We investigated the molecular epidemiology of foot-and-mouth disease virus (FMDV) serotype Asia 1, which caused outbreaks of disease in Asia during 2003–2007. Since 2004, the region affected by outbreaks of this serotype has increased from disease-endemic countries in southern Asia (Afghanistan, India, Iran, Nepal, Pakistan) northward to encompass Kyrgyzstan, Tajikistan, Uzbekistan, several regions of the People’s Republic of China, Mongolia, Eastern Russia, and North Korea. Phylogenetic analysis of complete virus capsid protein 1 (VP1) gene sequences demonstrated that the FMDV isolates responsible for these outbreaks belonged to 6 groups within the Asia 1 serotype. Some contemporary strains were genetically closely related to isolates collected historically from the region as far back as 25 years ago. Our analyses also indicated that some viruses have spread large distances between countries in Asia within a short time.

Foot-and-mouth disease virus (FMDV) is an *Aphthovirus* within the family *Picornaviridae* that infects domestic and free-ranging cloven-hoofed mammals. The virus occurs as 7 serotypes, and immunity after vaccination or after infection is type specific (1–3). Diversity is also apparent within serotypes, and phylogenetic studies have proved useful for tracing the origin of foot-and-mouth disease (FMD) outbreaks (4).

FMDV is highly contagious, and this, together with its ability to infect different hosts and to exist as multiple types and variants, makes FMD difficult to control and a severe constraint to international trade of livestock and their products. FMD is endemic to regions of South America and large areas of Africa and Asia, and it can readily cross international boundaries to cause epidemics in previously disease-free areas (5). High densities of ruminants and swine in Asia create potential reservoirs of virus maintenance and evolution not influenced by control measures. Intense trading of animals and their products from these reservoirs results in widespread dissemination of viruses within and outside this continent. Therefore, epidemiologic surveillance of FMD in Asia is essential for the timely detection of the emergence of new strains that could threaten neighboring countries (6) and for selecting the most appropriate vaccine strains for use and storage in emergency vaccine reserves (7).

Globally, FMDV serotypes O and the A are the most prevalent. However, Asia has its own unique serotype,
Asia 1, first detected in samples collected in India in 1951 through 1952 (8) and Pakistan in 1954 (9). The primary serotype-endemic region for Asia 1 seems to be the Indian subcontinent (Afghanistan, India, Pakistan, Bhutan, Nepal), where outbreaks occur regularly, and some have speculated that this distribution is related to that of the Asian water buffalo (Bubalus bubalis). The serotype has been more sporadically reported from countries to the west or east; it has spread periodically into the Middle East and occasionally to Europe (10–13), but it has not been reported from Africa or the Americas. However, even in its endemic heartland, the Asia 1 serotype has normally been the cause of only a small proportion of cases compared with the proportion caused by serotypes O and A. For example, a study that reviewed FMDV in the West Bengal region of India described recovery of Asia 1 from only 15% of FMD cases examined between 1985 and 2002 (14). Similarly, in Southeast Asia, where serotypes O and A are prevalent every year, outbreaks due to Asia 1 have been reported only sporadically in the past 10 years; a recent gap in reporting occurred between 2002 and 2005 (Table; online Technical Appendix Table 1, available from www.cdc.gov/EID/content/15/7/1046-Techapp.pdf).

During 2004, evidence showed possible northward spread of the Asia 1 serotype; outbreaks were reported in Kyrgyzstan and Tajikistan. In early 2005, an outbreak was recorded in Hong Kong Special Administrative Region, People’s Republic of China, which suggested that the virus might have crossed China. Later in 2005 and 2006, outbreaks of FMD Asia 1 were reported in several provinces and autonomous regions of China and in Mongolia and Eastern Russia (15). In 2005 and 2006, this serotype reappeared in Southeast Asia (Vietnam and Myanmar). This apparent upsurge in cases across a wide geographic area (Figure 1; online Technical Appendix Table 1) prompted the current collaborative study to determine the relationships between viruses, with the goal of better understanding the origin of these Asia 1 disease outbreaks.

Materials and Methods

Viruses

Clinical samples containing FMDV Asia 1 were received from Afghanistan, China, Hong Kong, Iran, Kyrgyzstan, Mongolia, Myanmar, Pakistan, Russia, and Tajikistan by the Food and Agriculture Organisation World Reference Laboratory for FMD (WRLFMD), FGI All-Russian Research Institute for Animal Health (Russian Federation), Lanzhou Veterinary Research Institute (China), Project Directorate on FMD (India), Plum Island Animal Disease Center (USA), and Pakchong Regional Reference Laboratory for FMD (Thailand) (online Technical Appendix Table 2).

RNA Extraction, Reverse Transcription–PCR, and DNA Sequencing

RNA extraction, 1-step reverse transcription–PCR (RT-PCR), and DNA sequencing were performed as previously described (6), except that the primer annealing temperature in the RT-PCR was 55°C. The primers used for RT-PCR and DNA sequencing are listed in online Technical Appendix Table 3. Specific methods used by each laboratory can be obtained on request.

Phylogenetic Analysis

Sequences of these viruses were compared with complete VP1 sequences of Asia 1 viruses stored in the WRLFMD database (n = 300) that have previously been published

| Country                      | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|------------------------------|------|------|------|------|------|------|------|------|------|
| India                        | x    | x    | x    | x    | x    | x    | x    | x    | x    |
| Pakistan                     |      | x    | x    | x    | x    | x    | x    |      |      |
| Iran                         | x    | x    | x    | x    | x    | x    | x    | x    |      |
| Nepal                        | x    | x    | x    | x    | x    | x    | x    | x    |      |
| Bhutan                       |      | x    |      |      |      |      |      |      |      |
| Tajikistan                   |      |      |      |      |      |      |      |      |      |
| Kyrgyzstan                   |      |      |      |      |      |      |      |      |      |
| Afghanistan                  |      |      |      |      |      |      |      |      |      |
| Turkey                       |      |      |      |      |      |      |      |      |      |
| Myanmar                      |      | x    |      |      |      |      |      |      |      |
| Laos                         |      |      |      |      |      |      |      |      |      |
| Thailand                     |      |      |      |      |      |      |      |      |      |
| Vietnam                      |      |      |      |      |      |      |      |      |      |
| People’s Republic of China   |      |      |      |      |      |      |      |      |      |
| Hong Kong                    |      |      |      |      |      |      |      |      |      |
| Mongolia                     |      |      |      |      |      |      |      |      |      |
| North Korea                  |      |      |      |      |      |      |      |      | x    |
| Russian Federation           |      |      |      |      |      |      |      |      |      |

*Since 2005, countries are required to report a change in their foot-and-mouth epidemiologic situation only to the World Organisation for Animal Health.

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Results

The phylogenetic analysis of the complete VP1 gene sequences from isolates of serotype Asia 1 characterized in this study showed that recent viruses (isolated during 2003–2007) belonged to 6 different groups (I–VI) (Figure 2; online Technical Appendix Figure 1). These groups were defined by members of a group having 95%–100% nucleotide identity (online Technical Appendix Figure 2). All groups were supported by bootstrap values of 80%–100% (online Technical Appendix Figure 1) and were found by using alternative phylogenetic algorithms (maximum parsimony and maximum likelihood) (data not shown). Most virus groups were monophyletic. However, 1 group (VI) fell into 3 distinct lineages (a, b, c) and appeared to be ancestral to group II viruses (Figure 3, panel B). This grouping was also evident from the percentage identity matrix, in which the values between viruses in group VI and those in group II were 91.8%–95.9% (online Technical Appendix Figure 2). Relationships between groups II, III, and VI and between group IV and some unnumbered groups were also evident (online Technical Appendix Figure 2).

(10,16–18) or published in this article. Complete VP1 sequences were used to construct a midpoint-rooted neighbor-joining tree using the Kimura 2-parameter nucleotide substitution model as implemented in the program MEGA 4.0 (19). The robustness of the tree topology was assessed with 1,000 bootstrap replicates as implemented within the program. The topography of this tree was also checked by the maximum-parsimony (MEGA 4.0) and maximum-likelihood (TREE-PUZZLE 5.2) (20) methods, including a selection of isolates from each group to check the robustness of the topography. Subsequently, the sequences were ordered, based on their position in the neighbor-joining phylogenetic tree, and a matrix of percentage nucleotide differences was constructed by using MEGA 4.0. The matrix was imported into Excel 2007 (Microsoft Corporation, Redmond, WA, USA), and conditional formatting was used to identify relationships between sequences in the ranges 95%–100% and 90%–94.9%. The former value was used to group the most closely related virus sequences.

Figure 1. Origin (country and/or region) of isolates of foot-and-mouth disease virus serotype Asia 1 that were responsible for outbreaks in Asia during 2003–2007. The 6 different groups and their localities are indicated by different colors. AR, Autonomous Region; SAR, Special Administrative Region.

Figure 2. Midpoint-rooted neighbor-joining tree showing the relationships between the complete VP1 sequences of Asia 1 foot-and-mouth disease virus isolates studied. Only the tree structure is shown; details of the labeled groups are given in Figure 3. Scale bar indicates nucleotide substitutions per site. The complete tree with all viruses labeled is shown in online Technical Appendix Figure 1 (available from www.cdc.gov/EID/content/15/7/1046-Techapp.pdf). SEA, group of viruses found in only in Southeast Asia and Hong Kong.
Viruses that were circulating in Iran in 2004 belonged to 2 different groups (I and VI) (Figures 3, panels A and B). One isolate in group I, collected in Iran in 2004 (IRN/25/2004), was closely related to 8 viruses collected in Afghanistan and Iran in 2001. Other isolates collected in Iran during 2004 belonged to group VIb (e.g., IRN/30/2004) and had <7% nucleotide differences with isolates in group II that were collected in Uzbekistan (2003), Tajikistan (2003–2004), Afghanistan (2004), Kyrgyzstan (2004), Hong Kong (2005), and Pakistan (2002–2004). The report of FMDV Asia 1 in Hong Kong in 2005 was the first since 1980. Notably, the viruses collected in Uzbekistan, Tajikistan, Kyrgyzstan, and Hong Kong in 2003–2005 had <3% nucleotide differences, which suggests that the outbreaks were closely connected and that this virus may have spread a long distance in a short period; however, how this occurred remains unexplained.

Similarly, other viruses collected from Pakistan in 1998, 2003, and 2005 (group VIa) were closely related to viruses responsible for outbreaks in Iran (IRN/58/99), Turkey (TUR/3/2000 and TUR/6/2000), Armenia, Greece (GRE/2/2000), and Georgia from 1999 through 2001 (Figure 3, panel B) and from partial VP1 sequences (data not shown) (10,12). These data suggest that this epidemic may have originated in Pakistan. Previously, Asia 1 epidemics occurred in 1973 and 1983–1985. In 1973, the virus spread through Iran and Turkey without any traceable origin (10) (Figure 3, panel A), and in 1983–1985, genetically closely related viruses were found in many Middle Eastern countries, including Armenia, Azerbaijan, Bahrain, Georgia, Greece, Israel, and Lebanon (represented in online Technical Appendix Figure 1 by LEB/83 and GRE/1/84). However, the ultimate source of this virus strain was also not established (4,10). Surprisingly, FMD isolates collected in Pakistan in 2003 and 2005 (group VIa) were closely related to PAK/2/98, which had been isolated 5–7 years earlier, with 0.3% and 0.0% nucleotide differences, respectively (Figure 3, panel B). These differences would be consistent with a laboratory escape, use of an improperly inactivated vaccine, or laboratory contamination.

Group III contained only viruses that were collected in India during 2001–2004 and Bhutan (n = 2) during 2002 (Figure 3, panel C). Many other older virus lineages were evident in the phylogenetic analysis (online Technical Appendix Figure 1), showing the diversity of Asia 1 viruses in India. However, most of these lineages have not been detected outside the region, which suggests that endemic Asia 1 viruses rarely spread outside the Indian subcontinent. The reason is not understood.

Within group IV (Figure 3, panel A), FMD Asia 1 viruses responsible for outbreaks in China (Yunnan Province) and Vietnam in 2005 and 2006 were related to viruses originating from Southeast Asia that were collected in Thailand in 1998 and Myanmar in 2005. Viruses in group IV belonged to a larger, more diverse, group of viruses that were found in only in Southeast Asia and Hong Kong from 1974 through 2006 (indicated in Figures 2 and 3, panel A, as SEA). Only 2 viruses originating from Southeast Asia fell outside this supergroup, Bangkok/Thailand/60 (an old vaccine virus strain) and MYA/2/2001 (online Technical...
Appendix Figure 1). The latter virus clustered with Indian virus isolates, suggesting a possible introduction into Myanmar from the west. In addition, in Myanmar, several viruses belonging to 2 sublineages of group IV were detected in a relatively short period (1997–2000 and 2005; Figure 3, panel A), which implies that either multiple lineages are present or that multiple introductions have been made into that country.

FMDV isolates collected in different places in China, the Russian Federation, and Mongolia, during 2005–2006 (group V) were different from viruses isolated in Hong Kong in 2005 (group II) with 16.1%–17.2% nucleotide difference. Another virus belonging to group V has recently (2007) been identified as causing an outbreak of FMD in North Korea (NKR/2/2007) (Figure 3, panel A). The disease likely was introduced by importation of live calves from Liaoning Province, China. Of the 461 susceptible cattle, 431 (≈93%) were infected. All 461 susceptible cattle were destroyed. No cases were exhibited in swine, but 2,630 susceptible swine were destroyed (21). Viruses collected in the different provinces or regions of China, Russia, Mongolia, and North Korea during 2005–2007 were closely related to older viruses from India (Tamil Nadu) collected in 1976 and 1980–1981. The nucleotide differences between the Indian viruses and those from China, Mongolia, Russia, and North Korea (Figure 3, panel A) were 0.8%–4.6%, yet the viruses differed markedly from those that were collected more recently in India (group III; Figure 3, panel C) during 2003–2004 (n = 20); nucleotide difference was 12.8%–14.7%. No explanation is readily available, and further investigations need to be performed to determine the origin of the virus responsible for the outbreaks in China. Recently, 7 complete VP1 sequences of Asia 1 FMDV, originating from samples taken from cattle in 2006 in Yunnan Province close to the Myanmar border, were deposited in the public databases (accession nos. EU091342–EU091348; W. Zhang, Y. Hu, F. Zhang, unpub. data). An additional VP1 sequence from a virus from pigs in Sichuan Province in 2006 was also deposited (accession no. EU887277; H. Wang, X. Yang, H. Luo, unpub. data). Five of these sequences belonged to group IV and 2 belonged to group V (Figure 3, panel A), indicating movements of viruses between China and Southeast Asia and the presence of group V viruses in a more southerly distribution than has previously been reported.

Discussion

This phylogenetic study demonstrates that the viruses from groups II and V that have been responsible for FMD outbreaks in China appear to have spread large distances in a short time, although the means is unknown. The possibility of spread of viruses of these 2 groups beyond the border where they have been detected must be considered as a potential risk. Furthermore, the close relationships between some recent and older isolates within group V (India 1976–1981 vs. China/Mongolia/Russia/North Korea 2005–2007) and group VIa (Pakistan 1998 vs. Pakistan 2003–2005) raises the question of their origins, either as a result of an unusually slow evolutionary rate or as reintroductions of laboratory/vaccine virus strains.

In Asia, vaccination against FMD varies from country to country; generally, only cattle and water buffalo are vaccinated. Various vaccine strains are used in the region, and vaccines are produced either by large pharmaceutical companies or by national or regional FMD vaccine laboratories. Vaccine matching studies are performed in various FMD reference laboratories on an ad hoc basis, and reference reagents for all the vaccine strains are not always available. This situation requires improvement.

These studies suggest rapid spread of FMD viruses across Asia, but the means by which the viruses are moved has rarely been determined. The spread of some of these FMDV Asia 1 lineages across large parts of Asia, and occasionally outside Asia, demonstrates the continuing need for active surveillance to be improved in Asia to provide real-time monitoring of virus evolution and to disclose more effectively the links between outbreaks. The means of virus transport needs also to be defined, taking into consideration the role played by large antelope populations in central Asia. This information is needed as a prerequisite for further development of regional control programs. India, Pakistan, and China, with their large livestock populations, are expected to play a major role in FMD control in this part of the world.

Acknowledgments

We thank Geoff Hutchings, Jemma Wadsworth, Kate Swabey, Paul Davies, and Rebecca Midgley for valuable technical assistance. We also thank Don King and an anonymous referee for valuable suggestions on the improvement of the manuscript.

This work was supported by the Department for Environment, Food and Rural Affairs, UK (Reference Laboratory Contract and Research Grant numbers SE2921 and SE2935). Virus isolation and serotyping at the Institute for Animal Health (IAH) was also supported by Defra under a Reference Laboratory Contract. The work conducted at the IAH was registered by the British Standards Institution to ISO 9001:2000 (certificate number FS 60875).

Dr Valarcher is a veterinary clinician and virologist. His research interests focus on infectious diseases of livestock and their control.
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Multiple Origins of Foot-and-Mouth Disease
Virus Serotype Asia 1 Outbreaks,
2003–2007

Technical Appendix

Table 1. Geographic information and virus phylogenetic characterization on outbreaks of FMD type Asia 1 reported to the OIE or detected by FMD reference laboratories between 2003 and 2007*

| Country                        | Location                             | Date      | Phylogenetic group | Information source (comment)                      |
|--------------------------------|--------------------------------------|-----------|--------------------|---------------------------------------------------|
| Afghanistan                    | Ghazni                               | 2004      | II                 | PIADC                                             |
| Afghanistan                    | Balkh                                | 2004      | II                 | PIADC                                             |
| China                          | Sheung Shui, New Territories, Hong Kong SAR | 2005 Mar 9 | II              | OIE; WRLFMD                                       |
| China                          | Wuxi city, Huishan district, Jiangsu Province | 2005 Apr 18 | V                | OIE (1 outbreak)                                 |
| China                          | Tai’an city, Daiyue district, Shandong Province | 2005 Apr   | V                 | OIE (1 outbreak)                                 |
| China                          | Beijing Province                    | 2005 May  | V                  | OIE                                               |
| China                          | Xinjiang Autonomous Region           | 2005 May  | NK                 | OIE                                               |
| China                          | Hebei Province                      | 2005 May–June | V              | OIE                                               |
| China                          | Qinghai Province                    | 2005 Jul  | V                  | OIE                                               |
| China                          | Gansu Province                      | 2005 Dec  | NK                 | OIE                                               |
| China                          | Ningxia Autonomous Region           | 2005 Dec  | NK                 | OIE                                               |
| China                          | Qinghai Province                    | 2005 Dec  | NK                 | OIE                                               |
| China                          | Shandong Province                   | 2005 Dec  | NK                 | OIE                                               |
| China                          | Jiangsu Province                    | 2005 Dec  | NK                 | OIE                                               |
| China                          | Hubei Province                      | 2006 May  | V                  | OIE                                               |
| China                          | Gansu Province                      | 2006 May–Jun | NK            | OIE                                               |
| China                          | Qinghai Province                    | 2006 Jul-Sep | NK              | OIE                                               |
| China                          | Tibet Autonomous Region             | 2006 Sep  | NK                 | OIE                                               |
| China                          | Yunnan Province                     | 2006      | IV, V              | Centre for Animal Disease Control and Prevention of Yunnan Province |
| China                          | Chongqing, Sichuan Province         | 2006 Nov  | V                  | OIE                                               |
| China                          | Gansu Province                      | 2006 Nov  | NK                 | OIE                                               |
| China                          | Xinhe, Xinjiang Province            | 2007 Jan 23 | NK               | OIE (subclinical infection)                       |
| China                          | Jintai Agri-Animal Industry Group, Jintai, Gansu Province | 2007 Jan 28 | V                | OIE (clinical disease)                           |
| China                          | Qinglin, Datong, Qinghai Province   | 2007 Feb 8 | NK           | OIE (clinical disease)                           |
| China                          | Nalong, Huanyuan, Qinghai Province  | 2007 Feb 25 | NK       | OIE (clinical disease)                           |
| China                          | Nalong, Huanyuan, Qinghai Province  | 2007 May 12 | NK       | OIE (clinical disease)                           |
| China                          | Duona, Yushu prefecture, Qinghai Province | 2007 Jun 7 | NK                | OIE (107 cattle plus 50 yaks were infected and showed clinical signs) |
| China                          | Jiaqiao, Qinghai Province           | 2007 Oct 24 | NK              | OIE (clinical disease)                           |
| China                          | Quokou, Pingjao, Ningxia Hui Autonomous Region | 2008 Mar 12 | NK              | OIE (1 outbreak)                                 |
| China                          | Qiangganyu, Gangu, Tianshui, Gansu Province | 2008 Nov 6 | NK              | OIE (1 outbreak)                                 |
| India                          | Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Tamil Nadu, Tripura, West Bengal | 2003–2004 | III               | PD-FMD                                            |
| Iran                           | Damshahr, Qom, Qom                   | 2004 Sep 28 | II               | WRLFMD                                            |
| Iran                           | Oromieh, West Azerbaijan             | 2004 Nov 8 | I                 | WRLFMD                                            |
| Iran                           | Not known                            | 2004      | II                | WRLFMD/ARRIAH                                     |
| Kyrgyzstan                     | Not known                            | 2004      | II                | WRLFMD/ARRIAH                                     |
| Country        | Location                                      | Date          | Phylogenetic group | Information source (comment) |
|---------------|-----------------------------------------------|---------------|--------------------|-----------------------------|
| Myanmar       | Demaw-Hsoe, Likaw, Kayah                      | 2005 Jul 27   | IV                 | OIE                         |
| Myanmar       | Saw, Gantgaw, Magway                          | 2005 Nov 22   | NK                 | OIE                         |
| Mongolia      | Dormod                                        | 2005 Aug      | V                  | OIE, ARRIAH                 |
| North Korea   | Pyongyang                                     | 2007          | V                  | WRLFMD                      |
| Pakistan      | Not known                                     | 2005 Oct 9    | II                 | WRLFMD                      |
| Pakistan      | Lahore, Punjab                                | 2003          | VI                 | WRLFMD                      |
| Pakistan      | Not known                                     | 2004          | II                 | WRLFMD                      |
| Pakistan      | Lahore and Kharian, Punjab                    | 2005 Jan–Feb  | VI                 | WRLFMD                      |
| Russia        | Chitinskaya                                   | 2006 Jan      | V                  | OIE, ARRIAH                 |
| Russia        | Amur                                          | 2005 Jun      | V                  | OIE, ARRIAH                 |
| Russia        | Amur                                          | 2005 Dec      | V                  | OIE, ARRIAH                 |
| Russia        | Khabarovsk                                    | 2005 Aug      | V                  | OIE, ARRIAH                 |
| Russia        | Khabarovsk                                    | 2005 Dec      | V                  | OIE, ARRIAH                 |
| Russia        | Primorsky                                     | 2005 Sep      | V                  | OIE, ARRIAH                 |
| Tajikistan    | Khatlonsky region, Vakhdatsky region, Gissarsky region | 2003 | II | ARRIAH |
| Tajikistan    | NK                                            | 2004          | II                 | ARRIAH                      |
| Uzbekistan    | NK                                            | 2003          | II                 | ARRIAH                      |
| Vietnam       | Van Ninh, Khanh Hoa                           | 2005 Oct 10   | IV                 | OIE                         |
| Vietnam       | Si Ma Cai, Lao Cai                           | 2005 Oct 13   | IV                 | OIE                         |
| Vietnam       | NK                                            | 2006 May      | IV                 | NK                          |
| Vietnam       | Various, Quang Tri                            | 2007 Jun–Nov 30 | NK | OIE |
| Vietnam       | Hoang Phuc, Hoang Hoa, Thanh Hoa              | 2007 Jun 22   | NK                 | OIE                         |

*FMD, foot-and-mouth disease; OIE, World Organisation for Animal Health; PIADC, Plum Island Animal Disease Center; SAR, Special Administrative Region; WRLFMD, Food and Agriculture Organisation World Reference Laboratory for Foot-and-Mouth Disease; NK, not known; CADCP, Centre for Animal Disease Control and Prevention of Yunnan Province; PD-FMD, Project Directorate on Foot-and-Mouth Disease; ARRIAH, All-Russian Institute for Animal Health.
Table 2. The designations, origins, sequence accession numbers and references for the FMD viruses studied

| Reference no. | Geographic origin | Country         | Date collected | Host species | Laboratory | Accession no. | Reference |
|---------------|-------------------|-----------------|----------------|--------------|------------|---------------|-----------|
| AFG/1/2001    | Dand, Kandahar    | Afghanistan     | 2001 Feb 8     | Bovine       | WRLFMD     | DQ121109     | (1)       |
| AFG/2/2001    | Dand, Kandahar    | Afghanistan     | 2001 Feb 10    | Bovine       | WRLFMD     | FJ785226     | This study|
| AFG/3/2001    | Dand, Kandahar    | Afghanistan     | 2001 Feb 10    | Bovine       | WRLFMD     | FJ785227     | This study|
| AFG/4/2001    | Dand, Kandahar    | Afghanistan     | 2001 Feb 10    | Bovine       | WRLFMD     | DQ121110     | (1)       |
| AFG/22/2003†  | Nangahar          | Afghanistan     | 2003 Dec       | Bovine       | PIADC      | EF457987     | (2)       |
| AFG/24/2003†  | Nangahar          | Afghanistan     | 2003 Dec       | Bovine       | PIADC      | EF457988     | (2)       |
| AFG/26/2003†  | Balh              | Afghanistan     | 2003 Dec       | Bovine       | PIADC      | EF457989     | (2)       |
| AFG/33/2003†  | Nangahar          | Afghanistan     | 2003 Dec 17    | Bovine       | PIADC      | EF457990     | (2)       |
| AFG/40/2003†  | Kapisa            | Afghanistan     | 2003 Dec 29    | Bovine       | PIADC      | EF457991     | (2)       |
| AFG/44/2003†  | Kapisa            | Afghanistan     | 2003 Dec 29    | Bovine       | PIADC      | EF457992     | (2)       |
| AFG/138/2004† | Ghazni            | Afghanistan     | 2004 Feb 13    | Bovine       | PIADC      | EF457994     | (2)       |
| AFG/116/2004† | Balh              | Afghanistan     | 2004 Mar 17    | Bovine       | PIADC      | EF457993     | (2)       |
| BAN/5/87      | Duthia, Rajshami, | Bangladesh      | 1987 Feb 14    | Bovine       | BFAV       | NA           | (3)       |
| BAN/2/96      | Savar             | Bangladesh      | 1996 Feb 3     | NK           | BFAV       | NA           | (3)       |
| BAN/4/96      | Savar             | Bangladesh      | 1996 Oct 25    | NK           | BFAV       | NA           | (3)       |
| BHU/27/2002   | Chhokha           | Bhutan          | 2002 Feb 4     | NK           | WRLFMD     | DQ121111     | (1)       |
| BHU/34/2002   | Paro              | Bhutan          | 2002 Feb 12    | NK           | WRLFMD     | DQ121112     | (1)       |
| CAM/9/80†     | Tuk Vil, Siem Reap| Cambodia        | 1980 Nov 27    | NK           | WRLFMD     | FJ785228     | This study|
| CAM/5/97†     | Chun Lease Dey,   | Cambodia        | 1997 Jun 20    | Bovine       | WRLFMD     | FJ785229     | This study|
| YNBS/CHA/58   | Yunnan province   | China           | 1958           | Bovine       | LVRI       | AY390432     | Chang et al., unpub. data |
| Jiangsu/CHA/2005 (a) | Jiangsu Province | China         | 2005 Apr       | Bovine       | LVRI       | DQ156527     | (7)       |
| Jiangsu/CHA/2005 (b) | Wuxi city, Huishan district, Jiangsu province | China | 2005 Apr | Bovine | LVRI | EF149009 | This study |
| Beijing/CHA/2005 | Beijing municipality, Yangning county | China | 2005 May | Bovine | LVRI | EF185303 | This study |
| HeB/CHA/2/2005 | Sanhe city, Hebei province | China      | 2005 May | Bovine | LVRI | EF187273 | This study |
| HeB/CHA/12/2005 | Zhangjiakou city, Hebei province | China | 2005 Jun | Bovine | LVRI | EF187274 | This study |
| JingNing/GS/CHA/2005 | Pingliang city, Jingning county, Gansu province | China | 2005 Jul | Bovine | LVRI | EF185304 | This study |
| TongRen/QH/CHA/2005 | Huangnan district, Tongren county, Qinghai province | China | 2005 Jul | Bovine | LVRI | EF187272 | This study |
| BR/MYA/001/2006† | Yunnan Province (border region with Myanmar) | China | 2006 | Bovine | CADCP | EU091342 | Zhang et al., unpub. data |
| BR/MYA/002/2006† | Yunnan Province (border region with Myanmar) | China | 2006 | Bovine | CADCP | EU091343 | Zhang et al., unpub. data |
| BR/MYA/003/2006† | Yunnan Province (border region with Myanmar) | China | 2006 | Bovine | CADCP | EU091344 | Zhang et al., unpub. data |
| BR/MYA/004/2006† | Yunnan Province (border region with Myanmar) | China | 2006 | Bovine | CADCP | EU091345 | Zhang et al., unpub. data |
| BR/MYA/005/2006† | Yunnan Province (border region with Myanmar) | China | 2006 | Bovine | CADCP | EU091346 | Zhang et al., unpub. data |
| BR/MYA/006/2006† | Yunnan Province (border region with Myanmar) | China | 2006 | Bovine | CADCP | EU091347 | Zhang et al., unpub. data |
| BR/MYA/007/2006† | Yunnan Province (border region with Myanmar) | China | 2006 | Bovine | CADCP | EU091348 | Zhang et al., unpub. data |
| CHA/WHN 06† | Sichuan Province | China | 2006 | Porcine | Sichuan Univ. | EU887277 | Wang et al., unpub. data |
| GRE/1/84      | Evros             | Greece          | 1984           | Bovine       | WRLFMD     | EU553909     | (4)       |
| GRE/2/2000    | Feres, Evros      | Greece          | 2000 Jul 1     | NK           | WRLFMD     | DQ121113     | (1)       |
| Reference no.  | Geographic origin                     | Country                  | Date collected | Host species | Laboratory | Accession no. | Reference       |
|---------------|---------------------------------------|--------------------------|----------------|--------------|------------|---------------|----------------|
| HKN/19/74     | Ping Yeung, San Tsuen, Takwuling, NT, Kowloon | Hong Kong               | 1974 Oct 3    | Bovine       | WRLFMD     | FJ785230      | This study      |
| HKN/2/75 (1974) | Ping Che, Takwuling, NT, Kowloon        | Hong Kong               | 1974 Dec 23   | Bovine       | WRLFMD     | FJ785231      | This study      |
| HKN/24/75     | Dairy Farm, Pokfulam Road, Hong Kong Island | Hong Kong               | 1975 Feb 15   | Bovine       | WRLFMD     | FJ785232      | This study      |
| HKN/18/76     | Wong Ka Wai, Tung Chung, Lantau Island  | Hong Kong               | 1976 Feb 10   | Bovine       | WRLFMD     | FJ785233      | This study      |
| HKN/22/80     | Shek Po Tsuen, Hong Shui Kui, Ping Shan, Yuen Long | Hong Kong               | 1980 Aug 23   | Bovine       | WRLFMD     | FJ785234      | This study      |
| HKN/1/2005    | Sheung Shui, New Territories           | Hong Kong               | 2005 Mar 9    | Bovine       | WRLFMD     | DQ121114      | (1)            |
| HKN/2/2005    | Sheung Shui, New Territories           | Hong Kong               | 2005 Mar 9    | Bovine       | WRLFMD     | DQ121115      | (1)            |
| HKN/3/2005    | Sheung Shui, New Territories           | Hong Kong               | 2005 Mar 9    | Bovine       | WRLFMD     | FJ785235      | This study      |
| HKN/4/2005    | Sheung Shui, New Territories           | Hong Kong               | 2005 Mar 9    | Bovine       | WRLFMD     | FJ785236      | This study      |
| HKN/5/2005    | Sheung Shui, New Territories           | Hong Kong               | 2005 Mar 10   | Bovine       | WRLFMD     | FJ785237      | This study      |
| HKN/6/2005    | Sheung Shui, New Territories           | Hong Kong               | 2005 Mar 10   | Bovine       | WRLFMD     | FJ785238      | This study      |
| HKN/7/2005    | Sheung Shui, New Territories           | Hong Kong               | 2005 Mar 10   | Bovine       | WRLFMD     | FJ785239      | This study      |
| HKN/8/2005    | Sheung Shui, New Territories           | Hong Kong               | 2005 Mar 10   | Bovine       | WRLFMD     | FJ785240      | This study      |
| IND/2/71 (1964) | Mukteswar Dairy                        | India                   | 1964 Feb 25   | Bovine       | WRLFMD     | FJ785241      | This study      |
| IND/63/72†   | Maharashtra                           | India                   | 1972          | Bovine       | other       | Y09949        | (5)            |
| IND/16/76     | Ranipet, Vellore District, Tamil Nadu  | India                   | 1976          | NK           | WRLFMD     | FJ785242      | This study      |
| IND/8/79      | NK                                    | India                   | 1979          | NK           | WRLFMD     | EU553910      | (4)            |
| IND/18/80     | Kargundy, Tamil Nadu                  | India                   | 1980 Sep 20   | Bovine       | WRLFMD     | DQ121116      | (1)            |
| IND/15/81     | Mandakarai, Nilgiris, Tamil Nadu       | India                   | 1981 Feb 17   | Bovine       | WRLFMD     | DQ121117      | (1)            |
| WBN/117/85†   | Nadia, West Bengal                    | India                   | 1985          | NK           | WRLFMD     | EU553911      | (4)            |
| IND/WBN/117/85†  (IND 491/97†)       | Nadia, West Bengal                    | India                   | 1985          | NK           | PD-FMD      | AY687334      | (6)            |
| IND/WBN/117/85†  (IND 491/97†)       | Nadia, West Bengal                    | India                   | 1985          | NK           | PD-FMD      | AF392922      | (7)            |
| IND 4/86†     | NK                                    | Bhutan                  | 1986          | Bovine       | PD-FMD      | AF392944      | Sanyal et al., unpub. data |
| IND 75/86†    | Assam                                 | India                   | 1986 Oct 5    | Bovine       | PD-FMD      | AF390702      | (7)            |
| IND 46/87†    | Rajasthan                             | India                   | 1986 Feb 14   | Bovine       | PD-FMD      | AF390692      | (7)            |
| IND 22/88†    | Assam                                 | India                   | 1987 Sep 28   | Bovine       | PD-FMD      | AF390685      | (7)            |
| IND 120/88†   | Maharashtra                           | India                   | 1988 Mar 24   | Bovine       | PD-FMD      | AF390675      | (7)            |
| IND 177/88†   | Maharashtra                           | India                   | 1988 Jan 19   | Bovine       | PD-FMD      | AF392904      | (7)            |
| IND 19/89†    | Uttar Pradesh                         | India                   | 1989 Apr 29   | Buffalo      | PD-FMD      | AF390684      | (7)            |
| IND 45/85†    | Uttar Pradesh                         | India                   | 1989          | Buffalo      | PD-FMD      | AF390691      | (7)            |
| IND 2/90†     | Uttar Pradesh                         | India                   | 1990 Jan 6    | Bovine       | PD-FMD      | AF392912      | (7)            |
| IND 116/90†   | Haryana                               | India                   | 1990          | Bovine       | PD-FMD      | AF392926      | Sanyal et al., unpub. data |
| IND 132/90†   | Uttar Pradesh                         | India                   | 1990 Apr 26   | Bovine       | PD-FMD      | AF390676      | (7)            |
| IND 13/91†    | Maharashtra                           | India                   | 1990 Sep 21   | Ovine        | PD-FMD      | AF390677      | (7)            |
| IND 17/91†    | Maharashtra                           | India                   | 1990 Nov 10   | Porcine      | PD-FMD      | AF390682      | (7)            |
| IND 68/92†    | Andhra Pradesh                        | India                   | 1992          | Bovine       | PD-FMD      | AF392946      | Sanyal et al., unpub. data |
| IND 247/92†   | Maharashtra                           | India                   | 1992          | Bovine       | PD-FMD      | AF392932      | Sanyal et al., unpub. data |
| IND 46/93†    | Uttar Pradesh                         | India                   | 1993 Feb 17   | Bovine       | PD-FMD      | TBS           | (8)            |
| IND 49/93†    | Uttar Pradesh                         | India                   | 1993 Feb 22   | Buffalo      | PD-FMD      | AF392945      | (8)            |
| Reference no. | Geographic origin | Country   | Date            | Host species | Laboratory | Accession no. | Reference                  |
|--------------|-------------------|-----------|-----------------|--------------|------------|---------------|---------------------------|
| IND 53/93†   | Karnataka         | India     | 1993 Mar 15     | Bovine       | PD-FMD     | AF390695      |                           |
| IND 152/94†  | Haryana           | India     | 1993 Dec 16     | Bovine       | PD-FMD     | AF392930      |                           |
| IND 175/94†  | Karnataka         | India     | 1994 Jul 21     | Bovine       | PD-FMD     | AF392931      |                           |
| IND 298/94†  | Uttar Pradesh     | India     | 1994            | Bovine       | PD-FMD     | AF392935      | Sanyal et al., unpub. data |
| IND 305/94†  | Andhra Pradesh    | India     | 1994            | Bovine       | PD-FMD     | AF392936      |                           |
| IND 1/95†    | Karnataka         | India     | 1994 Sep 14     | Bovine       | PD-FMD     | AF390683      |                           |
| IND 6/95†    | Karnataka         | India     | 1994 Sep 7      | Bovine       | PD-FMD     | AF390697      |                           |
| IND 14/95†   | Andhra Pradesh    | India     | 1995            | Bovine       | PD-FMD     | AF390678      |                           |
| IND 24/95†   | Karnataka         | India     | 1994 Dec 22     | Bovine       | PD-FMD     | AF392933      |                           |
| IND 26/95†   | Uttar Pradesh     | India     | 1995            | Bovine       | PD-FMD     | AF392947      |                           |
| IND 36/95†   | Tamil Nadu        | India     | 1995 Dec 17     | Bovine       | PD-FMD     | TBS           |                           |
| IND 47/95†   | Andhra Pradesh    | India     | 1995            | Bovine       | PD-FMD     | AF392921      |                           |
| IND 50/95†   | Uttar Pradesh     | India     | 1995            | Buffalo      | PD-FMD     | AF390694      |                           |
| IND 57/95†   | Andhra Pradesh    | India     | 1995            | Bovine       | PD-FMD     | AF390696      |                           |
| IND 33/96†   | West Bengal       | India     | 1995 Dec 6      | Bovine       | PD-FMD     | AF390689      |                           |
| IND 43/96†   | Maharashtra       | India     | 1996 Feb 8      | Bovine       | PD-FMD     | AF390690      |                           |
| IND 72/96†   | Maharashtra       | India     | 1995            | Bovine       | PD-FMD     | AF390700      |                           |
| IND 73/96†   | Pondicherry       | India     | 1995            | Bovine       | PD-FMD     | AF390701      |                           |
| IND 60/96†   | Karnataka         | India     | 1996 Mar 12     | Bovine       | PD-FMD     | AF390703      |                           |
| IND 81/96†   | Karnataka         | India     | 1996 Mar 16     | Bovine       | PD-FMD     | AF390704      |                           |
| IND 83/96†   | Himachal Pradesh  | India     | 1996            | Bovine       | PD-FMD     | AF392905      |                           |
| IND 89/96†   | Punjab            | India     | 1996 Mar 29     | Buffalo      | PD-FMD     | AF390706      |                           |
| IND 173/96†  | Haryana           | India     | 1996 Jun 6      | Buffalo      | PD-FMD     | AF390681      |                           |
| IND 339/96†  | Kerala            | India     | 1996            | Bovine       | PD-FMD     | AF392939      | Sanyal et al., unpub. data |
| IND 256/97†  | Tamilnadu         | India     | 1997            | Bovine       | PD-FMD     | AF392906      |                           |
| IND 386/97†  | Karnataka         | India     | 1994 May 19     | Bovine       | PD-FMD     | AF392914      |                           |
| IND 388/97†  | Karnataka         | India     | 1994 Jul 4      | Bovine       | PD-FMD     | AF392915      |                           |
| IND 390/97†  | Karnataka         | India     | 1994 Jul 13     | Bovine       | PD-FMD     | AF392940      |                           |
| IND 396/97†  | Karnataka         | India     | 1994 Sep 28     | Bovine       | PD-FMD     | AF392941      |                           |
| IND 44/98†   | Maharashtra       | India     | 1998            | Bovine       | PD-FMD     | AF392943      |                           |
| IND 125/98†  | Orissa            | India     | 1998 Jan 8      | Bovine       | PD-FMD     | AF392928      |                           |
| IND 270/98†  | West Bengal       | India     | 1998 Mar 25     | Bovine       | PD-FMD     | AF392907      |                           |
| IND 271/98†  | West Bengal       | India     | 1998 Apr 16     | Bovine       | PD-FMD     | AF392908      |                           |
| IND 69/99†   | Karnataka         | India     | 1998 Nov 24     | Bovine       | PD-FMD     | AF392947      |                           |
| IND 92/99†   | Haryana           | India     | 1998            | Bovine       | PD-FMD     | AF392925      |                           |
| IND 102/99†  | Haryana           | India     | 1999 Jan 7      | Buffalo      | PD-FMD     | AF392897      |                           |
| IND 104/99†  | Haryana           | India     | 1999 Jan 7      | Buffalo      | PD-FMD     | AF392898      |                           |
| IND 105/99†  | Haryana           | India     | 1999            | Bovine       | PD-FMD     | AF392899      |                           |
| IND 107/99†  | Punjab            | India     | 1998 Dec 31     | Bovine       | PD-FMD     | AF392900      |                           |
| IND 126/99†  | Karnataka         | India     | 1998 Dec 17     | Bovine       | PD-FMD     | AF392903      |                           |
| IND 127/99†  | Karnataka         | India     | 1998 Dec 17     | Bovine       | PD-FMD     | AF392929      |                           |
| IND 192/99†  | West Bengal       | India     | 1999 Jan 24     | Bovine       | PD-FMD     | TBS           |                           |
| IND 196/99†  | Karnataka         | India     | 1999 Feb 2      | Bovine       | PD-FMD     | AF392905      |                           |
| IND 235/99†  | Haryana           | India     | 1999            | Buffalo      | PD-FMD     | TBS           |                           |
| IND 277/99†  | Karnataka         | India     | 1999 Mar 12     | Bovine       | PD-FMD     | AF392909      |                           |
| IND 278/99†  | Karnataka         | India     | 1999 Mar 12     | Bovine       | PD-FMD     | AF392934      |                           |
| IND 286/99†  | Haryana           | India     | 1999            | Bovine       | PD-FMD     | AF392911      |                           |
| IND 367/00†  | West Bengal       | India     | 2000 Oct 14     | Bovine       | PD-FMD     | TBS           |                           |
| IND 374/00†  | Karnataka         | India     | 2000            | Bovine       | PD-FMD     | TBS           |                           |
| IND 377/00†  | Karnataka         | India     | 2000            | Bovine       | PD-FMD     | TBS           |                           |
| IND 378/00†  | Karnataka         | India     | 2000            | Bovine       | PD-FMD     | TBS           |                           |
| IND 379/00†  | Karnataka         | India     | 2000            | Bovine       | PD-FMD     | TBS           |                           |
| IND 383/00†  | Karnataka         | India     | 2000 Oct 13     | Bovine       | PD-FMD     | TBS           |                           |
| IND 384/00†  | Karnataka         | India     | 2000 Oct 17     | Bovine       | PD-FMD     | TBS           |                           |
| IND 387/00†  | Karnataka         | India     | 2000 Oct 25     | Bovine       | PD-FMD     | TBS           |                           |
| IND 51/01†   | Karnataka         | India     | 2001            | Bovine       | PD-FMD     | TBS           |                           |
| IND 52/01†   | Karnataka         | India     | 2001            | Bovine       | PD-FMD     | TBS           |                           |
| IND 107/01†  | Himachal Pradesh  | India     | 2001            | Bovine       | PD-FMD     | TBS           |                           |
| IND 140/01†  | Gujarat           | India     | 2000 Dec 22     | Bovine       | PD-FMD     | TBS           |                           |
| IND 148/01†  | Gujarat           | India     | 2000 Dec 20     | Bubaline     | PD-FMD     | TBS           |                           |

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| Reference no. | Geographic origin | Country | Date collected | Host species | Laboratory | Accession no. | Reference |
|---------------|-------------------|---------|----------------|--------------|------------|--------------|-----------|
| IND 149/01†  | Gujarat           | India   | 2001 Jan 10    | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 152/01†  | Gujarat           | India   | 2001 Jan 20    | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 160/01†  | Gujarat           | India   | 2001 Feb 23    | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 248/01†  | West Bengal       | India   | 2001 Mar 8     | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 321/01†  | Madhya Pradesh    | India   | 2001 Aug       | Bovine       | PD-FMD     | AY687333     | (6)       |
| IND 335/01†  | Uttar Pradesh     | India   | 2001 Sep 15    | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 342/01†  | Bihar             | India   | 2001 Aug 22    | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 354/01†  | Assam             | India   | 2001 Sep 28    | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 373/01†  | West Bengal       | India   | 2001 Jul 25    | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 387/01†  | Uttar Pradesh     | India   | 2001 Nov 27    | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 388/01†  | Uttar Pradesh     | India   | 2001 Nov 27    | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 396/01†  | Uttar Pradesh     | India   | 2001 Dec 4     | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 397/01†  | Uttar Pradesh     | India   | 2001 Dec 4     | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 423/01†  | Haryana           | India   | 2001           | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 60/02†   | Gujarat           | India   | 2002           | Bovine       | PD-FMD     | DQ101243     | (1)       |
| IND 61/02†   | Gujarat           | India   | 2002           | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 139/02†  | Bihar             | India   | 2002 Feb 27    | Bovine       | PD-FMD     | DQ101242     | (1)       |
| IND 141/02†  | West Bengal       | India   | 2002 Oct 3     | Bovine       | PD-FMD     | TBS          | (8)       |
| IND 180/02†  | West Bengal       | India   | 2002 Dec 24    | Bovine       | PD-FMD     | FJ785291     | This study |
| IND 193/02†  | West Bengal       | India   | 2002           | Bovine       | PD-FMD     | DQ101244     | (1)       |
| IND 673/2003†| Tamil Nadu        | India   | 2003           | Bovine       | PD-FMD     | DQ101238     | (1)       |
| IND 762/2003†| Andhra Pradesh    | India   | 2003           | Bovine       | PD-FMD     | DQ101240     | (1)       |
| IND 763/2003†| Andhra Pradesh    | India   | 2003           | Bovine       | PD-FMD     | FJ785292     | This study |
| IND 4/2004†  | Karnataka         | India   | 2003 Nov       | NK           | PD-FMD     | FJ785293     | This study |
| IND 114/2004†| (2003)            | West Bengal | 2003 Oct 30 | Bovine       | PD-FMD     | DQ101239     | (1)       |
| IND 147/2004†| West Bengal       | India   | 2003 Dec 3     | Bovine       | PD-FMD     | FJ785294     | This study |
| IND 150/2004†| West Bengal       | India   | 2003 Dec 9     | Bovine       | PD-FMD     | FJ785295     | This study |
| IND 153/2004†| West Bengal       | India   | 2003 Dec 22    | Bovine       | PD-FMD     | FJ785296     | This study |
| IND 156/2004†| West Bengal       | India   | 2003 Dec 17    | Bovine       | PD-FMD     | FJ785297     | This study |
| IND 158/2004†| West Bengal       | India   | 2003 Dec 24    | Bovine       | PD-FMD     | FJ785298     | This study |
| IND 161/2004†| West Bengal       | India   | 2003 Jan 27    | Bovine       | PD-FMD     | DQ101238     | (1)       |
| IND 168/2004†| West Bengal       | India   | 2004 Feb 12    | Bovine       | PD-FMD     | FJ785299     | This study |
| IND 175/2004†| Tripura           | India   | 2004           | Bovine       | PD-FMD     | DQ101237     | (1)       |
| IND 268/2004†| Madhya Pradesh    | India   | 2004 Apr 9     | Bovine       | PD-FMD     | DQ101236     | (1)       |
| IND 322/2004†| West Bengal       | India   | 2004 Mar 10    | Bovine       | PD-FMD     | FJ785300     | This study |
| IND 325/2004†| West Bengal       | India   | 2004 Mar 18    | Bovine       | PD-FMD     | FJ785301     | This study |
| IND 327/2004†| West Bengal       | India   | 2004 Mar 18    | Bovine       | PD-FMD     | FJ785302     | This study |
| IND 328/2004†| West Bengal       | India   | 2004 Mar 9     | Bovine       | PD-FMD     | FJ785303     | This study |
| IND 388/2004†| Gujarat           | India   | 2004           | Bovine       | PD-FMD     | DQ101235     | (1)       |
| IND 389/2004†| Gujarat           | India   | 2004           | Bovine       | PD-FMD     | FJ785304     | This study |
| IRN/1/73     | NK                | Iran    | 1973           | NK           | WRLFMD     | EU653912     | (4)       |
| IRN/56/99    | NK                | Tehran  | 1999 Jun 20    | NK           | WRLFMD     | DQ101222     | (1)       |
| IRN/4/2001   | Lov, Mohamad Abad, Esfahan, Mohamad Abad | Iran | 2001 Jul 6 | Bovine | WRLFMD | DQ121118 | (1) |
| IRN/11/2001  | Shimiz Abad, Markalay | Iran | 2001 Jul 8 | Bovine | WRLFMD | FJ785243 | This study |
| IRN/25/2001  | NK                | Iran    | 2001           | NK           | WRLFMD     | FJ785244     | This study |
| IRN/63/2001  | Takly, Talesh, Gilan | Iran | 2001 Dec 17 | Bovine | WRLFMD | FJ785245 | This study |
| IRN/10/2004  | Damshahr, Qom, Qom | Iran    | 2004 Sep 28    | Bovine       | WRLFMD     | DQ121119     | (1)       |
| IRN/25/2004  | Oromieh, West Azerbaijan | Iran | 2004 Nov 8 | Bovine | WRLFMD | DQ121120 | (1) |
| IRN/30/2004  | NK                | Iran    | 2004           | NK           | WRLFMD     | FJ785246     | This study |
| IRN/31/2004  | NK                | Iran    | 2004           | NK           | WRLFMD     | DQ121121     | (1)       |
| ISR/1/57     | NK                | Israel  | 1957           | NK           | WRLFMD     | EU553913     | (4)       |
| ISR/3/63     | Yokneam           | Israel  | 1963           | NK           | PIADC      | AT593787     | (9)       |
| Shamir/ISR/89| Shamir            | Israel  | 1989           | NK           | BFAV       | NA          | (3)       |
| KRG/1/2004† | South Kyrgyzstan  | Kyrgyzstan | 2004 | NK | WRLFMD | FJ785247 | This study |
| KRG/1/2004† | North Kyrgyzstan  | Kyrgyzstan | 2004 | NK | ARRIAH | FJ785248 | This study |
| KRG/2/2004† | North Kyrgyzstan  | Kyrgyzstan | 2004 | NK | ARRIAH | FJ785249 | This study |
| Reference no. | Geographic origin | Country          | Date collected | Host species | Laboratory | Accession no. | Reference |
|--------------|-------------------|------------------|----------------|--------------|------------|---------------|-----------|
| LAO/1/96     | Vientiene Municipality | Laos             | 1996 Jun 12   | NK           | WRLFMD     | EU667460 (10) |           |
| LAO/3/98     | Vientiene Municipality | Laos             | 1998 Jan 5    | Bovine       | WRLFMD     | EU667461 (10) |           |
| LEB/83       | Kfar Kela          | Lebanon          | 1983 Nov      | Bovine       | PIADC      | AY593799 (9)  |           |
| LEB/83       | Kfar Kela          | Lebanon          | 1983 Nov      | Bovine       | WRLFMD     | AJ294931 (11) |           |
| MAY/8/97     | Block 15, Felda Kemamping, Tanah Meran, Sedok | Malaysia | 1997 Aug 13   | Bovine       | WRLFMD     | FJ785250        | This study|
| MAY/9/99     | Kawasan, Masjid Tanah | Malaysia         | 1999 Apr 16   | Bovine       | WRLFMD     | FJ785251        | This study|
| MOG/2005†    | Dornod             | Mongolia         | 2005 Aug      | Bovine       | ARRIAH     | FJ785252        | This study|
| MYA/2/97     | U Kyi Win, Moe Nat Kone, Thayet | Myanmar | 1997 Nov 23   | Bovine       | WRLFMD     | FJ785253        | This study|
| MYA/3/2000   | U Aung Khin, Kayin Gyaung, Kyauk Taw | Myanmar | 2000 Jun 12   | Bovine       | WRLFMD     | FJ785254        | This study|
| MYA/4/2000   | U Kan Tun, Pho Kalar, Tike Gti | Myanmar | 2000 Jun 21   | Bovine       | WRLFMD     | FJ785255        | This study|
| MYA/5/2000   | U Myo Hyaing, Lei Pyin, Tharyarnady | Myanmar | 2000 May 11   | Bovine       | WRLFMD     | FJ785256        | This study|
| MYA/2/2001   | Uhatun Aye, Taunyo, Mrauk-u, Rakhine | Myanmar | 2001 Jul 13   | Bovine       | WRLFMD     | DQ121123 (1)   |           |
| MYA 1/05†    | Kwethawdaw, Demawsoe, Loikaw, Kayah State | Myanmar | 2005 Jul 28   | NK           | TRRL       | FJ785257        | This study|
| MYA/1/2005   | Kwethawdaw, Demawsoe, Loikaw, Kayah State | Myanmar | 2005 Jul 28   | NK           | WRLFMD     | FJ785258        | This study|
| NKR/2/2007   | Pyongyang          | DPR of Korea     | 2007          | Bovine       | WRLFMD     | FJ785259        | This study|
| PAK/1/54     | Okara, Punjab      | Pakistan         | 1954 Mar 4    | Buffalo      | PIADC      | AY593795 (9)   |           |
| PAK/1/85     | Lahore City, Punjab | Pakistan         | 1985          | Bovine       | WRLFMD     | FJ785260        | This study|
| PAK/2/98     | 20 Miles from Lahore, Punjab | Pakistan | 1998          | Bovine       | WRLFMD     | EU553914 (4)   |           |
| PAK/3/98     | 20 Miles from Lahore, Punjab | Pakistan | 1998          | Bovine       | WRLFMD     | FJ785261        | This study|
| PAK/30/2002  | NK                  | Pakistan         | 2002 Oct 31   | Buffalo      | WRLFMD     | DQ121124 (1)   |           |
| PAK/31/2002  | NK                  | Pakistan         | 2002 Nov 6    | Buffalo      | WRLFMD     | DQ121125 (1)   |           |
| PAK/33/2002  | NK                  | Pakistan         | 2002 Nov 6    | Buffalo      | WRLFMD     | FJ785262        | This study|
| PAK/34/2002  | NK                  | Pakistan         | 2002 Nov 6    | Buffalo      | WRLFMD     | FJ785263        | This study|
| PAK/20/2003  | Lahore, Punjab     | Pakistan         | 2003          | NK           | WRLFMD     | DQ121126 (1)   |           |
| PAK/69/2003  | NK                  | Pakistan         | 2003 Oct 9    | Bovine       | WRLFMD     | DQ121127 (1)   |           |
| PAK/1/2004   | NK                  | Pakistan         | 2004          | NK           | WRLFMD     | DQ121128 (1)   |           |
| PAK/2/2004   | NK                  | Pakistan         | 2004          | NK           | WRLFMD     | FJ785264        | This study|
| PAK/19/2005  | Lahore, Punjab     | Pakistan         | 2005 Jan 25   | Bovine       | WRLFMD     | FJ785265        | This study|
| PAK/22/2005  | Kharian, Punjab    | Pakistan         | 2005 Feb 7    | Bovine       | WRLFMD     | FJ785266        | This study|
| Amursky/RUS/2005 | Amursky             | Russia          | 2005          | Bovine       | ARRIAH     | DQ121461 (1)   |           |
| Khabarovsky/RUS/2005 | Khabarovsky      | Russia          | 2005          | Russian Federation | ARRIAH | FJ785267        | This study|
| Prymorsky/RUS/2005 | Prymorsky        | Russia          | 2005          | Russian Federation | ARRIAH | FJ785268        | This study|
| Bangkok/60   | Bangkok            | Thailand         | 1960          | NK           | WRLFMD     | FJ785269        | This study|
| TAI/85†      | Petchaburi Province | Thailand       | 1985          | Bovine       | WRLFMD     | NA            | This study|
| TAI/5/96†    | Khlong Toei (Bang Lamphu) | Thailand | 1996          | NK           | BFAV       | NA            | (3)        |
| TAJ/1/98     | Chiangrai (Chiang Rai) | Thailand     | 1996 Jan 10   | Buffalo      | WRLFMD     | DQ121129 (1)   |           |
| TAJ/1/2003†  | Khatlonsky region  | Tajikistan       | 2003 Oct 11   | Bovine       | ARRIAH     | FJ785270        | This study|
| TAJ/2/2003†  | Vakhodsky region   | Tajikistan       | 2003 Aug 10   | Bovine       | ARRIAH     | FJ785271        | This study|
| TAJ/3/2003†  | Gissarsky region   | Tajikistan       | 2003 Mar 10   | Bovine       | ARRIAH     | FJ785272        | This study|
| TAJ/1/2004†  | NK                  | Tajikistan       | 2004          | NK           | ARRIAH     | DQ121402 (1)   |           |
| TAJ/2/2004†  | NK                  | Tajikistan       | 2004          | NK           | ARRIAH     | DQ121403 (1)   |           |
| TAJ/3/2004†  | NK                  | Tajikistan       | 2004          | NK           | ARRIAH     | FJ785273        | This study|
| TAJ/4/2004†  | NK                  | Tajikistan       | 2004          | NK           | ARRIAH     | FJ785274        | This study|
| TAJ/5/2004†  | NK                  | Tajikistan       | 2004          | NK           | ARRIAH     | FJ785275        | This study|
| TAJ/6/2004†  | NK                  | Tajikistan       | 2004          | NK           | ARRIAH     | FJ785276        | This study|
| Reference no. | Geographic origin | Country | Date collected | Host species | Laboratory | Accession no. | Reference |
|---------------|------------------|---------|----------------|--------------|------------|--------------|-----------|
| TUR/15/73     | Bayrampaşa, Merkez, Kars | Turkey | 1973 Aug 12    | Bovine       | WRLFMD     | EU553917     | (4)       |
| TUR/8/99      | Sadikli (Sadaklı), Eleskirt, Agri | Turkey | 1999 Jan 10    | Bovine       | WRLFMD     | DQ121130     | (1)       |
| TUR/10/99     | Gifteanar (Ciftepcn̄ar), Eleskirt, Agri | Turkey | 1999 Jan 10    | Bovine       | WRLFMD     | DQ121131     | (7)       |
| TUR/3/2000    | Tukat/Zile, Kirıkale | Turkey | 2000           | Bovine       | WRLFMD     | EU553915     | (4)       |
| TUR/6/2000    | Sivas            | Turkey | 2000           | Bovine       | WRLFMD     | EU553916     | (4)       |
| UZB/2003      | NK               | Uzbekistan | 2003          | NK           | ARRIAH     | FJ785277     | This study |
| USSR challenge strain | NK | NK | NK | Other | U87835 | (12)       |
| Tajikistan/USSR/64 vaccine strain | Tajikistan | USSR | 1964 | NK | ARRIAH | FJ785278 | This study |
| Tajikistan/USSR/64 challenge strain | Tajikistan | USSR | 1964 | NK | ARRIAH | FJ785279 | This study |
| VIT/1/92      | Binh Ba (202 km from Ho Chi Minh City) | Vietnam | 1992 Oct 19   | Bovine       | WRLFMD     | FJ785280     | This study |
| VIT/15/2005   | Khan Hoa         | Vietnam | 2005 Oct 18   | Bovine       | WRLFMD     | FJ785281     | This study |
| VIT/16/2005   | Khan Hoa         | Vietnam | 2005 Oct 27   | Bovine       | WRLFMD     | FJ785282     | This study |
| VIT/8/2006    | Khanh Hoa Province | Vietnam | 2005 Oct 27   | Bovine       | WRLFMD     | FJ785283     | This study |
| VIT 1/06†     | Khanh Hoa Province | Vietnam | 2005 Oct 27   | Bovine       | TRRL       | FJ785284     | This study |
| VIT 2/06†     | Khanh Hoa Province | Vietnam | 2005 Oct 27   | Bovine       | TRRL       | FJ785286     | This study |
| VIT/10/2006   | Lao Cai Province | Vietnam | 2005 Nov 11   | Buffalo      | WRLFMD     | FJ785287     | This study |
| VIT 3/06†     | Lao Cai Province | Vietnam | 2005 Nov 11   | Buffalo      | TRRL       | FJ785288     | This study |
| VIT/11/2006   | Lao Cai Province | Vietnam | 2005 Nov 11   | Buffalo      | WRLFMD     | FJ785289     | This study |
| VIT 4/06†     | Lao Cai Province | Vietnam | 2005 Nov 11   | Buffalo      | TRRL       | FJ785290     | This study |

*FMD, foot-and-mouth disease; WRLFMD, Food and Agriculture Organisation World Reference Laboratory for Foot-and-Mouth Disease; PIADC, Plum Island Animal Disease Center; BFAV, Bundesforschungsanstalt für Viruskrankeiten der Tiere; NA, not available; NK, not known; LVRI, Lanzhou Veterinary Research Institute; CADCP, Centre for Animal Disease Control and Prevention of Yunnan Province; SAR, Special Administrative Region; PD-FMD, Project Directorate on Foot-and-Mouth Disease; TBS, to be submitted; ARRIAH, All-Russian Institute for Animal Health; TRRL, Thailand Regional Reference Laboratory.
†Not a WRLFMD reference number.

Table 3. Oligonucleotide primers used for RT-PCR and cycle sequencing of FMDV*

| Primer | Primer sequence (5′ → 3′) | Direction | Location on the FMDV genome | Use |
|--------|--------------------------|-----------|------------------------------|-----|
| As1-1C505F | TACACTGCTTCTGAGCGTGGC | Forward | 1C 3066–3085 | PCR |
| As1-1C530F | CCACRAGTGTCAARGGATGGGT | Forward | 1C 3091–3112 | PCR |
| As1-1C613F | GGCAGCARGAYTTTGAGTTYC | Forward | 1C 3174–3196 | PCR |
| As1-1C616F | GCAAGGTCATTGAGGTCAC | Forward | 1C 3177–3197 | Sequencing |
| As1-1D205F | GCCAAGGCACACGACTTGC | Forward | 1D 3423–3445 | Sequencing |
| As1-1D370R | GTTGTAYACTGTYGCCAGCACACG | Reverse | 1D 3588–3611 | Sequencing |
| NK72 | GAAAGGCCAGGTTGGAGCTC | Reverse | 2A/2B 3885–3905 | Sequencing |
| NK61 | GACATGTCCTCTCTGATC | Reverse | 2B 3963–3982 | RT-PCR |
| EUR-2B52R | GACATGTCCTCTCTGATC | Reverse | 2B 3957–3982 | RT-PCR |

*RT-PCR, reverse transcription–PCR; FMDV, foot-and-mouth disease viruses;†On the genome of Asia1/IND/63/72 (EMBL/GenBank accession no. AY304994).
Technical Appendix Figure 1. Midpoint-rooted neighbor-joining tree showing the relationships between the complete VP1 sequences of Asia 1 foot-and-mouth disease virus isolates studied.
Technical Appendix Figure 2. Percentage nucleotide identity matrix showing the relationships between all the foot-and-mouth disease Asia 1 viruses VP1 sequences examined.

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