among 1183 strains G and P typed, there were 5
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52 211 isolates (0.4% of total) belonging to genotype P[19]. These isolates were identified from
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54 212 specimens collected from different years, one in 2005 (0.8%), one in 2007 (0.3%), two in
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56 213 2008 (1%) and one in 2009 (0.6%). Thus, these rare strains were circulating among humans or
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58 214 alternatively in an animal host in Taiwan during most of the surveillance period.
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3 215 There have been a few reports on rotavirus P[19] strain detection among animals and
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6 216 humans since 1990, beginning with the first report of the isolation and characterization of
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8 217 P[19] prototype strain 4F in 1994 [Burke et al., 1994]. Several other studies document
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10 218 detection of the virus in humans from Thailand [Urasawa et al., 1992], India [Varghese et al.,
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12 219 2004] and Vietnam [Nguyen et al., 2008]. In the present study, phylogenetic analysis revealed
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14 220 that the Taiwanese strains were genetically closely related to each other but were distinct from
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16 221 human or animal strains from other countries. For example, in the VP8* fragment of VP4
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18 222 there were 5 conserved aa substitutions found in Taiwanese P[19] strains compared to human
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20 223 or animal P[19] strains from other countries. In addition, 4 other aa sites, positions 15, 44, 73
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22 224 and 254, are more closely related to the prototype 4F strain than human or animal P[19]
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24 225 strains isolated from other Asian countries.
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29 226 The most prevalent VP7 genotypes in Taiwan were G1 (48.3%), G3 (24.5%), G9
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31 227 (14.1%), G2 (8.0%) and some rare genotypes like G4, G5 and G8 [Wu et al., 2009]. In most
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33 228 studies globally, G1 represented approximately 50-65% of the strains, followed by G3, G4,
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35 229 and G2 [Gentsch et al., 2005; Santos and Hoshino, 2005]. In addition, an increasing number
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37 230 of rare genotypes have been described recently, many of which have strong genetic
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39 231 relationships with animal rotaviruses [Matthijnssens et al., 2009].
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43 232 Among the G3 strains, we found 3 with P[19] specificity, one each from 2005, 2008
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45 233 and 2009. The nucleotide sequences of these 3 strains showed only moderate similarity
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47 234 between them (only 92.8% - 93.4%), and less similarity to 183 reference G3 strains. The most
48
49 235 closely related strain was a porcine isolate, CP-1 which clustered on a distinct branch by
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51 236 phylogenetic analysis. Demonstration that there were several amino-acid substitutions in the
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53 237 antigenic sites of these Taiwan G3 strains supports the proposal that they represent a new G3
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55 238 lineage.
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3 239 Human G5 rotaviruses were first reported in combination with genotype P[8] as a
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5 240 regionally common strain in Brazil during 2004 [Alfieri et al., 1996]. Unusual human G5P[6]
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8 241 rotaviruses were identified from AGE children under 5 in China and Vietnam [Ahmed et al.,
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10 242 2007; Li et al., 2008] and more recently, a G5P[7] strain new to humans, has been detected in
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12 243 Cameroon [Esona et al., 2009]. However, G5 strains had not previously been reported in
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15 244 Taiwan. In addition, this is the first report on detection and molecular characterization of a
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17 245 G5P[19] strain. Molecular features of the G5 VP7 gene of our Taiwanese strain belonged to a
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20 246 phylogenetic lineage distinct from those represented by other strains.
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22 247 Unlike the G5P[19] strain, the single Taiwanese G9P[19] strain is not the first
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24 248 representative of this particular antigen combination [Okada et al., 2000; Das et al., 2004;
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26 249 Mukherjee et al., 2010], however, it carried a G9 VP7 gene highly divergent from other
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29 250 currently known G9 VP7 genes, indicating that introduction of this particular gene into the
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31 251 human population in Taiwan was an independent evolutionary event from those events that
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34 252 occurred in other parts of the world during the past 3 decades. In a historical perspective, the
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36 253 DC706-like G9P[8] strains detected exclusively on the eastern coast of the USA represents
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38 254 the first documented evidence for human infection with G9 strains and could have caused a
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41 255 minor local outbreak [Cao et al., 2008]. Independent introduction associated with a different
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43 256 G9 VP7 gene lineage (WI61-like G9P[8]) was seen northeast from the site where DC706-like
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45 257 strains were detected during 1983 and this strain seemed to have some capacity to spread into
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48 258 other areas as evidenced by detections of closely related strains in subsequent years in Japan
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50 259 [Clark et al., 1987; Green et al., 1989]. A novel strain, Mc345-like G9P[19], was identified in
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53 260 Thailand in 1989 and its descendants were detected subsequently in this region [Urasawa et
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55 261 al., 1992; Okada et al., 2000; Das et al., 2004; Mukherjee et al., 2010]. Another novel strain,
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57 262 116E-like G9P[11], appeared during early 1990s in India in asymptomatic neonates [Das et
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60 263 al., 1993; Gentsch et al., 1993]. The first description of the globally spread variant of G9

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3 264 strains was also first detected in South Asia and genetically it was most closely related to
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5 265 Mc345-like strains. This variant of G9 strains that subsequently spread worldwide to become
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8 266 the 5th most common strain during a 10-year period are additional examples of introductions
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10 267 of G9 VP7 into human populations [Gentsch et al., 2005; Matthijnsens et al., 2009].
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12 268 Additional emergences seen in central region of the USA during mid-1990s by a divergent
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15 269 G9P[8] strain (OM46-like) [Laird et al., 2003], and other G9 strains (97'SZ37 and T203) with
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17 270 divergent VP7 genes were reported in far-east Asia [Xu et al., GenBank record; Dong et al.,
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19 271 2008]. While to date only the lineage III G9 strains have been proven to possess significant
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21 272 epidemiologic potential, the data on a new G9 VP7 gene variant from Taiwan clearly
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23 273 demonstrates that interspecies transmission events are more frequent and the G9 VP7 gene is
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25 274 genetically more divergent than previously thought based on a limited number of gene
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27 275 sequences.

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31 276 Overall, our findings demonstrate that the P[19] strains circulating in Taiwan are
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33 277 different from those in other Asian countries. The distinct evolutionary patterns of these
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35 278 strains may be explained by Taiwan's geographic separation from the rest of Asia by the
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37 279 Pacific Ocean and consequently minimal genetic contact with rotavirus strains of suspect
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39 280 animal reservoirs from other countries. Since P[19] strains may have originated in porcine
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41 281 species, it will be important to conduct surveillance and determine whether similar strains are
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43 282 also present among pigs in Taiwan.
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7
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3 456 **Figure legends**
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8 458 Fig. 1. A – Nucleotide sequence based phylogenetic trees of the P[19] VP4 gene. The arrows
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10 459 indicate the Taiwanese G3P[19], G5P[19], and G9P[19] strains. Bootstrap values >90% are
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12 460 indicated. Scale bars are proportional to the phylogenetic distance. Proposed lineage
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14 461 designation of the P[19] VP4 gene is indicated with I, II, and III, respectively. B – Amino
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16 462 acid alignment of the VP8* domain of VP4 gene. Lineage specific substitutions characteristic
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18 463 to Taiwanese strains are highlighted. Identical residues are shown with dashed line.
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24 465 Fig. 2. Nucleotide sequence based phylogenetic trees of the G3, G5 and G9 VP7 genes. The
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26 466 arrows indicate the Taiwanese G3P[19], G5P[19], and G9P[19] strains. Strain designated 03-
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28 467 98sP50 is a G5P[6] Taiwanese strain. Bootstrap values >90% are indicated. Scale bars are
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30 468 proportional to the phylogenetic distance.
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34 469
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36 470 Fig. 3. Primary structure of the predicted VP7 antigenic sites A, B, C, and F of Taiwanese and
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38 471 reference G3, G5, and G9 rotavirus strains. Dashed line indicates amino acid residue identities
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40 472 in the alignment.
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43 473
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45 474 Fig. 4. Nucleotide sequence based phylogenetic trees of the VP6 and the NSP4 genes of
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47 475 Taiwanese P[19] strains (the arrows indicate these strains). Bootstrap values >80% are
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49 476 indicated. Scale bars are proportional to the phylogenetic distance.
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55 478 Fig. 5. RNA profiles of P[19] rotavirus strains from children with diarrhea in Taiwan. Viral
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57 479 RNA was analyzed by polyacrylamide gel electrophoresis and silver staining. Lanes 1-5,
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3 480 strains Wa, DS-1. 04-97s51, 07-96s1118, and 03-98s185, respectively. Segments of the
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6 481 genome from the reference strain Wa are shown on the left.
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For Peer Review

Fig. 1A.

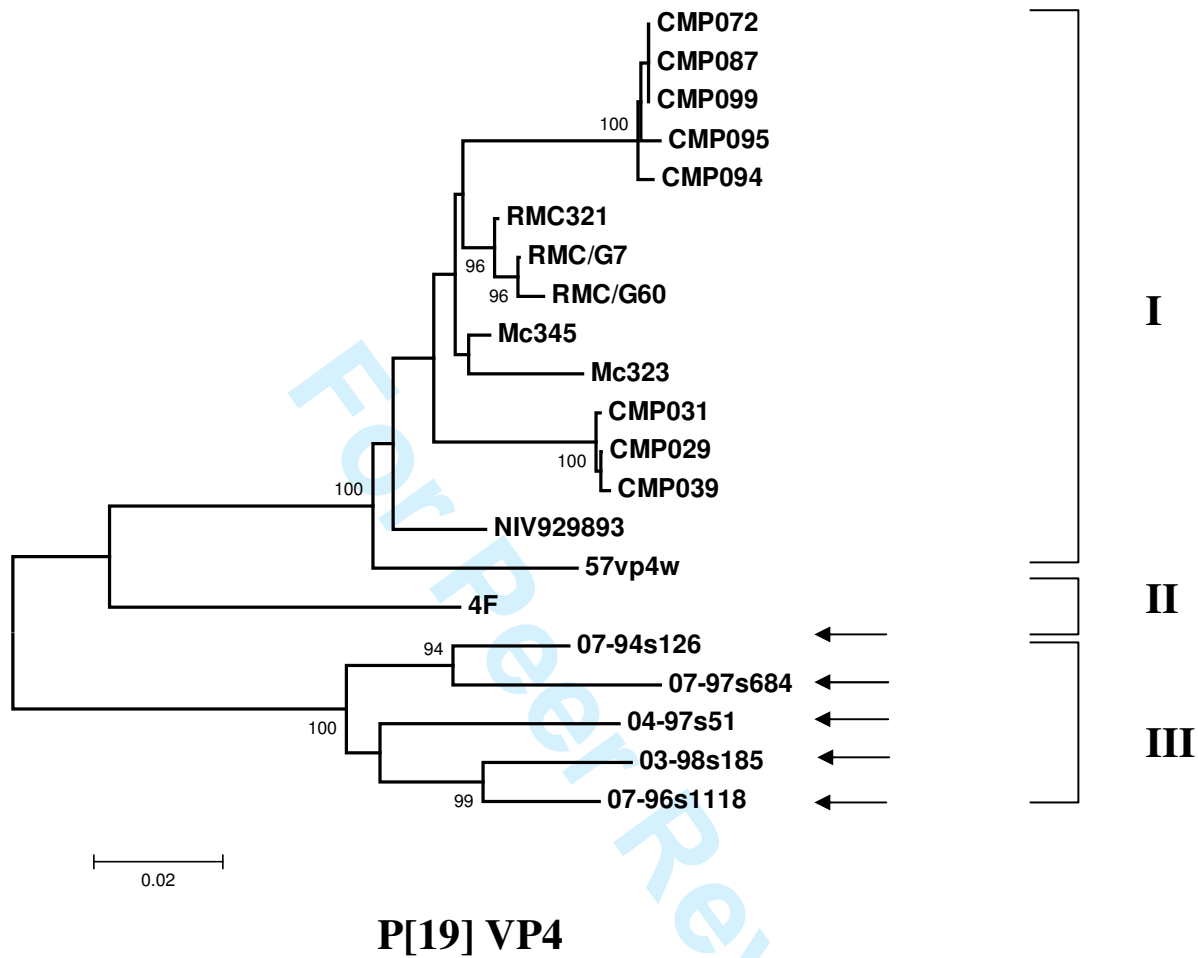


Fig. 1B.

	9	133
03-98s185	LLTNSYAVEL SDEIESIGSE KQWVTINPG PFAQTNYAPV NUGHGEINDS TTVEPVLDDG YQPVSFKPPN DYWILVNSNS NGVVLEGTNN TDVWVAIIIV EPNVNSERQ YSLFGVNRQI TVVNT	
04-97s51	-----D-----L-----I-----D-----	N----
07-94s126	-----D-----K-----D-----	-----Y-----
07-96s1118	-----D-----L-----D-----	-----F-----N----
07-97s684	-----D-----L-----D-----	-----F-----N----
NIV929893	-----T-----D-----A-----S-----S-----T-----I-----	-----I-----F-----N----
RMC321	-----T-----D-----T-----S-----S-----A-----I-----	-----I-----I-----
Mc345	-----T-----D-----T-----S-----S-----A-----I-----	-----I-----I-----
RMC/G7	-----T-----D-----T-----S-----S-----A-----I-----	-----I-----I-----
RMC/G60	-----T-----D-----T-----S-----S-----A-----I-----	-----I-----I-----
Mc323	-----T-----D-----TL-----S-----S-----A-----P-----I-----	-----I-----I-----V-----
CMP072	-----T-----D-----T-----S-----S-----A-----I-----	-----I-----I-----V-----
CMP029	-----T-----D-----TL-----S-----S-----A-----I-----	-----I-----I-----
CMP039	-----T-----D-----TL-----S-----S-----A-----I-----	-----I-----I-----
4F	-----D-----D-----ST-----D-----T-----S-----I-----L-----D-----	

	134	258
03-98s185	SSKWK FMEMFRNNS AEFQHKRTL SSTRLVGILK HGRRLWYHG ETPNATTDYS ATSNLNEISV TTHAEFYIIP RSQESKCTEY INTGLPPIQN TRWVPLSLT SRTVVYNTAQ VNEDIVISKA	
04-97s51	-----S-----	-----I-----R-----
07-94s126	-----V-----	-----I-----R-----
07-96s1118	-----I-----	-----I-----R-----
07-97s684	-----I-----	-----I-----R-----
NIV929893	-----K-----	-----M-----A-----IL-----R-----
RMC321	-----K-----	-----IHKR-----I-----
Mc345	-----K-----	-----IHKR-----I-----
RMC/G7	-----K-----	-----IHKR-----I-----
RMC/G60	-----K-----	-----IHKR-----I-----
Mc323	-----K-----NI-----	-----IHKR-----I-----
CMP072	-----N-----R-----K-----I-----	-----IHKR-----I-----
CMP029	-----V-----R-----K-----N-----	-----IHKR-----I-----
CMP039	-----V-----R-----K-----N-----	-----IHKR-----I-----
4F	-----V-----R-----K-----N-----	-----I-----KR-----

1 Fig. 2.

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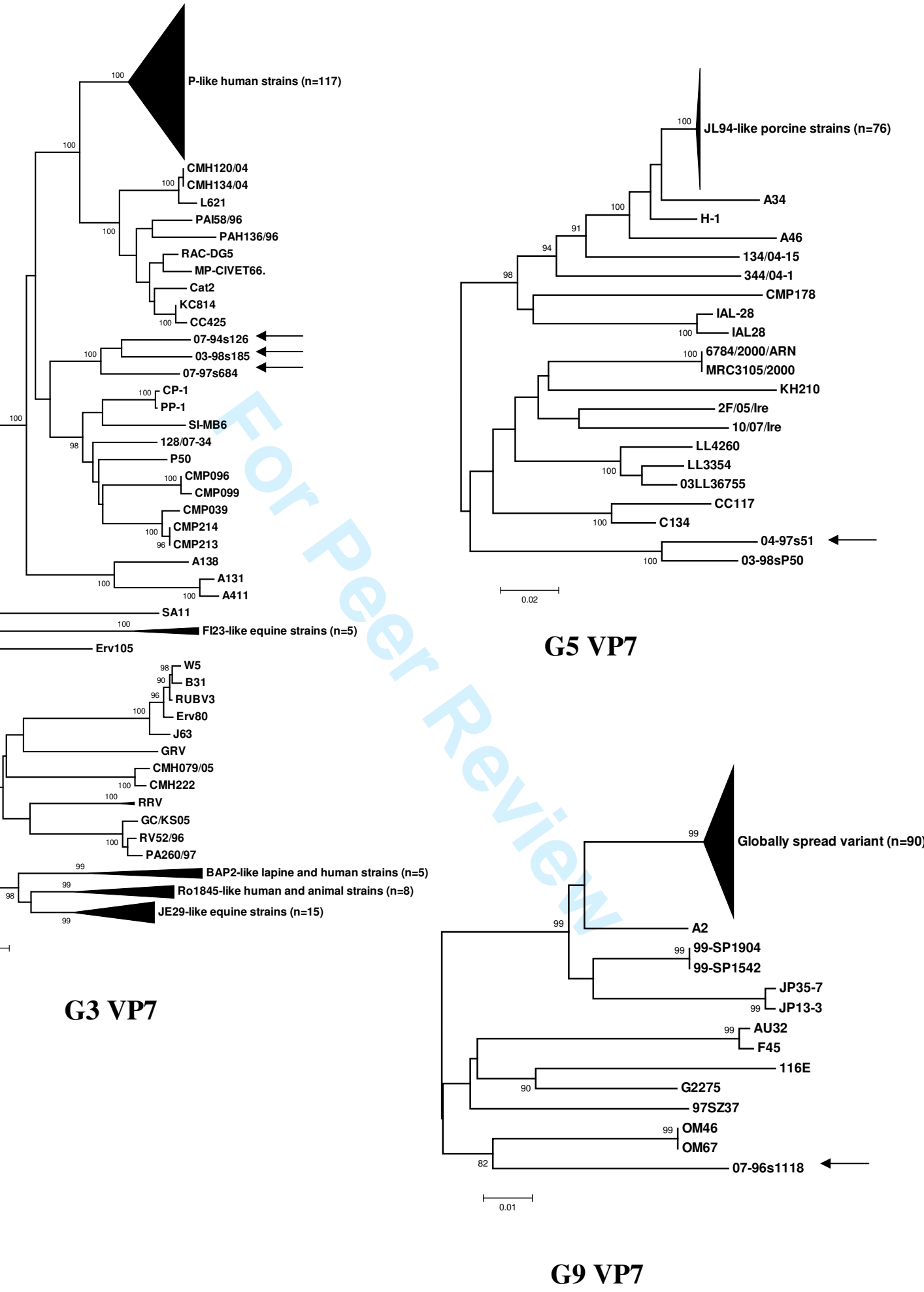
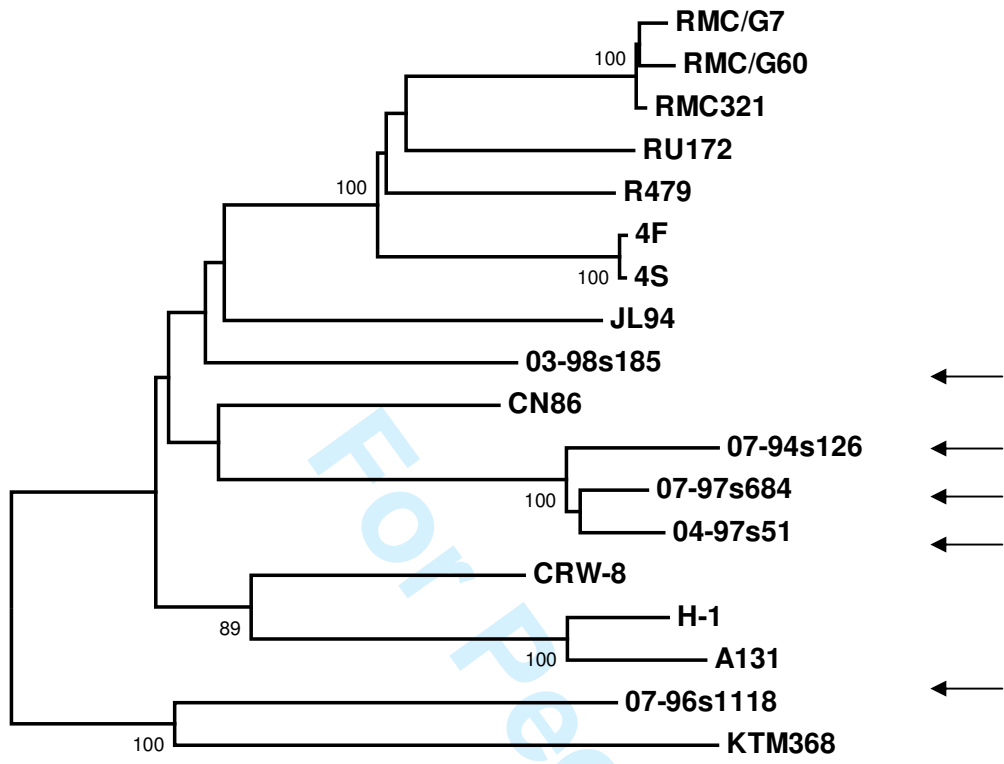


Fig. 3.

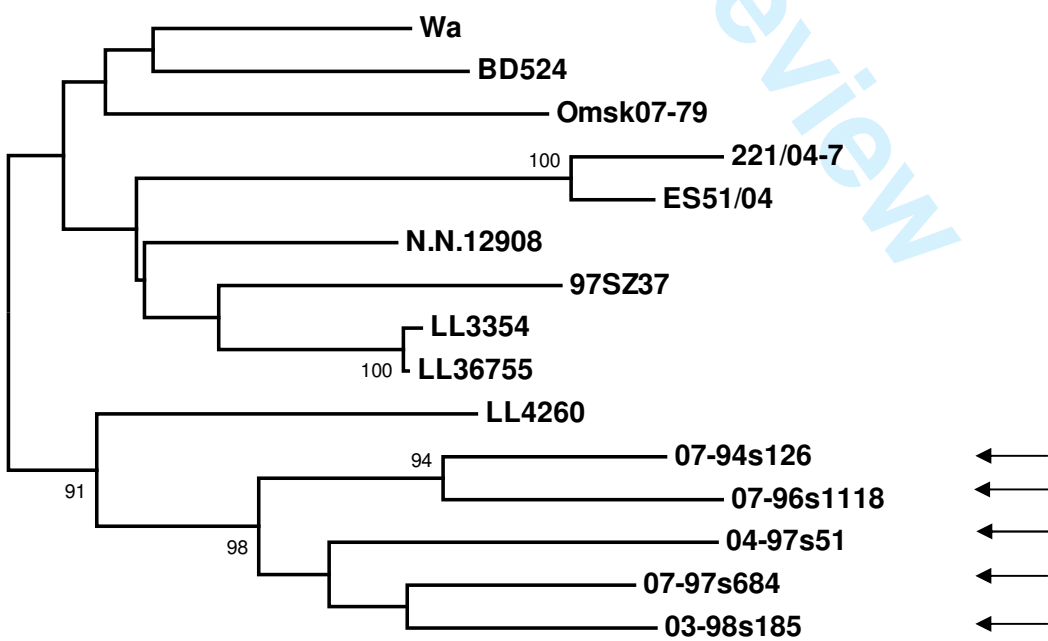
ANTIGENIC REGION:	A (87-101)	B (143-152)	C (208-221)	F (235-245)
G3 VP7				
07-94 _s 126	AEAAREINDNSWKDT	KYDATLQLDM	LTTDTNTFEEVATA	HKLSVTTNTCT
07-97 _s 684	T-----	---A---	-----	-----MD---
03-98 _s 185	-----	---A---	-----	-----
CMP039	T---TQ-----	---A---	-----	-----
CP-1	T---TQ-----	-----	-----	-----
T108	T---T---D---	-----	-----	---N-----
P	T---T-----	-----	-----	---N-----
Cat2	T---T-----	-----	---S-----	---N-----
A131	T---T-----	-----	---I-N-----	-----
RRV	T---T-----	-----	---A-----	---D---A---
J63	T---T-----	---V-----	-A-AT-----	---D---T---
Erv105	T---T-----	---V-----	---T-----	---D---A---
JE29	T---VA-----	---NE-----	---T-----	---D---S---
HCR3A	T---T-----	---A-----	---VS-----T	---D---T---
30/96	T---T-----	---A-----	---NAA-----	---D---A---
G5 VP7				
04-97 _s 51	NEAATEIADNKWTET	KYDANLQLDM	TTTDINSFEVVANA	HKLDVTTNTCT
C134	-----Q-----	-----	L---T---T---S-	-----
LL4260	-----	-----	L---T---I---	-----S---
A34	-----T-----	---G-----	S-----T---	-----S---
KJ75	-----T-----	---G-----	S---D---T---	-----S---
H-1	-----T-----	---G-----	S-----T---ST	-----S---
6784/2000/ARN	-----S-----	-----	S---TS---T---	-----
10/07/Ire	-----	-----	S---T---T---	-----
2F/05/Ire	-----T-----	-----	S---T---M---	-----
IAL28	-----D---D-	---I-----	L---TS---T---ST	-----S---
344/04-1	-----T-----	---G-----	S---K---T---	-----
A46	-----T-----	---G-----	S-----I---	-----
134/04-15	-----A-----	---E-----	L-----T---	-----
G9 VP7				
07-96 _s 1118	TEASTQIGDTEWKNT	KHDSTLELDM	TTTNPATFEEVAKN	HKLDVTTSSCT
99-SP1542	-----	T-----	---A-----TS	-----NT--
978Z37	-----D-	-Y-----	-----AS	-----NT--
CMH274	-----D-	-Y-----	I---T-----TS	-----NT--
116E	I-----G-	-YN-----	---T-----T-	-----NT--
F45	A-----D-	-Y-----	---T-----AS	-----TT--
OM46	-----D-	-Y-----	---T-----AS	-----NT--
G2275	-----D-	-Y-----	---T-----AS	-----NT--
JP35-7	-----P-----	-Y-----	---T-----TG	-----NT--
A2	-----	-Y-----	I---K---T-	-----NT--
US1206	-----D-	-Y-----	I---T-----TS	-----NT--

Fig. 4.

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VP6 gene



NSP4 gene

Fig. 5.

